DIAGNOSTIC AND FEASIBILITY STUDY OF LAKE ARCADIA

PHASE I OF A CLEAN LAKES PROJECT
DRAFT FINAL REPORT

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EXECUTIVE SUMMARY

Introduction

Arcadia Lake is located in Oklahoma County, approximately 1.5 miles southwest of the town of Arcadia, in the metropolitan areas of Oklahoma City and Edmond. Arcadia Lake lies in the Central Great Plains ecoregion, and is characterized by slightly irregular plains with shallow relief originally vegetated with bluestem/grama prairie, bluestem prairie, or buffalo grass. The lake was formed in 1986 by impounding the Deep Fork arm of the Canadian River below its convergence with Spring Creek. At conservation pool elevation of 1006 NGVD, Lake Arcadia is a 1,725 acre reservoir with a volume of 29,705 acre-feet, mean depth of 17 feet and maximum depth of 49 feet. Arcadia Lake has approximately 26 miles of shoreline and a watershed area of 105 square miles. Water released from Arcadia Lake flows east into the Deep Fork of the Canadian River until it reaches Lake Eufaula.

Arcadia Lake is a source of recreation for the Oklahoma City metropolitan area. Popular recreational activities include boating, sightseeing, camping, picnicking, fishing, swimming, skiing, sailing, group meetings and hunting. Arcadia Lake is unique because it is the only municipal water supply reservoir in Oklahoma County that allows swimming. Although a recreational destination for many, Arcadia Lake is classified as eutrophic with water quality problems. Historical problems in Arcadia Lake include excess nutrients, sediment, pesticides, metals, fecal bacteria, and trash. These concerns helped initiate a Clean Lakes Diagnostic/Feasibility Study of Lake Arcadia. Objectives of the study were to diagnose the source of eutrophication, assess the potential impact of lake sediment on fish and wildlife propagation and suggest alternatives to mitigate diagnosed lake problems.

Diagnostic Study

Water quality sampling occurred at regular intervals from February, 1996 through September, 1997. Stormwater data were collected 18 times during the period between February 18, 1997 and September 23, 1997. Collections were taken 14 times during high flow events and 4 times during low flow. Lake sediment was sampled in March of 1997 in cooperation with Region VI EPA to screen littoral sediment for toxicity.

Arcadia Lake has a relatively short residence time with a moderate sedimentation rate. Gross sedimentation for Arcadia Lake since impoundment was estimated at 105 acre-feet per year from 1986 to 1997. Mean lake depth has reduced 0.2 feet, with a loss of approximately 1162 acre-feet of volume. 1997 reservoir volume was estimated at approximately 29,705 acre-feet at conservation pool. At the current rate of sedimentation, the portion of the conservation pool allocated for sediment should be filled in 2036. Shoreline erosion was also identified as a contributor to the turbid lake water. Shoreline erosion contributes to decreased water clarity, increases evaporative water loss, loss of property and presents increased risk to recreationalists.

Arcadia Lake was classified as a eutrophic reservoir. Available historical algae data supports ongoing eutrophication. Application of trophic state indices and TN:TP ratios indicate that nitrogen rather than phosphorus is the limiting chemical nutrient. Application of Carlson's

Trophic State indices indicate that light availability limits algae growth at times when nitrogen is not limiting. A detailed analysis of the algae and zooplankton communities suggest that an over-abundance of zooplankton feeding fish may be a contributor to excessive algae growth in the summer.

No toxicity was expressed in any sediment tests. Chemical analysis did indicate significant, but relatively low level, sediment contamination. While additional toxicity tests would aid in determining sediment quality, the existing data indicate that pollutants, in combination, are not present at toxic levels. The data indicate that nonpoint source controls to reduce pollutant loads (metals, PAHs) would benefit sediment quality and reduce risks to benthic organisms.

Feasibility Study

Non-point sources were identified as the contributors to Arcadia Lake eutrophication and low level toxic contamination. The feasibility portion of the study was designed to identify viable management options to eliminate or reduce diagnosed problems. Feasibility options have been broken into two sections: in-lake and watershed. In-lake options outline management techniques that can be applied within the confines of the lake, an area of approximately 1,800 acres managed in concert by the City of Edmond and Tulsa District Corps of Engineers. Watershed options outline techniques to be applied in the lake's drainage basin, approximately 67,000 acres in size and managed by a conglomerate of Oklahoma City, City of Edmond, the State of Oklahoma, individual landowners and businesses.

In-lake Measures:

Most traditional in-lake management options will have little impact on lake water quality without first improving the quality of inflowing water. There are some in-lake measures that could benefit the lake regardless of changes in watershed land management practices.

Arcadia Lake would benefit immediately from a comprehensive program to control shoreline erosion. Shorelines receiving high recreational use or large waves will require hard treatments such as rip-rap, rock gabions or bulkheads. Soft treatment using dead and living vegetation would provide control in the lower impact areas for approximately one-quarter the cost of hard treatments. Aside from reduced cost of implementation, soft treatments have secondary benefits for fish, wildlife and aesthetics. Stocking of top predator fishes such as the sauger-walleye or striped bass-white bass hybrid shows promise to help reduce summer algae growth through food web manipulation. Techniques such as aeration or reservoir partitioning should be evaluated based on whether watershed improvements are made.

Watershed Measures:

Approximately 60% of the Arcadia Lake watershed is designated as some type of urban land use. Runoff from rainfall events accounts for 90% of the lake water recharge. This runoff is heavily laden with solids and nutrients from the watershed. Although most of the material washed into the lake settles out in the upper end, the soluble nutrient portion stimulates algae growth. The myriad of activities associated with urban land use (ranging from vehicular traffic to groundbreaking construction to aging sewerage systems or homeowner lawn fertilization) can account for the lion’s share of non-point source pollutant loadings to Arcadia Lake.

Soil stabilization and flood storage are general measures that will show the greatest improvement to inflowing water quality. The Urban Water Resources Research Council of the American Society of Civil Engineers (ASCE) entered into a cooperative agreement with the U.S. Environmental Protection Agency (EPA) to develop a scientifically-based approach to evaluate the effectiveness of urban stormwater runoff BMPs nationwide. When completed, an extensive screening of over 800 existing BMP's with performance measures will be available for use on personal computers. For updates on this project please visit the following website: http://www.asce.org/peta/tech/nsbd01.html

Specific BMPs to employ in the watershed should be determined in consultation with the Oklahoma Conservation Commission and other concerned state and federal officials, such as the United States Department of Agriculture, the National Resources Conservation Service, the Agricultural Stabilization and Conservation Service, City of Oklahoma City, City of Edmond and individual landowners.

DIAGNOSTIC STUDY

TASK ONE - LAKE IDENTIFICATION

Arcadia Lake is located in Oklahoma County, approximately 1.5 miles southwest of the town of Arcadia in the metropolitan areas of Oklahoma City and Edmond. The dam is located in the Arkansas River Basin on the Deep Fork River at mile 213.8, Lat. 3538’10", Long. 9721’43" in Sec 36, T14N, R2W in Oklahoma County (**OWRB 1990**). Arcadia Lake lies in the Central Great Plains ecoregion, which is characterized as slightly irregular plains with shallow relief originally vegetated with a bluestem/grama prairie, bluestem prairie, or buffalo grass.

The Arcadia Lake watershed originates in southwest Oklahoma City near Will Rogers Park, and extends northeast approximately 20 miles through Oklahoma City and Edmond to the dam (**Figure 1.1**). The US Army Corps of Engineers began construction in October 1980, and the lake became fully operational for flood control in November 1986 (**USACE 1994**). Total cost of the project was $90,400,000. The primary purposes of Arcadia Lake are flood control, water supply, and recreation.

At a conservation pool elevation of 1006 NGVD, Lake Arcadia is a 1,820 acre body of water with a shoreline length of 26 miles, a volume of 27,520 acre-feet, and a drainage area of 105 square miles. The lake was formed by impoundment of the Deep Fork arm of the Canadian River below its convergence with Spring Creek. The Deep Fork River then flows east from the dam to southeast Okmulgee County, OK, where it forms an arm of Lake Eufaula. Arcadia Lake has a mean depth of 15.14 ft. and a maximum depth of 56 ft. at normal pool elevation (**OWRB 1990**). The Water Quality Standards applicable to Arcadia Lake are listed in **Appendix A**.

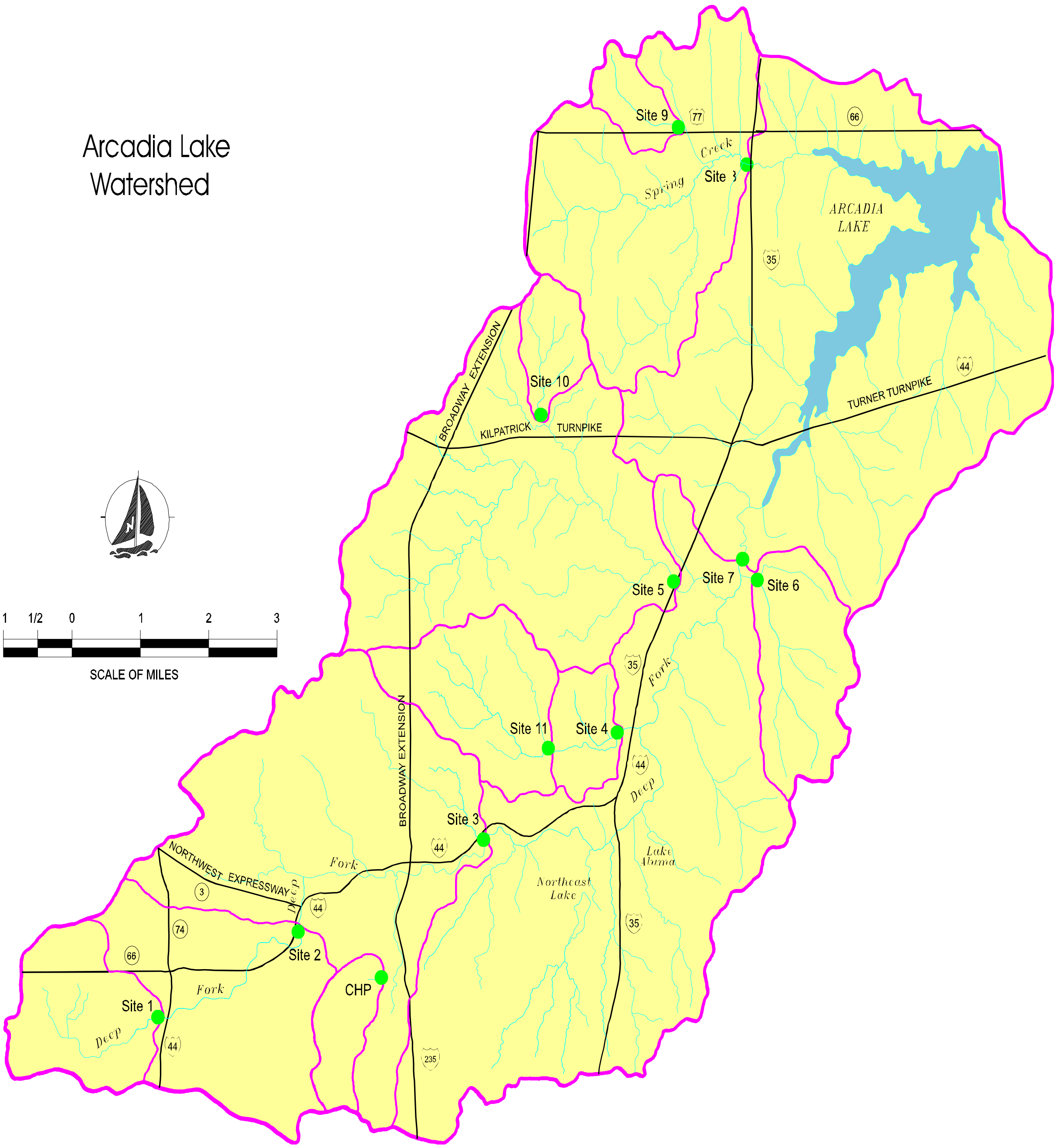

Figure 1.1 Arcadia Lake watershed and tributary sample sites

TASK TWO -- DESCRIPTION OF DRAINAGE BASIN GEOLOGY AND SOILS

Geology and soil types of the basin will be described in Task 9, where they are combined to assess non-point source pollution contributions to Arcadia Lake. These two tasks have been combined because of the integrated link between the geology of the basin and its contribution to the non-point source pollution.

TASK THREE - PUBLIC ACCESS

Arcadia Lake is easily accessible through Interstate Highway 35, which runs along the western shoreline of the reservoir, and also through State Highway 66, which runs along the northern shoreline of the reservoir (**Figure 3.1**). The lake is also accessible through City of Edmond streets and county roads. Primary transportation to the lake is by car, although cycling, jogging, and horseback are also used to access the lake. Public transportation is not provided by the surrounding communities.

Quality access roads and a multitude of facilities make Arcadia Lake an extremely accessible, popular feature of the Oklahoma City Metropolitan area. During the years from 1990 through 1996, the lake has had an estimated 1,350,000 visitors. Future population projections predict increasing public use of this lake.

Arcadia Lake offers many recreation opportunities for residents of Oklahoma County and the many travelers visiting the area. The entire lake and shoreline of Arcadia Lake are open to the public for recreation, although some areas require an entry fee. The lake offers an abundance of recreational activities throughout the year. There are four parks, allowing the public to access a multitude of park facilities. These facilities include more than 144 camping grounds ranging from primitive sites to full hook up lots, multiple group picnic areas, three boat ramps along with courtesy docks, three swimming beaches, two kids fishing ponds, a bird watching blind, a multi-use trail, an educational trail, a softball field, four playgrounds, and a 36-hole disk golf course.

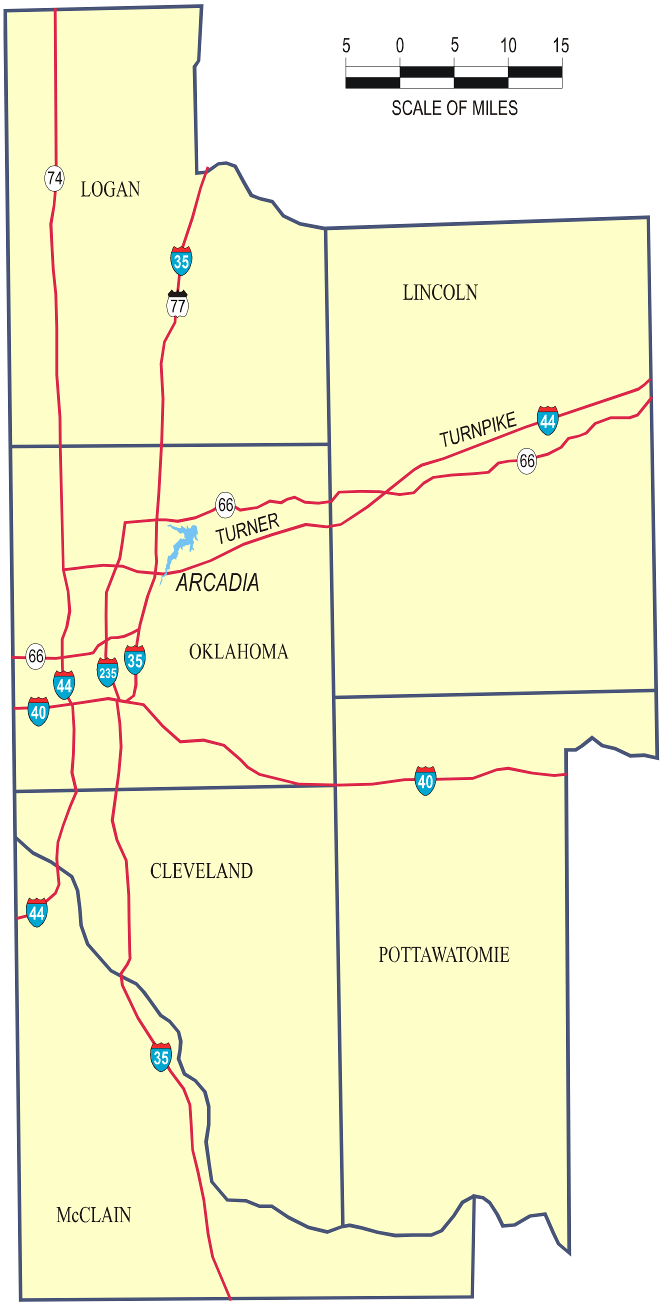

Figure 3.1 Map of major highways leading to Lake Arcadia

TASK FOUR -- ADJACENT POPULATION AND ECONOMIC STRUCTURE

Arcadia Lake, located in Oklahoma County, has a surrounding population of 599,611 people. A population of 958,839 living in the greater Oklahoma City metropolitan area is in close proximity to the lake. The primary population using the lake is centered near the reservoir. These populations are in the cities of Oklahoma City (est. pop. 444,719), Edmond (est. pop. 52,315), and Midwest City (est. pop. 52,267). Statistical data for the Oklahoma City metropolitan area were used to identify the size and economic structure of the population residing near Arcadia Lake. The Oklahoma City metropolitan area includes Oklahoma, Canadian, Cleveland, McClain, Logan, and Pottawatomie Counties (**Figure 4.1**).

The 1990 Census recorded the population in this area as 958,839 (**DECA, 1990**). By race, the population composition is 81.10% white; 10.54% black; 4.77% American Indian, Eskimo, or Aleut; 1.85% Asian or Pacific Islander; and 1.74% classified as other. Compared to the 1980 Census, a 14.96% increase in population occurred. According to population projections, this trend is expected to continue into the twenty-first century. The Oklahoma City metropolitan area population is estimated to be 1,025,163 in 1997. This trend is projected to continue at an approximate rate of 1.1% change every year. Because of the predicted population growth for the area, the lake and its facilities are expected to receive increasingly heavier use.

The civilian labor force is approximately 526,300, with the annual average number employed 506,900 in the metropolitan area (**OESC, 1997**). The unemployment rate was 3.1% during the first quarter of 1997. When broken down by division, the trade industry accounted for approximately 117,300 jobs, services for 138,200, manufacturing for 50,500, government for 102,200, finance, insurance, and real estate for 26,900, transportation and public utilities for 21,400, mining for 6,800, and construction for 17,900 (**Table 4.1**). The per capita income given for the Oklahoma City metropolitan area in the 1990 census was $13,269. Approximately 13.9% of the income in the metropolitan area falls below the poverty line, according to the 1990 census.

The 1990 Census of Housing recorded 367,775 households in the Oklahoma City metropolitan area. Whites occupied 310,665 housing units and were ranked highest among races on average household income of $35,579. Blacks occupied 33,617 housing units and ranked last with an average household income of $23,407. American Indians, Eskimos, and Aleut residents occupied approximately 14,633 houses and earned an average household income of $27,358. Asian and Pacific Islander occupancy status accounted for 5,086 homes with the second highest average household income of $32,409. Other races accounted for 4,501 of the housing units in the Oklahoma City metropolitan area, with an average household income of $25,035. **Table 4.2** demonstrates the information above, along with the amount of renter-occupied housing compared to owner-occupied housing and the amount of families in poverty status.

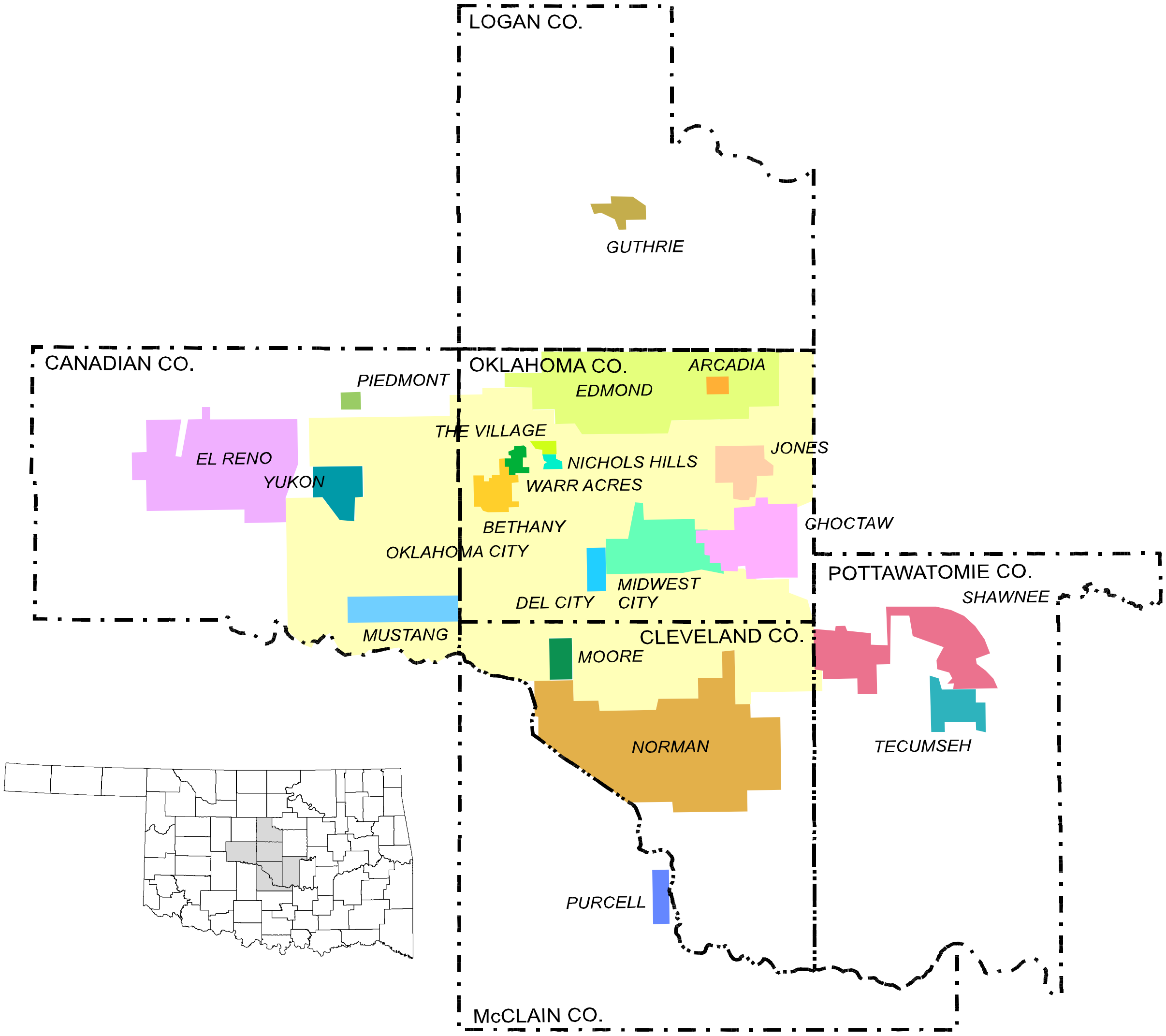

Figure 4.1 Oklahoma City Metropolitan Area

Table 4.1 Oklahoma City Metropolitan Area Labor Force and Employment Average for the First Quarter 1997 (**OESC, 1997**)

Description	Persons (In Thousands)
Total Labor Force	523.3
Total Employment	506.9
Total Non-farm Employment	499.8
Manufacturing	50.5
-Durable Goods	34.2
-Non-durable Goods	16.3
Non-Manufacturing	430.8
-Mining	6.8
-Construction	17.9
-Transportation & Public Utilities	21.4
Trade	117.3
-Wholesale	25.0
-Retail	92.3
Finance, Insurance, and Real Estate	26.9
Service	138.2
Government	102.2

Table 4.2 Housing and Median Income Specified by Race and Families in Poverty Status by Race in 1990 Census.

CATEGORY	Oklahoma City Metropolitan Area	White	Black	American Indian, Eskimo or Aleut	Asian or Pacific Islander	Other
Occupied housing units	367,775	310,665	33,617	14,633	5,086	4,501
Median household income	$16,602	$35,759	$23,407	$27,358	$32,409	$25,035
Owner-occupied housing	236,478	209,334	15,037	8,260	2,060	1,787
Renter-occupied housing	131,297	101,006	18,471	6,319	2,914	2,587
Families under poverty status	26,333	16,123	6,615	2,146	560	889

TASK FIVE - HISTORICAL LAKE USES

Arcadia Lake is a young body of water. Initiated in October 1980, Arcadia Reservoir was impounded on the Deep Fork River approximately five miles east of Edmond. The lake was completed in 1986 at a total cost of $90,400,000, and was officially opened in 1987. The lake was constructed as a cooperative effort between the U.S. Army Corps of Engineers and the City of Edmond.

Arcadia Lake was designed for a variety of functions. The four major functions are: (1) to supply the City of Edmond with water; (2) to control floods for the Deep Fork River Basin; (3) to provide recreational and educational opportunities for the community; and (4) to provide habitat for fish and wildlife.

Water supplied by Arcadia Lake benefits the City of Edmond. In 1988, the City of Edmond constructed a state of the art water treatment plant. This plant is situated on a highly visible 40-acre site located on the northeast section of the lake. The site includes an administration building, chemical feed and ozone building, high lift pump station, low lift pump station, shop building, treatment basins, and eight million gallons of ground storage. The plant is designed to treat twelve million gallons per day and is a statement of the City of Edmond's belief in future growth. Currently, the plant services approximately half of the City of Edmond's population, approximately 26,000 people. **Figure 5.1** illustrates the project office with the dam in the background.

Figure 5.1 Lake Arcadia project office with dam in background

The Deep Fork Basin has a watershed of 272.0 km^2 (105 miles^2). The lake provides flood control for approximately 64,430 acre-feet of water. Prior to impoundment, major floods occurred on the average of once every five years and minor floods twice a year in downstream areas. Arcadia Lake has a surface area of 1,820 acres and a volume of 27,520 acre-feet at an elevation 306 m (1006 ft) above sea level. The total shoreline of the lake is 48 m (26 miles).

Other ways in which Arcadia Lake benefits the community are education and recreation. Four parks allow the public to access a multitude of park facilities (**Figure 5.2**). These facilities include camp sites, picnic areas, swimming beaches, fishing, bird watching, a softball field, playgrounds, and a 36-hole disk golf course. The park also provides educational programs for both adults and children throughout the year. Educational highlights include the education trail and wildlife classes which touch on a broad range of subjects concerning the lake's wildlife.

Figure 5.2 Picnic facilities at Arcadia Lake

Central Park, Spring Creek Park, Edmond Park and the Scissortail Campground provided water oriented recreation for 1,350,000 visitors from 1990 through 1996 (**Table 5.1**). There are a number of factors that affect the amount of visitation to the lake. These factors include closures of the parks due to flooding, as well as the economic activity of the area. The link between the water quality of the lake and the visitation rate is difficult to quantify without extensive research.

Table 5.1 Historical Recreational Use of Arcadia Lake

Year	Visitors
1990	188,000
1991	209,000
1992	239,000
1993	179,000*
1994	212,000
1995	165,000*
1996	158,000

*Parks closed due to flooding approximately three weeks to one month during a peak visitation period

Since its inception, Arcadia Lake was designed to provide fish and wildlife habitats. After construction of the dam, the lake was allowed to fill in stages over a three-year time frame. This time frame not only allowed the dam to mature for better response to water pressure, but also allowed for the development of lake fisheries.

Fishing is popular with visitors because of the extensive stocking done by the Oklahoma Department of Wildlife Conservation. Stocking began with the earliest stages of the lake. Today the lake contains populations of bluegill, bass, catfish and others. Arcadia Lake is also home to a wide assortment of birds, mammals, reptiles, amphibians and insects. The abundance of wildlife illustrates how important Arcadia Lake is to the surrounding biosphere.

The fisheries' project was led by the Oklahoma Department of Wildlife Conservation. The first stage was the stocking of an inundated 1.5 acre abandoned quarry located within the lake's basin. This was done during the pre-impoundment stage, and included populations of channel catfish and bluegill sunfish. The next stage took place while the lake was filling. During this period, blue catfish were introduced. In the final stage, populations of floridabass were introduced once the lake reached conservation pool elevation.

Since the introduction of fish, the Oklahoma Department of Wildlife Conservation has been monitoring the populations to forecast fishing success at the lake. This monitoring has shown that the bass population is struggling. This problem is most likely related to lack of suitable habitat for young bass. The Oklahoma Department of Wildlife Conservation began a revegetation effort in early 1997 to provide habitat for recruitment of the young-of-year black bass. No determination of the success of the project has been made at this point.

There is also a multitude of wildlife that utilizes the lake's water and surrounding wood lands. The area is in the Cross Timbers ecoregion. This region combines tall grass prairie with scrubby oak trees, creating a unique niche between the semi-arid West and the humid East. This provides an ideal setting for a wide assortment of wildlife. 1,400 acres of the total lake area have been set aside exclusively for wildlife management. Over the years, an archery harvest program and other hunting oriented activities have been used to control certain populations of birds and deer. Both for sport and education, the fish and wildlife at Arcadia Lake are important parts of the past, present, and future of the area.

In conclusion, Arcadia Lake, although young, has become a multipurpose, community oriented park. The lake also has a bright future because of such programs as “Arcadia Lake Sweep,” where volunteers help preserve the beauty of the lake through an annual trash pickup day, while serving to heighten public awareness of protecting this vital urban resource.

TASK SIX -- EFFECTS OF LAKE DEGRADATION ON LAKE USAGE

Arcadia Lake is a source of recreation for the Oklahoma City metropolitan area, which includes Oklahoma, Canadian, Cleveland, McClain, Logan, and Pottawatomie counties. The 1990 Census recorded a population of 958,839 (**DECA, 1990**), a 14.96% increase from the 1980 Census. This trend is expected to continue beyond the year 2000. Based on this information, recreational use of Arcadia Lake is projected to continue increasing.

Residents of Oklahoma County, as well as travelers visiting the area, find many opportunities for recreation at Arcadia Lake. The lake and its environs may be used for various activities, such as boating, sightseeing, camping, picnicking, fishing, swimming, skiing, sailing, group meetings (i.e., family reunions) and hunting. Arcadia Lake also serves as a primary drinking water supply for the City of Edmond and some of the smaller surrounding communities. Eutrophication and contamination can impair all of the above mentioned recreational uses and can also lead to intense water treatment procedures.

The pre-impoundment survey projected significant water quality problems in Arcadia Lake as a consequence of historical land and water usage in the watershed. In an effort to alleviate some of these potential water quality problems, point source discharges were diverted outside the Arcadia watershed. Thus, all pollutants in Arcadia Lake and its watershed are derived from nonpoint sources.

Problems in the Arcadia Lake watershed

Arcadia Lake is classified as eutrophic with numerous water quality problems. Specific problems in Arcadia Lake include excess nutrients, sediment, pesticides, metals, fecal bacteria, and trash (**Figure 6.1**). Because of the largely urban land use of the lake basin, the inability to identify any one factor as the source contributes to the difficulty of water quality remediation in Arcadia Lake.

Figure 6.1 Arcadia Lake trash .washed in from its urban watershed

Nutrients

Arcadia Lake and its tributaries (the Deep Fork River, Spring Creek, and Tinker Creek) contain high concentrations of nitrogen and phosphorus. Nitrogen and phosphorus are the elements which most commonly limit algal growth, because large amounts are required relative to available concentrations (**Vollenweider, 1968**). Water quality data indicate excessive nutrient concentrations in Arcadia Lake and its watershed. These nutrients stem from both background and anthropogenic nonpoint sources. Although comparison of current concentrations to historical concentrations suggests a decrease in tributary concentrations, current nutrient concentrations are typical of eutrophic systems (**Carlson, 1977; Vollenweider, 1979**). Increased algal growth means greater cost by the City of Edmond to produce clean, safe potable water.

Sediment

The pre-impoundment survey along with the current Secchi disk measurements and photosynthetic active radiation data suggest primary productivity is light limited rather than nutrient limited. Water quality data in the limnological section of this report support that conclusion. Turbidity in the Deep Fork arm often exceeds 25 NTU, Oklahoma's Water Quality Standard for Lakes. The high NTU count indicates an influx of excessive turbidity into Arcadia Lake, as well as frequent resuspension of sediment in the shallow regions of the lake. Sediment in Arcadia Lake comes from background and anthropogenic nonpoint sources. Higher turbidity is aesthetically unpleasant, and also requires greater cost and effort by the City of Edmond to produce clean, safe potable water.

Pesticides

The pre-impoundment survey identified DDT, dieldrin, chlordane, lindane, diazanon, 2,4-D, 2,4,5-T, and silvex as potential water quality problems in Arcadia Lake and downstream water resources, based on USGS monitoring data near Arcadia (**USACE, 1977**). Since impoundment, pesticides in sediments, water, and fish flesh have been closely monitored. The toxics monitoring program performed by the Oklahoma State Department of Health (OSDH) (**ODEQ, 1995**) detected chlordane levels in fish which exceeded various state and federal warning levels. Follow up sampling has not resulted in chlordane advisories. Recent lake sediment surveys were free of detectable levels of pesticides (**Bates, 1989**). Postings of fish flesh advisories in the early 1990s adversely affected public opinion of the lake's aesthetics. Although no known concerns exist currently, there is still a segment of negative public opinion related to these events.

Metal

The environmental impact statement identified iron, lead, manganese, and mercury as metals likely to exceed criteria for freshwater aquatic life and public drinking supply, based on USGS monitoring data in the Deep Fork River between 1969 and 1974 (**USACE, 1977**). The Toxics in Reservoirs Survey monitored metals concentrations in fish flesh between 1987 and 1995. Concentrations exceeded OSDH concern levels in gizzard shad and white crappie in 1987, but have since been below state or federal concern levels (**ODEQ, 1995**). Examination of lake sediments indicated that the Deep Fork River and Deep Fork arm of Arcadia Lake were heavily contaminated with lead and were the major source of manganese, while the Spring Creek arm had the highest mercury concentrations. Metals in Arcadia Lake are believed to be predominantly from anthropogenic nonpoint sources (**Bates, 1989**).

Fecal Bacteria

Coliform bacteria was identified as a potential problem in Arcadia Lake during the pre-impoundment survey, based on coliform concentrations in the Deep Fork River (**USACE, 1977**). It was assumed that coliform counts would be drastically reduced by diverting point sources out of the watershed. The Oklahoma Department of Environmental Quality established a concern level of 400 cells/100 ml. Concentrations measured during Phase I data collection exceeded this level in the Deep Fork arm on several occasions. Beaches on Arcadia Lake were closed once during 1996 because of excessive fecal bacteria concentrations, with a direct negative effect on recreational use of the lake. Fecal bacteria contamination in the Arcadia watershed stems from both anthropogenic and non- anthropogenic sources. Current potential sources of bacterial contamination are aging sewer lines, septic tanks, and runoff from animal waste.

Trash

Urban trash is a significant problem in the Arcadia Lake watershed. The local news media documented large amounts of trash in the lake, and suggested that the City of Edmond was responsible for cleanup. The Phase I study documented a large raft of trash (approximately 2 acres in size) in the Deep Fork arm following a storm event in early summer of 1996. This, along with watershed reconnaissance, indicated that most of the influent trash originates in Oklahoma City. Trash is especially concentrated in the northeastern portions of the city and on the outskirts of town. The trash represents not only an aesthetic nuisance, but also a potential for toxic contamination and increased organic loading. Trash in the Arcadia watershed is entirely due to anthropogenic sources (**Figure 6.2**).

Figure 6.2 Floatable solids washed into Arcadia Lake

Summary of Problems

Although a young reservoir, Arcadia Lake has water quality problems. These problems were predicted in a pre-impoundment environmental impact statement which suggested pollution from urban sources would be significant in Arcadia Lake. Nonpoint source pollutants evident in Arcadia Lake include nutrients, sediment, pesticides, metals, fecal bacteria, and trash. Although a portion of the nonpoint source loading in Arcadia Lake is from natural weathering of basin material, the majority of the load is related to human activity in the watershed.

TASK SEVEN - COMPARATIVE LAKE USE WITHIN AN 80 KM RADIUS

One hundred seventy-seven (177) public and private reservoirs having a storage volume of 50 acre-feet or greater lie within an 80-km radius of Arcadia Lake (**Table 7.1**). A statistical breakdown of these reservoirs reveals an average lake size of 845.6 surface acres, a minimum of 4 acres, and maximum of 6,070 surface acres. Eight lakes have a surface area of greater than 1,000 acres. These include Lakes Arcadia, Hefner, Carl Blackwell, McMurtry, Overholser, Shawnee Twin Lakes No. 1 and 2, Thunderbird, and Stanley Draper. Using only lakes of similar size and public use as the criterion for comparative lake use, the water use of the lakes in **Table 7.2** will be compared to that of Lake Arcadia in the following narrative. (See **Table 7.3** for a tabular summary of the limnological features of these reservoirs for comparative purposes).

Arcadia Reservoir Initiated in October 1980, Arcadia Reservoir was created by impounding the Deep Fork River approximately five miles east of Edmond. The Corps of Engineers and the City of Edmond built the reservoir for the purpose of flood control, water supply, and recreation. The lake controls the runoff from a watershed of 105 square miles and provides flood control for approximately 64,430 acre-feet of water. It has the fourth largest storage capacity of the major reservoirs in Oklahoma County. Arcadia Lake has a surface area of 1,820 acres and embodies 27,520 acre-feet at an elevation 1006 feet above sea level. The total shoreline is 26 miles.

Central Park, Spring Creek Park, and Edmond Park provide water oriented recreation for 1,150,000 annual visitors. From January to November of 1990, 67,000 day passes and 2900 annual passes have been issued, generating revenues of approximately $300,000 combined. In the winter months, only Central Park is operated.

Facilities available for use are 3 boat ramps, 3 picnic areas, 2 designated campsites, 3 drinking water fountains, 2 group shelters, 3 swimming beaches, 3 restrooms, 2 trailer dump stations, 2 electric outlets, and a playground. Recreational opportunities include picnicking, camping, swimming, waterskiing, boating, hiking and fishing. It is the only municipal water supply in Oklahoma County that allows swimming. The lake is stocked with bluegill, redear sunfish, channel catfish, largemouth bass, and black and white crappie.

Hefner Reservoir Lake Hefner was constructed by the impoundment of Bluff Creek in 1947 by the City of Oklahoma City, and serves as a water supply for northwestern Oklahoma City, Warr Acres, Nichols Hills, Bethany, and the Village. Upon completion, Lake Hefner had a storage capacity of 75,000 acre-feet at an elevation of 1,999 National Geodetic Vertical Datum (NGVD), and a surface area of 2,500 acres. Total shoreline length was 18 miles. In addition to serving as a water supply, the lake was developed for recreation. It receives heavy use from the Oklahoma City Metropolitan Area. **Table 7.4** displays revenues generated from permits issued July 1989 to June 1990.

Table 7.4 Revenues generated from permit sales for Lake Hefner July 1989

	Daily	Annual
Fishing	$35,544	$28,963
Hunting	$200	$150
Boating	$10,050	$39,435

Lake Hefner is considered a prime fishing lake. The state record walleye was caught in this lake in 1967. Good populations of white bass, walleye, and catfish are present. Other popular activities include sailing, boating, wind surfing, golfing, picnicking, jogging, and cycling. The facilities available for recreational use are two parks with playground equipment, a soccer field, a softball field, a marina, a group shelter, picnic areas, a nature trail, a fishing dock, boat docks, a running track, grill, 4 trash receptacles, restroom, drinking water fountain, a model airplane field, and a golf course.

Stanley Draper Reservoir Stanley Draper Reservoir is located twelve miles from downtown Oklahoma City. It was completed in 1962 by the city of Oklahoma City for the purposes of water supply and recreation. The reservoir is located on East Elm Creek in Cleveland County. Approximately 60% to 65% of the 32.6 billion gallons of water stored in the waterbody is pumped from Lake Atoka, approximately 80 miles southeast of Stanley Draper. With 100,000 acre-feet, Stanley Draper has the second largest storage capacity compared to the other lakes. It has 2,900 surface acres, and the natural drainage area is 7,400 acres. With a length of 5 miles and a width of 2 miles, the total shoreline comprises 34 miles. The average depth is 34 feet.

Stanley Draper receives heavy attendance, and lake uses are diverse. Facilities available for recreation consist of a marina, a boat dock, boat ramps, fishing docks, picnic areas, concession, a model airplane field, a motorcycle area, a mountain bike area, restrooms, drinking fountain, water grills, trash receptacles, and a riding stable. Several acres of land have been devoted to a wildlife refuge. Popular activities include boating, personal water craft, duck hunting, jogging, biking, and fishing. Hunting is restricted to waterfowl, and no swimming is allowed. The main sport fish are largemouth bass, white crappie, channel catfish, and blue catfish. A 1988 study of Oklahoma reservoirs indicated that fish populations in the lake will continue to decline as a result of increasing turbidity. Permits are required for fishing and boating. **Table 7.5** displays the revenues obtained by purchase of the permits in July through August of 1990..

Table 7.5 Revenues generated from permit sales for Lake Stanley Draper July through August 1990.

	Daily	Annual
Fishing	$4,704	$1,587
Boating	$7,275	$3,200

Overholser Reservoir Compared to Lake Hefner and Stanley Draper Reservoir, Lake Overholser is the smallest and oldest of the city lakes. In 1919, the North Canadian River was impounded by the City of Oklahoma City to create the reservoir. Overholser serves as both a water supply and a source of recreation. At the normal pool elevation of 1,242 NGVD, the surface area is 12.8 km^2 (8.0 $miles^2$) and the storage capacity is 15,000 acre-feet. It has a natural drainage area of 15.4 km^2 (8,300 $miles^2$), a shoreline length of 11.2 km^2 (7 $miles^2$), and a maximum depth of 3.6 m (12 ft).

Recreational facilities include boat ramps, a concession stand, a fishing dock, picnic areas, group shelters, nature trails, a soccer field, a tennis court, grills, trash receptacles, restrooms, and a drinking water fountain. The primary activities are fishing and boating. **Table 7.6** displays the revenues generated from permits issued July through August of 1990.

Table 7.6 Revenues generated from permit sales for Lake Overholser July and August 1990.

	Daily	Annual
Fishing	$10,510	$3,337
Boating	$2,905	$2,215

Moderate populations of hybrid striped bass, white bass and channel catfish exist in the lake. Sampling indicated the population of white crappie is low, but the population may not be well represented in the sampling group. The abundance of white bass, which appears to be governed by the flow from the North Canadian River, is expected to increase in the future.

Thunderbird Reservoir Thunderbird Reservoir is located in the Arkansas River Basin on Little River about 13 miles east of Norman. Construction began in August, 1962 by the Bureau of Reclamation, and was completed in March, 1965. With 6,070 acres in surface area, it is the largest body of water within an 80 km radius of Lake Arcadia. At normal pool elevation, the mean depth is 5.9 m (19.7 ft) and the maximum depth is 27.8 m (91 ft). The lake has a drainage area of 411.9 km (256 miles) and has 138.4 km (86 miles) of shoreline.

The lake serves as a supplemental municipal water supply for the cities of Norman, Del City, and Midwest City. The normal pool capacity is 119,600 acre-feet. The water stored is pumped into two pipelines, one extending to Norman, and the other leading to a relift pumping plant where the pipeline separates to Del City and Midwest City.

The flood control capacity is 76,000 acre-feet at an elevation of 1039 to 1049 MSL. Reductions in flood hazards on Little River to its confluence with the North Canadian River were achieved to protect downstream areas south and east of the lake. Releases from the flood control pool are determined by the Corps of Engineers.

Recreation is a major use of the lake. From July 1996 through June 1997, approximately 1,509,410 people visited the lake to enjoy such activities as boating, water skiing, picnicking, hiking, swimming, camping, sightseeing, horseback riding, hunting and fishing. The facilities include recreational areas, a riding stable, an archery range, boat ramps, picnic areas, designated campsites, a drinking water fountain, group shelters, restrooms, showers, swimming beaches, change houses, trailer dump stations, electric outlets, concession stands, nature trails, a marina, and a boat rental.

Lake Thunderbird also serves as a fish and wildlife management area. Fishing is excellent, and the most sought after species are largemouth bass, catfish, and walleye. The first Oklahoma introduction of the walleye-saugeye hybrid species was at this lake.

Shawnee Twins Reservoir Located seven miles west of Shawnee, Shawnee Reservoir No.1 was constructed in 1932, and Shawnee Reservoir No.2 was impounded in 1960 on South Deer Creek by the city of Shawnee for the purpose of a water supply and recreation. The larger of the two, Shawnee No.1, contains 1,336 surface acres and a storage capacity of 22,600 acre-feet. Shawnee No.2 has 1,100 surface acres and stores 11,400 acre-feet.

Facilities present for lake use are boat ramps, boat docks, a fishing dock, a campsite, camper parking, picnic areas, grills, trash receptacles, restrooms, a playground, a group shelter, a drinking water fountain, and a concession stand. From January 1989 to December 1989, a total of 5,933 daily and annual boating, fishing and hunting permits were issued. Hunting is restricted to dove, quail, squirrel, rabbit, and duck in season. No toutlines or jugs are allowed on Shawnee No.2. Fishery predictions for largemouth bass, white bass, channel catfish and bluegill are poor. The outlook for crappie abundance is fair.

McMurtry Reservoir Located in Noble County, McMurtry Reservoir was constructed on North Stillwater Creek in 1971 by the City of Stillwater for the purpose of water supply, flood control and recreation. At an elevation of 950 NGVD, the normal pool capacity is 19,733 acre-feet and the surface area is 1,155 acres. Lake McMurtry has a shoreline length of 45.0 km (28 miles).

Two recreational areas provide the following facilities: boat ramps, boat docks, a fishing dock, campsites, camper parking, electrical hookups, picnic areas, grills, a mountain biking trail, trash receptacles, restrooms, group shelters, drinking water fountains, and concession stands.

During the fiscal year of 1989/1990, the revenues obtained from permits issued for daily fishing and camping were $9,417 and $6,623 respectively. Hunting is limited to waterfowl, no toutlines are allowed, and swimming is permitted in designated areas only. The fishing quality of largemouth bass should continue to be excellent. White bass and flathead catfish were collected for the first time in 1989, and the populations continue to increase in abundance. White crappie and channel catfish angling are predicted to be fair to good.

Carl Blackwell Reservoir Carl Blackwell Reservoir, owned by Oklahoma State University, was impounded on Stillwater Creek in 1937 to provide water supply and recreation. It is located 10 miles west of Stillwater Creek in Payne County. The shoreline length is 58 miles. The normal pool is 3,370 surface acres and storage capacity is 61,500 acre-feet at an elevation of 944 NGVD.

Seven recreational areas are available for use, with the following facilities provided: boat ramps, boat docks, campsites, camper parking, electrical hookups, picnic areas, grills, trash receptacles, restrooms, group shelters, drinking water fountains, a concession stand, a canoe trail , a hiking trail, and a sanitary dump. **Table 7.7** displays the revenues generated from purchase of permits during the fiscal year July 1989 through June 1990.

Table 7.7 Revenues generated from permit sales for Lake McMurtry July 1989 through June 1990.

Fishing:	$7,310
Hunting:	$1,511
Boating:	$16,015
Skiing:	$5,780
Camping:	$22,195
Visitor Fee:	$2,932

The main sport fish in the lake are largemouth bass, white crappie, and bluegill. Quality size bass (> 12 inches) should be found in the next few years if an extended drought does not occur.

CONCLUSION

Many reservoirs of 50 acre-feet or greater are located within an 80 km radius of Arcadia Lake. Of the eight lakes having a surface area greater than 1,000 acres, Lake Thunderbird and Stanley Draper have the largest storage capacity, with 119,600 and 100,000 acre-feet respectively (**Table 7.2**). Lake Thunderbird also has the greatest surface area at 6,070 acres, while Carl Blackwell has the second largest surface area at 3,370 acres. Compared to the other reservoirs, Shawnee No. 2 has the smallest storage capacity and surface area at 11,400 acre-feet and 1,100 acres respectively. Seven lakes, including Hefner, Overholser, Stanley Draper, Arcadia, Thunderbird, and Shawnee, lie in the Oklahoma City Metropolitan Area and receive heavy recreational use. All the lakes allow boating and fishing, but swimming is only permitted at Arcadia, Thunderbird, McMurtry, and Carl Blackwell Reservoirs. Lake Thunderbird and Lake Carl Blackwell possess the most recreational facilities. Comparing the other lakes, they each have approximately the same number of facilities (**Table 7.3**).

In summary, Arcadia Lake is an important reservoir in Central Oklahoma. It has the fourth largest storage capacity, and is the only large reservoir in Oklahoma County that allows swimming. It attracts many visitors in the Oklahoma City area for a variety of activities, and possesses facilities on par with the other major reservoirs within the region.

Table 7.1 Reservoirs of Storage Volume 50 Acre-Feet or Greater Within 80 Km Radius of Arcadia Lake. An asterisk (*) denotes known public use.

LAKE	COUNTY	OWNER	LOCATION SEC TWP RGE	SURFACE AREA (ACRES)	STORAGE (ACRE/FEET)
Scott Dam	Blaine	Leslie Scott	25 16N 13W	3	100
Shawyer, John	Blaine	Shawyer, John	24 13N 11W	4	50
Chickasha*	Caddo	City of Chickasha	34 08N 09W	820	41,080
Harrison, J D	Caddo	Harrison, J D	17 09N 10W	4	50
Killingworth, Kathryn	Caddo	Killingworth, Kathryn	23 12N 11W	-	78
Kimble, Troy	Caddo	Kimble, Troy	06 11N 11W	5	60
Rasser, Melvin	Caddo	Rasser,Melvin	30 10N 09W	10	80
Smith, Randall Dean	Caddo	Smith, Randall Dean	29 12N 12W	-	100
Wyatt, L B	Caddo	Wyatt, L B	18 11N 12W	7	80
Zobisch	Caddo	Carlile, Zelda	14 11N 11W	8	140
Abbot, Fay	Canadian	Abbot, Fay	31 12N 10W	6	120
Acres, Jacob	Canadian	Acres, Jacob	26 11N 06W	4	80
Alvin, R & Leigh R	Canadian	Alvin, R & Leigh R	31 12N 10W	22	80
Brueggen, Michael & Karen	Canadian	Brueggen, Michael & Karen	15 14N 06W	8	50
Carter, Jim	Canadian	Carter, Jim	16 12N 09W	-	64
Cedar	Canadian	Western Sportsman Club	18 11N 09W	62	1,125
Chiles, Chester	Canadian	Chiles, Chester	29 12N 09W	13	180
Cypert 209	Canadian	Cypert	02 14N 05W	-	240

LAKE	COUNTY	OWNER	LOCATION SEC TWP RGE	SURFACE AREA (ACRES)	STORAGE (ACRE/FEET)
Cypert-Holcomb-Eli 209	**Canadian**	**Cypert**	**02 14M 05W**	**24**	**120**
El Reno[*]	**Canadian**	**City of El Reno**	**07 12N 07W**	**170**	**709**
Freeman, Chas No.1	**Canadian**	**Freeman, Chas**	**15 11N 10W**	**9**	**80**
Huchteman, Herbert	**Canadian**	**Huchteman, Herbert**	**33 12N 08W**	**22**	**100**
Laughlin	**Canadian**	**Laughlin, John**	**16 13N 09W**	**25**	**100**
Maberry	**Canadian**	**Maberry**	**02 12N 10W**	**2**	**50**
Mann, Rose Ann	**Canadian**	**Mann, Rose**	**30 14N 08W**	**-**	**70**
Matthies, William T	**Canadian**	**Matthies, William T**	**07 11N 07W**	**8**	**90**
McClain No.209	**Canadian**	**McClain**	**22 14N 06W**	**3**	**50**
McClain, M W	**Canadian**	**McClain, M W**	**32 14N 06W**	**19**	**130**
McClain, M L	**Canadian**	**McClain, M L**	**32 14N 06W**	**7**	**50**
Mustang No.1[*]	**Canadian**	**Canadian County District 2**	**31 11N 05W**	**-**	**50**
Northwood	**Canadian**	**Burger Development Inc**	**08 13N 05W**	**190**	**800**
Richardson, Dave No.1	**Canadian**	**Richardson, Dave**	**31 11N 08W**	**-**	**60**
Smith	**Canadian**	**Smith & Able Enterprises**	**13 13N 06W**	**12**	**55**
Stokes, Roy	**Canadian**	**Stokes, Roy**	**19 13N 09W**	**7**	**60**
Wallace, Jessie M	**Canadian**	**Wallace, Jessie M**	**19 14N 06W**	**5**	**85**
Wittrock, Harold	**Canadian**	**Wittrock, Harold**	**06 14N 06W**	**9**	**54**
Bill, Mere	**Cleveland**	**Bell, Mere**	**01 06N 01E**	**13**	**58**
Buchanan, Jack V	**Cleveland**	**Buchanan, Jack V**	**08 10N 03W**	**21**	**85**

LAKE	COUNTY	OWNER	LOCATION SEC TWP RGE	SURFACE AREA (ACRES)	STORAGE (ACRE/FEET)
Dahlgren[*]	**Cleveland**	**State of Oklahoma**	**28 07 01E**	**30**	**222**
Decker, Edwin E	**Cleveland**	**Decker, Edwin E**	**07 10N 02W**	**13**	**110**
Greenbriar Mgt Co	**Cleveland**	**Greenbriar Mgt Co**	**17 10N 03W**	**37**	**150**
Grider, Gordon L	**Cleveland**	**Grider, Gordon L**	**27 07N 01E**	**2**	**50**
Hall Park	**Cleveland**	**Western Homes Service Co**	**21 09N 02W**	**9**	**98**
John, R	**Cleveland**	**John, R**	**01 06N 01W**	**-**	**60**
Kitchen[*]	**Cleveland**	**City of Oklahoma City**	**09 10N 02W**	**24**	**80**
Lazy Day	**Cleveland**	**Urban, Vernon**	**33 10N 02W**	**21**	**380**
Lessmann, Norma	**Cleveland**	**Lessmann, Norma**	**09 10N 03W**	**11**	**78**
Liberty Nat Bank & Trust	**Cleveland**	**Liberty Nat Bank & Trust**	**35 08N 02W**	**5**	**50**
Meadowwood Estates	**Cleveland**	**Meadowwood Estates**	**34 09N 02W**	**13**	**130**
Mussel Shoals	**Cleveland**	**Bigelow, Louise**	**36 10N 03W**	**12**	**60**
National Properties Inc	**Cleveland**	**National Properties Inc**	**27 09N 02W**	**7**	**50**
National Properties Inc	**Cleveland**	**National Properties Inc**	**27 09N 02W**	**13**	**55**
Oklahoma City, City of[*]	**Cleveland**	**City of Oklahoma City**	**13 10N 04W**	**4**	**95**
Oklahoma, State of[*]	**Cleveland**	**State of Oklahoma**	**28 09N 02W**	**8**	**90**
Oklahoma, State of[*]	**Cleveland**	**State of Oklahoma**	**20 09N 02W**	**14**	**130**
Page, James A	**Cleveland**	**Page, James A**	**23 07N 01E**	**9**	**60**
Pyle, Ronny	**Cleveland**	**Pyle, Ronny**	**35 09N 03W**	**12**	**50**
Reece, Joe	**Cleveland**	**Reece, Joe**	**29 08N 01W**	**11**	**140**

LAKE	COUNTY	OWNER	LOCATION SEC TWP RGE	SURFACE AREA (ACRES)	STORAGE (ACRE/FEET)
Salyer, Al	**Cleveland**	**Salyer, Al**	**36 07N 01E**	**-**	**80**
Sooner Lake Addition	**Cleveland**	**Rutherford, David**	**29 10N 02W**	**10**	**60**
Stanley Draper*	**Cleveland**	**City of Oklahoma City**	**24 10N 02W**	**2,900**	**100,000**
Thunderbird*	**Cleveland**	**Bureau of Reclamation**	**29 09N 01E**	**6,070**	**119,600**
Tull, Travis Arthur	**Cleveland**	**Tull, Travis Arthur**	**19 09N 02E**	**24**	**130**
University of Oklahoma*	**Cleveland**	**University of Oklahoma**	**08 08N 02W**	**7**	**55**
McGee, Jack	**Garfield**	**McGee, Jack**	**33 20N 07W**	**4**	**35**
Shell	**Garfield**	**Shell**	**17 20N 03W**	**20**	**575**
Brooks, Bill	**Grady**	**Brooks, Bill**	**12 07N 05W**	**14**	**50**
Brooks, Leroy	**Grady**	**Brooks, Leroy**	**25 08N 05W**	**4**	**50**
Burtschi*	**Grady**	**State of Oklahoma**	**29 06N 08W**	**180**	**2,140**
Corley, Alvin J	**Grady**	**Corley, Alvin J**	**21 09N 06W**	**-**	**70**
Daugherty, Beauna	**Grady**	**Daugherty, Beauna**	**28 06N 05W**	**2**	**50**
Eckroat, Paul H	**Grady**	**Eckroat, Paul H**	**20 09N 06W**	**3**	**60**
Hall, Calias E	**Grady**	**Hall, Calias E**	**30 08N 05W**	**-**	**70**
Hartin, Joe A	**Grady**	**Hartin, Joe A**	**13 09N 06W**	**4**	**50**
Hoffman, Henry	**Grady**	**Hoffman, Henry**	**18 08N 07W**	**7**	**60**
Schafer, Kermit	**Grady**	**Schafer, Kermit**	**33 09N 07W**	**-**	**120**
Schafer, Kermit	**Grady**	**Schafer, Kermit**	**33 09N 07W**	**11**	**60**
Timberlake	**Grady**	**Jones, Mary**	**13 09N 05W**	**11**	**54**

LAKE	COUNTY	OWNER	LOCATION SEC TWP RGE	SURFACE AREA (ACRES)	STORAGE (ACRE/FEET)
Trayler, W J Jr	**Grady**	**Trayler, W J Jr**	**28 09N 05W**	**3**	**50**
Windburn, Mary M	**Grady**	**Windburn, Mary M**	**18 07N 05W**	**4**	**50**
Windburn, Mary M	**Grady**	**Windburn, Mary M**	**17 07N 05W**	**23**	**90**
Elmer*	**Kingfisher**	**State of Oklahoma**	**07 16N 07W**	**60**	**1,080**
Johnson, Don	**Kingfisher**	**Johnson, Don**	**14 15N 05W**	**7**	**50**
Lankard, George R	**Kingfisher**	**Lankard, George R**	**06 16N 07W**	**9**	**135**
Vieth, Buena	**Kingfisher**	**Vieth, Buena**	**26 16N 05W**	**7**	**60**
Weggener, Helen	**Kingfisher**	**Weggener, Helen**	**29 16N 05W**	**9**	**60**
White, Connie J	**Kingfisher**	**White, Connie J**	**23 16N 05W**	**11**	**200**
A C M	**Lincoln**	**Morrison, Jack**	**08 14N 05E**	**14**	**120**
Bishop, Troy O	**Lincoln**	**Bishop, Troy O**	**15 13N 04E**	**11**	**60**
Chandler*	**Lincoln**	**City of Chandler**	**32 15N 04E**	**129**	**2,778**
Davenport*	**Lincoln**	**City of Davenport**	**15 14N 05E**	**7**	**220**
Duffle, David P	**Lincoln**	**Duffle, David P**	**28 16N 02E**	**5**	**50**
Greenfield, Truman	**Lincoln**	**Greenfield, Truman**	**15 15N 04E**	**10**	**50**
Mahar, Carl E	**Lincoln**	**Mahar, Carl E**	**06 16N 02E**	**10**	**80**
McNinch, Lloyd	**Lincoln**	**McNinch, Lloyd**	**05 12N 04E**	**9**	**50**
Meeker*	**Lincoln**	**Town of Meeker**	**24 12N 03E**	**250**	**1,818**
Murphy, James L	**Lincoln**	**Murphy, James L**	**21 15N 02E**	**11**	**100**
Poplin	**Lincoln**	**Wilson, Floyd E**	**20 12N 04E**	**3**	**50**

LAKE	COUNTY	OWNER	LOCATION SEC TWP RGE	SURFACE AREA (ACRES)	STORAGE (ACRE/FEET)
Scissortail Ranch Inc	**Lincoln**	**Scissortail Ranch Inc**	**31 15N 05E**	**6**	**70**
Wood, James N	**Lincoln**	**Wood, James N**	**11 16N 04E**	**5**	**65**
Birch, Nellmae	**Logan**	**Birch, Nellmae**	**26 17N 02W**	**6**	**65**
Cedar Canyon Dev Corp	**Logan**	**Cedar Canyon Dev Corp**	**01 16N 03W**	**22**	**480**
Day, George	**Logan**	**Day, George**	**09 16N 03W**	**-**	**55**
Glazebrook, Juliana	**Logan**	**Glazebrook, Juliana**	**19 16N 01W**	**8**	**80**
Griffey, Paul M	**Logan**	**Griffey, Paul M**	**35 19N 04W**	**9**	**70**
Groves, Marvin	**Logan**	**Groves, Marvin**	**06 16N 03W**	**4**	**80**
Guthrie[*]	**Logan**	**City of Guthrie**	**32 16N 02W**	**274**	**3,875**
Guthrie Country Club[*]	**Logan**	**City of Guthrie**	**11 16N 02W**	**97**	**612**
Haskell, Askew J	**Logan**	**Haskell, Askew J**	**14 16N 03W**	**10**	**50**
Jones, Forrest A	**Logan**	**Jones, Forrest A**	**30 18N 04W**	**9**	**70**
Kerr McGee	**Logan**	**Kerr McGee**	**12 16N 04W**	**-**	**110**
Kerr McGee	**Logan**	**Kerr McGee**	**12 16N 04W**	**12**	**132**
Krob, Herbert R	**Logan**	**Krob, Herbert R**	**04 15N 03W**	**8**	**70**
Langston[*]	**Logan**	**Langston Public Works Authority**	**26 17N 01W**	**304**	**5,792**
Lattawanna	**Logan**	**Lake Lattawanna Inc**	**02 16N 04W**	**16**	**140**
Liberty[*]	**Logan**	**City of Guthrie**	**01 15N 03W**	**167**	**2,740**
Minyard, Chas	**Logan**	**Minyard, Chas**	**28 16N 03W**	**4**	**50**
Mueller, James	**Logan**	**Mueller, James A**	**13 15N 02W**	**4**	**70**

LAKE	COUNTY	OWNER	LOCATION SEC TWP RGE	SURFACE AREA (ACRES)	STORAGE (ACRE/FEET)
Perdue, Donald & Joseph	Logan	Perdue, Donald & Joseph	24 19N 04W	6	110
Ran, Rick Jr	Logan	Ran, Rick Jr	06 17N 03W	9	115
Ringrose, R F	Logan	Ringrose, R F	02 16N 01W	6	80
Ringrose, R F	Logan	Ringrose, R F	04 16N 01W	5	50
Stanbeck, Thomas	Logan	Stanbeck, Thomas	06 16N 02W	5	70
Stephens, Thomas N	Logan	Stephens, Thomas N	03 15N 04W	6	50
Swain, J L	Logan	Swain, J L	03 16N 04W	11	80
Tenny, H E	Logan	Tenny, H E	19 16N 01W	11	200
Adams, Russel C	McClain	Adams, Russel C	16 06N 02W	29	165
Baker, John	McClain	Baker, John	19 05 03W	4	82
Bell, Ollie	McClain	Bell, Ollie	18 08N 04W	12	80
Dannels, Ken	McClain	Dannels, Ken	34 07N 03W	2	50
Green, A B	McClain	Green, A B	17 06N 02W	13	140
Griffith, W R	McClain	Griffith, W R	35 09N 04W	3	55
Lamar, Ted	McClain	Lamar, Ted	18 08N 03W	9	80
Livingstone, D	McClain	Livingstone, D	36 09N 04W	5	110
Livingstone, D	McClain	Livingstone, D	36 09N 04W	3	75
Luttrel, E E	McClain	Luttrel, E E	16 05N 03W	5	115
McPherson, P G	McClain	McPherson, P G	22 08N 03W	6	80
Meyer, Daryl	McClain	Meyer, Daryl	01 05N 02W	4	90

LAKE	COUNTY	OWNER	LOCATION SEC TWP RGE	SURFACE AREA (ACRES)	STORAGE (ACRE/FEET)
Perkinson, Mary Nell	**McClain**	**Perkinson, Mary Nell**	**22 07N 02W**	**5**	**64**
Prie, Irene	**McClain**	**Prie, Irene**	**13 07N 04W**	**5**	**73**
Purcell*	**McClain**	**City of Purcell**	**14 06N 02W**	**150**	**2,600**
Rose, C L	**McClain**	**Rose, C L**	**09 05N 01W**	**-**	**92**
Simpson, C C	**McClain**	**Simpson, C C**	**06 09N 04W**	**4**	**77**
Cornish, Cecil	**Noble**	**Cornish, Cecil**	**25 20N 02W**	**-**	**50**
McMurtry*	**Noble**	**McMurtry**	**34 20N 01E**	**1,155**	**19,733**
Abbot, W Rogers	**Oklahoma**	**Abbott, W Rogers**	**33 11N 02W**	**3**	**50**
Aluma	**Oklahoma**	**Lake Aluma Club**	**07 12N 02W**	**13**	**140**
Arcadia*	**Oklahoma**	**Corps of Engineers**	**36 14N 02W**	**1,820**	**27,520**
Blue Stem	**Oklahoma**	**John W Johnston**	**21 13N 04W**	**10**	**175**
Booher	**Oklahoma**	**Booher, Allen K**	**14 13N 01E**	**5**	**50**
Brixton Heights Addition	**Oklahoma**	**Catholic Archdiocese of OKC**	**32 13N 04W**	**5**	**86**
Brown, Donald I	**Oklahoma**	**Brown, Donald I**	**08 13N 04W**	**11**	**110**
Brown, Mart D	**Oklahoma**	**Brown, Mart D**	**17 13N 04W**	**14**	**150**
Eagle Lake	**Oklahoma**	**S & L Dev Corp**	**29 13N 04W**	**4**	**55**
Eddie Lake	**Oklahoma**	**Eddie, B D**	**01 13N 04W**	**11**	**280**
Fox Lake	**Oklahoma**	**Gene Phillips**	**32 14N 03W**	**10**	**132**
Fuehner, Gladys	**Oklahoma**	**Fuehner, Gladys**	**18 13N 04W**	**11**	**110**
Harris, Roy C & James C	**Oklahoma**	**Harris, Roy C & James C**	**18 13N 04W**	**9**	**50**

LAKE	COUNTY	OWNER	LOCATION SEC TWP RGE	SURFACE AREA (ACRES)	STORAGE (ACRE/FEET)
Hiwassee	**Oklahoma**	**Lake Hiwassee IMP CO**	**33 14N 01W**	**132**	**2,400**
J M Ranch	**Oklahoma**	**McCauley, Worth O**	**29 14N 03W**	**19**	**200**
Kloss, E L	**Oklahoma**	**Kloss, E L**	**07 13N 04W**	**34**	**140**
Lansbrook	**Oklahoma**	**Lansbrook Homeowners Assn**	**33 13N 04W**	**5**	**100**
Leven[*]	**Oklahoma**	**ODOT**	**04 12N 04W**	**5**	**110**
Noftsger, M Lawrence & G	**Oklahoma**	**Noftsger, M Lawrence & G**	**30 14N 04W**	**7**	**60**
Northeast[*]	**Oklahoma**	**Oklahoma City Zoo**	**12 12N 03W**	**29**	**480**
Oakes, Francis D	**Oklahoma**	**Oakes, Francis D**	**34 14N 03W**	**4**	**60**
Overholser[*]	**Oklahoma**	**City of Oklahoma City**	**30 12N 04W**	**1,500**	**15,000**
Pines, East The	**Oklahoma**	**Pines Homeowner Assn**	**04 12N 04W**	**-**	**51**
Quillian, J W No.209	**Oklahoma**	**Quillian, J W**	**09 13N 03W**	**3**	**80**
Regal	**Oklahoma**	**Regal Lake Homeowner Assn**	**28 13N 04W**	**7**	**60**
Sanditen, Ira E	**Oklahoma**	**Sanditen, Ira E**	**08 13N 03W**	**3**	**53**
Ski Island	**Oklahoma**	**Ski Island Lake Club Inc**	**28 13N 04W**	**45**	**206**
Sportsman's Country Club	**Oklahoma**	**Sportsman's club Inc**	**14 12N 04W**	**25**	**138**
Twin Bridges	**Oklahoma**	**Salvo, Jogh M**	**12 14N 03W**	**8**	**101**
Willow	**Oklahoma**	**Willow Lake Homeowners Assn**	**28 13N 04W**	**3**	**50**
Woodlake Apts	**Oklahoma**	**PRC Dev Corp LTD**	**04 12N 04W**	**3**	**50**

LAKE	COUNTY	OWNER	LOCATION SEC TWP RGE	SURFACE AREA (ACRES)	STORAGE (ACRE/FEET)
Carl Blackwell[*]	**Payne**	**Oklahoma State University**	**10 19N 01E**	**3,370**	**61,500**
Johnson, Orville	**Pottawatomie**	**Johnson, Orville**	**09 09N 04E**	**-**	**70**
Shawnee City No.1[*]	**Pottawatomie**	**City of Shawnee**	**11 10N 02E**	**1,330**	**22,600**
Shawnee City No. 2[*]	**Pottawatomie**	**City of Shawnee**	**11 10N 02E**	**1,100**	**11,400**
Tecumseh[*]	**Pottawatomie**	**City of Tecumseh**	**35 10N 03E**	**127**	**1,118**
Terfertiller, Lottie	**Pottawatomie**	**Terfertiller, Lottie**	**24 09N 03E**	**12**	**52**

Table 7.2 Lake Characteristics of Reservoirs Within an 80 Km Radius of Lake Arcadia.

LAKE CHARACTERISTICS	H.R.	O.R.	S.R.	A.R.	T.R.	S.R. No. 1	S.R. No. 2	M.R.	C.R.
Storage Capacity (acre-feet)	75,000	15,000	100,000	27,520	119,600	22,600	11,400	19,733	61,500
Surface Area (acres)	2,500	1,700	2,900	1,820	6,070	1,336	1,100	1,155	3,370
Mean Depth (feet)	31	10	34	15.14	19.7	*	*	16	16
Max Depth (feet)	*	*	*	56	91	*	*	28	58
Shoreline Length (miles)	18	7	34	26	86	*	*	*	*
Watershed Area	3217.68 Acres	8,300 miles	400 acres	105 $miles^2$	256 $miles^2$	*	*	*	0

H.R. - Hefner Reservoir
O.R. - Overholser Reservoir
S.R. - Stanley Draper Reservoir
A.R. - Arcadia Reservoir
T.R. - Thunderbird Reservoir
S.R. No.1 - Shawnee Reservoir No. 1
S.R. No.2 - Shawnee Reservoir No. 2
M.R. - McMurtry Reservoir
C.R. - Carl Blackwell Reservoir
* Information Unavailable

Table 7.3 Recreational use comparison of selected reservoirs.

RECREATIONAL USES	A.R.	O.R.	S.D.R.	H.R.	T.R.	S.T.R.	M.R.	C.B.R.
parks	4	*	*	2	11	*	*	0
playground equipment	2	*	*	2	3	1	*	*
change houses	3	*	*	*	15	*	*	*
showers	3	*0	*	*	11	*	*	*
restrooms	18	4	6	1	>15	3	2	7
marina	*	*	1	1	2	*	*	*
boat ramps	3	3	2	2	9	2	2	3
nature trails	1	2	*	1	3	*	*	1
swimming beaches	3	*	*	*	2	*	*	*
campsites	>144	48	*	*	>250	1	2	6

LEGEND: A.R. - Arcadia Reservoir
H.R. - Hefner Reservoir
O.R. - Overholser Reservoir
S.D.R. - Stanley Draper Reservoir
T.R. - Thunderbird Reservoir
S.T.R. - Shawnee Twins Reservoir
M.R. - McMurtry Reservoir
C.B.R. - Carl Blackwell Reservoir
* Facility or information unavailable

TASK EIGHT - POINT SOURCE POLLUTION

All major point source discharges were removed from the watershed prior to impoundment. In 1987, Congress amended the Clean Water Act, adding section 402(p)(4) which authorized the EPA to devise new point source regulations, including storm water discharges. Phase I of the storm water regulations specified that by October 1, 1992, certain point storm water dischargers must apply for a permit through the EPA. The dischargers included in the act were ones with previous permits, ones associated with industrial activity, ones from medium or large separate sewer systems, or any other discharge which the director of the EPA or state director determines to be a violation. The EPA has since transferred authority to ODEQ for issuance of industrial permits. Presently, there are 35 storm-water dischargers permitted in the Lake Arcadia watershed. Industry accounts for 13 of these permits, and the other 22 are construction permits. ODEQ reports that all facilities are in compliance with their permit. **Table 8.1** contains a detailed listing of all permitted stormwater dischargers in the Arcadia Lake watershed.

Table 8.1 Tabular Summary of Stormwater Permits within the Arcadia Lake watershed

Permit #	Permit Holder	Facility	Receiving Water	Type of Discharge
OKSM00084	Tuboscope Vetco Intl.	OK Inspection Div	Road Ditch to Deep Fork	Industrial
OKSM00329	Farley Foods USA	Farley Foods USA	Pond SE of Facility	Industrial
OKSM00420	City of Oklahoma City	Witcher Pump Station	Deep Fork	Industrial
OKSM00511	Macklanburg-Duncan	Macklanburg-Duncan	Deep Fork	Industrial
OSKM00513	Tribonetics Corp.	Tribonetics Corp.	Deep Fork	Industrial
OKSM00514	Summit Machine Tool Manufacturing Co.	Great Western Industrial Machines	Deep Fork	Industrial
OKSM00901	Ziese Manufacturing Co.	Ziese Manufacturing Co.	Lake Arcadia	Industrial
OKSM00916	Gill Reprographics, Inc.	Gill Reprographics, Inc.	None Listed	Industrial
OKSM00936	OK Army National Guard	Army National Guard	OKC Storm Water Collection	Industrial
OKSM00953	Carlisle Food Product Services	Carlisle Food Product Services	Deep Fork	Industrial
OKSM00955	Carlisle Food Product Services	Carlisle Food Product Services	Deep Fork	Industrial
OKSM01115	Governair Corporation	Governair Corporation	Deep Fork	Industrial

OKSM01310	Swedish Import Used Volvo Parts	Swedish Import Used Volvo Parts	Deep Fork	Industrial
OKSC00044	Thelma Spencer	Raintree Acres	unnamed tributary to Arcadia	Construction
OKSC00278	Coleman Family Partnership	Kensington Place, 1st and 2nd Addition	Spring Lake Trib. #2	Construction
OKSC00334	The Links at OKC	The Links at OKC	unnamed tributary of Deep Fork	Construction
OKSC00397	J & M Investment Co.	Kirkwood Addition	Deep Fork Trib. #17	Construction
OKSC00399	Sapphire Properties	Belle Isle Center	Deep Fork	Construction
OKSC00616-C	OK DOT	Street Project No STP-558B(676)A	Deep Fork	Construction
OKSC00616-C	Allen Contracting, Inc	Street Project No STP-558B(676)A	Deep Fork	Construction
OKSC00747	U. S. Food Service, Inc.	U. S. Food Service, OK Division	Deep Fork	Construction
OKSC00796-C	OK DOT	Hwy Project #CIP-155N(136)	Deep Fork	Construction
OKSC00796-C	Haskell Lemon Construction Co.	Hwy Project #CIP-155N(136)	Deep Fork	Construction
OKSC00822	Wildewood Executive Park, Inc.	Wildewood Business Park	Deep Fork	Construction
OKSC00842	Wal-Mart Stores, Inc.	Wal-Mart Store #2876	unnamed Spring Creek tributary	Construction
OKSC00844	The Links at OKC	The Links at OKC	Deep Fork	Construction

OKSC00849-C	OK DOT	ODOT Project No. CIP-155N(139)	Deep Fork	Construction
OKSC00849-C	Haskell Lemon Construction Co.	ODOT Project No. CIP-155N(139)	Deep Fork	Construction
OKSC00855	Carlisle Food Service Products	Carlisle Manufacturing	unnamed Deep Fork Tributary	Construction
OKSC0868	Millenium Golf Properties	River Oaks Golf Club Maintenance Building	Deep Fork	Construction
OKSC00869	Sooner Investment Group, Inc.	University Village	unnamed Spring Creek tributary	Construction
OKSC00900	Woody Creek, L. L. C.	Woody Creek	Spring Creek	Construction
OKSC00902	Temple B'Nai Israel	Temple B'Nai Israel	Deep Fork	Construction
OKSC01044	D & V of Edmond, Inc	Fairway Estates 5th Edition	Spring Creek, Trib. #1	Construction
OKSC01103	Sooner Investments	University Plaza	unnamed Spring Creek Tributary	Construction

TASK NINE - LAND USE AND NON-POINT SOURCE POLLUTION

GEOLOGY OF BASIN

The primary source of groundwater recharge into Arcadia Lake is the Garber-Wellington aquifer, lying in the sandstone layers of the Garber Sandstone and Wellington formation. The estimated yield is 25-50 gallons per minute. The chemical quality of the water is considered to be generally satisfactory for most uses, but the presence of an undesirable constituent or excessive hardness may make the water undesirable for some purposes. In addition, water is available from bedrock aquifers under the overlying alluvium and terrace deposits. There are six major soil formations in the Arcadia Lake watershed.

The alluvium formation is formed from sand, silt, clay, and lenticular beds of gravel. Thickness ranges from about 30 to 100 feet, and averages about 50 feet along major streams. Alluvium is a major aquifer in parts of the county.

The terrace deposits are lenticular beds of sand, silt, clay, and gravel, with thickness ranging from a few feet to about 100 feet. It averages about 50 feet along major streams.

The Salt Plains Formation is made up of red brown blocky shale and orange-brown siltstone. Thickness is about 200 feet. The Kingman Siltstone Formation is orange-brown to greenish-gray, even-bedded siltstones, with some fine grained sandstone and red-brown shale, and a thickness of about 30 feet. The Fairmont Shale Formation is red-brown blocky shale which grades into Garber sandstone at the base. Its thickness is 30 feet at Oklahoma City.

The major formations underlying the Arcadia Lake watershed are the Garber sandstone and the Wellington formation. The Garber sandstone is mostly orange-brown to red-brown, fine-grained sandstone, irregularly bedded with red-brown shale and some chert and mudstone conglomerate. Thickness ranges from 150 feet to 400 feet. The Wellington formation is red-brown shale and orange-brown fine-grained sandstone, containing much maroon mudstone conglomerate and chert conglomerate. Thickness ranges from about 150 feet to 500 feet. The Garber and underlying Wellington are the major aquifers in Oklahoma County.

Soil Associations

The following description of the soil associations found within the watershed was generated from the Soil Survey for Oklahoma County prepared by the Soil Conservation Service (**Fisher and Chelf, 1969**). Four soil associations occur within the watershed.

Darnell-Stephenville association - Shallow and deep, sloping to strongly sloping, loamy soils on wooded uplands. The soils of this association are well drained to somewhat excessively drained. They have moderate to moderately rapid permeability. About 70% of this association lies idle, or is used for native range and wildlife habitat. In cultivated areas, wheat is the main cash crop on most farms. Paved roads or other roads that have a firm surface follow most section lines.

Darnell - Composed of shallow, brown, loamy soils. The surface layer is brown fine sandy loam, about 3 inches thick. The subsoil is reddish-yellow fine sandy loam about 9 inches thick. It is underlain by red sandstone. Soils are somewhat excessively drained, have rapid runoff, and have moderately rapid permeability. Water-holding capacity and natural fertility are low. These soils are subject to water erosion if not managed well.

Stephenville - Composed of loamy soils on timbered uplands. The surface layer consists of fine sandy loam that is about 14 inches thick. The subsoil is a yellowish-red sandy clay loam in the upper part, and red sandy clay loam in the lower part, and is about 26 inches thick. It is underlain by light-red sandstone. Soils are well drained, with medium internal drainage, moderate permeability, and moderate water-holding capacity. Natural fertility is low.

Renfrow-Vernon-Bethany association - Deep and shallow, nearly level to sloping, loamy and clayey soils on prairie uplands. Mainly nearly level to sloping. The dominant soils are well drained to somewhat excessively drained. They have slow to very slow permeability. Most is cultivated, and the rest is in native grasses. The soils are well suited to farming, and respond favorably to good management.

Renfrow - Deep, gently sloping reddish brown soils of the uplands. Surface layer is reddish-brown clay loam, 10 inches thick, overlying a claypan subsoil which is about 26 inches thick. The underlying material is red clay underlain by partly weathered, calcareous shale and clay. Soils are naturally well drained. Permeability is very slow, and water-holding capacity is high. Soils are very high in fertility, but susceptible to water erosion.

Vernon - Composed of shallow, reddish-brown upland soils. The surface layer is reddish-brown, calcareous clay loam, about 6 inches thick. The subsoil is red clay about 9 inches thick. Underlying material is partly weathered shale, clay, and siltstone. Soils are somewhat excessively drained, permeability is very slow, and water-holding capacity is high. These soils are medium to low in fertility, and erode severely when tilled. Typically used for native grasses.

Bethany - Composed of deep, dark-colored, nearly level upland soils. The surface layer is dark grayish-brown silt loam, about 14 inches thick. The subsoil is about 43 inches thick and contains less clay in the upper part than in the lower part. The upper part is dark grayish-brown silty clay loam, and the lower part is brown light clay. The underlying material is brown light clay. Soils are naturally well drained, permeability is slow, and water-holding capacity is high. Fertility of these soils is high. Well suited to cultivation.

Dale-Canadian-Port association - Composed of deep, loamy, nearly level soils formed in alluvium. The dominant soils of the association are well drained, and have moderate to moderately rapid permeability. The soils are well suited to farming.

Dale - Composed of deep loamy soils. Surface layer is very dark grayish-brown or brown silty clay loam that is about 12 inches thick. The subsoil is about 12 inches thick, and is a dark grayish-brown silty clay loam. The underlying material is brown loamy alluvium. These soils are well drained, and have high water-holding capacity. Natural fertility is high. Well suited to cultivation.

Canadian - Composed of deep, dark-colored soils on alluvium. The surface layer is dark grayish-brown sandy loam about 15 inches thick. The subsoil, which is about 15 inches thick, contains a little more clay in its upper part than in its lower. The subsoil is brown fine sandy loam. The underlying material is loamy alluvium, very friable and calcareous. These soils are well drained, and permeability is moderately rapid. Water-holding capacity is moderate. The soils are about medium in natural fertility, but are susceptible to soil-blowing in tilled areas.

Port - Composed of deep, reddish-brown bottom land soils, subject to occasional flooding. The surface layer is reddish-brown loam about 10 inches thick. Subsoil is reddish-brown loam about 20 inches thick. The underlying material is red, weakly stratified, calcareous light clay loam. It is friable alluvium. These soils are naturally well drained, permeability is moderate, and water-holding capacity is high. Natural fertility is high. Well suited to cultivation.

Dougherty-Norge-Teller association - Composed of gently sloping to strongly sloping or hummocky sand and loamy soils on uplands. The dominant soils in this association are well drained and have moderate to slow permeability. They are generally well suited to farming, and respond well to good management.

Dougherty - Composed of deep, hummocky, sandy upland soils. The surface layer is grayish-brown, neutral loamy fine sand about 4 inches thick. The next layer is to a depth of 22 inches, and is light yellowish-brown loamy fine sand. The subsoil is about 28 inches thick. The upper part is yellowish-red sandy clay loam. The lower part is similar to the upper part, but contains less clay. The underlying material is coarse sandy loam that grades into deep fine sand. These soils are well drained, with moderate permeability. Water-holding capacity is moderate. The soils are low in natural fertility, and are susceptible to water and wind erosion.

Norge - Composed of deep upland soils. The surface layer is reddish-brown loam that is about 12 inches thick. The subsoil is 48 inches thick or more. It contains less clay and is more friable in the upper part than in the lower. The upper part is reddish-brown light clay loam. The subsoil from 16-40 inches is reddish-brown clay loam. Below 40 inches, the subsoil consists of clay loam. Soils are well drained with slow permeability and moderate to high water-holding capacity. They are high in natural fertility, but are subject to both wind and water erosion when tilled.

Teller - Composed of deep brown loamy upland soils. The surface layer is brown fine sandy loam that is about 8 inches thick. The subsoil is light clay loam about 28 inches thick, with more clay in the lower part than in the upper part. The underlying material is loamy. These soils are naturally well drained, permeability is moderate, and water-holding capacity is moderate. Natural fertility is moderately high, but tilled areas are susceptible to both water erosion and soil blowing.

OVERVIEW OF LAND USE

Non-point source pollution is closely related to land use, although other factors such as topography and hydrology are also important. Sources of pollution in the Arcadia watershed are typical of urban watersheds. These sources include limited agricultural practices, construction, lawn and garden maintenance, septic and sewer systems, vehicular traffic, impervious areas, tributary and riparian zone maintenance, and past and present industry.

Agricultural Practices

Agriculture in the watershed is limited. Most of the remaining agricultural areas are becoming more urbanized. The watershed contains numerous ranchettes (one to five acre plots with three to five horses or cattle). The Tinker Creek watershed contains most of the agricultural activity in the watershed. Approximately 1% of the watershed is cropland, and although approximately 32% of the watershed is agricultural related, these areas drain to low flow and ephemeral tributaries; thus, the average portion of the load from agricultural areas is not anticipated to be excessive.

Numerous livestock exist in the basin, primarily horses. Although livestock manure contributes to the nutrient loading and perhaps fecal bacteria concentrations, a more significant impact is on erosion potential. Concentrated livestock overgraze areas, denuding the ground of cover and compacting the soil, reducing permeability and infiltration. Reduction in permeability results in more runoff, increasing erosion. Agricultural practices contribute primarily sediment, nutrients and fecal bacteria to the watershed.

Construction

Urban land use in the Arcadia Lake watershed has grown from 28% of the watershed to 58% in the last fifteen years. Most of this construction has occurred in the City of Edmond, which drains primarily to Spring Creek. Although use of construction best management practices (BMPs) is increasing, erosion from construction has contributed large amounts of sediment and nutrients in the past, and this trend will likely continue. Deltas are observable at the mouths of the Deep Fork, Spring Creek and ephemeral streams which drain from the City of Edmond to Arcadia Lake.

Lawn and Garden Maintenance

The chemicals which beautify lawns and increase garden productivity can cause significant problems to water bodies when they reach the lake. Negative impacts from pesticides and fertilizers arise from improper timing and rates of application. Three or four golf courses exist in the Arcadia watershed. Golf courses are notorious for runoff high in nutrients and pesticides. However, literature specifically outlining BMPs for golf courses is readily available **(King County Environmental Division 1993)**.

Septic and Sewer Systems

The Arcadia watershed contains a large older area of Oklahoma City. Consequently, this area also contains some of the older sewarage lines. Complaints of broken sewer lines and smells emanating from sewers and streams are year round. Although line breaks are addressed by county and city personnel in a timely fashion, sewarage loss to lake tributaries is to be expected, given the urban nature of the watershed.

Impervious Substrates

Impervious land cover is characteristic of urban areas, and has recently emerged as an environmental indicator. Impervious surfaces can be defined as any material that prevents the infiltration of water into the soil. With increased development, the percentage of the land covered by impervious surfaces increases. The paving over of natural areas frequently results in degraded water resources. Impervious substrates do not themselves generate pollution; however, they are a critical contributor to the hydrologic changes that degrade waterways. They are a major component of the intensive land uses that do generate pollution. They prevent natural pollutant processing in the soil by preventing percolation. They serve as an efficient conveyance system that transports pollutants into waterways (**Arnold and Gibbons 1996**). In many cases, increased runoff from impervious areas is shunted into small areas which may discharge to a drainage ditch or storm sewer. The impact is a hydrograph with higher peaks over a shorter time period.

The percentage of land covered by impervious surfaces is determined by land use. In urban residential areas, percentage of imperviousness is inversely related to lot size, going from about 20% with one unit per acre to as much as 65% with eight units per acre. There are two major categories of impervious surfaces: rooftops and transport systems, with the transport system being the dominant component. In general, the rooftop component has less impact than the roadways, which channel the runoff directly into the stormwater system (**Arnold and Gibbons 1996**).

Recent EPA initiatives have addressed the unique problems associated with urban runoff by providing impetus for development of models of urban storm water quality and urban BMPs. These include models such as STORM (**USACE 1977**), SWMM (**Huber and Dickinson 1988**), and the P8 Urban Catchment Model (**Palmstrom and Walker 1990**). Examples of applications for the models include prediction of contaminant concentrations in runoff and optimization of BMP efforts.

Tributary and Riparian Zone Maintenance

One effect of urbanization is a decrease in the amount of open land. This decrease often encompasses riparian areas. Many urban streams lack significant buffer zones. A government survey of 36 BMP programs across the U.S. estimated that 60% of property owners were unaware of the benefits, boundaries, and uses of buffer zones (**Heraty from Schueler 1995**). Benefits of proper buffer zone maintenance include 5% reduction in watershed imperviousness, effective flood control insurance, reduction of stream bank erosion, increased pollutant removal, creation of wildlife travel corridors, and numerous other benefits. Buffer zone removal eliminates the benefits of buffer zone maintenance.

Many urban streams are channelized. In an effort to maximize land available for development, channels are straightened and, to reduce stream bank erosion, artificial substrates such as concrete and gabions line stream channels. This is especially prevalent in urban portions of the Arcadia Lake watershed.

The impacts of channelization are twofold. First, straightening the channel causes increases in velocity, increasing erosion potential. The velocity in storm events often precludes the development of aquatic communities of plants and invertebrates which might further breakdown the contaminants. The force created by moving water which was once broken down gradually by a sinuous channel now impacts fewer points along the stream channel. Most waterways are not adequately protected from erosion. Erosion occurs directly above channelization and at the point where channelization ends. In this way, channelization can drastically increase downstream stream bank erosion. Second, as time of travel is reduced, so is the time needed to deliver sediment to the lake. Loads which were once assimilated before reaching the main water body are now deposited in the main water body.

Industry- Past and Present

Industry, both historical and current, can produce significant non-point source pollution in urban environments. Although industrial point source discharges were diverted out of the basin, non-point source effects of industry are potentially a significant contributor to water quality degradation in Arcadia.

The pre-impoundment survey listed a door and window manufacturing plant, a plastics plant, and a power generating plant as potential industrial sources of pollution in the Arcadia Watershed (**USACE 1975**). Other sources of industrial non-point source pollution deal with impacts of oil and gas well exploration and development. Ground water in the Arcadia area is frequently contaminated with chlorides, which are sometimes linked to oil and gas well development. Several oil wells were inundated with the impoundment of the lake, and little information is available to ascertain whether they were properly capped and whether any structure exists for maintenance of the caps.

Table 9.1 contrasts historical land use to current assessment. Approximate dates are given. Historical land use percentage estimates are consistent with data reported in the Corps of Engineers pre-impoundment environmental impact statement of November, 1975. The 1996 land use estimate was generated by combining City of Oklahoma City and City of Edmond land use maps in a GIS format and extracting generalized land use features by surface area. These data indicate that at the time of impoundment, the watershed was used predominantly for agricultural and rural purposes, and only approximately 28% of the watershed was urbanized. This can be compared with the current data, presented in **Table 9.2.**

Table 9.1 Comparison of land use in Arcadia watershed over time. Note that 1975 land uses of cropland, pastureland, and rangeland are combined in 1996.

LAND USE	**PERCENTAGE WATERSHED ABOUT 1975***	**PERCENTAGE WATERSHED ABOUT 1996***
Forestland	16%	10%
Cropland	05%	32%
Pastureland	30%	
Rangeland	21%	
Urban	28%	58%

[*] Percentages listed are estimates

Current data indicate that over 50% of the Arcadia Lake watershed is urban in use, and that agricultural and rural uses have been decreasing. The trend is consistently toward urbanization and commercialization of agricultural lands. **Table 9.2** details this trend toward urbanization. If the trend toward urban and commercial development continues, it could be expected to have an adverse impact on the lake in the form of increased non-point source loadings, which will be discussed in further detail later in this task.

Table 9.2 Summary of current land use in Arcadia watershed

LAND USE	PERCENTAGE OF WATERSHED[*]
SINGLE FAMILY RESIDENTIAL	37.14
MULTI FAMILY RESIDENTIAL	2.38
COMMERCIAL/MIXED	7.05
OFFICE	1.63
INSTITUTIONAL / PUBLIC	4.97
INDUSTRIAL	3.08
PARKS/ OPEN SPACE	10.29
TRANSPORTATION CORRIDORS	1.59
AGRICULTURE	31.59
OIL AND GAS	0.11
UNKNOWN	0.16
Watershed area totals	100.00

[*] Percentages listed are estimates

Statistical analysis was done on the stormwater data to determine if there were any particular “hot spots” within the Arcadia Lake watershed that were contributing higher levels of non-point source pollutants to the lake than other sites. Twelve sites were sampled (see **Figure 1.1** for exact location of sample sites) on 18 occasions, 14 of these during periods of stormflow. Testing was done for nutrients, bacteria, and organics. Non-parametric testing was used, as the data were not normally distributed. No significant difference was found in any parameter between the different sample sites tested. No sites appear to be significantly different in non-point source contribution to the lake.

NON-POINT SOURCE POLLUTION LOAD ESTIMATES

Modeling was done to determine the percent loadings from non-point source polluters. These figures are based on data collected from 2-18-97 through 9-23-97. Samples were taken on 18 occasions during this period, 14 of which were rainfall events. Baseflow was determined from streamflow data collected at Site 7 by the United States Geological Survey (USGS). No data on streamflow were available from the other sites, so the baseflow figures obtained from site 7 data were used to extrapolate the baseflow and stormflow loadings from the other key sites, based on drainage area of the site. Although the figures obtained by extrapolation are not exact, the percentages obtained using this method can be assumed to be a reasonable estimation of the actual stormflow loadings. Analysis of these figures shows that most of the organic and nutrient load entering Arcadia Lake (94.6 to 99.3%) comes from non-point source pollutants following rainfall events. **Table 9.3** shows the estimated annual load partitioned by stormflow events vs. baseflow. This data was plugged into **Vollenweider's** (**1968**) model predicting lake trophic status based on annual external phosphorus load versus mean depth. Eutrophic conditions for a lake with a mean depth of 5.1 meters is predicted with an areal phosphorus load value of 0.1 g/m^2/yr. Arcadia Lake's areal phosphorus load estimate is 4.67 g/m^2/yr; a value far into the eutrophic range.

Table 9.3 Annual load estimate partitioned into baseflow and stormflow with relative percentages

		Suspended Solids	Total P	Total N
stormflow	kg	25,330,934	32,114	146,240
	%	99.3%	98.5%	94.6%
baseflow	kg	169,174	475	8,276
	%	0.7%	1.5%	5.4%
Total estimated load	kg	25,500,108	32,589	154,516
	%	100%	100%	100%

Fate and Impact of Inflowing Stormwater

Nutrient load estimates indicate that 24,321,422 kg suspended solids, 27,123 kg total phosphorus and 96,922 kg total nitrogen are assimilated by the lake per year. On an annual basis these values translate into lake sequestering of 96 % suspended solids, 84% total phosphorus and 63% total nitrogen from stormwater. The high loadings and retention by Arcadia Lake draws the question of fate and impact to the lake by stormwater. The following section attempts to draw out annual generalities from available data.

Increased density of stormwater because of cooler temperature and greater solids concentration supports the idea of a plunging inflow. **Figure 10.35** shows suspended solids were consistently higher in the hypolimnion than the epilimnion. This further supports a plunging inflow. A hypothesis was drawn that the parameters of suspended solid, total nitrogen and total phosphorus stormwater plunge as they enter the lake and settle out as they approach the dam.

To address these questions, a statistical investigation of the current lake data was performed. All data were log transformed in an attempt to normalize the data and allow for parametric testing procedures when possible. Prior to executing any interpretive statistical test, the Anderson-Darling test for normality was applied. The Anderson-Darling test is an empirical cumulative distribution function (ECDF) based test (**Ryan and Joiner, 1976**). When the p-value exceeds 0.100, the tested data set was assumed to be normal. When a data series was determined to not be normal in distribution, the Kruskal-Wallis k-sample test was applied to test for significant differences (**Lehmann, 1975**). When a data set was assumed to be normal, a one-way analysis of variance was performed. Both parametric and non-parametric tests assume significance when the p-value is 0.05 or less. **Table 9.4** summarizes specific tests of the lake data.

First, mean lake concentrations and mass for suspended solids, total nitrogen and total phosphorus were compared to the 7 day total of previous inflow volume. No statistical significance was noted between lake water quality and volume of inflowing water. This suggested that the bulk of these parameters were lost from the water column. Next, lake surface and bottom sample analysis of total nitrogen, total phosphorus and suspended solids were examined to look for differences based on a plunging stormwater flow. The entire data set was examined without factoring in rainfall, revealing significant differences between surface and bottom samples. Additional testing showed that the surface samples were significantly less than the bottom samples for suspended solids and total phosphorus. The entire data set was then segregated into wet (prior runoff) versus dry (lack of prior runoff) sample dates and tested for differences. Results of these tests showed significant differences for suspended solids and total phosphorus following rainfall events. This supports the idea of plunging stormwater. Total nitrogen did not follow this pattern. A plausible explanation is the diffusive properties of dissolved nitrogen did not follow a plunging inflow. A relatively higher proportion of dissolved nitrogen (55% of the total) and greater proportion of particulate associated phosphorus (greater than 55% of the total) in the stormwater supports this assertion.

Table 9.4 Summary of statistical test results examining impact of inflowing stormwater on lake water quality.

Comparison (data type)	**Parameter Tested**	**p-value**	**Significance**
Surface vs Bottom (all data)	Suspended solids	0.000	Yes
Surface vs Bottom (all data)	total nitrogen	0.438	No
Surface vs Bottom (all data)	total phosphorus	0.000	Yes
Wet vs Dry (all data)	Suspended solids	0.012	Yes
Wet vs Dry (all data)	total nitrogen	0.334	No
Wet vs Dry (all data)	total phosphorus	0.001	Yes

Additional segregation of the wet sample dates was performed to examine relative impact. Results of these tests showed that for the surface samples, site 5 was significantly greater than all other sites. Test results for the bottom samples showed this impact to extend to site 4, approximately 1.75 miles downstream of site 5. These results suggest inflowing stormwater directly impacts water quality at site 5 (see **Figure 10.1** for map of sample sites). By the time the inflow has reached site 4, stormwater has plunged and significantly effects solids and phosphorus water quality at the lake bottom. This supports settling of the stormwater solids fraction (as measured by phosphorous and suspended solids) occur as it flows towards the dam.

Figures 10.37 and **10.38** show how water transparency, measured by secchi depth and turbidity, varies across the lake. In general site 5, the upper end of the Deep Fork arm, has the least water clarity, and site 1, at the dam, has the greatest water clarity. **Figure 10.39** illustrates how chlorophyll-a concentration varies between sites. Here the highest values are noted at site 5. It appears that the influx stormwater has a net effect of stimulating algae growth.

Detailed lake sampling occurred on July 9, 15 and 23 1996 to bracket the effect stormwater inflows might have on lake water quality. Unfortunately, one sequence of three consecutive sample events was not enough for statistical testing; however, differences were noted by simple examination. At sites 1-4, secchi depth and chlorophyll-a increased and turbidity decreased after a stormwater inflow event. Site 5 showed an increase of turbidity and decrease of chlorophyll-a and secchi depth following a storm event. These data confirm the influence of stormwater inflows to site 5, and also confirm the stimulation of algae growth at all other sites. **Table 9.5** provides a summary of this site-by-site comparison.

Table 9.5 Summary of water quality changes by sample site following a storm event.

SITE	Secchi Depth (inches)		Turbidity (NTU)		Chlorophyll-a (µg/L)	
	Initial	Change	Initial	Change	Initial	Change
1	19.7	+ 7.9	8.8	- 1.8	12.1	+10.9
2	22.4	+13.0	10.3	- 1.8	14.0	+15.6
3	18.5	+11.4	12.0	- 4.9	15.6	+ 7.2
4	15.4	+ 8.6	20.7	- 6.2	19.7	+ 4.7
5	26.8	-15.8	15.7	+36.2	39.4	-14.8

Initial = *value prior to the storm event*

Change = *direction and amount of variation following the storm event.*

A close examination of nutrient constituents before, during and after a storm event showed few discernable differences, with the exception of ammonia nitrogen. Prior to the storm event, surface ammonia nitrogen was not detected. Following the storm event, surface ammonia nitrogen was detected at every site. Two strong possibilities exist to explain the increased detection of ammonia. Inflow of soluble nitrogen in the form of ammonia could diffuse throughout the water column in a destratified reservoir. Turbulent flow of stormwater across the lake sediment would also serve to transfer ammonia from the lake sediment into the water column. **Figure 10.55** plot clearly shows that nitrogen is the predicted limiting nutrient for all sites during July 1996. During periods of nitrogen limitation, ammonia enrichment of Arcadia Lake by stormwater flow appears to stimulate algae growth.

CONCLUSIONS

It is likely that the bulk of the phosphorus washing into the lake is associated with the particulate fraction. Most of this particulate seems to settle out as it approaches the dam with little direct impingement upon the epilimnion. Additional examination of water quality data indicates that dissolved nutrients may be a greater determinant of phytoplankton growth than the particulate fraction. In-lake dynamics may be an indirect contributor to dissolved nutrient enrichment following stormwater events. A vigorous plan to control both dissolved nutrients, particulate nutrients and in-lake suspension would be needed to produce a discernable change in phytoplankton growth based on external loading functions alone.

Arcadia Lake is a reservoir impacted by urban non-point source pollution. Specific water quality concerns in the watershed include nutrients, sediment, pesticides, metals, fecal bacteria, and trash. Sources of these pollutants include the large numbers of people and intense land use practices in a concentrated area. These sources include "urbanized" agricultural practices, construction, lawn and garden maintenance, septic and sewer systems, tributary and riparian zone maintenance, impervious substrates, and current and historical industry. Pollutants from these sources are exacerbated by high stormflow velocity rushing into the lake.

TASK TEN - LIMNOLOGICAL INVESTIGATION

HISTORICAL INFORMATION

Pre-impoundment reports were completed by Oklahoma State University (OSU) and the U.S. Army Corps of Engineers (USCOE). These reports contribute historical insight into water quality aspects predicted for the lake. Predictions given by pre-impoundment reports are quantified by later water quality reports and current data. Post-impoundment collections of water quality data have been completed by USCOE, Oklahoma Water Resources Board (OWRB), University of Central Oklahoma (UCO), Oklahoma Department of Environmental Quality (DEQ), Oklahoma Conservation Commission (OCC), and Oklahoma Department of Wildlife Conservation (ODWC). Because of its close proximity to the lake, UCO has conducted numerous studies of Arcadia Lake and will continue to study the lake in the future. The DEQ has regularly sampled fish flesh to determine the extent of toxic contamination in the reservoir. Data collected by the OCC as part of their historical lake sampling program are also referenced. The following narrative summarizes this information.

Pre-impoundment Reports

In 1972, Oklahoma State University conducted an in-depth water quality study of the Deep Fork River, prompted by concerns of how future beneficial uses of Arcadia Lake might be affected by water quality. This study found that concentrations of ammonia, nitrate, chloride, aldrin, lindane, DDT, endrin, iron, manganese, and lead often exceeded surface water criteria for public water supplies (**OSU, 1972**). Results of this study prompted EPA to recommend that water in the proposed reservoir not be used for public, industrial, or recreational use. Following recommendations from the OSU study, point source pollution discharges were diverted out of the proposed Arcadia Lake watershed. Because of these actions, the OSU study was not considered applicable to the future water quality of the proposed Arcadia Lake.

In 1977, personnel from the U. S. Army Corps of Engineers Waterways Experiment Station (WES) were contracted by the Tulsa district of the USCOE to respond to potential water quality problems based on the O.S.U. study. Corps personnel conducted a predictive water quality study for Arcadia lake that combined existing and newly generated data. By applying mathematical predictive models, the WES concluded that water quality would meet the use requirements of industrial and public water supply. Specific conclusions are as follows:

- The lake would be thermally stratified intermittently during the summer months, but no permanent or stable stratification was expected;
- During the periods of stratification the hypolimnion may become devoid of dissolved oxygen;
- Iron and manganese concentrations were expected to exceed drinking water standards in the head waters or in the hypolimnion near the dam during stratification;
- The total dissolved solids were expected to exceed standards throughout the impoundment, and it was suggested this be taken into account during water treatment plant design;
- Pesticides and heavy metals were not expected to be a major problem for purposes of the project;

- Fecal coliform were expected to exceed standards in the headwater areas and may be high in the impoundment's upper third during storm events.

Because of the predicted high fecal coliform levels, placement of recreation areas were suggested to minimize impact to recreationalists. By comparing the proposed project to similar lakes, two to three algal blooms per year were expected, depending on weather patterns. These blooms could cause taste and odor problems in the water supply. It was suggested this also be taken into account during the water treatment plant design. After the predictions, the USCOE suggested a stringent sampling of the lake before, during, and after construction of the impoundment to assess the water quality.

Post-impoundment Reports

In 1989, the Tulsa District COE conducted a water quality study of Arcadia Lake. This study was a follow up of the predictive study done in 1977, and concluded that lake water quality was acceptable for municipal, industrial, and recreational use. It also showed that manganese concentrations in the lake consistently exceeded EPA criterion of 50 μg/L for domestic water supplies, and that occasional algal blooms during spring and summer caused taste and odor problems with drinking water (**USCOE, 1994**). The study also determined that the lake was eutrophic by the chlorophyll-a and total phosphorous levels (**Carlson, 1977**) . Eutrophication of the lake at two years after impoundment was said to be related to agricultural land use practices within the watershed. This report also stated that it is unlikely that the conditions of the lake will change because of the turnover time of the lake and the low sedimentation rate. The measurements of the 1989 USCOE report will be compared to the values completed during this report to suggest the progression of water quality since 1989.

Sediment analysis by the USCOE revealed contamination by mercury, lead, and pesticides (**Bates, 1989**). The highest average mercury concentration (>0.1 mg/kg dry weight) was found in the Spring Creek arm. The highest average lead concentration (>60 mg/kg dry weight) was found in the Deep Fork arm. The highest average manganese concentration (>500 mg/kg dry weight) was found in the Deep Fork arm and the central pool by the dam. The distribution of sediment contamination in the lake suggested that each tributary contributed large loads of metal contamination to Arcadia Lake.

In 1992, OSU conducted a water quality analysis focusing on the trophic status of the lake and the odors in the water treatment process. The City of Edmond commissioned the study to assess the lake's stratification patterns and algal biomass in order to determine possible causes of musty odors noticed in the water treatment process. The lake was sampled between June and September in 1992 and 1993. Four stations were established throughout the lake as sampling locations. The conclusions drawn from the study indicated that the lake was high in turbidity and nutrients, particularly phosphorus and ammonia. Based on the results of the total P and total N levels the lake was classified as mesotrophic-eutrophic, and on the basis of chlorophyll-*a* the lake was eutrophic (**Toetz, 1993**). Other findings of the 1992 OSU study indicated that the lake was light limited and not nutrient limited.

In 1992, Dr. David Bass of University of Central Oklahoma published a report on the benthic macro invertebrates in Arcadia Lake. The data were recorded over a four-year period, spanning from pre-impoundment through post-impoundment. Measurements of temperature, dissolved oxygen concentration, pH, specific conductance, and secchi disk depth were recorded. The physicochemical data characterized a turbid reservoir with variable water quality (surface dissolved oxygen percent saturation showed a minimum of 57% and a maximum of 116%; specific conductance showed a minimum of 340 µmhos/cm and a maximum of 1350 µmhos/cm). Using the benthic surveys, this study reported a variable community structure with low diversity and relatively low abundance, and concluded that pollutants entering Arcadia Lake were keeping benthic community populations and diversity low.

Arcadia Lake was monitored by the OWRB as part of the 1992 State Lake Water Quality Assessment (LWQA). In the 1992 LWQA, it was determined that Arcadia Lake was eutrophic. The lake average chlorophyll-*a* value in 1992 was 15.6 µg/L; in 1993, the average value was 21.7 µg/L. In May of 1992, it was noted that an anoxic hypolimnion had already formed by the dam. Follow-up monitoring in July of 1992 showed that the anoxia had expanded to all three sample sites on Arcadia Lake. Maximum dissolved oxygen values at all lake sites ranged from 119% to 145% saturation. These dissolved oxygen values reflected the ongoing eutrophication process in Arcadia Lake.

Surveys by the Oklahoma Department of Wildlife Conservation indicate that the abundance of largemouth bass in Arcadia Lake has declined since 1988. This population decline has been attributed to low survival of young-of-year bass. Strict state regulations for largemouth bass harvest were implemented to increase the lake population. Also, a revegetation project was begun to provide habitat for the young bass. Preliminary results of the project are favorable, with minor problems arising from consumption of the vegetation by resident herbivores.

A lake sampling program, which included Arcadia Lake, was conducted by the Oklahoma Conservation Commission (OCC) in the summer of 1987 through the spring of 1993 . Grab samples were taken from the dam face, and parameters tested included chlorophyll-*a*, turbidity, and conductivity. The overall average chlorophyll-*a* was 19.3 ppb. The Carlson’s trophic state index from the chlorophyll-*a* value is 59, which indicates a eutrophic state. The overall average values during the study period were 14 (NTUs) for turbidity and 436.5 (micromhos) for conductivity.

Sampling of fish flesh was conducted by the Oklahoma Department of Environmental Quality (ODEQ) from 1987 through 1993. In 1987, chlordane and mercury were detected in fish flesh tissue at levels which exceeded the Food and Drug Administration (FDA) action level for chlordane. Mercury was detected at levels which exceeded the Oklahoma State Department of Health (OSDH) concern level. Subsequent sampling in 1988, 1989, 1990, 1991, and 1992 indicated that chlordane contamination continued to be a serious problem (detection levels exceeding the OSDH concern level). Sampling in 1993 failed to detect chlordane in levels which exceeded any concern levels, but history demonstrates that chlordane contamination is significant in Arcadia Lake and should be closely studied to determine possible sources.

Summary of Historical Information

Historical studies on Arcadia Lake consistently show water quality symptoms of an impacted reservoir. Many of the problems predicted in the pre-impoundment study have now been confirmed and quantified by historical data. Residue from eliminated point source loadings and non-point source loadings of nutrients and contaminants have been seen in the physicochemical, sediment, and fish flesh analyses.

Hydrology

An estimate of the hydraulic residence time has been constructed using COE lake and USGS stream flow data. The entire 20 month monitoring period was used to allow for concurrent nutrient budgeting. Hydraulic residence time is estimated by dividing the reservoir volume from outflow (or release) volume and then weighting this result by the monitoring period, 1.6 years. This calculation estimates an annual hydraulic residence time of 0.29 yr^{-1} (or 3.48 months). **Table 10.1** summarizes hydraulic variables used to estimate hydraulic residence time.

Table 10.1 Parameters Estimated for Hydraulic Residence Calculation of Arcadia Lake Feb.1996 - Sept.1997. All units in acre-feet unless otherwise noted.

WATER GAINS		**WATER LOSSES**	
Estimated Runoff	69,648	Dam Releases	53,863
Direct Precipitation	7,357	Water Supply	5,741
Total	**77,005**	**Total**	**59,604**
Gains - Losses(Outlet Flow) = 15,804		**Lake Volume = 27,380**	
Calculation = (27,380/59,604)/1.6 years			

ESTIMATED HYDRAULIC RESIDENCE TIME (LAKE VOLUME/OUTLET FLOW)/YEARS = 0.29 YR^{-1}

Sedimentation

The Tulsa District COE performed a sediment data survey of Arcadia reservoir in December, 1997 (**COE, 1998**). 18 ranges were used, partitioned between the Deep Fork River arm (7.2 miles) and the Spring Creek arm (3.1 miles). Results of this survey are compared to pre-impoundment measurements to evaluate sedimentation processes within the lake. Arcadia Lake is partitioned by elevation (MSL) into three distinct pools: flood pool (1029.5 - 1006.0), conservation pool(1006.0 -970.0) and inactive pool (970 - 957). The conservation pool has been allocated to municipal water supply, recreation and sedimentation. **Table 10.2** displays sediment survey results.

Table 10.2 Tulsa District COE Sediment Survey Results. Areas are in acres, while volume is in acre-feet.

Lake Pool (elevation)	**1986**	**1997**	**Change**	% Change
Flood Pool Area (1029.5 MSL)	3718	3739	21	
Flood Pool Volume (1029.5 to 1006 MSL)	61524	61440	-84	-0.14%
Conservation Pool Area (1006 MSL)	1765	1725	-40	
Conservation Pool Volume (1006 to 970 MSL)	30466	29517	-949	-3.11%

Maximum Depth (from 1006 MSL)	49	44	-5.0	
Mean Depth (from 1006 MSL)	17.3	17.1	-0.1	
Inactive Pool Area (970 MSL)	107	78	-29	
Inactive Pool Volume (970 to 957 MSL)	317	188	-129	-40.69%
Total Change in volume (from 1029.5 MSL)			-1162	-1.26%

Overall, less than 2% of the lake volume has been lost to sedimentation, with an estimated rate of 105 acre-feet per year. 4,290 acre-feet of the conservation pool has been allocated to sedimentation. Approximately 22% of this sediment pool has accumulated sediment at a rate of 85 acre-feet per year. Should this rate stay constant over time, the remaining 3,341 acre-feet of sediment volume will be full by the year 2036. When the sediment allocation is full, additional sedimentation may effect recreation and water supply uses.

Sediment deposition was also partitioned on a percentage basis by depth range and reach. A notable aspect of this data was that scouring occurred 3 to 8 feet above the conservation pool and the upper most reaches of the lake. High velocity inflowing stormwater is the most likely explanation for this scouring. Although negligible on a volume basis, the soil scoured out of flood pool is being deposited into the conservation pool. Greater than 1/4 of all deposited sediment was within the first six and one-half feet of the conservation pool. This shows that the bulk of stormwater inflowing sediment is deposited soon after reaching the lake. Examination of sediment deposition by reach was harder to interpret, but clearly shows that 65% of the accumulated sediment is deposited between the Phase I sample Site 4 and the Memorial Street bridge.

Overall, these data show sediment deposition in Arcadia Lake to be a function of inflowing stormwater, and that deposition of the sediment is concentrated toward the upper reaches of the lake. The predictability of sediment deposits indicates that each new load of sediment functions to cover or bury the previous load.

Current Limnological Data

The current limnological data set is composed of data from February, 1996 through September, 1997 (**Table 10.3**). The data were collected at five sampling points within the lake (**Figure 10.1**). The results of the raw data collected for field profiles are in **Appendix B**. Field observations made at each sample event were site number, instrument type and number, date, time, estimated air temperature, estimated wind speed and direction, estimated cloud cover, reservoir conditions, and observations. These data sheets are available and on file with the OWRB. Field parameters collected include date, time, temperature, dissolved oxygen, pH, specific conductance, salinity, percent saturation of dissolved oxygen, redox potential, depth, and secchi depth. Water samples collected in the field were delivered to the laboratory for analysis of chlorophyll-*a*, total alkalinity, total hardness, settleable solids, suspended solids, total dissolved solids, sulfate, ammonia-nitrogen, kjeldahl-nitrogen, nitrate-nitrogen, nitrite-nitrogen, total nitrogen, ortho-phosphorus, and total phosphorus. **Appendix C** contains all laboratory data by site and date. Characterization of the biological quality of Arcadia Lake was accomplished through analysis of phytoplankton, zooplankton, and benthic macroinvertebrates. Algal and zooplankton assemblages were enumerated by numerical density and biovolume of each identified plankton. Stormwater data were collected 18 times during the period between February 18, 1997 and September 23, 1997. These collections were taken 14 times during high flow events and 4 times during low flow. The stormwater samples were analyzed for bacteria, organics, nutrients, and metals. The analysis is included in the non-point source discussion of this report.

The purpose of the collected data was to provide the OWRB with essential tools to assess the current conditions of the lake and to propose possible solutions to the complex problems of Arcadia Lake. An alternative purpose for monitoring water quality during lake diagnosis was to collect baseline data for comparison with similarly collected data after completion of lake restoration measures.

Table 10.3 Arcadia Lake Water Quality Sample Collection Dates

29 Feb 96	19 Dec 96
15 Mar 96	09 Jan 97
01 Apr 96	21 Jan 97
22 Apr 96	11 Feb 97
07 May 96	25 Feb 97
20 May 96	12 Mar 97
03 Jun 96	26 Mar 97
17 Jun 96	15 Apr 97
09 Jul 96	29 Apr 97
15 Jul 96	14 May 97
12 Aug 96	27 May 97
27 Aug 96	10 Jun 97
10 Sep 96	24 Jun 97
24 Sep 96	08 Jul 97
08 Oct 96	28 Jul 97
23 Oct 96	12 Aug 97
05 Nov 96	26 Aug 97
19 Nov 96	16 Sep 97
03 Dec 96	30 Sep 97

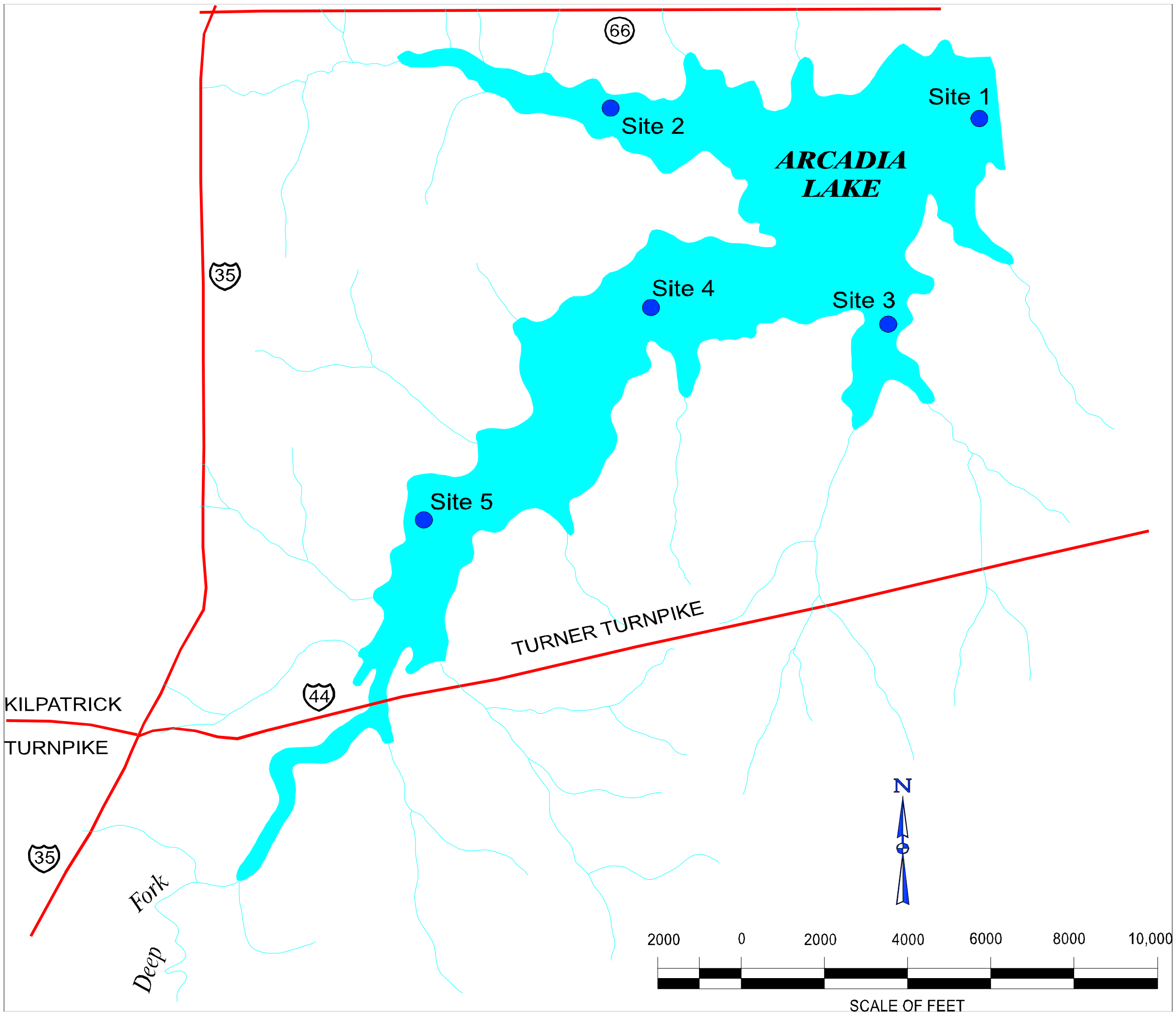

Figure 10.1 Arcadia Lake Water Quality Sampling Site Locations

Data Summary

Table 10.4 summarizes water quality data collected from all five sites on Arcadia Lake during monitoring. Below detection limit values were assigned the value of zero to calculate average annual values. The following narrative describes this data with figures which graphically represent the lake's current status.

Table 10.4 Tabular summary of lake surface water quality data accumulated from February 1996 through November 1997 for Arcadia Lake. (DL = detection limit)

Parameter	Mean	Minimum	Maximum
Secchi Depth (cm)	48.21	7.62	130
pH	8.13	6.90	10.17
Specific Conductance (µmhos/cm^2)	408.37	6.00	732.00
Alkalinity (mg/L)	158.34	132.00	201.00
Total Dissolved Solids (mg/L)	242.02	198.00	321.00
Suspended Solids (mg/L)	17.27	3.00	67.00
Settleable Solids (mg/L)	0.02	<DL	0.70
Sulfate (mg/L)	27.46	<DL	49.40
Total Phosphorus (mg/L)	0.072	0.011	0.229
Ortho-phosphorus (mg/L)	0.012	<DL	0.05
Total Nitrogen (mg/L)	0.926	0.520	1.838
Nitrate (mg/L)	0.2997	<DL	1.40
Nitrite (mg/L)	0.140	<DL	0.010
Ammonia (mg/L)	0.0291	<DL	0.422
Turbidity (NTU)	15.70	4.79	139
Chlorophyll-*a* (µg/L)	16.04	1.30	46.52

Trophic State Index

Trophic state can be loosely defined as the nutritional status of a lake, and can provide insight into the productivity and health of a lake. The Trophic State Index (TSI) is a summary statistic used because of its convenience, which outweighs the disadvantage of information lost in summarization (**Reckhow 1979**). **Carlson (1977)** developed one of the most widely used TSI, with lakes classified on a scale of 1 to 100. Carlson delineated this scale into four major trophic categories: 0-40 Oligotrophic, 40-50 Mesotrophic, 50-60 Eutrophic, 60-100 Hypereutrophic. Each major division of 10 TSI units represents a doubling in algal biomass. Carlson prescribed a TSI for chlorophyll-*a* as the primary index to best describe a lake's trophic state. Along with the chlorophyll-*a* TSI, Carlson proposed other indices for secchi disk depth and total phosphorous concentration to further describe a lake's status. Epilimnetic summer season variables were designed as the input values for Carlson's TSI. Uniform numbers among all three TSI indices establish a confidence in the trophic state described. Differences between the indices may obscure the lakes trophic status, but can provide insight to various processes and components of the lake and the watershed.

Arcadia Lake's median TSI for chlorophyll-*a* classified the lake as eutrophic. The median TSI value for chlorophyll-*a* ranged from a minimum of 53.7 at site 1 to a maximum of 59.2 at site 5. Site 5's value, approaching a classification of hypereutrophic, and site 4's value as the lakes second highest TSI, show the influence of the Deep Fork River upon the lake (**Figure 10.2**). The Spring Creek tributary, site 3, was calculated to have the third highest median TSI.

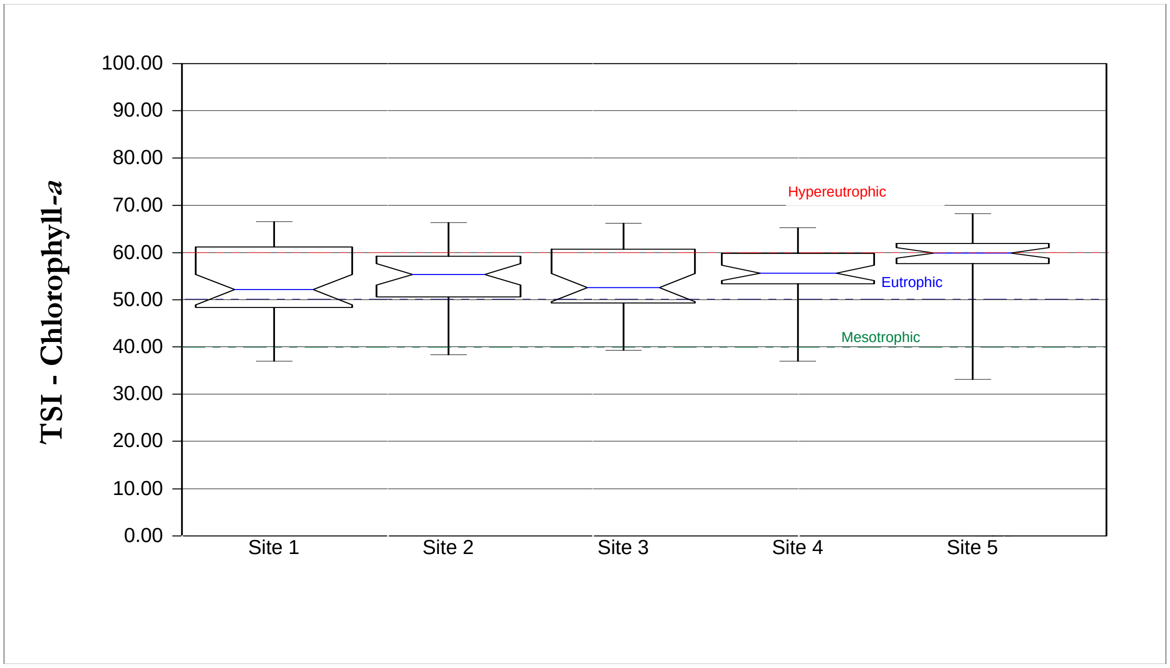

Figure 10.2 Box plot of Arcadia Lake Carlson's Trophic State Index for Chlorophyll-*a* with median values

The Carlson TSI for total phosphorous classified Arcadia Lake as hypereutrophic at all five sites (**Figure 10.3**). Similar to the chlorophyll-*a* TSI, the highest median TSI levels were found at site 5 (72.00), with the next highest at site 4 (66.27). This again shows the influence of the Deep Fork tributary upon Arcadia lake. The lowest median TSI values were at Site 1, with a value of 61.01, which is classified as hypereutrophic.

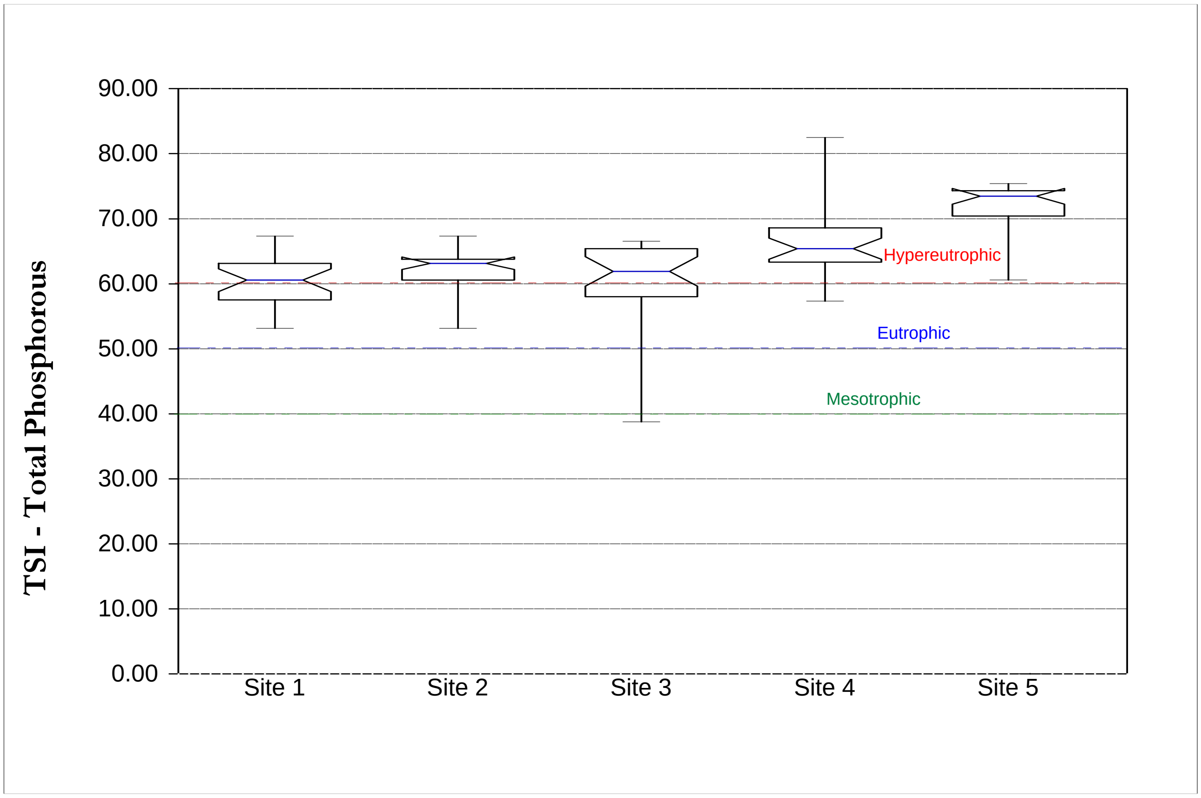

Figure 10.3 Box plot Arcadia Lake Carlson's Trophic State Index - Total Phosphorous with median values

Arcadia Lake mean TSI values for secchi disk depth were the highest of the three TSI calculations, placing the lake well into the hypereutrophic zone at all stations (**Figure 10.4**). Carlson stated that this parameter would not provide a proper assessment of the algal biomass in turbid lakes. It would be inaccurate to classify Arcadia Lake by this TSI calculation because of the high turbidity levels. This value can show the influence of the tributaries on secchi disk depths. Again, the Deep Fork tributary to the lake had the highest median TSI values, with 79.79 at site 5 and 73.56 at site 4.

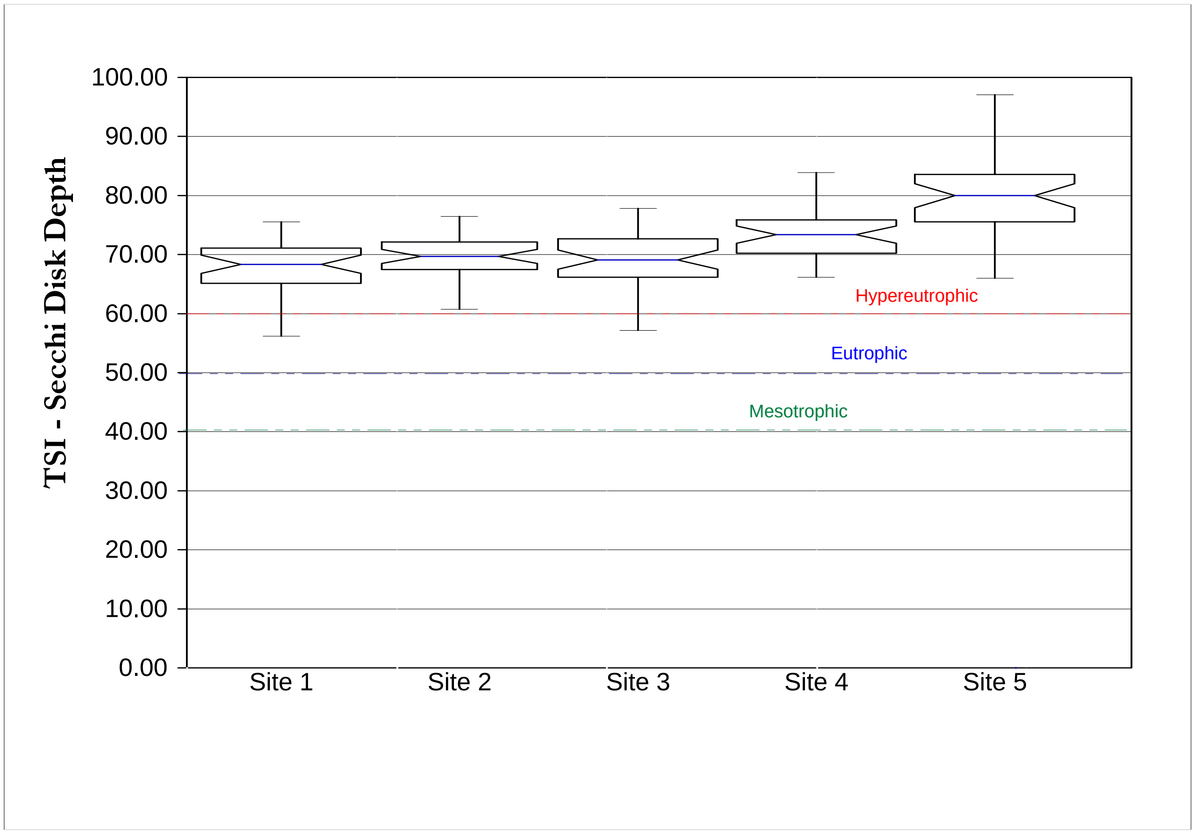

Figure 10.4 Box plot of Arcadia Lake Carlson's Trophic State Index - Secchi Disk Depth with median values

The TSI values of Arcadia Lake can be compared to provide insight into the processes of the lake. The TSI for total phosphorus is higher than the TSI for chlorophyll-*a*, indicating that the lake has a potential for higher primary productivity than what is expressed in the chlorophyll-*a*. The fact that the actual primary productivity was lower than predicted indicates that there is another limiting factor. Factors most commonly limiting primary productivity include nutrient availability, photic zone, and grazing of plantivorous animals (**Wetzel 1983**). With consideration of the secchi disk depth TSI, it can be concluded that light availability is the primary factor limiting productivity. This is a common scenario in turbid lakes. Although there were some differences in the TSI values, the chlorophyll-*a* TSI should be given the most weight, and this would classify Arcadia Lake as eutrophic.

Water Temperature

Water temperature has a dramatic impact on processes that occur within the lake. Water converts light energy into heat. The amount and distribution of the heat depends upon factors such as wind energy, currents, basin morphometry and water losses. Resulting patterns of density-induced stratification influence physical and chemical properties. Cycles of lakes, in turn, govern their productivity and decomposition (**Wetzel, 1983**). Many lakes experience thermal stratification, which simply put, consists of a layer of warm, relatively light water at the surface and a cold, dense layer at the bottom. These layers are separated from each other by a transition layer with a strong density gradient. The density difference is often thermally induced, but can also be affected by suspended and dissolved solids. The upper layer is the epilimnion, the middle layer is the metalimnion, and the bottom layer is the hypolimnion. The density gradient in the metalimnion prevents the water of the epilimnion from circulating any deeper, thus sealing off the hypolimnion from the lake surface. This scenario was observed in Arcadia Lake during the warm months.

Surface water temperatures of Arcadia Lake were typical of an Oklahoma reservoir throughout the year. The temperature minimum was achieved in December, 1996. The temperature increased throughout the summer, and the maximum was recorded in late July, 1997. In May of 1996 and 1997, vertical temperatures at each sampling location varied little from surface to bottom (**Figure 10.5-6 and Figure 10.7-11**). By mid-June of both years, Arcadia Lake demonstrated weak thermal stratification. The most distinct stratifications were seen on 17 Jun 96 and 24 Jun 97. Because Arcadia Lake is shallow, strong winds and inflowing stormwater often broke up the stratification, and it reformed during calm periods. Arcadia Lake's strongest stratification was near the dam, and weaker stratification was at the shallower samples sites as expected. This makes Arcadia Lake an exception to the usual framework of the turnover event. The turnover event usually occurs when a cold front alters lake surface temperatures, making the density uniform throughout the lake and allowing for mixing. An atypical break up was evident on 28 Jul 97 when the lake was well mixed with no stratification present, after being deeply stratified on 8 Jul 97. Weak stratification reestablished by 12 Aug 97. The wind-driven atypical stratification breakup may explain the taste and order problems experienced by water treatment plant employees, as noted in a 1995 report concerning Arcadia Lake (**Toetz, 1995**). We assume that the data represents typical conditions because thermal regimes are dictated by climatic conditions. Because of the numerous periods of stratification, we classified Arcadia Lake as a warm polymictic lake (**Wetzel 1983**).

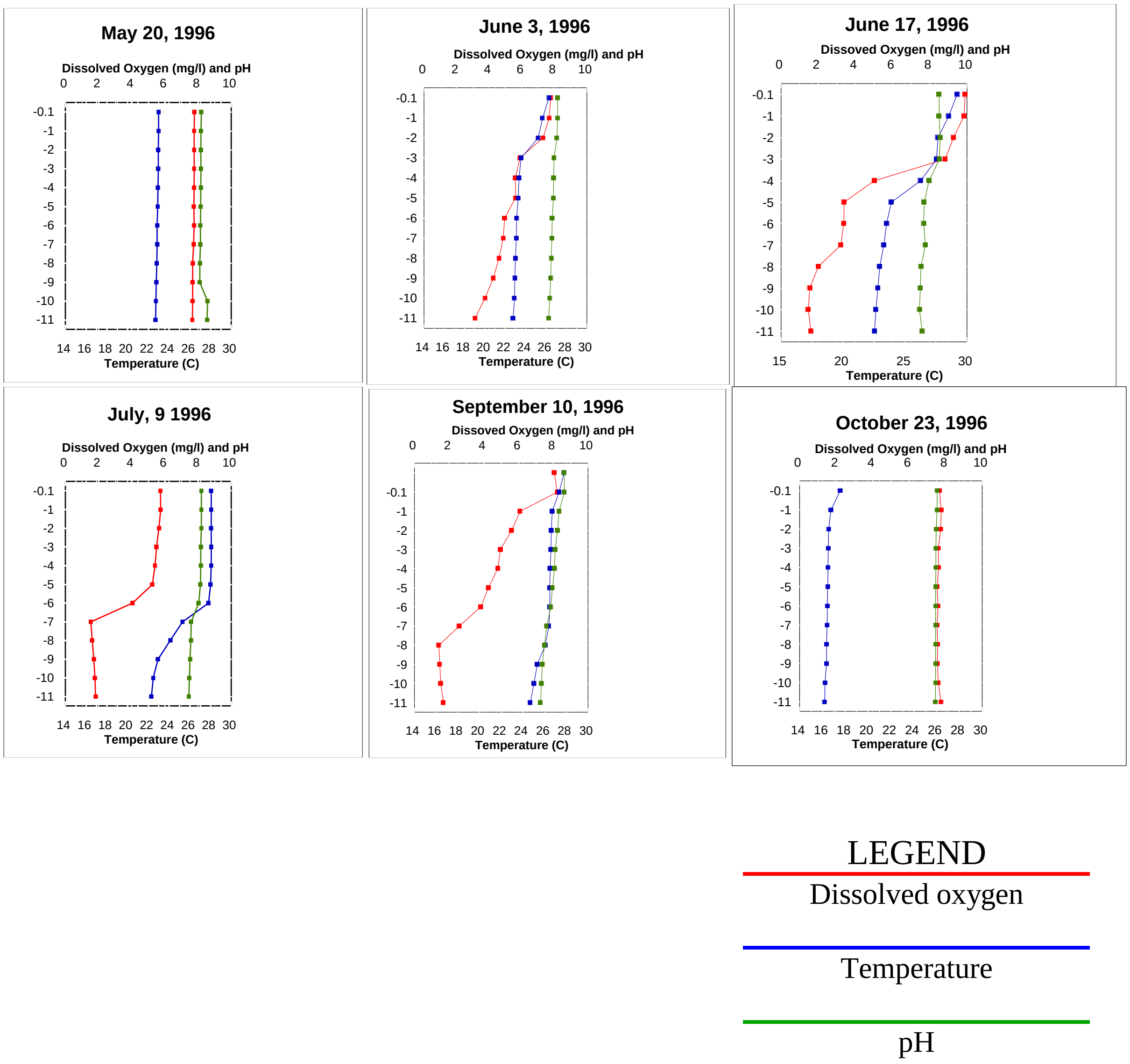

Figure 10.5 Arcadia Lake stratification patterns, 1996. Units are in meters.

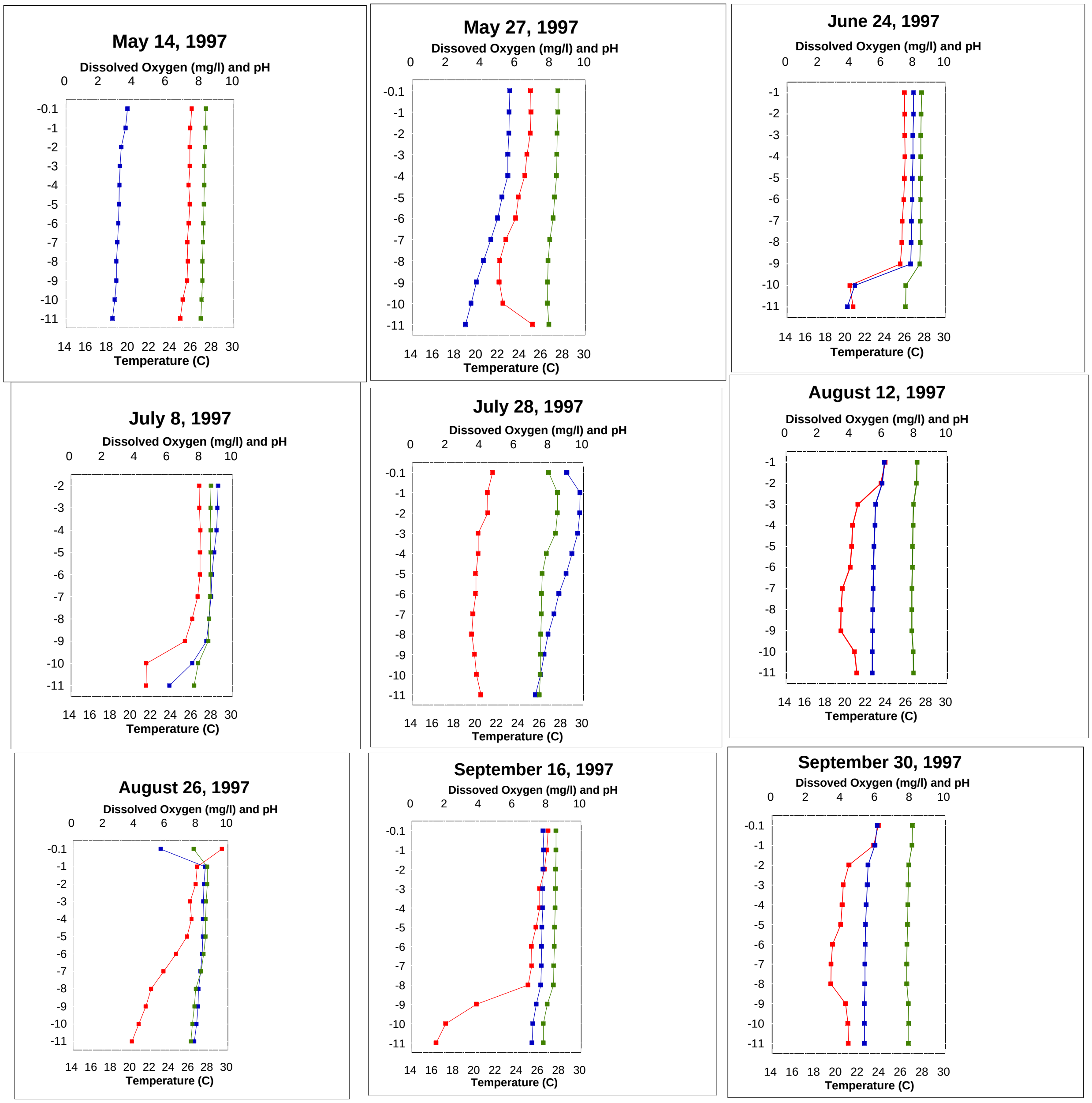

Figure 10.6 Arcadia Lake stratification patterns, 1997. Units are in meters.

LEGEND

🟥 Dissolved oxygen

🟦 Temperature

🟩 pH

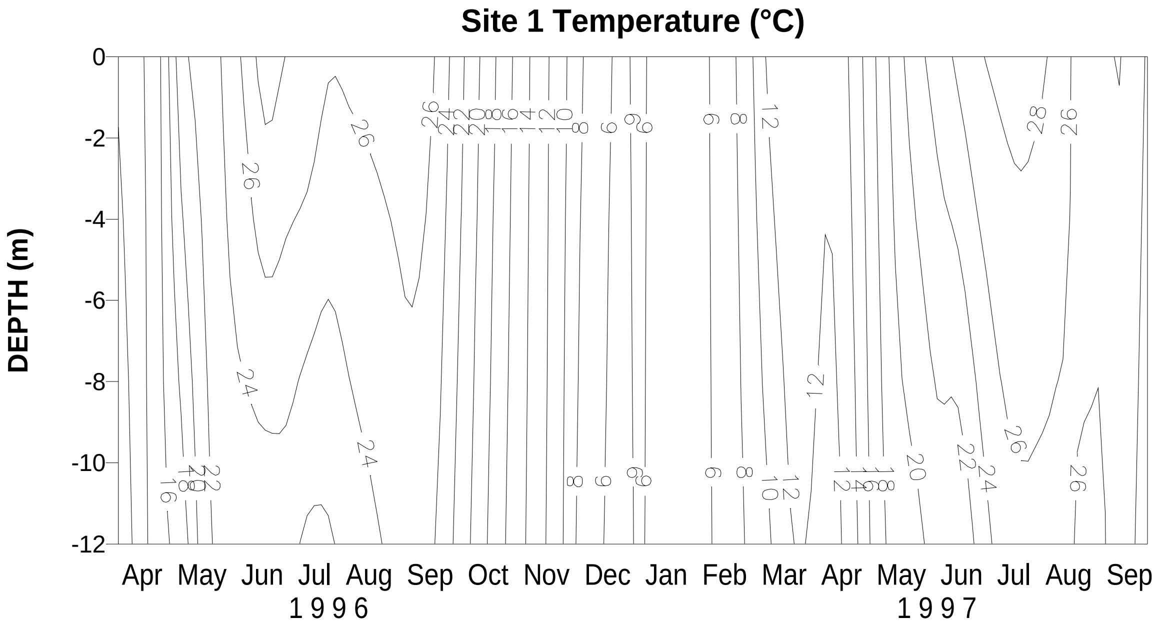

Figure 10.7 Site 1 temperature isopleth

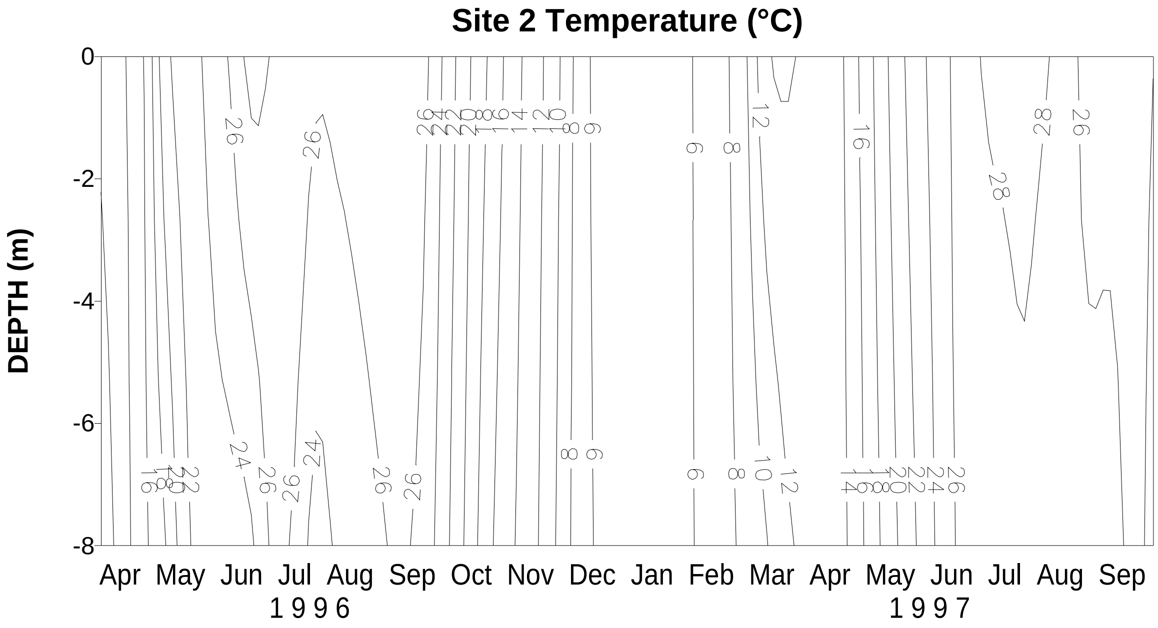

Figure 10.8 Site 2 temperature isopleth

Figure 10.10 Site 4 temperature isopleth

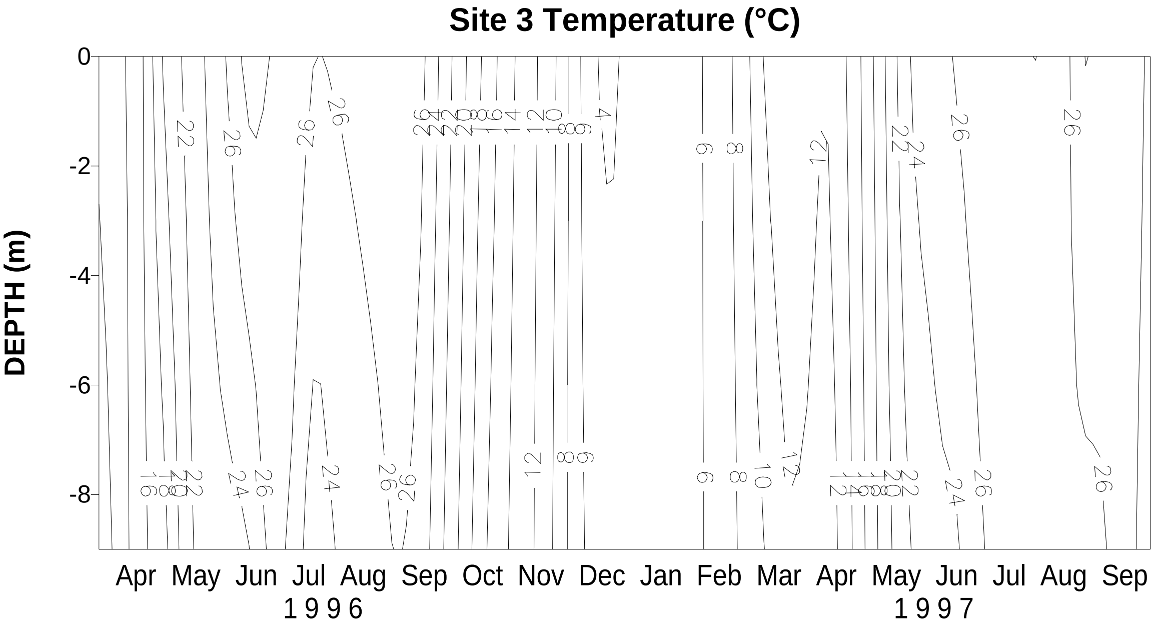

Figure 10.9 Site 3 temperature isopleth

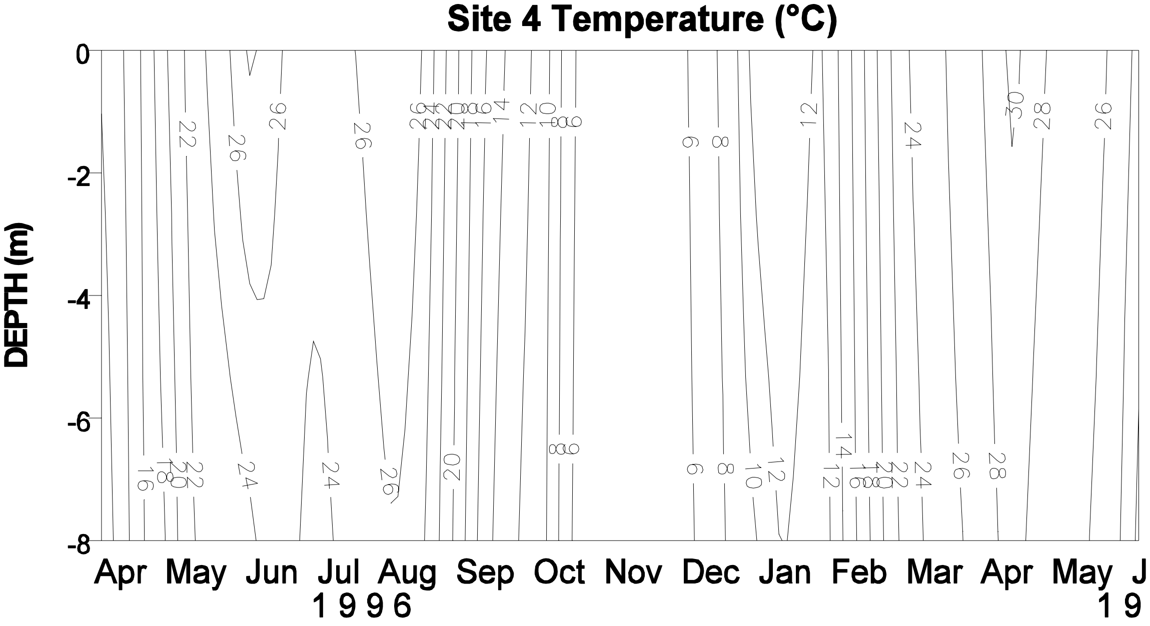

Figure 10.10 Site 4 temperature isopleth

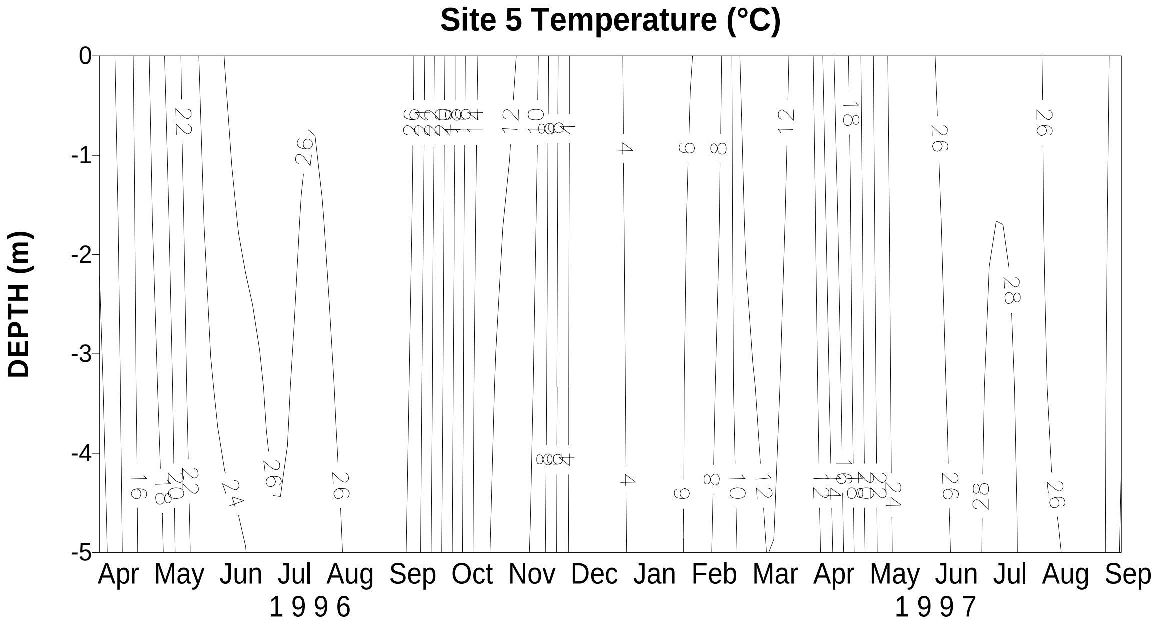

Figure 10.11 Site 5 Temperature isopleth

Dissolved Oxygen

Dissolved oxygen (DO) refers to the oxygen freely available in water. DO is vital to fish and other aquatic life. Low or high levels can cause harm to aquatic populations. Even short periods of low DO can cause a shift of the populations, which causes a decrease in species diversity. The DO on the surface of Arcadia Lake ranged from a maximum of 19.57 mg/l at site 5 on 19 Dec 96 to a minimum of 4.7 mg/l at site 1 on 28 Jul 97. The DO concentrations were altered by the periods of stratification. In October, 1996 through late May, 1997 the DO concentrations were the same from surface to bottom, demonstrating that the lake water was well mixed and oxygenated. During stratification periods, DO profiles in Arcadia Lake were clinograde, or decreased with depth, a typical condition of eutrophic systems (**Wetzel 1983**). Stratification in Arcadia Lake, although weak, is significant because there is no exchange of dissolved gasses, such as oxygen, between the epilimnion and the hypolimnion. During the summer, organic material is either produced in the epilimnion from algae growth, or comes in from the tributaries following stormflow events. This organic matter settles into the hypolimnion and into the bottom sediments where it is decomposed by biological action. In this process, DO is consumed, which lowers the DO content until the fall turnover event. In Arcadia Lake, shortly after the onset of thermal stratification, hypolimnetic oxygen concentrations decreased. During periods of stratification, near anoxic levels in the hypolimnion occurred on several instances (**Figure 10.12-16**). Periods and depths where anoxic conditions were noted are indicated by shading in **Figures 10.12-16.**

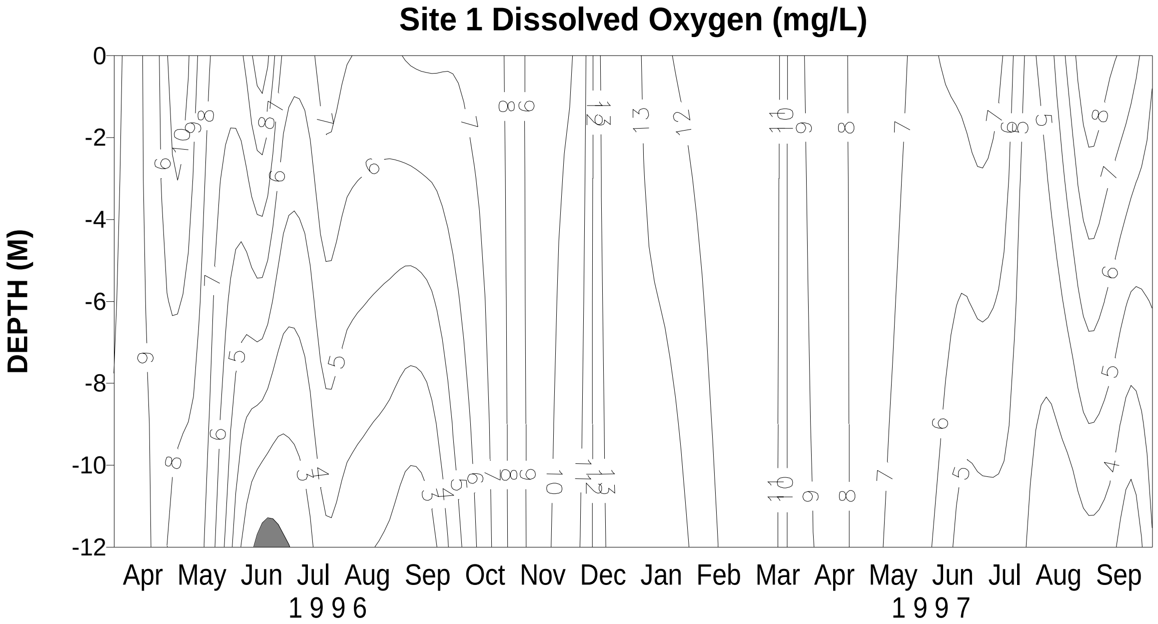

Figure 10.12 Site 1 Dissolved oxygen isopleth

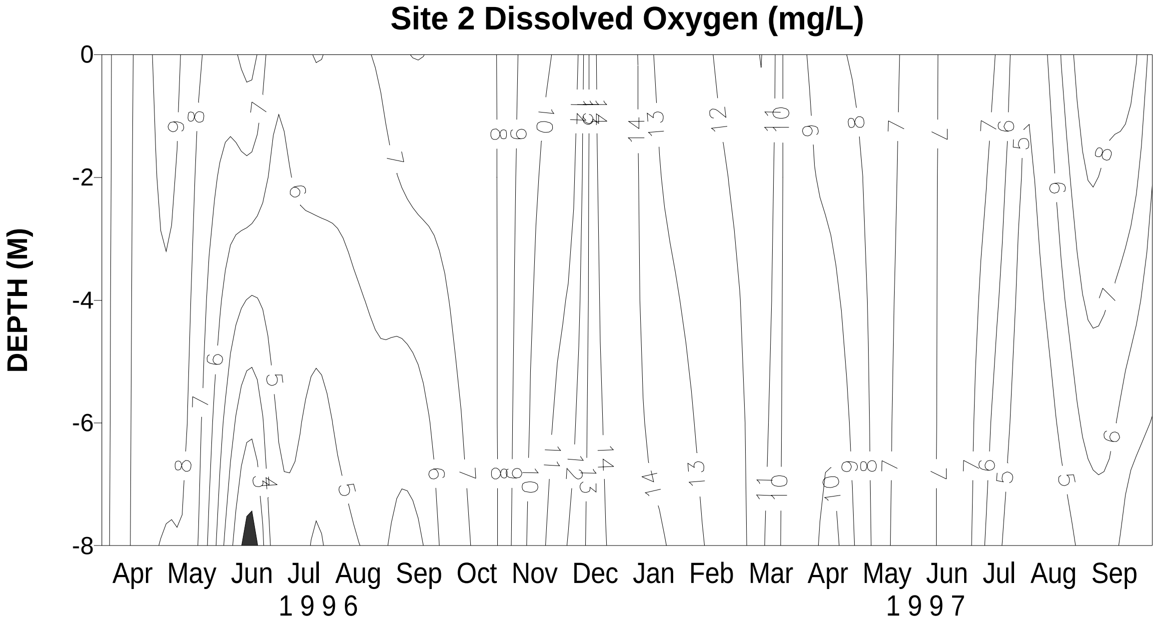

Figure 10.13 Site 2 Dissolved oxygen isopleth

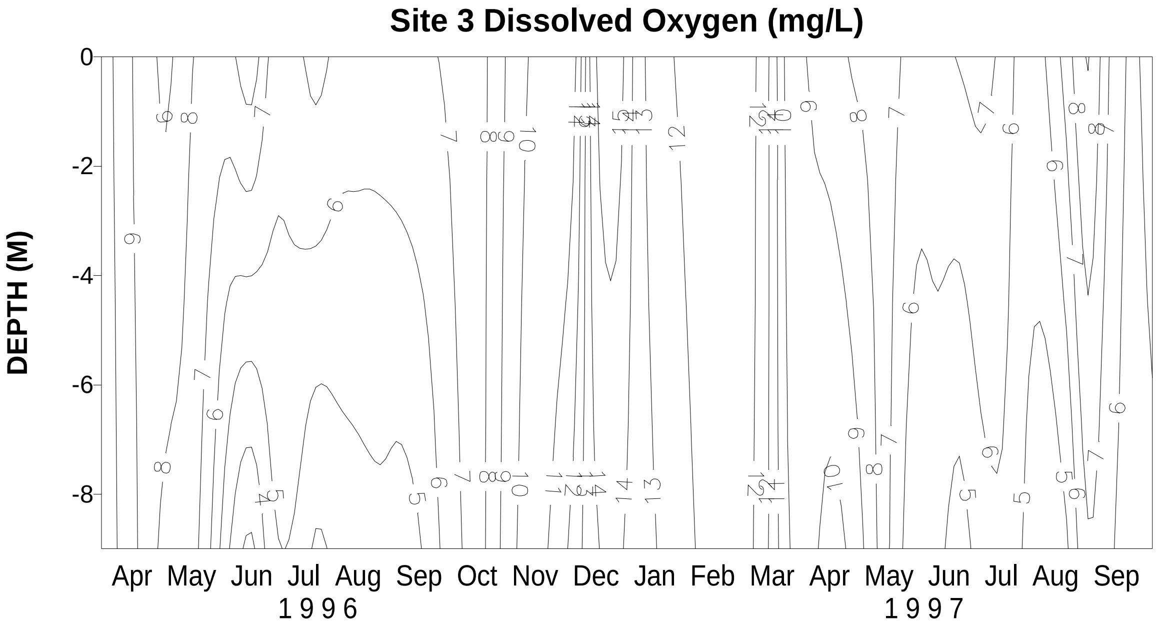

Figure 10.14 Site 3 Dissolved oxygen isopleth

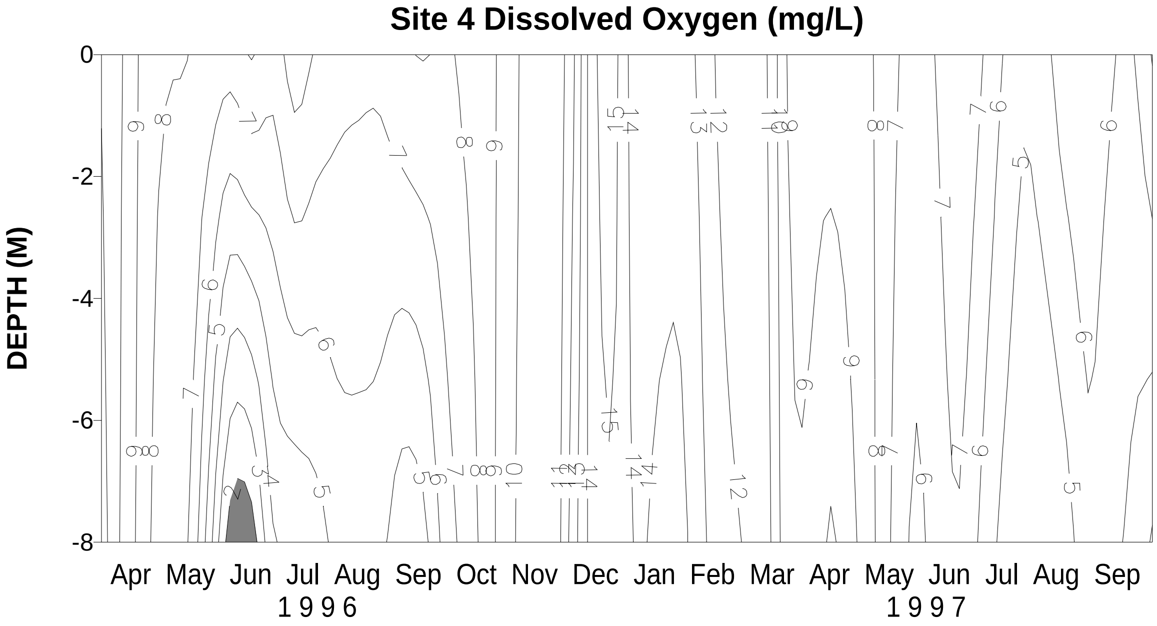

Figure 10.15 Site 4 Dissolved oxygen isopleth

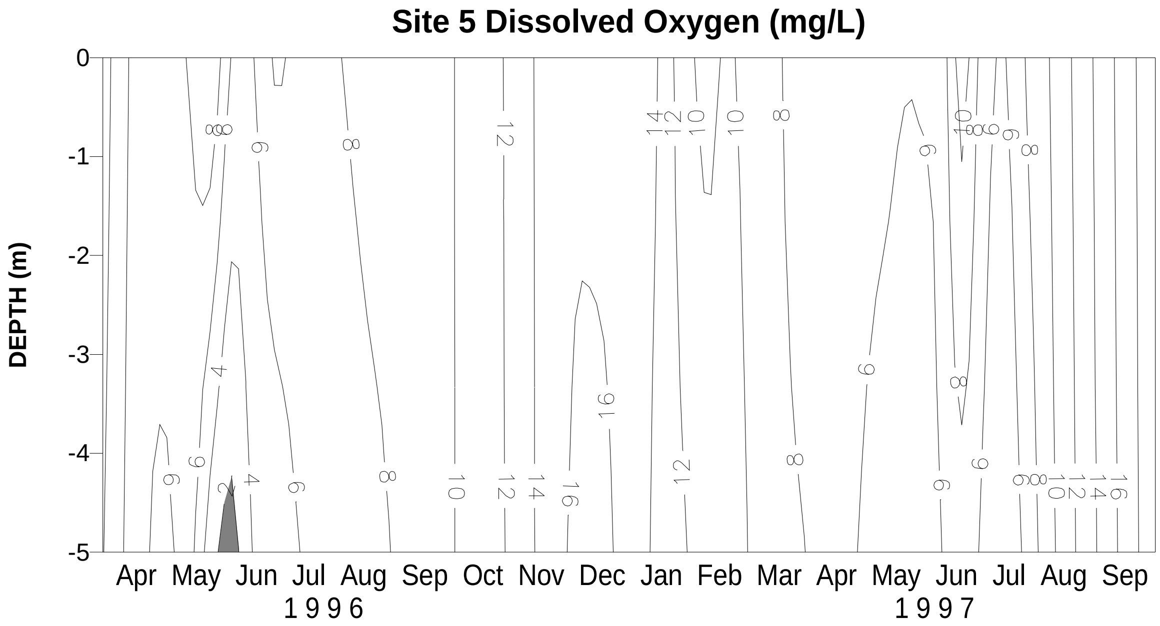

Figure 10.16 Site 5 Dissolved oxygen isopleth

pH

pH is the negative log of hydrogen ion concentration. The reproductive success of aquatic organisms is often directly affected by pH levels . A pH value of 7.0 is neutral, above 7.0 is basic and below 7.0 is acidic. Arcadia Lake pH was slightly basic. pH levels have been shown to be elevated by photosynthetic activity, and decreased by bacterial respiration. pH ranges varied from a maximum of 10.17 in a surface water collection at site 2 on 16 Sep 97 to a minimum of 6.90 in a surface water collection at site 3 on 5 Nov 96. Although the maxima and minima may present a wide range of readings, these were extreme outliers and the patterns of values did not differ greatly at each station. The lake mean was 8.13, and pH normally decreased with depth. During periods of stratification, the hypolimnion showed the lowest mean values (**Figure 10.17-21**). The low hypolimnion values indicate an environment dominated by respiration. The fluctuation of pH throughout the year is an indication of primary productivity in Arcadia Lake.

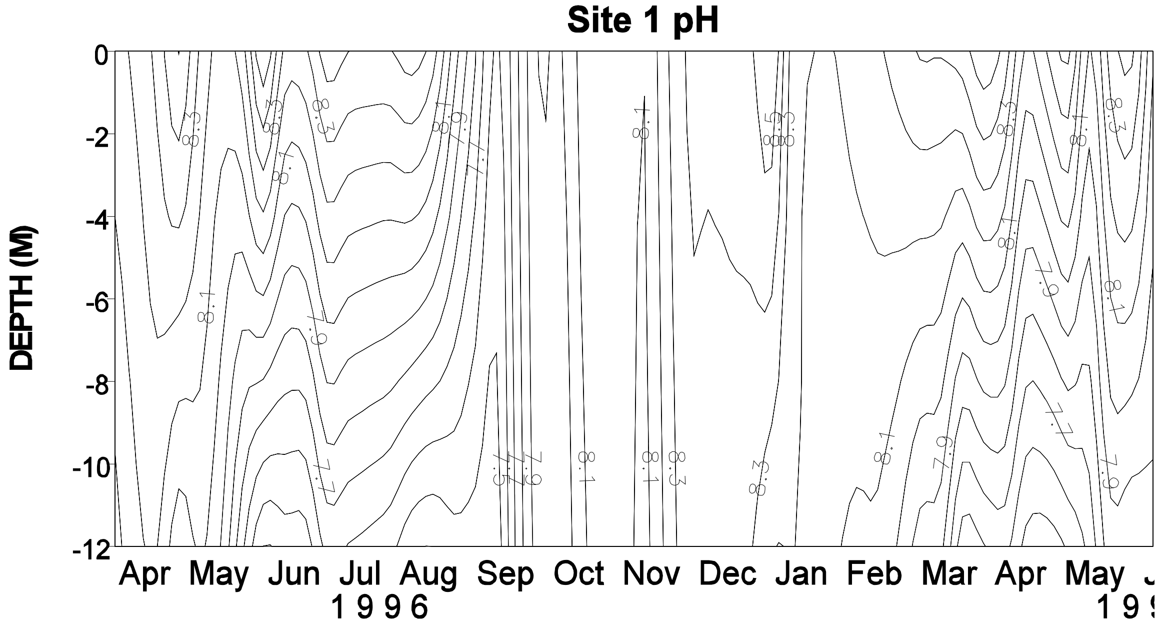

Figure 10.17 Site 1 pH isopleth

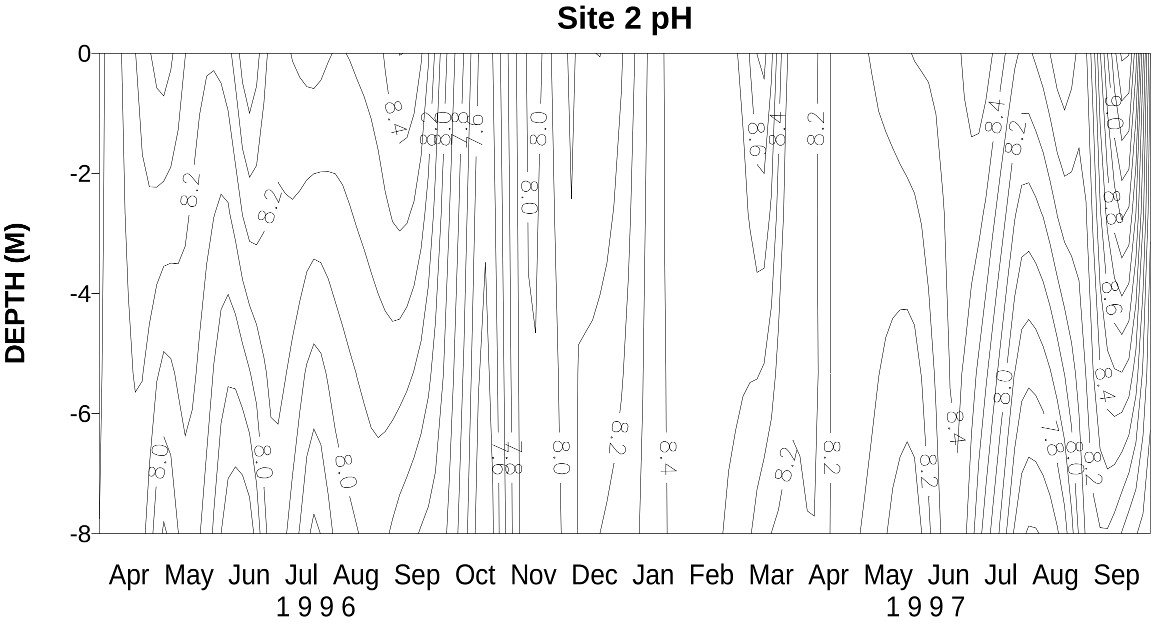

Figure 10.18 Site 2 pH isopleth

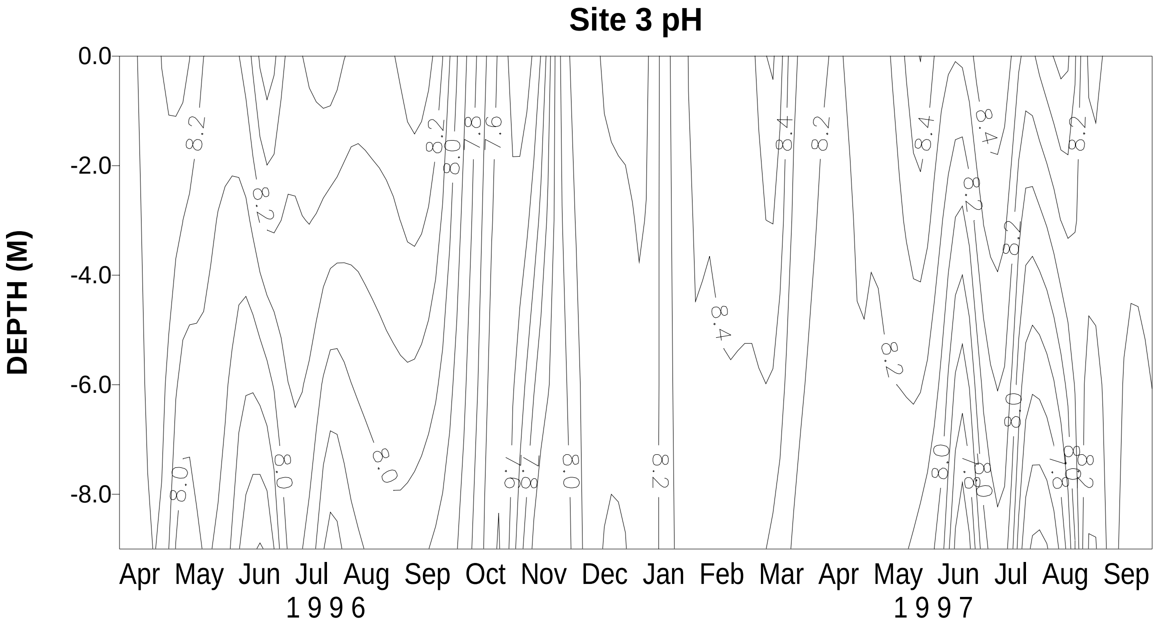

Figure 10.19 Site 3 pH isopleth

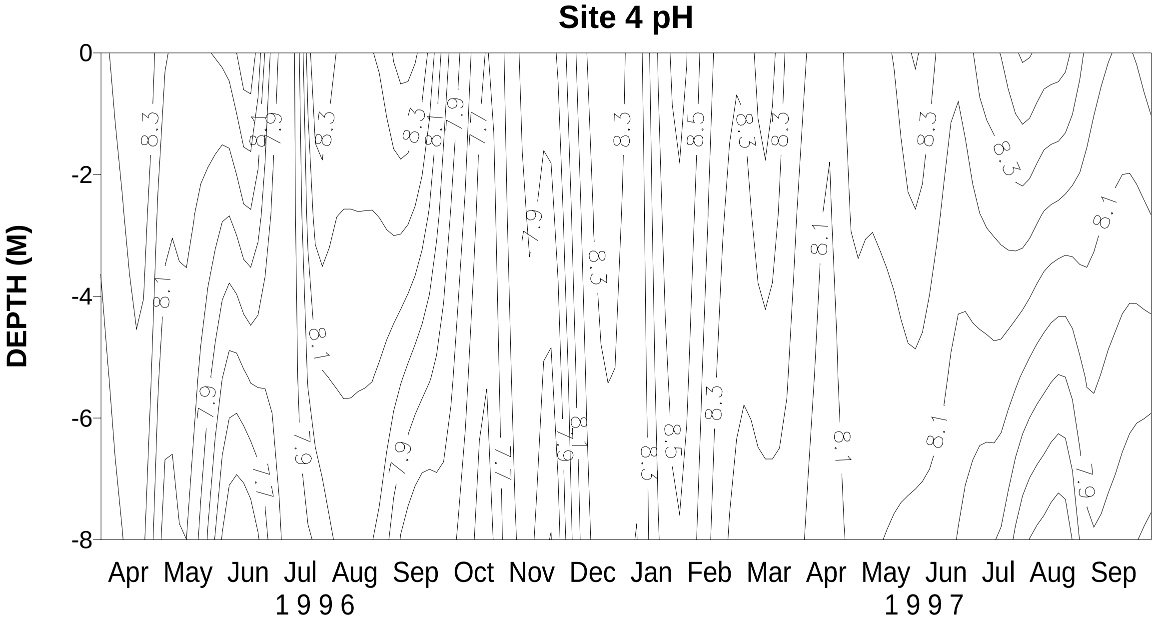

Figure 10.20 Site 4 pH isopleth

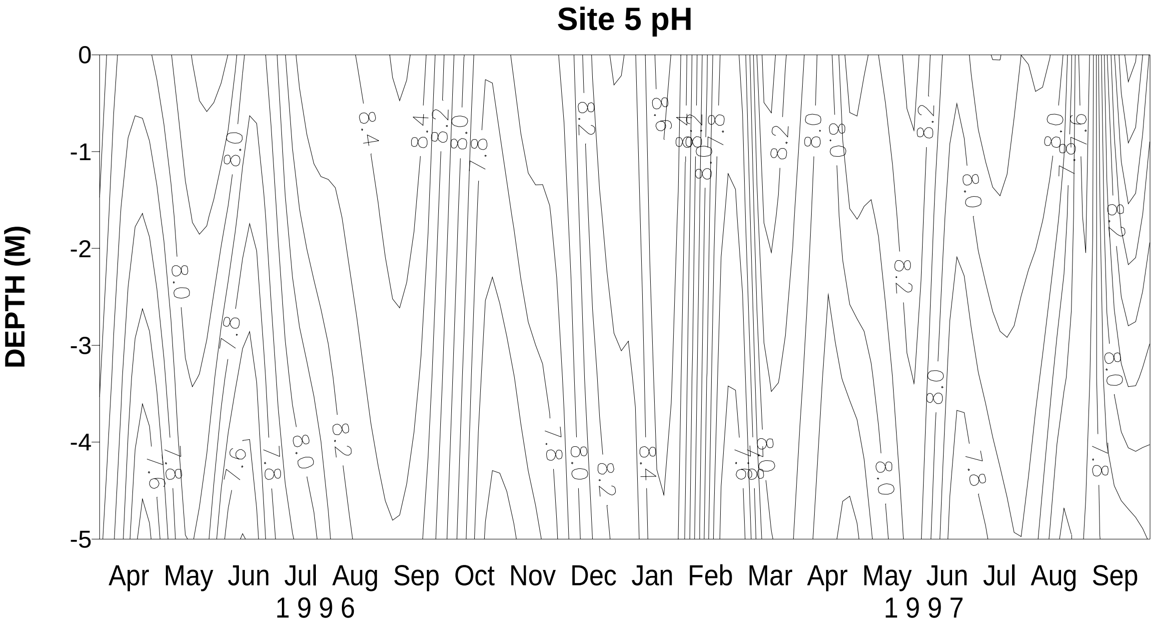

Figure 10.21 Site 5 pH isopleth

Redox Potential

Oxidation-reduction (redox) states, governed by photosynthetic and bacterial metabolism, can regulate the internal cycling of essential micronutrients (**Wetzel 1983**). Redox potential (E_h) is usually high (300-500 mV) and constant throughout the water column if dissolved oxygen is present (**Wetzel 1983**). However, under anoxic conditions, E_h decreases precipitously. Under reducing conditions, nutrients and metals normally tied up in the sediments are reduced, become more soluble, and thus are liberated. This process increases nutrient and metal transport through the system and can increase availability to biota, ultimately increasing primary productivity throughout the water column.

Redox potentials of Arcadia Lake ranged from 11 mV to 535 mV, with a mean of 386 mV. Redox potential trends were similar to dissolved oxygen trends (**Figure 10.22-26**). Redox potential was constant throughout the oxygenated water column. However, during stratification, hypolimnetic anoxia occurred and the E_h dropped to a minimum of 11 mV on 12 Aug 97 at site 1. Arcadia Lake hypolimnion redox potentials during stratification were < 250 mV, which are similar to a eutrophic system (**Hutchinson 1957**). The shaded area in **Figures 10.22-26** represent redox potential of 100 mV or below. 100 mV is commonly a threshold where phosphorus is solubilized.

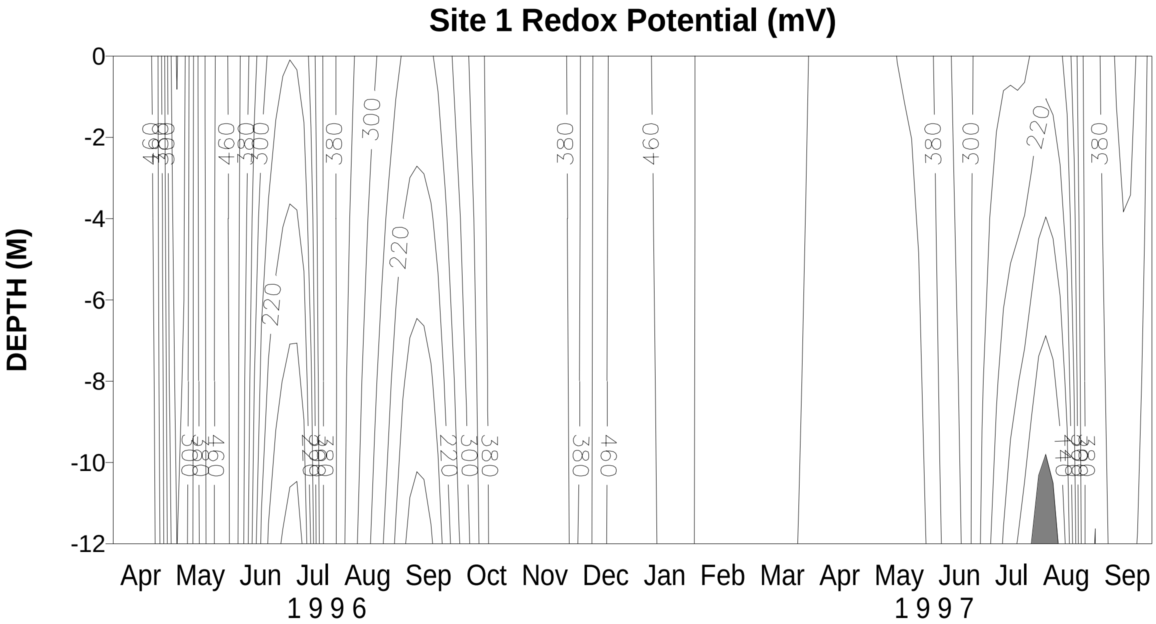

Figure 10.22 Site 1 Redox potential isopleth

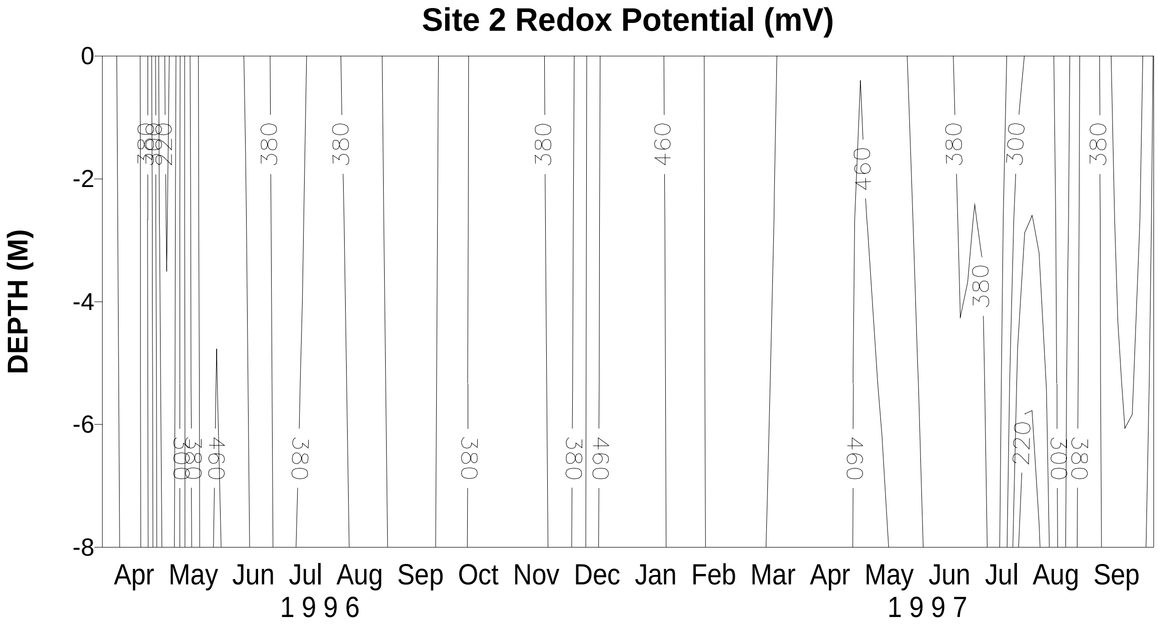

Figure 10.23 Site 2 Redox potential isopleth

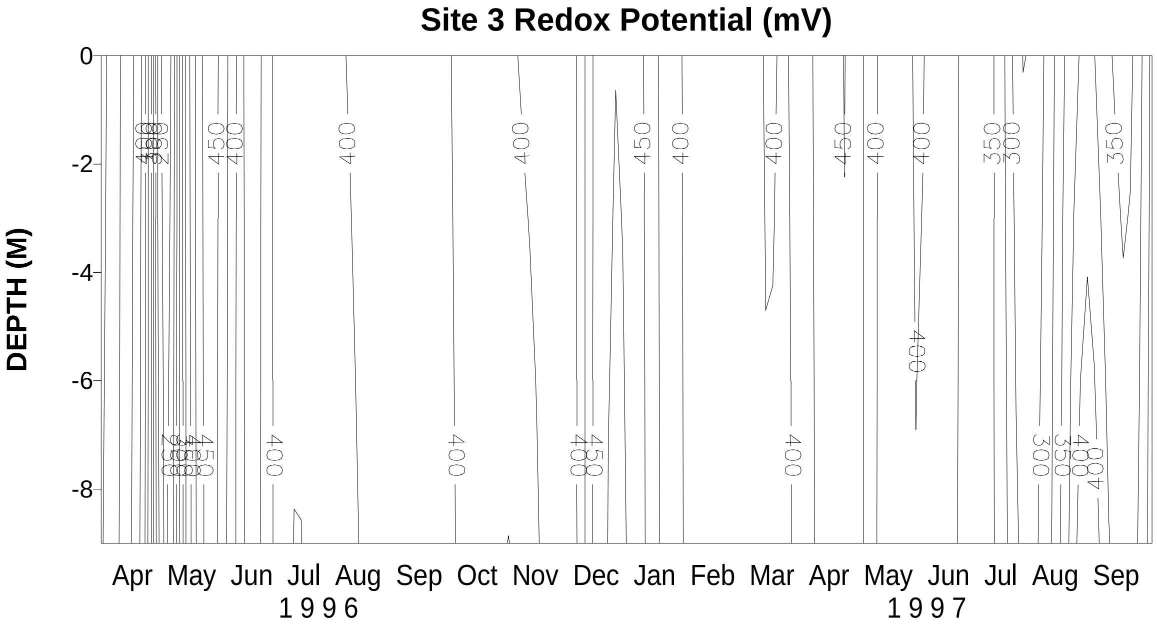

Figure 10.24 Site 3 Redox potential isopleth

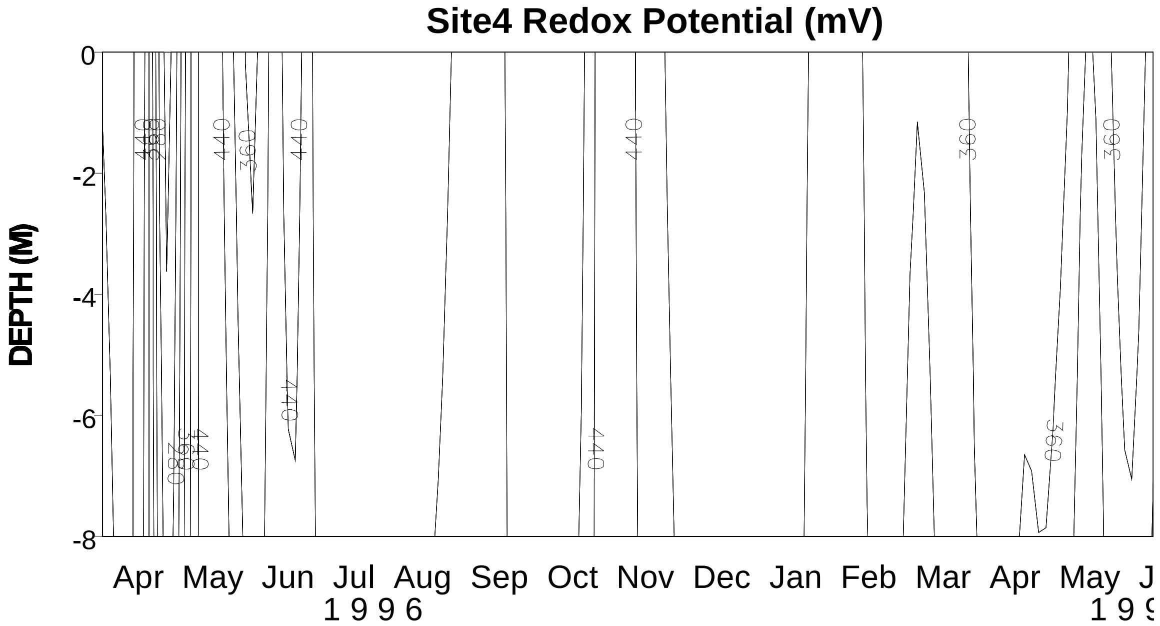

Figure 10.25 Site 4 Redox potential isopleth

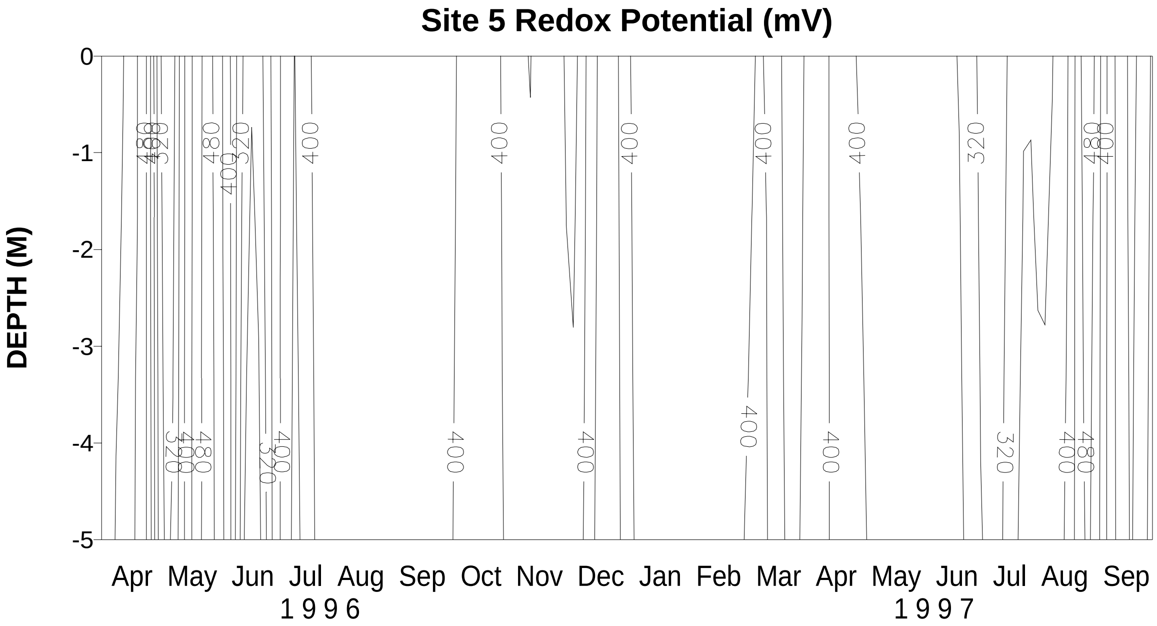

Figure 10.26 Site 5 Redox potential isopleth

Hardness

Hardness is caused by magnesium, calcium and other ions. Hardness levels in Arcadia Lake ranged from 97mg/l to 218 mg/l , averaging 167 mg/l of $CaCO_3$. Arcadia Lake is considered a hard water lake when compared to the USGS hardness levels (**Table 10.5**). Decreased concentrations of calcium in the epilimnion are directly associated with rapid increases in photosynthetic rate (**Wetzel, 1983**). This was not seen in Arcadia Lake during this study, probably because of the high turbidity throughout the lake without much settling. Total hardness did not vary significantly among sites, nor were minima and maxima highly variable among stations (**Figure 10.27**). The highest epilimnion values and variability were observed at site 5, showing the influence of the Deep Fork arm of the lake. The highest hypolimnion variability was observed at site 1 because of periods of stratification.

Table 10.5 USGS Classification of Water Hardness (**USGS, 1984**)

Hardness Classification	**mg/L as $CaCO_3$**
Soft	0 - 60
Moderately Hard	61 - 120
Hard	121 - 180
Very Hard	> 180

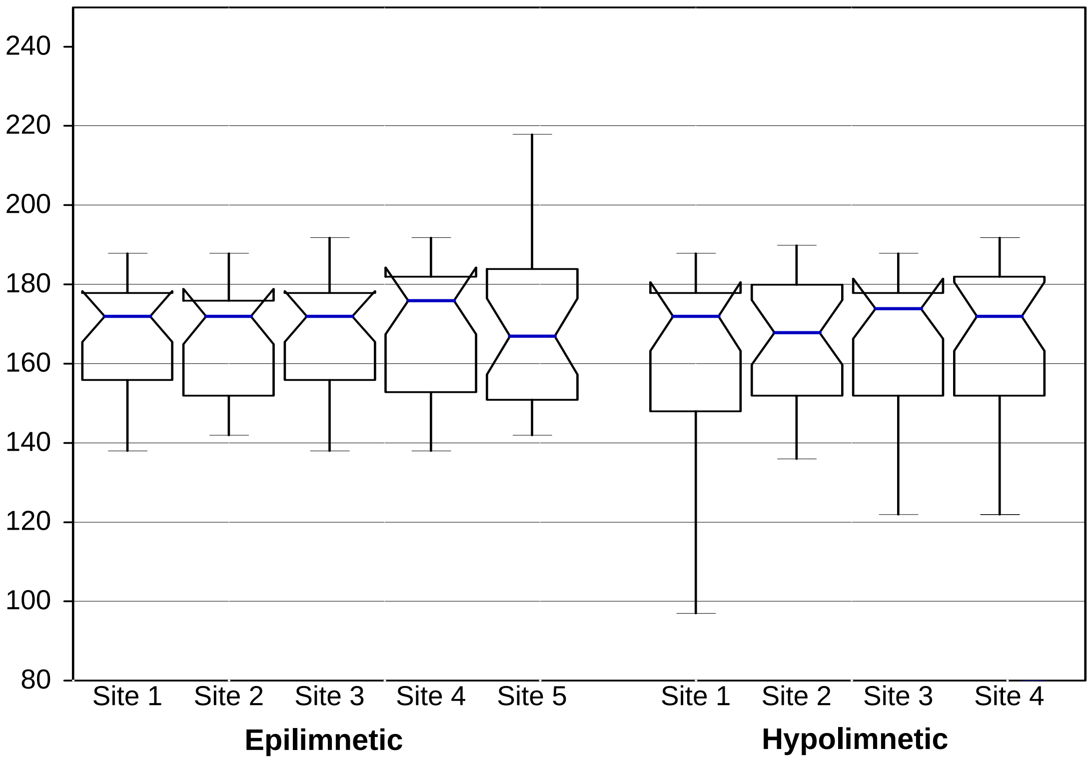

Figure 10.27 Box plot of Arcadia Lake Total Hardness (mg $CaCO_3$/l), Apr 96 - Sep 97 with median values

Alkalinity

Alkalinity is a measure of the buffering capacity of water against changes in pH. These changes can occur as photosynthetic activity varies within a lake. Arcadia Lake is well buffered against any drastic pH changes that may occur. Arcadia Lake values ranged from 92.2 mg/l to 201 mg/l $CaCO_3$ and averaged 157.45 mg/l $CaCO_3$. Fresh water systems at or below 20 mg/l $CaCO_3$ are considered poorly buffered (**EPA, 1986**). Maximum values of total alkalinity were seen from February to July in both years because the carbonate system, in a sense, is over compensating for the lower levels of pH observed in the hypolimnion during stratification (**Figure 10.28**). The total alkalinity did not vary significantly among sites, nor were minima and maxima highly variable among stations (**Figure 10.29**). The highest epilimnion values and variability were observed at site 5, which shows the influence of the Deep Fork arm of the lake. The highest hypolimnion values and variability were observed at site 1 because of the periods of stratification.

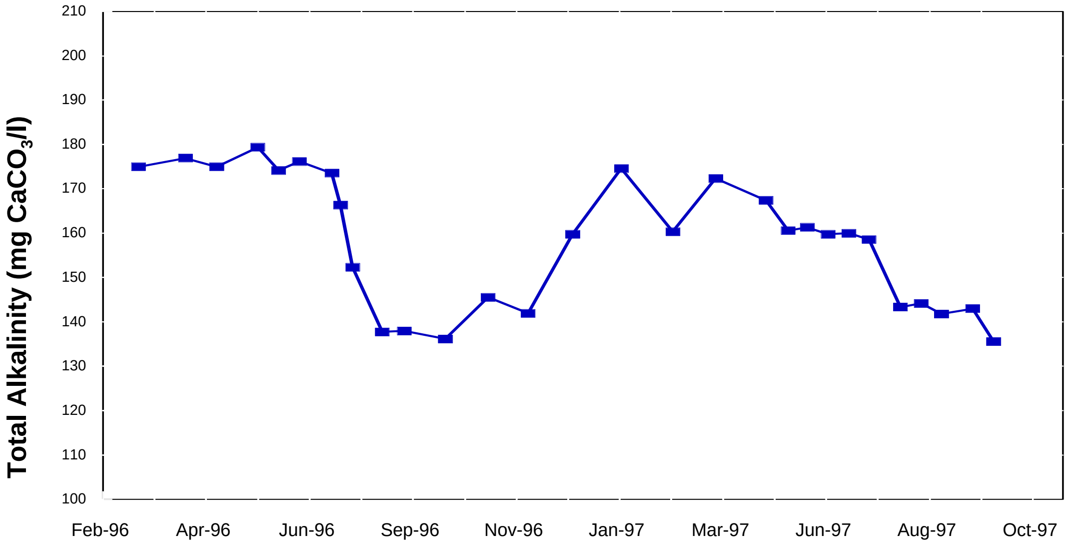

Figure 10.28 Arcadia Lake Mean Total Alkalinity (mg $CaCO_3$/l) Apr 1996 - Sep 1997.

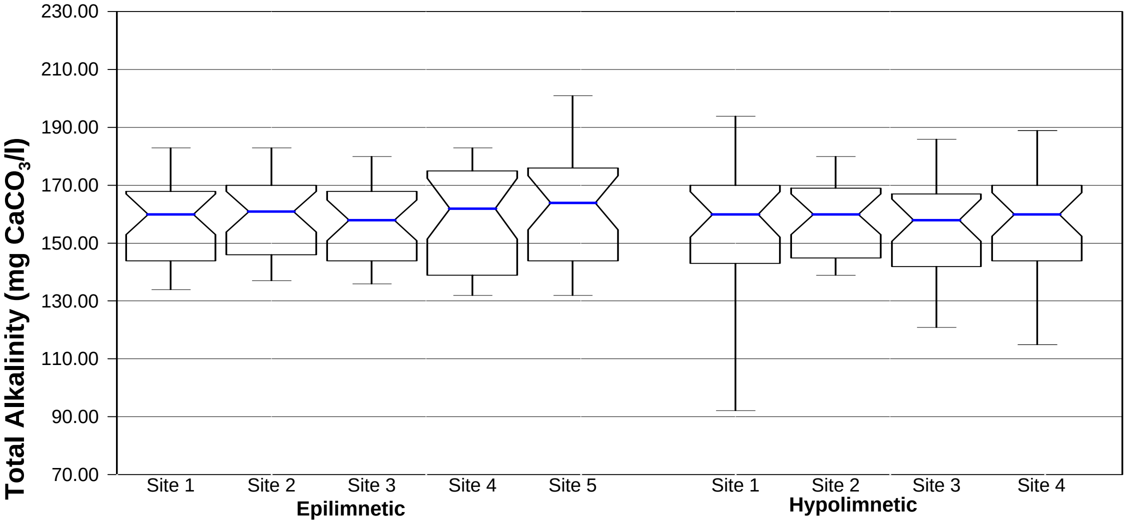

Figure 10.29 Box plot of Arcadia Lake Total Alkalinity (mg $CaCO_3$/l), Apr 1996 - Sept 1997 with median values

Conductivity

Conductivity is the measure of resistance of a solution to electrical flow. The purer the water, the greater the resistance to electrical flow (**Wetzel, 1983**). Inversely, in a general sense, the greater the level of impurities in the water, the greater the conductivity. Conductivities in Arcadia Lake indicate fairly high concentrations of ionized salts. Conductivity values ranged from 6 mS to 732.0 mS, with a mean of 408.4 mS. Conductivity values were similar throughout the lake, suggesting that influent matter was not being diluted or settled in the lower reaches of the lake. During the 1996 thermal stratification, there were differences between the hypolimnetic and epilimnetic concentration, but no distinct chemical stratification; however, during the thermal stratification of 1997, there was distinct chemical stratification. This was seen mostly in the central pool and at sites 2 and 3, and may be related to runoff in the watershed (**Figures 10.30-34**). There was also some gradient seen in November and December of 1996 in several of the sites.

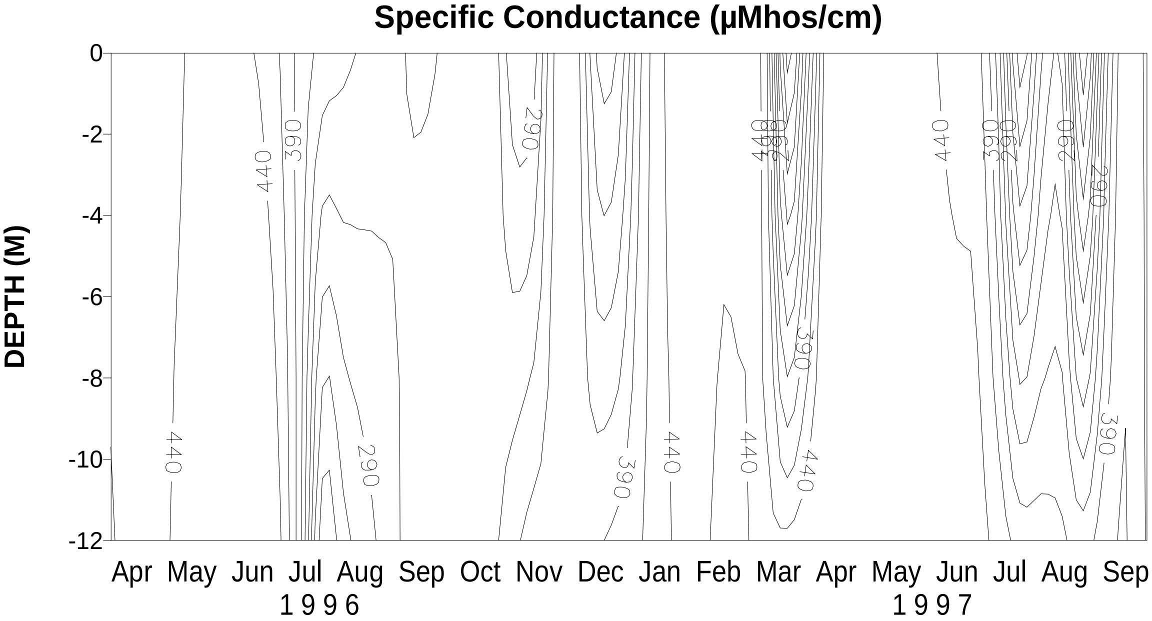

Figure 10.30 Site 1 specific conductance isopleth

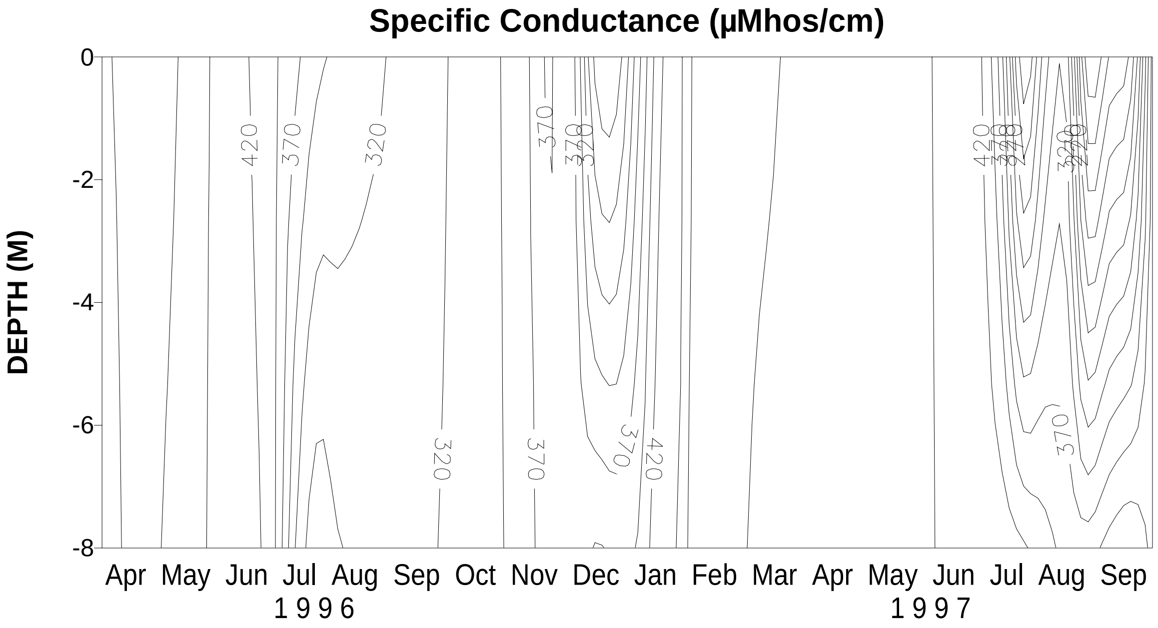

Figure 10.31 Site 2 specific conductance isopleth

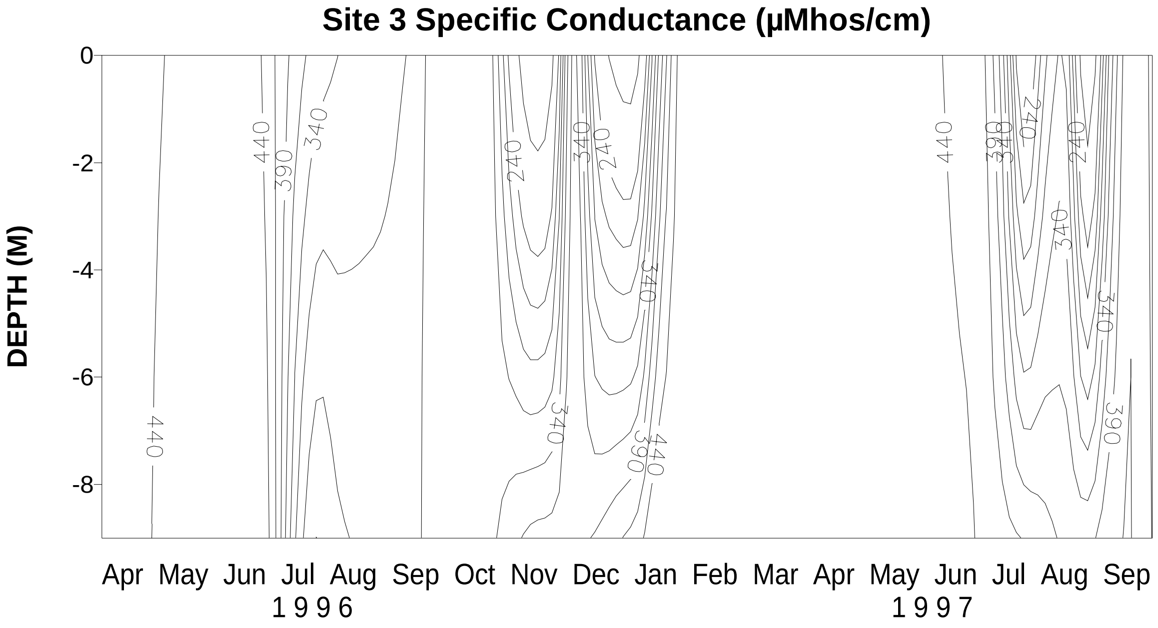

Figure 10.32 Site 3 specific conductance isopleth

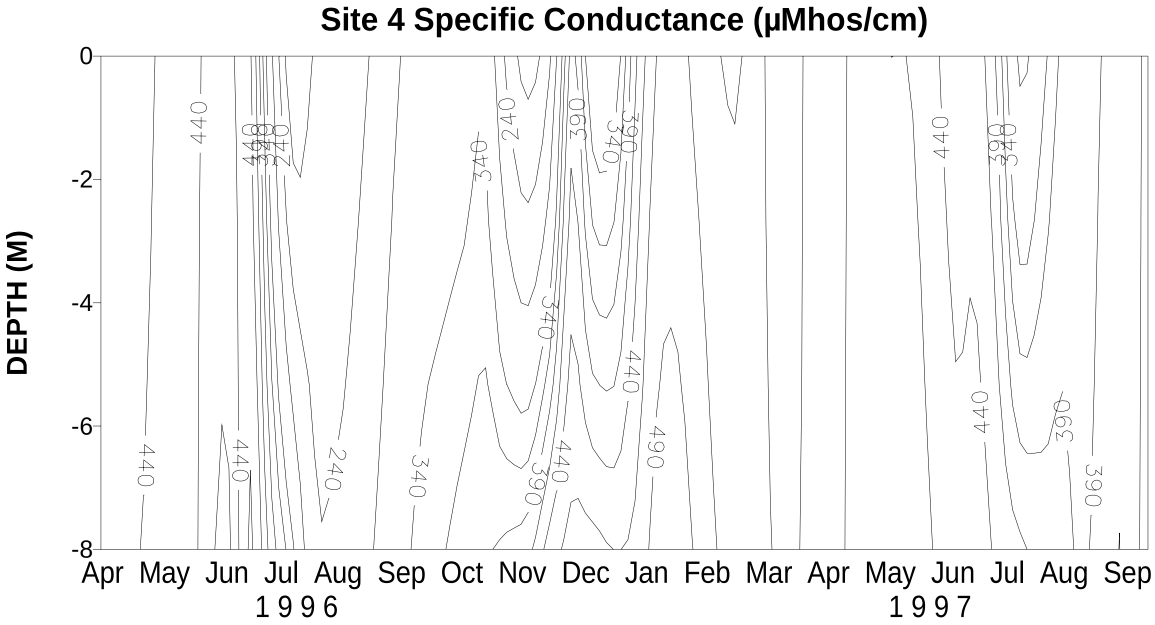

Figure 10.33 Site 4 specific conductance isopleth

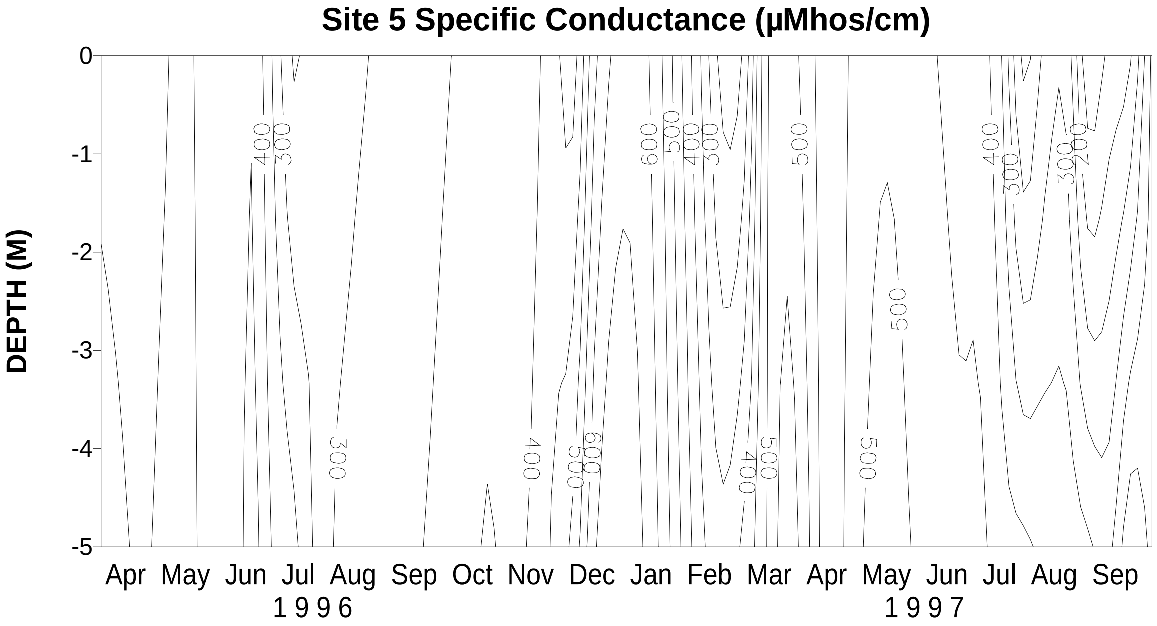

Figure 10.34 Site 5 specific conductance isopleth

Total Solids

Particulate matter in lakes can contribute to taste, odor, and aesthetic problems. Removing solids from drinking water is expensive and time consuming. Oklahoma Water Quality Standards

(**OWRB, 1994**) state that the surface waters of the state shall be essentially free from floating debris, bottom deposits, scum , foam, and other materials including suspended substances of a persistent nature from other than natural sources. Analysis of the solids concentration of Arcadia Lake shows that sites 4 and 5 contain high levels of dissolved solids, and that site 5 has the highest level of suspended solids (**Figure 10.35**). Load estimates given in **Task 9** indicate that storm driven non-point source pollution from the watershed causes the high suspended solids seen at sites 4 and 5. These solids are of an organic nature, coming primarily from living organisms, such as bacteria, algae and zooplankton. Organic solids have the potential to be THM precursors, and are also difficult and costly to remove from the drinking water. **Figure 10.36** demonstrates the median concentrations of dissolved solids in Arcadia Lake.

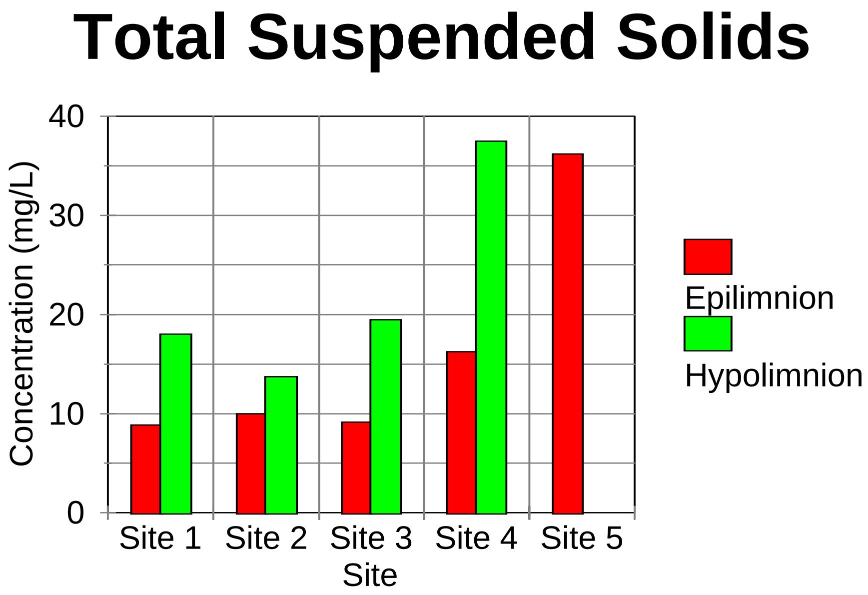

Figure 10.35 Median suspended solids in Arcadia Lake

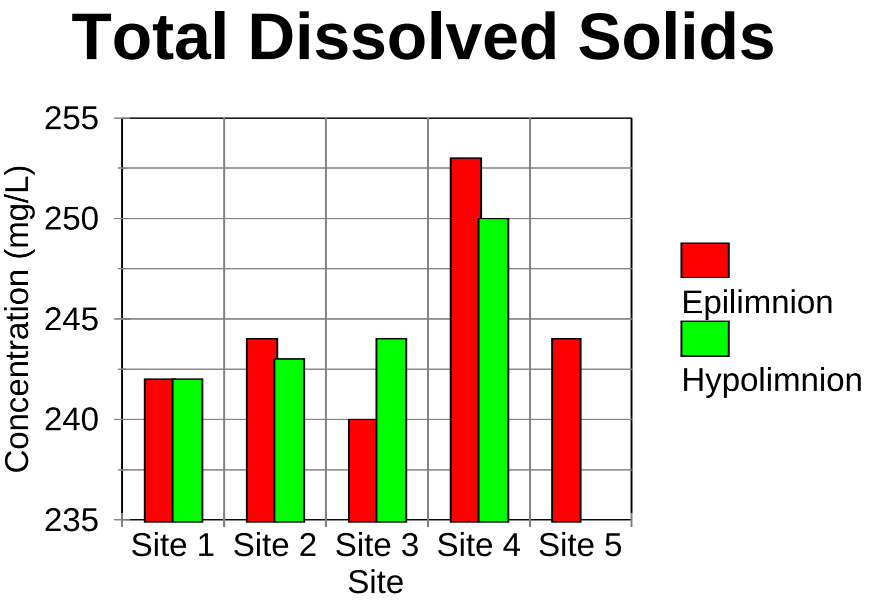

Figure 10.36 Median dissolved solids in Arcadia Lake

Secchi Disk Transparency

The measurement of secchi disk depth is an approximate evaluation of the transparency of water to light. The greater the secchi depth measurement, it is assumed, the higher the quality of the water. In Arcadia Lake, secchi depths ranged from a minimum of 7.6 cm at site 5 to a maximum of 130 cm at site 1. The overall lake mean during the study was approximately 48 cm. The Deep Fork arm of the lake showed the lowest mean secchi depths (**Figure 10.37**). The secchi depth trends were not typical of annual patterns, where the minimum depths are during the growing season and maximum depths are during the colder unproductive season. The values followed a trend that is inverse to the typical pattern. This dissimilarity may be due to the loads of inorganic turbidity from the Deep Fork arm regulating the secchi depth rather than the chlorophyll-*a* concentrations.

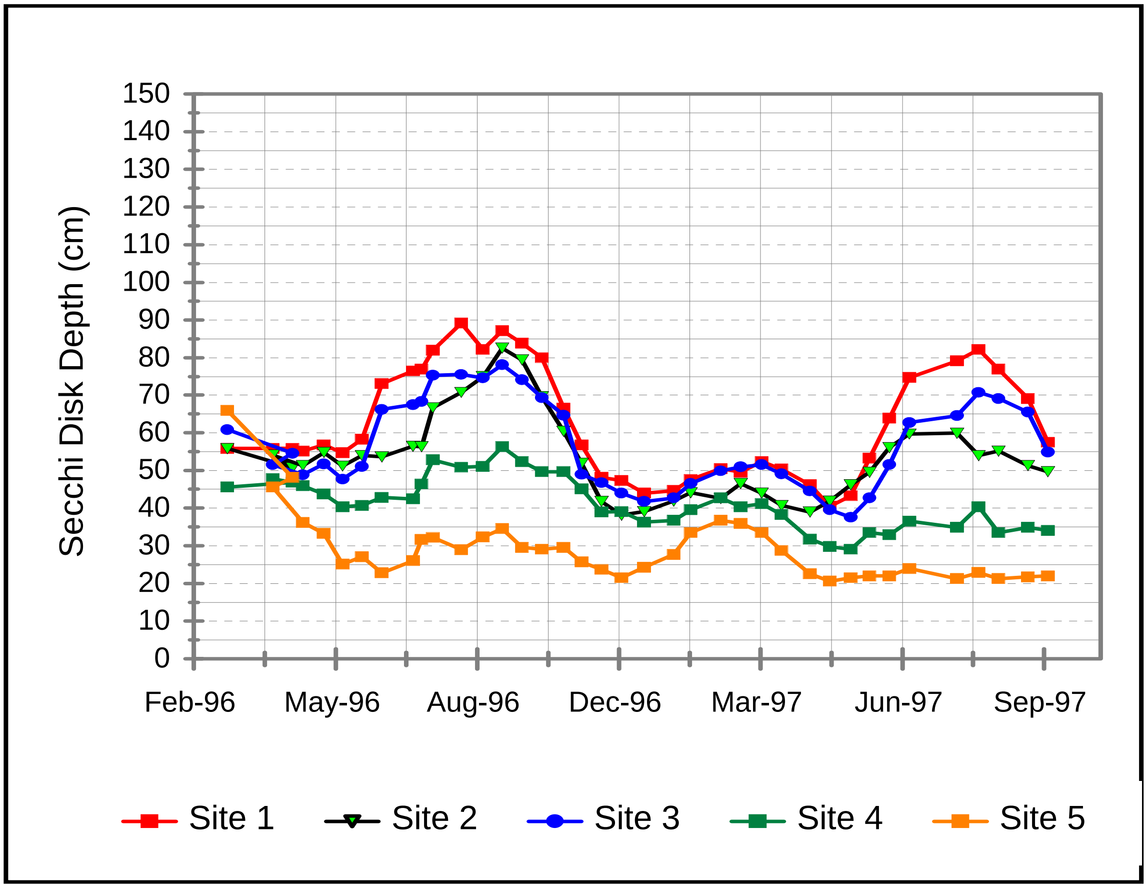

Figure 10.37 Secchi disk depth by sampling site. Values are reported in centimeters.

Turbidity

Turbidity refers to the presence of suspended solids which reduce the transmission of light through either scattering or absorption (**Lind 1979**). Turbidity is caused by suspended inorganic and organic matter, such as clay, silt, carbonate particles, fine organic particulate matter, plankton and other small organisms. Because of the suspended particulate matter, high turbidity is a major concern for water treatment operations and cannot be tolerated by many aquatic organisms. The epilimnion turbidity of Arcadia Lake ranged from a minimum of 4.8 NTU at site 1 in June, 1997 to a maximum of 139 NTU at site 5 in April, 1996. The Oklahoma Water Quality Standards criteria for lake turbidity is 25 NTU (**OWRB, 1994**). The overall lake mean turbidity was in compliance with the standard, with a value of 22.5 NTU. Site specific mean evaluation indicated that all sites were in compliance with standards, with the exception of site 5 (**Figure 10.38**). Site 5 consistently showed extremely high levels, with a mean turbidity of 43 NTU. Site 4 maintained the second highest overall mean of 23 NTU. Sites 1,2, and 3 means were lower, and all possessed similar overall means ranging from 13 to 15 NTUs.

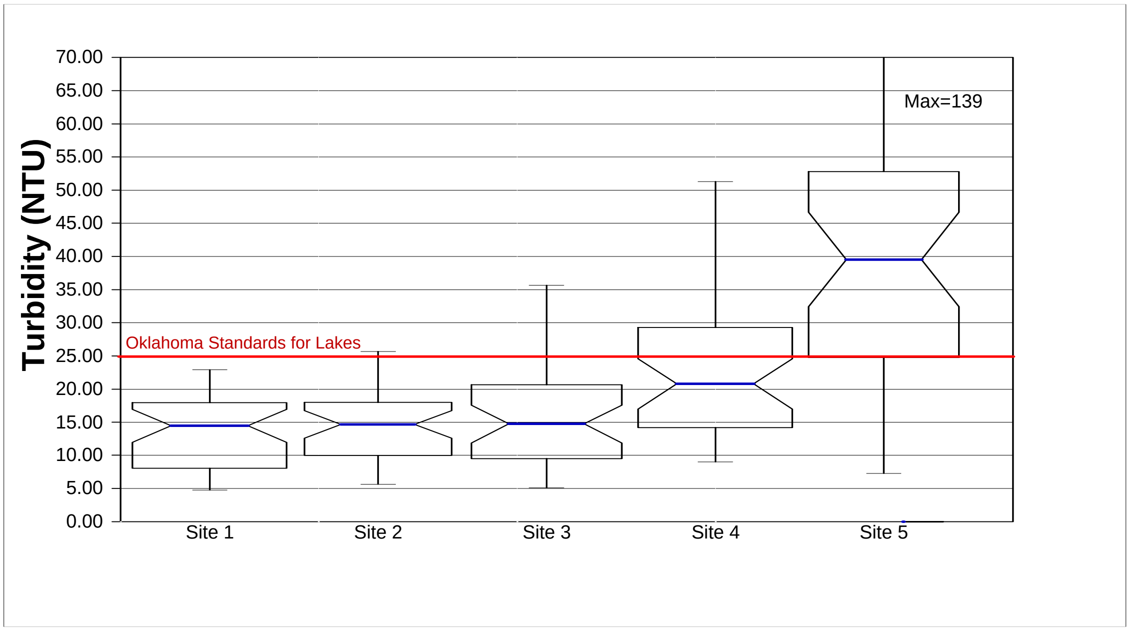

Figure 10.38 Box plot of Arcadia Lake Turbidity (NTU), Apr 1996 - Sep 1997 with median values

Annual trends in epilimnion turbidity were similar among all five stations, although at different amplitudes. Trends at sites 1,2, and 3 were very similar throughout the sampling period. Sites 4 and 5 had much higher levels of turbidity. Peaks of sites often mimic each other, indicating the influence of stormwater. The minimum lake-wide mean turbidity was observed on 21 Jan 97, a very windy day (15-30 mph southwest wind, oceanic waves). The peak lake-wide mean turbidity was observed on 22 Apr 96, a windy rainy day (rain, 15 mph north/northwest wind, moderate waves). This indicates that the turbidity is not wind-driven, but rather initiated through other forces. In comparing turbidity trends for 1996 and 1997 to weather patterns, there was no significant relationship discernable.

Water Transparency

Water transparency exerts important regulatory controls on the physiology and behavior of aquatic organisms, including the productivity of the organisms (**Wetzel and Likens, 1979**). When light irradiates the surface of a water body, much of it is reflected. The light that passes through the surface is rapidly diminished by further reflection, scattering, and absorption by the water itself and the suspended materials within a water body. The light that does penetrate effectively through the water provides energy that is essential for photosynthesis and, in turn, productivity. Photosynthetic active radiation (PAR) was measured throughout the sampling period at all sites with depth. The depth to which light can penetrate, and in which photosynthesis can exceed respiration, is called the euphotic zone. The lower limit of this zone, where photosynthesis and respiration are equal, is called the compensation depth. Below the compensation depth, respiration exceeds photosynthesis in the profundal or aphotic zone. The compensation depth depends on both dissolved and particulate materials in the water. Extinction coefficients were computed along with the compensation depth. The mean compensation depth over the study period was 0.94 meters. The results revealed that photosynthetic reactions occur in approximately 1 meter at the top of Arcadia Lake.

Chlorophyll-*a*

Chlorophyll-*a* levels are an indirect measure of the quantity of planktonic algae present in a reservoir. Chlorophyll-*a* has several attributes that make it ideal for the measurement of algal presence. Chlorophyll-*a* is found in all photosynthesizing plants; it is the most common algal pigment; it is the dominant pigment in blue-green and eukaryote photosynthesis; and it provides an essential energy transfer from light energy to chemical energy. Therefore, chlorophyll-*a* is essential in the assessment of the primary productivity of a water body.

Chlorophyll-*a* levels were taken at each sampling event and at each site on Arcadia Lake. The highest Chlorophyll-*a* levels of 46.52 µg/l were found at site 5 on 12 Aug 97. The lowest values were also found at site 5, with a value of 1.30 µg/l on 12 Aug 96 (**Figure 10.39**). Sites 4 and 5 showed the highest levels, followed by site 2. The overall lake mean value was 16.04 µg/l. Arcadia Lake had chlorophyll-*a* levels that would classify the lake as eutrophic according to Carlson’s trophic state index. The expected trend for chlorophyll-*a* was lowest values at Site 4 and 5, with increasing values toward the dam. Secchi disk trophic state prediction of light limitation, coupled with the highest turbidity values at Sites 4 and 5 also point to this expected trend. **Figure 10.39** clearly shows the highest median chlorophyll-*a* values were at site 5. This was the opposite predicted from the data presented to date. Two factors contribute to this seeming anomaly: shallow depth of the upper site, and the plunging stormwater stimulating algae growth. Algae cells in a water column 4 meters deep will receive considerably more light than one in a water column 8 meters deep while neither site displays thermal stratification. **Task 9** outlined how plunging stormwater added ammonia to the water column, stimulating algae growth.

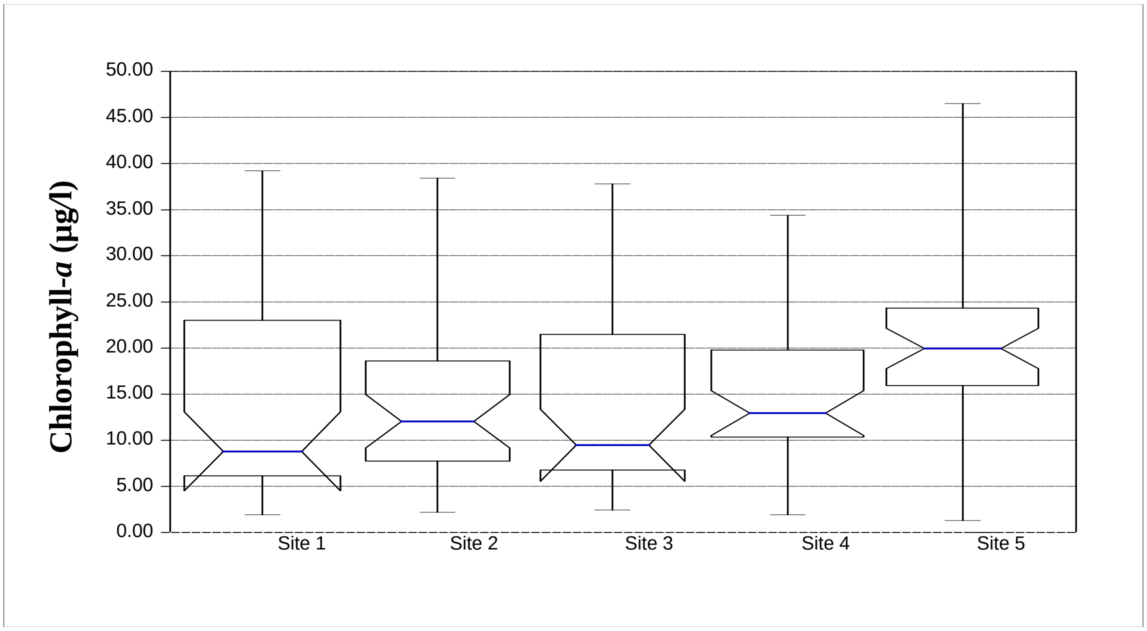

Figure 10.39 Box plot of Arcadia Lake chlorophyll-*a* concentrations (µg/l), Apr. 1996 - Sept. 1997, with median values

Fecal Coliform and Fecal Streptococci

Fecal coliform results indicate the presence of fecal material from warm blooded animals. As an indicator of fecal pollution, it is a quick test of pollution identification. Likely sources for fecal coliform in a reservoir are municipal sewage collection systems, septic tank leakage, runoff from livestock, and of course, migrating and resident waterfowl. There are several limitations on the use of fecal coliform data in a water body. The one limitation that effects this study is the life span, which is approximately 48 hours in water bodies. Because of this limitation, this measurement may be more adequately quantified by the storm water data located in **Task 9** of this report.

Fecal streptococci bacteria is distinct from the fecal coliform group. Similar to fecal coliform, the fecal streptococci inhabit the intestinal tract of warm blooded animals and can be used as an indicator of fecal pollution. The difference between the two fecal indicators is that fecal streptococci is found in greater numbers in other organisms than in man. By using the ratio of the two types of fecal indicators, the sources of the pollution can be expressed.

The State of Oklahoma Water Quality Standards Criteria sets a concentration of 200 colonies/100 mL for fecal bacteria contamination for primary contact recreation beneficial use, based upon monthly geometric mean concentrations collected between the period of May 1 to September 3. According to the standards for public and private water supply, the monthly geometric mean cannot exceed 5000 colonies/ 100 ml at the point of intake. The OWRB fecal collections were not frequent enough to apply this standard; however, the values collected by the OWRB can be compared to these standards to ascertain potentially detrimental conditions. Median values for fecal bacteria in Arcadia Lake were below detection limits; however, all sites showed some positive detections a percentage of the time (**Table 10.6**). Site 5 showed the most contamination, and was the only site that exceeded the beneficial use criteria of 200 colonies/100 ml. The dates of the excesses at Site 5 corresponded to high precipitation patterns, as did the frequency of detections among all sites (**Table 10.7, Figure 10.40**). A likely explanation for the high values is stormwater overflows from the Oklahoma City area which contain fecal contamination. Stormwater frequently contains elevated fecal levels from washing of urban pet feces, ranchette livestock, and sewerage overflows because of excessive infiltration.

Arcadia Lake fecal bacteria levels are extremely sensitive to rainfall events throughout the watershed. This was especially evident at site 5, which represents the Deep Fork basin, and which demonstrated the highest levels of fecal contamination. The fecal contamination ratios between fecal coliform and the fecal streptococci at site 5 indicate that the contamination is most likely from a mixture of anthropogenic and non-anthropogenic sources. At site 3, the bulk of the contamination appeared to be from warm blooded mammals other than man. This can be explained by Tinker Creek's rural drainage basin flowing into site 3.

Table 10.6 Percentage of sampling events where a positive detection of fecal bacteria was found (greater or equal to 20 colonies/100 ml)

Site	Fecal Coliform	Fecal Streptococci
1	20.69%	13.79%
2	34.48%	31.03%
3	6.90%	27.59%
4	44.83%	31.03%
5	65.52%	37.93%

Table 10.7 Arcadia Lake Site 5 Coliform Detections Above Beneficial Use Criteria (200 colonies/100 ml) Compared to 96 Hour Basin Rainfall Amount.

DATE	Fecal Coliform (Colonies/100 ml)	Fecal Streptococci (Colonies/100 ml)	Previous 96 hour Basin Rainfall (inches)
4/22/96	2400	3500	1.37
7/23/96	300	120	0.05
8/27/96	220	40	1.00
9/24/96	230	90	0.23
11/19/96	500	140	0.76
2/25/97	1700	500	1.96
3/26/97	500	90	0.69

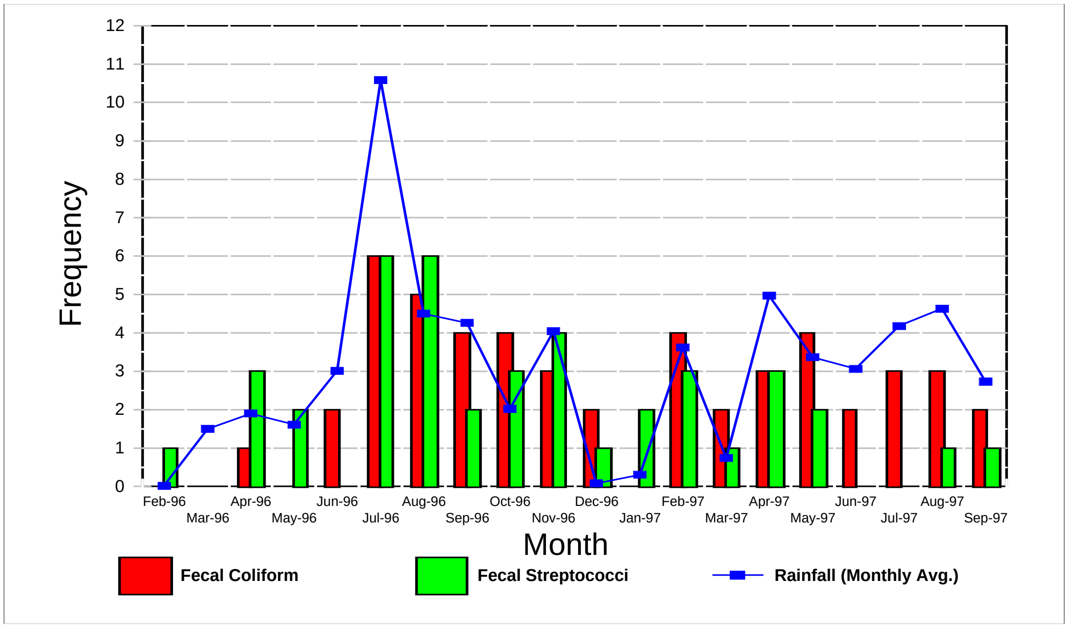

Figure 10.40 Arcadia Lake Comparison of Frequency of Fecal Bacteria Detections Above Detection Limit (20 colonies/100 ml) to Monthly Rainfall Averages - Feb 1996 - Sep 1997.

Sulfate

Sulfate ($SO_4^=$) is the predominant form of dissolved sulfur in water (**Wetzel 1983**). Sulfate may result from the chemical weathering of geologic formations, organic decomposition, or biologically mediated oxidations of reduced sulfur species (**Faust and Aly, 1981**). Sulfate concentrations in Arcadia Lake were within the usual range of 5-30 mg $SO_4^=$/l (**Wetzel 1983**), with an overall mean concentration of 27.01 mg $SO_4^=$/l. The median concentrations did not differ significantly among sites, nor between epilimnetic and hypolimnetic samples (**Figure 10.41**). Below detection limit values were only found in 2.4% (4 samples) of all the valid samples taken. Three of the four samples which had concentrations below the detection limit were collected on July 15, 1997 in the hypolimnion of Arcadia Lake. The low concentrations were because of biologically mediated reduction of sulfate during low redox potential (**Stumm & Baccini, 1978**). The other below detection limit value was in the epilimnion at site 5 on 25 Feb 97. In the 120 hours prior to the 25 Feb 97 sampling event, the basin received rainfall in the amount of 2.71 inches, which may have contributed to the low concentrations by flushing out resident lake water with low concentration runoff water. The maximum concentration in the epilimnion of 49.4 mg $SO_4^=$/l occurred on 14 May 97 at site 5. The hypolimnion maximum concentration of 37.9 mg $SO_4^=$/l occurred on 8 Jul 97 at site 4. Both of the maximum concentrations were seen under oxic conditions which cause hydrogen sulfide to be oxidized to sulfate (**Hutchinson 1957**). Overall, the sulfate concentrations in Arcadia Lake may be attributed to the combustion of coal and oil, the use of fertilizers, the weathering of rocks, and from biologically mediated oxidations of reduced sulfur species .

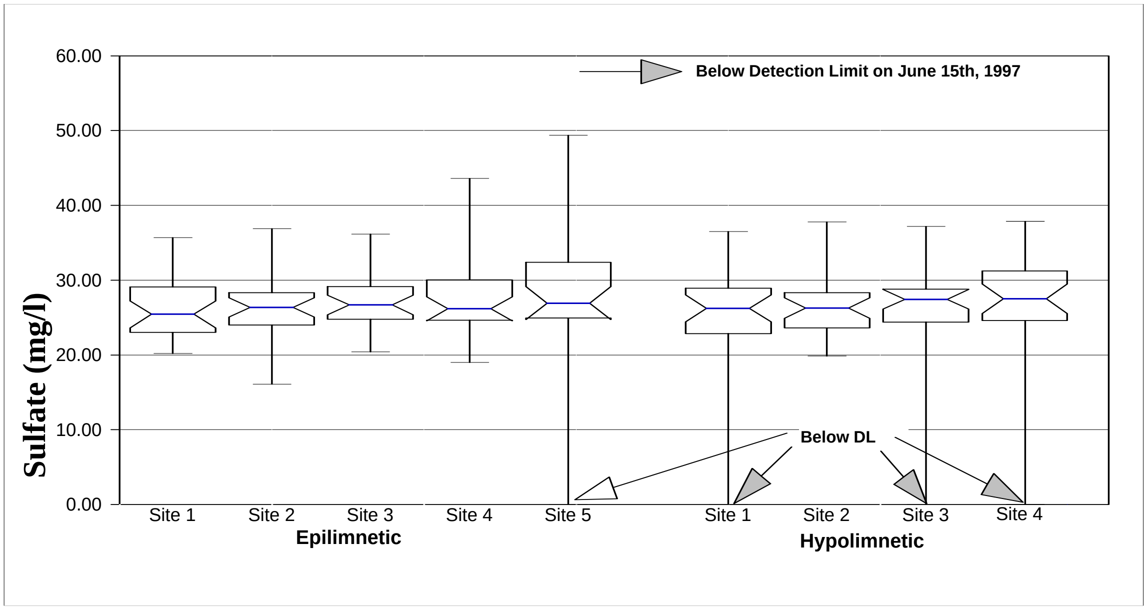

Figure 10.41 Box plot of Arcadia Lake Sulfate Concentrations (mg/l), Apr 96 - Sep 97 with median values

Nutrient Budget

A nutrient budget for Arcadia Lake was prepared by applying monitoring water quality data to the estimated hydraulic budget. Watershed load calculations from **Task 9** were combined with in-lake data to construct a comprehensive nutrient budget. **Table 10.8** summarizes the constructed budget. This budget indicates a large assimilation capacity for Arcadia Lake.

Table 10.8 Annual Nutrient Budget for Arcadia Lake 2/96 - 9/97, reported as kilograms.

Source	Sus. Solids	Total-P	Total-N
Watershed	25,500,108	32,589	154,517
Outflow	-542,098	-2,892	-29,245
Net Load	24,958,010	29,696	125,272
In-lake Mass	636,588	2,573	28,350
In-lake Loss	-24,321,422	-27,123	-96,922

Phosphorus

Phosphorous plays a major role in biological metabolism. In comparison with the other macronutrients required by biota, phosphorous is the least abundant and commonly the first element to limit biological productivity (**Wetzel 1983**). The governing effect of phosphorous becomes apparent when an increase in phosphorous allows for the use of other nutrients already present for plant growth. Total phosphorus is the measure of the phosphorous of unfiltered water, which consists of dissolved and particulate portions (**Ohle 1938**). The maximum total phosphorous concentration collected in Arcadia Lake was 0.54 mg/l, collected on 09 Jun 96 in the hypolimnion of site 1. The cause of this maximum was the release of phosphorous at the sediment water interface. As the oxygen content of the water near the interface declines, the oxidized microzone barrier weakens, which leads to release of phosphorous and other ions (**Wetzel 1983**). Arcadia Lake median concentrations of total phosphorous in the hypolimnion peaked during the summer months in both 1996 and 1997 because of the high levels at site 1 (**Figure 10.42**).

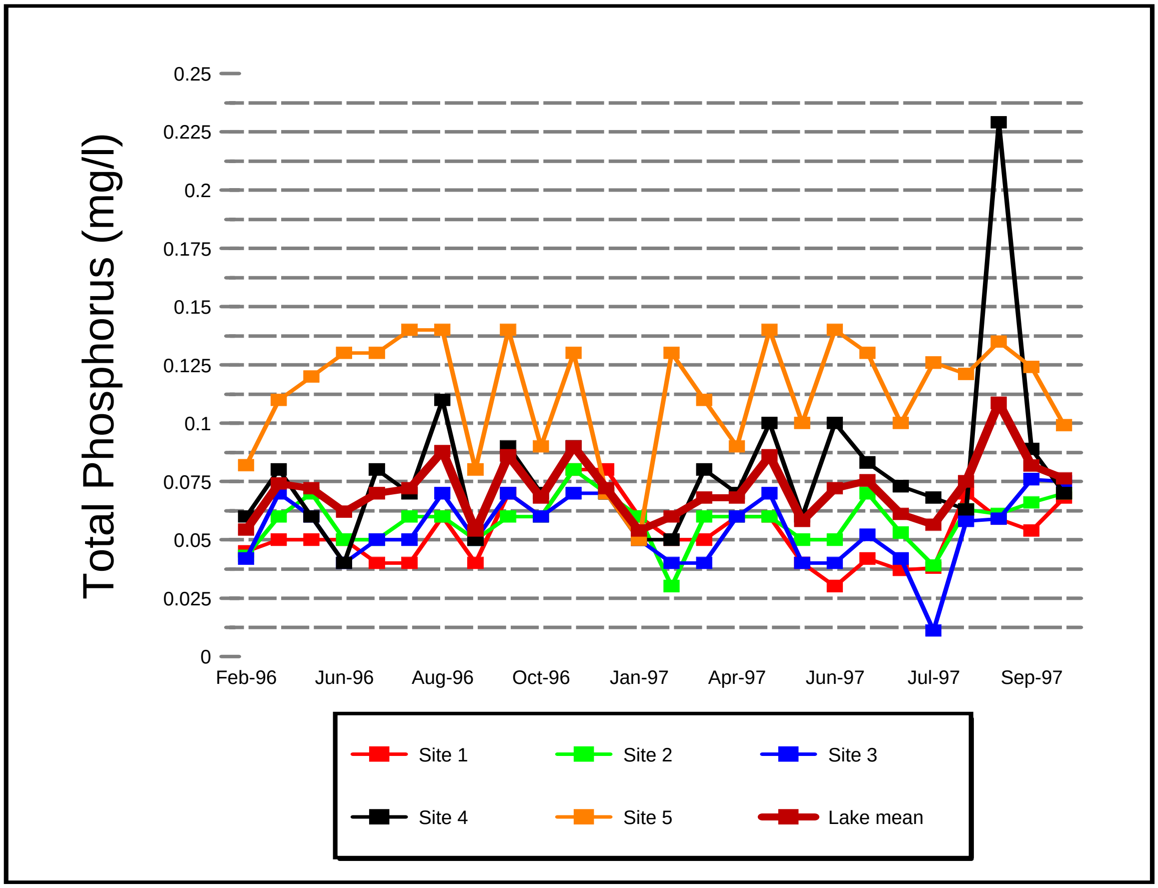

Figure 10.42 Arcadia Lake Total Phosphorus (mg/l), Apr 1996 - Sep 1997

The maximum epilimnion concentration was 0.22 mg/l at site 4 on 26 Aug 97. This concentration was correlated to a storm event. The basin received rainfall in the amount of 1.94 inches from 18 Aug 97 to 23 Aug 97. The concentration made site 4 the most variable epilimnion site, and supports **Thornton's (1990)** explanation of longitudinal zonation where nutrient concentrations are expected to vary most in headwater stations because of storm events. The lake average for all collected total phosphorous was 0.082 mg/l. The overall epilimnion total phosphorous mean was 0.072 mg/l, with the hypolimnion mean higher at 0.094 mg/l. The higher hypolimnion value stems from the peaks during stratification. The total phosphorous concentrations classify Arcadia Lake as a hypereutrophic system (**Chapra and Reckhow 1983, Carlson 1977**). Concentrations among stations varied from one another. The Deep Fork arm of Arcadia Lake (sites 4 and 5) exhibited the highest median in both the hypolimnion and the epilimnion (**Figure 10.43**). Variability was higher in the hypolimnion samples than any other part of the lake because of both longitudinal zonation and reducing conditions.

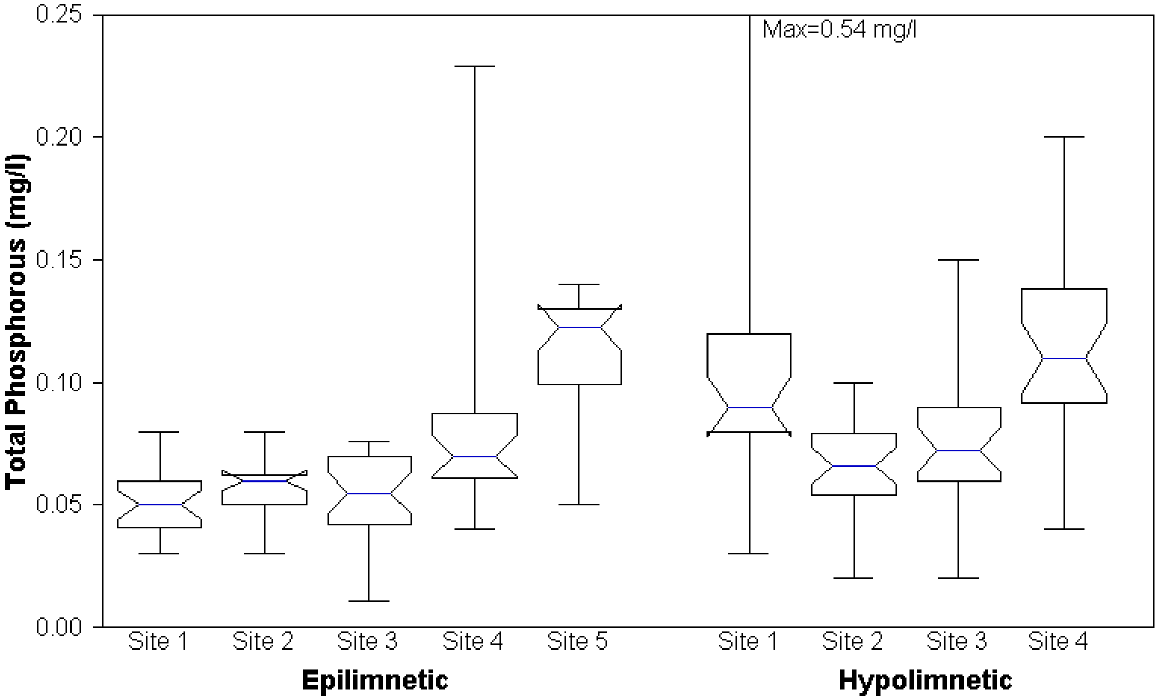

Figure 10.43 Box plot of Arcadia Lake Mean Hypolimnetic Total Phosphorus (mg/l), Apr 1996-Sep 1997 with median values

Ortho-phosphorus is the inorganic soluble phosphorous and is the fraction that is immediately available to autotrophic plants (**Cole, 1994**). Epilimnion ortho-phosphorus concentrations were somewhat lower than hypolimnion concentrations. The medians were similar among stations in the epilimnion, but there was variability in the medians of the hypolimnion (**Figure 10.44**).

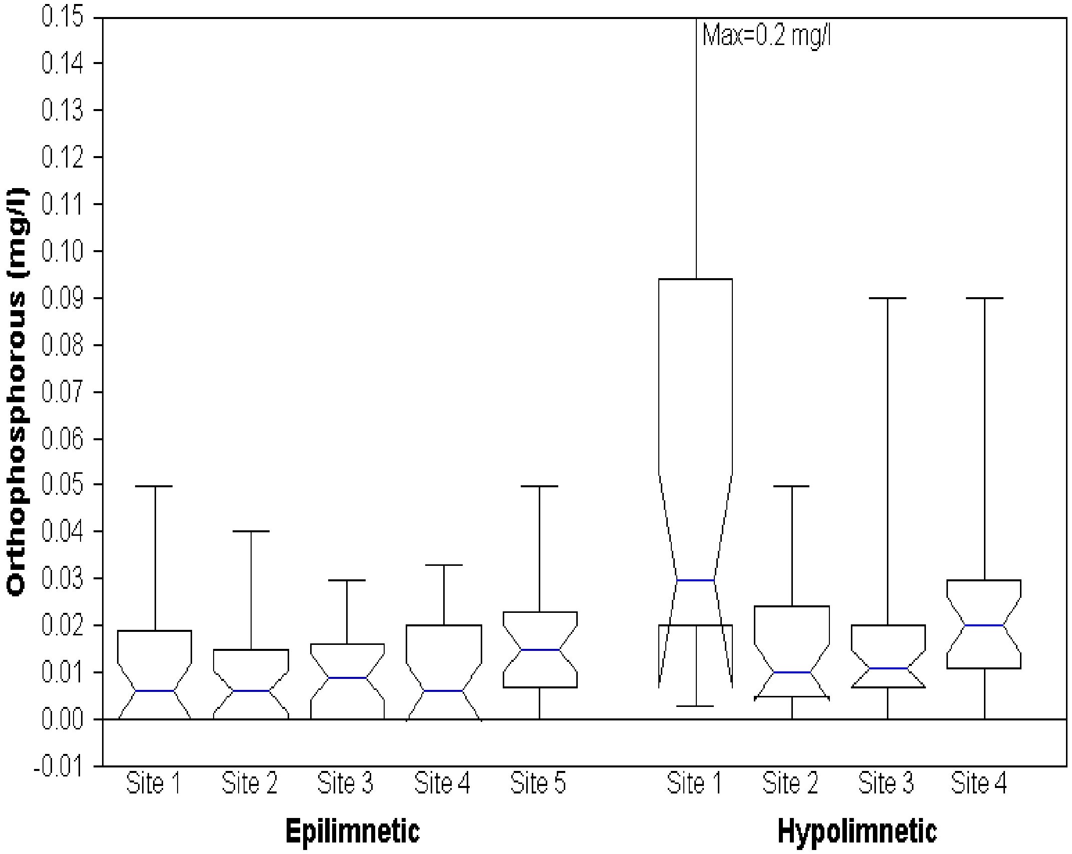

Figure 10.44 Box plot of Arcadia Lake Ortho-phosphate (mg/l), Apr 1996 - Sep 1997 with median values

The lake mean for all collected ortho-phosphorous levels was 0.016 mg/l. The overall epilimnion ortho-phosphorous mean was 0.012 mg/l, with the mean of the hypolimnion higher at 0.028 mg/l. Leading the epilimnion, site 5 had the highest median and variability, while the other sites in the epilimnion had similar medians and variability among hypolimnion concentrations. Site 1 exhibited the highest median and variability, while the other sites conveyed similar medians and variability in ortho-phosphorus concentrations. Lake epilimnion ortho-phosphorous peaked on two separate occasions. The observed peaks of 0.05 mg/l occurred during high rainfall events. The maximum at site 5 was collected following a reported 1.47 inches in the lake's basin during the 48 hours preceding the sampling. The second maximum was collected at site 1 on 29 Apr 97 following a reported 2.53 inches in the 72 hours prior to collection. The hypolimnion maximum was 0.20 mg/l, collected on 09 Jul 96 at site 1 during stratified conditions. Strong reducing conditions mediated by bacterial processes at the sediment water interface is the main factor contributing to the hypolimnetic ortho-phosphorous peaks.

Nitrogen

Nitrite-nitrogen concentrations in Arcadia Lake were below detection limits in 42.2% of the total 319 valid samples collected. The maximum of 0.14 mg/l was collected on 10 Jun 97 at site 1 with a depth of 3 meters. The lake mean was 0.012 mg/l. The overall epilimnion nitrite mean was 0.010 mg/l, with the hypolimnion mean higher at a level 0.014 mg/l. Lake epilimnion average nitrate levels peaked on three separate occasions (**Figure 10.45**).

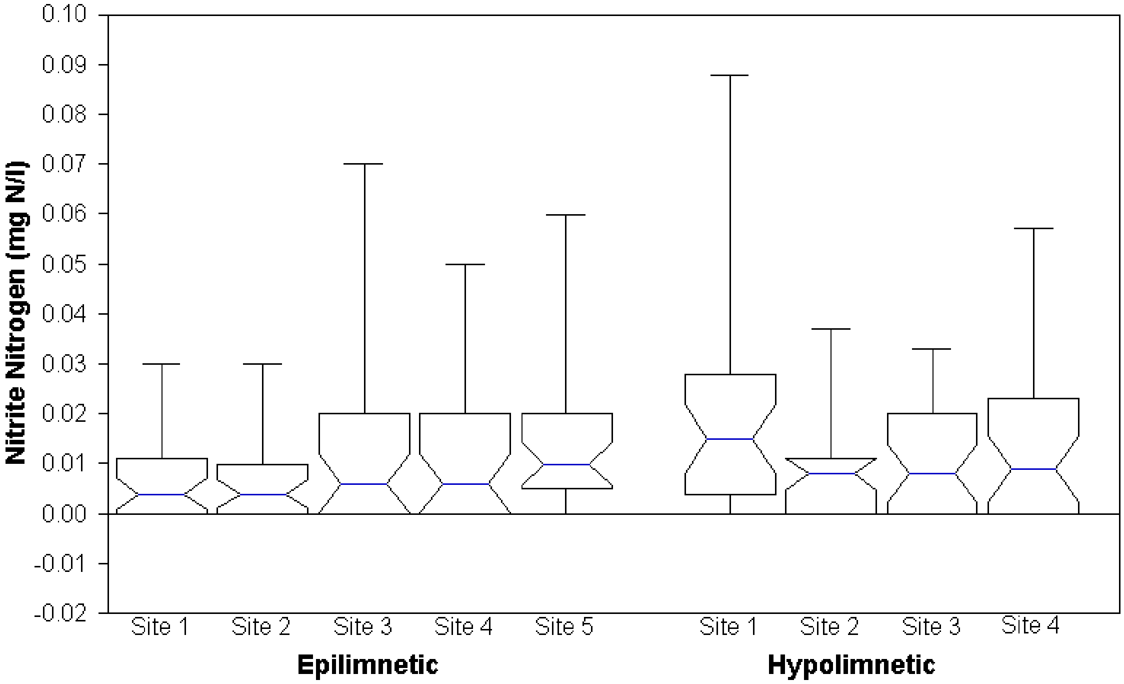

Figure 10.45 Box plot of Arcadia Lake Mean Nitrite-Nitrogen Trends (mg N/l), Apr 1996-Sep 1997 with median values

Two of the observed peaks were seen during May of each sampling year, 20 May 96 (0.032 mg/l) and 14 May 97 (0.034 mg/l). Rainfall was not significant prior to these events. The third peak was seen on 12 Aug 96 (0.032 mg/l), with approximately 1.47 inches of rainfall in the 48 hours prior to collection. Concentrations among stations were not significantly different from one another, nor were epilimnion samples significantly different from hypolimnion samples (**Figure10.46)**. Epilimnion samples at site 5 had the highest levels and variability; otherwise, variability was similar among stations. Hypolimnion samples at site 1 had the highest levels and variability; otherwise, variability was similar among stations. Concentrations of nitrite-nitrogen increase in the anaerobic hypolimnion waters and in lakes receiving heavy organic-matter pollution (**Wetzel 1983**) . The high levels in the hypolimnion at site 1 may be explained by biologically mediated reducing conditions, while the high levels in the epilimnion of site 5 were detected in oxygenated waters and may be explained by organic matter pollution of the Deep Fork River.

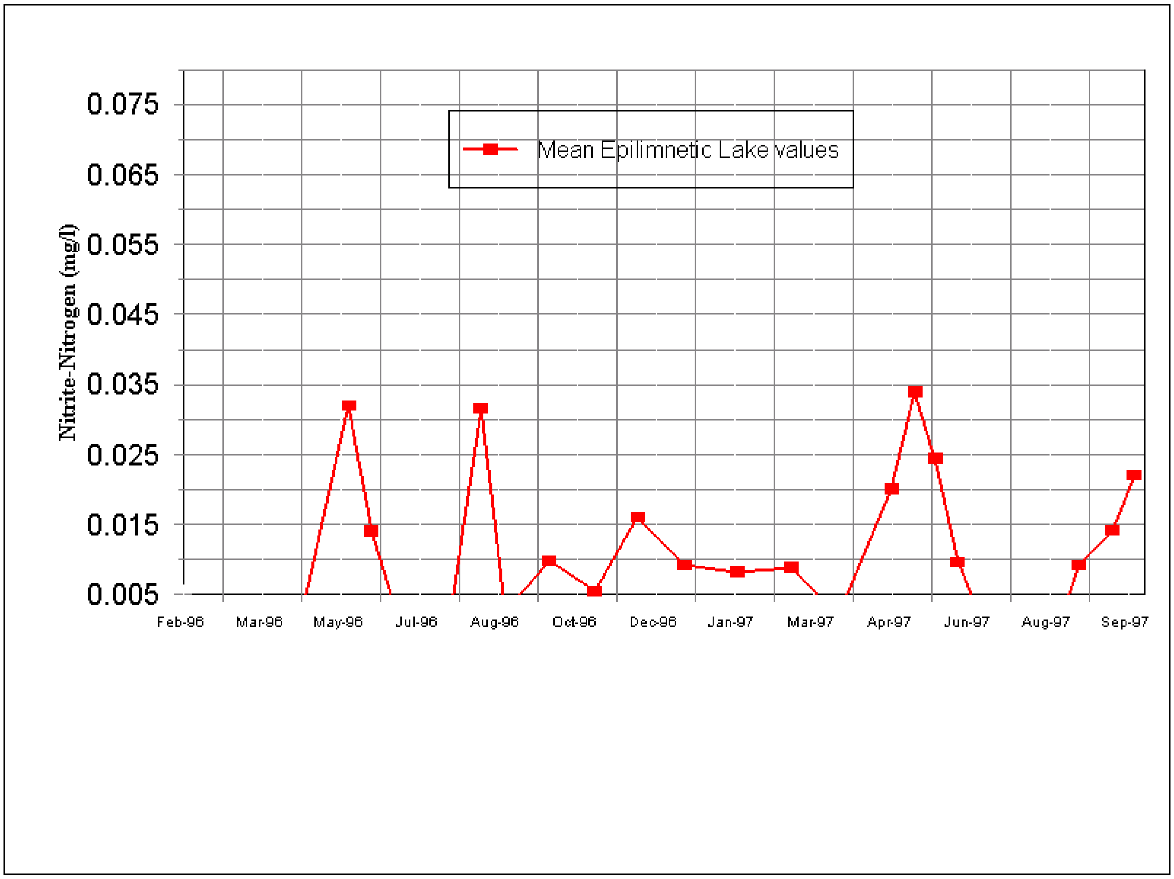

Figure 10.46 Arcadia Lake Nitrite-Nitrogen (mg N/l), Apr 1996-Sep 1997

Nitrate-nitrogen (NO_3) usually occurs in fairly small concentrations in unpolluted fresh waters, ranging from 0 to nearly 10 mg/l with seasonal and spatial variability (**Wetzel 1983**). Nitrate-nitrogen concentrations in Arcadia Lake were below detection limits in 12.6% of the total 270 valid samples collected. The maximum nitrate concentration was 1.40 mg/l, collected on 21 Jan 97 at site 1 in a surface sample. The lake average was 0.32 mg/l. The over all epilimnion nitrate mean was 0.30 mg/l, with the hypolimnion mean higher at 0.35 mg/l. Lake epilimnion average nitrate levels peaked drastically during the winter of 1997, with the highest values seen at all sites on 21 Jan 97 (**Figure 10.47**)

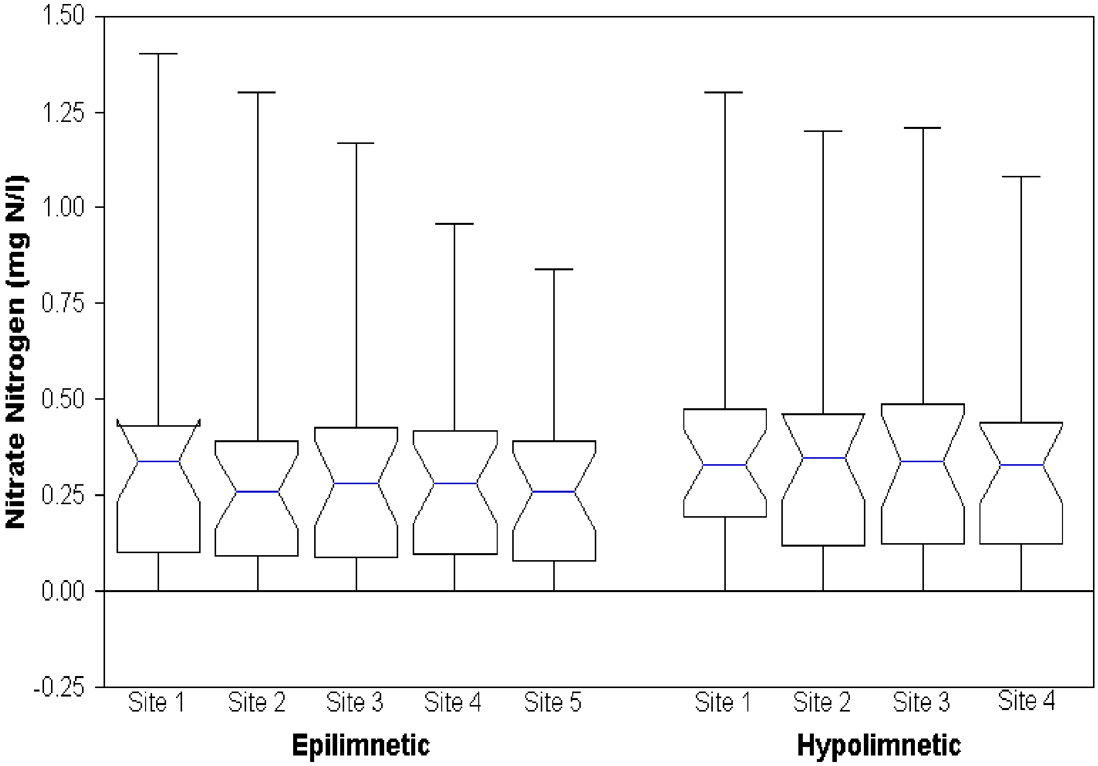

Figure 10.47 Box plot of Arcadia Lake Nitrate-Nitrogen (mg N/l), Apr 1996-Sep 1997 with median values

The lowest values (below the detection limit of 0.05 mg/l) were seen from June through September in both 1996 and 1997. Concentrations among stations were not significantly different from one another, nor were epilimnion samples significantly different from hypolimnion samples (**Figure 10.48**). Both epilimnion and hypolimnion samples at site 1 had the highest levels and variability. Under normal conditions, the amount of nitrate in solution at a given time is determined by metabolic processes in the body of water. The high levels during winter months and the minimums seen during summer months may be explained by reduced consumption by phytoplankton, increased oxidation of ammonia to nitrate and decreased dilution by inflowing stormwater.

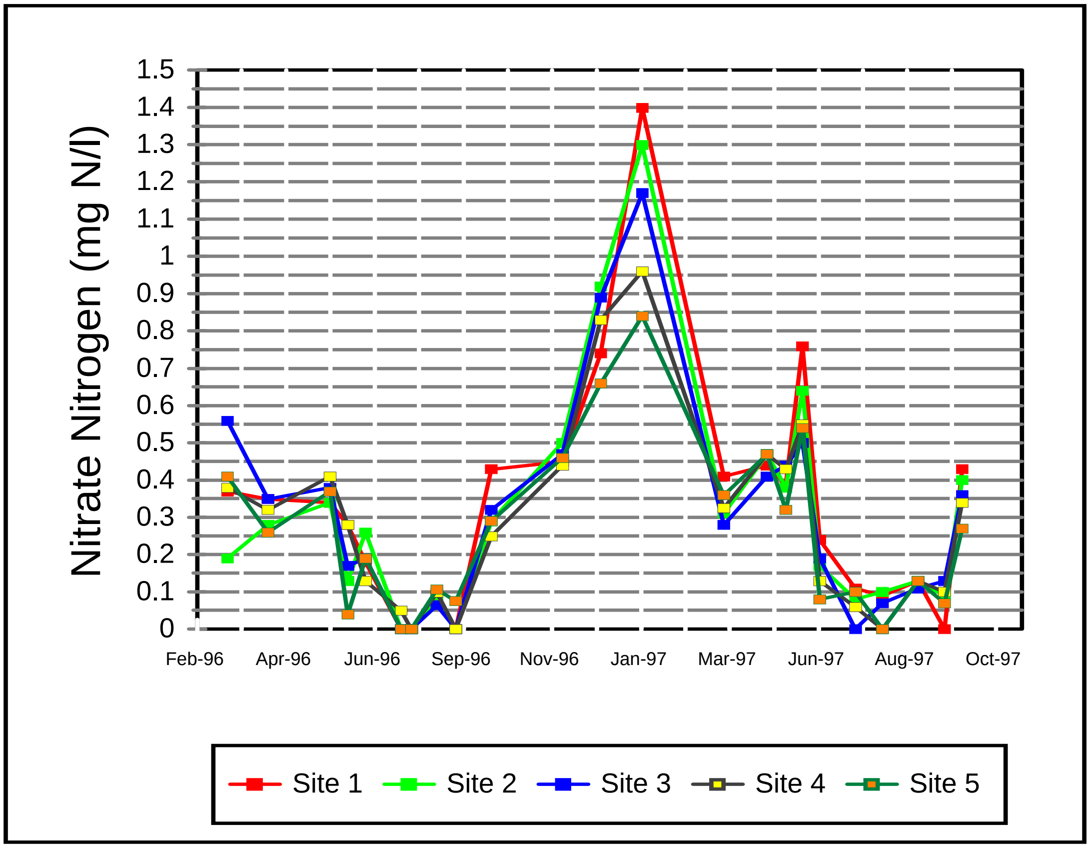

Figure 10.48 Arcadia Lake Nitrate-Nitrogen (mg N/l), Apr 1996-Sep 1997.

Ammonia-nitrogen (NH^+_4) is generated by heterotrophic bacteria as a primary end product of decomposition of organic matter (**Wetzel 1983**). Ammonia is an energy-efficient source of nitrogen for plants (nitrate must be reduced to NH^+_4-N before it can be assimilated) (**Wetzel 1983**). Ammonia-nitrogen concentrations in Arcadia Lake were below detection limits in 56.8% of the total 280 valid samples. The maximum ammonia concentration was 0.7 mg/l, collected on 09 Jun 96 at site 1 in a hypolimnion sample. The lake average was 0.050 mg/l. The overall epilimnion ammonia mean was 0.029 mg/l, with the hypolimnion mean higher at 0.074 mg/l. Arcadia Lake epilimnion ammonia levels moderately peaked during the months of July through September in both 1996 and 1997 during stratification. The highest epilimnion value of 0.422 mg/l was seen at site 4 on 26 Aug 97 because of longitudinal zonation. The basin had reported rainfall amounts of 1.94 inches from 18 Aug 97 to 23 Aug 97. Concentrations among stations were not significantly different from one another, nor were epilimnion samples significantly different from hypolimnion samples (**Figure 10.49**). Sites 1 and 4 did report higher median values. Anoxic release explains the higher hypolimnetic median at site 1, while stormwater inflows can explain the higher hypolimnetic median at site 4. Variability in hypolimnion samples was greater than in epilimnion samples. Epilimnion variability was highest at site 4. Hypolimnion samples at site 1 had higher peak values than all other sites. Ammonia-nitrogen is more likely to accumulate in anoxic hypolimnia of stratified lakes than in oxygenated water (**Wetzel 1983**) because of anaerobic metabolism. The maximum is related to the extent and duration of anoxia occurring more at site 1 than at other any other sites.

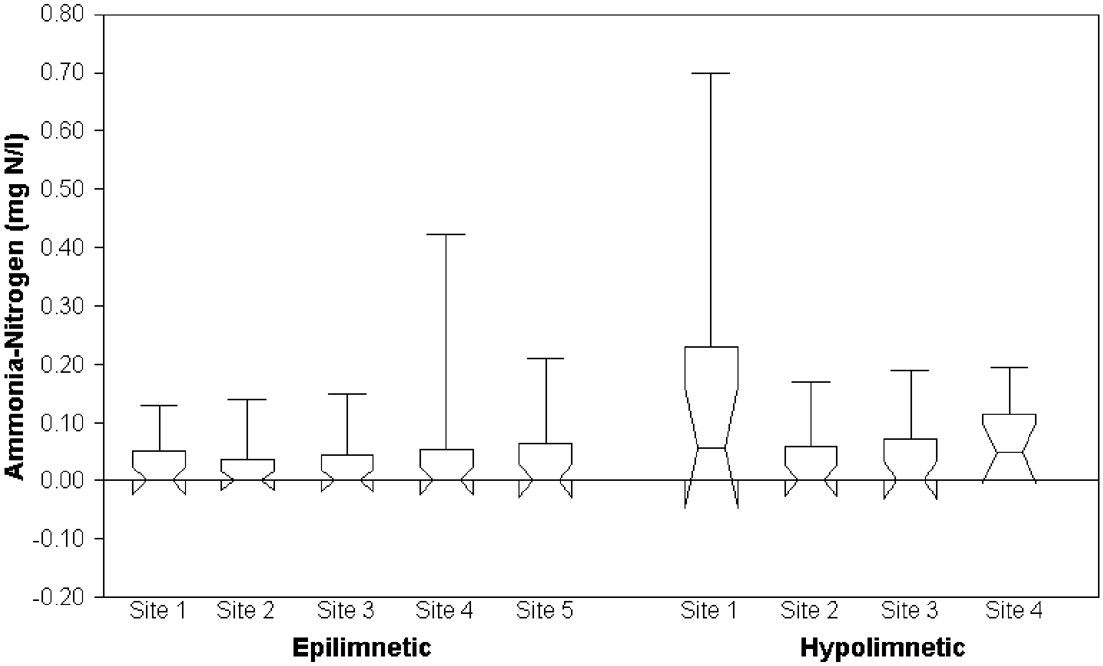

Figure 10.49 Box plot of Arcadia Lake Ammonia-Nitrogen Concentrations (mg N/l), Apr 1996-Sep 1997 with median values

Organic nitrogen generally occurs in forms which are resistant to rapid bacterial breakdown and often accounts for more than half of the total dissolved nitrogen (**Wetzel 1983**). Nitrogen in biota is in the form of organic nitrogen. Residues from farm animals contain considerable quantities of organic nitrogen compounds (**Faust & Aly 1981**). Over half of the nitrogen concentrations in Arcadia Lake were made up of organic fractions. Organic-nitrogen concentrations in Arcadia Lake were above detection limits on all 305 valid samples. The maximum organic-nitrogen concentration was 1.47 mg/l, collected on 16 Sept 97 at site 5 in a surface sample. The minimum was 0.24 mg/l, collected on 19 Dec 96 at site 3.

Figure 10.48 illustrates the variability of organic-nitrogen throughout the sample period. Comparing **Figure 10.48** against **Figure 10.46** indicates that organic nitrogen varies inversely with nitrate concentration. This suggests that organic nitrogen content is driven mostly by bacterial processes and inflow events. The lake average for all organic-nitrogen levels was 0.53 mg/l. The overall epilimnion organic-nitrogen mean was 0.58 mg/l, with the hypolimnion mean similar at 0.52 mg/l. Lake epilimnion mean for organic-nitrogen levels was highly variable throughout the sampling period (**Figure 10.50**).

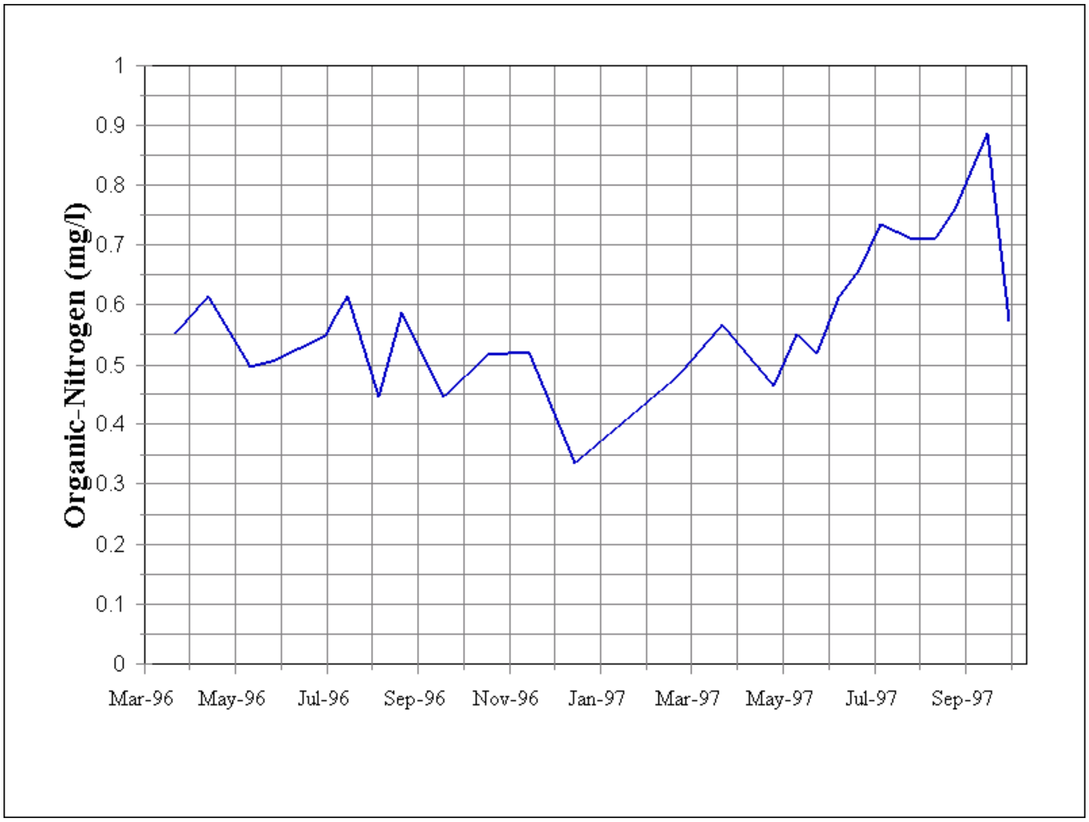

Figure 10.50 Arcadia Lake Organic-Nitrogen Concentrations (mg/l), Apr 1996 - Sep 1997.

Epilimnion concentrations among stations were not significantly different from one another, with the exception of site 5 (**Figure10.51**). The high variability and levels at sites 4 and 5 demonstrated the contributing force of the Deep Fork, while the variability at site 2 shows the Spring Creek influence. Hypolimnion variability at site 1 was caused by periods of stratification.

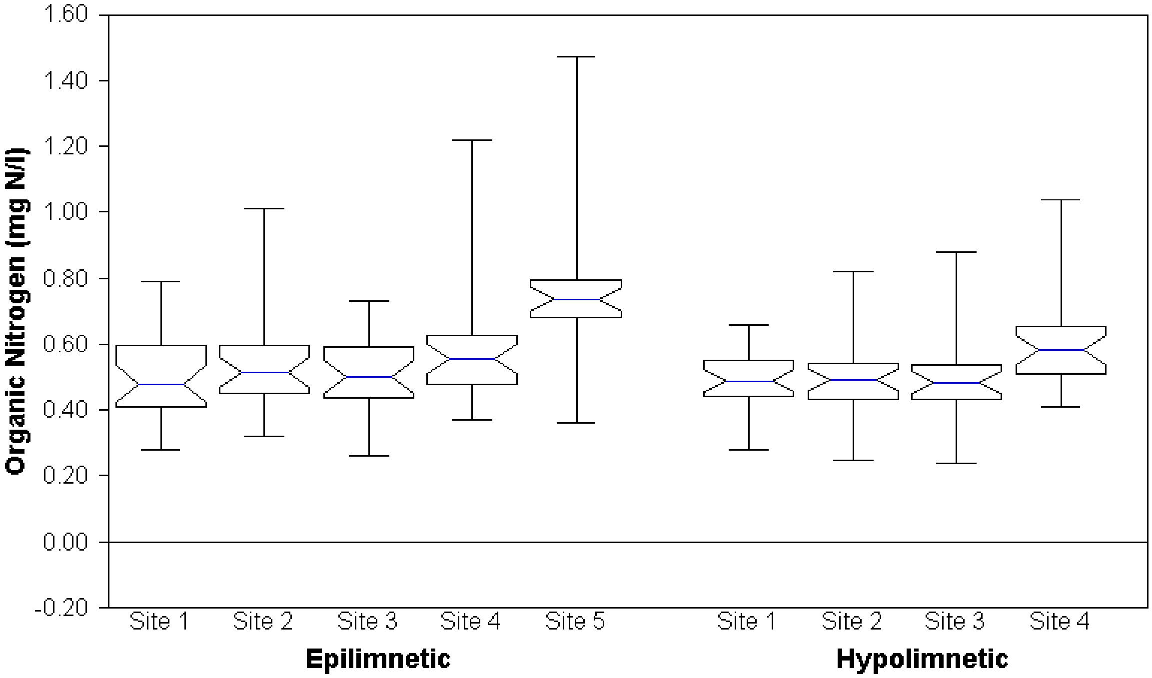

Figure 10.51 Box plot of Arcadia Lake Organic Nitrogen Trends (mg N/l), Apr 1996 - Sep 1997 with median values

Total kjeldahl nitrogen (TKN) refers to the combined quantities of organic nitrogen and ammonia (**APHA 1995**). The overall epilimnion TKN mean was 0.616 mg/l, with the hypolimnion mean similar at 0.607 mg/l. Concentrations among stations were not significantly different from one another, with the exception of site 5. The epilimnion samples were similar to hypolimnion samples at all sites (**Figure 10.52**). In the epilimnion, high variability and levels at sites 4 and 5 show the contributing force of the Deep Fork, while the variability at site 2 shows the Spring Creek influence. In the hypolimnion, all sites demonstrated similar values, with site 4 slightly higher due to the influence of the Deep Fork River.

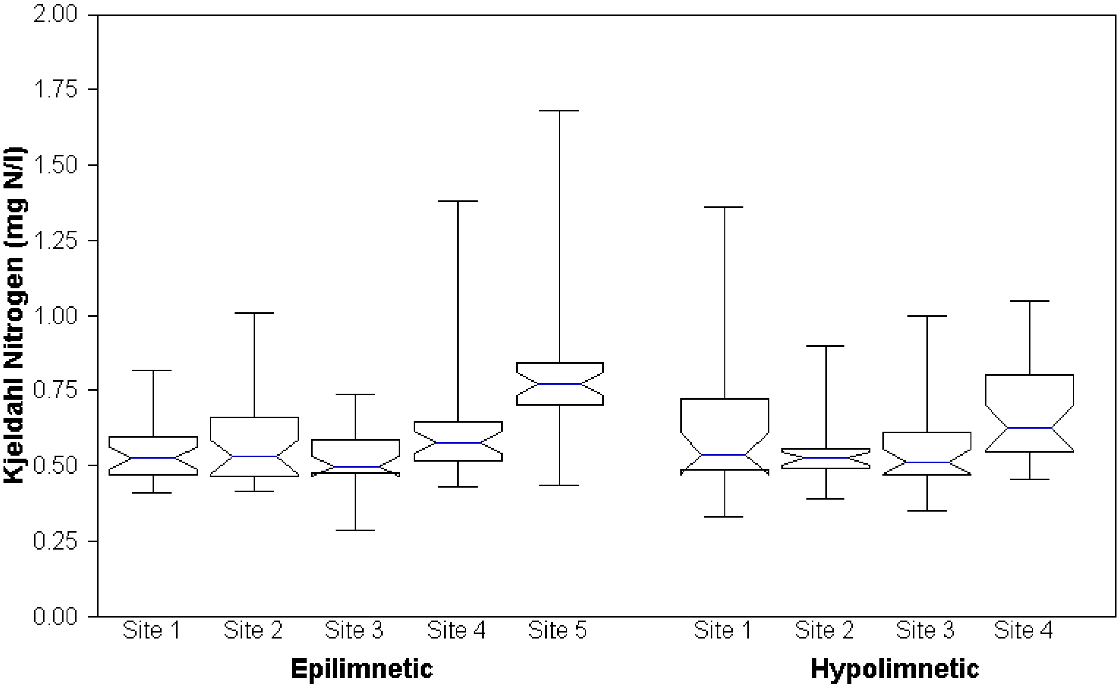

Figure 10.52 Box plot of Arcadia Lake Kjeldahl-Nitrogen Concentrations (mg/l), Apr 1996- Sep 1997 with median values

Median total nitrogen concentrations, or the sum of nitrate, nitrite, and total Kjeldahl nitrogen (**APHA 1995**) did differ slightly among sites (**Figure 10.53**). Site 5 exhibited the highest epilimnion mean of 1.056 mg/l. Contributions from high nitrite-nitrogen levels during periods of stratification allowed site 1 to maintain the highest hypolimnion mean. Variability among stations was similar. Median total nitrogen concentration classified Arcadia Lake as a mesotrophic-eutrophic system using **Vollenweider's (1979)** general trophic classification in relation to phosphorous and nitrogen. In addition, all total nitrogen concentrations were above 0.3 mg/ℓ, **Sawyer's (1947)** limit for probable development of nuisance algal growths during the growing season

Figure 10.52 Box plot of Arcadia Lake Kjeldahl-Nitrogen Concentrations (mg/l), Apr

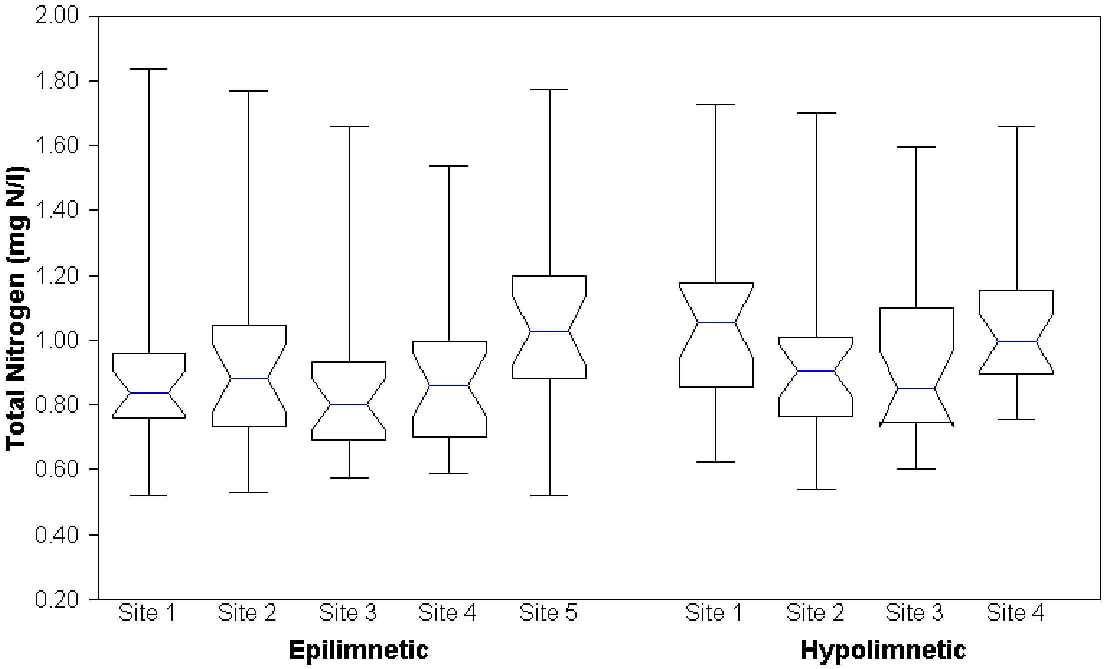

Figure 10.53 Box plot of Arcadia Lake Total Nitrogen Concentrations (mg N/l), Apr 1996 - Sep 1997 with median values

TN:TP Ratio

Nitrogen and phosphorus are the elements which most commonly limit algal growth because large amounts are required relative to available concentrations (**Vollenweider 1968**). Because different concentrations of each element are required, the ratio of total nitrogen to total phosphorus (TN:TP) is as important as the relative concentrations of each element in consideration of algal productivity. The ratio is commonly used to estimate which factor, N or P, could limit algal growth (**Schindler 1977**). The ratio may also provide insight into which types of algae may prevail within the lake **(EPA 1986)**.

The TN:TP ratio was highest at the central pool, site 1, and lowest in the Deep Fork arm of the lake, sites 4 and 5. (**Figure 10.54**). Median values were approximately 13:1, suggesting slight overabundance of phosphorus rather than insufficient nitrogen, but the central pool had a median near 16:1. **Sakamoto (1966)** suggested nitrogen limitation could occur when TN:TP ratios were <15-17:1. Nitrogen-fixing blue green algae often dominate nitrogen limited systems. Blue greens are undesirable because of their propensity to form massive blooms which often cause taste, odor, and oxygen demand problems. The ratio, however, did swing from a low of approximately 6:1 at site 5 on 12 Aug 96 to 67:1 at site 3 on 29 July 97 (**Figure 10.55)**. There

Figure10.53 Box plot of Arcadia Lake Total Nitrogen Concentrations (mg N/l), Apr

were 1.47 inches of rainfall recorded within 48 hours prior to the minimum ratio, and no significant rainfall recorded prior to the maximum ratio. The maximum was caused by the phosphorous levels at site 3 dropping drastically rather than nitrogen increasing.

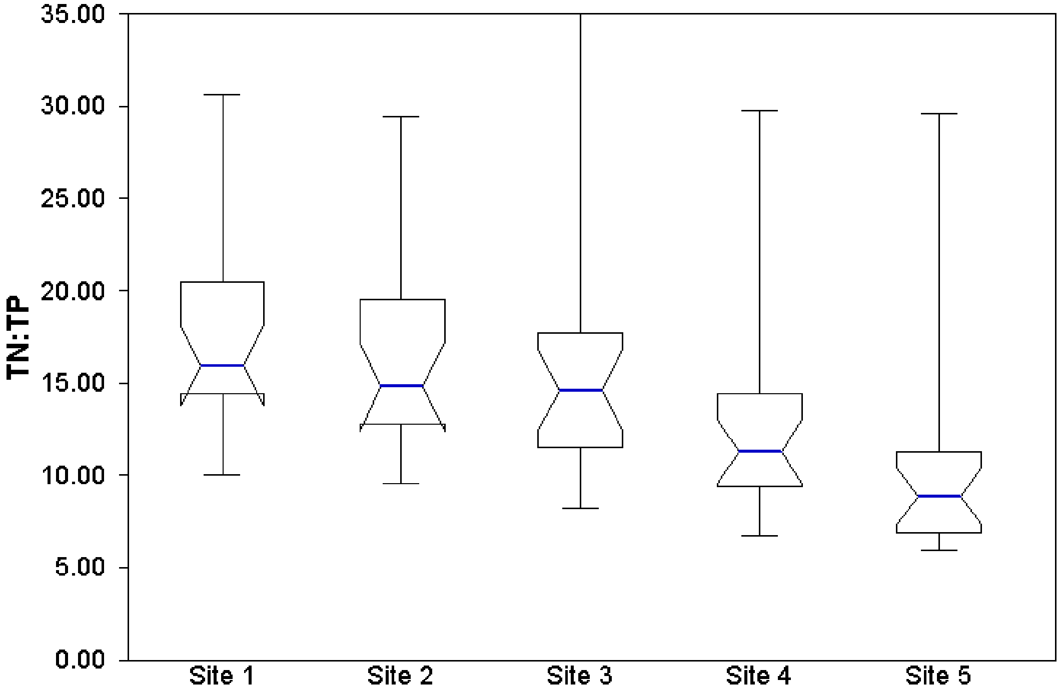

Figure 10.54 Box plot of Arcadia Lake Total Nitrogen:Total Phosphorous Ratio Trends, Apr1996-Sep1997 with median values

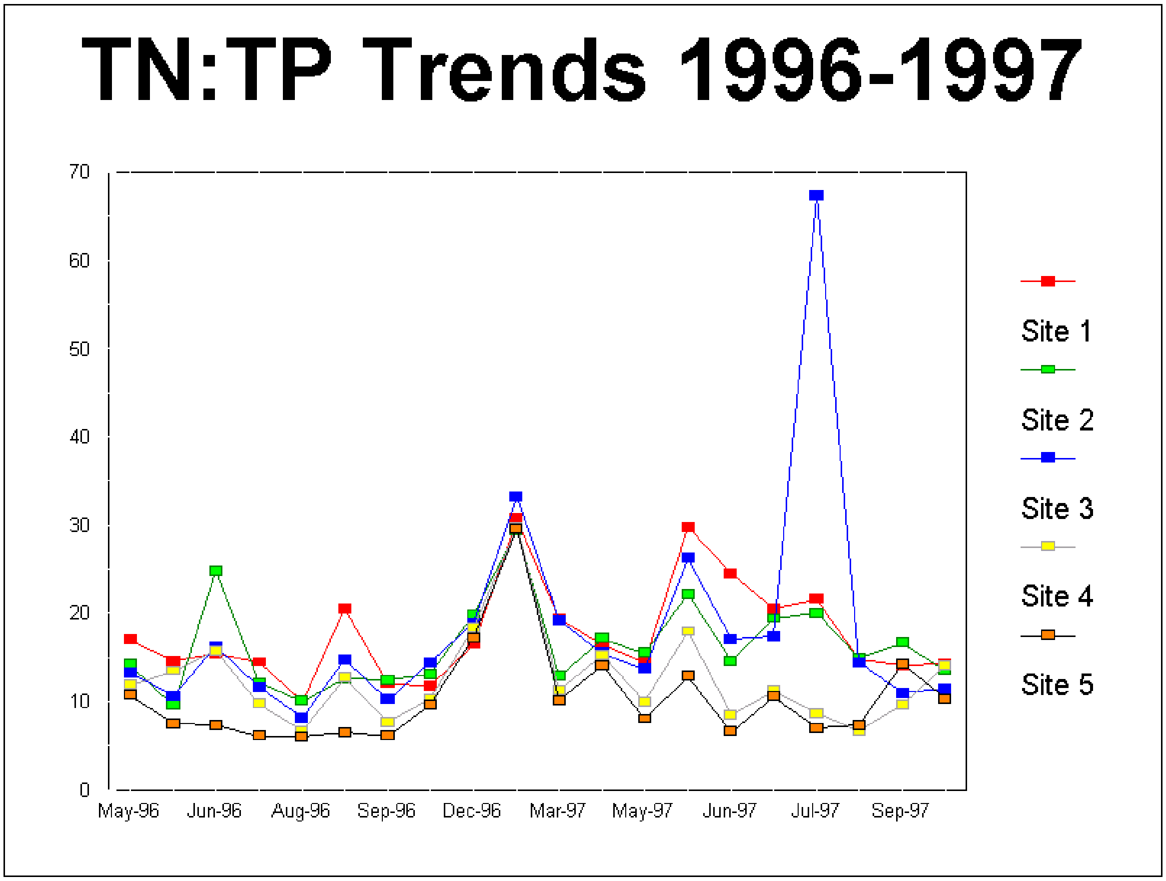

Figure 10.55 Arcadia Lake Total Nitrogen:Total Phosphorus Ratio Trends, Apr 1996-Sep 1997

Sediment Toxicity

A sediment quality survey was conducted on Arcadia Lake as a cooperative effort between Region VI EPA and OWRB, because it is located in an urban watershed and is heavily influenced by nonpoint pollutant sources. Follow-up sampling was subsequently conducted in two tributaries of the lake, Spring Creek and Deep Fork. The purpose of this study was to collect additional sediment quality data to determine if contamination by metals and organic chemicals is a concern. The following is an excerpt from the report of that study. See **Appendix D** for complete results of this survey, and description of sampling locations.

Overall, the data indicate significant, but relatively low level of sediment contamination. The data demonstrate the preponderance of PAHs in lake sector B. Dieldrin was also found in this sector. Metals were most elevated in sector C, as was bis(2-ethylhexyl)phthalate. These sectors comprise the upper and lower Deep Fork arm of the lake. Cadmium was found throughout (except for the two tributary sites), including the Liberty Lake reference site. The elutriate toxicity tests indicated that pollutants were not elevated enough to elicit a significant toxic effect; however, it should be realized that these tests are primarily reflective of water soluble contaminants, and thus may be less conservative than whole sediment tests. Whole sediment tests reflect exposure to all pollutants through exposure to the sediments themselves. The finding of no toxicity is consistent with EPA Region VI experience that sediment toxicity is generally only observed in relatively close proximity to pollutant sources.

Sediment contaminant levels are a good indicator of nonpoint source pollution in this urban watershed. Pollutant levels in sediment were not high enough to warrant remediation (i.e., removal of sediment); however, if opportunities or programs become available, nonpoint source controls to reduce pollutant loads (metals, PAHs) would benefit sediment quality and reduce risks to benthic organisms. Concentrating watershed protection efforts in the Deep Fork portion of the watershed would be the most appropriate to enhance and protect sediment quality in Arcadia Lake.

Storm Water Toxicity

Because storm water can have a significant influence on lake water and sediment quality, samples were tested following a major rainfall event. On 6-17-97, samples were taken from site 7, the Deep Fork arm, and site 8, the Spring Creek arm (see **Figure 1.1** for map of sites). Parameters analyzed were pH, hardness, alkalinity, conductivity, total ammonia, total chlorine, and salinity. Fathead minnows and *Ceriodaphnia* were exposed to water samples from each site to measure the effect of the storm water on zooplankton. (See **Appendix E** for chemistry data).

Following seven days exposure to the water samples, no significant effect on fathead minnows was noted at either site. Exposure of *Ceriodaphnia* to the storm water samples, however, showed 100% mortality after 24 hour exposure to the site 8 water sample. No significant effect was observed in those organisms exposed to the water from site 7.

On 7-28-97 and 7-31-97, samples were collected of both sediment and water at sites 7 and 8. Sediment samples were collected using Eckman grabs, 9 at site 8 composited, and 4 at site 7 composited. Sediment samples were analyzed for VOCs, metals, organics, TOC, and grain size. Water samples were analyzed using the same parameters as the earlier samples.

Grain size analysis showed that both sites were predominantly sandy. The percent of total solids at site 7 was 79.2%, and at site 8 was 72.69%. TOC at site 7 was 6990 mg/Kg, and at site 8 was 1660 mg/Kg. Testing of the sediment did not show any significant toxicity. At site 8, testing indicated the presence of detectable amounts of bis(2-ethylhexyl)phtahalate, flouranthene, phenanthrene, and pyrene. Testing also revealed an unknown adipate and an unknown hydrocarbon. Metals were not present in significant amounts in the sediment at either site, with the exception of calcium and iron.

Fathead minnow and *Ceriodaphnia* were exposed to both the water samples and an eluate of the sediment samples. After seven days, no significant effect was noted on either organism at either site.

Following the next similar storm event on 8-22-97, samples were again collected from the Arcadia Lake watershed at site 7 and site 8 for comparison testing. GC/MS (Gas chromatography/mass spectrometry) testing and metals testing were done. Testing revealed levels of zinc in the watershed that exceeded the levels established by the Oklahoma Water Quality Standards (**OWRB, 1994**) at both site 7 and site 8. Since *Ceriodaphnia* is sensitive to elevated zinc, this could explain the mortality seen in earlier testing, although the levels seen on this date were not elevated to a level that would be expected to result in 100% mortality over a 24-hour period. For a further discussion of zinc, refer to the section on non-point source pollution.

The cause for the 100% mortality of *Ceriodaphnia* following the first storm event was not fully explained by subsequent testing. No toxic compounds were detected at significant levels which could be expected to result in this level of mortality. It could be that this was an isolated incidence of a compound passing through the Spring Creek arm without leaving a residual level in either the water or the sediment. It could also possibly be explained by the elevated levels of zinc in the stormwater; however, with only one sample, this conclusion would be premature without additional sampling to verify whether this is an acute or chronic condition.

TASK ELEVEN - BIOLOGICAL RESOURCES

The ODWC reported 182 bird species, 12 amphibian species, 40 reptile species and 32 mammal species as occurring or potentially occurring in the Arcadia Lake watershed. Some species are strictly migratory, while others are year-round residents. For example, the white pelican pictured in **Figure 11.1** is a common visitor to Arcadia Lake, but does not reside the full year. There are no species in Oklahoma County that are on the state endangered species list, but there are some species that potentially use the lake that are on the federal endangered species list (**Table 11.1**). An endangered species is a native species whose prospects of survival or recruitment is in imminent jeopardy. A threatened species is a native species that, although not presently in danger of extirpation, is likely to become endangered in the foreseeable future in the absence of special protection and management efforts. A Special Concern II species is identified by technical experts as possibly threatened or vulnerable to extirpation, but for which little, if any, evidence exists to document the population level, range, or factors pertinent to its status. Some of these species do not make their home in Arcadia Lake, but only use the lake seasonally, such as the Interior least tern, which is at best seen only during migration. The bald eagle, which is listed as a threatened species, is known to visit Arcadia Lake every winter, and the City of Edmond provides bald eagle tours for visitors. The Loggerhead shrike and the Texas horned lizard, although included on this list, are not likely in this area of the state, but could possibly extend into this range.

Table 11.1 Vertebrate species listed as state endangered, threatened or of special concern which potentially occur in the Arcadia Lake watershed.

Scientific Name	Common Name	Status
Lanius ludovicianus	Loggerhead shrike	special concern II
Camphora coccinea	Northern scarlet snake	special concern II
Phrynosoma cornutum	Texas horned lizard	special concern II
Mustella frenata	Long-tailed weasel	special concern II
Haliaeetus leucocephalus	Bald eagle	threatened
Sterna antillarum	Interior least tern	endangered

Figure 11.1 American white pelican migrating north above Arcadia Lake, 1996. This was during the breeding season, as indicated by the knob on the beak.

Vertebrate Species

The Arcadia Lake watershed could potentially include 29 species of fish. Game fishes present in the watershed are largemouth bass (*Micropterus salmoides),* spotted bass *(Micropterus punctulatus),* bluegill sunfish (*Lepomis macrochirus*), longear sunfish (*Lepomis megalotis*), redear sunfish (*Lepomis microlophus*), white crappie, (*Pomoxis annularis*), channel catfish (*Ictaluris punctatus*), and flathead catfish (*Pylodictus olivaris*). No endangered, threatened or special concern fish species are known to occur within the Arcadia Lake watershed.

Aquatic Macrophytes

Aquatic macrophytes have largely been absent in Arcadia Lake since impoundment with the exception of sparse cattail (*Typha* sp) stands. A few scattered populations of American pondweed (*Potamogeton nodosus*), and Eurasian milfoil (*Myriophyllum spicatum*) were present within a few years after impoundment, but did not persist.

Aquatic plant contribution to the productivity of a lake ecosystem normally is significant (**Wetzel, 1983**). Arcadia Lake, however, is an exception. Shoreline erosion has precluded the growth of emergent aquatic plants at or above the shoreline. Until recent efforts of the COE and ODWC, Arcadia Lake has not supported an appreciable plant community. Thus, phytoplankton growth was the sole source of primary production within the Arcadia Lake ecosystem.

In the summer of 1996, ODWC began a program to establish aquatic macrophyte populations in the lake to improve largemouth bass nursery habitat. Test plots of nine submersed, two floating leaved and five emergent species were planted to determine which species were most suitable for the environment and thus would provide founder colonies for the spread of plants into unvegetated areas (**Table 11.2**).

Table 11.2 Aquatic plant species planted in Arcadia Lake by the ODWC.

Scientific Name	**Common Name**
Submersed	
Chara sp	muskgrass
Najas guadalupensis	southern naiad
Potamogeton pusillus	narrow-leaved pondweed
Zannichellia palustris	horned pondweed
Ceratophyllum demersum	coontail
Elodea canadensis	American elodea
Heteranthera dubia	water stargrass
Potamogeton pectinatus	sago pondweed
Vallisneria americana	tape grass
Floating leaved	
Nelumbo lutea	American lotus
Potamogeton nodosus	American pondweed
Emergent	
Echinodorus cordifolius	creeping water plantain
Eleocharis macrostachya	flatstem spikerush
Eleocharis quadrangulata	squarestem spikerush
Sagittaria sp	arrowhead
Scirpus validus	softstem bulrush

Problems with survival of the young-of- year bass can be attributed to absence of vegetative cover in the lake, according to Gene Gilliland at the ODWC. Lack of suitable nursery cover for the young fish results in increased predation, and a subsequent decrease in the adult fish population. In an attempt to provide this missing component for fish fry, several plant species have been introduced into the lake, including *Heteranthera dubia* (water stargrass); *Potamogeton pusillus*, *Potamogeton nodosus* and *Potamogeton nodosus* (pondweed); *Ceratophyllum demersum* (coontail); *Vallisneria americana* (tape grass); and *Elodea canadensis* (American elodea). Some early success has been realized in establishment and reproduction of the aquatic plants. Gilliland stated that the fish catch for 1999 contained a higher number of young-of-year black bass than in previous years. **Figure 11.2** is an illustration of the planting effort.

Figure 11.2 *Potamogeton nodosus* planted in Arcadia Lake.

Benthic Macroinvertebrates

The benthic macroinvertebrate community of Arcadia Lake was sampled on December 31, 1996 and again on March 25, 1997. The following five sample sites were established for the December 31, 1996 sample collection: Deep Fork River, Spring Creek arm, Tinker Creek arm, midlake (6 meters), and dam (11 meters). The following five sample sites were established for the March 25, 1997 sample collection in conjunction with the Arcadia Lake sediment study (based on USACOE study sites): Deep Fork River (B-2, B-6), Spring Creek arm (E-6, E-8), and Tinker Creek arm (D-3). Sediment collected were grab samples using a Petite Ponar in December, 1996, and an Ekman Grab sampler in March, 1997. The Ekman grab was used in March because of the sediment type of Arcadia Lake. Macroinvertebrates were separated from the sediment using graded sieves and then preserved in 100% ethanol. Samples were sorted, identified and counted upon return to the OWRB laboratory. The community consisted of 2 Phyla, 3 Classes, 6 Families for the December

1996collection and 2 Phyla, 3 Classes, and 5 Families for the March 1997 collection. Taxa and densities of the collected organisms are summarized in following tables.

Table 11.3 Benthic macroinvertebrates collected in Arcadia Lake.

Date collected	Phylum	Class	Order	Family
12/31/96 03/25/97	Arthropoda	Insecta	Diptera	Chaoboridae
12/31/96 03/25/97	Arthropoda	Insecta	Diptera	Chironomidae
12/31/96 03/25/97	Annelida	Oligochaeta	Haplotaxida	Tubificidae
12/31/96 03/25/97	Annelida	Oligochaeta	Lumbriculida	Lumbriculida
12/31/96	Arthropoda	Crustacea	Copepoda	
12/31/96	Arthropoda	Crustacea	Cladocera	Daphnidae

In December 1996, no one species of benthic macroinvertebrates was dominant. Almost equal numbers of oligochaetes, chironomids, and phantom midges were present in Arcadia Lake based on this sample collection. The presence of Cladocera and Copepoda was probably accidental, since most accounts of these organisms belong to zooplankton sample collections. All other organisms identified at each site are classified as tolerant organisms, according to Beck's biotic index (**Terrell and Perfetti 1991**). *Chaeoborus* (phantom midge) was the only macroinvertebrate found in all sample site locations in the lake.

Table 11.4 December 31, 1996 sample results sorted by site, showing number of individuals collected

Lacustrine Transition Riverine

Classification	**6m midlake**	**11m dam**	**Tinker Creek**	**Deep Fork**	**Spring Creek**	TOTAL
Chaeoboridae	29	16	2	4	5	56
Chironomidae	3	1	3		38	45
Tubificidae		2	38		14	54
Lumbriculidae			15		4	19
Copepoda					2	2
Cladocera					2	2
TOTAL	32	19	58	4	65	178
Sp. Diversity	0.311	0.537	0.896	0.000	1.228	1.413

In March 1997, both chironomids and oligochaetes were abundant. The decrease in the number of phantom midges was probably due to seasonal influence. Other than the accidental cladoceran, all organisms identified at each site are classified as tolerant organisms according to Beck's biotic index (**Terrell and Perfetti 1991**). Chironomids were the only organisms present in both the lacustrine and transition zones, in all but one sample site location.

Table11.5 March 25, 1997 sample results sorted by site showing number of individuals collected

Transition Riverine

Classification	Tinker Creek (D3)	Deep Fork (B2)	Deep Fork (B6)	Spring Creek (E8)	Spring Creek (E6)	TOTAL
Chaeoboridae					1	1
Chironomidae	4		27	47	1	79
Tubificidae		64			11	75
Lumbriculidae			2			2
Cladocera					1	1
TOTAL	4	64	29	47	14	158
Sp. Diversity	0.000	0.000	0.251	0.000	0.755	0.820

Oligochaetes tolerate a broad range of water quality conditions and often dominate in polluted water situations (**Pennak 1989**). Some tubificid oligochaete species are considered indicative of organic pollution; however, none of the annelids observed in this study were classified to genus. The true midges (Chironomidae) were prevalent in both December 1996 and March 1997 sample collections, which is expected because this group is commonly found in benthic sample collections. **Cole (1994)** stated that a typical macroinvertebrate assemblage would include chironomids, phantom midges, and some oligochaetes and this seems representative of these two Arcadia Lake sample collections.

Bass (**1992**) noted six of thirty species collected in pre-impoundment collections were present in post-impoundment collections of Arcadia Lake. Thirty-three additional macroinvertebrate species were present following impoundment, with dominant species including tubificid oligochaetes, oligochaetes (Naididae), phantom midges, true midges (chironomids), and a dipteran species. **Bass (1992)** suggested pollutants from metals, pesticides, and siltation may be the reason benthic populations were relatively low in species diversity. For this study, species diversity was calculated using **Shannon's** index (**1948**), as modified by **Wilhm and Dorris (1968).** Species diversity was low for both sample collections, with only 178 individuals belonging to six different species in December 1996 and 158 individuals belonging to five different species in March 1997. The overall species diversity measured 1.413 for December 1996 and 0.0820 for March 1997. The decline in species diversity from winter to spring probably indicates an emergence of phantom midges, one of the abundant groups in the December 1996 collection. The diversity indices calculated in this study may not be truly representative because of poor sample storage techniques and the loss of several sample vials. This may also explain the significantly fewer number of species encountered in this study compared to the colonization and succession study of Arcadia Lake (**Bass 1992**).

Algae

Analysis of phytoplankton was completed by Phycotech, Inc. A summary of their findings is included here. For the complete text of their report, refer to **Appendix F**. The phytoplankton data indicate that Arcadia Lake is rich in nutrients, but the densities and biovolume reflect a system limited more by light than nutrients. Arcadia Lake would be classified as eutrophic by algal density and mesotrophic-eutrophic by algal biovolume. Algal taxa indicate a eutrophic system. Predominant taxa numerically are small blue-greens, easily edible by a variety of filter-feeding zooplankton. These small blue-greens could significantly impact nutrient cycling and energy flow in the upper waters of the lake. Other algae present during different times of the year are associated with nutrient enriched conditions and are also mostly in the edible range in terms of size, especially the diatom, cryptomonad and green (mostly below 30 µm diameter). Smaller size also allows these algae to stay suspended for longer periods of time, an advantage in a light limited system. Dinoflagellate blooms are consistent with those observed in other reservoirs and are controlled primarily by nutrients and extreme temperatures. Euglenoids at stations 4 and 5 confirm high organic enrichment entering Arcadia Lake from the Deep Fork River. Several of the divisions and taxa in Arcadia Lake are capable of facultative heterotrophy (dinoflagellates, euglenoids, to some extent the cryptomonads and potentially diatoms), which would allow them to augment photosynthesis in such highly enriched, light limited circumstances. Nitrogen-fixing blue-greens include several taxa that can cause not only taste and odor problems, but toxicity and impairment as well. Light limitation keeps these potentially troublesome blue-greens from becoming extremely noxious and prevents lake wide or large expanses of surface blooms, but densities and biovolume can still be quite high at certain times of the year, markedly affecting water quality. Comparison of summertime densities between years shows algal biovolume and concentrations to be markedly higher in 1997 than in 1996.

Zooplankton

Analysis of the zooplankton in Arcadia Lake was completed by Beaver Schaberg Associates, Inc., Environmental Services. A summary of their findings is included here. For the complete text of their report, see **Appendix G.**

Zooplankton function as pivotal intermediaries between fish and lower trophic levels. Temporal and spatial alterations in plankton community structure have long been recognized as biological manifestations of eutrophication (**Crisman and Beaver 1990**). Among the environmental factors potentially structuring zooplankton communities, abundance and composition of the phytoplankton and the intensity of predation by planktivorous fish are frequently important. Plankton dynamics are often attributed to abiotic (e. g. nutrients and transparency) and/or biotic (top-down forces) factors. It is likely that both types of factors to some degree operate on the plankton community of Arcadia Lake. Furthermore, these influences can vary spatially and seasonally within a lake.

Food availability seemed to be a strong controlling factor for zooplankton abundance, particularly for rotifers. The relationship between crustacean zooplankton components and trophic state variables was significant only during spring. This observation suggests that, although populations of adult crustaceans responded somewhat to increased food availability in the spring, other controlling factors were limiting their populations during other seasons. The seasonal abundance of adult crustaceans in Arcadia Lake may be strongly influenced by grazing activities of planktivores.

Although increased phytoplankton biomass should support elevated zooplankton densities in general (**McCauley and Kalff, 1981**), the poor correlations observed in our study strongly suggest that this trophic link is only seasonally coupled in Arcadia Lake. Adult crustacean densities were greatest during the late fall and early spring but reached the lowest levels in summer densities coincident with peaks in algal biomass. During summer, the decline in large zooplankton in Arcadia Lake may have resulted from predation by fish. The importance of zooplankton as food for juvenile and adult fish (**Jones and Hoyer 1982, Guest et al. 1990**) and the ability of planktivorous fish to decimate larger-bodied zooplankton (**Nauwerck, 1963, Brooks and Dodson, 1965**) are well established. Detailed fish data for Arcadia Lake are lacking, but it is likely that the fish community is dominated by common carp (*Cyprinus carpio*). This omnivorous fish is considered typical of eutrophic habitats, feeding on both the plankton and the benthos (**Baker et al. 1993**).

Axler et al (1988) have demonstrated the clear relationship among phosphorus, primary productivity, various water quality variables, and fisheries; however, nutrient enrichment or reduction, respectively, does not necessary translate into a one-to-one increase or decrease in zooplankton abundance. Phytoplankton responses to modest nutrient enrichment may include an increase in more favorable food items for herbivorous zooplankton (**McCauley and Kalff 1981, Elser and Goldman 1991**), but greater nutrient enrichment may increase the abundance of larger colonial and filamentous cyanophytes which are less desirable for herbivorous crustacean zooplankton (**Porter 1977**). We suggest that all components of the zooplankton community in Arcadia Lake responded positively to increased algal biomass, but rotifer populations peaked in summer only when competition from more efficient filter-feeding cladocerans and copepods was reduced by planktivory from fish (**Brooks and Dodson 1965**).

When viewed as a group, cladoceran seasonality was more pronounced than copepods. However, within the cladocerans a definite species succession representing a progressive increase in the size of the dominant species occurred each year of the study (*Bosmina*, *Diaphanosoma*, *Daphnia*). The small-bodied *Bosmina* dominated the cladoceran community in early spring, while the large bodied *Daphnia pulex* reached its annual maximum during early fall. During summer *Daphnia* were at very low densities, while the small-bodied *Bosmina* and rotifers dominated the zooplankton community.

The effects of increased nutrients on phytoplankton in aquatic systems have been well documented. The fact that station 5 had the highest density of cladocerans yet station 4 had the highest biomass suggests that there were zooplankton compositional differences among the sites. Station 5 had the lowest percentage of the large-bodied cladoceran *D. pulex*, as well as the highest percentage of the small-bodied *B. longirostris*. Furthermore, station 5 was the only site where *Bosmina* abundance exceeded *D. pulex*. Such a difference between areas could indicate either an increase in predation on the larger bodied crustacean by planktivores, or a more nutrient rich environment, where small-bodied cladocerans often fare better (**Gannon and Stemberger 1978**). Increased grazing pressure from visual feeding predators does not seem likely since the transparency was the lowest at the Deep Fork arm of the lake. However, because of the higher concentration of TP, it is possible that *Bosmina* were more prevalent in that site because of their high reproductive rates, which allow a more rapid response to the high nutrient levels (**Allan 1976, Hofmann 1996**). *Bosmina longirostris* is also a typical eutrophic species (**Gannon & Stemberger 1978**) and has been shown to exhibit strong selectivity for green algae and diatoms, especially during summer blooms of cyanophytes (**Mason & Abdul-Hussein 1991**). Because *Bosmina* has a preferred filtering range for small particles (1-5 :m), they may be able to survive on alternate food material such as small detrital particles and bacterioplankton.

Rotifers were also the most abundant in the nutrient rich arm of the lake when compared to the other lake sites. The relationship rotifer abundance and percentage composition of the zooplankton community and lake/seasonal trophic state is well established (**e.g., Bays and Crisman 1983**).

Beaver and Havens (1996) have underscored the importance of fish community structure in structuring the temporal and spatial distribution of zooplankton in a lake with widely ranging trophic conditions. Vertebrate predators are believed to be the primary determinants of crustacean zooplankton abundance and mean zooplankton body-size in a variety of North American lakes. It is likely that the abundance of small-bodied zooplankton (*Bosmina*, rotifers) in Arcadia Lake is most strongly controlled by food availability, while the abundance of large-bodied zooplankters (cladocerans, copepods) is primarily limited by predation from fish.

Another factor that could influence cladoceran community structure is the occurrence of *Daphnia lumholtzi*. This exotic cladoceran is a native of tropical and subtropical lakes in east Africa, east Australia, and the Asian subcontinent of India (**Havel and Hebert 1993**). It is distinguished by a long helmet and tail spines. The helmet is much larger than the native species, and the tail spine is normally as long as the body length (up to 3.5mm). *D. lumholtzi* has been detected in 56 reservoirs in the southern and midwestern United States, including waters leading into major river drainages such as the Arkansas, Cumberland, Illinois, Mississippi, Missouri, South Atlantic-Gulf, Tennessee, and Texas-Gulf. Occurrences of *D. lumholtzi* have been recorded in the following states: Alabama, Arkansas, Florida, Illinois, Kentucky, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, and Texas (**Havel et al. 1995**). The ecological impacts of this invader are unclear, but one study indicates it does not appear to be displacing other daphnia species (**Goulden et al. 1995**) as has been observed with other exotic invertebrates such as zebra mussels. The abundance of *D. lumholtzi* in Arcadia Lake was never more than one percent of the total cladoceran abundance during the period of study, but further monitoring is suggested.

Biological Indicators for Arcadia Lake Based on Zooplankton

Zooplankton communities of lakes and reservoirs are often good indicators of water quality (**e.g., Gannon and Stemberger, Bays and Crisman, 1983**). Given that herbivorous zooplankton may exert significant controls over the abundance, biomass, and composition of the phytoplankton community, and as a result determine water clarity and prevalence of nuisance algal species, they may be an important consideration in lake and reservoir management strategies. Development of bioassessment techniques to measure community condition based on regional expectations (i.e., ecoregion) would be desirable. Various biological components have been considered in developing biological indicators including fish, macroinvertebrate, zooplankton, and phytoplankton. The goal of such an approach would be to collect long-term information to refine knowledge of lake conditions (i.e., define baseline conditions, measure spatial and temporal variability of community attributes). Such a program would use representative multiple sampling of zooplankton populations and physical/chemical (limnological) variables to predict community condition. Presented below is a preliminary step towards developing a biological indicators approach for Oklahoma lakes and reservoirs based on the current study of the zooplankton of Arcadia Lake.

The relative abundance, biomass, and size structure of the major zooplankton groups and certain taxa at station 5 suggest that the poorer water quality characteristics were reflected in the zooplankton community. Although total cladocerans were higher at station 5, the biomass was very low because of the dominance by *Bosmina,* a small bodied, small particle specialist considered to be a good indicator of eutrophic conditions. Similarly, the rotifer community at station 5 had significantly higher biomasses of *Asplanchna* and *Brachionus*, rotifer species also considered indicative of eutrophic conditions (**Pejler 1983, Beaver and Crisman 1990**).

The increase in the abundance/biomass of *Bosmina* and *Brachionus* may be associated with increased availability of small particles, including detritus, which may have been more available at station 5. Because smaller-bodied zooplankton such as *Bosmina* and *Brachionus* have high intrinsic growth rates, they should respond concurrently to environmental changes and may be more sensitive indicators of water quality. If similar trends are observed in other lakes of the region, this approach may have some value in developing biological indicators based on zooplankton community structure for Oklahoma lakes and reservoirs.

TASK 12 - POLLUTION CONTROL AND LAKE RESTORATION ALTERNATIVES

The following narrative outlines restoration alternatives identified through this Clean Lakes Study. These alternatives have been categorized into two distinct areas: in-lake and watershed. In-lake measures would be a cooperative effort including the Tulsa District Corps of Engineers, the City of Edmond, and any other interested parties, and apply to the lake itself. Only general alternatives have been presented for watershed Best Management Practices (BMPs). The Arcadia Lake watershed refers to the 67,000 acre drainage basin managed by a conglomerate of Oklahoma City, City of Edmond, smaller municipalities, the State of Oklahoma, individual landowners and businesses.

In-lake

Arcadia Lake would benefit immediately from a comprehensive program to control shoreline erosion. Shorelines receiving high recreational use or large waves will require hard treatments such as rip-rap, rock gabions or bulkheads. Soft treatment using dead and living vegetation would provide control in the lower impact areas for approximately one-quarter the cost of hard treatments. Aside from reduced cost of implementation, soft treatments have secondary benefits for fish, wildlife and aesthetics. Stocking of top predator fishes such as the sauger-walleye or striped bass-white bass hybrid show promise to help reduce summer algae growth through food web manipulation. Techniques such as aeration or reservoir partitioning should be evaluated based on whether watershed improvements are made.

Diagnosed problems of Arcadia Lake are high algae growth because of high nutrient content and shoreline erosion. During most of the year Arcadia Lake is nitrogen limited. The high annual concentration of phosphorus in Acadia Lake indicate that significant phosphorus control would be difficult if not impractical. In-lake remedial measures should target reducing ammonia concentrations and controlling erosion processes. Aeration and reservoir partitioning could help to reduce main body ammonia concentrations while reservoir partitioning or rip-rap and establishing native aquatic vegetation would serve to control erosion processes.

The following itemizes each in-lake treatment method:

Aeration/Destratification

Aeration or destratification of Arcadia Lake would likely be a marginal application. Arcadia lake does not stratify reliably. This makes design and operation of a system difficult. The best application of this technique would be to reduce in-lake nitrogen loading from sediments. Aeration or destratification would reduce sediment release of ammonia and provide an environment for oxidation of influent ammonia to nitrate. Internal release of ammonia is significant, but did not seem to simulate algae growth as much as influent stormwater. For this reason, the cost of equipment, installation and maintenance for aeration or destratification does not seem justified. Should measures be implemented in the watershed that produce significant load reductions, then this method warrants further investigation.

Chemical Treatment

The application of a chemical such as alum would precipitate out nutrients in the water column and inactivate nutrients in the sediment, and produce an immediate improvement of lake water quality. This treatment is justified when cost can be amortized over a period of ten years or greater. The enormous influx of sediment and nutrients per stormwater event would require at least one treatment per year. The influx of sediment and nutrients from the watershed precludes further consideration of this technique as a long-term restoration alternative.

Reservoir Partitioning

Reservoir partitioning is generally used to enhance the operation of another in-lake management technique. Arcadia Lake may benefit by constructing a barrier across the lake downstream of Memorial Road bridge. This would be designed to distribute inflowing stormwater more evenly across this area of the lake, reducing water velocity and increasing the settling rate of solids. This method could be used to slow the advance of inflowing stormwater and enhance rapid precipitation of solids in the upper end of the lake. Should no BMPs be implemented in the watershed to reduce the influent load, this technique warrants additional investigation.

Erosion Control & Shoreline Stabilization.

Measures to protect the shoreline from erosion should be performed. Erosion serves to suspend solids, increase evaporation and increase risk to recreational lake users. Shoreline treatments should be prioritized based on intensity of the problem and probability of success. Areas receiving high shoreline traffic or large waves generally require “hard” treatments, such as rip-rap or rock gabions, to achieve control. All other areas of the lake could achieve control through the establishment of native aquatic vegetation along the shoreline. The ODWC, City of Edmond and COE are currently establishing native aquatic plants in small areas to increase the survival of fish fry. A long term effort to establish aquatic vegetation along the lake’s shoreline would serve to reduce erosion and increase water quality.

The proceedings from a national workshop on the topic were used (**COE, 1993**) for the development of Arcadia Lake shoreline erosion control treatments. The simplest method of control would be to focus on changing the passive features of erosion:.changing the shoreline composition to a less erodible type. Techniques to accomplish this range from soft to hard structure treatments. In general, hard treatments cost more per foot than soft treatments. Hard structure bulkheads, such as gabions, address the passive component of shoreline erosion and allow for complete recreational access to the waterline. Material cost for a hard treatment such as the gabion would be approximately $25 per foot.

Soft structure treatments, such as the use of living and dead vegetative material, would address both passive and active components of shoreline erosion. Implications of soft treatments would be colonization of organisms which are obligate to the water-land interface, and the establishment of a more balanced lake ecosystem. The cooperative effort between the ODWC, City of Edmond and COE introduce aquatic vegetation for fish habitat is an example of secondary benefits from using a soft treatment for shoreline erosion control. Material cost for a soft treatment such as planted coconut fiber mat would be approximately $6 per foot. This cost is less than 1/4 of a hard treatment such as gabions. A combination of soft and hard treatments would allow for full recreational access to portions of the lake, and enable the initiation of a balanced aquatic ecosystem. Selection and implementation of control techniques should occur as a result of public input. Arcadia Lake shoreline encompasses approximately 26 linear miles.

Food Web Manipulation

Food web manipulation is based on reducing phytoplankton growth without the use of expensive machines and chemicals. This technique has been shown effective when phytoplankton growth is controlled by zooplankton eating the phytoplankton. **Task 11**, Biological Resources, showed that zooplankton populations normally follow the growth of the phytoplankton community. **Task 11** also showed that during the summer this normal pattern does not occur, and suggested that increased consumption of zooplankton by zooplankton feeding fish is the cause. Zooplankton feeders graze selectively on the largest zooplankton species (such as *Daphnia* spp), leaving the zooplankton community dominated by smaller species, such as *Bosmina* spp. Larger zooplankton have the highest grazing rates and ingest the largest particles. Lakes with substantial populations of zooplankton feeders are therefore less likely to exhibit control of phytoplankton biomass through zooplankton grazing. Food web manipulation enhances and maintains the density of predatory fish which feed on the zooplankton feeding fish population. This leads to an increase in survival of the zooplankton population, and with greater amounts of zooplankton to eat the phytoplankton, phytoplankton content would decrease (**Cooke et al. 1993**). **Figure 12.1** is a pictorial representation of how food web manipulation can help to decrease the phytoplankton population. The figure on the left represents where Arcadia Lake is at this time. A shift in the populations toward the figure on the right could result in decreased phytoplankton, and an improvement in water clarity. This technique would be cost effective if it is successful. Potential predators are the blue catfish, flathead catfish, white bass-striped bass hybrid and the walleye-sauger hybrid. Attempts by the ODWC to establish a reproducing blue catfish population in Arcadia Lake has been unsuccessful to date. Flathead catfish are known for their consumption of fish but also their lack of selectivity. Many fishery managers express concern that large flathead catfish populations would reduce all other fishes in the lake. The lack of natural reproduction by the hybrid fishes lends a means of control and adjustment for food web manipulation. These fishes should be examined in cooperation with the ODWC for introduction into Arcadia Lake to reduce zooplankton feeder populations.

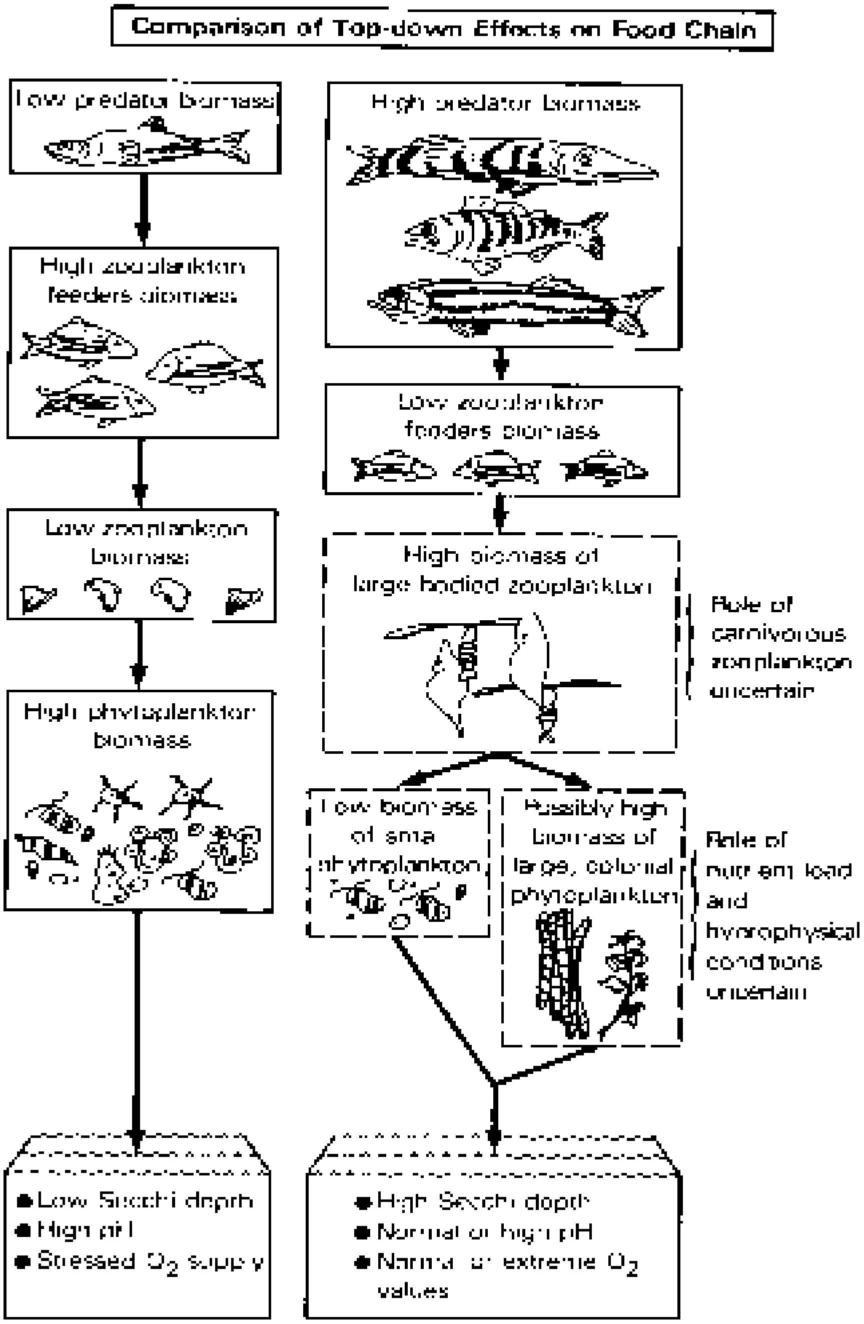

Figure 12.1 Hypothetical scheme showing the connections involved in food web manipulation (**EPA 1990**)

Watershed

Non-point sources have been identified as the source of all nutrients and solids in Arcadia Lake. Approximately 60% of the lake's watershed is designated as urban. Identification of Best land Management Practices (BMPs) that will control solids and nutrients in urban settings were targeted for this task. The USDA has comprehensive list of 109 BMPs to reduce or eliminate non-point source pollutant problems (**Appendix H**). These BMPs were examined and prioritized to target decreasing runoff and subsequent increasing stormwater retention within the watershed. A brief description of these identified potential BMPs (**EPA, 1990**) follow. **Table 12.1** summarizes advantages and disadvantages of each.

Table 12.1 Potential Urban BMPs for Arcadia Lake Watershed

BMP	**Advantages**	**Disadvantages**
Nonvegetative Soil Stabilization	•excellent effectiveness for sediment •temporary, only until construction ends.	•No effect on soluble pollutants
Flood Storage	•excellent potential for sediment removal •can be incorporated into park system •reduced stream bank erosion	•effectiveness is design dependent •requires dedicated land •possibility to contaminant groundwater
Grassed Waterways	•Good to excellent sediment effectiveness •poor to good nutrient effectiveness •augments flood storage BMP	•Urban applications will require summer maintenance. •Requires dedicated land
Upgrade/ Maintain Septic Systems	•onsite residential sewerage disposal •ODEQ inspected method •reliable with 20 year lifespan	•requires cleaning every 3-5 years •Dependant on soil and site conditions
Stream Buffer Strips	•excellent reduction in sediment, nutrients & volume of runoff •minimal costs •excellent longevity	•shading may alter diversity & number of organisms in stream

Nonvegetative Soil Stabilization

This includes the use of mulches, netting, blankets or mats from textile material. The purpose is to reduce erosion from construction sites.

Flood Storage (Runoff Detention/Retention)

Facilities treat or filter out pollutants or hold water until treated. Retention facilities provide no treatment. Examples of detention/retention facilities include ponds, surface basins, underground tunnels, excess sewer storage and underwater flexible or collapsible holding tanks.

Grasses Waterways

Grassed waterways are placed along broad and shallow drainage channels where erosion resistant grasses are grown.

Upgrade/Maintain Residential Septic Systems

> Reduces nutrient loads from increasing residential development and is requires when centralized sewerage is not available.

Additional BMPs listed by the USDA that could provide water quality benefits include *Debris Basin, Roof Runoff Management, & Timing and Placement of Fertilizers*.

The American Society of Civil Engineers (ASCE) entered into a cooperative agreement with EPA to develop a scientifically-based approach and management tool for the information needed to evaluate the effectiveness of urban stormwater runoff BMPs nationwide. This cooperative project is ongoing, 800 journal articles concerning urban BMP implementation are being evaluated to compile its database. One outcome of this project will be detailed urban BMP plans using specific water quality based performance measures. Some preliminary information is available now. For an update on this project or specific request for information please visit the following website: http://www.asce.org/peta/tech/nsbd01.html.

Specific BMPs to employ in the watershed should be determined in consultation with the Oklahoma Conservation Commission and other concerned state and federal officials such as the United States Department of Agriculture, the Soil Conservation Service, the Agricultural Stabilization and Conservation Service, City of Oklahoma City and the City of Edmond.

TASK 13 - ANTICIPATED BENEFITS FROM LAKE RESTORATION

Several benefits should be expected from implementation of lake restoration activities. The establishment of a native aquatic plant community in Arcadia Lake would provide valuable habitat for fish and wildlife. Survival of fish fry would increase. Water quality would also benefit from colonization of the littoral zone by the creation of a physical barrier between the sediment and overlying water column. This would serve to reduce resuspension of sediment in the shallow flats of the lake. Water quality benefits include reduction of episodic turbidity and internal nutrient loading. Reduction of internal phosphorus loading from deeper nutrient rich sediment will translate into reduced potential for algae growth. A reduction in the growth of taste and odor producing algae is also anticipated. Reduction or elimination of shoreline erosion will also reduce risk of injury to recreationalists, as well as reduce loss of property.

A reduction in the amount of sediment reaching the lake would greatly reduce the sedimentation rate. This would in turn extend the life of the current water supply reliable yield. This sediment reduction from stormwater inflows would also translate into reduced algae growth. Watershed BMP implementation would also reduce the influx of coliform bacteria into the Arcadia Lake. A coliform bacteria reduction in the lake would reduce health threats to lake users involved with primary body contact.

Successful food web manipulation would increase the number of sport fishes available, while reducing algae growth and potentially taste and odor events in the drinking water.

Reduced algae content and inorganic turbidity would also lead to reduced cost of treating raw water for human consumption. These cost savings would be realized through a reduction in the amount of treatment chemicals per unit raw water, reduced concentrations of trihalomethane precursors in the raw water, and reduced production of sludge. Consumer satisfaction with the finished product would also increase, with a decrease in taste and odor complaints.

Finally, another benefit of the restoration would be improvement of lake water quality from a purely aesthetic point of view. Reduction in turbidity, both inorganic and organic, would enhance the recreational uses of this high use urban reservoir.

TASK 14 - PHASE II MONITORING PROGRAM

A Phase II monitoring program which was developed could be implemented to monitor the effectiveness of restoration activities. **Table 14.1** summarizes the outlined monitoring program. Parameters such as chlorophyll-*a*, algal community composition, zooplankton community composition, phosphorus series, nitrogen series, total suspended solids, turbidity, aquatic plant community and fish surveys would be the primary parameters for a post-implementation project. A proposed monitoring program and milestone work schedule for the project are presented below.

Table 14.1 Outline of a Phase II monitoring program

DATE	PARAMETERS	MONITORING FREQUENCY
1st month after Grant Award Date	Parameters selected	Monitoring program pre-work implemented
1st month through 3rd month after award date	Selected parameters monitored	pre-work monitoring performed on at least a monthly basis
3rd month work begins	Selected parameters monitored	Restoration work begins with monitoring occurring on at least a monthly basis
4th month through month 15	Selected parameters monitored	Monitoring performed during restoration implementation and post restoration monitoring performed on at least a monthly basis

TASK 15 - MILESTONE WORK SCHEDULE

For a description of the milestone work schedule please see the previous task.

TASK 16 - NON-FEDERAL FUNDING SOURCES

The City of Edmond holds primary interest in the welfare of Arcadia Lake. The City of Oklahoma City and City of Edmond comprise virtually 100% of watershed and so would be a part of any watershed BMP solution. The ODWC actively manages the sport fish populations of Arcadia Lake. Partnerships with state agencies such as the OWRB, ODEQ, ODOT, Oklahoma Corporation Commission and Oklahoma Conservation Commission have potential for improving inflowing or in-lake water quality.

TASK 17 - PROJECT RELATION TO OTHER ENVIRONMENTAL PROGRAMS

Other Environmental Programs/Agencies which are currently involved in the Arcadia Lake watershed would include:

City of Edmond;
Oklahoma Department of Environmental Quality;
Association of Central Oklahoma Governments;
Oklahoma Conservation Commission;
Oklahoma State Department of Agriculture;
Oklahoma County Conservation District;
Natural Resources Conservation Service;
Oklahoma Department of Wildlife Conservation;
United States Geological Survey.

The Oklahoma Department of Wildlife Conservation monitors the lake fishery and performs stocking activities in the lake. The lake fishery is sampled on a routine basis to determine trends in the lake fishery, if stocking should occur, and if so, what form should it take.

The Oklahoma Department of Environmental Quality (DEQ) oversees point source discharge permits in the lake watershed. In addition to these activities, the DEQ regularly conducts the rotating lakes toxics monitoring survey. The toxics monitoring survey monitors toxics in fish flesh tissue collected from lakes all over the state. ODEQ also has responsibility for preparing Total Maximum Daily Load estimates (TMDLs), and for oversight of the Source Water Protection Program and the Safe Drinking Water Act.

The Association of Central Oklahoma Governments (ACOG) performs various planning activities in Oklahoma counties. ACOG is compiling a comprehensive land use GIS coverage for the Oklahoma County area.

The Oklahoma Conservation Commission (OCC) has oversight responsibility for the 319 nonpoint source program. The 319 program has identified problems in the Arcadia Lake watershed pertaining to urban land management practices. At this time the Conservation Commission is not performing any high priority monitoring in the lake watershed. The OCC works in conjunction with the local county conservation districts to fund and implement non-point source control projects.

The Natural Resources Conservation Service(NRCS) manages activities in the watershed designed to control pollution to rivers and streams. The NRCS encourages land owners to implement good land management practices over a period of time. This is accomplished through a cost-share program between themselves and local land owners. The activities of the NRCS in the Arcadia Lake watershed were not known at the time this report was written.

The Oklahoma Water Resources Board grants water rights permits, coordinates Planning Assistance Grants to the States grants through the USACOE, Financial Assistance Loan program, promulgates the State Water Quality Standards, conducts Clean Lake studies and Clean Lakes restoration projects. OWRB stands ready to lend technical assistance, loan and grant coordination to optimize Arcadia Lake management. OWRB could also provide further monitoring through the Beneficial Uses Monitoring Program (BUMP).

TASK 18 - PLAN OF OPERATION AND MAINTENANCE

Operation and maintenance (O&M)are planned and supported by the City of Edmond and COE Arcadia Lake project office. Reduction of shoreline erosion with soft treatments will reduce O&M for shoreline erosion (replacing rip-rap). No other recommendations are made that would effect O&M.

TASK 19 - REQUIRED PERMITS

A United States Army Corps of Engineers 401 dredge and fill permit would be required before any invasive in-lake activities could be initiated. Also, a state 404 permit certifying that Oklahoma's water quality standards would not be violated by these activities would also be needed from the Oklahoma Department of Environmental Quality.

TASK 20 - PUBLIC PARTICIPATION

Several public activities were conducted in the Arcadia watershed to educate local residents, including school children, on non-point source pollution, the problems and solutions that affect Arcadia Lake, and how they can help reduce future pollution. The Oklahoma Water Resources Board (OWRB) coordinated with the Oklahoma County Blue Thumb program, which is a Non-point Source Urban Education Program, to inform the public about the Clean Lakes study being conducted, and about pollution issues regarding Arcadia Lake. Activities included annual attendance at the University of Central Oklahoma’s Earth Day celebration, which attracted several college students interested in environmental issues. A few students have pursued careers in lake and watershed management as a result of our displayed information. Water Festivals, coordinated through Blue Thumb, involved staff teaching elementary school children about water quality in fun, exciting curricula. These children take home messages about proper automotive waste disposal, household chemical disposal, anti-littering, etc. Outdoor classes were also taught by OWRB staff, educating youth with hands on activities that occurred at the lake.

Educational signs were purchased through a cooperative effort with Blue Thumb, City of Edmond, and Oklahoma Water Resources Board. The purpose of these signs was to inform lake users what a watershed is and how runoff can affect the lake. (A photograph of the sign is included below - **Figure 20.1**).

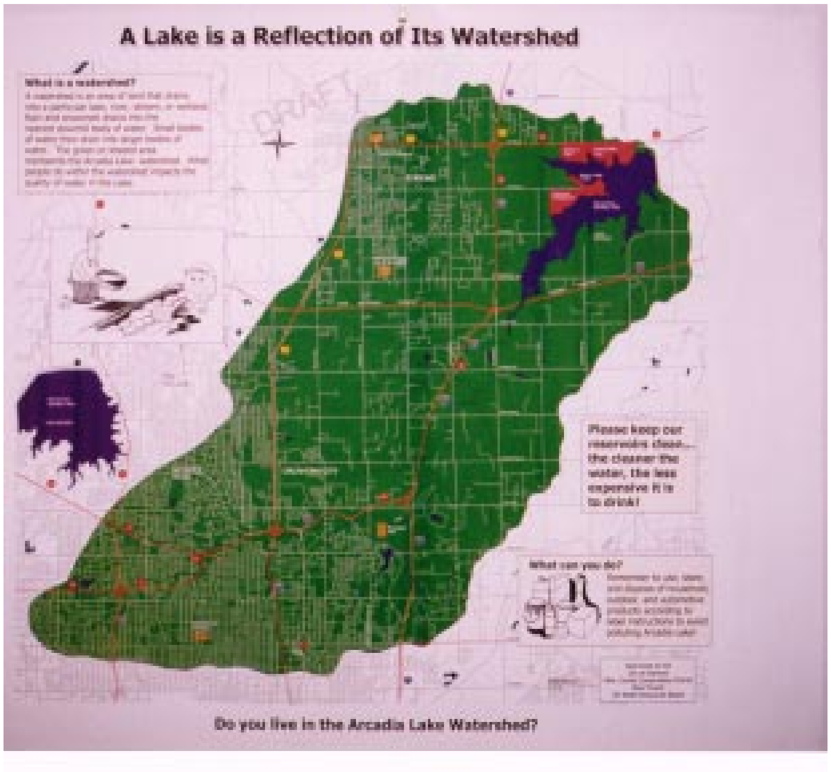

Figure 20.1 Arcadia Lake sign.

Lake Sweep

Arcadia Lake Sweep is an annual event which was started during the Phase I study. In 1997, the first year of the event, approximately 60-75 citizens participated. In 1998, the number of participants increased to 150, with 5 dumpsters of trash collected, for a total of about 40 cubic yards of trash cleaned up from the lake area (**Figures 20.2 and 20.3**). In 1999, the third year of this event, over 200 volunteers accumulated over 20 cubic yards of trash. The Phase I project allowed OWRB staff to coordinate and organize this successful event on the shores of Arcadia Lake. Arcadia Lake Sweep is now an annual event sponsored by the Oklahoma Clean Lakes Association, local businesses, and the City of Edmond.

The continued success of this event for three years in a row is an indication of the commitment of the citizens of the City of Edmond to the health of their lake, and the involvement of the community in lake restoration. Community participation in this event continues to grow on a yearly basis, and plans are already underway for the year 2000 lake sweep. An additional budget item is being added to the advertising budget in the form of a banner to be placed on the Edmond Women's Club sign.

Figure 20.2 Trash in Arcadia Lake washed in from the watershed

Figure 20.3 Trash in Arcadia Lake. Note the plastics indicative of urban land use.

Figure 20.4 Lake Sweep Logo

Volunteer Monitoring

In an effort to increase environmental awareness and community involvement in managing Oklahoma's surface water resources, and to supplement data collected for the Arcadia Lake Watershed Protection Program, a volunteer monitoring program was initiated in the Arcadia watershed in early 1997. Science teacher Brandi Misialeck and several of her classes from Edmond Memorial High School, a public school within the watershed, formed the Bulldog Water Watch and began training in January 1997.

Through the Oklahoma Water Watch (OWW), each potential group is required to establish detailed goals, elect chapter officers to facilitate quality control efforts, and undergo a three-phase training program to become Certified Water Quality Monitors. Students initially set long-term goals tailored to the needs of their environmental education program and the data collection needs of the Oklahoma Water Resources Board. The students wanted to become familiar with water quality monitoring topics and techniques in order to create an ongoing record of water quality in the Arcadia Lake watershed, identify potential problems in the watershed, and explore possible solutions.

Through initial six (6) hour Phase I and Phase II training sessions in January of 1997, seventeen (17) students and Ms. Misialeck, the project coordinator, were introduced to water quality concepts and water quality test parameters. They became familiar with watershed and non-point source pollution concepts, learned which parameters affect lake water quality and aging processes, and were educated on how the activities of people in urban and rural settings affect lake processes. In April 1997, Phase III training for the group was conducted at the group's established sample site in the watershed. Students practiced proper water collection and testing techniques and were tested on these techniques. A new class of twenty-two (22) students was introduced to the program through Phase I and Phase II training in October 1997. These students completed Phase III training and became certified monitors in February 1998. The students were then introduced to a laboratory quality assurance/ quality control (QA/QC) session in April, 1998.

The partnership between Edmond Memorial High School and the OWW has been only marginally successful in meeting long term goals. The objective to improve knowledge and awareness of water quality issues and watershed concepts was met for these individual classes. Through four separate training sessions, forty (40) volunteers were trained and familiarized with limnological theories; however, the goals to establish a long term record of water quality and identify potential problems within the watershed were not satisfied. In eighteen months, only one sampling event occurred. Spring Creek, a stream above Arcadia Lake, was monitored on March 13, 1998. The reasons for lack of productivity are twofold. Primarily, volunteers did not receive certification to monitor in an adequate period of time during the school year because of consistent scheduling conflicts between the OWW staff and the coordinating teacher. The second reason was only weak commitment from the coordinating teacher and the students to consistently monitor. The OWW provides all training, equipment, and supplies necessary for a group to monitor water quality. In return, the OWW staff asks that the monitor provide a two year commitment to the program, consistent test dates and times, and quality testing procedures.

Each volunteer must sign a pledge to the program before certification as a water quality monitor can be granted. The OWW Quality Assurance Project Plan (QAPP) requires six months of data for every twelve-month period, which would equate to nine sampling events over an eighteen month period. The group has completed one sampling event, which is approximately 11% of the required data. The inconsistent monitoring efforts have also led to a lack of procedural understanding. The April 1998 QA/QC session yielded only a 40% accuracy rating and a 56% precision rating for the group.

Following submission of this draft final report to Region VI EPA for review, project results will be reported to the City of Edmond for review and comment. An effort will be made to present the project results before the City of Edmond Fish and Game Commission. This commission oversees City of Edmond lake management.

TASK 21 - ENVIRONMENTAL EVALUATION

An environmental evaluation required by Appendix A of the regulations also depends upon the methods selected for pollution control and lake restoration. Therefore, it also is included in the schedule for the final report to be written during the last four months of the study. The required environmental evaluation consists of answering the following 14 questions.

1. Will the project displace any people? **NO**

2. Will the project deface any residences or residential areas? **NO**

3. Will the project lead to a change in land use patterns? **Implementation of BMPs in the Arcadia Lake watershed would result in designation of more open areas to retain flood waters and improved construction BMPs. Perhaps more wet detention basins would also result. Wet detention basins often become a recreational focus for local residents.**

4. Will the project adversely affect a significant amount of agricultural land or operations? **NO**

5. Will the project adversely affect a significant amount of park land, other public land, or land with recognized scenic value? **No, perhaps increase this area.**

6. Has the State Historical Society or State Historical Preservation Officer been contacted? **YES**

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

8. Will the project result in significant short-term or long-term adverse changes in air quality or noise levels? **No, retention pond construction usually occurs concurrent with the local development project.**

9. What short-term or long-term effects can be expected from use of in-lake chemical treatment, if any? **No in-lake chemical treatment is recommended at this time.**

10. Does the proposal contain all of the information that EPA requires to determine compliance with Executive Order 11988 on floodplains? **YES**

11. What steps will be taken to minimize adverse effects of physical modification of the shoreline, bed, or watershed of the lake? Specifically, how will spoils from dredging be disposed of to minimize their potential impact? **This project proposed actions that would enhance the lake shoreline for fish and wildlife. No dredge activity is recommended atthis time.**

12. Does the proposal contain all of the information that EPA requires to determine compliance with Executive Order 11990 on wetlands? **YES**

13. Describe any feasible alternatives to the project in terms of environmental impact, resources, public interests, and costs? Defend the choice if necessary. **One alternative to remediation or restoration is no action. This is a likely option. Arcadia Lake will continue to fill with sediment in the upper end of the lake, shoreline will continue to erode and algae blooms will occur unabated. The portion of the conservation pool allocated to sediment is estimated to fill by the year 2036.**

14. Describe other measures not discussed previously that are necessary to mitigate any adverse environmental impacts caused by the project. **No other measures need to be discussed at this time.**

TASK 22 - GRANTEE ADMINISTRATION

Materials will be provided by the Office of the Secretary of Environment as requested by EPA.

TASK 23 - PROJECT LEADER ADMINISTRATION

Information will be provided to the EPA by the Oklahoma Water Resources Board upon request.

TASK 24 - DRAFT FINAL REPORT

The Draft Final Report is the current document. This draft document will be amended to a Final Report following approval by Region VI EPA. If no amendments to this document are made, then this document will represent the Final Report.

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Appendix A

LAKES.

(1) "For lakes.....the following beneficial uses are designated:"
  - (A) Fish and Wildlife Propagation (Warm Water Aquatic Community) (785:45-5-12).
  - (B) Agriculture (785:45-5-13).
  - (C) Industrial and Municipal Process and Cooling Water (785:45-5-15).
  - (D) Primary Body Contact Recreation (785:45-5 16).
  - (E) Aesthetics (785:45-5-19).

(2) "The beneficial use of Public and Private Water Supplies (785:45-5-10) is specifically designated for certain lakes.....otherwise the beneficial uses designated in this paragraph take control.....".

BENEFICIAL USES AND CRITERIA

785:45-5-10. Public and Private Water Supplies
The following criteria apply to surface waters of the state having the designated beneficial use of Public and Private Water Supplies:

(1) Raw Water Numerical Criteria. For surface water designated as public and private water supplies, the numerical criteria for substances listed below shall not be exceeded.

RAW WATER NUMERICAL CRITERIA

SUBSTANCES (Total)	NUMERICAL CRITERIA (mg/L)
Inorganic Elements:	
Arsenic	0.10
Barium	1.00
Cadmium	0.020
Chromium	0.050
Copper	1.000
Cyanide	0.200
Fluoride (at 90°F)	4.0
Lead	0.100
Mercury	0.002
Nitrates (as N)	10.000
Selenium	0.010
Silver	0.050
Zinc	5.000

Organic Elements:

Benzedrine	0.001
Detergents (total	0.200
Methylene blue active substances	0.500
Phthalate esters (except butylbenzyl)	0.003
Butylbenzyl	0.150
2,4-D	0.100
2,4,5-TP Silvex	0.010
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.100
Toxaphene	0.005

(2) Radioactive Materials.

(A) There shall be no discharge of radioactive materials in excess of the criteria found in Oklahoma Radiation Protection Regulations, 1969, or its latest revision.

(B) The concentration of gross alpha particles shall not exceed the criteria specified in (I) through (iv) of this subparagraph, or the naturally occurring concentration, whichever is higher.

(I) The combined dissolved concentration of Radium-226 and Radium-228, and Strontium-90, shall not exceed 5 picocuries/liter, and 8 picocuries/liter, respectively.

(ii) Gross alpha particle concentrations, including Radium-226 but excluding radon and uranium, shall not exceed 15 picocuries/liter.

(iii) The gross beta concentration shall not exceed 50 picocuries/liter.

(iv) The average annual concentration of beta particle and photon radioactivity from man-made radionuclides in waters having the designated use of Public and Private Water supply shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem/year.

(3) Coliform Bacteria.

(A) The bacteria of the total coliform group shall not exceed a monthly geometric mean of 5,000/100 ml at a point of intake for public or private water supply.

(B) The geometric mean will be determined by multiple tube fermentation or membrane filter procedures based on a minimum of not less than five (5) samples taken over a period of not more than thirty (30) days.

(C) Further, in no more than 5% of the total samples during any thirty (30) day period shall the bacteria of the total coliform group exceed 20,000/100 ml.

(D) In cases where both public and private water supply and primary body contact recreation uses are designated, the primary body contact criteria will apply.

(4) Oil and Grease (Petroleum and Non-Petroleum Related). For Public and Private Water Supplies, surface waters of the State shall be maintained free from oil and grease and taste and odors.

(5) General Criteria.

(A) The quality of the surface waters of the state which are designated as public and private water supplies shall be protected, maintained, and improved when feasible, so that the waters can be used as sources of public and private raw water supplies.

(B) These waters shall be maintained so that they will not be toxic, carcinogenic, mutagenic, or teratogenic to humans.

(6) Water Column Criteria to Protect for the Consumption of Fish Flesh and Water.

(A) Surface waters of the State with the designated beneficial use of Public and Private Water Supply shall be protected to allow for the consumption of fish, shellfish and water.

(B) The water column numerical criteria listed in Table 1 to protect human health for the consumption of fish flesh and water shall apply to all surface waters designated with the beneficial use of Public and Private Water Supply. Water column criteria to protect human health for the consumption of fish flesh only may be found in 785:45-5-12(9).

785:45-5-11. Emergency Public and Private Water Supplies

(a) During emergencies, those waters designated Emergency Public and Private Water Supplies may be put to use.

(b) Each emergency will be handled on a case-by-case basis, and be thoroughly evaluated by the appropriate State agencies and/or local health authorities.

785:45-5-12. Fish and Wildlife Propagation

(a) "The narrative and numerical criteria in this section are designated to promote fish and wildlife propagation for the fishery classifications of....., Warm Water Aquatic Community......".

Table 1. WATER COLUMN NUMERICAL CRITERIA TO PROTECT HUMAN HEALTH FOR THE CONSUMPTION OF FISH FLESH AND WATER.

Substances (Total Recoverable)	Criteria (µg/l)
Acrylonitrile	0.59
Aldrin	0.001273
Arsenic	0.175
Benzene	11.87
Chlordane	0.00575
Dieldrin	0.001352
DDT	0.005876
Gamma BHC (Lindane)	0.1458
Heptachlor	0.00208
Hexachlorobenzene	0.009026
Carbon Tetrachloride	2.538
Chloroform	56.69
PCB	0.00079
2,3,7,8-TCDD (Dioxin)	0.00000013
1-1-1 TCE	3094.0
Cadmium	14.49
Chromium (Total)	166.3
Endrin	0.7553
Ethylbenzene	3120.0
Lead	5.0
Mercury	0.5563
Nickel	607.2
Pentachlorophenol	1014.0
Phenol	20900.0
Silver	104.8
Tetrachloroethylene(PCE)	8.0
Thallium	1.7
Toluene	10150.0

(d) Warm Water Aquatic Community means a subcategory of the beneficial use category "Fish and Wildlife Propagation" where the water quality and habitat are adequate to support intolerant climax fish communities and includes an environment suitable for the full range of warm water benthos.

(e) The narrative and numerical criteria shall include:

(1) Dissolved Oxygen.

(A) Dissolved oxygen (DO) criteria are designed to protect the diverse aquatic communities of Oklahoma.

(B) Allowable loadings are designed to attain these criteria. For streams with sufficient historical data, the allowable load shall be based on meeting the dissolved oxygen concentration standard at the seven-day, two-year low flow and the appropriate seasonal temperatures. For streams lacking sufficient historical data, or when the appropriate flow is less than one (1) cubic foot per second (cfs), the allowable load shall be based on meeting the dissolved oxygen concentration standard at one (1) cfs and the appropriate seasonal temperature.

(C) Except for naturally occurring conditions, the dissolved oxygen criteria are set forth in Table 2.

Table 2 DISSOLVED OXYGEN CRITERIA[1].

Fishery Class	Dates Applicable	D.O. Criteria (mg/L)	Seasonal Temp (^{O}C)
Warm Water Aquatic Community			
Early Life Stages	4/1-6/15	6.0[2]	25[3]
Other Life Stages			
Summer Condition	6/16-10/15	5.0[2]	32
Winter Condition	10/16-3/31	5.0	18
Cool Water Aquatic Community			
Early Life Stages	3/1-5/31	7.0[2]	22
Other Life Stages			
Summer Condition	6/1-10/15	6.0[2]	29
Winter Condition	10/16-2/28	6.0	18

1 For use in calculation of the allowable load.

2 Because of natural diurnal dissolved oxygen fluctuation, a 1.0 mg/l dissolved oxygen concentration deficit shall be allowed for not more than eight (8) hours during any twenty-four (24) hour period.

3 Discharge limits necessary to meet summer conditions will apply from June 1 of each year. However, where discharge limits based on Early Life Stage (spring) conditions are more restrictive, those limits may be extended to July 1.

(2) Temperature.

(A) At no time shall heat be added to any surface water in excess of the amount that will raise the temperature of the receiving water more than 2.8°C.

(B) The normal daily and seasonal variations that were present before the addition of heat from other than natural sources shall be maintained.

(C) In streams, temperature determinations shall be made by averaging representative temperature measurements of the cross sectional area of the stream at the end of the mixing zone.

(D) In lakes, the temperature of the water column and/or epilimnion, if thermal stratification exists, shall not be raised more than 1.7°C above that which existed before the addition of heat of artificial origin, based upon the average of temperatures taken from the surface to the bottom of the lake, or surface to the bottom of the epilimnion if the lake is stratified.

(E) No heat of artificial origin shall be added that causes the receiving stream water temperature to exceed the maximums specified below:

(I) The critical temperature plus 2.8°C in warm water and habitat limited aquatic community streams and lakes except in the segment of the Arkansas River from Red Rock Creek to the headwaters of Keystone Reservoir where the maximum temperature shall not exceed 34.4°C.

(F) Water in privately-owned lakes and reservoirs used in the process of cooling water for industrial purposes is not classified as "waters of the state" (see 785:45-1-2), and is exempt from these temperature restrictions, provided the water released from any such lake or reservoir into a stream system shall meet the water quality standards of the receiving stream.

(3) pH (Hydrogen Ion Activity). The pH values shall be between 6.5 and 9.0 in waters designed for fish and wildlife propagation; unless pH values outside that range are due to natural conditions.

(4) Oil and Grease (Petroleum and Non-Petroleum Related).

(A) All waters having the designated beneficial use of any subcategory of fish and wildlife propagation shall be maintained free of oil and grease to prevent a visible sheen of oil or globules of oil or grease on or in the water.

(B) Oil and grease shall not be present in quantities that adhere to stream banks and coat bottoms of water courses or which cause deleterious effects to the biota.

(5) Biological Criteria.

(A) Aquatic life in all waterbodies designated Fish and Wildlife Propagation (excluding waters designated "Trout, put-and-take") shall not exhibit degraded conditions as indicated by one or both of the following:

(1) comparative regional reference data from a station of reasonably similar watershed size or flow, habitat type and Fish and Wildlife beneficial use subcategory designation.

or

(2) by comparison with historical data from the waterbody being evaluated.

(B) Compliance with this criterion shall be based upon, but not limited to such measures as diversity, similarity, community structure, species tolerance, trophic structure, dominant species, indices of biotic integrity (IBI's), indices of well being (IWB's), or other measures.

(6) Toxic Substances (for Protection of Fish and Wildlife).

(A) Surface waters of the state shall not exhibit acute toxicity and shall not exhibit chronic toxicity outside the mixing zone.

(B) Procedures to implement these narrative criteria are found in Oklahoma's Continuing Planning Process document, adopted by the Pollution Control Coordinating Board.

(C) Toxicants for which there are specific numerical criteria are listed after (G) of this paragraph.

(D) For toxicants not specified in the table following (G) of this paragraph, concentrations of toxic substances with bio-concentration factors of 5 or less shall not exceed 0.1 of published LC_{50} value(s) for sensitive representative species using standard testing methods, giving consideration to site specific water quality characteristics.

(E) Concentrations of toxic substances with bio-concentration factors greater than 5 shall not exceed 0.01 of published LC_{50} value(s) for sensitive representative species using standard testing methods, giving consideration to site specific water quality characteristics.

(F) Permit limits to prevent toxicity caused by discharge of chlorine and ammonia are determined pursuant to the narrative criteria contained within (A) and (B) of this paragraph.

(G) The following acute and chronic numerical criteria listed in the table apply to all waters of the state designed with any of the beneficial use sub-categories of Fish and Wildlife Propagation. Equations are presented for those substances whose toxicity varies with water chemistry. Metals listed in the following table are measured as total metals in the water column.

(7) Fish Tissue Levels.

(A) Surface waters of the state shall be maintained to prevent bio-concentration of toxic substances in fish, shellfish, or other aquatic organisms.

(B) Concentrations of substances in fish tissue (fillets) in excess of the listed concern levels listed in Table 3 shall be cause for further investigation by the appropriate regulatory agency.

(C) Concentrations of substances in fish tissue (fillets) in excess of the listed alert levels listed in Table 4 shall be cause for evaluation of discharge permits to determine if point source discharges are causing or contributing to the alert level exceedance.

(D) Waste discharge permit limits shall be modified or established as necessary to restrict the discharge of the exceeded substance where an evaluation determines that point source discharge(s) are causing or contributing to the alert level exceedance.

(E) Non-point sources of these substances should be restricted by application of best management practices in areas where concern or alert levels are exceeded.

(8) Water Column Criteria to Protect for the Consumption of Fish Flesh.

(A) Surface waters of the State with the designated beneficial use of Warm Water Aquatic Community, Cool Water Aquatic Community or Trout Fishery shall be protected to allow for the consumption of fish and shellfish.

(B) The water column numerical criteria listed in Table 5 to protect human health for the consumption of fish, shellfish and aquatic life shall apply to all surface waters designated with the beneficial use of Warm Water Aquatic Community, Cool Water Aquatic Community or Trout Fishery.

Table 3 NUMERICAL CRITERIA FOR TOXIC SUBSTANCES (µg/L).

<u>**Substance**</u>	<u>**Acute**</u>	<u>**Chronic**</u>
Acrlyonitrile	7550.0	——
Aldrin	3.0	——
Arsenic	360.0	190.0
Benzene	——	2,200.0
Cadmium	e(1.128[ln(hardness)]-	e(.7852[ln(hardness)]-3.490)
Chlordane	2.4	0.17
Chlorpyrifos (Dursban)	0.083	0.041
Chromium (Total)	——	50.0
Copper	e(0.9422[ln(hardness)]-	e(0.8545[ln(hardness)]-
Cyanide	45.93	10.72
DDT	1.1	0.001
Demeton	——	0.1
Dieldrin	2.5	0.0019
Endosulfan	0.22	0.056

Substance	**Acute**	**Chronic**
Endrin	0.18	0.0023
Guthion	——	0.01
Heptachlor	0.52	0.0038
Hexachlorocyclohexane	2.0	0.08
Lead	e(1.273[ln(hardness)]-1.460)	e(1.273[ln(hardness)]-4.705)
Malathion	——	0.10
Mercury	2.4	0.012
Methoxychlor	——	0.03
Mirex	——	0.001
Nickel	e(.8460[ln(hardness)]+3.361	e(.8460[ln(hardness)+1.1645
PCB's (Total)	——	0.044
Parathion	0.065	0.013
Pentachlorophenol	e[1.005(pH)-4.830]	e[1.005(pH)-5.290]
Selenium	20	5.0
Silver	e(1.72[ln(hardness)]-6.52)	——
2,4,5-TP Silvex	——	10.0
Tetrachloroethylene(PCE	5280.0	——
Thallium	1400.0	—
Toluene	—	875.0
Toxaphene	0.78	0.0002
2,4,6-Trinitrotoluene	450.0	———
Zinc	e(.8473[ln(hardness)+.8604)	e(.8473[ln(hardness)]+.7614

Table 4 ALERT AND CONCERN LEVELS IN FISH TISSUE.

Substance	Alert Level (mg/kg)	Concern Level (mg/kg)
Aldrin	0.3	0.15
Chlordane	0.3	0.15
DDT	5.0	2.5
Dieldrin	0.3	0.15

Endrin	0.3	0.15
Heptachlor	0.3	0.15
Mercury	1.0	0.5
PCB's	2.0	1.0
Toxaphene	5.0	2.5

Table 5. WATER COLUMN NUMERICAL CRITERIA TO PROTECT HUMAN HEALTH FOR THE CONSUMPTION OF FISH FLESH.

Substances (Total Recoverable)	Criteria (µg/l)
Acrylontrile	6.7
Aldrin	0.001356
Arsenic	1.399
Benzene	714.1
Chlordane	0.00587
Dieldrin	0.00144
DDT	0.0059
Gamma BHC (Lindane)	0.4908
Heptachlor	0.00214
Hexachlorobenzene	0.009346
Carbon Tetrachloride	44.18
Chloroform	4708.0
PCB	0.00079
2,3,7,8-TCDD (Dioxin)	0.000000138
1-1-1 TCE	173100.0
Cadmium	84.13
Chromium (Total)	3365.0
Endrin	0.814
Ethylbenzene	28720.0
Lead	25.0
Mercury	0.5874
Nickel	4583.0
Pentachlorophenol	29370.0
Phenol	4615000.0
Silver	64620.0
Tetrachloroethylene(PCE)	88.5
Thallium	6.0
Toluene	301900.0

(9) Turbidity.

(A) Turbidity from other than natural sources shall be restricted to not exceed the following numerical limits:

(ii) Lakes.................25 Nephelometric Turbidity Units

(B) In waters where background turbidity exceeds these values, turbidity from point sources shall be restricted to not exceed ambient levels.

(C) Numerical criteria listed above apply only to normal stream flow conditions.

(D) Elevated turbidity levels may be expected during, and for several days after, a runoff event.

(E) Nephelometric turbidity unit (NTU) is the method based upon a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension (formazin). The higher the intensity of scattered light, the higher the turbidity. Readings in NTUs are considered comparable to the previously reported Jackson Turbidity Units (JTU).

785:45-5-13. Agriculture: Livestock and Irrigation

(a) The surface waters of the State shall be maintained so that toxicity does not inhibit continued ingestion by livestock or irrigation of crops.

(b) Highly saline water should be used with best management practices as outlined in "Diagnosis and Reclamation of Saline Soils," United States Department of Agriculture Handbook No. 60 (1958).

(c) Guidelines for suitability of water quality for livestock and irrigation purposes are provided in Appendix C of this Chapter.

(d) For chlorides, sulfates and total dissolved solids at 180°C (see Standard Methods), the arithmetic mean of the concentration of the samples taken for a year in a particular segment shall not exceed the historical "yearly mean standard" determined from the table following subsection (g) of this and 785:45-1-2 calculated for that segment. Furthermore, not more than one (1) in twenty (20) samples randomly collected at a site shall exceed the historical value of the "sample standard" calculated for that segment.

(e) Increased mineralization from other elements such as calcium, magnesium, sodium and their associated anions shall be maintained at or below a level that will not restrict any beneficial use.

(f) The data from sampling stations in each segment are averaged, and the mean chloride, sulfate, and total dissolved solids at 180°C are presented in the table following (g) of this Section. Segment averages shall be used unless more appropriate data are available.

(g) The table below contains statistical values from historical water quality data of mineral constituents. In cases where mineral content varies within a segment, the most pertinent data available should be used.

785:45-5-16. Primary Body Contact Recreation

(a) Primary Body Contact Recreation involves direct body contact with the water where a possibility of ingestion exists. In these cases the water shall not contain chemical, physical or biological substances in concentrations that are irritating to skin or sense organs or are toxic or cause illness upon ingestion by human beings.

(b) In waters designated for Primary Body Contact Recreation the following limits for bacteria set forth in (c) shall apply only during the recreation period of May 1 to September 30. The criteria for Secondary Body Contact Recreation will apply during the remainder of the year.

(c) Compliance with 785:45-5-16 shall be based upon meeting the requirements of one of the three (3) options specified below for bacteria. Upon selection of one (1) group or test method, said method shall be used exclusively over that thirty (30) day period.

(1) Coliform Bacteria: The bacteria of the fecal coliform group shall not exceed a monthly geometric mean of 200/100 ml, as determined by multiple-tube fermentation or membrane filter procedures based on a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. Further, in no more than 10% of the total samples during any thirty (30) day period shall the bacteria of the fecal coliform group exceed 400/100 ml.

(2) Escherichia coli (E. coli): E. coli shall not exceed a monthly geometric mean of 126/100 ml based upon a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. No sample shall exceed a 75% one-sided confidence level of 235/100 ml in lakes and high use waterbodies and the 90% one-sided confidence level of 406/100 ml in all other Primary Recreation beneficial use areas. These values are based upon all collected samples. Analysis procedures shall follow EPA-600/4-85/076, "Test Methods for Escherichia coli and Enterococci in Water by the Membrane Filter Procedure."

(3) Enterococci: Enterococci shall not exceed a monthly geometric mean of 33/100 ml based upon a minimum of not less than five (5) samples collected over a period of not more than thirty (30) days. No sample shall exceed a 75% one-sided confidence level of 61/100 ml in lakes and high use waterbodies and the 90% one-sided confidence level of 108/100 ml in all other Primary Recreation beneficial use areas. These values are based upon all collected samples. Analysis procedures shall follow EPA-600/4-85/076, "Test Methods for Escherichia coli and Enterococci in Water by the Membrane Filter Procedure."

785:45-5-19. Aesthetics

(a) To be aesthetically enjoyable, the surface water of the State must be free from floating materials and suspended substances that produce objectionable color and turbidity.

(b) The water must also be free from noxious odors and tastes, from materials that settle to form objectionable deposits, and discharges that produce undesirable effects or is a nuisance to aquatic life.

(c) The following criteria apply to protect this use:

(1) Color. Surface waters of the State shall be virtually free from all coloring materials which produce an aesthetically unpleasant appearance. Color producing substances, from other than natural sources, shall be limited to concentrations equivalent to 70 Platinum-cobalt color units.

(2) Nutrients. Nutrients from point source discharges or other sources shall not cause excessive growth of periphyton, phytoplankton, or aquatic macrophyte communities which impairs any existing or designated beneficial use.

(3) Solids (Suspended and/or Settleable). The surface waters of the State shall be maintained so as to be essentially free of floating debris, bottom deposits, scum, foam and other materials, including suspended substances of a persistent nature, from other than natural sources.

(4) Taste and Odor. Taste and odor producing substances from other than natural origin shall be limited to concentrations that will not interfere with the production of a potable water supply by modern treatment methods or produce abnormal flavors, colors, tastes and odors in fish flesh or other edible wildlife, or result in offensive odors in the vicinity of the water, or otherwise interfere with beneficial uses.

Appendix B

LAKE ARCADIA
Transparancy, chlorophyll-a, and pheo-a data
CCHDOC Laboratory Analyses:

Date	Site #	Secchi Depth (in)	Turbidity (NTU)	Chlorophyll-*a* Spec/Lab (G/L)	Pheo-*a* Spec/Lab (g/L)
29-Feb-96	1	22	16.7	6.23	3.67
15-Mar-96	1	22	14.6	8.81	2.7
01-Apr-96	1	22	16.7	6.26	3.56
22-Apr-96	1	21	21.1	4.7	4.25
07-May-96	1	25	8.36	39.14	9.47
20-May-96	1	18	21.5	5.53	3.65
03-Jun-96	1	29	10.6	7.09	1.45
17-Jun-96	1	51	7.82	12.16	2.54
09-Jul-96	1			12.07	3.36
15-Jul-96	1	20	8.82	26.41	0.81
18-Jul-96	1		4.67	32.34	4.54
23-Jul-96	1	28	7.01	23.01	4.56
12-Aug-96	1	43	16.7	9.28	4.43
27-Aug-96	1	37	5.81	32.56	6.47
10-Sep-96	1	37	5.89	25.98	3.56
24-Sep-96	1	19	20.5	10.56	6.07
08-Oct-96	1	20	17.6	11.64	4.92
23-Oct-96	1	17	19.3	8.34	3.74
05-Nov-96	1	18	16.4	4.8	2.93
19-Nov-96	1	20	18.3	2.95	2.45
03-Dec-96	1	18	22.2	1.93	1.26
19-Dec-96	1	13	22.5	3.4	2.75
09-Jan-97	1	19	13.7	5.42	3.11
21-Jan-97	1	24	9.81	7.66	2.91
11-Feb-97	1	26	14.6	20.67	7.87
25-Feb-97	1	16	18.8	9.59	5.86
12-Mar-97	1	19	16.2	34.23	5.35
26-Mar-97	1	15	22.9	6.15	3.26
15-Apr-97	1	15	22.3	2.58	2.04
29-Apr-97	1	15	17.5	22.03	2.2
14-May-97	1	21	14.5	5.5	4.11
27-May-97	1	39	9.58	8.62	2.16
10-Jun-97	1	35	4.79	6.88	4.79
24-Jun-97	1	37	6.05	13	9.29
08-Jul-97	1	24	7.38	7.35	9.4
12-Aug-97	1	27	5.68	39.21	6.52
26-Aug-97	1	28	7.74	32.53	4.51
16-Sep-97	1	20	10.8	33.53	8.82

29-Feb-96	2	22	17.8	7.48	3.2
15-Mar-96	2	18	17.5	9.53	3.1
01-Apr-96	2	24	14.7	5.94	2.96
22-Apr-96	2	17	23.3	5.25	3.17
07-May-96	2	27	10	15.63	5.49
20-May-96	2	15	25.3	9.47	4.9
03-Jun-96	2	24	13.8	13.57	2.98
17-Jun-96	2	23	10.9	17.33	6.38
09-Jul-96	2	22	10.3	13.97	5.05
15-Jul-96	2	22	10.7	20.31	3.41
18-Jul-96	2	35	8.46	29.55	5.03
23-Jul-96	2	31	15.1	18.11	8.36
12-Aug-96	2	31	8.19	26.72	7.98
27-Aug-96	2	37	6.6	16.65	12
24-Sep-96	2	20	17.2	13.77	6.71
08-Oct-96	2	16	24.2	11.44	6.88
23-Oct-96	2	13	18	8.83	3.86
05-Nov-96	2	15	15.1	6.64	1.9
19-Nov-96	2	17	19.1	3.39	2
03-Dec-96	2	13	25.3	2.22	1.06
19-Dec-96	2	18	23.8	3.81	2.54
21-Jan-97	2	19	9.24	8.74	3.16
11-Feb-97	2	19	12.6	21.81	5.02
25-Feb-97	2	14	20.6	11.22	5.7
12-Mar-97	2	21	13.4	33.57	4.74
26-Mar-97	2	13	25.7	8.01	3.56
29-Apr-97	2	16	20.2	19.11	3.43
14-May-97	2	20	17	6.63	2.41
27-May-97	2	30	16	3.77	2.37
10-Jun-97	2	20	10.2	9.91	6.94
24-Jun-97	2	26	9.07	12.6	3.54
08-Jul-97	2	23	10.6	17.92	3.3
12-Aug-97	2	20	7.5	30.06	5.8
26-Aug-97	2	18	7.27	26.69	5.66
16-Sep-97	2	23	5.69	38.43	9.72
29-Feb-96	3	24	17.4	6.84	3.16
15-Mar-96	3	19	15.8	8.04	3.11
01-Apr-96	3	18	17.3	7.25	2.22
22-Apr-96	3	16	33.6	4.48	3.67
07-May-96	3	25	9.92	22.02	6.91
20-May-96	3	16.1	28	6.7	5.09
03-Jun-96	3	25.6	12.8	8.97	1.4
17-Jun-96	3	48	10.2	12.17	2.91

09-Jul-96	3	19	12	15.64	5.17
23-Jul-96	3	40	7.14	22.84	4.3
12-Aug-96	3	26	22.3	14.43	5.42
27-Aug-96	3	46	7.07	28.43	6.68
10-Sep-96	3	26	10	21.53	6.1
24-Sep-96	3	19	24.5	8.92	5.49
08-Oct-96	3	20	20.2	24.75	6.65
23-Oct-96	3	17	17.2	9.33	3.35
05-Nov-96	3	15	14.5	5.87	2.73
19-Nov-96	3	21	18	4.07	2.21
03-Dec-96	3	13	22	2.44	2.04
19-Dec-96	3	16	21.6	3.95	2.16
09-Jan-97	3	19	12.9	7.34	3.65
21-Jan-97	3	22	8.45	7.64	2.87
11-Feb-97	3	28	12.8	21.49	5.99
25-Feb-97	3	15	18.1	10.75	6.34
12-Mar-97	3	17	16.9	37.79	5.82
26-Mar-97	3	14	24.3	6.32	2.53
29-Apr-97	3	18	20.8	19.29	1.56
14-May-97	3	11	27.7	3.86	2.82
27-May-97	3	28	8.21	12.11	1.94
10-Jun-97	3	31	6.43	5.31	4.3
24-Jun-97	3	35	5.39	9.48	4.13
08-Jul-97	3	22	716	20.99	5.86
12-Aug-97	3	24	7.21	34.45	3.6
26-Aug-97	3	24	5.12	31.82	6.49
16-Sep-97	3	24	11.7	23.93	7.85
29-Feb-96	4	18	22.5	9.64	4.41
15-Mar-96	4	19	16.4	8.11	2.83
01-Apr-96	4	20	16.2	12.77	4.63
22-Apr-96	4	16	38	10.82	3.31
07-May-96	4	35	28.3	17.62	7.53
20-May-96	4	11	40.1	7.99	7.81
03-Jun-96	4	20	14	19.79	3
17-Jun-96	4	24	12.8	12.8	3.42
09-Jul-96	4	15	20.7	19.68	6.56
15-Jul-96	4	26	12.4	32.08	4.48
23-Jul-96	4	4	14.5	24.4	5.45
12-Aug-96	4	16	45.6	10.78	5.04
27-Aug-96	4	24	13.3	22.14	4.68
10-Sep-96	4	26	9.25	18.39	2.86
24-Sep-96	4	14	30.3	11.31	6.77
08-Oct-96	4	19	19.5	26.69	9.05

23-Oct-96	4	16	20.8	16.28	5.5
05-Nov-96	4	15	17.5	12.95	3.76
19-Nov-96	4	13	26.9	5.17	3.96
03-Dec-96	4	14	22.4	4.28	2.29
19-Dec-96	4	13	15.8	10.34	4.42
09-Jan-97	4	17	14.4	14.63	6.07
21-Jan-97	4	20	9.04	16.27	4.42
11-Feb-97	4	20	13.4	29.88	5.78
25-Feb-97	4	9	38.3	9.48	6.54
12-Mar-97	4	15	22.9	32.45	6.29
26-Mar-97	4	11	36.8	10.73	5.16
15-Apr-97	4	7	51.3	4.11	3.72
29-Apr-97	4	16	23.5	15.67	2.99
14-May-97	4	8	34.7	6.45	3.16
27-May-97	4	24	11.7	11.05	2.26
10-Jun-97	4	10	34.7	1.92	12
24-Jun-97	4	15	12.5	12.42	4.91
08-Jul-97	4	13	24.4	13.89	6.17
12-Aug-97	4	19	9.25	34.38	6.18
26-Aug-97	4	10	26.5	27.1	7.49
16-Sep-97	4	13	29.5	23.99	9.6
29-Feb-96	5	11	34	15.96	6.45
15-Mar-96	5	12	26.3	7.5	3.12
01-Apr-96	5	16	28.6	21.23	10
22-Apr-96	5	3	139	12.33	6.84
07-May-96	5	22	46.9	20.67	12.55
20-May-96	5	10	58.1	16.11	6.01
03-Jun-96	5	16	31.8	43.99	8.69
17-Jun-96	5	8	52.9	28.44	10.25
15-Jul-96	5	27	15.7	39.4	4.92
18-Jul-96	5		39.8	21.34	5.53
23-Jul-96	5	11	51.9	24.55	9.73
12-Aug-96	5	9	69.6	1.3	16.87
27-Aug-96	5	14	21.7	21.7	4.74
10-Sep-96	5	14	22.1	30.76	7.77
24-Sep-96	5	10	46.8	15.49	10.62
08-Oct-96	5	10	44.8	42.43	10.1
23-Oct-96	5	8	24.3	21.63	7.95
05-Nov-96	5	7	31.9	19.65	6.03
19-Nov-96	5	10	42.5	17.27	6.2
03-Dec-96	5	6	61.3	12.6	3.73
19-Dec-96	5	16	13.9	16.93	4.02
09-Jan-97	5	17	12.6	20.35	6.28

21-Jan-97	5	18	7.31	23.71	3.65
11-Feb-97	5	16	18.3	32.72	7.25
25-Feb-97	5	4	115	7.2	8.06
12-Mar-97	5	11	30	30.04	8.28
26-Mar-97	5	7	55	15.33	6.52
15-Apr-97	5	6	73.1	5.23	6.73
29-Apr-97	5	12	22.5	19.51	5.67
14-May-97	5	6	62.8	14.89	3.76
27-May-97	5	12	42.8	21.15	5.87
10-Jun-97	5	7	52.4	30.03	7.36
24-Jun-97	5	10	22.2	19.97	8.56
08-Jul-97	5	7	47.1	15.93	6.82
12-Aug-97	5	9	27.2	46.52	5.39
26-Aug-97	5	9	48.4	19.97	16.69
16-Sep-97	5	8	60.4	18.17	12.45

DATE	SITE	SITE DEPTH (m)	TOTAL ALKALINITY	TOTAL HARDNESS	SETTLEABLE SOLIDS	TSS	TOTAL SOLIDS	TDS (180 °°C)	SULFATE	AMMONIA AS N	NITRATE AS N	NITRITE AS N	KJELDAHL AS N	NITROGEN ORGANIC	TN	Phosphorus Constituents	
																ortho	Total
29-Feb-96	1	0.1	163	172	<0.1		256	244	21.9	0.046	0.37	0.004		-0.046		0.003	0.045
01-Apr-96	1	0.1	172.8	178	<0.1	11	-	248	24.9	<0.05	0.35	<0.01	0.48	0.48	0.83	0.006	
22-Apr-96	1	0.1	173	182	<0.2		-	245	24.8	0.06		<0.01	0.59	0.53		0.01	
20-May-96	1	0.1	180	188	<0.5	21	-	321	25.5	0.061	0.34	0.03	0.48	0.42	0.85		0.05
03-Jun-96	1	0.1	168	188	<0.1	8.7	-	267	29.1		0.28	0.02	0.43	0.388	0.73	0.01	0.05
17-Jun-96	1	0.1	183	176	<0.1	7.7	-	252	21.1	<0.05	0.18	<0.005	0.59		0.77	<0.005	0.05
09-Jul-96	1	0.1	169	178	<0.1	2.5	-	252	24.8	<0.05	0.14	<0.005	0.44	0.44		<0.005	0.04
15-Jul-96	1	0.1	169	165	<0.1	3.0	-	239	25.6	0.052	<0.05	<0.005	0.52	0.468	0.52	<0.005	
23-Jul-96	1	0.1	152	160	<0.1	7.3	-	221	27.8	0.058	<0.05	<0.005	0.58	0.52	0.58	<0.005	0.04
12-Aug-96	1	0.1	140	150	<0.1	10.5	-	203	20.8		0.091	0.02	0.49	0.4	0.60	0.02	0.06
27-Aug-96	1	0.1	141	138	<0.1		-	210	21.8	0.053	<0.05	<0.005	0.82	0.77	0.82	<0.005	0.04
24-Sep-96	1	0.1	135	144	<0.1	16.5	-	209	20.2	<0.05	0.43	0.006	0.41	0.41	0.85	0.02	0.07
23-Oct-96	1	0.1	143	152	<0.1	-	221	213	22.7	0.03		0.009	0.41	0.38	0.42	0.017	0.06
19-Nov-96	1	0.1	139	144	<0.1	10.5	-	198	23.2	<0.05	0.45	0.01	0.48	0.48	0.94	0.03	0.08
19-Dec-96	1	0.1	144	157	<0.1	15.5	-	233	28.6		0.74	0.011	0.57	0.28	1.32	0.027	0.08
21-Jan-97	1	0.1	163	171	<0.1	10	-	248	25.4		1.4	0.008	0.43		1.84	0.01	0.06
25-Feb-97	1	0.1	160	174	<0.1		-	240	22.34	<0.1		0.007	0.487	0.487			0.05
26-Mar-97	1	0.1	169	176	<0.1	16	-	249	35.6	<0.05	0.41	<0.005	0.56	0.56	0.97		0.05
29-Apr-97	1	0.1	163	176	<0.1	8	-	254	25.5	0.13	0.44	0.02	0.53	0.4	0.99	0.05	0.06
14-May-97	1	0.1	148	180	<0.1		-	251	24.8	<0.05	0.39	0.03	0.45	0.45	0.87	0.02	0.06
27-May-97	1	0.1	155	172	<0.1	5.8		256	32.8	<0.05	0.76	0.02	0.41	0.41	1.19		0.04
10-Jun-97	1	0.1	160	178	<0.1	3.6		263		<0.05	0.24	0.014	0.48	0.48	0.73	0.012	0.03
24-Jun-97	1	0.1	161	180	<0.1	5		254	35.7	<0.05		<0.005	0.62	0.62	0.62	<0.005	0.042
08-Jul-97	1	0.1	161	174	<0.1	8		242	33.1		0.11	<.005	0.65	0.65	0.76	<0.005	0.037
29-Jul-97	1	0.1	145	162	<0.1	8		230	35	<0.05	0.09	<0.005	0.73	0.73	0.82	<0.05	0.038
12-Aug-97	1	0.1	141	156	<0.1	9		230	29.2	<0.05		<0.005	0.79	0.79	0.79	<0.005	0.07
26-Aug-97	1	0.1	146	148	<0.1	5		229	34.3	<0.05	0.13	<0.005	0.739	0.609	0.87	<0.005	0.059
16-Sep-97	1	0.1	146	156	<0.1	12		234	24.6	0.05	<0.05	<0.010	0.76	0.71	0.76	<0.005	0.054
30-Sep-97	1	0.1	134	148	<0.1	15		210	27.8	<0.05	0.43	0.007	0.53	0.53	0.97	0.019	0.068
29-Feb-96	1	3	164	172	<0.1		254	238	27.3	0.061	0.31	0.004				0.004	0.061
01-Apr-96	1	3	173.6	182	<0.1	11	-	236	23.9	<0.05	0.26	<0.01	0.44	0.44	0.70	0.008	

22-Apr-96	1	3	175	182	<0.2		-	249	25.9	0.04		<0.01	0.52	0.48	0.52	0.01	
20-May-96	1	3	183	186	<0.5	20	-	308	26	0.051	0.35	0.03	0.48	0.43	0.86		0.05
03-Jun-96	1	3	176	186	<0.1	10	-	267	27.3		0.21	0.02	0.38	0.337	0.61	0.01	0.05
17-Jun-96	1	3	172	173	<0.1	9	-	245	24.3	<0.05	0.09	<0.005	0.55			<0.005	0.05
09-Jul-96	1	3	165	176	<0.1	5.1	-	244	25.6	<0.05	0.08	<0.005	0.49	0.49	0.49	<0.005	0.04
15-Jul-96	1	3	164	168	<0.1	5.0	-	239	25.2	<0.05	<0.05	<0.005	0.58	0.580	0.58	0.005	
23-Jul-96	1	3	148	152	<0.1	6.7	-	218	27.2	0.056	<0.05	<0.005	0.64	0.58	0.64	<0.005	0.05
12-Aug-96	1	3	140	142	<0.1	12	-	207	22		0.085	0.02	0.53	0.43	0.64	0.02	0.06
27-Aug-96	1	3	136	137	<0.1		-	206	23.5	0.062	<0.05	<0.005	0.58	0.52	0.58	<0.005	0.04
24-Sep-96	1	3	139	141	<0.1	15.5	-	209	20.5	<0.05	0.37	0.006	0.39	0.39	0.77	0.02	0.08
23-Oct-96	1	3	143	158	<0.1	-	223	209	22.4	0.03		0.007	0.41	0.38	0.42	0.018	0.06
19-Nov-96	1	3	142	142	<0.1	10.5	-	197	22.7	<0.05	0.45	0.01	0.5	0.5	0.96	0.03	0.07
19-Dec-96	1	3	145	156	<0.1	15	-	233	27.7		0.84	0.011	0.45	0.28	1.30	0.03	0.08
21-Jan-97	1	3	170	170	<0.1	8	-	247	26.2		1.4	0.008	0.53			0.01	0.05
25-Feb-97	1	3	165	176	<0.1		-	253.1	24.26	<0.1		0.006	0.5	0.5	0.51		0.06
26-Mar-97	1	3	161	180	<0.1	15	-	251	35.8	<0.05	0.41	<0.005	0.46	0.46	0.87		0.06
29-Apr-97	1	3	169	176	<0.1	7	-	253	24.3	0.12	0.43	0.02	0.46	0.34	0.91	0.05	0.06
14-May-97	1	3	144	174	<0.1		-	248	31.5	<0.05	0.38	0.02	0.45	0.45	0.85	0.02	0.06
27-May-97	1	3	160	176	<0.1	6		257	31.5	<0.05	0.73	0.02	0.46	0.46	1.21		0.04
10-Jun-97	1	3	161	184	<0.1	4.8		258		<0.05	0.3	0.14	0.4	0.4	0.84	0.022	0.03
24-Jun-97	1	3	156	196	<0.1	4		251	33.9	<0.05		<0.005	0.55	0.55	0.55	<0.005	0.045
08-Jul-97	1	3	163	174	<0.1	9		242	36.6		0.12	<.005	0.65	0.65	0.77	<.005	0.039
29-Jul-97	1	3	142	161	<0.1	8.5		227	34.8	<0.05	0.06	0.008	0.52	0.52	0.59	<0.005	0.05
12-Aug-97	1	3	147	154	<0.1	9		224	29.6	<0.05		<0.005	0.61	0.61	0.61	0.007	0.053
26-Aug-97	1	3	139	152	<0.1	6		224	35.5	<0.05	0.15	<0.005	0.784	0.634	0.93	<0.005	0.053
16-Sep-97	1	3	136	154	<0.1	10		239	27.5	<0.05	<0.05	0.01	0.76	0.76	0.77	<0.005	0.063
30-Sep-97	1	3	138	149	<0.1	15		236	27.8	<0.05	0.47	0.009	0.46	0.46	0.94	0.024	0.07
08-Jul-97	1	5	155	174	<0.1	8		246	36.9		0.12	<.005	0.59	0.59	0.71	<0.05	0.037
29-Feb-96	1	6	166	176	<0.1		244	230	24.9	0.062	0.33	0.004		-0.062	0.33	0.004	0.049
01-Apr-96	1	6	171.2	178	<0.1	17	-	241	24.2	<0.05	0.38	<0.01	0.44	0.44	0.82	0.008	
20-May-96	1	6	177	188	<0.5	21.5	-	316	25.7	0.054	0.38	0.03	0.39	0.34	0.80		0.06
03-Jun-96	1	6	178	188	<0.1	12	-	267	27.6		0.31	0.01	0.49	0.374	0.81	0.03	0.07
17-Jun-96	1	6	176	178	<0.1	11.5	-	259	25.2	<0.05	0.46	<0.005	0.38		0.84	0.03	0.06
09-Jul-96	1	6	168	177	<0.1	6.3	-	243	52.4	<0.05	<0.05	<0.005	0.43	0.43	0.43	<0.005	0.05
15-Jul-96	1	6	146	148	<0.1	10.0	-	214	24.6	0.231	0.11	0.02	0.63	0.400	0.63	0.05	
23-Jul-96	1	6	162	156	<0.1	8	-	216	27.9	0.195	<0.05	<0.005	0.63	0.44	0.63	<0.005	0.06
12-Aug-96	1	6	141	143	<0.1	12.5	-	206	21.9		0.083	0.02	0.49	0.39	0.59	0.02	0.06

27-Aug-96	1	6	137	140	<0.1		-	214	21.5	0.091	0.07	0.011	0.52	0.43	0.60	0.013	0.05
24-Sep-96	1	6	139	147	<0.1	18	-	208	20.2	<0.05	0.31	0.006	0.28	0.28	0.60	0.02	0.08
23-Oct-96	1	6	143	151	<0.1	-	221	216	22.5	0.02		0.007	0.43	0.41	0.44	0.018	0.06
19-Nov-96	1	6	138	148	<0.1	10	-	204	23.7	<0.05	0.46	0.01	0.4	0.4	0.87	0.03	0.08
19-Dec-96	1	6	148	154	<0.1	14	-	231	29.3		0.86	0.011	0.46	0.3	1.33	0.029	0.08
25-Feb-97	1	6	164	174	<0.1			247.1	23.54	<0.1		0.005	0.41	0.41	0.42		0.05
26-Mar-97	1	6	165	180	<0.1	15		248	36	<0.05	0.41	<0.005	0.46	0.46	0.87		0.06
29-Apr-97	1	6	167	178	<0.1	7		258	25	0.12	0.46	0.02	0.49	0.37	0.97	0.04	0.05
14-May-97	1	6	154	176	<0.1		-	248	30.4	<0.05	0.37	0.02	0.44	0.44	0.83	0.02	0.07
27-May-97	1	6	163	176	<0.1	9		258	30.4	<0.05	0.71	0.026	0.41	0.41	1.15		0.05
10-Jun-97	1	6	164	194	<0.1	5.6		260		<0.05	0.59	0.007	0.52	0.52	1.12	0.029	0.05
24-Jun-97	1	6	162	188	<0.1	6		252	35.5	<0.05		<0.005	0.47	0.47	0.47	<0.005	0.048
08-Jul-97	1	6	160	176	<0.1	12		251	37.9		0.12	<.005	0.59	0.59	0.71	<..005	0.037
29-Jul-97	1	6	146	161	<0.1	13		228	6.28	0.17	0.08	0.017	0.54	0.37	0.64	0.031	0.076
12-Aug-97	1	6	147	156	<0.1	9		232	29.5	0.16		0.042	0.54	0.38	0.58	0.013	0.053
26-Aug-97	1	6	149	152	<0.1	4		227	35.6	<0.05	0.16	0.016	0.678	0.502	0.85	<0.005	0.057
16-Sep-97	1	6	143	154	<0.1	9		238	28.3	<0.05	<0.05	0.012	0.71	0.71	0.72	<0.005	0.063
30-Sep-97	1	6	134	146	<0.1	18		238	26.8	<0.05	0.49	0.011	0.49	0.49	0.99	0.026	0.081
29-Feb-96	1	9	164	172	<0.1		259	227	29.1	0.062	0.25	0.004		-0.062	0.25	0.004	0.055
03-Jun-96	1	9	174	188	<0.1	11	-	270	26.8		0.19	0.01	0.45	0.349	0.65	0.03	0.07
17-Jun-96	1	9	174	184	<0.1	12.5	-	256	25.9	<0.05	0.72	<0.005	0.41		1.13	0.04	0.09
15-Jul-96	1	9	130	131	<0.1	16.0	-	191	16.3	0.148	0.09	0.02	0.58	0.432	0.58	0.08	
23-Jul-96	1	9	153	148	<0.1	12	-	214	26.8	0.23	0.06	0.04	0.54	0.31	0.64	0.03	0.08
12-Aug-96	1	9	139	142	<0.1	13	-	208	21.8		0.081	0.02	0.5	0.39	0.60	0.02	0.06
24-Sep-96	1	9	133	148	<0.1	18.5	-	208	20.1	<0.05	0.34	0.005	0.43	0.43	0.78	0.02	0.07
23-Oct-96	1	9	143	156	<0.1	-	227	210	23.6	0.02		0.008	0.46	0.44	0.47	0.019	0.06
19-Nov-96	1	9	138	143	<0.1	11.5	-	203	23.6	<0.05	0.44	0.01	0.46	0.46	0.91	0.03	0.08
25-Feb-97	1	9	172	172	<0.1			264	23.35	<0.1		0.005	0.414	0.414	0.42		0.05
26-Mar-97	1	9	172	172	<0.1	18		253	38.2	<0.05	0.35	<0.005	0.45	0.45	0.80		0.05
29-Apr-97	1	9	169	176	<0.1	7.5		258	6.94	0.13	0.42	0.02	0.55	0.42	0.99	0.05	0.06
14-May-97	1	9	156	174	<0.1		-	254	32.3	<0.05	0.42	0.02	0.48	0.48	0.92	0.02	0.07
29-Jul-97	1	9	152	154	<0.1	29.5		215	7.82	0.514	0.08	<0.005	0.9	0.39	0.98	0.108	0.209
12-Aug-97	1	9	149	156	<0.1	8		235	30.5	0.29		0.035	0.64	0.35	0.68	0.022	0.064
26-Aug-97	1	9	142	152	<0.1	6		217	34.7	0.245	0.2	0.09	0.722	0.432	1.01	0.017	0.07
16-Sep-97	1	9	134	153	<0.1	12		243	27.4	0.11	0.19	0.028	0.75	0.64	0.97	<0.005	0.062
29-Feb-96	1	Bottom	164	176	<0.1		255	229	29.1	0.062	0.24	0.004		-0.062	0.24	0.004	0.047
22-Apr-96	1	Bottom	177	182	<0.2		-	257	24.4	0.04		<0.01	0.43	0.39	0.43	0.01	

20-May-96	1	Bottom	180	187	<0.5	42.5	-	302	26.8	0.054	0.39	0.03	0.48	0.43	0.90		0.08
03-Jun-96	1	Bottom	178	184	0.2	39	-	262	25.7		0.22	0.03	0.59	0.453	0.84	0.03	0.12
17-Jun-96	1	Bottom	182	183	0.14	24.5	-	254	27.2	<0.05	0.69	<0.005	0.52		1.21	0.04	0.11
09-Jul-96	1	Bottom	194	177	<0.1	36.5	-	264	22.9	0.7	<0.05	<0.005	1.36	0.66	1.36	0.20	0.54
15-Jul-96	1	Bottom	92.2	97	<0.1	33.0	-	153	<2.0	0.223	0.25	0.02	0.69	0.467	0.69	0.11	
23-Jul-96	1	Bottom	124	120	<0.1	14	-	176	21.5	0.059	<0.05	0.08	0.72	0.66	0.80	0.09	0.15
12-Aug-96	1	Bottom	141	144	<0.1	18.5	-	211	21.8		0.077	0.02	0.53	0.35	0.63	0.03	0.09
27-Aug-96	1	Bottom	144	143	0.13		-	233	21.4	0.49	0.07	0.009	1.04	0.55	1.12	0.129	0.22
24-Sep-96	1	Bottom	139	143	<0.1	28	-	214	20.3	<0.05	0.33	0.007	0.33	0.33	0.67	0.02	0.09
23-Oct-96	1	Bottom	141	152	<0.1	-	239	215	22.8	0.02		0.006	0.48	0.46	0.49	0.003	0.08
19-Nov-96	1	Bottom	138	144	<0.1	17.5	-	209	23.3	<0.05	0.45	0.02	0.52	0.52	0.99	0.03	0.1
19-Dec-96	1	Bottom	145	156	<0.1	14.5	-	231	28.9		0.91	0.011	0.44	0.28	1.36	0.029	0.08
21-Jan-97	1	Bottom	160	170	<0.1	8	-	243	27.7		1.3	0.008	0.42		1.73	0.01	0.05
25-Feb-97	1	Bottom	164	172	<0.1		-	256	23	<0.1		0.005	0.487	0.487	0.49		0.03
26-Mar-97	1	Bottom	162	176	<0.1	25	-	253	33.8	<0.05	0.3	<0.005	0.49	0.49	0.79		0.06
29-Apr-97	1	Bottom	170	178	<0.1	29.5	-	259	34.3	0.14	0.47	0.04	0.62	0.48	1.13	0.03	0.09
14-May-97	1	Bottom	160	176	0.2		-	254	29.3	<0.05	0.48	0.02	0.52	0.52	1.02	0.03	0.08
27-May-97	1	Bottom	159	176	<0.1	23		266	28.3	<0.05	0.9	0.051	0.5	0.5	1.45		0.1
10-Jun-97	1	Bottom	167	188	<0.1	17		262		0.1	0.52	0.017	0.62	0.62	1.16	0.096	0.12
24-Jun-97	1	Bottom	174	188	<0.1	17.5		260	32.9	0.32		0.017	0.72	0.4	0.74	0.094	0.156
08-Jul-97	1	Bottom	169	182	<0.1	12		251	37.9		0.12	<.005	1.06	0.56	1.18	0.111	0.172
29-Jul-97	1	Bottom	146	153	0.2	43		222	4.22	0.66	0.08	<0.005	1.17	0.51	1.25	0.131	0.267
12-Aug-97	1	Bottom	151	154	<0.1	8		232	29.7	0.29		0.028	0.73	0.44	0.76	0.03	0.074
26-Aug-97	1	Bottom	143	148	<0.1	8		215	36.5	0.233	0.18	0.088	0.857	0.589	1.13	0.025	0.096
16-Sep-97	1	Bottom	146	151	<0.1	17		242	28.8	0.23	0.21	0.038	0.84	0.61	1.09	0.015	0.09
30-Sep-97	1	Bottom	137	148	<0.1	21		237	27.5	<0.05	0.44	0.015	0.55	0.55	1.01	0.024	0.085
01-Apr-96	1	Bottom	173.4	176	<0.1	14	-	226	24.4	<0.05	0.36	<0.01	0.48	0.48	0.84	0.008	
29-Feb-96	2	0.1	183	174	<0.1		257	230	26.5	0.054	0.19	0.004		-0.054	0.19	0.004	0.043
01-Apr-96	2	0.1	177.2	180	<0.1	11	-	264	24.7	<0.05	0.28	<0.01	0.47	0.47	0.75	0.006	
22-Apr-96	2	0.1	175	184	<0.2		-	256	24	0.03		<0.01	0.52	0.49	0.52	0.01	
20-May-96	2	0.1	179	186	<0.5	24	-	287	27.2	0.056	0.34	0.03	0.48	0.42	0.85		0.06
03-Jun-96	2	0.1	180	188	<0.1	12	-	262	25.9		0.13	0.01	0.53	0.476	0.67	<0.01	0.07
17-Jun-96	2	0.1	175	172	<0.1	7.7	-	247	24.7	<0.05	0.26	<0.005	0.98		1.24	<0.005	0.05
09-Jul-96	2	0.1	168	174	<0.1	9.0	-	248	25.0	<0.05	<0.05	<0.005	0.42	0.42	0.42	<0.005	0.05
15-Jul-96	2	0.1	164	164	<0.1	6.0	-	232	16.1	<0.05	<0.05	<0.005	0.53	0.530	0.53	0.006	
23-Jul-96	2	0.1	170	152	<0.1	8	-	222	28.3	0.058	<0.05	<0.005	0.73	0.67	0.73	<0.005	0.06
12-Aug-96	2	0.1	143	149	<0.1	14.5	-	213	21.9		0.076	0.008	0.52	0.44	0.60	0.006	0.06
27-Aug-96	2	0.1	140	144	<0.1		-	203	24	0.071	<0.05	<0.005	0.63	0.56	0.63	<0.005	0.05

24-Sep-96	2	0.1	140	142	<0.1	15	-	209	20.3	<0.05	0.29	0.005	0.45	0.45	0.75	0.02	0.06
23-Oct-96	2	0.1	146	154	<0.1	-	237	210	22.3	0.01		0.006	0.52	0.51	0.53	0.015	0.06
19-Nov-96	2	0.1	140	144	<0.1	8	-	202	21.6	<0.05	0.5	0.01	0.54	0.54	1.05	0.03	0.08
19-Dec-96	2	0.1	148	157	<0.1	14.5	-	224	28.5		0.92	0.01	0.46	0.32	1.39	0.029	0.07
21-Jan-97	2	0.1	161	168	<0.1	6	-	244	27.9		1.3	0.008	0.46		1.77	0.01	0.06
25-Feb-97	2	0.1	172	174	<0.1		-	256	22.13	<0.1		0.005	0.459	0.459	0.46		0.03
26-Mar-97	2	0.1	164	184	<0.1	19	-	252	33.4	<0.05	0.31	<0.005	0.46	0.46	0.77		0.06
29-Apr-97	2	0.1	165	178	<0.1	10	-	254	27	0.14	0.47	0.02	0.54	0.4	1.03	0.04	0.06
14-May-97	2	0.1	158	174	<0.1		-	242	32	<0.05	0.38	0.03	0.52	0.52	0.93	0.01	0.06
27-May-97	2	0.1	162	172	<0.1	7		252	25.2	<0.05	0.64	0.02	0.45	0.45	1.11		0.05
10-Jun-97	2	0.1	165	174	<0.1	8.4		257		<0.05	0.17	0.01	0.55	0.55	0.73	0.016	0.05
24-Jun-97	2	0.1	158	176	<0.1	18		254	35.9	<0.05		<0.005	0.66	0.66	0.66	<0.005	0.07
08-Jul-97	2	0.1	157	177	<0.1	11		255	36.9		0.08	<.005	0.95	0.84	1.03	<0.005	0.053
29-Jul-97	2	0.1	138	153	<0.1	9		225	26.4	<0.05	0.1	<0.005	0.68	0.68	0.78	<0.005	0.039
12-Aug-97	2	0.1	152	155	<0.1	8		228	29.4	0.1		<0.005	0.71	0.61	0.71	0.005	0.063
26-Aug-97	2	0.1	148	152	<0.1	10		226	33.2	<0.05	0.13	<0.005	0.784	0.654	0.91	0.012	0.061
16-Sep-97	2	0.1	142	152	<0.1	10		245	26.4	<0.05	0.09	<0.010	1.01	1.01	1.10	0.006	0.066
30-Sep-97	2	0.1	137	148	<0.1	14		234	27.6	<0.05	0.4	0.007	0.54	0.54	0.95	0.017	0.07
29-Feb-96	2	Bottom	167	170	<0.1		242	231	25	0.053	0.18	0.004		-0.053	0.18	0.004	0.053
01-Apr-96	2	Bottom	178	172	<0.1	12	-	245	24.8	<0.05	0.36	<0.01	0.49	0.49	0.85	0.005	
22-Apr-96	2	Bottom	176	184	<0.2		-	241	24.8	0.03		<0.01	0.49	0.46	0.49	0.009	
20-May-96	2	Bottom	179	186	<0.5	28	-	295	25.7	0.049	0.36	0.03	0.59	0.54	0.98		0.06
03-Jun-96	2	Bottom	177	186	<0.1	26	-	260	27.2		0.24	0.01	0.54	0.4	0.79	0.03	0.1
17-Jun-96	2	Bottom	180	182	<0.1	8.7	-	260	26.1	<0.05	0.7	<0.005	0.41		1.11	0.03	0.07
09-Jul-96	2	Bottom	169	175	<0.1	10.0	-	250	25.7	<0.05	<0.05	<0.005	0.49	0.49	0.49	0.01	0.06
15-Jul-96	2	Bottom	152	151	<0.1	14.0	-	218	22.0	0.170	0.05	0.01	0.66	0.490	0.66	0.05	
23-Jul-96	2	Bottom	145	168	<0.1	6	-	226	28.3	0.058	<0.05	<0.005	0.54	0.48	0.54	<0.005	0.05
12-Aug-96	2	Bottom	142	146	<0.1	18.5	-	209	22.1		0.063	0.008	0.54	0.45	0.61	0.007	0.07
27-Aug-96	2	Bottom	139	136	<0.1		-	207	23.6	0.1	<0.05	<0.005	0.69	0.59	0.69	<0.005	0.07
24-Sep-96	2	Bottom	140	144	<0.1	30.5	-	207	19.9	<0.05	0.26	0.007	0.49	0.49	0.76	0.02	0.09
23-Oct-96	2	Bottom	146	150	<0.1	-	236	215	22.6	0.02		0.006	0.45	0.43	0.46	0.016	0.07
19-Nov-96	2	Bottom	139	144	<0.1	9	-	202	23.7	<0.05	0.51	0.01	0.39	0.39	0.91	0.03	0.06
19-Dec-96	2	Bottom	149	153	<0.1	11.5	-	229	27.9		0.86	0.01	0.44	0.25	1.31	0.027	0.07
21-Jan-97	2	Bottom	170	168	<0.1	6	-	246	27.8		1.2	0.008	0.49		1.70	0.01	0.06
25-Feb-97	2	Bottom	174	174	<0.1		-	244	23.4	<0.1		0.005	0.454	0.454	0.46		0.02
26-Mar-97	2	Bottom	168	180	<0.1	25	-	251	34.8	<0.05	0.35	<0.005	0.53	0.53	0.88		0.07
29-Apr-97	2	Bottom	166	174	<0.1	11.5	-	253	23.1	0.13	0.46	0.02	0.53	0.4	1.01	0.04	0.05
14-May-97	2	Bottom	160	184	<0.1		-	249	33	<0.05	0.44	0.02	0.54	0.54	1.00	0.02	0.09

27-May-97	2	Bottom	162	168	<0.1	27		268	28.5	<0.05	0.64	0.028	0.51	0.51	1.18		0.09
10-Jun-97	2	Bottom	160	190	<0.1	5.2		264		<0.05	0.46	0.01	0.43	0.43	0.90	0.024	0.03
24-Jun-97	2	Bottom	164	180	<0.1	13.5		245	34.9	<0.05		<0.005	0.55	0.55	0.55	<0.005	0.062
08-Jul-97	2	Bottom	160	178	<0.1	10		252	37.8		0.09	<0.005	0.8	0.73	0.89	<0.005	0.038
29-Jul-97	2	Bottom	148	161	<0.1	10.5		236	28.2	0.061	0.12	<0.005	0.52	0.46	0.64	0.007	0.053
12-Aug-97	2	Bottom	152	154	<0.1	20.5		236	26.5	0.11		0.028	0.51	0.4	0.54	0.005	0.058
26-Aug-97	2	Bottom	143	152	<0.1	31		224	34.8	<0.05	0.15	0.037	0.79	0.603	0.98	0.011	0.087
16-Sep-97	2	Bottom	140	154	<0.1	41		243	28.8	0.08	0.12	0.011	0.9	0.82	1.03	<0.005	0.091
30-Sep-97	2	Bottom	140	149	<0.1	26		237	26.6	<0.05	0.35	0.011	0.63	0.63	0.99	0.014	0.082
29-Feb-96	3	0.1	169	182	<0.1		250	234	25.8	0.148	0.56	0.004		-0.148	0.56	0.004	0.042
01-Apr-96	3	0.1	168	178	<0.1	9	-	235	25.2	<0.05	0.35	<0.01	0.5	0.5	0.85	<0.005	
22-Apr-96	3	0.1	177	184	<0.2		-	240	24.8	0.04		<0.01	0.5	0.46	0.50	0.008	
20-May-96	3	0.1	178	186	<0.5	26	-	273	24.1	0.049	0.38	0.03	0.52	0.47	0.93		0.07
03-Jun-96	3	0.1	180	188	<0.1	9.3	-	255	25.4		0.17	0.02	0.45	0.403	0.64	0.01	0.06
17-Jun-96	3	0.1	171	170	<0.1	8	-	247	24.7	<0.05	0.19	<0.005	0.46		0.65	<0.005	0.04
09-Jul-96	3	0.1	172	177	<0.1	6.0	-	249	24.9	<0.05	<0.05	<0.005	0.5	0.50	0.50	<0.005	0.05
15-Jul-96	3	0.1	168	164	<0.1	5.0	-	236	27.6	<0.05	<0.05	<0.005	0.62	0.620	0.62	<0.005	
23-Jul-96	3	0.1	148	164	<0.1	6.5	-	222	26.2	0.053	<0.05	<0.005	0.58	0.53	0.58	<0.005	0.05
12-Aug-96	3	0.1	138	142	<0.1	17	-	213	21.3		0.064	0.02	0.49	0.41	0.57	0.01	0.07
27-Aug-96	3	0.1	139	138	<0.1		-	207	24	0.062	<0.05	<0.005	0.74	0.68	0.74	<0.005	0.05
24-Sep-96	3	0.1	136	144	<0.1	16.5	-	208	20.4	<0.05	0.32	0.008	0.39	0.39	0.72	0.02	0.07
23-Oct-96	3	0.1	143	162	<0.1	-	236	217	23.3	0.03		0.006	0.57	0.54	0.58	0.016	0.06
19-Nov-96	3	0.1	140	143	<0.1	9	-	205	22.9	<0.05	0.47	0.02	0.52	0.52	1.01	0.03	0.07
19-Dec-96	3	0.1	144	156	<0.1	13	-	231	28.6		0.89	0.01	0.42	0.26	1.32	0.027	0.07
21-Jan-97	3	0.1	172	172	<0.1	3	-	250	28.7		1.17	0.008	0.48		1.66	0.01	0.05
25-Feb-97	3	0.1	162	172	<0.1		-	250	31.54	<0.1		0.006	0.286	0.286	0.29		0.04
26-Mar-97	3	0.1	166	176	<0.1	17	-	260	33.6	<0.05	0.28	<0.005	0.49	0.49	0.77		0.04
29-Apr-97	3	0.1	168	178	<0.1	11	-	254	26.5	0.12	0.41	0.02	0.5	0.38	0.93	0.03	0.06
14-May-97	3	0.1	158	174	<0.1		-	247	33.1	<0.05	0.44	0.03	0.49	0.49	0.96	0.02	0.07
27-May-97	3	0.1	161	176	<0.1	10		249	29.9	<0.05	0.5	0.018	0.53	0.53	1.05		0.04
10-Jun-97	3	0.1	160	192	<0.1	4.8		262		<0.05	0.19	0.013	0.48	0.48	0.68	0.014	0.04
24-Jun-97	3	0.1	157	188	<0.1	6.5		248	35.8	<0.05		<0.005	0.53	0.53	0.53	<0.005	0.052
08-Jul-97	3	0.1	157	176	<0.1	10		262	36.2		<0.05	<.005	0.73	0.73	0.73	<0.005	0.042
29-Jul-97	3	0.1	144	158	<0.1	9		230	26.9	<0.05	0.07	<0.005	0.67	0.67	0.74	<0.005	0.011
12-Aug-97	3	0.1	146	160	<0.1	7		233	27.5	<0.05		<0.005	0.61	0.61	0.61	0.007	0.058
26-Aug-97	3	0.1	148	144	<0.1	6		226	33.8	<0.05	0.11	<0.005	0.739	0.629	0.85	0.01	0.059
16-Sep-97	3	0.1	140	152	<0.1	13		247	28.9	0.06	0.13	0.025	0.68	0.62	0.84	0.009	0.076
30-Sep-97	3	0.1	136	148	<0.1	17		229	28.2	<0.05	0.36	0.07	0.43	0.43	0.86	0.017	0.075

29-Feb-96	3	Bottom	167	174	<0.1		249	230	27.6	0.078	0.44	0.004		-0.078	0.44	0.004	0.049
01-Apr-96	3	Bottom	172.6	182	<0.1	11	-	245	24.7	<0.05	0.36	<0.01	0.47	0.47	0.83	0.006	
22-Apr-96	3	Bottom	176	186	0.2		-	220	23.4	0.04		<0.01	0.48	0.44	0.48	0.008	
20-May-96	3	Bottom	174	188	<0.5	25	-	254	27.4	0.05	0.35	0.03	0.49	0.44	0.87		0.07
03-Jun-96	3	Bottom	186	188	<0.1	19	-	268	27.7		0.2	0.02	0.47	0.375	0.69	0.02	0.08
17-Jun-96	3	Bottom	182	180	<0.1	23	-	262	26.4	<0.05	0.5	<0.005	0.52		1.02	0.01	0.1
09-Jul-96	3	Bottom	172	177	<0.1	17.8	-	248	26.1	<0.05	<0.05	<0.005	0.49	0.49	0.49	0.01	0.06
15-Jul-96	3	Bottom	121	122	<0.1	23.0	-	187	<2.0	0.189	0.15	0.02	0.63	0.441	0.63	0.09	
23-Jul-96	3	Bottom	145	160	<0.1	22	-	225	27.7	0.058	<0.05	<0.005	0.6	0.54	0.60	0.007	0.07
12-Aug-96	3	Bottom	138	142	<0.1	30	-	212	21.7		0.069	0.02	0.53	0.43	0.62	0.02	0.09
27-Aug-96	3	Bottom	133	140	0.2		-	207	26.2	0.07	<0.05	<0.005	0.81	0.74	0.81	<0.005	0.12
24-Sep-96	3	Bottom	136	143	<0.1	20	-	207	20.4	<0.05	0.3	0.009	0.35	0.35	0.66	0.02	0.07
23-Oct-96	3	Bottom	142	152	<0.1	-	238	218	22.2	0.02		0.005	0.4	0.38	0.41	0.016	0.06
19-Nov-96	3	Bottom	138	143	<0.1	13	-	201	23.6	<0.05	0.51	0.02	0.51	0.51	1.04	0.03	0.08
19-Dec-96	3	Bottom	146	157	<0.1	13	-	225	28.3		0.87	0.01	0.38	0.24	1.26	0.028	0.07
21-Jan-97	3	Bottom	168	170	<0.1	3.5	-	247	26.3		1.21	0.008	0.38		1.60	0.01	0.05
25-Feb-97	3	Bottom	167	180	<0.1		-	270	23.44	<0.1		0.005	0.386	0.386	0.39		0.02
26-Mar-97	3	Bottom	167	176	<0.1	15	-	259	33.8	<0.05	0.34	<0.005	0.44	0.44	0.78		0.05
29-Apr-97	3	Bottom	164	178	<0.1	38.5	-	252	32.4	0.12	0.48	0.02	0.62	0.5	1.12	0.06	0.09
14-May-97	3	Bottom	158	174	<0.1		-	254	32.1	<0.05	0.46	0.03	0.5	0.5	0.99	0.02	0.09
27-May-97	3	Bottom	165	176	<0.1	16		261	29.8	<0.05	0.64	0.028	0.5	0.5	1.17		0.07
10-Jun-97	3	Bottom	162	184	<0.1	61.8		272		<0.05	0.52	0.006	0.68	0.68	1.21	0.049	0.15
24-Jun-97	3	Bottom	163	176	<0.1	7		251	37.2	<0.05		<0.005	0.56	0.56	0.56	<0.005	0.053
08-Jul-97	3	Bottom	156	178	<0.1	13		255	37		0.06	<0.005	0.61	0.61	0.67	<0.005	0.045
29-Jul-97	3	Bottom	143	158	<0.1	17.5		229	27.5	0.156	0.08	0.014	0.64	0.48	0.73	0.023	0.093
12-Aug-97	3	Bottom	149	154	<0.1	18		234	30.3	0.12		0.014	0.55	0.43	0.56	0.007	0.075
26-Aug-97	3	Bottom	144	152	0.5	100		224	25.5	<0.05	0.11	0.01	1	0.88	1.12	0.011	0.13
16-Sep-97	3	Bottom	139	154	<0.1	21		244	28.5	0.15	0.14	0.033	0.72	0.57	0.89	0.005	0.076
30-Sep-97	3	Bottom	136	152	<0.1	28		228	27.6	<0.05	0.26	0.007	0.52	0.52	0.79	0.016	0.094
29-Feb-96	4	0.1	172	186	<0.1		267	248	27.3	0.044	0.38	0.004		-0.044	0.38	0.004	0.06
01-Apr-96	4	0.1	179.8	182	<0.1	11	-	260	24.7	<0.05	0.32	<0.01	0.54	0.54	0.86	<0.005	
22-Apr-96	4	0.1	179	186	0.3		-	274	26.1	0.03		<0.01	0.56	0.53	0.56	0.006	
20-May-96	4	0.1	177	187	0.5	39	-	299	26.4	0.053	0.41	0.03	0.51	0.46	0.95		0.08
03-Jun-96	4	0.1	178	186	<0.1	13	-	262	26.3		0.28	0.01	0.52	0.456	0.81	<0.01	0.06
17-Jun-96	4	0.1	176	171	<0.1	10	-	247	24.5	<0.05	0.13	<0.005	0.5		0.63	<0.005	0.04
09-Jul-96	4	0.1	175	180	<0.1	19.0	-	259	26.0	<0.05	<0.05	<0.005	0.63	0.63	0.63	0.01	0.08
15-Jul-96	4	0.1	167	166	<0.1	6.0	-	237	26.1	<0.05	0.05	<0.005	0.59	0.590	0.59	<0.005	
23-Jul-96	4	0.1	148	160	<0.1	13	-	224	24.3	0.059	<0.05	<0.005	0.68	0.62	0.68	0.01	0.07

12-Aug-96	4	0.1	136	138	<0.1	31	-	203	19		0.098	0.05	0.59	0.47	0.74	0.03	0.11
27-Aug-96	4	0.1	132	140	<0.1		-	202	24.4	0.056	<0.05	0.006	0.63	0.57	0.64	<0.005	0.05
24-Sep-96	4	0.1	138	144	<0.1	24.5	-	206	21.3	<0.05	0.25	0.011	0.43	0.43	0.69	0.02	0.09
23-Oct-96	4	0.1	143	153	<0.1	-	241	216	23.1	0.01		0.003	0.53	0.52	0.53	0.014	0.07
19-Nov-96	4	0.1	138	144	<0.1	15.5	-	200	23.8	<0.05	0.44	0.02	0.47	0.37	0.93	0.03	0.09
19-Dec-96	4	0.1	162	176	<0.1	10	-	256	31		0.83	0.008	0.45	0.37	1.29	0.019	0.07
21-Jan-97	4	0.1	183	186	<0.1	11	-	259	30		0.96	0.009	0.52		1.49	<0.005	0.05
25-Feb-97	4	0.1	172	172	<0.1		-	269.4	25.34	<0.1		0.008	0.498	0.498	0.51		0.05
26-Mar-97	4	0.1	177	192	<0.1	20	-	277	39	<0.05	0.325	<0.005	0.58	0.58	0.91		0.08
29-Apr-97	4	0.1	172	180	<0.1	11	-	259	31.8	0.12	0.47	0.02	0.58	0.46	1.07	0.03	0.07
14-May-97	4	0.1	169	176	<0.1		-	252	43.6	<0.05	0.43	0.04	0.53	0.53	1.00	0.03	0.1
27-May-97	4	0.1	163	180	<0.1	12		261	25.1	<0.05	0.55	0.027	0.5	0.5	1.08		0.06
10-Jun-97	4	0.1	155	188	<0.1	24.5		264		<0.05	0.13	0.006	0.71	0.71	0.85	0.031	0.1
24-Jun-97	4	0.1	156	176	<0.1	24		253	39.4	<0.05		<0.005	0.67	0.67	0.67	<0.005	0.083
08-Jul-97	4	0.1	160	180	<0.1	25		260	38.9		0.06	<0.005	0.76	0.67	0.82	<0.005	0.073
29-Jul-97	4	0.1	139	154	<0.1	18.5		224	27	<0.05	<0.05	<0.005	0.59	0.59	0.59	<0.005	0.068
12-Aug-97	4	0.1	138	150	<0.1	10		230	28.9	0.06		<0.005	0.69	0.63	0.69	0.005	0.063
26-Aug-97	4	0.1	135	152	0.2	65		215	25.8	0.422	0.13	0.027	1.38	1.22	1.54	0.033	0.229
16-Sep-97	4	0.1	142	153	<0.1	25		255	30.2	0.12	0.1	0.022	0.74	0.62	0.86	<0.005	0.089
30-Sep-97	4	0.1	135	146	<0.1	17		219	27.5	<0.05	0.34	0.009	0.64	0.64	0.99	0.015	0.07
29-Feb-96	4	Bottom	166	184	<0.1		268	250	21.1	0.044	0.4	0.004		-0.044	0.40	0.004	0.06
01-Apr-96	4	Bottom	178.4	182	<0.1	16	-	240	26.3	<0.05	0.33	<0.01	0.48	0.48	0.81	<0.005	
22-Apr-96	4	Bottom	177	188	<0.2		-	275	24.4	0.03		<0.01	0.55	0.52	0.55	0.006	
20-May-96	4	Bottom	181	188	1	65	-	276	26.1	0.055	0.36	0.03	0.56	0.51	0.95		0.11
03-Jun-96	4	Bottom	148	172	<0.1	51	-	228	24.7		0.21	0.03	0.87	0.582	1.11	0.05	0.18
17-Jun-96	4	Bottom	189	178	0.16	32.5	-	255	27.4	<0.05	0.44	<0.005	0.54		0.98	0.02	0.11
09-Jul-96	4	Bottom	176	180	<0.1	36.0	-	260	28.1	<0.05	<0.05	<0.005	0.61	0.61	0.61	0.01	0.09
15-Jul-96	4	Bottom	115	122	<0.1	38.0	-	184	<2.0	0.193	0.14	0.02	0.73	0.537	0.73	0.09	
23-Jul-96	4	Bottom	144	160	<0.1	58.5	-	223	26.5	0.11	<0.05	0.007	0.75	0.64	0.76	0.03	0.14
12-Aug-96	4	Bottom	133	138	<0.1	33.5	-	205	18.8		0.102	0.05	0.62	0.5	0.77	0.03	0.11
27-Aug-96	4	Bottom	126	134	0.26		-	196	24.3	0.195	0.11	0.017	1.05	0.86	1.18	0.053	0.2
24-Sep-96	4	Bottom	134	142	<0.1	41.5	-	209	22.6	<0.05	0.22	0.016	0.53	0.53	0.77	0.02	0.12
23-Oct-96	4	Bottom	146	164	<0.1	-	277	230	28	0.02		0.003	0.62	0.6	0.62	0.018	0.12
19-Nov-96	4	Bottom	136	148	<0.1	37	-	228	37	<0.05	0.44	0.02	0.56	0.48	1.02	0.04	0.14
19-Dec-96	4	Bottom	166	172	<0.1	10	-	259	31.3		0.91	0.008	0.5	0.41	1.42	0.019	0.08
21-Jan-97	4	Bottom	179	186	<0.1	12.5	-	262	29.3		1.08	0.009	0.57		1.66	<0.005	0.05
25-Feb-97	4	Bottom	160	172	<0.1		-	262	24.86	<0.1		0.008	0.459	0.459	0.47		0.04

26-Mar-97	4	Bottom	170	186	<0.1	47	-	265	31.6	<0.05	0.32	<0.005	0.5	0.5	0.82		0.11
29-Apr-97	4	Bottom	168	180	<0.1	4.5	-	263	31.9	0.13	0.5	0.02	0.64	0.51	1.16	0.05	0.08
14-May-97	4	Bottom	164	174	<0.1		-	255	33.8	<0.05	0.44	0.03	0.54	0.54	1.01	0.03	0.1
27-May-97	4	Bottom	163	180	0.2	65.5		274	36	<0.05	0.56	0.057	0.66	0.66	1.28		0.14
10-Jun-97	4	Bottom	176	188	0.3	45.4		266		0.06	0.49	0.009	0.64	0.58	1.14	0.063	0.14
24-Jun-97	4	Bottom	163	192	0.4	74		253	31.2	0.07		<0.005	0.81	0.74	0.81	0.013	0.119
08-Jul-97	4	Bottom	155	176	<0.1	19		258	37.9		<.05	<0.005	1.04	1.04	1.04	<0.005	0.057
29-Jul-97	4	Bottom	144	159	<0.1	40.5		233	28.7	0.169	<0.05	<0.005	0.97	0.8	0.97	0.011	0.133
12-Aug-97	4	Bottom	144	152	<0.1	33		237	31.1	0.15		<0.005	0.83	0.68	0.83	0.02	0.118
26-Aug-97	4	Bottom	138	148	<0.1	19		221	25.8	0.052	0.14	0.023	0.778	0.615	0.94	0.011	0.097
16-Sep-97	4	Bottom	147	152	0.2	34		244	27.6	0.16	0.08	0.027	0.8	0.64	0.91	0.017	0.106
30-Sep-97	4	Bottom	134	144	0.1	81		225	23.7	0.108	0.33	0.033	0.91	0.8	1.27	0.024	0.186
29-Feb-96	5	0.1	188	208	<0.1		307	280	37.9	0.043	0.41	0.005		-0.043	0.42	0.004	0.082
01-Apr-96	5	0.1	187	184	<0.1	27	-	238	28.6	<0.05	0.26	<0.01	0.78	0.78	1.04	0.006	
22-Apr-96	5	0.1	171	182	0.7		-	242	15.8	0.13		0.02	1.19	1.06	1.21	0.02	
20-May-96	5	0.1	183	188	0.5	67	-	275	26.8	0.061	0.37	0.04	0.77	0.71	1.18		0.11
03-Jun-96	5	0.1	165	162	<0.1	27	-	244	25.3		0.04	0.01	0.85	0.801	0.90	<0.01	0.12
17-Jun-96	5	0.1	176	167	0.2	39.5	-	244	26.6	<0.05	0.19	0.02	0.74		0.95	0.01	0.13
09-Jul-96	5	0.1	184	183	<0.1	47.5	-	271	28.7	<0.05	<0.05	<0.005	0.75	0.75	0.75	0.02	0.13
15-Jul-96	5	0.1	164	164	<0.1	9.3	-	238	27.1	<0.05	<0.05	<0.005	0.69	0.690	0.69	0.007	
23-Jul-96	5	0.1	144	148	0.1	46.5	-	215	26.7	0.109	<0.05	0.007	0.85	0.74	0.86	0.03	0.14
12-Aug-96	5	0.1	132	144	0.13	53	-	211	21.5		0.107	0.06	0.67	0.51	0.84	0.05	0.14
27-Aug-96	5	0.1	138	151	<0.1		-	212	22.1	0.076	0.076	0.006	0.44	0.36	0.52	0.015	0.08
24-Sep-96	5	0.1	132	142	<0.1	51	-	205	22.5	<0.05	0.29	0.019	0.55	0.55	0.86	0.03	0.14
23-Oct-96	5	0.1	153	166	<0.1	-	257	237	26.4	0.03		0.003	0.67	0.64	0.67	0.015	0.09
19-Nov-96	5	0.1	153	158	<0.1	28.3	-	226	28.3	<0.05	0.46	0.02	0.78	0.7	1.26	0.04	0.13
19-Dec-96	5	0.1	201	218	<0.1	9	-	321	36.8		0.66	0.007	0.54	0.45	1.21	0.007	0.07
21-Jan-97	5	0.1	194	197	<0.1	9.5	-	281	33.6		0.84	0.008	0.63		1.48	<0.005	0.05
25-Feb-97	5	0.1	136	148	<0.1		-	252	<2.0	<0.1		0.018	0.795	0.675	0.81		0.13
26-Mar-97	5	0.1	186	208	<0.1	36	-	297	42.2	<0.05	0.36	0.008	0.75	0.75	1.12		0.11
29-Apr-97	5	0.1	169	180	<0.1	14	-	265	17.7	0.1	0.47	0.02	0.78	0.68	1.27	0.02	0.09
14-May-97	5	0.1	170	174	0.2		-	277	49.4	<0.05	0.32	0.04	0.77	0.77	1.13	0.02	0.14
27-May-97	5	0.1	166	184	<0.1	37.5		272	30.6	<0.05	0.54	0.037	0.71	0.71	1.29		0.1
10-Jun-97 5	0.1	159	192	0.2	40.8		257		<0.05	0.08	0.005	0.84	0.84	0.93	0.031	0.14	
24-Jun-97	5	0.1	168	196	<0.1	52		255	41.1	<0.05		0.012	0.81	0.81	0.82	0.023	0.13
08-Jul-97	5	0.1	158	174	<0.1	45		262	42		0.1	<0.005	0.96	0.78	1.06	<0.005	0.1
29-Jul-97	5	0.1	151	153	0.1	35.5		228	26.1	<0.05	<0.05	<0.005	0.88	0.88	0.88	0.007	0.126
12-Aug-97	5	0.1	144	150	<0.1	28		224	32	<0.05		<0.005	0.91	0.91	0.91	0.012	0.121

26-Aug-97	5	0.1	132	144	<0.1	36.4		214	23.8	0.134	0.13	0.019	0.84	0.691	0.99	0.025	0.135
16-Sep-97	5	0.1	145	154	<0.1	47		250	28.5	0.21	0.07	0.024	1.68	1.47	1.77	0.021	0.124
30-Sep-97	5	0.1	136	144	<0.1	23		213	25.8	<0.05	0.27	0.017	0.73	0.73	1.02	0.013	0.099

Arcadia Lake
Biological Water Quality Data
(From CCHDOC lab)

DATE	SITE	TIME	Fecal Coliform	Fecal Streptococci
3/1/96	1	11:20 AM	0	0
3/1/96	2	11:50 AM	0	70
3/1/96	3	12:16PM	0	0
3/1/96	4	12:30 PM	0	0
3/1/96	5	01:00 PM	0	0
4/2/96	1	01:25 PM	0	0
4/2/96	2	01:55 PM	0	0
4/2/96	3	12:55 PM	0	0
4/2/96	4	12:25 PM	0	0
4/2/96	5	11:53 AM	0	0
4/23/96	1	01:05 PM	0	0
4/23/96	2	01:30 PM	0	0
4/23/96	3	12:25 PM	0	40
4/23/96	4	12:00 PM	0	20
4/23/96	5	11:30 AM	2400	3500
5/21/96	1	12:25 PM	0	90
5/21/96	2	01:00 PM	0	130
5/21/96	3	12:00 PM	0	0
5/21/96	4	11:20 AM	0	0
5/21/96	5	10:50 AM	0	0
6/7/96	1	01:05 PM	0	0
6/7/96	2	01:45 PM	0	0
6/7/96	3	12:45 PM	0	0
6/7/96	4	12:15 PM	20	0
6/7/96	5	11:50 AM	110	0
6/18/96	1	11:00 AM	0	0
6/18/96	2	11:30 AM	0	0
6/18/96	3	12:50 PM	0	0
6/18/96	4	11:00 PM	0	0
6/18/96	5	11:45 AM	0	0
7/10/96	1	12:05 PM	0	0
7/10/96	2	13:10 PM	0	0
7/10/96	3	11:40 AM	0	0
7/10/96	4	11:05 AM	0	0
7/10/96	5	10:50 AM	0	0
7/16/96	1	11:20 AM	40	170
7/16/96	2	11:40 AM	80	40

7/16/96	3	11:05 AM	0	130
7/16/96	4	10:50 AM	170	80
7/16/96	5	10:30 AM	170	20
7/24/96	1	11:25 AM	0	0
7/24/96	2	13:00 PM	0	0
7/24/96	3	10:45 AM	0	0
7/24/96	4	10:15 AM	20	0
7/24/96	5	09:50 AM	300	120
8/13/96	1	11:40 AM	0	0
8/13/96	2	12:15 PM	0	20
8/13/96	3	11:20 AM	0	0
8/13/96	4	10:40 AM	80	20
8/13/96	5	10:25 AM	60	80
8/28/96	1	13:05 PM	0	0
8/28/96	2	14:10 PM	20	20
8/28/96	3	12:30 PM	0	0
8/28/96	4	12:00 PM	40	20
8/28/96	5	11:35 AM	220	40
9/25/96	1	13:00 PM	20	0
9/25/96	2	13:30 PM	20	0
9/25/96	3	12:20 PM	0	0
9/25/96	4	11:45 PM	20	20
9/25/96	5	11:30 AM	230	90
10/24/96	1	11:40 AM	20	0
10/24/96	2	12:10 PM	110	0
10/24/96	3	11:15 AM	0	40
10/24/96	4	10:55 AM	20	20
10/24/96	5	10:30 AM	230	40
11/20/96	1	13:25 PM	0	20
11/20/96	2	14:05 PM	130	80
11/20/96	3	13:05 PM	0	0
11/20/96	4	12:35 PM	40	20
11/20/96	5	12:15 PM	500	140
12/20/96	1	13:30 PM	20	0
12/20/96	2	13:45 PM	0	20
12/20/96	3	13:15 PM	20	0
12/20/96	4	12:50 PM	0	0
12/20/96	5	12:25 PM	0	0
1/22/97	1	13:45 PM	0	20
1/22/97	2	14:10 PM	0	0
1/22/97	3	13:25 PM	0	20
1/22/97	4	12:55 PM	0	0
1/22/97	5	12:35 PM	0	0
2/26/97	1	13:30 PM	70	0

2/26/97	2	14:00 PM	60	0
2/26/97	3	13:00 PM	0	20
2/26/97	4	12:45 PM	130	130
2/26/97	5	12:22 PM	1700	500
3/27/97	1	12:50 PM	0	0
3/27/97	2	13:20 PM	110	0
3/27/97	3	12:30 PM	0	0
3/27/97	4	12:10 PM	0	0
3/27/97	5	11:50 AM	500	90
4/30/97	1	13:00 PM	20	0
4/30/97	2	13:45 PM	0	20
4/30/97	3	12:45 PM	0	20
4/30/97	4	12:25 PM	20	70
4/30/97	5	12:00 PM	40	0
5/15/97	1	12:40 PM	0	0
5/15/97	2	13:20 PM	0	0
5/15/97	3	12:20 PM	20	20
5/15/97	4	12:00 PM	0	0
5/15/97	5	11:30 PM	40	0
5/28/97	1	12:30 PM	0	0
5/28/97	2	13:00 PM	20	40
5/28/97	3	11:50 PM	0	0
5/28/97	4	11:30 PM	0	0
5/28/97	5	11:10 PM	20	0
6/11/97	1	13:02 PM	0	0
6/11/97	2	13:45 PM	20	0
6/11/97	3	12:35 PM	0	0
6/11/97	4	12:05 PM	0	0
6/11/97	5	11:50 PM	0	0
6/25/97	1	12:50PM	0	0
6/25/97	2	13:20 PM	0	0
6/25/97	3	12:24PM	0	0
6/25/97	4	11:50 PM	0	0
6/25/97	5	11:30 PM	20	0
7/9/97	1	14:10 PM	0	0
7/9/97	2	13:10PM	0	0
7/9/97	3	13:45 PM	0	0
7/9/97	4	12:20PM	0	0
7/9/97	5	12:20PM	40	0
7/29/97	1	11:10AM	0	0
7/29/97	2	11:40 AM	0	0
7/29/97	3	12:00 PM	0	0
7/29/97	4	12:20 PM	80	0
7/29/97	5	12:45 PM	80	0

8/13/97	1	13:35PM	0	0
8/13/97	2	14:05PM	0	0
8/13/97	3	13:10PM	0	0
8/13/97	4	12:45PM	20	0
8/13/97	5	12:26PM	20	0
8/27/97	1	11:40AM	0	0
8/27/97	2	12:15PM	20	0
8/27/97	3	11:40AM	0	0
8/27/97	4	10:50AM	0	0
8/27/97	5	10:20AM	0	20
9/17/97	1	11:40AM	0	0
9/17/97	2	12:10PM	0	0
9/17/97	3	11:14AM	0	0
9/17/97	4	11:02AM	0	0
9/17/97	5	10:38AM	0	0
10/1/97	1	1:15PM	0	0
10/1/97	2	1:40PM	0	0
10/1/97	3	12:55PM	0	42
10/1/97	4	12:40PM	20	0
10/1/97	5	12:10PM	40	0

Appendix C

HYDROLAB DATA

Site	Date MMDDYY	Time HHMMSS	Temp degC	pH units	SpCond mS/cm	Salin ppt	DO %Sat	DO mg/l	Redox mV	Depth meters	Batt volts	
1	01-Apr-96	142053	10.21	7.96	0.414	0.2	87	9.76	492	11.7	15.4	&
1	01-Apr-96	142141	10.14	7.97	0.414	0.2	86.6	9.73	490	11	15.3	&
1	01-Apr-96	142200	10.13	7.99	0.412	0.2	87	9.77	490	10	15.3	&
1	01-Apr-96	142226	10.16	8	0.414	0.2	87.8	9.86	489	9	15.3	&
1	01-Apr-96	142249	10.19	8.01	0.41	0.2	87.9	9.86	489	8	15.4	&
1	01-Apr-96	142316	10.22	8.03	0.419	0.2	88.3	9.9	488	7	15.3	&
1	01-Apr-96	142337	10.24	8.04	0.418	0.2	88.3	9.89	487	6	15.3	&
1	01-Apr-96	142427	10.26	8.05	0.414	0.2	89	9.97	486	5	15.3	&
1	01-Apr-96	142446	10.26	8.06	0.417	0.2	88.9	9.96	486	4	15.4	&
1	01-Apr-96	142517	10.27	8.08	0.414	0.2	88.7	9.93	485	3	15.3	&
1	01-Apr-96	142539	10.29	8.1	0.415	0.2	88.8	9.93	484	2	15.3	&
1	01-Apr-96	142558	11.7	8.13	0.42	0.2	93.2	10.09	482	1	15.3	&
1	01-Apr-96	142628	12.29	8.17	0.419	0.2	97.8	10.45	480	0.1	15.3	&
2	01-Apr-96	145226	10.21	8.1	0.405	0.2	93.4	10.47	489	5.6	15.3	&
2	01-Apr-96	145317	10.28	8.04	0.409	0.2	96.5	10.8	487	5	15.3	&
2	01-Apr-96	145336	10.33	8.03	0.408	0.2	95.3	10.66	485	4	15.3	&
2	01-Apr-96	145415	10.45	8.02	0.419	0.2	93.7	10.45	484	3	15.3	&
2	01-Apr-96	145441	10.44	8.04	0.418	0.2	93.1	10.38	482	2	15.3	&
2	01-Apr-96	145520	11.52	8.05	0.416	0.2	96.5	10.5	480	1	15.3	&
2	01-Apr-96	145550	12.58	8.07	0.417	0.2	98.3	10.44	478	0.1	15.3	&
3	01-Apr-96	135720	10.34	8.1	0.425	0.2	96.9	10.84	518	6.7	15.4	&
3	01-Apr-96	135744	10.37	8.06	0.417	0.2	95.2	10.64	518	6	15.4	&
3	01-Apr-96	135800	10.36	8.06	0.415	0.2	94.5	10.56	517	5	15.4	&
3	01-Apr-96	135813	10.39	8.06	0.415	0.2	93.8	10.47	516	4	15.3	&
3	01-Apr-96	135829	10.38	8.06	0.417	0.2	93.1	10.4	516	3	15.4	&
3	01-Apr-96	135854	10.42	8.07	0.417	0.2	92.2	10.29	514	2	15.3	&
3	01-Apr-96	135915	11.49	8.13	0.419	0.2	93.9	10.22	510	1	15.3	&
3	01-Apr-96	135936	12.6	8.16	0.423	0.2	100.4	10.65	508	0.1	15.3	&

4	01-Apr-96	132808	10.52	8.13	0.431	0.2	105.1	11.7	535	6.5	15.3	&
4	01-Apr-96	132847	10.49	8.13	0.429	0.2	99	11.03	532	6	15.3	&
4	01-Apr-96	132915	10.44	8.13	0.431	0.2	96.6	10.77	531	5	15.3	&
4	01-Apr-96	132938	10.45	8.15	0.429	0.2	96.1	10.72	529	4	15.3	&
4	01-Apr-96	133012	10.45	8.16	0.43	0.2	95.5	10.64	527	3	15.3	&
4	01-Apr-96	133039	10.49	8.17	0.429	0.2	94.4	10.52	525	2	15.3	&
4	01-Apr-96	133111	10.57	8.22	0.425	0.2	95.3	10.6	522	1	15.3	&
4	01-Apr-96	133141	12.19	8.27	0.433	0.2	101.9	10.91	518	0.1	15.3	&
5	01-Apr-96	125712	10.84	8.07	0.456	0.2	97.8	10.81	506	1.4	15.3	&
5	01-Apr-96	125742	10.91	8.1	0.453	0.2	98.6	10.88	505	1	15.3	&
5	01-Apr-96	125758	12.79	8.17	0.443	0.2	104.2	11.01	502	0.1	15.3	&
1	22-Apr-96	130534	15.29	8.12	0.42	0.2	90.3	9.04	485	11	14.7	&
1	22-Apr-96	130615	15.35	8.2	0.43	0.2	88	8.79	480	10	14.7	&
1	22-Apr-96	130635	15.39	8.22	0.429	0.2	87.2	8.71	479	9	14.7	&
1	22-Apr-96	130707	15.39	8.23	0.424	0.2	86.9	8.68	477	8	14.6	&
1	22-Apr-96	130741	15.39	8.25	0.426	0.2	86.5	8.64	476	7	14.6	&
1	22-Apr-96	130810	15.39	8.26	0.429	0.2	86.2	8.6	475	6	14.6	&
1	22-Apr-96	130901	15.39	8.28	0.429	0.2	86	8.58	473	5	14.6	&
1	22-Apr-96	130934	15.39	8.3	0.429	0.2	85.9	8.57	472	3	14.6	&
1	22-Apr-96	131003	15.39	8.3	0.434	0.2	85.8	8.56	471	2	14.6	&
1	22-Apr-96	131023	15.4	8.33	0.432	0.2	85.6	8.55	469	1	14.6	&
1	22-Apr-96	131049	15.39	8.32	0.433	0.2	85.7	8.55	470	0.1	14.6	&
2	22-Apr-96	133615	15.24	8.16	0.434	0.2	83.4	8.36	424	7.2	14.7	&
2	22-Apr-96	133646	15.3	8.16	0.433	0.2	79.9	7.99	424	7	14.7	&
2	22-Apr-96	133713	15.44	8.24	0.432	0.2	85.1	8.49	423	6	14.6	&
2	22-Apr-96	133745	15.49	8.27	0.431	0.2	86.6	8.63	423	5	14.6	&
2	22-Apr-96	133814	15.47	8.29	0.431	0.2	86.6	8.63	423	4	14.6	&
2	22-Apr-96	133840	15.5	8.3	0.431	0.2	86.3	8.59	423	3	14.6	&
2	22-Apr-96	133905	15.52	8.32	0.431	0.2	86.3	8.59	422	2	14.5	&
2	22-Apr-96	133927	15.52	8.32	0.431	0.2	86	8.56	422	1	14.6	&
2	22-Apr-96	133949	15.49	8.34	0.431	0.2	85.9	8.56	421	0.1	14.6	&

3	22-Apr-96	123711	15.19	8.25	0.431	0.2	88.5	8.88	434	6.1	14.8	&
3	22-Apr-96	123737	15.2	8.23	0.431	0.2	86.5	8.68	435	6	14.7	&
3	22-Apr-96	123801	15.22	8.24	0.431	0.2	85.9	8.61	435	5	14.7	&
3	22-Apr-96	123824	15.22	8.26	0.431	0.2	85.9	8.61	435	4	14.7	&
3	22-Apr-96	123853	15.24	8.27	0.431	0.2	85.7	8.58	435	3	14.7	&
3	22-Apr-96	123924	15.25	8.28	0.431	0.2	85.5	8.56	435	2	14.7	&
3	22-Apr-96	123949	15.25	8.3	0.431	0.2	85.2	8.53	434	1	14.7	&
3	22-Apr-96	124008	15.24	8.3	0.431	0.2	85.2	8.53	434	0.1	14.7	&
4	22-Apr-96	121132	16.02	8.32	0.435	0.2	90.2	8.89	463	5.3	14.9	&
4	22-Apr-96	121155	16.02	8.33	0.434	0.2	89.4	8.81	463	5	14.8	&
4	22-Apr-96	121217	16.02	8.35	0.434	0.2	89.1	8.78	463	4	14.8	&
4	22-Apr-96	121258	16.01	8.37	0.434	0.2	88.9	8.76	462	3	14.7	&
4	22-Apr-96	121329	16.02	8.38	0.434	0.2	88.5	8.72	462	2	14.7	&
4	22-Apr-96	121359	16.02	8.41	0.434	0.2	88.3	8.7	460	1	14.7	&
4	22-Apr-96	121421	16.01	8.4	0.434	0.2	88.2	8.69	461	0.1	14.7	&
5	22-Apr-96	114637	16.64	7.49	0.439	0.2	72.1	7.01	535	2.4	14.9	&
5	22-Apr-96	114707	16.64	7.76	0.438	0.2	69.3	6.74	527	2	14.9	&
5	22-Apr-96	114738	16.66	7.92	0.437	0.2	68.1	6.62	521	1	14.9	&
5	22-Apr-96	114759	16.64	8	0.439	0.2	67.7	6.58	518	0.1	14.9	&
1	07-May-96	114824	17.43	7.9	0.45	0.2	73.8	6.89	193	8.7	15.9	&
1	07-May-96	114904	17.85	7.9	0.446	0.2	71.4	6.6	194	8	15.9	&
1	07-May-96	114936	18.47	7.9	0.454	0.2	73.8	6.74	194	7	15.8	&
1	07-May-96	115008	21.22	8.32	0.44	0.2	103.8	8.97	180	6	15.8	&
1	07-May-96	115038	21.36	8.35	0.443	0.2	109.9	9.47	179	5	15.8	&
1	07-May-96	115110	21.52	8.38	0.438	0.2	113.2	9.73	177	4	15.8	&
1	07-May-96	115148	21.91	8.44	0.436	0.2	123.5	10.53	174	3	15.8	&
1	07-May-96	115249	22.2	8.51	0.432	0.2	129	10.94	173	2	15.8	&
1	07-May-96	115326	22.27	8.54	0.432	0.2	137.5	11.65	171	1	15.8	&
1	07-May-96	115407	22.36	8.56	0.434	0.2	136.2	11.52	170	0.1	15.8	&
2	07-May-96	120155	18.45	7.79	0.451	0.2	85	7.76	192	6.1	15.8	&
2	07-May-96	120253	20.12	8.13	0.446	0.2	94.1	8.31	182	5	15.6	&

2	07-May-96	120307	21.56	8.35	0.441	0.2	106.9	9.18	175	4	15.5	&
2	07-May-96	120355	21.95	8.41	0.44	0.2	118.1	10.06	173	3	14.5	&
2	07-May-96	120440	22.09	8.43	0.439	0.2	118.2	10.05	172	2	14.5	&
2	07-May-96	120521	22.46	8.45	0.44	0.2	118.6	10.01	171	1	14.4	&
2	07-May-96	120541	22.59	8.5	0.44	0.2	118	9.93	168	0.1	14.4	&
3	07-May-96	113127	17.68	7.85	0.456	0.2	81.2	7.54	200	7.5	15.9	&
3	07-May-96	113158	17.85	7.91	0.452	0.2	75.8	7.01	199	7	16	&
3	07-May-96	113217	17.95	7.95	0.452	0.2	78.9	7.28	198	6	16	&
3	07-May-96	113235	17.99	7.95	0.451	0.2	78.1	7.2	198	5	15.9	&
3	07-May-96	113253	18.67	7.96	0.443	0.2	77.9	7.09	198	4	15.9	&
3	07-May-96	113318	19.39	8.05	0.451	0.2	84.6	7.58	195	3	15.9	&
3	07-May-96	113356	20.03	8.13	0.444	0.2	94.4	8.35	192	2	15.9	&
3	07-May-96	113424	20.66	8.26	0.443	0.2	105.3	9.2	187	1	15.9	&
3	07-May-96	113453	21.68	8.46	0.441	0.2	115.2	9.87	179	0.1	15.9	&
4	07-May-96	111353	18.62	7.93	0.45	0.2	76.6	6.97	198	5.3	16	&
4	07-May-96	111511	18.82	7.97	0.447	0.2	75.1	6.81	198	4	16	&
4	07-May-96	111538	20.03	8.12	0.446	0.2	86.8	7.68	193	3	16	&
4	07-May-96	111602	20.21	8.15	0.449	0.2	88.7	7.82	191	2	16	&
4	07-May-96	111630	20.42	8.17	0.449	0.2	88.9	7.81	190	1	16	&
4	07-May-96	111701	20.49	8.18	0.45	0.2	92	8.06	190	0.1	15.9	&
5	07-May-96	105641	18.24	7.69	0.459	0.2	57.2	5.25	270	3.8	16.1	&
5	07-May-96	105741	18.18	7.78	0.454	0.2	61.2	5.62	265	3	16.1	&
5	07-May-96	105837	19.36	7.98	0.451	0.2	75.7	6.78	256	2	16	&
5	07-May-96	105917	19.88	8.02	0.452	0.2	78.6	6.97	253	1	16	&
5	07-May-96	105957	20.75	8.16	0.45	0.2	87.1	7.6	247	0.1	16	&
1	20-May-96	85126	22.77	8.1	0.45	0.2	89.1	7.67	470	8.9	15.9	&
1	20-May-96	85201	22.8	8.11	0.447	0.2	89.3	7.68	473	8	15.9	&
1	20-May-96	85237	22.86	8.13	0.454	0.2	90	7.73	475	7	15.9	&
1	20-May-96	85313	22.86	8.13	0.454	0.2	90.3	7.75	477	6	15.8	&
1	20-May-96	85341	22.9	8.15	0.453	0.2	90.1	7.74	477	5	15.8	&
1	20-May-96	85414	22.93	8.16	0.456	0.2	90.3	7.75	478	4	15.8	&

1	20-May-96	85440	22.96	8.17	0.451	0.2	90.5	7.76	479	3	16	&
1	20-May-96	85519	22.96	8.16	0.45	0.2	90.5	7.76	481	2	15.9	&
1	20-May-96	85545	23	8.17	0.451	0.2	90.6	7.76	481	1	15.8	&
1	20-May-96	85611	22.99	8.18	0.453	0.2	90.7	7.77	481	0.1	15.8	&
2	20-May-96	92509	23.15	8.16	0.454	0.2	90.6	7.73	450	5.7	15.8	&
2	20-May-96	92655	23.24	8.17	0.453	0.2	92	7.84	461	5	15.8	&
2	20-May-96	92743	23.41	8.2	0.453	0.2	93.4	7.94	463	4	15.8	&
2	20-May-96	92808	23.47	8.21	0.453	0.2	93.5	7.94	464	3	15.8	&
2	20-May-96	92836	23.46	8.22	0.453	0.2	93.6	7.94	465	2	15.7	&
2	20-May-96	92903	23.47	8.23	0.453	0.2	93.6	7.95	465	1	15.8	&
2	20-May-96	92918	23.52	8.24	0.453	0.2	93.8	7.96	465	0.1	15.8	&
3	20-May-96	82856	22.74	8.09	0.451	0.2	88.9	7.65	468	6.4	16	&
3	20-May-96	82950	22.77	8.09	0.451	0.2	88.6	7.62	472	6	16	&
3	20-May-96	83027	22.82	8.11	0.454	0.2	89.5	7.69	473	5	16	&
3	20-May-96	83058	22.85	8.12	0.453	0.2	89.6	7.7	475	4	15.9	&
3	20-May-96	83138	22.93	8.15	0.455	0.2	90.2	7.74	476	3	15.9	&
3	20-May-96	83207	22.95	8.14	0.452	0.2	90.3	7.74	478	2	15.9	&
3	20-May-96	83238	22.95	8.15	0.452	0.2	90.2	7.73	479	1	15.9	&
3	20-May-96	83312	22.95	8.14	0.453	0.2	90.4	7.75	481	0.1	15.9	&
4	20-May-96	75159	22.79	8.09	0.458	0.2	87.6	7.53	468	7	16.1	&
4	20-May-96	75252	22.84	8.1	0.452	0.2	88.4	7.59	473	6	16	&
4	20-May-96	75340	22.86	8.11	0.456	0.2	89.3	7.67	477	5	16	&
4	20-May-96	75428	22.86	8.13	0.456	0.2	88.9	7.63	479	4	16	&
4	20-May-96	75512	22.89	8.13	0.456	0.2	89.5	7.68	481	3	16.1	&
4	20-May-96	75558	22.89	8.13	0.455	0.2	89.2	7.65	484	2	16	&
4	20-May-96	75625	22.9	8.15	0.454	0.2	89.2	7.65	485	1	16	&
4	20-May-96	75646	22.94	8.16	0.454	0.2	89.4	7.67	485	0.1	16	&
5	20-May-96	71821	22.98	8.07	0.469	0.2	89	7.63	498	3.7	16.2	&
5	20-May-96	72004	23.04	8.12	0.462	0.2	89.8	7.68	500	3	16.2	&
5	20-May-96	72107	23.13	8.15	0.466	0.2	90.7	7.74	500	2	16.1	&
5	20-May-96	72201	23.14	8.16	0.461	0.2	91	7.77	501	1	16.1	&

5	20-May-96	72239	23.15	8.17	0.463	0.2	91.2	7.79	502	0.1	16.1	&
1	03-Jun-96	93744	22.82	7.68	0.436	0.2	37.6	3.23	481	11.2	15.7	&
1	03-Jun-96	93854	22.75	7.66	0.437	0.2	36.6	3.15	480	11	15.8	&
1	03-Jun-96	94004	22.89	7.73	0.437	0.2	43.7	3.75	477	10	15.7	&
1	03-Jun-96	94108	22.94	7.78	0.438	0.2	49.8	4.27	476	9	15.7	&
1	03-Jun-96	94159	22.99	7.83	0.439	0.2	53.8	4.61	473	8	15.7	&
1	03-Jun-96	94255	23.09	7.86	0.439	0.2	57.1	4.88	472	7	15.7	&
1	03-Jun-96	94330	23.1	7.87	0.441	0.2	57.9	4.95	471	6	15.7	&
1	03-Jun-96	94424	23.26	7.95	0.441	0.2	65.9	5.62	469	5	15.7	&
1	03-Jun-96	94457	23.34	7.96	0.441	0.2	65.9	5.61	468	4	15.7	&
1	03-Jun-96	94556	23.55	7.99	0.441	0.2	69.6	5.9	467	3	15.7	&
1	03-Jun-96	94649	25.22	8.16	0.441	0.2	88.9	7.3	460	2	15.7	&
1	03-Jun-96	94745	25.65	8.21	0.441	0.2	94.4	7.7	456	1	15.7	&
1	03-Jun-96	94829	26.27	8.21	0.442	0.2	96.5	7.78	454	0.1	15.6	&
2	03-Jun-96	100856	23.03	7.71	0.432	0.2	41.8	3.57	462	7.2	15.6	&
2	03-Jun-96	100803	23.25	7.72	0.43	0.2	42.7	3.64	461	7.1	15.7	&
2	03-Jun-96	100931	23.03	7.71	0.428	0.2	42	3.59	462	7	15.7	&
2	03-Jun-96	101039	23.13	7.76	0.441	0.2	46.3	3.96	460	6	15.6	&
2	03-Jun-96	101156	23.29	7.9	0.44	0.2	61.7	5.26	455	5	15.6	&
2	03-Jun-96	101251	23.34	7.94	0.44	0.2	65.3	5.56	454	4	15.6	&
2	03-Jun-96	101339	23.54	7.96	0.446	0.2	67.1	5.69	453	3	15.6	&
2	03-Jun-96	101447	24.55	8.15	0.435	0.2	85.9	7.15	447	2	15.6	&
2	03-Jun-96	101537	25.45	8.29	0.436	0.2	104	8.51	440	1	15.6	&
2	03-Jun-96	101620	26.26	8.28	0.436	0.2	104.5	8.42	439	0.1	15.5	&
3	03-Jun-96	91603	23.2	7.78	0.449	0.2	53.5	4.57	456	6.3	15.9	&
3	03-Jun-96	91659	23.31	7.79	0.448	0.2	53.8	4.58	455	6	15.9	&
3	03-Jun-96	91821	24.21	7.99	0.435	0.2	75.2	6.3	450	5	15.8	&
3	03-Jun-96	91914	24.54	8.06	0.444	0.2	82	6.82	447	4	15.8	&
3	03-Jun-96	92024	24.67	8.1	0.444	0.2	84.7	7.03	445	3	15.8	&
3	03-Jun-96	92134	25	8.16	0.444	0.2	90	7.42	442	2	15.8	&
3	03-Jun-96	92236	25.54	8.21	0.438	0.2	97.4	7.96	440	1	15.7	&

3	03-Jun-96	92323	25.77	8.21	0.441	0.2	96.8	7.87	438	0.1	15.8	&
4	03-Jun-96	84723	22.58	7.46	0.376	0.2	9.3	0.8	466	7.8	16	&
4	03-Jun-96	84824	22.68	7.46	0.367	0.2	20.2	1.74	457	7	16	&
4	03-Jun-96	84922	22.95	7.56	0.383	0.2	32.5	2.78	455	6	16	&
4	03-Jun-96	85011	23.01	7.62	0.393	0.2	37	3.16	454	5	16	&
4	03-Jun-96	85053	23.13	7.68	0.403	0.2	40.1	3.43	452	4	15.9	&
4	03-Jun-96	85245	23.67	7.99	0.44	0.2	63.2	5.35	444	3	15.9	&
4	03-Jun-96	85424	24.08	8.12	0.434	0.2	75.3	6.32	439	2	15.9	&
4	03-Jun-96	85529	25.35	8.41	0.431	0.2	110.9	9.09	430	1	15.9	&
4	03-Jun-96	85632	25.68	8.32	0.436	0.2	103.6	8.44	431	0.1	15.9	&
5	03-Jun-96	82315	23.37	7.56	0.357	0.2	41.5	3.53	481	2.8	16	&
5	03-Jun-96	82415	23.47	7.63	0.372	0.2	45.2	3.84	477	2	16	&
5	03-Jun-96	82542	25.95	8.5	0.396	0.2	122.8	9.96	449	1	16	&
5	03-Jun-96	82705	26.51	8.58	0.393	0.2	133	10.67	442	0.1	15.9	&
1	17-Jun-96	72837	22.6	7.39	0.444	0.2	2.1	0.18	220	11.6	15	&
1	17-Jun-96	120634	22.55	7.6	0.474	0.2	18.6	1.61	220	11	13.4	&
1	17-Jun-96	72919	22.63	7.42	0.442	0.2	1.8	0.16	200	10.9	15	&
1	17-Jun-96	73009	22.93	7.45	0.429	0.2	1.7	0.15	230	10	15	&
1	17-Jun-96	120721	22.64	7.6	0.479	0.2	17	1.46	224	10	13.4	&
1	17-Jun-96	120800	22.82	7.6	0.483	0.2	18.1	1.55	236	9	13.4	&
1	17-Jun-96	73204	23.15	7.49	0.433	0.2	7.3	0.62	297	9	14.9	&
1	17-Jun-96	73347	23.28	7.53	0.437	0.2	12.3	1.04	323	8	14.9	&
1	17-Jun-96	120905	22.96	7.65	0.485	0.2	23.5	2.01	260	8	13.4	&
1	17-Jun-96	120954	23.29	7.77	0.479	0.2	37.8	3.22	277	7	13.4	&
1	17-Jun-96	73501	23.46	7.65	0.439	0.2	23.9	2.03	342	7	14.9	&
1	17-Jun-96	73548	23.58	7.68	0.437	0.2	26.5	2.25	350	6	14.9	&
1	17-Jun-96	121039	23.52	7.8	0.487	0.2	39.9	3.38	287	6	13.4	&
1	17-Jun-96	121114	23.89	7.8	0.484	0.2	40.3	3.39	294	5	13.4	&
1	17-Jun-96	73708	23.92	7.7	0.437	0.2	27	2.27	360	5	14.9	&
1	17-Jun-96	121309	26.26	8.29	0.467	0.2	62.4	5.03	304	4	13.4	&
1	17-Jun-96	73915	26	7.97	0.43	0.2	47.7	3.86	373	4	14.8	&

1	17-Jun-96	121355	27.55	8.52	0.453	0.2	112.1	8.83	304	3	13.3	&
1	17-Jun-96	74101	27.58	8.42	0.422	0.2	100.4	7.91	383	3	14.9	&
1	17-Jun-96	121430	27.65	8.56	0.456	0.2	118	9.28	310	2	13.4	&
1	17-Jun-96	74215	27.66	8.46	0.417	0.2	104	8.18	391	2	14.8	&
1	17-Jun-96	121536	28.52	8.62	0.453	0.2	127.2	9.85	315	1	13.3	&
1	17-Jun-96	74310	27.79	8.5	0.418	0.2	109.9	8.62	397	1	14.9	&
1	17-Jun-96	74347	28.49	8.5	0.419	0.2	108.3	8.39	399	0.1	14.9	&
1	17-Jun-96	121648	29.21	8.62	0.437	0.2	129.4	9.9	326	0.1	13.3	&
2	17-Jun-96	84313	23.39	7.72	0.431	0.2	15	1.28	421	5.6	15	&
2	17-Jun-96	84418	23.39	7.69	0.432	0.2	17.3	1.47	422	5	15	&
2	17-Jun-96	84624	24.1	7.69	0.438	0.2	21.8	1.83	424	4	14.9	&
2	17-Jun-96	84805	27.22	8.26	0.422	0.2	83.2	6.59	412	3	14.9	&
2	17-Jun-96	84909	27.83	8.45	0.417	0.2	102.8	8.06	411	2	14.9	&
2	17-Jun-96	85033	28.18	8.52	0.417	0.2	110.8	8.63	412	1	14.9	&
2	17-Jun-96	85054	28.91	8.52	0.42	0.2	111.3	8.56	412	0.1	14.9	&
3	17-Jun-96	113558	23.69	7.69	0.485	0.2	31.9	2.69	383	6.7	13.4	&
3	17-Jun-96	113654	23.81	7.69	0.479	0.2	30.9	2.61	383	6	13.4	&
3	17-Jun-96	113835	24.67	7.79	0.483	0.2	39.3	3.26	379	5	13.4	&
3	17-Jun-96	113923	26.24	8.09	0.474	0.2	67	5.4	371	4	13.4	&
3	17-Jun-96	114007	27.23	8.39	0.455	0.2	100.5	7.96	362	3	13.4	&
3	17-Jun-96	114111	27.53	8.5	0.456	0.2	111	8.75	359	2	13.4	&
3	17-Jun-96	114233	28.72	8.48	0.457	0.2	112.4	8.67	358	1	13.4	&
3	17-Jun-96	114425	28.84	8.48	0.455	0.2	113.1	8.71	358	0.1	13.4	&
4	17-Jun-96	105641	23.85	7.6	0.483	0.2	22.6	1.9	363	5.2	13.4	&
4	17-Jun-96	105715	23.72	7.59	0.479	0.2	20.9	1.76	363	5	13.4	&
4	17-Jun-96	105747	24.38	7.66	0.476	0.2	27.5	2.3	360	4	13.4	&
4	17-Jun-96	105836	26.65	8.21	0.46	0.2	84.6	6.77	346	3	13.4	&
4	17-Jun-96	105909	26.84	8.27	0.46	0.2	89.2	7.12	345	2	13.4	&
4	17-Jun-96	110012	27.67	8.43	0.457	0.2	106.7	8.39	343	1	13.4	&
4	17-Jun-96	110207	28.66	8.4	0.457	0.2	103.7	8.01	346	0.1	13.3	&
5	17-Jun-96	102919	23.91	7.53	0.475	0.2	16.7	1.41	226	3.9	13.4	&

5	17-Jun-96	102950	24.88	7.61	0.473	0.2	22.5	1.86	235	3	13.3	&
5	17-Jun-96	103014	26.01	7.78	0.463	0.2	47.4	3.84	255	2	13.4	&
5	17-Jun-96	103033	26.62	7.89	0.456	0.2	61.5	4.93	269	1	13.3	&
5	17-Jun-96	103127	28.02	7.96	0.452	0.2	75.3	5.88	290	0.1	13.3	&
1	09-Jul-96	83120	21.89	7.37	0.426	0.2	21.9	1.92	67	11.9	15.7	&
1	09-Jul-96	83139	22.28	7.44	0.41	0.2	21.1	1.83	53	11	15.7	&
1	09-Jul-96	83158	22.48	7.47	0.42	0.2	20.5	1.78	47	10	15.7	&
1	09-Jul-96	83209	22.93	7.51	0.405	0.2	20.1	1.72	46	9	15.7	&
1	09-Jul-96	83227	24.12	7.57	0.397	0.2	19.3	1.62	54	8	15.7	&
1	09-Jul-96	83244	25.3	7.58	0.392	0.2	18.8	1.54	56	7	15.7	&
1	09-Jul-96	83319	27.78	8.02	0.382	0.2	51.5	4.04	145	6	15.6	&
1	09-Jul-96	83354	28	8.13	0.389	0.2	66.9	5.23	190	5	15.7	&
1	09-Jul-96	83410	28.06	8.16	0.383	0.2	69.3	5.41	203	4	15.7	&
1	09-Jul-96	83429	28.06	8.16	0.388	0.2	70.3	5.49	215	3	15.7	&
1	09-Jul-96	83502	28.04	8.19	0.386	0.2	72.2	5.64	228	2	15.6	&
1	09-Jul-96	83523	28.06	8.2	0.385	0.2	73.5	5.74	234	1	15.6	&
1	09-Jul-96	83546	28.04	8.2	0.384	0.2	73.3	5.73	240	0.1	15.6	&
2	09-Jul-96	93951	28.17	8.22	0.378	0.2	76.2	5.94	347	5.6	15.6	&
2	09-Jul-96	94000	28.19	8.23	0.383	0.2	77	6	346	5	15.6	&
2	09-Jul-96	94010	28.19	8.23	0.378	0.2	77.4	6.03	346	4	15.6	&
2	09-Jul-96	94021	28.21	8.23	0.385	0.2	77.3	6.02	345	3	15.6	&
2	09-Jul-96	94042	28.21	8.24	0.383	0.2	77	6	343	2	15.6	&
2	09-Jul-96	94055	28.21	8.24	0.382	0.2	77.1	6.01	343	1	15.6	&
2	09-Jul-96	94122	28.19	8.24	0.381	0.2	77.4	6.03	343	0.1	15.6	&
3	09-Jul-96	80856	28	8.17	0.384	0.2	74.1	5.79	432	6.5	15.7	&
3	09-Jul-96	80911	28.07	8.2	0.383	0.2	75	5.85	430	6	15.7	&
3	09-Jul-96	80932	28.11	8.21	0.384	0.2	77	6.01	430	5	15.7	&
3	09-Jul-96	80946	28.13	8.22	0.385	0.2	76.8	5.99	429	4	15.7	&
3	09-Jul-96	81015	28.15	8.24	0.384	0.2	78.6	6.13	428	3	15.7	&
3	09-Jul-96	81034	28.17	8.25	0.384	0.2	78.3	6.1	427	2	15.8	&
3	09-Jul-96	81054	28.15	8.24	0.385	0.2	77.6	6.05	427	1	15.7	&

3	09-Jul-96	81123	28.15	8.24	0.384	0.2	77.7	6.06	426	0.1	15.7	&
4	09-Jul-96	73726	27.86	8.17	0.392	0.2	78.9	6.18	461	4	15.8	&
4	09-Jul-96	73746	27.92	8.18	0.393	0.2	78.5	6.14	459	3	15.8	&
4	09-Jul-96	73807	27.9	8.19	0.389	0.2	78.7	6.16	457	2	15.8	&
4	09-Jul-96	73832	27.9	8.19	0.392	0.2	78.7	6.16	456	1	15.8	&
4	09-Jul-96	73920	23.96	7.42	0.018	0	107.9	9.09	483	0.1	15.8	&
5	09-Jul-96	71527	26.81	8.06	0.395	0.2	77.3	6.17	461	3.8	15.8	&
5	09-Jul-96	71547	26.81	8.09	0.402	0.2	77.3	6.17	457	3	15.8	&
5	09-Jul-96	71600	26.83	8.11	0.399	0.2	77.8	6.21	454	2	15.8	&
5	09-Jul-96	71618	27	8.15	0.4	0.2	80	6.37	452	1	15.8	&
5	09-Jul-96	71712	26.6	8.15	0.137	0.1	88.1	7.07	454	0.1	15.7	&
1	15-Jul-96	75009	20.8	7.67	0.186	0.1	47.2	4.22	430	11.5	15.2	&
1	15-Jul-96	75040	21.03	7.68	0.186	0.1	48.3	4.3	431	10	15.2	&
1	15-Jul-96	75106	21.33	7.66	0.198	0.1	48.6	4.3	432	9	15.2	&
1	15-Jul-96	75140	21.96	7.56	0.259	0.1	35.5	3.1	435	8	15.2	&
1	15-Jul-96	75208	22.35	7.56	0.272	0.1	32.4	2.81	435	7	15.2	&
1	15-Jul-96	75242	23.13	7.61	0.295	0.1	35	2.99	435	6	15.2	&
1	15-Jul-96	75327	25.17	8.14	0.36	0.2	56	4.61	422	5	15.2	&
1	15-Jul-96	75406	25.51	8.31	0.36	0.2	85.6	7	415	4	15.2	&
1	15-Jul-96	75441	25.58	8.35	0.365	0.2	88.5	7.23	413	3	15.2	&
1	15-Jul-96	75521	25.79	8.45	0.361	0.2	96.5	7.85	409	2	15.2	&
1	15-Jul-96	75548	26.43	8.57	0.365	0.2	106.2	8.54	405	1	15.2	&
1	15-Jul-96	75630	26.56	8.57	0.364	0.2	109.1	8.75	404	0.1	15.2	&
2	15-Jul-96	80924	21.45	7.59	0.226	0.1	34.5	3.05	432	7.6	15.2	&
2	15-Jul-96	81027	22	7.52	0.264	0.1	24.5	2.14	435	7	15.1	&
2	15-Jul-96	81100	23.56	7.59	0.326	0.2	25.9	2.2	434	6	15.1	&
2	15-Jul-96	81138	24.51	7.79	0.341	0.2	45.8	3.81	429	5	15.2	&
2	15-Jul-96	81214	25.36	8.08	0.358	0.2	65.5	5.37	422	4	15.2	&
2	15-Jul-96	81248	25.68	8.21	0.364	0.2	73.5	5.99	416	3	15.2	&
2	15-Jul-96	81332	26.01	8.42	0.364	0.2	91.7	7.43	409	2	15.1	&
2	15-Jul-96	81408	26.41	8.52	0.363	0.2	101.4	8.16	405	1	15.2	&

2	15-Jul-96	81444	27.02	8.51	0.359	0.2	101.8	8.1	404	0.1	15.2	&
3	15-Jul-96	73642	21.57	7.67	0.221	0.1	40	3.53	423	8.5	15.2	&
3	15-Jul-96	73705	21.5	7.63	0.214	0.1	38.6	3.41	425	8	15.3	&
3	15-Jul-96	73739	22.46	7.61	0.265	0.1	39.3	3.4	427	7	15.2	&
3	15-Jul-96	73820	23	7.6	0.298	0.1	35.3	3.02	428	6	15.3	&
3	15-Jul-96	73856	23.71	7.73	0.326	0.2	43.8	3.7	425	5	15.2	&
3	15-Jul-96	73937	25.04	8	0.355	0.2	58.5	4.82	418	4	15.2	&
3	15-Jul-96	74018	25.94	8.4	0.369	0.2	91.3	7.41	406	3	15.2	&
3	15-Jul-96	74052	25.96	8.43	0.366	0.2	93	7.54	404	2	15.2	&
3	15-Jul-96	74113	26.33	8.55	0.367	0.2	104	8.37	401	1	15.2	&
3	15-Jul-96	74204	26.56	8.58	0.366	0.2	110.3	8.84	398	0.1	15.2	&
4	15-Jul-96	72352	22.02	7.74	0.23	0.1	44.3	3.87	412	7.4	15.3	&
4	15-Jul-96	72426	22.34	7.7	0.247	0.1	40.4	3.51	415	7	15.3	&
4	15-Jul-96	72504	22.52	7.72	0.251	0.1	41.8	3.62	416	6	15.3	&
4	15-Jul-96	72542	23.19	7.79	0.285	0.1	49.4	4.22	415	5	15.3	&
4	15-Jul-96	72624	23.8	7.82	0.317	0.2	51	4.31	415	4	15.3	&
4	15-Jul-96	72730	25.98	8.4	0.37	0.2	72.5	5.88	399	3	15.3	&
4	15-Jul-96	72807	26.39	8.5	0.364	0.2	97.8	7.87	396	2	15.3	&
4	15-Jul-96	72839	26.84	8.64	0.361	0.2	112.1	8.95	391	1	15.3	&
4	15-Jul-96	72902	26.94	8.64	0.165	0.1	114.9	9.16	389	0.1	15.3	&
5	15-Jul-96	70240	23.71	7.65	0.249	0.1	38.9	3.29	417	4.9	15.3	&
5	15-Jul-96	70317	24.25	7.63	0.255	0.1	50.5	4.23	418	4	15.3	&
5	15-Jul-96	70350	24.79	7.75	0.267	0.1	56.6	4.69	416	3	15.3	&
5	15-Jul-96	70436	26.62	8.55	0.363	0.2	104.3	8.35	396	2	15.3	&
5	15-Jul-96	70522	26.79	8.62	0.355	0.2	112.1	8.95	391	1	15.3	&
5	15-Jul-96	70550	27.02	8.65	0.357	0.2	116.7	9.28	389	0.1	15.3	&
1	10-Sep-96	132426	24.67	7.26	0.334	0.2	20	1.66	90	11.5	16	&
1	10-Sep-96	132512	25.01	7.32	0.349	0.2	18.5	1.52	77	11	16	&
1	10-Sep-96	132555	25.32	7.37	0.343	0.2	17.8	1.46	72	10	16	&
1	10-Sep-96	132640	26.07	7.49	0.322	0.2	17.4	1.41	80	9	16	&
1	10-Sep-96	132721	26.39	7.62	0.316	0.2	32	2.58	112	8	16	&

1	10-Sep-96	132808	26.46	7.85	0.32	0.2	47.5	3.82	149	7	16	&
1	10-Sep-96	132836	26.47	7.94	0.312	0.2	53.1	4.27	165	6	16	&
1	10-Sep-96	132915	26.5	8.07	0.311	0.2	59.9	4.81	188	5	16	&
1	10-Sep-96	133013	26.58	8.11	0.313	0.2	61.7	4.95	212	4	16	&
1	10-Sep-96	133107	26.62	8.24	0.313	0.2	69.8	5.59	231	3	15.9	&
1	10-Sep-96	133139	26.69	8.33	0.309	0.2	75.9	6.08	239	2	15.9	&
1	10-Sep-96	133206	27.33	8.63	0.307	0.1	104	8.23	243	1	15.9	&
1	10-Sep-96	133226	27.78	8.61	0.309	0.2	102.7	8.06	249	0.1	15.9	&
2	10-Sep-96	140950	26.43	7.85	0.317	0.2	49.4	3.97	317	6	15.9	&
2	10-Sep-96	141029	26.64	7.93	0.316	0.2	57.2	4.58	317	5	15.9	&
2	10-Sep-96	141102	26.69	8.01	0.313	0.2	59.7	4.78	317	4	15.9	&
2	10-Sep-96	141150	26.81	8.26	0.31	0.2	70.8	5.65	313	3	15.9	&
2	10-Sep-96	141235	27.28	8.63	0.309	0.2	104.5	8.28	307	2	15.9	&
2	10-Sep-96	141309	28.07	8.73	0.308	0.1	119.7	9.34	307	1	15.9	&
2	10-Sep-96	141338	28.62	8.73	0.307	0.1	120.6	9.33	308	0.1	15.8	&
3	10-Sep-96	130308	26.43	7.87	0.313	0.2	53	4.26	387	7.1	16.2	&
3	10-Sep-96	130333	26.43	7.86	0.316	0.2	52.5	4.22	389	7	16.2	&
3	10-Sep-96	130429	26.48	7.89	0.318	0.2	51.5	4.13	389	6	16.2	&
3	10-Sep-96	130513	26.54	8.04	0.315	0.2	61.7	4.96	386	5	16.2	&
3	10-Sep-96	130540	26.54	8.16	0.314	0.2	70.4	5.65	384	4	16.1	&
3	10-Sep-96	130622	26.69	8.38	0.309	0.2	81.7	6.54	379	3	16.2	&
3	10-Sep-96	130701	26.73	8.41	0.314	0.2	83.9	6.71	378	2	16.2	&
3	10-Sep-96	130750	27.02	8.48	0.31	0.2	89.2	7.09	376	1	16.1	&
3	10-Sep-96	130817	28.81	8.47	0.311	0.2	93.8	7.23	375	0.1	16.1	&
4	10-Sep-96	125013	26.24	7.67	0.327	0.2	45.7	3.69	392	5	16.2	&
4	10-Sep-96	125131	26.37	7.73	0.328	0.2	51.5	4.15	391	4	16.1	&
4	10-Sep-96	125228	26.54	7.88	0.324	0.2	59	4.73	388	3	16.2	&
4	10-Sep-96	125346	27.11	8.58	0.312	0.2	101	8.03	372	2	16.1	&
4	10-Sep-96	125454	27.78	8.71	0.309	0.2	116.8	9.17	367	1	16.1	&
4	10-Sep-96	125544	28.23	8.73	0.309	0.2	121.6	9.47	366	0.1	16.1	&
5	10-Sep-96	123416	27.43	8.36	0.331	0.2	96.8	7.65	362	1.9	16.2	&

5	10-Sep-96	123505	27.61	8.44	0.326	0.2	101.6	8	361	1	16.2	&
5	10-Sep-96	123604	28.49	8.64	0.317	0.2	120	9.3	357	0.1	16.2	&
1	23-Oct-96	114658	16.18	7.45	0.332	0.2	79.2	7.78	428	11.7	16	&
1	23-Oct-96	114807	16.18	7.44	0.337	0.2	78.8	7.74	425	11	16	&
1	23-Oct-96	115053	16.21	7.45	0.337	0.2	77.4	7.6	423	10	15.9	&
1	23-Oct-96	115132	16.35	7.45	0.336	0.2	77.2	7.55	423	9	15.9	&
1	23-Oct-96	115205	16.35	7.45	0.335	0.2	77.3	7.56	423	8	15.9	&
1	23-Oct-96	115238	16.4	7.45	0.337	0.2	77.1	7.54	422	7	15.9	&
1	23-Oct-96	115305	16.43	7.45	0.332	0.2	77.6	7.58	422	6	16	&
1	23-Oct-96	115603	16.45	7.45	0.337	0.2	77.2	7.54	421	5	15.9	&
1	23-Oct-96	115655	16.48	7.46	0.333	0.2	78	7.61	421	4	15.9	&
1	23-Oct-96	115736	16.5	7.46	0.338	0.2	77.8	7.59	421	3	15.9	&
1	23-Oct-96	115817	16.53	7.48	0.337	0.2	79.2	7.72	419	2	15.9	&
1	23-Oct-96	120147	16.73	7.54	0.334	0.2	79.8	7.75	417	1	15.9	&
1	23-Oct-96	120235	17.55	7.52	0.334	0.2	80.3	7.67	415	0.1	15.8	&
2	23-Oct-96	121607	15.44	7.36	0.33	0.2	77.7	7.75	416	5.7	15.8	&
2	23-Oct-96	121818	15.53	7.37	0.335	0.2	75	7.47	416	5	15.8	&
2	23-Oct-96	121853	15.86	7.42	0.336	0.2	76.6	7.57	415	4	15.8	&
2	23-Oct-96	122040	16.52	7.43	0.331	0.2	77.1	7.52	414	3	15.8	&
2	23-Oct-96	122151	16.57	7.44	0.336	0.2	78.1	7.61	413	2	15.8	&
2	23-Oct-96	122234	16.63	7.48	0.337	0.2	79.2	7.7	412	1	15.7	&
2	23-Oct-96	122256	17.58	7.5	0.332	0.2	80.8	7.71	411	0.1	15.7	&
3	23-Oct-96	112132	15.01	7.44	0.333	0.2	85	8.56	424	7	16.2	&
3	23-Oct-96	112203	15.39	7.46	0.34	0.2	83.5	8.34	423	6	16.2	&
3	23-Oct-96	112309	15.68	7.48	0.336	0.2	82.2	8.16	423	5	16.2	&
3	23-Oct-96	112349	15.81	7.48	0.336	0.2	81.8	8.1	422	4	16.1	&
3	23-Oct-96	112426	16.01	7.5	0.334	0.2	81.4	8.03	422	3	16.1	&
3	23-Oct-96	112528	16.08	7.51	0.338	0.2	81.2	7.99	421	2	16.1	&
3	23-Oct-96	112628	16.33	7.54	0.337	0.2	82.8	8.11	420	1	16.1	&
3	23-Oct-96	112716	17	7.52	0.335	0.2	84.6	8.17	419	0.1	16.2	&
4	23-Oct-96	105906	14.11	7.56	0.363	0.2	88.4	9.08	428	6	16.3	&

4	23-Oct-96	110010	14.16	7.59	0.361	0.2	87.6	8.99	426	5	16.3	&
4	23-Oct-96	110052	14.18	7.62	0.365	0.2	90.3	9.26	425	4	16.2	&
4	23-Oct-96	110141	14.38	7.62	0.352	0.2	87.9	8.97	425	3	16.2	&
4	23-Oct-96	110344	15.06	7.62	0.341	0.2	85.4	8.59	423	2	16.2	&
4	23-Oct-96	110435	15.38	7.66	0.341	0.2	86	8.6	422	1	16.2	&
4	23-Oct-96	110524	15.69	7.66	0.34	0.2	86	8.53	420	0.1	16.2	&
5	23-Oct-96	103737	12.4	7.57	0.403	0.2	86.9	9.27	437	2.6	16.3	&
5	23-Oct-96	103818	12.56	7.67	0.389	0.2	89.6	9.52	434	2	16.2	&
5	23-Oct-96	103855	12.91	7.76	0.379	0.2	91	9.6	431	1	16.2	&
5	23-Oct-96	103924	13.1	7.78	0.374	0.2	91.3	9.58	429	0.1	16.2	&
1	05-Nov-96	135843	13.69	7.97	0.375	0.2	89.4	9.27	386	11	15.5	&
1	05-Nov-96	140121	13.65	8	0.38	0.2	87	9.02	384	10	15.5	&
1	05-Nov-96	140232	13.65	8	0.385	0.2	86.4	8.96	383	9	15.4	&
1	05-Nov-96	140316	13.65	8	0.384	0.2	86.6	8.98	383	8	15.4	&
1	05-Nov-96	140350	13.65	8.01	0.373	0.2	86.2	8.94	382	7	15.4	&
1	05-Nov-96	140420	13.65	8.01	0.373	0.2	86.1	8.93	382	6	15.3	&
1	05-Nov-96	140505	13.65	8.01	0.369	0.2	88.1	9.13	382	5	15.3	&
1	05-Nov-96	140538	13.8	8.02	0.37	0.2	88.7	9.17	381	4	15.3	&
1	05-Nov-96	140607	13.85	8.02	0.375	0.2	89.7	9.26	381	3	15.2	&
1	05-Nov-96	140657	14	8.03	0.37	0.2	91.9	9.46	380	2	15.3	&
1	05-Nov-96	140737	14.06	8.04	0.372	0.2	91.8	9.44	379	1	15.3	&
1	05-Nov-96	140835	14.11	8.03	0.128	0.1	92.2	9.48	378	0.1	15.3	&
2	05-Nov-96	142841	13.62	8.02	0.367	0.2	94.8	9.85	398	5.8	15.4	&
2	05-Nov-96	142913	13.93	8.04	0.372	0.2	92.9	9.58	397	5	15.3	&
2	05-Nov-96	142948	13.95	8.05	0.371	0.2	91.7	9.45	396	4	15.3	&
2	05-Nov-96	143108	13.95	8.05	0.373	0.2	91	9.38	396	3	15.4	&
2	05-Nov-96	143153	13.96	8.05	0.373	0.2	90.6	9.34	395	2	15.4	&
2	05-Nov-96	143218	13.97	8.06	0.372	0.2	90.4	9.31	394	1	15.4	&
2	05-Nov-96	143256	14	8.04	0.372	0.2	90.4	9.31	394	0.1	15.4	&
3	05-Nov-96	134026	13.37	8.02	0.37	0.2	101	10.54	398	7.1	15.5	&
3	05-Nov-96	134106	13.37	8.04	0.37	0.2	98.4	10.27	398	6	15.5	&

3	05-Nov-96	134139	13.38	8.05	0.38	0.2	96.2	10.04	397	5	15.5	&
3	05-Nov-96	134223	13.38	8.06	0.373	0.2	92.3	9.63	396	4	15.5	&
3	05-Nov-96	134305	13.41	8.05	0.378	0.2	93.9	9.79	396	3	15.5	&
3	05-Nov-96	134324	13.6	8.07	0.373	0.2	93.9	9.76	396	2	15.5	&
3	05-Nov-96	134354	13.86	8.1	0.374	0.2	95.3	9.84	395	1	15.5	&
3	05-Nov-96	134441	13.46	6.9	0.006	0	98.2	10.24	435	0.1	15.5	&
4	05-Nov-96	131632	12.21	8.02	0.366	0.2	101	10.82	364	5	15.5	&
4	05-Nov-96	131717	12.25	8.03	0.362	0.2	97.9	10.47	364	4	15.5	&
4	05-Nov-96	131801	12.59	8.07	0.369	0.2	97.2	10.32	363	3	15.4	&
4	05-Nov-96	131843	13.17	8.17	0.372	0.2	99.5	10.43	361	2	15.4	&
4	05-Nov-96	131913	13.19	8.18	0.374	0.2	97.7	10.24	360	1	15.5	&
4	05-Nov-96	131935	13.27	7.82	0.01	0	98.2	10.28	380	0.1	15.5	&
5	05-Nov-96	125841	10.85	7.58	0.367	0.2	102.6	11.33	353	3.5	15.6	&
5	05-Nov-96	125929	10.81	7.63	0.358	0.2	98.1	10.85	348	3	15.6	&
5	05-Nov-96	130006	11.32	7.81	0.356	0.2	98.9	10.81	345	2	15.5	&
5	05-Nov-96	130048	11.98	8	0.363	0.2	101.8	10.96	341	1	15.5	&
5	05-Nov-96	130110	13.33	8.13	0.361	0.2	102.5	10.7	338	0.1	15.5	&
1	19-Nov-96	143156	11.21	7.87	0.375	0.2	93.2	10.21	389	11.5	15.7	&
1	19-Nov-96	143226	11.26	7.88	0.372	0.2	92.9	10.17	388	11	15.6	&
1	19-Nov-96	143312	11.29	7.89	0.369	0.2	89.1	9.74	388	10	15.6	&
1	19-Nov-96	143255	11.29	7.89	0.361	0.2	90.5	9.89	388	10	15.6	&
1	19-Nov-96	143342	11.31	7.9	0.371	0.2	89.1	9.74	387	9	15.6	&
1	19-Nov-96	143413	11.36	7.91	0.365	0.2	89.1	9.73	387	8	15.6	&
1	19-Nov-96	143456	11.38	7.91	0.369	0.2	89.3	9.75	388	7	15.6	&
1	19-Nov-96	143536	11.36	7.93	0.367	0.2	89.5	9.78	387	6	15.6	&
1	19-Nov-96	143618	11.38	7.93	0.371	0.2	89	9.72	388	5	15.6	&
1	19-Nov-96	143712	11.39	7.93	0.368	0.2	88.4	9.64	388	4	15.6	&
1	19-Nov-96	143741	11.39	7.93	0.368	0.2	88.7	9.68	388	3	15.6	&
1	19-Nov-96	143804	11.44	7.95	0.369	0.2	88.7	9.67	388	2	15.6	&
1	19-Nov-96	143828	11.52	7.96	0.366	0.2	89.2	9.71	388	1	15.5	&
1	19-Nov-96	143852	11.54	7.97	0.366	0.2	89.9	9.77	387	0.1	15.6	&

2	19-Nov-96	150401	11.33	7.91	0.37	0.2	100.9	11.02	377	5.6	15.6	&
2	19-Nov-96	150439	11.38	7.93	0.373	0.2	97.3	10.62	377	5	15.6	&
2	19-Nov-96	150504	11.46	7.94	0.372	0.2	94.8	10.33	377	4	15.5	&
2	19-Nov-96	150524	11.51	7.94	0.368	0.2	92.9	10.11	377	3	15.5	&
2	19-Nov-96	150542	11.52	7.94	0.371	0.2	92	10	377	2	15.5	&
2	19-Nov-96	150608	11.62	7.96	0.369	0.2	91.3	9.91	376	1	15.5	&
2	19-Nov-96	150630	11.92	7.98	0.367	0.2	91.3	9.84	376	0.1	15.5	&
3	19-Nov-96	141213	11.21	7.89	0.373	0.2	98.1	10.75	384	6.6	15.8	&
3	19-Nov-96	141251	11.25	7.92	0.366	0.2	96.7	10.59	384	6	15.8	&
3	19-Nov-96	141318	11.29	7.92	0.366	0.2	94.3	10.32	385	5	15.8	&
3	19-Nov-96	141340	11.33	7.92	0.366	0.2	92.2	10.08	385	4	15.8	&
3	19-Nov-96	141409	11.34	7.93	0.365	0.2	90.5	9.89	386	3	15.8	&
3	19-Nov-96	141432	11.41	7.94	0.366	0.2	90	9.82	385	2	15.8	&
3	19-Nov-96	141515	11.57	7.99	0.365	0.2	90.1	9.79	384	1	15.8	&
3	19-Nov-96	141538	11.67	8.03	0.006	0	92.8	10.08	382	0.1	15.8	&
4	19-Nov-96	135249	10.82	7.62	0.44	0.2	89.1	9.85	398	7.5	15.8	&
4	19-Nov-96	135312	10.87	7.67	0.431	0.2	86.6	9.57	397	7	15.8	&
4	19-Nov-96	135332	10.88	7.71	0.414	0.2	86.5	9.55	396	6	15.8	&
4	19-Nov-96	135403	10.9	7.78	0.398	0.2	87.3	9.63	395	5	15.8	&
4	19-Nov-96	135422	10.92	7.81	0.39	0.2	88.1	9.72	395	4	15.8	&
4	19-Nov-96	135454	11.02	7.87	0.379	0.2	89.3	9.83	393	3	15.8	&
4	19-Nov-96	135511	11.08	7.9	0.367	0.2	89.2	9.81	392	2	15.8	&
4	19-Nov-96	135528	11.15	7.91	0.36	0.2	89.6	9.83	392	1	15.8	&
4	19-Nov-96	135550	11.25	7.94	0.115	0	90	9.86	393	0.1	15.8	&
5	19-Nov-96	132610	10.29	7.76	0.431	0.2	96.7	10.82	397	3.1	16	&
5	19-Nov-96	132647	10.69	7.87	0.426	0.2	97.3	10.79	397	2	16.1	&
5	19-Nov-96	132720	10.87	7.9	0.432	0.2	96.7	10.68	397	1	16.1	&
5	19-Nov-96	132741	11	7.97	0.424	0.2	98.3	10.82	395	0.1	16	&
1	03-Dec-96	135830	7.11	8.09	0.382	0.2	91.5	11.06	380	10.4	16	&
1	03-Dec-96	140014	7.11	8.11	0.374	0.2	89	10.75	379	10	16	&
1	03-Dec-96	140129	7.11	8.11	0.384	0.2	88.3	10.67	379	9	16	&

1	03-Dec-96	140200	7.2	8.11	0.38	0.2	88	10.62	379	8	15.9	&
1	03-Dec-96	140243	7.23	8.11	0.378	0.2	87.9	10.59	379	7	15.9	&
1	03-Dec-96	140344	7.26	8.11	0.381	0.2	87.8	10.57	379	6	15.9	&
1	03-Dec-96	140415	7.29	8.12	0.384	0.2	87.7	10.55	379	5	15.9	&
1	03-Dec-96	140505	7.29	8.12	0.38	0.2	87.6	10.54	379	4	15.9	&
1	03-Dec-96	140534	7.31	8.13	0.381	0.2	87.6	10.53	379	3	15.9	&
1	03-Dec-96	140606	7.34	8.12	0.381	0.2	87.6	10.53	379	2	15.9	&
1	03-Dec-96	140644	7.46	8.13	0.383	0.2	87.7	10.5	378	1	15.9	&
1	03-Dec-96	140710	8.36	8.13	0.379	0.2	88.1	10.33	377	0.1	15.9	&
2	03-Dec-96	142132	7.2	8.09	0.379	0.2	102.4	12.34	383	4.9	15.9	&
2	03-Dec-96	142205	7.2	8.08	0.379	0.2	94	11.33	383	4	15.9	&
2	03-Dec-96	142259	7.2	8.08	0.378	0.2	88.9	10.73	382	3	15.9	&
2	03-Dec-96	142401	7.28	8.1	0.379	0.2	87.9	10.58	382	2	15.9	&
2	03-Dec-96	142431	7.36	8.11	0.378	0.2	87.7	10.53	381	1	15.9	&
2	03-Dec-96	142455	7.92	8.12	0.376	0.2	87.9	10.41	380	0.1	15.9	&
3	03-Dec-96	133220	7.01	8.14	0.386	0.2	102.6	12.43	393	5.5	16.1	&
3	03-Dec-96	133305	7.01	8.13	0.386	0.2	99.4	12.04	393	5	16.1	&
3	03-Dec-96	133343	7.03	8.13	0.386	0.2	97.1	11.75	393	4	16.1	&
3	03-Dec-96	133417	7.13	8.13	0.385	0.2	95.1	11.49	392	3	16.1	&
3	03-Dec-96	133524	7.23	8.15	0.386	0.2	91.7	11.05	392	2	16	&
3	03-Dec-96	133620	7.52	8.15	0.385	0.2	88.7	10.61	391	1	16	&
3	03-Dec-96	133640	7.57	8.15	0.384	0.2	88.4	10.56	390	0.1	16	&
4	03-Dec-96	130634	6.27	8.13	0.42	0.2	103.9	12.83	368	3	16.2	&
4	03-Dec-96	130734	6.7	8.16	0.406	0.2	101.2	12.36	366	2	16.1	&
4	03-Dec-96	130823	6.73	8.17	0.406	0.2	99.6	12.15	366	1	16.2	&
4	03-Dec-96	130921	6.97	8.17	0.407	0.2	97.9	11.87	366	0.1	16	&
5	03-Dec-96	124816	5.7	8.05	0.461	0.2	104.5	13.08	346	1	16.2	&
5	03-Dec-96	124917	5.79	8.07	0.367	0.2	106	13.24	346	0.1	16.1	&
1	19-Dec-96	142738	5.57	8.17	0.39	0.2	107.8	13.55	482	10.4	15	&
1	19-Dec-96	142809	5.57	8.18	0.386	0.2	108.9	13.69	481	9	15.1	&
1	19-Dec-96	142839	5.55	8.19	0.398	0.2	111.3	13.99	480	8	15	&

1	19-Dec-96	142905	5.55	8.2	0.389	0.2	112.3	14.11	479	7	15	&
1	19-Dec-96	142953	5.57	8.2	0.382	0.2	111.4	14	478	6	14.8	&
1	19-Dec-96	143017	5.63	8.21	0.392	0.2	114.1	14.31	477	5	14.8	&
1	19-Dec-96	143047	5.65	8.21	0.398	0.2	115	14.41	477	4	14.8	&
1	19-Dec-96	143113	5.76	8.21	0.393	0.2	114.4	14.3	476	3	14.8	&
1	19-Dec-96	143140	5.76	8.21	0.393	0.2	113.6	14.2	475	2	14.7	&
1	19-Dec-96	143201	5.78	8.21	0.39	0.2	112.4	14.04	475	1	14.9	&
1	19-Dec-96	143300	5.67	8.2	0.138	0.1	115.2	14.45	478	0.1	14.8	&
2	19-Dec-96	144957	5.2	8.2	0.389	0.2	112.2	14.23	490	5.3	14.5	&
2	19-Dec-96	145022	5.2	8.2	0.387	0.2	112.5	14.26	488	4	14.5	&
2	19-Dec-96	145057	5.25	8.21	0.392	0.2	113	14.31	487	3	14.5	&
2	19-Dec-96	145157	5.56	8.22	0.389	0.2	113.6	14.27	485	1	14.5	&
2	19-Dec-96	145241	4.05	7.78	0.089	0	122.3	15.99	479	0.1	14.6	&
3	19-Dec-96	141334	4.54	8.24	0.395	0.2	112.6	14.53	486	5.5	15	&
3	19-Dec-96	141421	4.54	8.25	0.393	0.2	113.7	14.66	484	5	15	&
3	19-Dec-96	141456	4.54	8.25	0.395	0.2	113.6	14.65	483	4	15	&
3	19-Dec-96	141520	4.55	8.25	0.395	0.2	113.4	14.63	482	3	15	&
3	19-Dec-96	141600	4.55	8.26	0.395	0.2	116.2	14.99	481	2	15	&
3	19-Dec-96	141629	4.54	8.26	0.396	0.2	116.6	15.04	481	1	15	&
3	19-Dec-96	141746	1.9	7.92	0.01	0	129.5	17.95	490	0.1	15	&
4	19-Dec-96	134931	3.9	8.38	0.444	0.2	118.6	15.56	479	4.5	15.1	&
4	19-Dec-96	135001	3.9	8.39	0.437	0.2	121.4	15.92	478	4	15.1	&
4	19-Dec-96	135029	3.95	8.4	0.435	0.2	122	15.98	477	3	15.1	&
4	19-Dec-96	135103	4.04	8.4	0.439	0.2	123.7	16.16	476	2	15.1	&
4	19-Dec-96	135151	4.04	8.4	0.435	0.2	122.7	16.04	475	1	15	&
4	19-Dec-96	135224	4.05	8.39	0.158	0.1	122.1	15.97	474	0.1	15	&
5	19-Dec-96	133114	1.15	8.24	0.732	0.4	140	19.77	484	2.1	15.1	&
5	19-Dec-96	133147	1.35	8.45	0.55	0.3	145.3	20.42	475	1	15.1	&
5	19-Dec-96	133215	1.32	8.47	0.539	0.3	139.2	19.57	472	0.1	15.2	&
1	09-Jan-97	154354	6.22	8.05	0.417	0.2	109.5	13.53	470	9.4	15.1	&
1	09-Jan-97	154414	6.22	8.06	0.419	0.2	106.9	13.21	469	9	15.1	&

1	09-Jan-97	154437	6.22	8.05	0.417	0.2	108.3	13.38	469	8	15.1	&
1	09-Jan-97	154455	6.24	8.06	0.417	0.2	106	13.08	468	7	15.1	&
1	09-Jan-97	154516	6.21	8.05	0.418	0.2	106.4	13.14	468	6	15	&
1	09-Jan-97	154557	6.26	8.04	0.418	0.2	105.5	13.03	468	5	15	&
1	09-Jan-97	154621	6.27	8.06	0.417	0.2	105.2	12.98	467	4	15	&
1	09-Jan-97	154644	6.26	8.08	0.418	0.2	104.8	12.94	465	3	15	&
1	09-Jan-97	154700	6.29	8.07	0.417	0.2	101.9	12.57	465	2	15	&
1	09-Jan-97	154719	6.31	8.08	0.417	0.2	101	12.46	464	1	15	&
1	09-Jan-97	154733	6.32	8.09	0.417	0.2	100.8	12.43	463	0.1	15	&
3	09-Jan-97	152521	5.67	8.11	0.42	0.2	105.5	13.22	458	5.1	15.2	&
3	09-Jan-97	152547	5.75	8.11	0.42	0.2	104.1	13.01	457	4	15.1	&
3	09-Jan-97	152609	5.73	8.11	0.42	0.2	103.4	12.93	457	3	15.1	&
3	09-Jan-97	152636	5.76	8.13	0.425	0.2	102.8	12.84	455	2	15.1	&
3	09-Jan-97	152657	5.79	8.15	0.423	0.2	102	12.74	454	1	15.2	&
3	09-Jan-97	152714	5.43	8.07	0.024	0	101.1	12.77	455	0.1	15.1	&
4	09-Jan-97	150018	5.66	8.2	0.449	0.2	104.3	13.07	426	3.5	15.2	&
4	09-Jan-97	150113	5.66	8.21	0.449	0.2	101	12.66	425	3	15.2	&
4	09-Jan-97	150142	5.65	8.22	0.457	0.2	102.7	12.87	424	2	15.2	&
4	09-Jan-97	150215	5.66	8.22	0.448	0.2	102.1	12.79	424	1	15.2	&
4	09-Jan-97	150241	5.66	8.23	0.446	0.2	99.6	12.48	423	0.1	15.1	&
5	09-Jan-97	143935	4.47	8.35	0.63	0.3	128.8	16.63	363	1.5	15.3	&
5	09-Jan-97	144010	4.47	8.4	0.63	0.3	124.4	16.07	359	1	15.3	&
5	09-Jan-97	144051	4.48	8.41	0.635	0.3	117.2	15.13	356	0.1	15.2	&
1	21-Jan-97	145112	3.6	8.36	0.446	0.2	103.5	13.69	438	7.9	15.2	&
1	21-Jan-97	145150	3.63	8.37	0.445	0.2	97	12.81	438	7	15.2	&
1	21-Jan-97	145229	3.63	8.38	0.445	0.2	93	12.29	438	6	15.2	&
1	21-Jan-97	145249	3.62	8.38	0.442	0.2	92	12.15	439	5	15.2	&
1	21-Jan-97	145314	3.62	8.38	0.446	0.2	91.6	12.1	439	4	15.2	&
1	21-Jan-97	145332	3.62	8.4	0.451	0.2	91	12.03	439	3	15.2	&
1	21-Jan-97	145350	3.62	8.4	0.453	0.2	90.5	11.96	439	2	15.2	&
1	21-Jan-97	145424	3.63	8.35	0.446	0.2	90	11.89	442	1	15.2	&

1	21-Jan-97	145442	3.63	8.42	0.448	0.2	89.7	11.85	438	0.1	15.2	&
2	21-Jan-97	151831	4.83	8.41	0.447	0.2	111.9	14.32	460	4.8	15.2	&
2	21-Jan-97	151900	4.83	8.42	0.446	0.2	105.2	13.46	459	4	15.2	&
2	21-Jan-97	151935	4.88	8.42	0.446	0.2	98.4	12.58	459	3	15.2	&
2	21-Jan-97	152003	4.87	8.43	0.446	0.2	95.8	12.25	459	2	15.2	&
2	21-Jan-97	152130	4.88	8.41	0.446	0.2	93.1	11.9	461	1	15.1	&
2	21-Jan-97	152201	4.9	8.45	0.446	0.2	92.4	11.81	458	0.1	15.1	&
3	21-Jan-97	143127	3.77	8.37	0.459	0.2	95.9	12.62	383	4.3	15.3	&
3	21-Jan-97	143202	3.77	8.38	0.454	0.2	94.1	12.38	396	4	15.3	&
3	21-Jan-97	143233	3.78	8.38	0.454	0.2	91.9	12.09	404	3	15.3	&
3	21-Jan-97	143254	3.8	8.4	0.454	0.2	91.5	12.04	407	2	15.2	&
3	21-Jan-97	143319	3.78	8.38	0.453	0.2	91.5	12.04	411	1	15.3	&
3	21-Jan-97	143342	3.87	8.41	0.453	0.2	90.8	11.92	412	0.1	15.2	&
4	21-Jan-97	140516	4.33	8.66	0.491	0.2	118.1	15.32	393	3.2	15.4	&
4	21-Jan-97	140559	4.33	8.66	0.486	0.2	109.8	14.23	393	3	15.4	&
4	21-Jan-97	140635	4.32	8.67	0.483	0.2	108.1	14.02	393	2	15.4	&
4	21-Jan-97	140721	4.35	8.67	0.486	0.2	103.7	13.43	394	1	15.4	&
4	21-Jan-97	140751	4.33	8.67	0.484	0.2	101.3	13.14	394	0.1	15.4	&
5	21-Jan-97	134802	4.95	8.71	0.537	0.3	134.4	17.14	380	2.5	15.5	&
5	21-Jan-97	134824	4.96	8.71	0.534	0.3	130.1	16.58	380	2	15.5	&
5	21-Jan-97	134848	5.02	8.72	0.533	0.3	125.2	15.94	381	1	15.5	&
5	21-Jan-97	134955	5.05	8.71	0.528	0.3	114.8	14.6	382	0.1	15.4	&
1	25-Feb-97	143021	7.53	8.34	0.435	0.2	97.2	11.63	386	11	15.4	&
1	25-Feb-97	143058	7.67	8.38	0.433	0.2	93.3	11.12	384	10	15.3	&
1	25-Feb-97	143140	7.69	8.39	0.44	0.2	93.1	11.09	383	9	15.3	&
1	25-Feb-97	143222	7.7	8.4	0.444	0.2	93.4	11.12	383	8	15.3	&
1	25-Feb-97	143255	7.74	8.4	0.438	0.2	92.6	11.02	382	7	15.3	&
1	25-Feb-97	143318	7.75	8.41	0.439	0.2	92.5	11	382	6	15.3	&
1	25-Feb-97	143338	7.77	8.41	0.444	0.2	92.6	11.01	382	5	15.2	&
1	25-Feb-97	143406	7.87	8.41	0.443	0.2	91.9	10.9	382	4	15.2	&
1	25-Feb-97	143441	7.98	8.43	0.443	0.2	94	11.12	381	3	15.2	&

1	25-Feb-97	143515	8	8.44	0.439	0.2	94.4	11.16	381	2	15.3	&
1	25-Feb-97	143553	8.02	8.44	0.439	0.2	93.4	11.04	381	1	15.2	&
1	25-Feb-97	143617	8.02	8.44	0.441	0.2	94.5	11.17	380	0.1	15.2	&
2	25-Feb-97	145954	7.82	8.39	0.439	0.2	107.8	12.8	388	6	15.2	&
2	25-Feb-97	150029	7.92	8.39	0.438	0.2	99.4	11.77	387	5	15.2	&
2	25-Feb-97	150052	8.1	8.41	0.436	0.2	98.6	11.63	386	4	15.2	&
2	25-Feb-97	150117	8.11	8.43	0.435	0.2	99	11.67	386	3	15.2	&
2	25-Feb-97	150137	8.15	8.44	0.436	0.2	99.2	11.68	385	2	15.1	&
2	25-Feb-97	150153	8.2	8.46	0.436	0.2	99.3	11.68	385	1	15.2	&
2	25-Feb-97	150217	8.2	8.47	0.437	0.2	99.3	11.68	384	0.1	15.1	&
3	25-Feb-97	141108	7.64	8.38	0.445	0.2	96	11.45	376	6.6	15.5	&
3	25-Feb-97	141133	7.69	8.39	0.445	0.2	94.1	11.2	375	6	15.5	&
3	25-Feb-97	141207	7.7	8.4	0.444	0.2	93.2	11.1	375	5	15.4	&
3	25-Feb-97	141233	7.7	8.41	0.444	0.2	92.7	11.04	374	4	15.4	&
3	25-Feb-97	141251	7.74	8.41	0.444	0.2	92.4	10.99	374	3	15.4	&
3	25-Feb-97	141313	7.79	8.43	0.442	0.2	92.2	10.96	374	2	15.4	&
3	25-Feb-97	141332	7.85	8.44	0.441	0.2	92.3	10.95	373	1	15.4	&
3	25-Feb-97	141350	7.85	8.44	0.441	0.2	92.3	10.95	373	0.1	15.4	&
4	25-Feb-97	134507	8.44	8.19	0.44	0.2	104.1	12.18	395	5	15.7	&
4	25-Feb-97	134551	8.49	8.22	0.437	0.2	95.7	11.17	392	4	15.5	&
4	25-Feb-97	134620	8.51	8.24	0.436	0.2	93.9	10.96	391	3	15.6	&
4	25-Feb-97	134651	8.51	8.25	0.436	0.2	93.1	10.87	390	2	15.5	&
4	25-Feb-97	134735	8.53	8.26	0.436	0.2	91.4	10.66	389	1	15.5	&
4	25-Feb-97	134757	8.56	8.28	0.438	0.2	92.4	10.78	388	0.1	15.5	&
5	25-Feb-97	132525	8.95	7.33	0.392	0.2	118	13.63	396	3.5	15.8	&
5	25-Feb-97	132544	8.95	7.45	0.403	0.2	113.3	13.09	393	3	15.8	&
5	25-Feb-97	132653	8.95	7.66	0.401	0.2	108.8	12.57	387	2	15.7	&
5	25-Feb-97	132741	9	7.72	0.395	0.2	103.3	11.92	384	1	15.7	&
5	25-Feb-97	132833	4.67	7.68	0.011	0	119.6	15.39	390	0.1	15.6	&
1	12-Mar-97	144000	9.61	8.21	0.444	0.2	104.3	11.86	399	11.3	15.3	&
1	12-Mar-97	144044	9.56	8.17	0.452	0.2	97.7	11.13	401	11	15.3	&

1	12-Mar-97	144100	9.59	8.21	0.443	0.2	97.2	11.06	400	10	15.3	&
1	12-Mar-97	144114	9.61	8.24	0.452	0.2	98.2	11.17	400	9	15.2	&
1	12-Mar-97	144143	9.64	8.26	0.448	0.2	96	10.9	399	8	15.2	&
1	12-Mar-97	144210	9.67	8.28	0.452	0.2	96.9	11	399	7	15.2	&
1	12-Mar-97	144251	10.15	8.32	0.444	0.2	97.7	10.97	398	6	15.2	&
1	12-Mar-97	144322	10.54	8.36	0.444	0.2	99.2	11.04	397	5	15.2	&
1	12-Mar-97	144402	10.98	8.45	0.447	0.2	102.7	11.31	395	4	15.2	&
1	12-Mar-97	144419	11.52	8.52	0.446	0.2	104.2	11.34	394	3	15.2	&
1	12-Mar-97	144442	11.97	8.58	0.444	0.2	107.7	11.6	392	2	15.1	&
1	12-Mar-97	144511	12.31	8.62	0.444	0.2	111.8	11.94	390	1	15.1	&
1	12-Mar-97	144532	12.41	8.62	0.443	0.2	113.1	12.06	390	0.1	15.1	&
2	12-Mar-97	145600	9.79	8.24	0.455	0.2	98	11.09	417	6.1	15.2	&
2	12-Mar-97	145650	10.21	8.38	0.451	0.2	97.4	10.92	415	5	15.1	&
2	12-Mar-97	145736	10.57	8.42	0.445	0.2	97.1	10.8	414	4	15.2	&
2	12-Mar-97	145810	10.75	8.44	0.446	0.2	97.3	10.77	414	3	15.1	&
2	12-Mar-97	145852	13.05	8.7	0.438	0.2	108.8	11.44	406	2	15	&
2	12-Mar-97	145937	13.65	8.76	0.436	0.2	115.8	12.01	402	1	15	&
2	12-Mar-97	150041	13.68	8.77	0.437	0.2	117.6	12.18	401	0.1	14.9	&
3	12-Mar-97	142658	9.79	8.3	0.46	0.2	110.1	12.47	408	6.9	15.4	&
3	12-Mar-97	142728	9.75	8.24	0.45	0.2	103	11.67	410	6	15.4	&
3	12-Mar-97	142746	9.72	8.25	0.45	0.2	100.9	11.45	409	5	15.3	&
3	12-Mar-97	142804	9.79	8.25	0.449	0.2	100.2	11.35	409	4	15.3	&
3	12-Mar-97	142822	10.26	8.31	0.447	0.2	100.7	11.27	409	3	15.3	&
3	12-Mar-97	142844	11.7	8.55	0.442	0.2	107.2	11.61	403	2	15.2	&
3	12-Mar-97	142911	11.8	8.61	0.443	0.2	113.4	12.25	401	1	15.4	&
3	12-Mar-97	142945	12.03	8.66	0.444	0.2	117	12.58	399	0.1	15.3	&
4	12-Mar-97	141132	9.97	8.16	0.46	0.2	104.1	11.74	397	7.8	15.5	&
4	12-Mar-97	141202	9.9	8.13	0.459	0.2	98.9	11.17	399	7	15.5	&
4	12-Mar-97	141242	9.88	8.14	0.451	0.2	96.8	10.94	399	6	15.4	&
4	12-Mar-97	141310	9.88	8.15	0.454	0.2	95.5	10.79	398	5	15.4	&
4	12-Mar-97	141346	9.93	8.16	0.449	0.2	94.8	10.69	398	4	15.4	&

4	12-Mar-97	141409	9.93	8.18	0.452	0.2	95.2	10.75	398	3	15.4	&
4	12-Mar-97	141435	10.79	8.28	0.454	0.2	97	10.73	396	2	15.4	&
4	12-Mar-97	141452	12.57	8.41	0.461	0.2	101.9	10.82	393	1	15.3	&
4	12-Mar-97	141519	13.55	8.52	0.463	0.2	109.9	11.42	389	0.1	15.3	&
5	12-Mar-97	134738	10.42	8.01	0.467	0.2	110.7	12.34	409	3.1	15.7	&
5	12-Mar-97	134853	11.21	8.03	0.471	0.2	98.1	10.75	409	2	15.6	&
5	12-Mar-97	135016	11.44	8.25	0.466	0.2	100.2	10.92	405	1	15.6	&
5	12-Mar-97	135105	13.69	8.38	0.497	0.3	105	10.88	402	0.1	15.5	&
1	26-Mar-97	135558	12.2	8.2	0.445	0.2	86.3	9.25	419	11.4	15.2	&
1	26-Mar-97	135642	12.2	8.2	0.444	0.2	87	9.32	418	11	15.2	&
1	26-Mar-97	135733	12.3	8.21	0.447	0.2	86.6	9.26	415	10	15.1	&
1	26-Mar-97	135822	12.35	8.21	0.464	0.2	86.5	9.23	415	9	15.1	&
1	26-Mar-97	135851	12.36	8.21	0.453	0.2	84.9	9.06	415	8	15.1	&
1	26-Mar-97	135919	12.38	8.21	0.449	0.2	85.6	9.14	415	7	15.1	&
1	26-Mar-97	140021	12.43	8.21	0.451	0.2	86.2	9.18	415	6	15.1	&
1	26-Mar-97	140110	12.41	8.21	0.456	0.2	85.6	9.13	414	5	15.1	&
1	26-Mar-97	140224	12.44	8.21	0.45	0.2	86.7	9.24	414	4	15.1	&
1	26-Mar-97	140306	12.49	8.21	0.458	0.2	87	9.26	414	3	15	&
1	26-Mar-97	140356	12.71	8.23	0.455	0.2	87.3	9.24	412	2	15	&
1	26-Mar-97	140514	13.32	8.26	0.452	0.2	89	9.3	410	1	15	&
1	26-Mar-97	140538	13.68	8.18	0.033	0	88	9.14	409	0.1	14.9	&
2	26-Mar-97	142834	12.4	8.19	0.46	0.2	88.2	9.41	454	5	15.1	&
2	26-Mar-97	143006	12.69	8.21	0.447	0.2	86.8	9.2	452	4	15.1	&
2	26-Mar-97	143200	13.07	8.23	0.456	0.2	87.4	9.18	449	3	15	&
2	26-Mar-97	143236	13.67	8.26	0.45	0.2	87.5	9.07	447	2	15	&
2	26-Mar-97	143354	14.18	8.26	0.452	0.2	90.5	9.28	445	1	15	&
2	26-Mar-97	143424	14.62	8.27	0.45	0.2	90.7	9.21	442	0.1	15	&
3	26-Mar-97	133814	12.07	8.18	0.458	0.2	89.8	9.65	402	6.8	15.3	&
3	26-Mar-97	133841	12.16	8.21	0.455	0.2	88.6	9.49	402	6	15.3	&
3	26-Mar-97	133902	12.21	8.21	0.455	0.2	88.6	9.49	402	5	15.3	&
3	26-Mar-97	133943	12.58	8.24	0.448	0.2	88.8	9.43	401	4	15.2	&

3	26-Mar-97	134000	12.89	8.26	0.451	0.2	88.8	9.36	400	3	15.2	&
3	26-Mar-97	134019	13.13	8.27	0.452	0.2	88.2	9.25	399	2	15.3	&
3	26-Mar-97	134107	13.37	8.27	0.453	0.2	89.9	9.38	398	1	15.2	&
3	26-Mar-97	134128	13.93	8.3	0.453	0.2	89.9	9.26	396	0.1	15.3	&
4	26-Mar-97	131839	12.31	8.18	0.47	0.2	84.4	9.02	383	7.4	15.4	&
4	26-Mar-97	131859	12.31	8.18	0.463	0.2	85.3	9.11	382	7	15.3	&
4	26-Mar-97	131920	12.36	8.18	0.459	0.2	84.7	9.04	382	6	15.4	&
4	26-Mar-97	131945	12.35	8.19	0.465	0.2	83.4	8.9	382	5	15.3	&
4	26-Mar-97	132009	12.37	8.2	0.462	0.2	84.8	9.05	382	4	15.3	&
4	26-Mar-97	132045	12.52	8.21	0.47	0.2	83	8.82	381	3	15.3	&
4	26-Mar-97	132124	12.9	8.22	0.485	0.2	82.6	8.71	380	2	15.3	&
4	26-Mar-97	132146	13.17	8.25	0.486	0.2	83.1	8.71	379	1	15.3	&
4	26-Mar-97	132217	14.18	8.26	0.493	0.2	84	8.61	377	0.1	15.3	&
5	26-Mar-97	130515	12.33	8.09	0.583	0.3	101	10.78	343	3.3	15.5	&
5	26-Mar-97	130548	12.43	8.09	0.586	0.3	96.6	10.29	343	3	15.5	&
5	26-Mar-97	130616	12.74	8.08	0.578	0.3	95.8	10.14	344	2	15.5	&
5	26-Mar-97	130659	12.58	8.15	0.508	0.3	95.1	10.09	343	1	15.5	&
5	26-Mar-97	130736	13.5	8.19	0.525	0.3	90.9	9.45	342	0.1	15.4	&
1	15-Apr-97	134015	11.2	8.11	0.479	0.2	82	8.98	445	11.6	15.6	&
1	15-Apr-97	134127	11.97	8.18	0.463	0.2	78.7	8.48	442	10	15.6	&
1	15-Apr-97	134200	12.01	8.19	0.472	0.2	78.5	8.44	441	9	15.5	&
1	15-Apr-97	134249	12.02	8.2	0.46	0.2	77.7	8.36	439	8	15.5	&
1	15-Apr-97	134319	12.1	8.2	0.468	0.2	77.4	8.31	439	7	15.5	&
1	15-Apr-97	134424	12.1	8.21	0.469	0.2	77.3	8.29	438	6	15.5	&
1	15-Apr-97	134521	12.16	8.21	0.47	0.2	77.7	8.32	437	5	15.4	&
1	15-Apr-97	134451	12.16	8.21	0.464	0.2	77.8	8.34	438	5	15.5	&
1	15-Apr-97	134542	12.21	8.21	0.468	0.2	77.3	8.27	437	4	15.5	&
1	15-Apr-97	134607	12.25	8.21	0.47	0.2	77.2	8.26	437	3	15.5	&
1	15-Apr-97	134638	12.25	8.21	0.465	0.2	77.3	8.27	437	2	15.5	&
1	15-Apr-97	134657	12.36	8.19	0.466	0.2	77.4	8.26	437	1	15.4	&
1	15-Apr-97	134719	12.36	8.2	0.469	0.2	79.9	8.52	436	0.1	15.6	&

2	15-Apr-97	135913	12.25	8.2	0.469	0.2	97	10.38	434	5.9	15.6	&
2	15-Apr-97	135949	12.33	8.2	0.468	0.2	85	9.08	433	5	15.5	&
2	15-Apr-97	140017	12.38	8.2	0.467	0.2	82.3	8.78	432	4	15.4	&
2	15-Apr-97	140113	12.44	8.2	0.465	0.2	80.3	8.55	432	3	15.4	&
2	15-Apr-97	140140	12.43	8.19	0.462	0.2	79.8	8.5	432	2	15.4	&
2	15-Apr-97	140232	12.49	8.19	0.462	0.2	77.8	8.28	431	1	15.3	&
3	15-Apr-97	132859	10.95	8.1	0.46	0.2	93.9	10.34	447	7.2	15.7	&
3	15-Apr-97	132929	11.11	8.1	0.464	0.2	85.4	9.37	447	7	15.8	&
3	15-Apr-97	133002	11.77	8.13	0.467	0.2	81.6	8.83	446	6	15.6	&
3	15-Apr-97	133025	11.77	8.14	0.463	0.2	80.8	8.74	445	5	15.6	&
3	15-Apr-97	133054	11.75	8.14	0.464	0.2	79.6	8.61	445	4	15.6	&
3	15-Apr-97	133131	11.78	8.15	0.465	0.2	79	8.55	444	3	15.6	&
3	15-Apr-97	133207	11.93	8.16	0.466	0.2	78.6	8.47	443	2	15.6	&
3	15-Apr-97	133237	12.03	8.16	0.466	0.2	78.7	8.46	443	1	15.6	&
3	15-Apr-97	133253	12.09	8.2	0.467	0.2	78.7	8.45	441	0.1	15.6	&
4	15-Apr-97	131544	10.84	8.05	0.445	0.2	92.4	10.21	435	7.4	15.9	&
4	15-Apr-97	131619	10.84	8.04	0.445	0.2	89.1	9.84	435	7	15.8	&
4	15-Apr-97	131724	11.26	8.06	0.435	0.2	83.9	9.19	433	6	15.8	&
4	15-Apr-97	131814	11.31	8.06	0.433	0.2	80.1	8.75	432	5	15.8	&
4	15-Apr-97	131854	11.33	8.06	0.433	0.2	79	8.63	432	4	15.8	&
4	15-Apr-97	131927	11.47	8.07	0.439	0.2	78.5	8.55	432	3	15.7	&
4	15-Apr-97	131949	11.68	8.08	0.445	0.2	78.4	8.5	431	2	15.7	&
4	15-Apr-97	132009	11.8	8.09	0.447	0.2	78.7	8.5	431	1	15.7	&
4	15-Apr-97	132031	11.79	8.11	0.447	0.2	78.5	8.49	429	0.1	15.7	&
5	15-Apr-97	125522	10.5	7.88	0.398	0.2	98.7	10.99	401	4	16	&
5	15-Apr-97	125558	10.81	7.91	0.41	0.2	93.3	10.32	402	3	15.9	&
5	15-Apr-97	125620	11	7.91	0.41	0.2	91.8	10.1	402	2	15.9	&
5	15-Apr-97	125649	11.13	7.91	0.409	0.2	90.1	9.89	403	1	15.9	&
5	15-Apr-97	125706	11.13	7.94	0.409	0.2	89.2	9.79	402	0.1	15.9	&
1	29-Apr-97	131446	13.57	8.09	0.471	0.2	73	7.58	453	11.2	15	&
1	29-Apr-97	131550	13.57	7.96	0.467	0.2	64.2	6.67	453	11	15	&

1	29-Apr-97	131618	13.75	7.97	0.47	0.2	63.9	6.62	453	10	15	&
1	29-Apr-97	131641	14.73	8.18	0.46	0.2	71.7	7.26	450	9	15.1	&
1	29-Apr-97	131703	14.76	8.23	0.464	0.2	75.2	7.61	448	8	15	&
1	29-Apr-97	131744	14.81	8.25	0.465	0.2	74	7.48	447	7	15	&
1	29-Apr-97	131803	14.81	8.25	0.462	0.2	74.7	7.56	447	6	15	&
1	29-Apr-97	131836	14.84	8.26	0.457	0.2	74.8	7.55	446	5	15	&
1	29-Apr-97	131858	14.88	8.26	0.461	0.2	75.1	7.58	446	4	15	&
1	29-Apr-97	131925	14.91	8.25	0.458	0.2	75.2	7.59	446	3	15	&
1	29-Apr-97	132005	14.93	8.26	0.461	0.2	75.7	7.63	445	2	15	&
1	29-Apr-97	132028	15.01	8.24	0.46	0.2	75.5	7.6	447	1	15	&
1	29-Apr-97	132043	15.11	8.26	0.459	0.2	76.3	7.67	445	0.1	15	&
2	29-Apr-97	135531	15.11	8.21	0.458	0.2	89.4	8.97	466	6.2	15	&
2	29-Apr-97	135623	15.14	8.24	0.46	0.2	81.7	8.2	466	6	15	&
2	29-Apr-97	135647	15.21	8.25	0.462	0.2	80.5	8.06	466	5	15	&
2	29-Apr-97	135720	15.27	8.26	0.459	0.2	79.6	7.97	465	4	15	&
2	29-Apr-97	135805	15.34	8.27	0.461	0.2	79.8	7.98	465	3	15	&
2	29-Apr-97	135906	15.69	8.29	0.458	0.2	79.8	7.92	464	2	15	&
2	29-Apr-97	135944	15.73	8.28	0.458	0.2	78.8	7.81	464	1	15	&
2	29-Apr-97	140011	15.69	8.28	0.459	0.2	79.3	7.86	464	0.1	15	&
3	29-Apr-97	125120	14.24	8.2	0.466	0.2	93.8	9.6	450	7	14.6	&
3	29-Apr-97	125149	14.23	8.17	0.466	0.2	87.4	8.95	451	6	14.6	&
3	29-Apr-97	125225	14.24	8.16	0.465	0.2	83.4	8.54	451	5	14.5	&
3	29-Apr-97	125249	14.28	8.16	0.465	0.2	79.9	8.17	450	4	14.5	&
3	29-Apr-97	125317	14.61	8.2	0.463	0.2	77.4	7.86	449	3	14.5	&
3	29-Apr-97	125349	14.89	8.23	0.462	0.2	77.4	7.81	448	2	14.5	&
3	29-Apr-97	125415	14.93	8.24	0.462	0.2	77.7	7.83	448	1	14.5	&
3	29-Apr-97	125444	14.91	8.23	0.462	0.2	77.4	7.81	448	0.1	14.5	&
4	29-Apr-97	123305	14.96	8.22	0.472	0.2	90.9	9.16	410	4.1	14.5	&
4	29-Apr-97	123330	15.09	8.24	0.472	0.2	88.4	8.88	410	4	14.5	&
4	29-Apr-97	123355	15.2	8.25	0.471	0.2	84.2	8.44	409	2	14.5	&
4	29-Apr-97	123422	15.2	8.25	0.475	0.2	81	8.12	410	1	14.8	&

4	29-Apr-97	123500	15.23	8.25	0.474	0.2	82.5	8.27	410	1	14.5	&
4	29-Apr-97	123520	15.25	8.26	0.472	0.2	82.3	8.24	409	0.1	14.4	&
5	29-Apr-97	121332	13.99	7.77	0.484	0.2	83	8.54	416	3.3	14.6	&
5	29-Apr-97	121416	13.93	7.8	0.481	0.2	80.8	8.32	415	3	14.6	&
5	29-Apr-97	121458	14.26	7.88	0.48	0.2	81.8	8.37	413	2	14.6	&
5	29-Apr-97	121559	16.22	8.27	0.475	0.2	89.8	8.81	403	1	14.6	&
5	29-Apr-97	121634	16.71	8.44	0.473	0.2	95.4	9.26	400	0.1	14.5	&
1	14-May-97	124750	18.44	8.03	0.46	0.2	72.7	6.81	438	11	15.7	&
1	14-May-97	124822	18.65	8.09	0.458	0.2	74.6	6.96	436	10	15.7	&
1	14-May-97	124910	18.8	8.13	0.458	0.2	77.6	7.21	433	9	15.6	&
1	14-May-97	124930	18.81	8.14	0.458	0.2	78.1	7.27	432	8	15.7	&
1	14-May-97	124952	18.92	8.16	0.458	0.2	78	7.23	430	7	15.6	&
1	14-May-97	125047	19	8.19	0.458	0.2	79	7.32	428	6	15.6	&
1	14-May-97	125112	19.05	8.22	0.458	0.2	79.6	7.37	425	5	15.6	&
1	14-May-97	125137	19.09	8.24	0.457	0.2	79.1	7.31	423	4	15.6	&
1	14-May-97	125204	19.15	8.24	0.457	0.2	79.8	7.37	423	3	15.6	&
1	14-May-97	125223	19.28	8.28	0.457	0.2	80.1	7.37	420	2	15.6	&
1	14-May-97	125247	19.68	8.32	0.456	0.2	81	7.4	418	1	15.6	&
1	14-May-97	125307	19.87	8.33	0.455	0.2	82.3	7.49	417	0.1	15.6	&
2	14-May-97	133522	18.69	8.13	0.464	0.2	77.8	7.26	469	6.2	15.7	&
2	14-May-97	133633	18.7	8.09	0.46	0.2	75.1	7	464	6	15.6	&
2	14-May-97	133730	18.85	8.14	0.458	0.2	75.4	7	460	5	15.6	&
2	14-May-97	133808	19.02	8.21	0.457	0.2	75.7	7.01	456	4	15.6	&
2	14-May-97	133908	19.52	8.28	0.456	0.2	82.1	7.52	451	3	15.6	&
2	14-May-97	133945	19.67	8.35	0.456	0.2	83.2	7.6	446	2	15.6	&
2	14-May-97	134054	19.89	8.34	0.455	0.2	83.6	7.61	443	1	15.6	&
2	14-May-97	134130	20.01	8.36	0.456	0.2	84.3	7.65	439	0.1	15.6	&
3	14-May-97	122730	18.94	8.13	0.456	0.2	80.2	7.44	380	6.7	15.7	&
3	14-May-97	122815	18.93	8.16	0.452	0.2	81.6	7.57	379	6	15.5	&
3	14-May-97	122830	18.94	8.15	0.454	0.2	82.7	7.67	379	6	15.6	&
3	14-May-97	122857	18.95	8.17	0.465	0.2	83	7.7	379	5	15.5	&

3	14-May-97	122928	18.97	8.19	0.459	0.2	80.6	7.47	378	4	15.6	&
3	14-May-97	122950	19.05	8.21	0.464	0.2	81.4	7.53	377	3	15.6	&
3	14-May-97	123023	19.12	8.24	0.454	0.2	83.2	7.69	377	2	15.5	&
3	14-May-97	123053	19.44	8.25	0.458	0.2	83.1	7.63	375	1	15.6	&
3	14-May-97	123121	19.7	8.27	0.458	0.2	82.7	7.55	374	0.1	15.5	&
4	14-May-97	120545	18.96	8.15	0.463	0.2	80.7	7.48	380	5.6	15.7	&
4	14-May-97	120642	18.97	8.15	0.462	0.2	81.1	7.51	379	5	15.7	&
4	14-May-97	120725	19.02	8.15	0.463	0.2	82	7.59	379	4	15.7	&
4	14-May-97	120802	19.08	8.16	0.466	0.2	82	7.58	378	3	15.7	&
4	14-May-97	120910	19.23	8.17	0.466	0.2	79.2	7.31	376	2	15.7	&
4	14-May-97	121006	19.63	8.21	0.466	0.2	81.4	7.44	374	1	15.6	&
4	14-May-97	121031	19.84	8.24	0.466	0.2	84.1	7.66	373	0.1	15.7	&
5	14-May-97	114352	19.4	7.96	0.51	0.3	90.8	8.34	378	3.2	15.8	&
5	14-May-97	114557	19.42	8.02	0.518	0.3	81.2	7.46	370	3	15.7	&
5	14-May-97	114642	19.58	8.1	0.491	0.2	83.4	7.63	367	2	15.7	&
5	14-May-97	114729	19.86	8.14	0.511	0.3	84.9	7.73	365	1	15.7	&
5	14-May-97	114816	20.07	8.2	0.505	0.3	85	7.71	361	0.1	15.7	&
1	27-May-97	123357	18.92	7.9	0.478	0.2	75	6.96	448	11.1	15.2	&
1	27-May-97	123427	19.44	7.81	0.462	0.2	57.1	5.24	449	10	15.1	&
1	27-May-97	123450	19.94	7.82	0.47	0.2	55.3	5.03	448	9	15.1	&
1	27-May-97	123513	20.6	7.85	0.457	0.2	56.2	5.05	446	8	15.1	&
1	27-May-97	123545	21.27	7.95	0.465	0.2	61.1	5.41	443	7	15.2	&
1	27-May-97	123637	21.89	8.15	0.464	0.2	68.4	5.98	436	6	15.1	&
1	27-May-97	123702	22.3	8.22	0.462	0.2	70.8	6.14	433	5	15.1	&
1	27-May-97	123728	22.85	8.35	0.459	0.2	75.8	6.51	428	4	15.1	&
1	27-May-97	123807	22.85	8.36	0.459	0.2	77.2	6.63	427	3	15.1	&
1	27-May-97	123842	22.94	8.38	0.463	0.2	79.5	6.82	424	2	15.1	&
1	27-May-97	123912	22.96	8.42	0.46	0.2	80.1	6.87	420	1	15.1	&
1	27-May-97	123930	23.01	8.43	0.462	0.2	79.9	6.84	419	0.1	15.2	&
2	27-May-97	130628	21.26	7.94	0.467	0.2	69.6	6.17	435	6.2	15.2	&
2	27-May-97	130831	22.11	8.19	0.459	0.2	69.8	6.08	425	5	15.1	&

2	27-May-97	130913	22.32	8.26	0.462	0.2	72.7	6.31	422	4	15.1	&
2	27-May-97	130957	22.48	8.34	0.46	0.2	75.4	6.52	419	3	15.1	&
2	27-May-97	131046	22.73	8.37	0.462	0.2	76.5	6.58	417	2	15.1	&
2	27-May-97	131125	22.91	8.42	0.459	0.2	75.3	6.46	413	1	15.1	&
2	27-May-97	131151	22.93	8.43	0.461	0.2	75.2	6.45	411	0.1	15.1	&
3	27-May-97	120210	21.91	8.11	0.473	0.2	59.6	5.21	418	6.7	15.1	&
3	27-May-97	120300	22.12	8.18	0.471	0.2	64.7	5.63	416	6	15.1	&
3	27-May-97	120328	22.47	8.23	0.471	0.2	67.6	5.85	415	5	15.1	&
3	27-May-97	120354	23.01	8.36	0.461	0.2	71.8	6.15	412	4	15.1	&
3	27-May-97	120425	23.46	8.43	0.461	0.2	73.5	6.24	409	3	15.1	&
3	27-May-97	120449	24.21	8.52	0.459	0.2	76.4	6.4	405	2	15.1	&
3	27-May-97	120508	24.43	8.56	0.459	0.2	78.3	6.52	402	1	15.1	&
3	27-May-97	120530	24.5	8.58	0.457	0.2	80.5	6.7	401	0.1	15.1	&
4	27-May-97	114121	22.54	8.09	0.478	0.2	63.7	5.51	413	5.7	15.1	&
4	27-May-97	114156	22.96	8.26	0.478	0.2	72.8	6.24	409	5	15.1	&
4	27-May-97	114252	22.99	8.29	0.477	0.2	74.1	6.35	407	4	15.1	&
4	27-May-97	114400	23.03	8.28	0.48	0.2	75.5	6.46	406	3	15.1	&
4	27-May-97	114509	23.08	8.38	0.474	0.2	73.6	6.29	403	2	15.1	&
4	27-May-97	114616	23.32	8.43	0.467	0.2	76.4	6.5	401	1	15.1	&
4	27-May-97	114658	23.36	8.46	0.467	0.2	77.9	6.63	398	0.1	15.1	&
5	27-May-97	112447	23.95	8.27	0.486	0.2	95.7	8.05	367	3	15.3	&
5	27-May-97	112624	24.03	8.33	0.487	0.2	89.5	7.52	364	2	15.2	&
5	27-May-97	112710	24.12	8.35	0.487	0.2	86	7.21	363	1	15.2	&
5	27-May-97	112747	24.11	8.35	0.487	0.2	83.6	7.01	363	0.1	15.2	&
1	24-Jun-97	125844	20.07	7.46	0.466	0.2	46	4.17	331	9.7		
1	24-Jun-97	125936	20.85	7.48	0.445	0.2	44.2	3.95	312	9		
1	24-Jun-97	130113	26.45	8.36	0.428	0.2	88.8	7.14	298	8		
1	24-Jun-97	130135	26.5	8.38	0.426	0.2	90.2	7.24	300	7		
1	24-Jun-97	130202	26.54	8.38	0.427	0.2	90.4	7.25	301	6		
1	24-Jun-97	130229	26.62	8.4	0.423	0.2	91.7	7.35	303	5		
1	24-Jun-97	130318	26.64	8.41	0.42	0.2	92.2	7.39	306	4		

1	24-Jun-97	130358	26.69	8.43	0.42	0.2	92.8	7.43	308	3		
1	24-Jun-97	130451	26.69	8.43	0.42	0.2	92.7	7.42	310	2		
1	24-Jun-97	130600	26.75	8.44	0.423	0.2	92.6	7.4	313	1		
1	24-Jun-97	130652	26.75	8.47	0.422	0.2	92.5	7.39	313	0.1		
2	24-Jun-97	132838	26.88	8.43	0.421	0.2	99.5	7.93	379	5.8		
2	24-Jun-97	132925	26.96	8.44	0.421	0.2	97.5	7.77	377	5		
2	24-Jun-97	133001	27.02	8.45	0.421	0.2	96.8	7.7	376	4		
2	24-Jun-97	133046	27.07	8.46	0.42	0.2	96.5	7.67	375	3		
2	24-Jun-97	133132	27.15	8.47	0.42	0.2	95.5	7.58	374	2		
2	24-Jun-97	133214	27.16	8.45	0.42	0.2	95.6	7.59	374	1		
2	24-Jun-97	133238	27.2	8.51	0.42	0.2	94.8	7.52	370	0.1		
3	24-Jun-97	123143	23.92	7.52	0.448	0.2	51.3	4.32	397	6.9		
3	24-Jun-97	123252	24.53	7.61	0.435	0.2	56	4.66	394	6		
3	24-Jun-97	123430	25.53	7.96	0.436	0.2	76.9	6.29	385	5		
3	24-Jun-97	123556	26.01	8.11	0.429	0.2	83.2	6.74	379	4		
3	24-Jun-97	123654	26.41	8.27	0.425	0.2	88.5	7.12	374	3		
3	24-Jun-97	123750	26.48	8.3	0.425	0.2	89.4	7.18	372	2		
3	24-Jun-97	123850	26.48	8.3	0.425	0.2	89	7.15	370	1		
3	24-Jun-97	123918	26.47	8.33	0.424	0.2	89	7.15	369	0.1		
4	24-Jun-97	120001	26.2	8.12	0.429	0.2	93.7	7.56	374	3.9		
4	24-Jun-97	120028	26.29	8.16	0.428	0.2	94.1	7.58	372	3		
4	24-Jun-97	120126	26.32	8.17	0.428	0.2	97.6	7.86	370	2		
4	24-Jun-97	120207	26.32	8.18	0.427	0.2	97.4	7.85	369	1		
4	24-Jun-97	120241	26.34	8.2	0.427	0.2	97.6	7.86	368	0.1		
5	24-Jun-97	114607	25.21	7.72	0.442	0.2	76.6	6.3	368	3		
5	24-Jun-97	114717	25.9	7.93	0.432	0.2	87.7	7.12	360	2		
5	24-Jun-97	114811	26.2	8.02	0.431	0.2	90.3	7.29	356	1		
5	24-Jun-97	114853	26.26	8.03	0.432	0.2	90.8	7.32	354	0.1		
1	08-Jul-97	142524	23.73	7.61	0.445	0.2	55	4.64	203	9.4	&	
1	08-Jul-97	142611	25.98	7.87	0.433	0.2	57.5	4.66	216	8	&	
1	08-Jul-97	142638	27.4	8.49	0.425	0.2	89.2	7.05	225	7	&	

1	08-Jul-97	142723	27.65	8.54	0.425	0.2	95.2	7.49	245	6	&	
1	08-Jul-97	142750	27.85	8.61	0.424	0.2	99.9	7.83	252	5	&	
1	08-Jul-97	142830	27.94	8.63	0.426	0.2	101.9	7.97	261	4	&	
1	08-Jul-97	142907	28.17	8.63	0.424	0.2	102.4	7.98	269	3	&	
1	08-Jul-97	142931	28.39	8.64	0.426	0.2	103	8	272	2	&	
1	08-Jul-97	142957	28.48	8.63	0.425	0.2	102.4	7.93	276	1	&	
1	08-Jul-97	143017	28.54	8.66	0.423	0.2	102.4	7.92	277	0.1	&	
2	08-Jul-97	133204	26.71	7.9	0.441	0.2	63.2	5.06	398	5.4	&	
2	08-Jul-97	133246	27.4	8.38	0.43	0.2	84.3	6.66	387	4	&	
2	08-Jul-97	133311	27.62	8.5	0.427	0.2	87.5	6.89	383	3	&	
2	08-Jul-97	133354	28.36	8.67	0.421	0.2	99.3	7.71	376	2	&	
2	08-Jul-97	133417	28.81	8.7	0.422	0.2	101.4	7.81	372	1	&	
2	08-Jul-97	133444	28.96	8.7	0.421	0.2	101.5	7.8	369	0.1	&	
3	08-Jul-97	140214	26.52	8.21	0.43	0.2	76.6	6.14	380	6.1	&	
3	08-Jul-97	140301	26.86	8.4	0.425	0.2	87.2	6.95	375	5	&	
3	08-Jul-97	140338	27.25	8.46	0.423	0.2	90.3	7.15	372	4	&	
3	08-Jul-97	140419	27.71	8.58	0.427	0.2	94.5	7.43	368	3	&	
3	08-Jul-97	140456	27.75	8.6	0.427	0.2	97.4	7.65	366	2	&	
3	08-Jul-97	140551	28.04	8.61	0.427	0.2	94.6	7.39	364	1	&	
3	08-Jul-97	140614	28.15	8.63	0.424	0.2	95.2	7.42	362	0.1	&	
4	08-Jul-97	123655	26.86	7.99	0.443	0.2	63.7	5.08	333	4.1	&	
4	08-Jul-97	123926	27.44	8.44	0.428	0.2	85.3	6.73	324	3	&	
4	08-Jul-97	124023	27.6	8.44	0.431	0.2	85.2	6.71	323	2	&	
4	08-Jul-97	124145	27.75	8.44	0.428	0.2	84.5	6.64	323	1	&	
4	08-Jul-97	124245	27.86	8.43	0.428	0.2	86.5	6.78	323	0.1	&	
5	08-Jul-97	122140	26.56	7.73	0.434	0.2	58.2	4.67	294	3.5	&	
5	08-Jul-97	122248	26.62	7.82	0.437	0.2	62.5	5.01	292	3	&	
5	08-Jul-97	122411	26.96	8.28	0.433	0.2	82.1	6.54	286	2	&	
5	08-Jul-97	122509	27.35	8.36	0.434	0.2	87.4	6.91	286	1	&	
5	08-Jul-97	122712	27.73	8.39	0.433	0.2	91.2	7.16	290	0.1	&	
1	28-Jul-97	121917	25.52	7.43	0.399	0.2	49.1	4.01	110	10.5	&	

1	28-Jul-97	121958	25.98	7.47	0.39	0.2	46.3	3.75	96	10	&	
1	28-Jul-97	122032	26.34	7.49	0.402	0.2	45.2	3.64	96	9	&	
1	28-Jul-97	122057	26.69	7.51	0.406	0.2	43.2	3.46	98	8	&	
1	28-Jul-97	122131	27.25	7.54	0.409	0.2	44.9	3.55	107	7	&	
1	28-Jul-97	122157	27.72	7.56	0.413	0.2	47.2	3.71	114	6	&	
1	28-Jul-97	122230	28.39	7.59	0.414	0.2	47.8	3.71	139	5	&	
1	28-Jul-97	122312	28.93	7.84	0.414	0.2	50	3.84	193	4	&	
1	28-Jul-97	122404	29.48	8.37	0.409	0.2	50.6	3.85	233	3	&	
1	28-Jul-97	122507	29.65	8.48	0.406	0.2	58.1	4.41	255	2	&	
1	28-Jul-97	122549	29.69	8.49	0.407	0.2	58.1	4.4	265	1	&	
1	28-Jul-97	122629	28.45	7.97	0.008	0	60.5	4.7	285	0.1	&	
2	28-Jul-97	124932	27.71	7.54	0.42	0.2	52.3	4.11	144	6	&	
2	28-Jul-97	125101	28.61	7.59	0.421	0.2	49.8	3.85	192	5	&	
2	28-Jul-97	125153	29.24	7.79	0.417	0.2	48.8	3.73	233	4	&	
2	28-Jul-97	125255	30.18	8.31	0.411	0.2	54.5	4.1	259	3	&	
2	28-Jul-97	125407	30.63	8.61	0.4	0.2	60.6	4.52	274	2	&	
2	28-Jul-97	125448	30.77	8.65	0.399	0.2	59.9	4.46	280	1	&	
2	28-Jul-97	125532	27.09	8.12	0.006	0	64.1	5.1	303	0.1	&	
3	28-Jul-97	120203	27.1	7.5	0.41	0.2	60	4.76	174	6.4	&	
3	28-Jul-97	120258	27.3	7.52	0.41	0.2	55.8	4.41	172	6	&	
3	28-Jul-97	120402	29.06	7.97	0.417	0.2	54.8	4.2	236	5	&	
3	28-Jul-97	120432	29.68	8.26	0.41	0.2	56	4.25	246	4	&	
3	28-Jul-97	120508	29.84	8.49	0.404	0.2	59.6	4.51	256	3	&	
3	28-Jul-97	120531	29.89	8.58	0.403	0.2	62.3	4.71	260	2	&	
3	28-Jul-97	120603	30.18	8.62	0.406	0.2	62.9	4.73	268	1	&	
3	28-Jul-97	120703	26.68	8.04	0.007	0	70.6	5.66	291	0.1	&	
4	28-Jul-97	114444	29.48	7.74	0.405	0.2	58.1	4.42	366	5.2	&	
4	28-Jul-97	114558	29.88	8.11	0.404	0.2	62.8	4.75	358	5	&	
4	28-Jul-97	114704	30.19	8.47	0.401	0.2	65.3	4.91	350	4	&	
4	28-Jul-97	114809	30.41	8.49	0.402	0.2	65.8	4.93	346	3	&	
4	28-Jul-97	114853	30.62	8.53	0.399	0.2	66.7	4.98	345	2	&	

4	28-Jul-97	115014	30.67	8.53	0.399	0.2	66.2	4.94	345	1	&	
4	28-Jul-97	115100	30.53	8.53	0.171	0.1	65.4	4.9	346	0.1	&	
5	28-Jul-97	111848	29.89	7.99	0.398	0.2	67.4	5.1	386	3.1	&	
5	28-Jul-97	112019	29.95	8.17	0.394	0.2	67	5.06	377	2	&	
5	28-Jul-97	112129	30.46	8.27	0.399	0.2	70.8	5.3	370	1	&	
5	28-Jul-97	112230	25.5	7.97	0.007	0	79.4	6.5	362	0.1	&	
1	12-Aug-97	133042	24.58	7.4	0.405	0.2	34.3	2.85	11	10.9	&	
1	12-Aug-97	133202	25.72	7.52	0.395	0.2	34	2.77	60	10	&	
1	12-Aug-97	133330	25.88	7.58	0.395	0.2	37.9	3.07	117	9	&	
1	12-Aug-97	133410	25.96	7.61	0.398	0.2	39.7	3.22	136	8	&	
1	12-Aug-97	133434	26.02	7.63	0.387	0.2	40.5	3.28	144	7	&	
1	12-Aug-97	133508	26.13	7.66	0.392	0.2	42.2	3.41	158	6	&	
1	12-Aug-97	133608	26.35	7.68	0.393	0.2	43.9	3.53	177	5	&	
1	12-Aug-97	133639	26.79	7.84	0.393	0.2	51.4	4.11	188	4	&	
1	12-Aug-97	133726	27.26	8.4	0.385	0.2	71.7	5.67	205	3	&	
1	12-Aug-97	133800	27.34	8.49	0.382	0.2	76.2	6.02	215	2	&	
1	12-Aug-97	133835	27.76	8.67	0.378	0.2	85	6.67	221	1	&	
1	12-Aug-97	133857	28.31	8.7	0.379	0.2	89.8	6.98	224	0.1	&	
2	12-Aug-97	140745	26.15	7.56	0.392	0.2	52.4	4.23	322	5.6	&	
2	12-Aug-97	140813	26.27	7.61	0.391	0.2	51.2	4.13	320	5	&	
2	12-Aug-97	140839	26.65	7.71	0.39	0.2	52.6	4.21	317	4	&	
2	12-Aug-97	140922	27.65	8.59	0.381	0.2	86.2	6.78	298	3	&	
2	12-Aug-97	140946	27.72	8.62	0.38	0.2	88.4	6.94	297	2	&	
2	12-Aug-97	141019	28.31	8.69	0.38	0.2	91	7.07	294	1	&	
2	12-Aug-97	141049	28.45	8.68	0.38	0.2	94.9	7.36	295	0.1	&	
3	12-Aug-97	130738	26.04	7.56	0.388	0.2	46.1	3.73	364	6.6	&	
3	12-Aug-97	130810	26.14	7.6	0.393	0.2	47.4	3.83	363	6	&	
3	12-Aug-97	130925	26.68	7.99	0.385	0.2	63.8	5.1	355	5	&	
3	12-Aug-97	131047	27.04	8.31	0.381	0.2	74.4	5.91	346	4	&	
3	12-Aug-97	131137	27.15	8.46	0.382	0.2	78.5	6.23	343	3	&	
3	12-Aug-97	131234	27.19	8.5	0.38	0.2	80.9	6.41	340	2	&	

3	12-Aug-97	131348	27.59	8.66	0.379	0.2	91.1	7.17	335	1	&	
3	12-Aug-97	131430	28.47	8.62	0.381	0.2	89.7	6.96	334	0.1	&	
4	12-Aug-97	124809	26	7.52	0.399	0.2	48.9	3.96	359	6.9	&	
4	12-Aug-97	124854	26.17	7.62	0.393	0.2	51.8	4.18	357	6	&	
4	12-Aug-97	124944	26.29	7.69	0.39	0.2	53.4	4.3	355	5	&	
4	12-Aug-97	125030	26.31	7.73	0.401	0.2	54.6	4.4	354	4	&	
4	12-Aug-97	125114	26.48	7.82	0.391	0.2	59	4.74	352	3	&	
4	12-Aug-97	125214	27.06	8.42	0.38	0.2	78.1	6.21	339	2	&	
4	12-Aug-97	125256	27.28	8.62	0.377	0.2	87	6.88	331	1	&	
4	12-Aug-97	125334	28.31	8.67	0.378	0.2	91.5	7.11	327	0.1	&	
5	12-Aug-97	123033	26.54	7.53	0.353	0.2	75.8	6.08	358	2.9	&	
5	12-Aug-97	123404	26.67	7.76	0.373	0.2	64.6	5.17	350	2	&	
5	12-Aug-97	123523	26.83	8.07	0.377	0.2	70.7	5.65	343	1	&	
5	12-Aug-97	123613	28.27	8.49	0.367	0.2	86.2	6.71	331	0.1	&	
1	26-Aug-97	114327	26.52	7.61	0.375	0.2	47.3	3.8	416	10.8	&	
1	26-Aug-97	114406	26.74	7.71	0.375	0.2	53	4.24	414	10	&	
1	26-Aug-97	114449	26.9	7.84	0.38	0.2	58.9	4.69	412	9	&	
1	26-Aug-97	114522	26.98	7.92	0.378	0.2	63.3	5.04	409	8	&	
1	26-Aug-97	114600	27.17	8.27	0.378	0.2	73.6	5.84	402	7	&	
1	26-Aug-97	114640	27.33	8.43	0.372	0.2	84	6.65	395	6	&	
1	26-Aug-97	114712	27.4	8.55	0.373	0.2	93.2	7.36	390	5	&	
1	26-Aug-97	114800	27.43	8.56	0.375	0.2	96.9	7.65	388	4	&	
1	26-Aug-97	114859	27.46	8.59	0.375	0.2	95.8	7.56	386	3	&	
1	26-Aug-97	114943	27.53	8.66	0.373	0.2	100.3	7.91	383	2	&	
1	26-Aug-97	115021	27.67	8.67	0.372	0.2	101.9	8.01	382	1	&	
1	26-Aug-97	115107	23.05	7.78	0.009	0	112.1	9.61	422	0.1	&	
2	26-Aug-97	121704	27.16	8.13	0.379	0.2	70.5	5.59	408	5.7	&	
2	26-Aug-97	121729	27.23	8.29	0.377	0.2	76.8	6.09	405	5	&	
2	26-Aug-97	121825	27.42	8.49	0.374	0.2	89	7.03	397	4	&	
2	26-Aug-97	121910	27.68	8.66	0.371	0.2	100.9	7.93	390	3	&	
2	26-Aug-97	121932	27.73	8.7	0.372	0.2	102.7	8.07	389	2	&	

2	26-Aug-97	122002	28.19	8.75	0.369	0.2	105.7	8.23	386	1	&	
2	26-Aug-97	122111	23.47	8.09	0.008	0	109.3	9.29	424	0.1	&	
3	26-Aug-97	111709	26.75	8.34	0.379	0.2	87.6	7	392	6.8	&	
3	26-Aug-97	111752	26.86	8.43	0.377	0.2	91	7.26	390	6	&	
3	26-Aug-97	111824	26.93	8.44	0.376	0.2	93	7.41	389	5	&	
3	26-Aug-97	111850	26.98	8.47	0.376	0.2	94.3	7.5	389	4	&	
3	26-Aug-97	111918	27.04	8.49	0.375	0.2	95	7.55	388	3	&	
3	26-Aug-97	111950	27.13	8.57	0.375	0.2	95.7	7.59	386	2	&	
3	26-Aug-97	112022	27.29	8.62	0.373	0.2	100.2	7.93	384	1	&	
3	26-Aug-97	112114	22.2	7.83	0.009	0	114.7	9.99	431	0.1	&	
4	26-Aug-97	105814	26.82	8.04	0.369	0.2	78.8	6.29	443	4.9	&	
5	26-Aug-97	103519	26.2	7.76	0.338	0.2	92.6	7.47	504	3.5	&	
5	26-Aug-97	103554	26.3	7.88	0.345	0.2	92.8	7.48	501	3	&	
5	26-Aug-97	103629	26.49	7.98	0.353	0.2	92.7	7.44	497	2	&	
5	26-Aug-97	103704	26.65	8.05	0.353	0.2	95.8	7.67	494	1	&	
5	26-Aug-97	103748	22.85	7.13	0.009	0	127.3	10.95	519	0.1	&	
1	16-Sep-97	111240	25.36	7.77	0.425	0.2	18.3	1.44	361	10.4	&	
1	16-Sep-97	111318	25.44	7.77	0.423	0.2	25.6	2	357	10	&	
1	16-Sep-97	111448	25.76	8	0.422	0.2	49.1	3.82	344	9	&	
1	16-Sep-97	111554	26.2	8.37	0.419	0.2	89.1	6.88	329	8	&	
1	16-Sep-97	111648	26.24	8.39	0.419	0.2	92	7.09	324	7	&	
1	16-Sep-97	111758	26.27	8.42	0.419	0.2	91.8	7.07	321	6	&	
1	16-Sep-97	111839	26.3	8.44	0.42	0.2	95.3	7.34	319	5	&	
1	16-Sep-97	111923	26.36	8.47	0.418	0.2	98.2	7.55	317	4	&	
1	16-Sep-97	112027	26.38	8.48	0.417	0.2	98	7.54	314	3	&	
1	16-Sep-97	112057	26.42	8.5	0.418	0.2	101.8	7.83	313	2	&	
1	16-Sep-97	112200	26.44	8.51	0.418	0.2	103.8	7.98	311	1	&	
1	16-Sep-97	112247	26.42	8.51	0.417	0.2	104.7	8.05	310	0.1	&	
2	16-Sep-97	114313	26.13	8.03	0.424	0.2	52.8	4.08	338	5.8	&	
2	16-Sep-97	114420	26.57	8.49	0.418	0.2	93	7.13	321	5	&	
2	16-Sep-97	114509	26.7	8.57	0.417	0.2	104.6	8	316	4	&	

2	16-Sep-97	114554	26.74	8.58	0.418	0.2	110	8.41	313	3	&	
2	16-Sep-97	114622	26.84	8.61	0.418	0.2	113.3	8.64	311	2	&	
2	16-Sep-97	114711	26.85	8.62	0.417	0.2	113.2	8.63	309	1	&	
2	16-Sep-97	114737	24.65	10.17	0.0009	0	115.1	9.15	280	0.1	&	
3	16-Sep-97	105229	25.4	8.02	0.424	0.2	71.5	5.6	347	6.5	&	
3	16-Sep-97	105329	25.46	8.04	0.427	0.2	72	5.63	343	6	&	
3	16-Sep-97	105441	25.5	8.03	0.424	0.2	68.2	5.33	340	5	&	
3	16-Sep-97	105547	25.58	8.01	0.42	0.2	62.7	4.89	339	4	&	
3	16-Sep-97	105650	25.64	8.02	0.421	0.2	61.7	4.81	336	3	&	
3	16-Sep-97	105747	25.89	8.14	0.42	0.2	71	5.51	330	2	&	
3	16-Sep-97	105848	25.98	8.2	0.422	0.2	77.3	5.99	327	1	&	
3	16-Sep-97	105933	25.97	8.21	0.421	0.2	77.5	6	325	0.1	&	
4	16-Sep-97	103612	25.65	7.95	0.423	0.2	68.8	5.36	336	3.8	&	
4	16-Sep-97	103653	25.68	8.04	0.423	0.2	72.8	5.67	332	3	&	
4	16-Sep-97	103750	25.74	8.15	0.423	0.2	71.9	5.6	325	2	&	
4	16-Sep-97	103843	25.79	8.17	0.423	0.2	71.4	5.55	323	1	&	
5	16-Sep-97	101935	25.33	7.85	0.43	0.2	50.8	3.98	297	3	&	
5	16-Sep-97	102106	25.37	7.91	0.428	0.2	55.1	4.32	296	2	&	
5	16-Sep-97	102236	25.55	7.94	0.431	0.2	54.6	4.26	296	1	&	
5	16-Sep-97	102320	24.38	9.2	0.0018	0	74.7	5.97	310	0.1	&	
1	30-Sep-97	131451	22.53	7.89	0.384	0.2	52.8	4.38	415	9.5		
1	30-Sep-97	131542	22.53	7.87	0.38	0.2	51	4.23	415	9		
1	30-Sep-97	131707	22.57	7.78	0.382	0.2	40.9	3.39	415	8		
1	30-Sep-97	131800	22.59	7.78	0.381	0.2	41	3.4	413	7		
1	30-Sep-97	131840	22.62	7.79	0.38	0.2	42.1	3.49	412	6		
1	30-Sep-97	131928	22.64	7.83	0.38	0.2	47.8	3.96	410	5		
1	30-Sep-97	132003	22.7	7.84	0.382	0.2	48.9	4.05	409	4		
1	30-Sep-97	132048	22.8	7.86	0.383	0.2	49.8	4.11	407	3		
1	30-Sep-97	132123	22.86	7.89	0.381	0.2	53.8	4.44	406	2		
1	30-Sep-97	132221	23.51	8.09	0.383	0.2	72.1	5.87	399	1		
1	30-Sep-97	132250	23.74	8.11	0.383	0.2	75.7	6.14	397	0.1		

2	30-Sep-97	134356	22.73	7.97	0.385	0.2	57.1	4.72	402	5.6		
2	30-Sep-97	134505	22.82	8.02	0.381	0.2	65.4	5.4	397	5		
2	30-Sep-97	134603	22.95	8.06	0.384	0.2	66.6	5.48	394	4		
2	30-Sep-97	134708	23.05	8.04	0.386	0.2	66.8	5.49	392	3		
2	30-Sep-97	134812	23.4	8.1	0.381	0.2	70.1	5.73	389	2		
2	30-Sep-97	134902	23.8	8.15	0.382	0.2	76.6	6.21	386	1		
2	30-Sep-97	134948	24.05	8.19	0.382	0.2	81.2	6.55	382	0.1		
3	30-Sep-97	125846	22.28	8.08	0.385	0.2	69.3	5.78	419	5.9		
3	30-Sep-97	125934	22.55	8.06	0.385	0.2	66.6	5.52	418	5		
3	30-Sep-97	130047	22.61	8.09	0.386	0.2	67.4	5.59	413	4		
3	30-Sep-97	130132	22.68	8.08	0.385	0.2	68.1	5.64	412	3		
3	30-Sep-97	130237	22.7	8.07	0.382	0.2	65	5.38	410	2		
3	30-Sep-97	130337	23	8.11	0.382	0.2	71.2	5.86	407	1		
3	30-Sep-97	130453	23.43	8.17	0.382	0.2	78.7	6.43	402	0.1		
4	30-Sep-97	123832	21.45	7.8	0.369	0.2	46.4	3.93	403	6.8		
4	30-Sep-97	123947	21.56	7.82	0.366	0.2	50.7	4.29	400	6		
4	30-Sep-97	124117	21.84	8	0.367	0.2	65.5	5.51	391	5		
4	30-Sep-97	124155	22.05	8.03	0.375	0.2	68.7	5.76	389	4		
4	30-Sep-97	124229	22.25	8.06	0.379	0.2	67.5	5.64	388	3		
4	30-Sep-97	124317	22.28	8.09	0.379	0.2	69.5	5.8	386	2		
4	30-Sep-97	124354	22.65	8.21	0.378	0.2	77.8	6.45	382	1		
4	30-Sep-97	124413	23.31	8.26	0.379	0.2	86.4	7.07	379	0.1		
5	30-Sep-97	122402	21.45	8	0.352	0.2	70.1	5.94	382	2.8		
5	30-Sep-97	122441	21.64	8.13	0.356	0.2	82.6	6.98	376	2		
5	30-Sep-97	122531	22.41	8.27	0.368	0.2	88.1	7.33	371	1		
5	30-Sep-97	122632	23.39	8.38	0.362	0.2	100.6	8.22	366	0.1		

MIN	6.9	0.0009	0	1.7	0.15
MAX	10.17	0.732	0.4	145.3	20.42
avg	8.13	0.41	0.20	82.88	8.08
med	8.16	0.43	0.20	87.60	7.87

Appendix D

Sediment Quality in Arcadia Lake, Oklahoma

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SEDIMENT QUALITY IN ARCADIA LAKE, OKLAHOMA

Executive Summary

In March 1997 EPA Region 6 assisted the Oklahoma Water Resources Board with an assessment of sediment quality of Arcadia Lake. This lake is within an urban watershed north of Oklahoma City, with two primary tributaries, Spring Creek and Deep Fork. Available historical data indicated potential sediment quality problems in several portions of the lake As part of an EPA-funded Clean Lakes Diagnostic/Feasibility Study, the state sought to ascertain the degree of sediment contamination within the lake. A cooperative EPA/State project was conducted to address this question through the use of sediment chemical analyses and toxicity testing.

Three samples were collected per site using an Ekman grab and subsequently composited. Ten sites throughout the lake, and an additional site at a reference lake (Liberty Lake), were sampled. Samples were chemically analyzed by the EPA Houston Laboratory for TOC, grain size, priority pollutants--including volatiles, semi-volatiles, PCBs, pesticides and heavy metals. Sediment toxicity tests were also conducted for five sites at the EPA lab and included elutriate testing using 7-day chronic Ceriodaphnia and fathead minnow embryo/larval tests. Elutriates were prepared by diluting one part sediment to four parts water, shaking for 24 hrs, and siphoning off the overlying water. These tests were used as a cost-effective alternative to standard bulk sediment tests.

Chemical data were evaluated using available screening levels, including NOAA Effects Range-Low (ER-L) and Effects Range-Median (ER-M) values, Ontario's Lowest and Severe Effects Levels (LEL, SEL), Apparent Effects Thresholds Low and High (AET-L, AET-H), EPA sediment quality advisory levels (SQAL) and sediment quality criteria (SQC). Sediment TOC ranged from 0.17 % to 2.88%. ER-M and SEL values were not exceeded for any parameters, indicating that the sediments were not severely contaminated. SQC and SQAL were also not exceeded, although values were available for only four of the contaminants detected. Table 1 summarizes the analytical results. No significant chronic toxicity was observed to Ceriodaphnia and fathead minows for the five stations tested.

Overall the data indicate significant, but relatively low level of sediment contamination. There was a preponderance of PAHs in lake sector B. Metals were most elevated in sector C, as was Bis(2ethylhexyl)phthalate. These sectors comprise the upper and lower Deep Fork arm of the lake. Cadmium was found throughout (except the two tributary sites), including the Liberty Lake reference site. While additional toxicity tests would aid in determining sediment quality the existing data indicate that pollutants, in combination, are not present at toxic levels.

The project demonstrated that sediment contaminant levels are a good indicator of nonpoint pollution in this urban watershed. The data indicate that nonpoint source controls to reduce pollutant loads (metals, PAHs) would benefit sediment quality and reduce risks to benthic organisms. Concentrating on watershed protection efforts in the Deep Fork portion of the watershed would be most appropriate to enhance and protect sediment quality in Arcadia Lake.

Comparison of Sediment Data with Screening Values

	STATION									
PARAMETER	B-2	B-6	C-6	D-3	E-6	E-8	E-9	F-9	F-13	L-178
Arsenic			ab							abab
Cadmium	ab	ab	ab	ab	a	a	ab	ab	ab	ab
Chromium			a							
Copper			a							
Lead										ab
Nickel			ab							
Dieldrin	a	a								
Fluoranthene		b								
Phenanthrene	b	b								
Benzo(ghi)Perylene	a	a								
Benzo(k)Fluoranthene	a									
Chrysene		a								
Ideno(1,2,3-cd)Pyrene	a	a								
Pyrene	a	a								
Dieldrin	a	a								
Bis(2-ethylhexyl) Phthalate		c								

a LEL Exceeded
b ER-L Exceeded
c AET-L and AET-H Exceeded

Introduction

Background

A sediment quality survey was conducted on Arcadia Lake near Oklahoma City, Oklahoma, in March, 1997. Follow-up sampling was subsequently conducted in two tributaries of the Lake, Spring Creek and Deep Fork, in July, 1997. This lake is located in an urban watershed and is heavily influenced by nonpoint pollutant sources. This survey was conducted in conjunction with a Clean Lakes Diagnostic/Feasibility Study being carried out by the Oklahoma Water Resources Board. Previous sediment data collected by other investigators indicated that metals may be elevated in some portions of the Lake. Since the lake was formed, fish tissue levels of chlordane have been elevated.

Purpose

The purpose of this study was to collect additional sediment quality data to determine if contamination by metals and organic chemicals is a concern. This was a cooperative project between the Oklahoma Water Resource Board and the U.S. Environmental Protection Agency. It was a case study under the EPA's Sediment Quality Assessment Project which provided support to states to specifically address sediment quality concerns during FY96-98.

Methods and Materials

Site Location

As part of the Clean Lakes project, the lake was divided into sectors (see **Figure 1**). Based upon the historical data, eight stations on Arcadia Lake, and two tributary stations (Spring Creek and Deep Fork) were selected. In addition, a relatively unimpacted station was selected in a nearby watershed, Liberty Lake, to serve as a reference site. Sampling sites are listed in **Table 1**.

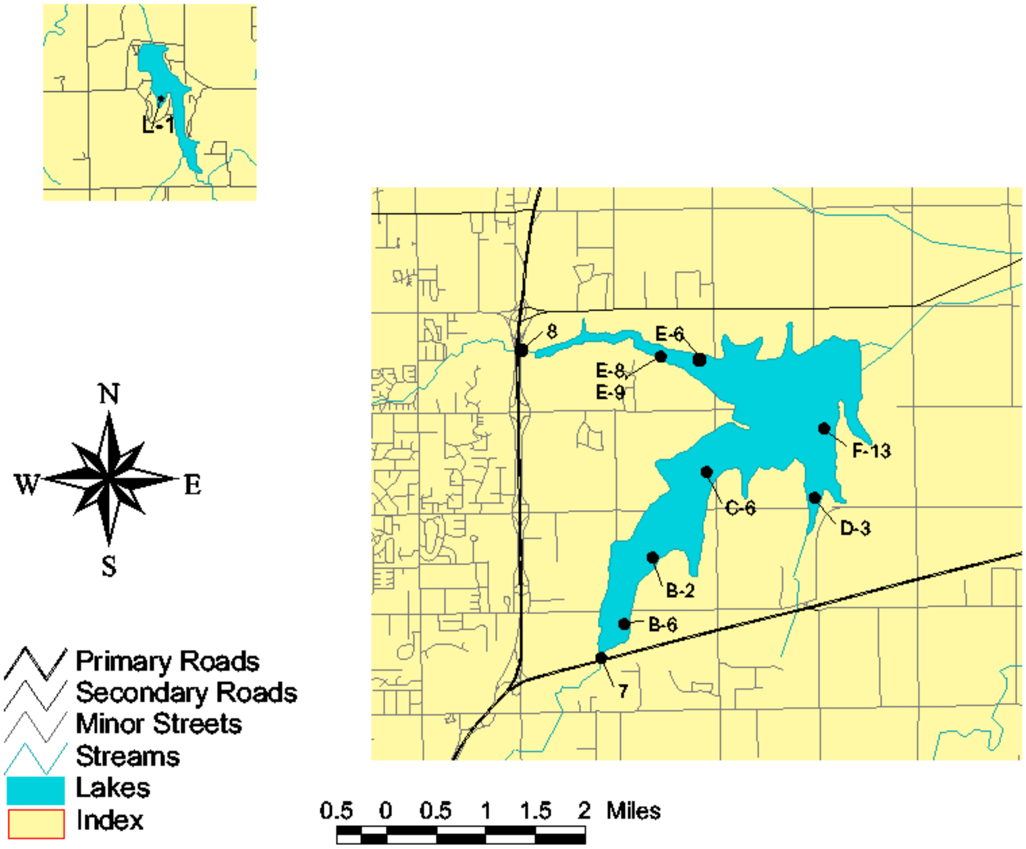
Table 1 Stations Sampled for Arcadia Lake Sediment Toxicity Study

Station	Description	Latitude	Longitude
B-2	Upper Deep Fork arm, 100 M from East Bank	97 24 12.01	35 36 48.99
B-6	Upper Deep Fork Arm, Deep Fork Outlet	97 24 12.18	35 36 49.07
C-6	Deep Fork Arm Cove, Inside Cove 10 M from Bank	97 23 07.32	35 37 33.96
D-3	Upper Tinker Creek Arm, 2 M from Bank	97 22 00.8	35 37 34.48
E-6	Spring Creek Arm, Midportion, Cove, 50 M from Bank	97 23 40.11	35 38 44.45
E-8	Upper Spring Creek Arm, 100 M from Both Banks	97 23 14.24	35 38 42.91
E-9	Upper Spring Creek Arm, 100 M from Both Banks	97 23 14.24	35 38 42.91
F-13	Central Pool, 50 M from East Bank	97 24 07.13	35 38 02.71
L-1	Liberty Lake, SW Cove, 20 M from West Bank (Ref Site)	97 27 54.58	35 47 45.93

7	Deep Fork River, Hefner Road Bridge	97 25 36.20	35 34 48.04
8	Spring Creek, I-35 Access Road, Sooner	97 25 27.21	35 38 49.92

Figure 1.

Detail of Arcadia and Liberty Lakes, Oklahoma



Sampling

Lake sites were sampled by boat on March 25, 1997 and tributary sites were sampled by wading on July 28 and 31, 1997. Whole sediment samples were collected using an Ekman grab. Field reporting forms were completed for each station sampled. These forms included information on location, collectors, appearance of the sediment, etc. A minimum of three grab samples were collected and composited for each site. Samples were placed in pre-cleaned sample jars and immediately placed on ice. Protective wrapping was applied and the samples were shipped to the laboratory using an overnight courier.

Analysis

Samples were chemically analyzed for conventional parameters (total organic carbon, grain size analysis), and priority pollutants including heavy metals, volatile, and semi-volatile organics. All analyses were performed at the EPA Houston Laboratory using standard methods. These analytical methods are contained in the Laboratory's standard operating procedures (SOPs) prepared by the laboratory.

Toxicity Testing

Sediment elutriate toxicity testing was conducted by the EPA Houston Laboratory for stations B-2, C-6, D-3, F-8 and L-1. This testing involved use of Ceriodaphnia dubia and fathead minnow chronic tests as described in **EPA** (**1994**). Elutriates were prepared by diluting one part sediment to four parts water, shaking for 24 hours, allowing the mixture to settle for 24 hours, and siphoning off the overlying water. Test organism were exposed to the eluate for 7 days. This testing served to supplement the chemical analyses and assess the biological availability of sediment-associated contaminants.

Data Assessment

Sediment chemistry results were compared with several sediment chemistry screening values which were utilized in the National Sediment Quality Survey (**EPA 1997**). These screening values include NOAA's effects range low and median (ER-L/ER-M), Ontario's lowest and severe effect levels (LEL/SEL), EPA's sediment quality advisory levels (SQAL) or sediment quality criteria (SQC); and the apparent effects threshold low and high (AET-L/AET-H). These screening levels are discussed in **U.S. EPA** (**1997**) and briefly described in Appendix A. SQC are scientifically supportable and are frequently used, however, relatively few SQC have been developed. Multiple screening levels were utilized here to reduce the uncertainty in assessing the degree of contamination.

Results and Discussion

Conventional Parameters

Sediment quality characteristics (TOC and grain size analysis) are presented in **Table 2**. Station C-6 was predominantly clay and silt, where as other sites were sandier. At the reference site and two tributary sites, the sediment consisted almost entirely of sand. TOC levels, with the exception of C-6 were relatively low, ranging from 0.17% to 2.88%. In three cases (stations B-

6, E-9 and F-13) TOC was inadvertently not analyzed. In these cases a default value of 1% was assumed for calculating TOC-dependent screening levels.

Table 2 Characteristics of Arcadia Lake Bottom Sediments

Characteristic	B-2	B-6	C-6	D-3	E-6	E-8	E-9	F-13	L-1	7	8
Color*	C.Br	C.Br	Br.G	C.Br	C.Br	C.Br	C.Br	C.Br	L.Br	NA**	NA
%Total Solids	61.1	56.1	33.3	75.6	56.3	73.6	72.2	72.5	79.6	79.2	72.6
%Clay	17	21.2	57.2	<2	10.4	8.8	6.4	4.4	<2	0	1.15
%Silt	37	22	44	12	48	6	8	12	4	1.32	1.67
%Sand	46	56.8	<2	87.2	41.6	85.2	85.6	83.6	95.2	91.8	97.2
%TOC	1.52	NA	2.88	0.394	NA	1.69	NA	NA	0.26	0.70	0.17

*Field Observation: C.Br. = Chocolate Brown; L.Br. - Light Brown; Br.G = Brownish Green
**NA = not recorded/analyzed

Screening Values

Screening values used in assessing chemical data are presented in **Table 3**. Site- specific screening values are provided in **Tables 4 and 5**. ER-M and SEL screening values were not exceeded for any parameter, indicating that sediments were not severely contaminated. SQC and SQAL, which are designed to be protect against chronic toxicity, were also not exceeded, although values were only available for four pollutants that were detected.

Table 3 Sediment Quality Screening Values

	Screening Value (μg/Kg TOC*)							
Pollutant	Er-L	ER-M	LEL	SEL	SQC	SQAL	AET-L	AET-H
Organics								
Acetone	-	-	-	-	-	-	-	-
Benzoic Acid	-	-	-	-	-	-	650	760
Benzo(a)Anthracene	261	1600	320	1480000	-	-	1600	5100
Benzo(a)Pyrene	430	1600	370	1440000	-	-	1600	3600
Benzo(b)Flouoranthene	-	-	-	-	-	-	3600	9900
Benzo(g)Perylene	-	-	170	320000	-	-	720	2600
Benzo(k)Fluoranthene	-	-	240	1340000	-	-	3600	9900
Bis(2-ethylhexyl)Phthalate	-	-	-	-	-	-	1300	1900
Butylbenzylphthalate	-	-	-	-	-	1100000	900	900
Carbazole	-	-	-	-	-	-	-	-
Chrysene	384	2800	340	460000	-	-	2800	9200
Fluoranthene	600	5100	750	1020000	620000	-	2500	30000
Ideno(1,2.3-cd)Pyrene	-	-	200	32000	-	-	690	2600
4-Methylphenol	-	-	-	-	-	-	-	-
Pehnanthrene	240	1500	560	95000	18000	-	1500	900
Pyrene	665	2600	490	85000	-	-	3300	1600

Dieldrin	-	-	2	91000	11000	-	-	-
Metals								
Arsenic	8.2	70	6	33	-	-	57	700
Beryllium	-	-	-	-	-	-	-	-
Cadmium	1.2	9.6	0.6	10	-	-	5.1	9.6
Chromium	81	370	26	110	-	-	260	270
Copper	34	270	16	110	-	-	270	390
Lead	46.7	218	31	250	-	-	450	650
Nickel	20.9	51.6	16	75	-	-	-	-
Zinc	150	410	120	820	-	-	410	1600

---

*Site specific values for organics may be calculated by multiplying this value by the percent TOC (e.g., 0.01 = 1%)

Table 4 Site-Specific* Severe Effect Levels (Ontario Approach).

SEL by Station (μg/Kg)											
	B-2	B-6**	C-6	D-3	E-6**	E-8	E-9	F-13**	L-1	7	8
Acetone	-	-	-	-	-	-	-	-	-	-	-
Benzoic Acid	-	-	-	-	-	-	-	-	-	-	-
Benzo(a) Anthracene	22496	14800	42624	5831	14800	25012	14800	14800	3848	10345	2457
Benzo(a)Pyrene	21888	14400	41472	5694	14400	24336	14400	14400	3744	10066	2390
Benzo(b) Flouoranthene	-	-	-	-	-	-	-	-	-	-	-
Benzo(ghi) Perylene	4864	3200	9216	1261	3200	5408	3200	3200	832	2237	531
Benzo(k) Fluoranthene	20368	13400	38592	5280	13400	22646	13400	13400	3484	9367	2224
Bis(2-ethylhexyl-Phthalate	-	-	-	-	-	-	-	-	-	-	-
Butylbenzyl-phthalate	-	-	-	-	-	-	-	-	-	-	-
Carbazole	-	-	-	-	-	-	-	-	-	-	-
Chrysene	6992	4600	13248	1812	4600	7774	4600	4600	1196	3215	764
Fluoranthene	15504	10200	29376	4019	10200	17238	10200	10200	2652	7130	1693
Ideno(1,2,3-cd) Pyrene	4864	3200	9216	1261	3200	5408	3200	3200	832	2237	531
4-Methylphenol	-	-	-	-	-	-	-	-	-	-	-
Phenanthrene	14440	9500	27360	3743	9500	16055	9500	9500	2470	6641	1577
Pyrene	12920	8500	24480	3349	8500	14365	8500	8500	2210	5942	1411

Dieldrin	1383	910	2621	359	910	1538	910	910	237	636	151

*Site specific values calculated using %TOC data for each station
**TOC values not available for these stations; a default value of 1% TOC was applied

Table 5 Site-Specific* Sediment Quality Criteria and Advisory Levels

SQC/SQAL by Station (μg/Kg)											
	B-2	B-6*	C-6	D-3	E-6*	E-8	E-9**	F-13**	L-1	7	8
Benzoic Acid	-	-	-	-	-	-	-	-	-	-	-
Benzo(a) Anthracene	-	-	-	-	-	-	-	-	-	-	-
Benzo(a)Pyrene	-	-	-	-	-	-	-	-	-	-	-
Benzo(b) Flouoranthene	-	-	-	-	-	-	-	-	-	-	-
Benzo(ghi) Perylene	-	-	-	-	-	-	-	-	-	-	-
Benzo(k) Fluoranthene	-	-	-	-	-	-	-	-	-	-	-
Bis(2-ethylhexyl-Phthalate	-	-	-	-	-	-	-	-	-	-	-
Butylbenzyl-phthalate***	16720	11000	31680	4334	11000	18590	11000	11000	2860	7689	1826
Carbazole	-	-	-	-	-	-	-	-	-	-	-
Chrysene	-	-	-	-	-	-	-	-	-	-	-
Fluoranthene	9424	6200	17856	24428	6200	10478	6200	6200	1612	4334	1029
Ideno(1,2,3-cd) Pyrene	-	-	-	-	-	-	-	-	-	-	-
4-Methylphenol	-	-	-	-	-	-	-	-	-	-	-
Phenanthrene	2736	1800	5184	709	1800	3042	1800	1800	468	1258	299
Pyrene	-	-	-	-	-	-	-	-	-	-	-
Dieldrin	167	110	317	43.3	110	186	110	110	28.6	76.9	18.3

*Site-specific values calculated using %TOC data for each station
**TOC values not available for these stations; a default value of 1% TOC was applied
***Values for this parameter are sediment quality advisories rather than sediment quality criteria

Metals

The metals data are presented in **Table 6**. ER-Ls were exceeded for several metals, arsenic (stations C-6, 7, 8), cadmium (stations B-2, B-6, C-6, D-3, E-9, F-13 and L-1), lead (station 7) and nickel (station C-6). Ontario LEL screening values are slightly lower than ER-Ls, but are in good agreement for most parameters. Those pollutants exceeding LELs included: arsenic (stations C-6, 7, 8), cadmium (same stations exceeding ER-Ls, plus stations E-6, E-8), and copper, chromium and nickel (station C-6). None of the metals exceeded ER-Ms or SELs, thus indicating a moderate rather than an acute level of contamination.

Table 6 Sediment Quality for Arcadia Lake: Metals, Detected Values

Concentration by Station (mg/Kg)										
Pollutant	B-2	B-6*	C-6	D-3	E-6	E-8	E-9	F-13	L-1	7	8
Priority Pollutant Metal											
Arsenic	4.4	4.1	10.8ab	2.3	5.0	3.8	2.9	2.2		15ab	6.4a
Beryllium	0.9	0.6	2	0.3	1	0.3	0.4	0.3	0.2		
Cadmium	2ab	2ab	4ab	2ab	1a	1a	1ab	2ab	2ab		
Chromium	24	15	53a	9	22	7	9	9	7	3	2
Copper	15	12	31a	5	15	4	5	4	6	2	4
Lead	23.1	19.4	26.4	5.9	18.7	9	6.5	6.6	3.7	52ab	17
Nickel	14	9	30ab	4	13	3	5	4	3		
Zinc	67	51	111	17	55	20	23	18	14	19	5
Non-Priority Pollutant Metal											
Aluminum	20300	10900	50800	5250	17900	5150	6220	6160	4230	1030	665
Barium	412	364	436	64	275	92	129	63	31	323	49
Cobalt	8	5	15	3	8	2	3	3	1.6	3	1*
Iron	16200	11100	37800	6040	16500	4690	5980	5310	3690	3600	1410
Manganese	459	441	2510	308	590	198	287	189	131	846	77
Vanadium	35	23	78	12	33	10	12	12	8	18	2*

a - Exceeds Ontario LEL; b - Exceeds NOAA ER-L
*Concentrations below minimum quantification level

Organics

Table 7 summarizes data for organic chemicals in sediment. Unusually high levels of acetone were found at stations 7 and 8. Acetone is commonly introduced during laboratory analysis. It may also be introduced through improperly cleaned sampling containers. Acetone was not detected in the lab blank. Confirmation is needed to resolve whether actual environmental contamination is a problem at these sites. ER-Ls were exceeded for two polynuclear aromatic hydrocarbons (PAH), fluoranthene (station B-6) and phenanthrene (stations B-2, B-6). Also, as evidenced by exceedances of the Ontario LELs, multiple PAHs and dieldrin were a problem at stations B-2 and B-6. Bis(2-ethylhexyl)phthalate was elevated at station C-6. The only screening levels available for this pollutant were AET-L and AET-H, both of which were exceeded.

Table 7 Sediment Quality Data for Arcadia Lake: Organics, Detected Values

Concentration by Station (μg/Kg)											
	B-2	B-6*	C-6	D-3	E-6	E-8	E-9	F-13	L-1	7	8
Acetone										85100	107000
Benzoic Acid		165*						69.4*			
Benzo(a) Anthracene	195*	202*									
Benzo(a)Pyrene	286										
Benzo(b) Flouoranthene	283	287			151*						
Benzo(ghi) Perylene	301a	295a			121*						
Benzo(k) Fluoranthene	350a	236			101*						
Bis(2-ethylhexyl-Phthalate	827	594	4280c	84.9*	428	245	281	402		101	
Butylbenzyl-phthalate***							145				
Carbazole	55.7	74.0									
Chrysene	324	352a			146*						
Fluoranthene	554	651b			205	92.7	88.3				161
Ideno(1,2,3-cd) Pyrene	261a	276a									
4-Methylphenol		833									
Phenanthrene	275b	339b			71.4						87.5
Pyrene	568a	640a			236	104	98.8				237
Dieldrin	2.6a	3.7a									

*Value detected below the minimum quantification level (MQL)
a - Exceeds Ontario LEL; b - Exceeds ER-L; c - Exceeds AET-L and AET-H

Sediment Toxicity

Sediment elutriate toxicity testing data are presented in **Table 8**. No significant toxicity was observed in 7-day chronic Ceriodaphnia and fathead minnow sediment elutriate tests.

Table 8 Sediment Quality for Arcadia Lake: Sediment Elutriate Toxicity Testing

Effect by Station						
Test Organism	Control	B-2	C-6	D-3	E-8	L-1
Ceriodaphnia Reproduction*	16.9	19.2	16.5	19.6	17.3	16.4
Fathead Minnow Survival**	0	7	0	0	10	0

*Values are young produced per female; zero mortality was observed for each treatment
**Values are percent survival, including embryos affected by tetrata and abnormal swimming behavior

Overall
EPA's National Sediment Quality Survey (**U.S. EPA 1997**) utilized ER-Ms rather than ER-Ls for assessing problem areas. ER-M exceedances, which are indicative of probable sediment contamination, were not found in this project. ER-L and LEL levels are considered to be indicators of marginally polluted bottom sediments which can be tolerated by most benthic organisms. Sensitive species are most affected in such situations. Synergistic or additive effects are also likely with the occurrence of multiple pollutants. These data are notable in that multiple ER-L/LEL values were exceeded for some stations, thus, subtle, long-term, additive effects are possible, particularly at station C-6.

Conclusions

Overall, the data indicate significant, but relatively low level of sediment contamination. The data demonstrate the preponderance of PAHs in lake sector B. Dieldrin was also found in this sector. Metals were most elevated in sector C, as was bis(2-ethylhexy)phthalate. These sectors comprise the upper and lower Deep Fork arm of the lake. Cadmium was found throughout (except for the two tributary sites), including the Liberty Lake reference site. The elutriate toxicity tests indicated that pollutants were not elevated enough to elicit a significant toxic effect. However, it should be realized that these tests are primarily reflective of water soluble contaminants, thus may be less conservative that whole sediment tests. Whole sediment tests reflect exposure to all pollutants through exposure to the sediments themselves. The finding of no toxicity is consistent with our experience that sediment toxicity is generally only observed in relatively close proximity to pollutant sources.

Sediment contaminant levels are a good indicator of nonpoint source pollution in this urban watershed. Pollutant levels in sediment were not high enough to warrant remediation (i.e., removal of sediment). However, if opportunities or programs become available, nonpoint source controls to reduce pollutant loads (metals, PAHs) would benefit sediment quality and reduce risks to benthic organisms. Concentrating watershed protection efforts in the Deep Fork portion of the watershed would be the most appropriate to enhance and protect sediment quality in Arcadia Lake.

Literature Cited

Ontario. 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ministry of Environment and Energy. August 1993.

U.S. EPA. 1994. Short-term methods for estimating the chronic toxicity of effluents and receiving water to freshwater organisms, third edition. U.S. Environmental Protection Agency, Office of Research and Development. July 1994. EPA-600-4-91-002.

U.S. EPA. 1997. The incidence and severity of sediment contamination in surface waters of the United States, Volume 1: National sediment quality survey. U.S. Environmental Protection Agency, Office of Science and Technology. September 1997. EPA 23-R-97-006.

Appendix A

Description of Sediment Quality Screening Values

NOAA ER-Ls and ER-Ms

These screening levels were developed by NOAA in 1990 and revised in 1995. The effects range approach involves matching biological effects with dry weight sediment contaminant concentrations. It was originally developed for evaluation of NOAA's Status and Trends Program data. Effects Range-Low (ER-L) and Effects Range-Median (ER-M) values were derived for 28 chemicals or classes of chemicals: 9 trace metals, total PCBs, 13 polynuclear aromatic hydrocarbons (PAHs), 3 classes of PAHs, and two pesticides. ER-L's consist of the lower 10th percentile of concentrations with observed biological effects. The ER-M consists of the 50th percentile (median) of concentrations. These values are designed to represent the possible and probable effect concentrations, respectively.

Ontario LELs and SELs

The Ontario Ministry of Environment and Energy has established guideline levels for specific contaminants, including the Lowest Effect Level (LELs) and Severe Effects Level (SELs). The LEL represents relatively clean to marginally polluted sediments that can be tolerated by the majority of benthic organisms, but having the potential to affect some sensitive water uses. The SEL represents marginally to significantly polluted sediments at which pronounced disturbance of the sediment-dwelling community, and would be detrimental to the majority of benthic species. Values have been developed for metals (analogous to the NOAA guidelines) and non-polar organics. Guidelines for organics are based on total organic carbon (TOC) content.

Sediment Quality Criteria and Advisory Levels

The EPA has not yet developed sediment quality criteria (SQC) for metals. EPA has prepared draft sediment quality criteria for five non-polar organic chemicals, including three PAHs and two pesticides. These were developed by utilizing available water column effects data and applying an equilibrium partitioning model to predict, based on the available TOC, the concentrations of specific contaminants that are bioavailable to benthic organisms in pore water. The criteria are designed to protect against chronic effects and have confidence levels which reflect the uncertainty associated with this approach. Recently the EPA developed 35 sediment quality advisory levels (SQALs) for additional non-polar organics. SQALs are calculated similarly to SQC, but are less rigorous in that data requirements are not as strict, and the values have not been individually peer reviewed. The SQALs are appropriate for screening level assessments.

Apparent Effects Thresholds

The Apparent Effects Threshold (AET) approach involves matched field data for sediment chemistry and any observable biological effects (bioassay responses, infaunal abundances, bioaccumulation). Using data from Puget Sound in Washington state, AET values have been developed for 52 chemicals (10 trace metals, 15 PAHs, three pesticides, 6 halogenated organics and 18 other compounds). The AET-Low (AET-L) and AET-High (AET-H) represent low and high ranges of biological effects. Because these values were derived in a watershed specific fashion for Puget sound, other nationally applicable screening levels were used if when available.

Appendix E

Site: Arcadia Lake - Water
I.D./Segment Number: Site# 7 and 8
Region: N/A
Submitted By Oklahoma Water Resources Board
Date Collected: 06/17/97

Test Organism: *Ceriodaphnia dubia*
Type of Test: 7-Day Survival and Reproduction
Laboratory Number: 7D2XL00301-02

Results: Measurements of chemistry data are given in Table 1.

After seven days, no significant effect was observed in organisms exposed to the Arcadia Lake #7 water sample, but total mortality occurred after 24 hours in the Arcadia Lake #8 water sample (Table 2).

Dissolved oxygen remained ≥ 98% of saturation throughout the exposure. Temperature was 25±1°C.

Table 1. Chemistry data recorded for the control and the water samples. Values are given as milligrams per liter.

	Parameter						
Site	pH	Hardness	Alkalinity	Conductivity	Total Ammonia	Total Chlorine	Salinity
Control	8.5	140	148	443	<0.1	<0.1	0
#7	8.4	244	226	585	0.4	<0.1	0
#8	7.9	120	102	318	0.2	<0.1	0

Table 2. Percentage mortality and mean number of young per female produced after seven days of exposure. Ten organisms were exposed to the control and water samples

Site	Mortality (%)	Young Per Female
Control	0	16.8
#7	0	17.9
#8	100	- - -

Site: Arcadia Lake - Water
I.D./Segment Number: N/A
Region: N/A
Submitted By: Oklahoma Water Resources Board
Date Collected: 07/28/97

Test Organism: *Pimphales promelas*
Type of Test: 7-Day Embryo/Larval
Laboratory Number: 7D2XLO0501-06

Results: Measurements of chemistry data are given in Table 1.

After seven days, no significant effect was observed in organisms exposed to the Arcadia Lake water samples (Table 2).

Dissolved oxygen remained ≥ 91% of saturation throughout the exposure. Temperature was 25±1°C.

Table 1. Chemistry data recorded for the control and the water samples. Values are given as milligrams per liter.

	Parameter						
Site	pH	Hardness	Alkalinity	Conductivity	Total Ammonia	Total Chlorine	Salinity
Control	8.1	115	192	513	<0.1	<0.1	0
#1	8.1	153	150	465	1.3	<0.1	0
#7	8.3	276	252	671	0.7	<0.1	0
#8	8.2	357	306	852	0.8	<0.1	0

Table 2. Percentage of fathead minnow embryo/larvae affected after seven days of exposure. Thirty embryos were exposed to the control and the water samples.

Site	Organisms Affected[a](%)
Control	0
#1	0
#7	7
#8	3

---

[a] Effects include the combined number of dead embryos (unhatched) and larvae, also, organisms exhibiting terata and abnormal swimming behavior.

Site: Arcadia Lake - Water
I.D./Segment Number: N/A
Region: N/A
Submitted By: Oklahoma Water Resources Board
Date Collected: 07/28/97

Test Organism: Ceriodaphnia dubia
Type of Test: 7-Day Survival and Reproduction
Laboratory Number: 7D2XLO0501-06

Results: Measurements of chemistry data are given in Table 1

After seven days, no significant effect was observed in organisms exposed to the Arcadia Lake water samples (Table 2)

Dissolved oxygen remained ≥ 90% of saturation throughout the exposure. Temperature was 25±1°C.

Table 1. Chemistry data recorded for the control and the water samples. Values are given as milligrams per liter.

	Parameter						
Site	pH	Hardness	Alkalinity	Conductivity	Total Ammonia	Total Chlorine	Salinity
Control	8.5	90	104	353	<0.1	<0.1	0
#1	8.1	153	150	465	1.3	<0.1	0
#7	8.3	276	252	671	0.7	<0.1	0
#8	8.2	357	306	852	0.8	<0.1	0

Table 2 Percentage mortality and mean number of young per female produced after seven days of exposure. Ten organisms were exposed to the control and water samples

Site	Mortality (%)	Young Per Female
Control	0	17.6
#1	0	18.2
#7	0	18.7
#8	0	19.1

Site: Arcadia Lake - Water
I.D./Segment Number: Site #7 and #8
Region: N/A
Submitted By: Oklahoma Water Resources Board
Date Collected: 06/17/97

Test Organism: Pimphales promelas
Type of Test: 7-Day Embryo/Larval
Laboratory Number: 7D2XLO0301-02

Results: Measurements of chemistry data are given in Table 1.

After seven days, no significant effect was observed in organisms exposed to the Arcadia Lake water samples (Table 2).

Dissolved oxygen remained ≥ 90% of saturation throughout the exposure. Temperature was 25±1°C.

Table 1. Chemistry data recorded for the control and the water samples. Values are given as milligrams per liter.

	Parameter						
Site	pH	Hardness	Alkalinity	Conductivity	Total Ammonia	Total Chlorine	Salinity
Control	7.9	196	184	496	<0.1	<0.1	0
Site #7	8.4	226	244	585	0.4	<0.1	0
Site #8	7.9	120	102	318	0.2	<0.1	0

Table 2 Percentage of fathead minnow embryo/larvae affected after seven days of exposure. Thirty embryos were exposed to the control and the water samples

Site	Organisms Affected*(%)
Control	7
Site #7	10
Site #8	3

---

*Effects include the combined number of dead embryos (unhatched) and larvae, also, organisms exhibiting terata and abnormal swimming behavior

Site: Arcadia Lake - Sediment
I.D./Segment Number: N/A
Region. N/A
Submitted By: Oklahoma Water Resources Board
Date Collected: 07/28/97

Test Organism: *Pimphales promelas*
Type of Test: 7-Day Embryo/Larval
Laboratory Number: 7D2XLO0501-06

Results: Measurements of chemistry data are given in Table 1.

After seven days, no significant effect was observed in organisms exposed to the Arcadia Lake eluate samples (Table 2).

Dissolved oxygen remained ≥ 89% of saturation throughout the exposure. Temperature was 25±1°C.

Table 1. Chemistry data recorded for the control and the eluate samples. Values are given as milligrams per liter.

	Parameter						
Site	pH	Hardness	Alkalinity	Conductivity	Total Ammonia	Total Chlorine	Salinity
Control	8.1	115	192	513	<0.1	<0.1	0
#1	7.9	176	180	520	15.6	0.1	0
#7	8.1	207	206	568	1.0	<0.1	0
#8	8.1	89	168	503	0.6	<0.1	0

Table 2. Percentage of fathead minnow embryo/larvae affected after seven days of exposure. Thirty embryos were exposed to the control and the eluate samples.

Site	Organisms Affected[a] (%)
Control	3
#1	0
#7	7
#8	3

---

[a] Effects include the combined number of dead embryos (unhatched) and larvae, also, organisms exhibiting terata and abnormal swimming behavior.

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Site: Arcadia Lake - Sediment
I.D./Segment Number: N/A
Region: N/A
Submitted By Oklahoma Water Resources Board
Date Collected: 07/28/97

Test Organism: Ceriodaphnia dubia
Type of Test: 7-Day Survival and Reproduction
Laboratory Number: 7D2XLO0501-06

Results: Measurements of chemistry data are given in Table 1.

After seven days, no significant effect was observed in organisms exposed to the Arcadia Lake eluate samples (Table 2).

Dissolved oxygen remained ≥ 98% of saturation throughout the exposure. Temperature was 25±1°C.

Table 1. Chemistry data recorded for the control and the eluate samples. Values are given as milligrams per liter.

	Parameter						
Site	pH	Hardness	Alkalinity	Conductivity	Total Ammonia	Total Chlorine	Salinity
Control	8.5	90	104	353	<0.1	<0.1	0
#1	7.9	176	180	520	15.6	0.1	0
#7	8.1	207	206	568	1.0	<0.1	0
#8	8.1	89	168	503	0.6	<0.1	0

Table 2. Percentage mortality and mean number of young per female produced after seven days of exposure. Ten organisms were exposed to the control and eluate samples.

Site	Mortality (%)	Young Per Female
Control	0	17.8
#1	0	17.6
#7	0	18.3
#8	0	17.7

[redacted]	6		7	
	01		02	
ABN/METHOD 625 - RESULTS				
REPORTING UNITS	ug/kg		ug/kg	
2,4-Dinitrophenol	ND	600	ND	570
2,4-Dinitrotoluene	ND	120	ND	114
2,6-Dinitrotoluene	ND	120	ND	114
Di-n-butylphthalate	ND	40	ND	38
Di-n-octylphthalate	ND	80	ND	76
Fluoranthene		161	ND	38
Fluorene	ND	40	ND	38
Hexachlorobenzene	ND	40	ND	38
Hexachlorobutadiene	ND	100	ND	95
Hexachlorocyclopentadiene	ND	200	ND	190
Hexachloroethane	ND	60	ND	57
Indeno(1,2,3-cd)pyrene	ND	160	ND	152
Isophorone	ND	80	ND	76
2-Methylnaphthalene	ND	40	ND	38
2-Methylphenol	ND	120	ND	114
4 Methylphenol	ND	120	ND	114
Naphthalene	ND	40	ND	39
2-Nitroaniline	ND	160	ND	152
3-Nitroaniline	ND	160	ND	152
4 Nitroaniline	ND	160	ND	152
Nitrobenzene	ND	40	ND	38
2-Nitrophenol	ND	200	ND	190
4-Nitrophenol	ND	260	ND	247
N-Nitrosodiphenylamine	ND	80	ND	76
N-Nitroso-di-n-propylamine	ND	120	ND	114
Pentachlorophenol	ND	300	ND	285
Phenanthrene		87.5	ND	38
Phenol	ND	80	ND	76
Pyrene		237	ND	38
1,2,4-Trichlorobenzene	ND	80	ND	76
2,4,5-Trichlorophenol	ND	120	ND	114
2,4,6-Trichlorophenol	ND	120	ND	114
% DRY WEIGHT	82.2 %		86.6 %	

Results based on dry weight * ND = Not detected above the listed limit

[redacted]	6 01		7 02
ABN/METHOD 625 - TICs*			
REPORTING UNITS	ug/kg		ug/kg
UNKNOWN ADIPATE (RT 15.9)	EST	1300	
UNKNOWN HYROCARBON (RT 18.3)	EST	277	

*TENTATIVELY IDENTIFIED COMPOUNDS
ALL CONCENTRATIONS ARE ESTIMATED

Results based on dry weight

[redacted]	01		02	
PES/PCB/METHOD 608 - RESULTS				
REPORTING UNITS	ug/g		ug/g	
Aldrin	ND	0.05	ND	0.05
alpha-BHC	ND	0.05	ND	0.05
beta-BHC	ND	0.05	ND	0.05
delta-BHC	ND	0.05	ND	0.05
gamma-BHC (lindane)	ND	0.05	ND	0.05
alpha-Chlordane	ND	0.05	ND	0.05
gamma-Chlordane	ND	0.05	ND	0.05
4,4'-DDD	ND	0.10	ND	0.10
4,4'-DDE	ND	0.10	ND	0.10
4,4'-DDT	ND	0.10	ND	0.10
Diazinon	ND	3.00	ND	3.00
Dieldrin	ND	0.10	ND	0.10
Endosulfan I	ND	0.05	ND	0.05
Endosulfan II	ND	0.10	ND	0.10
Endosulfan sulfate	ND	0.10	ND	0.10
Endrin	ND	0.10	ND	0.10
Endrin aldehyde	ND	0.10	ND	0.10
Endrin ketone	ND	0.10	ND	0.10
Heptachlor	ND	0.05	ND	0.05
Heptachlor epoxide	ND	0.05	ND	0.05
Methoxychlor	ND	0.10	ND	0.10
Toxaphene	ND	5.00	ND	5.00
Aroclor-1016	ND	1.00	ND	1.00
Aroclor-1221	ND	2.00	ND	2.00
Aroclor-1232	ND	1.00	ND	1.00
Aroclor-1242	ND	1.00	ND	1.00
Aroclor-1248	ND	1.00	ND	1.00
Aroclor-1254	ND	1.00	ND	1.00
Aroclor-1260	ND	1.00	ND	1.00
% DRY WEIGHT	82.2 %		86.6 %	

Results based on dry weight * ND = Not detected above the listed limit

[redacted]	01		02	
PES/PCB/METHOD 608 -	RESULTS			
REPORTING UNITS	ug/g		ug/g	
Aldrin	ND	0.05	ND	0.05
alpha-BHC	ND	0.05	ND	0.05
beta-BHC	ND	0.05	ND	0.05
delta-BHC	ND	0.05	ND	0.05
gamma-BHC (lindane)	ND	0.05	ND	0.05
alpha-Chlordane	ND	0.05	ND	0.05
gamma-Chlordane	ND	0.05	ND	0.05
4,4'-DDD	ND	0.10	ND	0.10
4,4'-DDE	ND	0.10	ND	0.10
4,4'-DDT	ND	0.10	ND	0.10
Diazinon	ND	3.00	ND	3.00
Dieldrin	ND	0.10	ND	0.10
Endosulfan I	ND	0.05	ND	0.05
Endosulfan II	ND	0.10	ND	0.10
Endosulfan sulfate	ND	0.10	ND	0.10
Endrin	ND	0.10	ND	0.10
Endrin aldehyde	ND	0.10	ND	0.10
Endrin ketone	ND	0.10	ND	0.10
Heptachlor	ND	0.05	ND	0.05
Heptachlor epoxide	ND	0.05	ND	0.05
Methoxychlor	ND	0.10	ND	0.10
Toxaphene	ND	5.00	ND	5.00
Aroclor-1016	ND	1.00	ND	1.00
Aroclor-1221	ND	2.00	ND	2.00
Aroclor-1232	ND	1.00	ND	1.00
Aroclor-1242	ND	1.00	ND	1.00
Aroclor-1248	ND	1.00	ND	1.00
Aroclor-1254	ND	1.00	ND	1.00
Aroclor-1260	ND	1.00	ND	1.00
% DRY WEIGHT	82.2 %		86.6 %	

Results based on dry weight * ND = Not detected above the listed limit

[redacted]	6		7	
	01		02	
VOA/METHOD 624 - RESULTS				
REPORTING UNITS	ug/kg		ug/kg	
Acetone		107,000		85,100
Acrolein	ND	5000	ND	5000
Acrylonitrile	ND	5000	ND	5000
Benzene	ND	100	ND	100
Bromodichloromethane	ND	100	ND	100
Bromoform	ND	100	ND	100
Bromomethane	ND	250	ND	250
2-Butanone	ND	500	ND	500
Carbon disulfide	ND	250	ND	250
Carbon tetrachloride	ND	100	ND	100
Chlorobenzene	ND	250	ND	250
Chloroethane	ND	250	ND	250
Chloroform	ND	100	ND	100
Chloromethane	ND	250	ND	250
Dibromochloromethane	ND	100	ND	100
1,1 Dichloroethane	ND	100	ND	100
1,2-Dichloroethane	ND	100	ND	100
1 1-Dichloroethene	ND	100	ND	100
cis-1 2-Dichloroethene	ND	100	ND	100
trans 1,2-Dichloroethene	ND	100	ND	100
1,2-Dichloropropane	ND	100	ND	100
cis-1,3-Dichloropropene	ND	100	ND	100
trans-1,3-Dichloropropene	ND	100	ND	100
Ethylbenzene	ND	250	ND	250
2-Hexanone	ND	250	ND	250
Methylene chloride	ND	250	ND	250
4-Methyl-2-pentanone	ND	250	ND	250
Styrene	ND	250	ND	250
1,1 2,2-Tetrachloroethane	ND	100	ND	100
Tetrachloroethene	ND	100	ND	100
Toluene	ND	250	ND	250
1,1,1-Trichloroethane	ND	100	ND	100
1,1,2-Trichloroethane	ND	100	ND	100
Trichloroethene	ND	100	ND	100
Vinyl chloride	ND	250	ND	250
m,p-Xylene	ND	250	ND	250
o-Xylene	ND	250	ND	250

* ND = Not detected above the listed limit

[redacted]	6		7	
	01		02	
ABN/METHOD 625 - RESULTS				
REPORTING UNITS	ug/kg		ug/kg	
Acenaphthene	ND	40	ND	38
Acenaphthylene	ND	40	ND	38
Anthracene	ND	40	ND	38
Benzidine	ND	400	ND	380
Benzoic Acid	ND	200	ND	190
Benzo(a)anthracene	ND	160	ND	152
Benzo(a)pyrene	ND	160	ND	152
Benzo(b)fluoranthene	ND	160	ND	152
Benzo(g,h,i)perylene	ND	160	ND	152
Benzo(k)fluoranthene	ND	160	ND	152
Benzyl Alcohol	ND	80	ND	76
bis(2-Chloroethoxy)methane	ND	40	ND	38
bis(2-Chloroethyl)ether	ND	40	ND	38
bis(2-chloroisopropyl)ether	ND	40	ND	38
bis(2-Ethylhexyl)phthalate		101	ND	76
4-Bromophenyl-phenylether	ND	160	ND	152
Butylbenzylphthalate	ND	80	ND	76
Carbazole	ND	40	ND	38
4-Chloroaniline	ND	80	ND	76
4-Chloro-3-methylphenol	ND	160	ND	152
2-Chloronaphthalene	ND	40	ND	38
2-Chlorophenol	ND	80	ND	76
4-Chlorophenyl-phenylether	ND	160	ND	152
Chrysene	ND	160	ND	152
Dibenzofuran	ND	40	ND	38
Dibenz(a,h)anthracene	ND	160	ND	152
1,2-Dichlorobenzene	ND	60	ND	57
1,3-Dichlorobenzene	ND	60	ND	57
1,4-Dichlorobenzene	ND	60	ND	57
3,3'-Dichlorobenzidine	ND	200	ND	190
2,4-Dichlorophenol	ND	120	ND	114
Diethylphthalate	ND	40	ND	38
2,4-Dimethylphenol	ND	120	ND	114
Dimethylphthalate	ND	40	ND	38
4,6-Dinitro-2-methylphenol	ND	400	ND	380

Results based on dry weight * ND = Not detected above the listed limit

Appendix F

Arcadia Lake Algal Data Analysis
1996 and 1997
Provided for:
Oklahoma Water Resources Board

Completed By:
PhycoTech
620 Broad St., Ste. 100
St. Joseph, MI 49085
(616) 983-3654

Concentration Comparisons by Division for 1996 and 1997:

In 1996, all dates and stations were dominated numerically by blue-greens, with varying concentrations of diatom, cryptomonad and green algae (**Figure 1**). The primary taxon responsible for the dominance is a small, unicellular blue-green likely related to *Synechococcus* sp., that is less than 1.1 µm in diameter. Also quite abundant are single celled *Aphanothece* sp. cells (less than 1.8 µm in length). Miscellaneous microflagellates, which are likely algal in origin, were also numerically important. This was especially the case in late spring. Early spring was characterized by high concentrations of small single celled blue-greens which often appear in relatively high numbers in western reservoirs (**Steve Canton, Chadwick and Associates, Lakewood CO, personal communication**), as well as substantial numbers of diatoms. Algal abundance then started varying in May, with mid-summer and late fall peaks. Algal abundance and types in 1996 indicate a mesotrophic to eutrophic system which is consistent with other biological water quality data from Arcadia Lake (**Task 9**). Although data are missing for stations 3, 4, and 5 for September and October, 1996, the overall pattern would likely be similar to stations 1 and 2 for total numerical abundance.

In 1997, the overall pattern is similar where all stations are dominated numerically by small unicellular blue-greens with other divisions represented in varying abundances (**Figure 3**). However, 1997 data indicate a pattern of more consistent, and often higher, algal abundances throughout the year, while peaks are sustained for longer periods of time in the late summer. Chryosphytes were never important contributors to the phytoplankton in either 1996 or 1997.

Interestingly, nutrient concentrations indicate a system which could be classified as eutrophic to hypereutrophic in both 1996 and 1997 (cells counts are also often well above 15, 000 per ml, an indicator of eutrophic systems), however, because of high particulates in Arcadia Lake (suspended inorganic and organic matter, such as clays, carbonate particles, fine organic particulate matter) the algal populations, although containing potential nuisance taxa (such as *Aphanizomenon* sp., *Microcystis* sp. and *Cylindrospermopsis* sp.), are more light limited than nutrient limited. This is confirmed by reports of relatively shallow Secchi readings with an average lake-wide depth of only 48 cm (**Task 10**) that are not linked to biological activity. Several of the taxa which could be become potential bloom participants are thus more limited by light than by available nutrients.

Biovolume Comparisons by Division for 1996 and 1997:

In 1996, biovolume indicates, in contrast to strict numerical data, that Arcadia Lake has a predictable succession of divisions and taxa throughout the year (**Figure 2**). The small unicellular blue-greens that dominated numerically do not dominate the biovolume. Other, larger, blue-greens dominate the mid-late summer assemblage. Diatoms are the most obvious dominant in the early to late spring, with cryptomonads sometimes contributing a substantial amount of biomass. Blue-greens are present in early spring, but do not become dominant until mid-late summer (May-September). Dinoflagellates also are important on certain dates and at certain stations (especially station 2). Stations 4 and 5 experience substantial euglenoid blooms in mid-late spring, and later in the fall at the same stations, indicating organic nitrogen influences (**Wetzel, 1983**). The euglenoids are indeed symptomatic of high organic inputs contributed by the Deep Fork River as it enters above station 5 and still heavily influences station 4. This effect is confirmed by nutrient and particulate data reported in **Task 10.** Green algae become important and consistent contributors to the biovolume in early summer to late summer, but do not become overwhelming dominants as the other divisions already mentioned.

Blue-greens dominate in mid-late summer, but are composed of larger, mostly filamentous forms in comparison to the small, unicellular forms which dominate the numerical abundance. The most important taxa are potential bloom formers such as *Oscillatoria* sp,. *Aphanizomenon* sp., *Cylindrospermopsis* sp. and *Microcystis* sp. As mentioned earlier, although these blue-green taxa could form particularly noxious blooms, the particulate conditions limit their productivity to abundant concentrations which can cause some water quality problems short of wide spread surface blooms.

1997 data, although again indicating higher biomass than in 1996 consistent with abundance data, follow similar patterns as in 1996 (**Figure 4**). Early assemblages are dominated primarily by diatoms and cryptomonads, with dinoflagellates occasionally becoming important, especially in early-mid summer. Dinoflagellate dominance differs in 1997, though. In 1997, *Gymnodinium* sp. was the primary taxon with a marked Ceratium sp. bloom, compared with only an isolated *Ceratium* sp. bloom in 1996. January and May total nitrogen concentrations were high in 1997 (**Task 10**), which combined with higher spring light, nutrient concentrations, and rising temperatures can trigger dinoflagellate blooms. (**Van Den Hoek, 1995, Pollingher, 1988**).

Euglenoids are even more important at stations 4 and 5 during 1997, triggered by the same high organic content of the incoming Deep Fork River. June and July experienced larger total algal biomass blooms at all stations compared with 1996, with dinoflagellates and blue-greens dominating the assemblage until declines in August. By September, diatoms and other divisions (greens and at station 5, euglenoids) were again becoming important as blue-greens decreased, possibly influenced by lower temperatures in late summer (dropping from 26-30 ^{0}C in July and August to 22-24 ^{0}C in September) and the breakdown of any stratification. Chrysophytes were never an important component of the phytoplankton by biovolume in either 1996 or 1997.

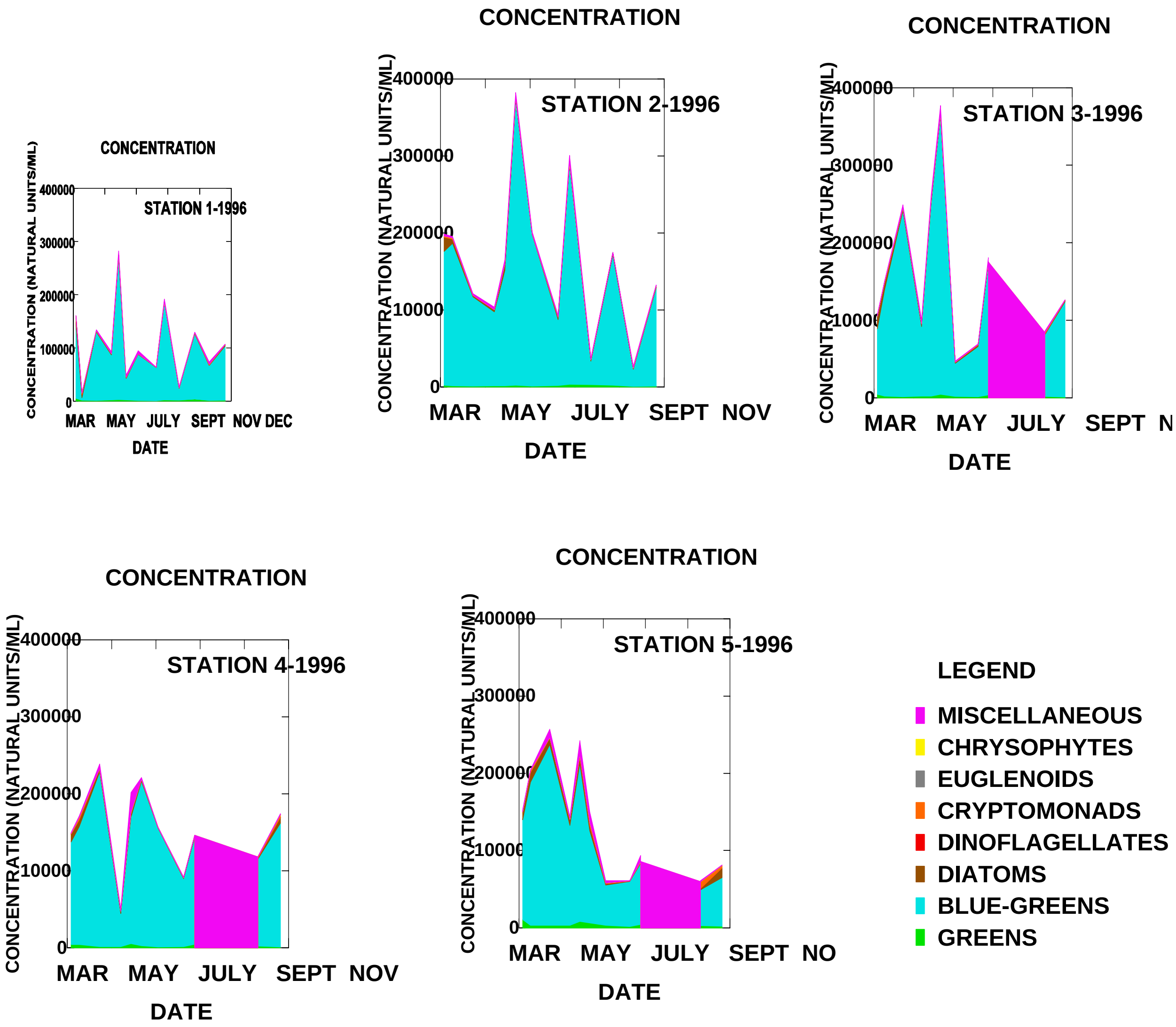

Figure 1 Concentration for 1996 algal data by division. Algal data for September and October, 1996 are missing for Stations 3, 4, and 5 (shown by solid magenta pattern).

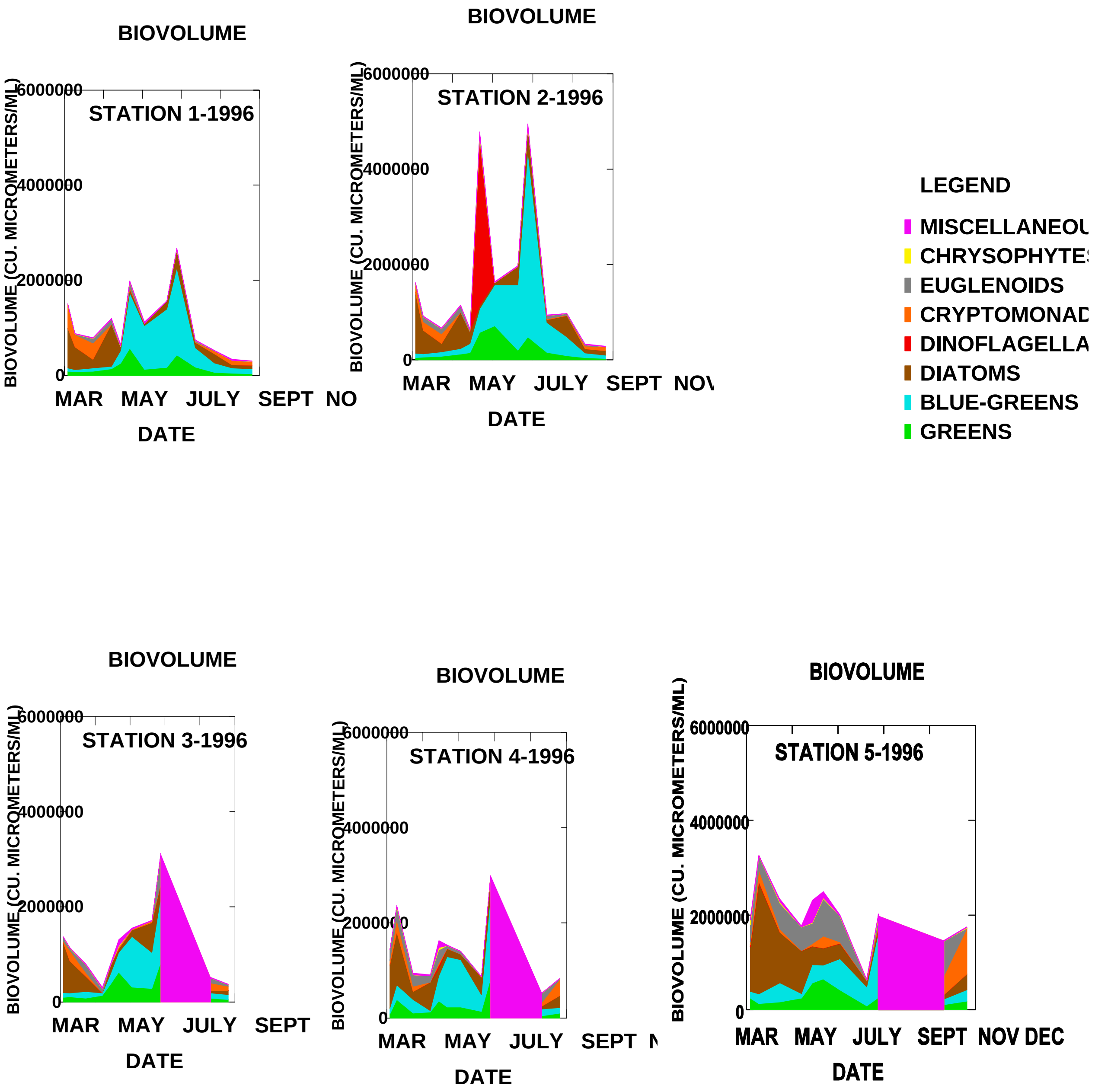

Figure 2 Biovolume estimates for 1996 algal data by division. Algal data for September and October, 1996 are missing for Stations 3, 4, and 5 (shown by solid magenta pattern).

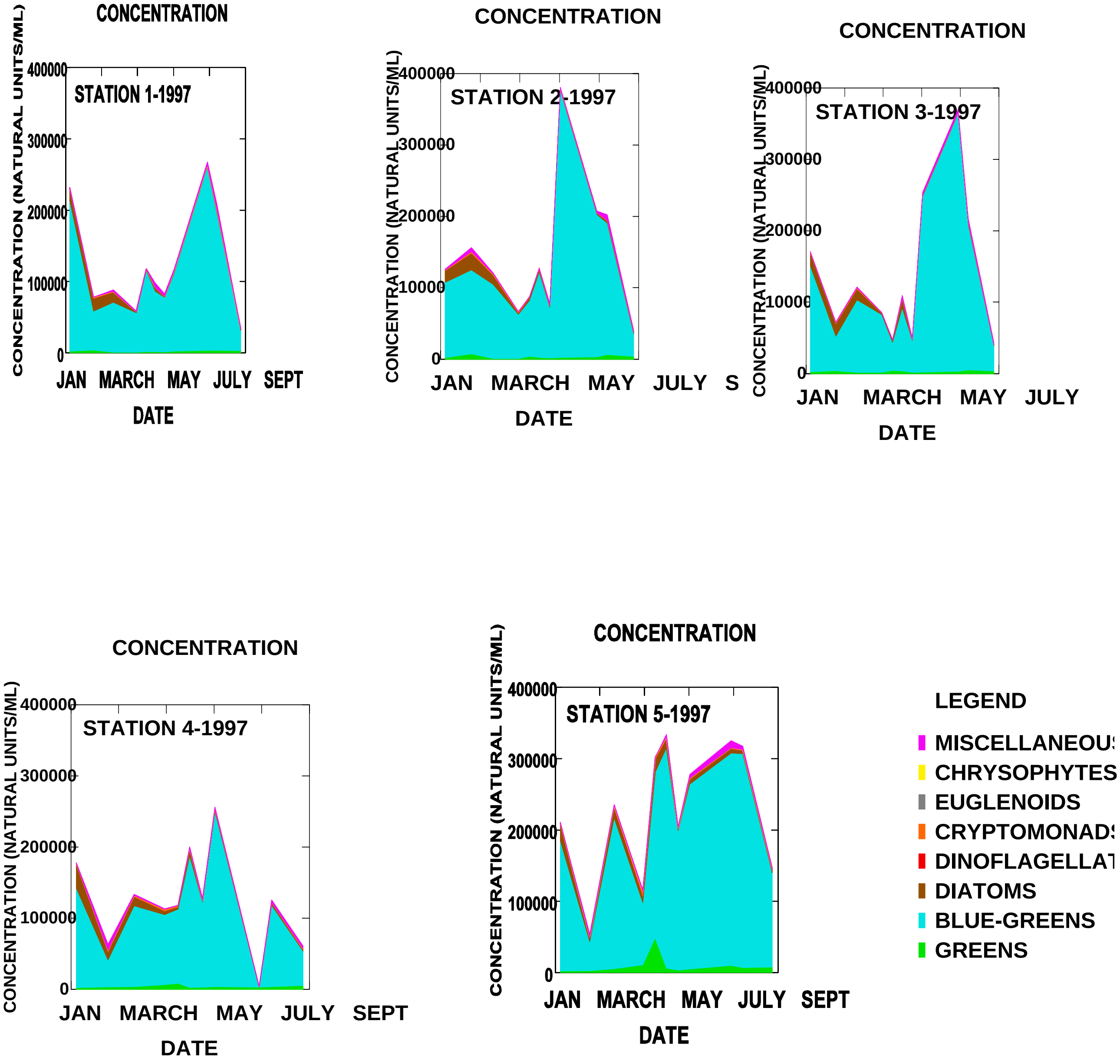

Figure 3 Concentration for 1997 algal data by division.

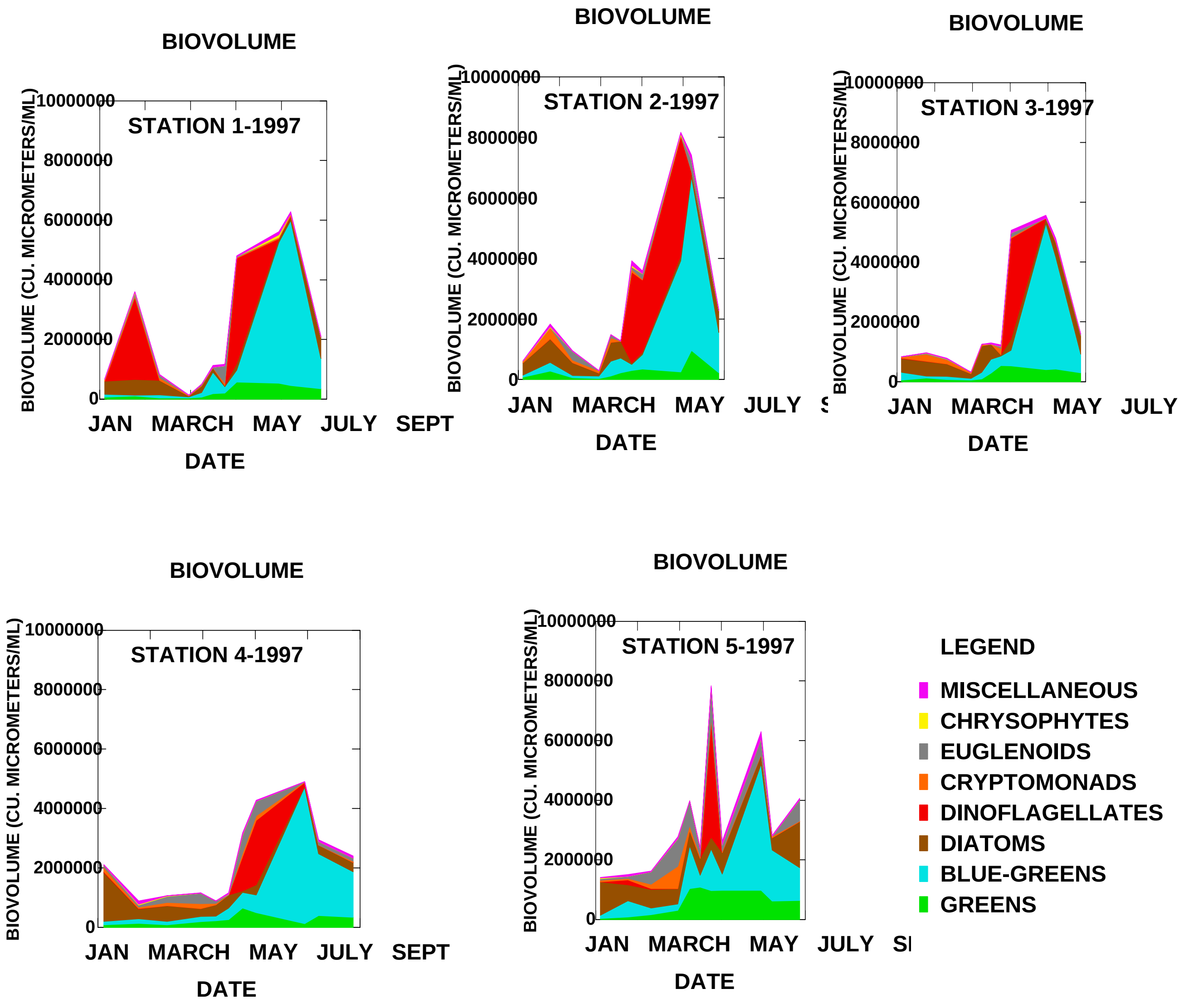

Figure 4 Biovolume estimates for 1997 algal data by division.

Genus Level Comparisons for 1996 and 1997:

Because the patterns were so often similar from 1996 to 1997, examples were chosen for certain ecological features of the data with specific stations and dates, depending on what best illustrated the point and whether data was available for that station and year.

Figure 5 shows an example of the numerical dominance of small, unicellular blue-greens (<1.1 µm) by percent concentration. These algae often contributed 50-90% percent to the assemblage. Although these small algal cells do not also dominate the biovolume of Arcadia Lake, they may contribute significantly to energy flow for two reasons. First, such small cells reproduce quickly, recycling nutrients very quickly within the system, and likely contributing significantly to the primary productivity of Arcadia Lake, as has been documented in other marine and freshwater systems (**Waterbury et al, 1986**) . This could have important consequences for nutrient measurements and would affect nutrient availability to other algal groups. Secondly, they are likely an important food source to the microzooplankton in Arcadia Lake and potentially to some of the known phagotrophic algae in the lake (e.g. dinoflagellates and cryptomonads). As bacteria have been noted to be an important food source for filter feeders in planktonic systems (**Güde, 1989**), small autotrophic algae in the same size range also would make appropriate food for non-specific filter feeders or algae that require a very small size for phagotrophy to occur (**St. Amand, 1990**).

Other blue-greens that figure more prominently in biovolume contribution, as well as in perceived water quality, include *Oscillatoria* sp. (**Figures 6 and 7**). Percent biovolume is more consistent throughout the year and generally higher at station 5 than at earlier stations. This is directly related to the influence of the Deep Fork River. Biovolume data also indicate that although blue-greens such as *Oscillatoria* sp. appear in pronounced blooms at station 1, there are multiple blooms at station 5, sustaining the biomass in the water column for longer periods of time throughout the year. This pattern appears consistent from 1996 to 1997, despite some missing data for station 5 in September and October, 1996. *Oscillatoria* sp. often appear with more noxious, nitrogen fixing blue-greens which not only contribute to taste and odor problems, but also are potential toxin producers and problem bloom formers. Figure 8 demonstrates the percent biovolume of *Aphanizomenon* sp., *Cylindrospermopsis* sp. and *Microcystis* sp. on August 27 and August 12, respectively. Both *Aphanizomenon* and *Cylindrospermopsis*, which form heterocysts, are highest at stations 1 and 5. While *Microcystis* sp. increases progressively from station 1 to its highest percent biomass at station 5. *Microcystis* sp. has been observed to fix nitrogen without heterocysts. Station 5 has, on average, lower TN:TP ratios, favoring the heterocystic blue-greens. All stations, though, often have TN:TP ratios below 15-17, indicating favorable conditions for nitrogen fixing blue-greens (**Task 10**).

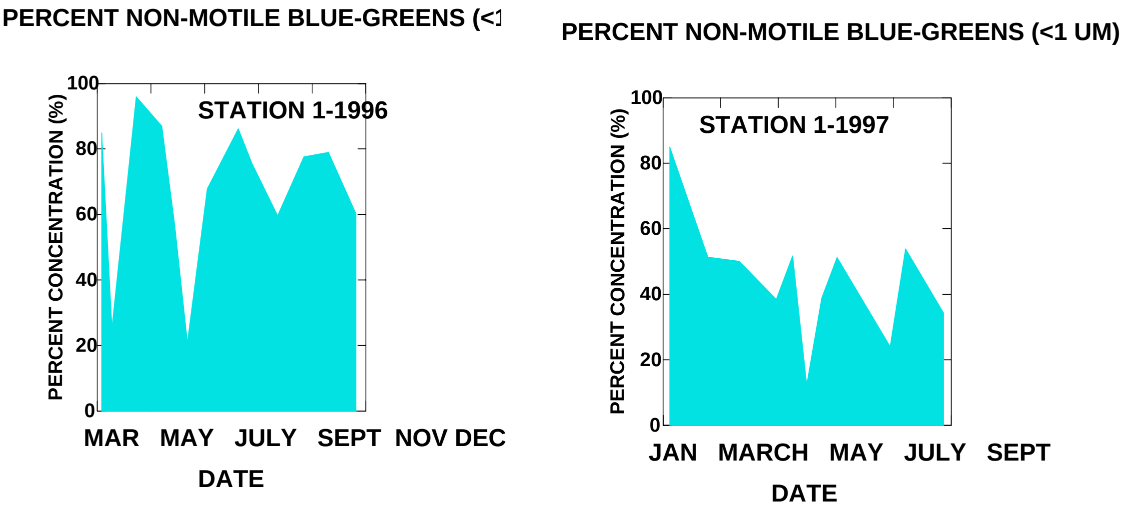

Figure 5 Concentration of small non-motile blue-greens (<1 µm) at Station 1, 1996 and 1997.

Higher concentrations at station 1 for *Aphanizomenon* sp. and *Cylindrospermopsis* sp. may be due to the often higher levels of anoxia at depth at station 1 (**Task 10**) still diffuse into the epilimnion due to the high differential gradients, at a TN:TP ratio favoring nitrogen fixing blue-greens. These particular blue-greens are also buoyant. As they achieve higher biomass and travel upwards in the water column, they also are able to escape some of the light limitation issues of the other non-buoyant algae.

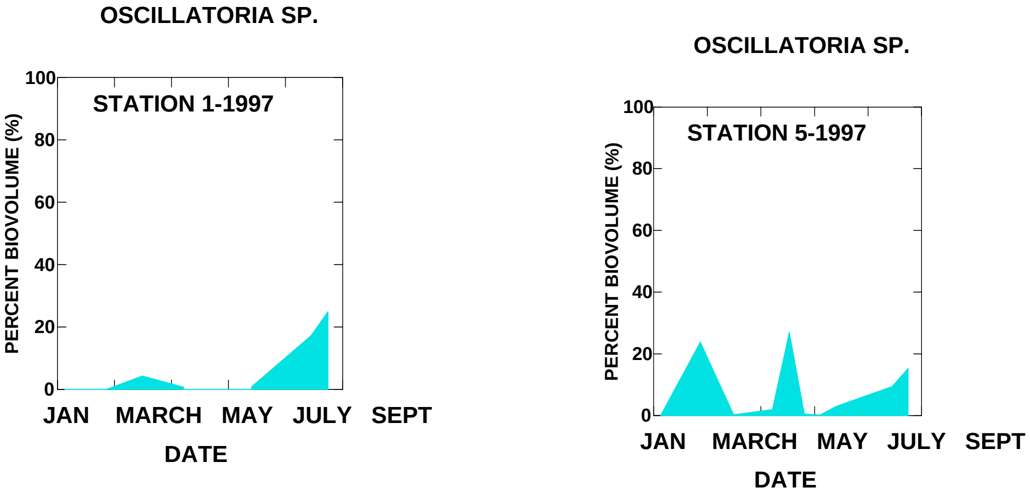

Figure 6 Percent biovolume of *Oscillatoria* sp at Station 1 and Station 5, 1997.

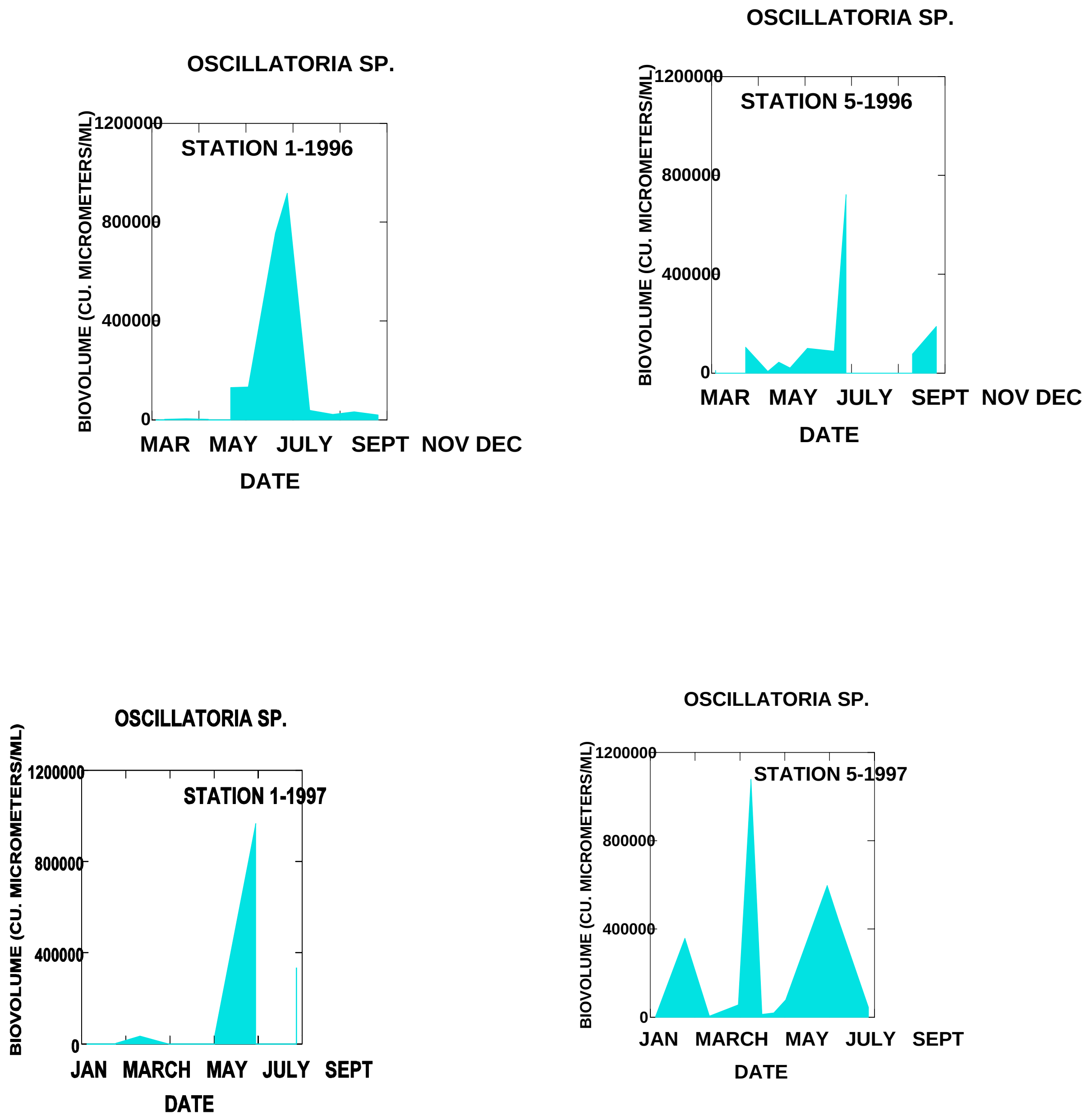

Figure 7 Biovolume of *Oscillatoria* sp at Station 1 and 5 in 1996 (upper panel) and 1997 (lower panel), respectively. Note that data are missing for September and October, 1996 for Station 5.

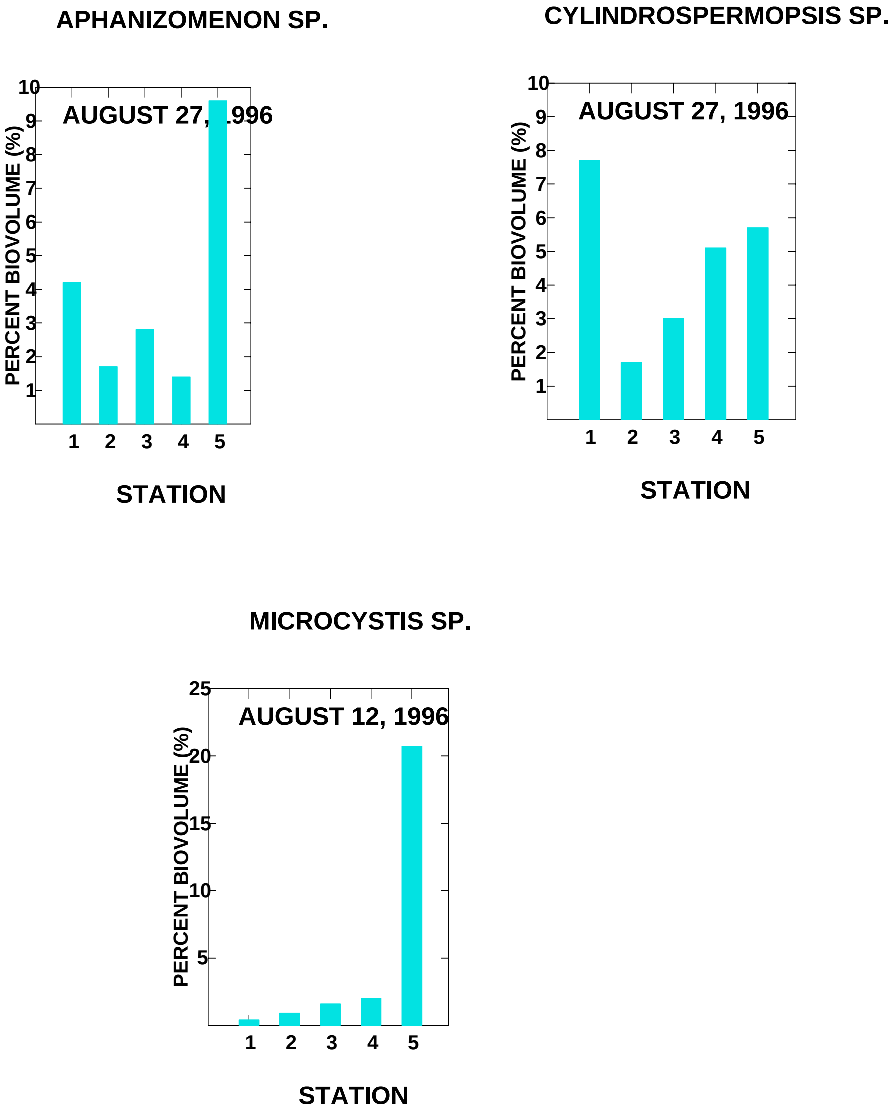

Figure 8 Percent Biovolume for *Aphanizomenon* sp, *Cylindrospermopsis* sp, and *Microcystis* sp on August 27 and August 12, 1997, respectively.

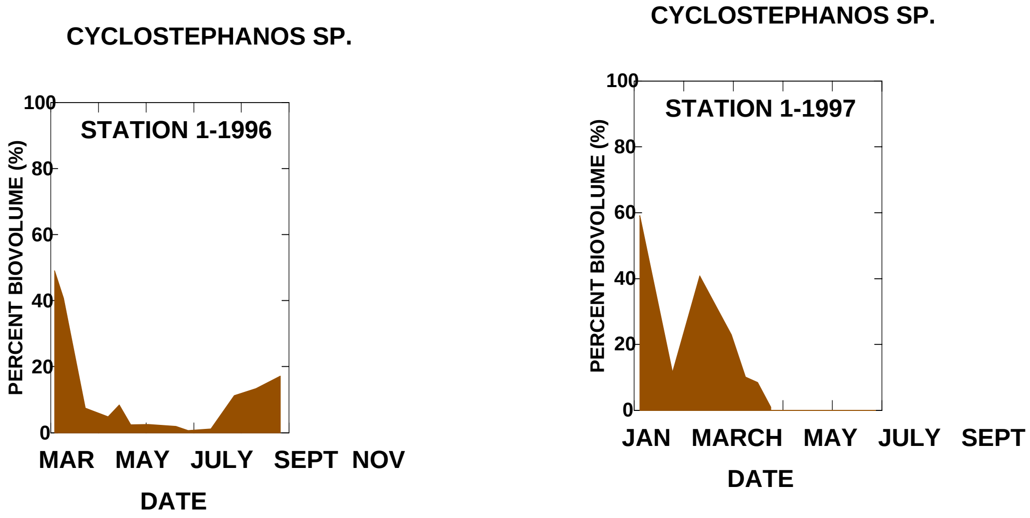

Figure 9 Percent Biovolume of *Cyclostephanos* sp at Station 1 in 1996 and 1997

Spring and fall diatom blooms were dominated first by *Cyclostephanos* sp. and then by *Stephanodiscus* sp. (**Figures 9 and 10**). Both are small centric diatoms, characteristic of winter and early spring diatom blooms and eutrophic conditions (**Reynolds, 1984**). **Sommer** (**1988**) also indicates that because of their small diameter (4-15µm) and other possible buoyancy mechanisms (spiny extensions that are pectinaceous in origin), these small centric diatoms can sink slower than even other non-siliceous algae. This could account for the smaller diatoms staying in the plankton through to December in 1996 and well into May in 1997 (into September at stations 4 and 5, 1997). Other diatoms which didn't bloom as early or last as long into the growing season included *Aulacoseira* sp., *Nitzschia* sp. and to a lessor extent *Synedra* sp. Fall blooms were again dominated by the small centric diatoms.

Figure 11 illustrates *Euglena* sp. concentrations and their spring and single date, early fall, blooms at station 5, often accounting for up to 20-30% of the biovolume in spring during both 1996 and 1997, and up to almost 50% of the biovolume in November, 1996. As mentioned earlier, substantial euglenoid populations such as bloomed at stations 4 and 5 in both 1996 and 1997, are indicative of organically enriched, high alkalinity waters (**Wetzel, 1983**). In this case, the source is the Deep Fork River. Also, due to the high incoming particulates, euglenoid taxa may be particularly well suited to stations 4 and 5 due to their photoauxotrophic nutritional requirements, which allows them to augment photosynthesis either by phagotrophy or differentially absorbing organic compounds from the surrounding water (**Lee, 1989**). Euglenoids use this nutritional diversity to tolerate low light conditions, which exist in Arcadia Lake to some extent.

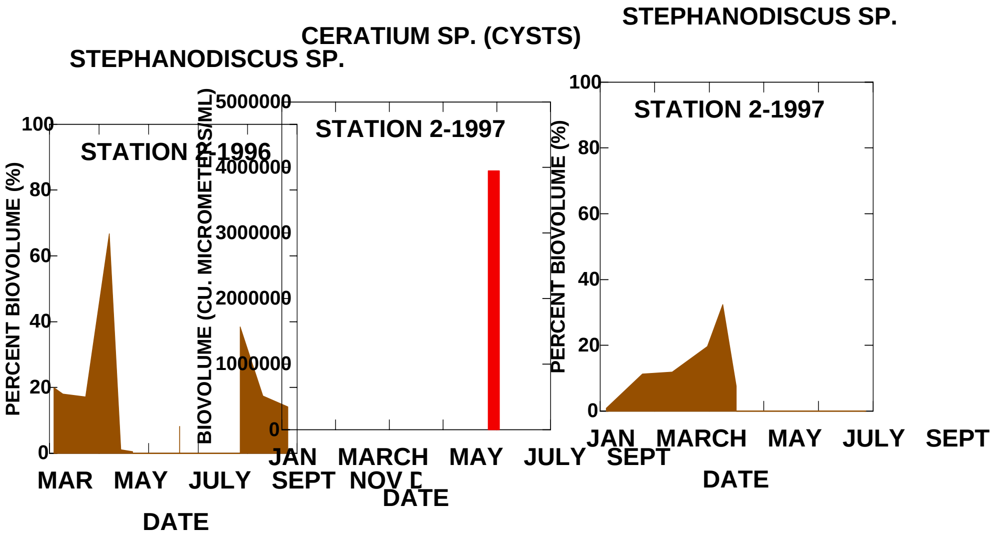

Figure 10 Percent Biovolume of *Stephanodiscus* sp at Station 2 in 1996 and 1997.

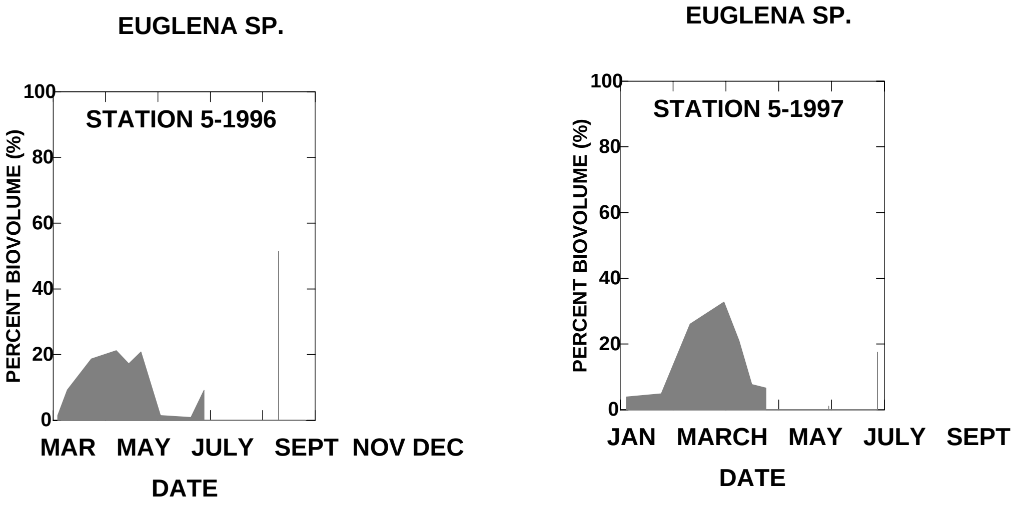

Figure 11 Percent Biovolume for *Euglena* sp at Station 5 in 1996 and 1997.

Figure 12 Biovolume of *Ceratium* sp and *Ceratium* cysts at Station 2, 1997.

Although the dinoflagellate populations were more substantial in 1997, especially at stations 1, 2, and 3 (nutrients were generally higher in 1997), representing both *Gymnodinium* sp. and *Ceratium* sp, the most interesting feature of the dinoflagellate bloom is the encystment of *Ceratium* sp. in 1997 (**Figure 12**). Because encystment is often short-lived, occurring over a few hours or days in many dinoflagellate taxa, its unusual to catch the encystment of an entire population. In 1997, however, *Ceratium* sp. showed a classic encystment event in July, 1997 following a May bloom. The bloom effect was most pronounced at station 2 (perhaps due to the influence of Spring Creek upstream at station 3 or some other isolating effect in that arm of the lake). The cysts were only present on one July date at station 2, and no vegetative cells were observed on the July date. The encystment was likely triggered by increasing summer temperatures since dinoflagellates don't tolerate extremely high temperatures (much above 24-26 ^{0}C), allowing the cysts to fall to the sediments and await cooler, more favorable conditions. *Gymnodinium* sp. likewise leaves the water column in mid-summer, again likely due to the higher temperatures and lower available nutrients in the epilimnion and upper waters of Arcadia Lake as summer progressed. Dinoflagellates have been observed to utilize phagotrophy (using bacteria, small blue-greens and in the case of *Ceratium*, cells or colonies larger than 200+ µm) to augment photosynthesis, again an advantage in a potentially light limited system. Dinoflagellate blooms can be quite common in reservoir systems due to their ability to scavenge nutrients throughout the entire water column by migrating vertically, as well as their ability to thrive in potentially turbid, light limited systems, again by modifying their depth and augmenting photosynthesis (**Pollingher, 1988**).

Green algae normally represented approximately 10-15% of the assemblage by biovolume and essentially were consistent, but less dominating components of the phytoplankton. Most times, the green algae were dominated by small flagellates (*Carteria/Pyramichlamys* spp., *Chlamydomonas* sp.- both in 6-17 µm range) or other small, non-motile and motile green algae (most notably *Coelastrum* spp., *Ankistrodesmus* spp., *Scenedesmus* spp., *Sphaerocystis* sp, *Crucigenia* spp. and *Pandorina* sp., again in the 4-30 µm range). The most important features of the green algae were that they were generally small and were present most consistently during mid-summer. The diversity of the green algae and taxa present are both indicative of high nutrient (especially nitrogen) conditions. In addition, the small size range for most of the taxa would allow the taxa to take advantage of the quick nutrient recycling rates and would suggest lower sinking rates, perhaps a response to the lower light, high particulate conditions. Cryptomonads which also were sporadically important during certain parts of both years (primarily spring and fall) are also small, motile cells. Cryptomonads are also capable of facultative heterotrophy, allowing them to augment photosynthesis by phagotrophy of smaller algal and bacterial cells. The small size range and relatively high food quality of several of the green, diatom and especially cryptomonad taxa, would also present a reasonably good food source for many zooplanktors as well.

Summary

In summary, the phytoplankton data indicate that Arcadia Lake is rich in nutrients, but the densities and biovolume reflect a system limited more by light than nutrients. Arcadia Lake would be classified as eutrophic by algal density and mesotrophic-eutrophic by algal biovolume. Algal taxa indicate a eutrophic system. Predominant taxa numerically are small blue-greens, easily edible by a variety of filter-feeding zooplankton. These small blue-greens likely significantly impact nutrient cycling and energy flow in the upper waters of the lake. Other algae present during different times of the year are associated with nutrient enriched conditions and are also mostly in the edible range in terms of size, especially the diatoms, cryptomonads and greens (mostly below 30 µm). Smaller size also allows these algae to stay suspended for longer periods of time, an advantage in a light limited system. Dinoflagellate blooms are consistent with those observed in other reservoirs and are controlled primarily by nutrients and extreme temperatures. Euglenoids at stations 4 and 5 confirm high organic enrichment entering Arcadia Lake from the Deep Fork River. Several of the divisions and taxa in Arcadia Lake are capable of facultative heterotrophy (dinoflagellates, euglenoids, to some extent potentially diatoms and especially the cryptomonads), which would allow them to augment photosynthesis in such highly enriched, light limited circumstances. Nitrogen-fixing blue-greens include several taxa that can cause not only taste and odor problems, but toxicity and impairment as well. Light limitation keeps these potentially troublesome blue-greens from becoming extremely noxious and prevents lake wide or large expanses of surface blooms, but densities and biovolume can still be quite high at certain times of the year, markedly affecting water quality.

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Appendix G

Introduction

Numerous investigations of temperate and subtropical lakes have documented changes in zooplankton community structure associated with increasing eutrophication. Typically, total zooplankton biomass increases with lake productivity and is accompanied by species replacements within the Cladocera and Copepoda (**Hall et al. 1970, O'Brien and De Noyelles 1974**). Within the macrozooplankton, calanoid copepods decrease in proportional abundance (**McNaught 1975, Gliwicz 1969**), while small-bodied cladocerans and cyclopoid copepods dominate the zooplankton communities of eutrophic lakes (**Brooks 1969**). The overall importance of macrozooplankton decreases to favor dominance by microzooplankton, especially rotifers and ciliated protozoa (**Gannon and Stemberger 1978, Bays and Crisman 1983**).

Compositional shifts in zooplankton community structure associated with eutrophication are attributable in part to enhanced predation pressure (**Brooks 1969**). The abundance of planktivorous fish increase along with lake productivity (**Larkin and Northcote 1969**), decimating large-bodied zooplankton populations due to the latter's higher susceptibility to vertebrate predation. Invertebrate predators such as *Chaoborous* and cyclopoid copepods also increase with eutrophication and may alter zooplankton community size structure through selective predation (**Zaret 1980**).

This chapter summarizes zooplankton dynamics and composition for Arcadia Lake using data from two growing seasons (February 1996 - September 1997). An analysis of the likely factors structuring the dynamics and composition of the zooplankton community of Arcadia Lake is also presented, with special attention to the relationship between zooplankton components and water quality variables.

Methods

Zooplankton samples were collected from Arcadia Lake (twice monthly during mid-summer, and monthly during other seasons) by vertical tows of a plankton net (diameter = 12 cm) at stations 1 through 5.

The volume of sample concentrate was measured, and three 1-ml aliquots were examined at 100x for microzooplankton (nauplii and rotifers) on a Wilovert inverted microscope equipped with phase contrast. If the total tally is less than 200, additional aliquots up to a maximum of 10 ml were examined. In samples for which the abundance of macrozooplankton was low, additional aliquots were examined at 60x for these large zooplankton. Taxonomic identification followed **Ruttner-Kolisko** (**1977**), **Edmundson** (**1959**), and **Pennak** (**1989**).

Biomass estimates were based on established length/width relationships (**Dumont et al. 1975, McCauley 1984, Lawrence et al. 1987**). The lengths or the lengths and widths of each species encountered were measured from a composite sample formed by pooling approximately 5 ml from each sample for that date. The number of specimens examined was equal to at least 10 percent of the total tally for each species or zooplankton component. For cladocerans, the length was measured from the tip of the head to the end of the body (shell spines excluded). For copepods, the length was determined from the tip of the head to the insertion of the caudal ramus. The length of rotifers was measured from the tip of the head to the end of the body (spines, toes, etc. excluded). In accordance with **McCauley** (**1984**), biomass was computed for the appropriate number of individuals for each sample location and the arithmetic mean biomass was multiplied times the species abundance to produce a species biomass for each sample.

Results

Zooplankton community seasonality with respect to abundance and biomass

The total abundance of total zooplankton in Arcadia Lake generally followed a bimodal seasonality. Average total zooplankton (cladocerans, copepods, and rotifers) abundances were generally high in 1996 and 1997 in May and June (**Fig. 1**). After a low-density period from the end of September through January, density peaked again in February during each year. Similar seasonal abundance patterns and densities were evident during both sampling years, although abundances were generally higher in 1996 than in 1997, with the exception of April 1997.

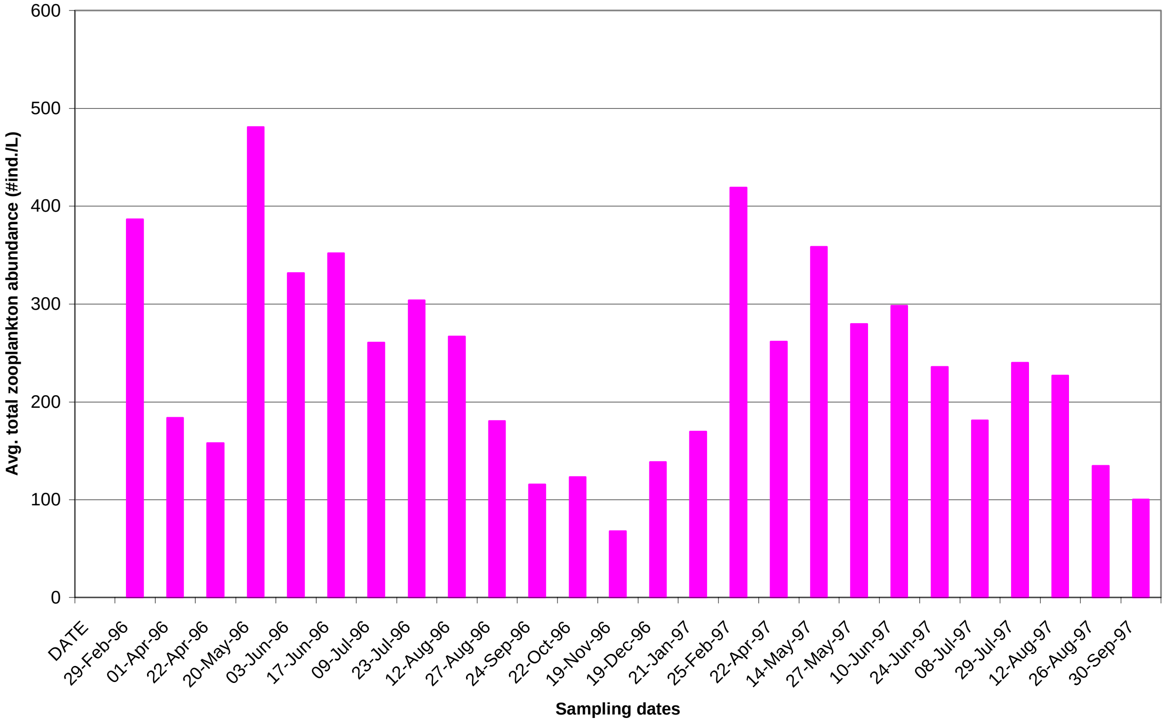

Figure 1 Average total zooplankton abundance

Unlike total zooplankton densities, seasonal abundance peaks for cladocerans varied somewhat between 1996 and 1997. Although peaks in cladoceran densities were detected in early June of both years (**Fig. 2**), a secondary peak in August 1996 (~59 ind./L) was not observed in 1997. The cooler months (October - February) consistently displayed the lowest cladoceran population.

Average copepod densities showed similar trends in both sampling years with peak abundances from mid-July until the end of August (highest densities > 60 ind./L) (**Fig. 3**). As with total zooplankton, markedly more copepods were present in February 1996 than in February 1997. Average nauplii densities followed the same seasonal patterns as adult copepod densities; however, nauplii densities were usually at least double that of adult densities at every sampling date (highest peak was ~130 ind./L in July 1996) (**Fig. 4**).

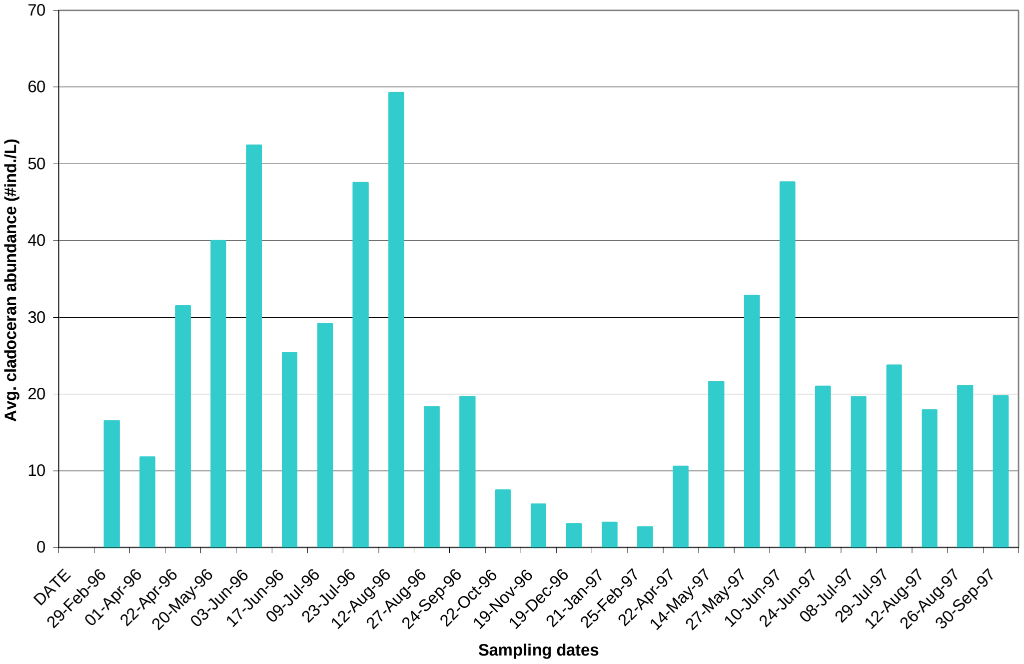

Figure 2 Average Cladoceran abundance

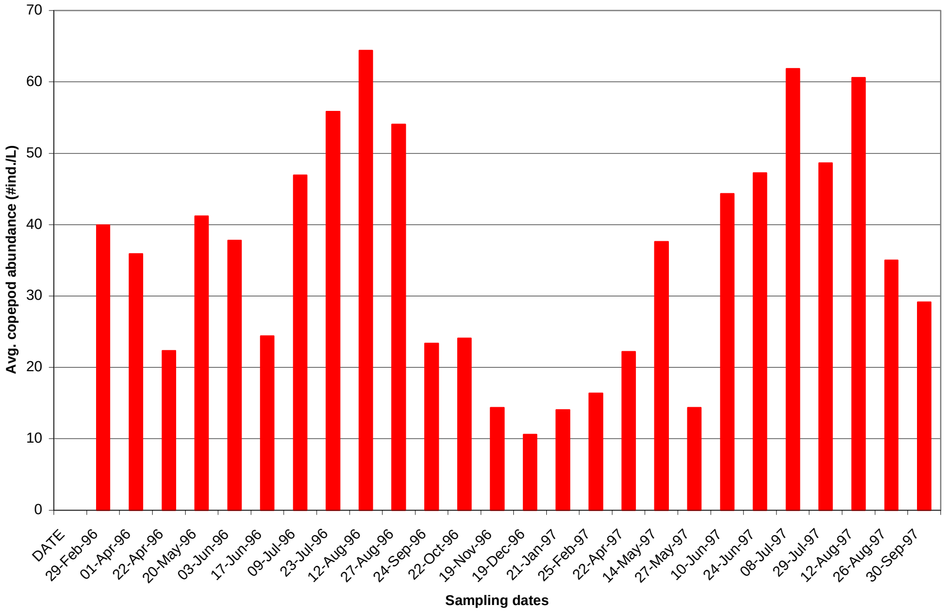

Figure 3 Average Copepod abundance

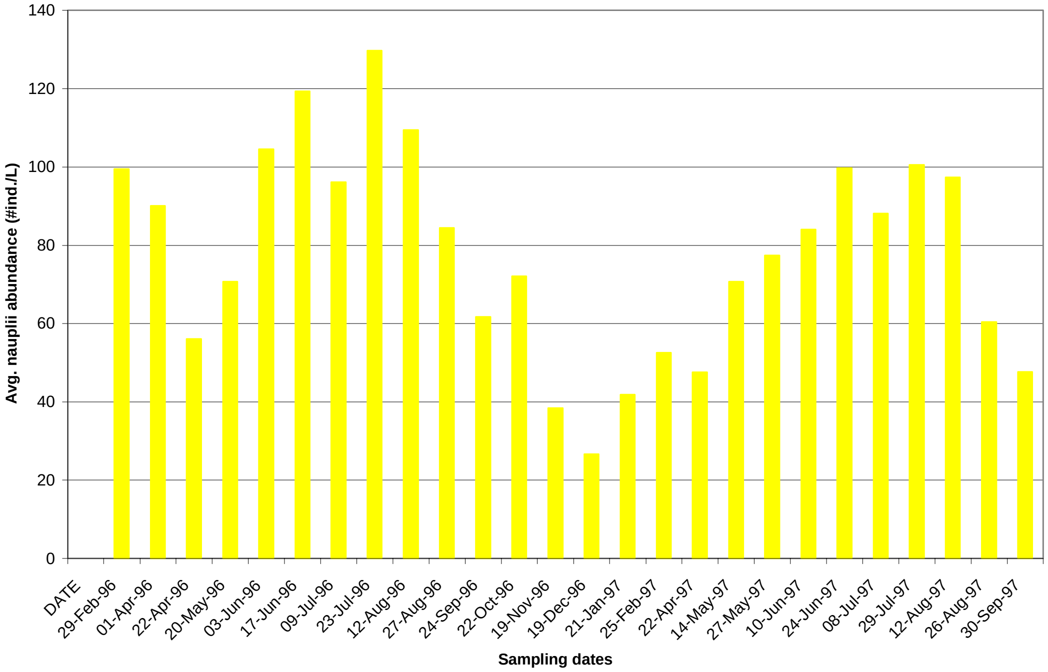

Figure 4 Average Nauplii abundance

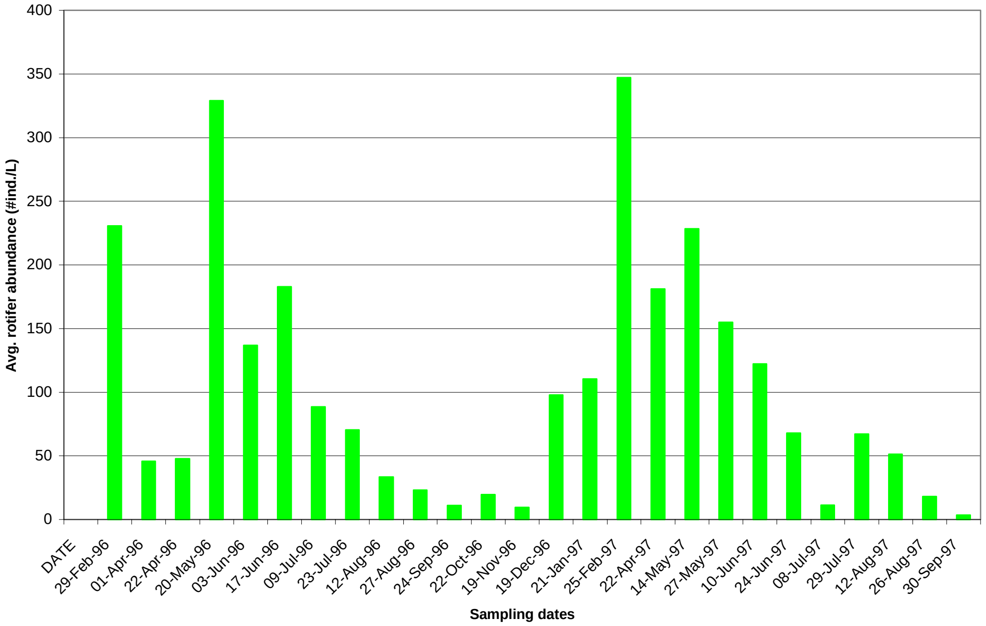

Figure 5 Average rotifer abundance

Rotifers were the most numerous zooplankton component with average density peaks greater than 300 ind./L in both years (**Fig. 5**). Rotifer populations peaked during May of 1996 and February of 1997. While the abundance patterns were similar for both years, three times as many rotifers were present in April 1997 than in April 1996. Rotifer populations started to decline in July and remained low through January. Ostracods were found in only one sampling date each year (Aug. in 1996 and July in 1997) (**Fig. 6**) and at very low densities.

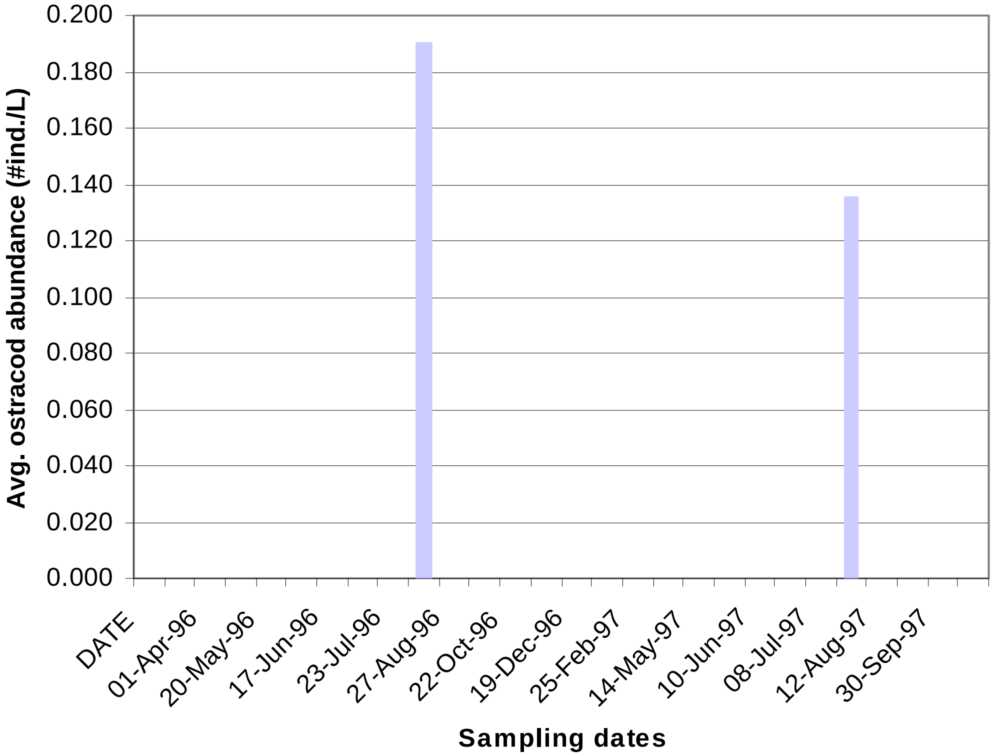

Figure 6 Average Ostracod abundance

In contrast to zooplankton abundance, average total zooplankton biomass was generally greater in 1997 than in 1996. In 1997, biomass peaked in May and remained relatively high until August, whereas more discrete peaks were evident in February, July, and August in 1996 (**Fig. 7**). Cladocerans and copepods accounted for the majority of zooplankton biomass in relatively equal proportions. Average copepod biomass, however, did not decline as much in the cooler months as did cladoceran biomass (**Fig. 8 and 9**). Cladocerans peaked in May through June in both years. The only zooplankton component whose average biomass was greater in 1996 than 1997 was nautili (**Fig. 10**). Rotifers (**Fig. 11**), and ostracods (**Fig. 12**) contributed very little to overall biomass.

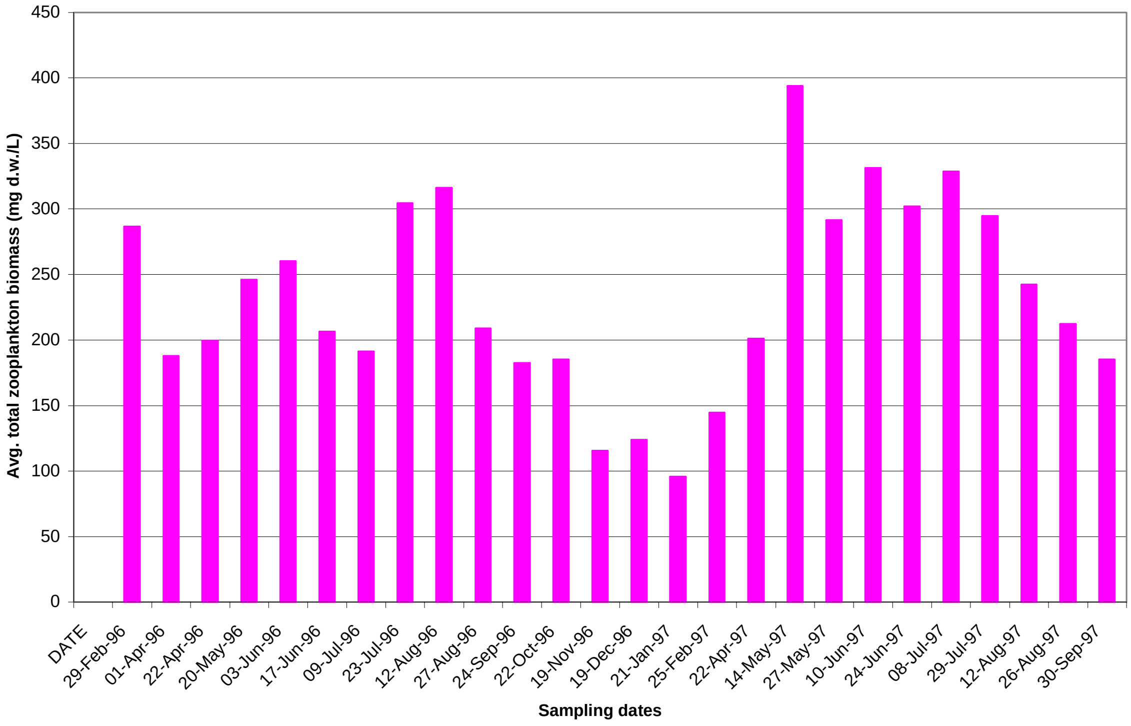

Figure 7 Average total zooplankton biomass

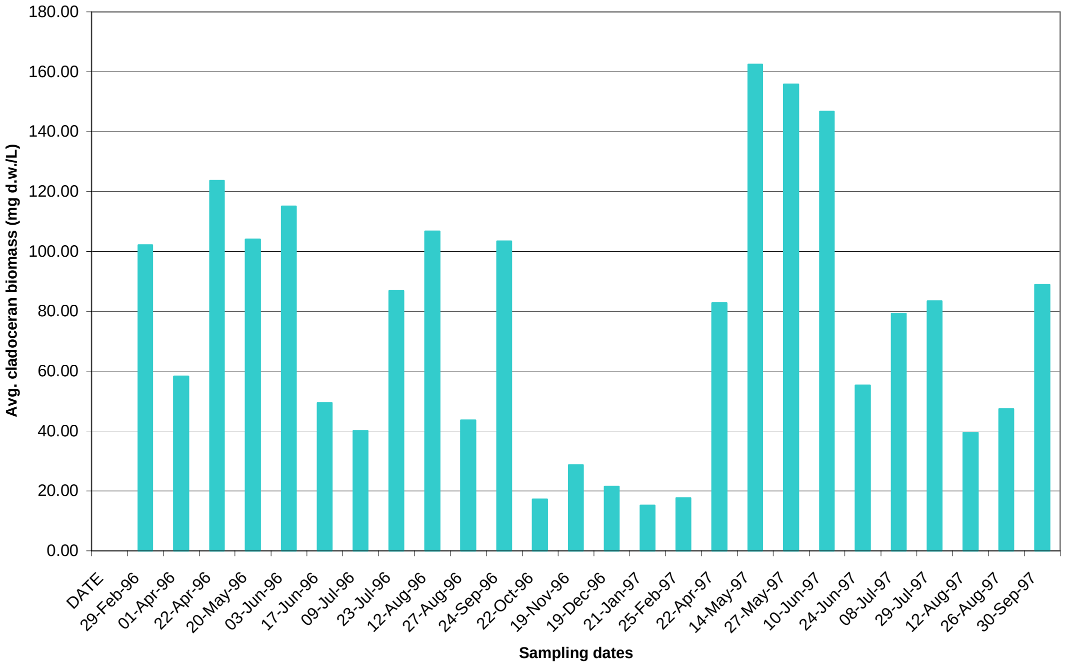

Figure 8 Average Cladoceran biomass

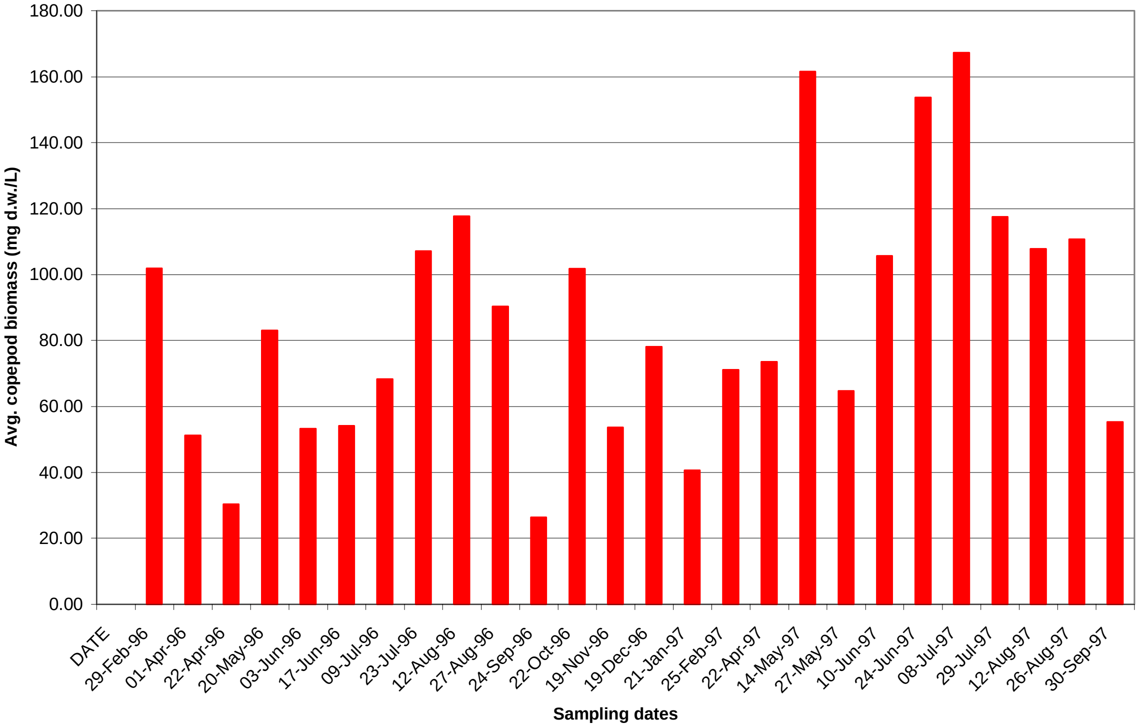

Figure 9 Average Copepod biomass

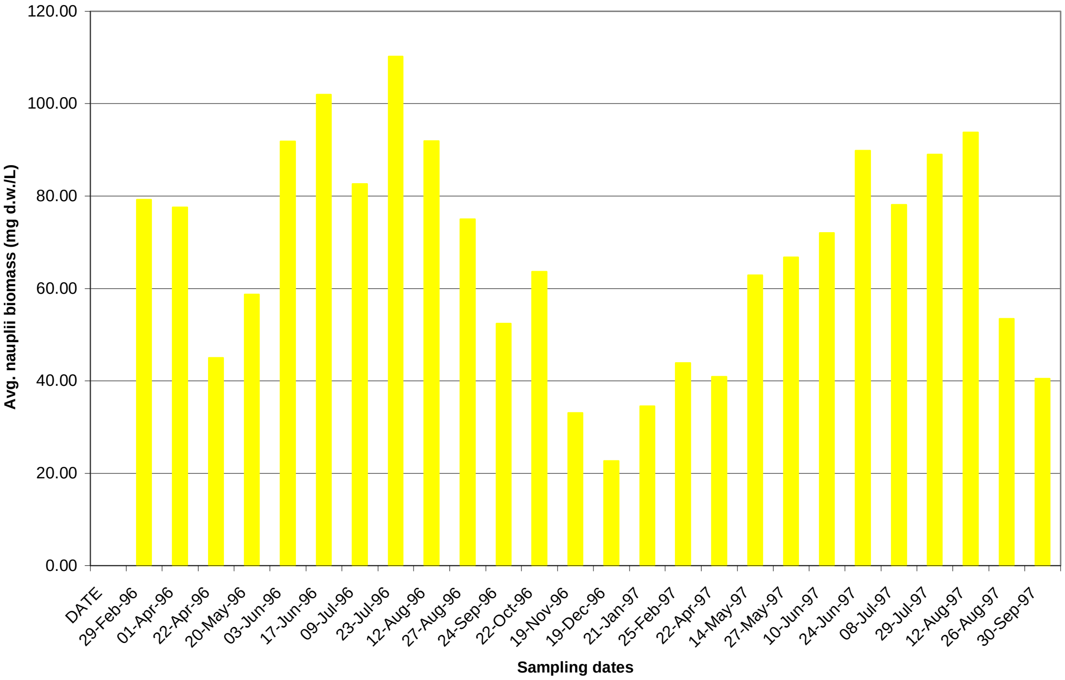

Figure 10 Average Nauplii biomass

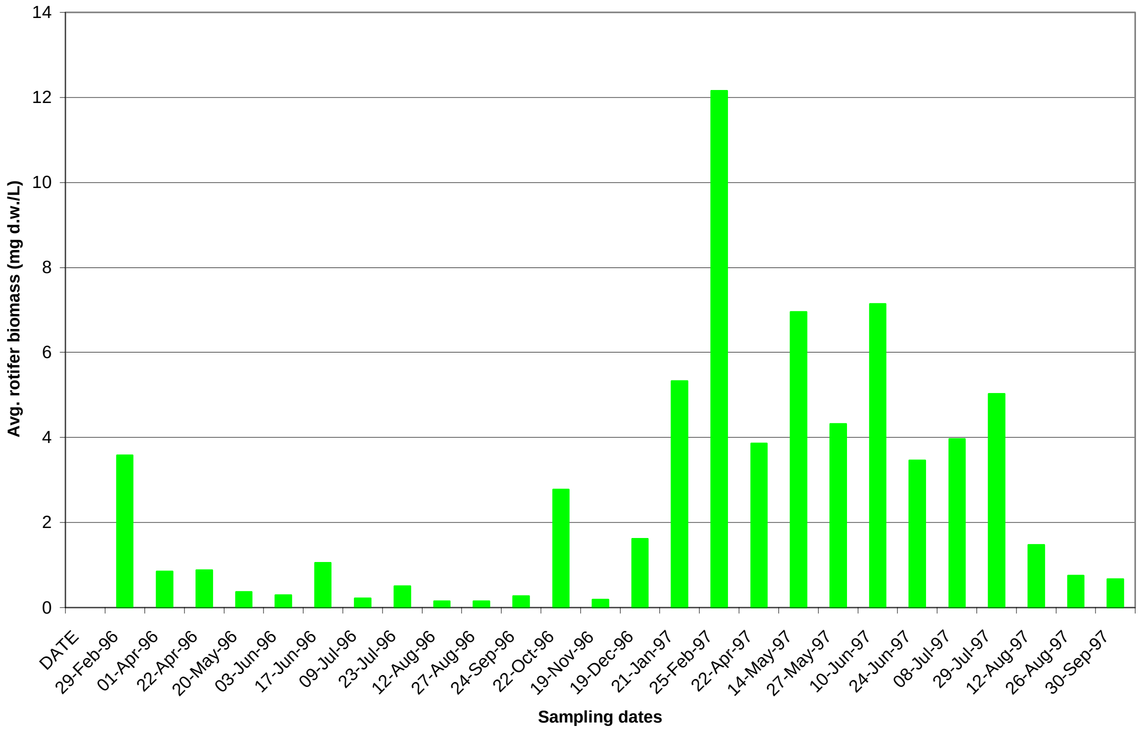

Figure 11 Average rotifer biomass

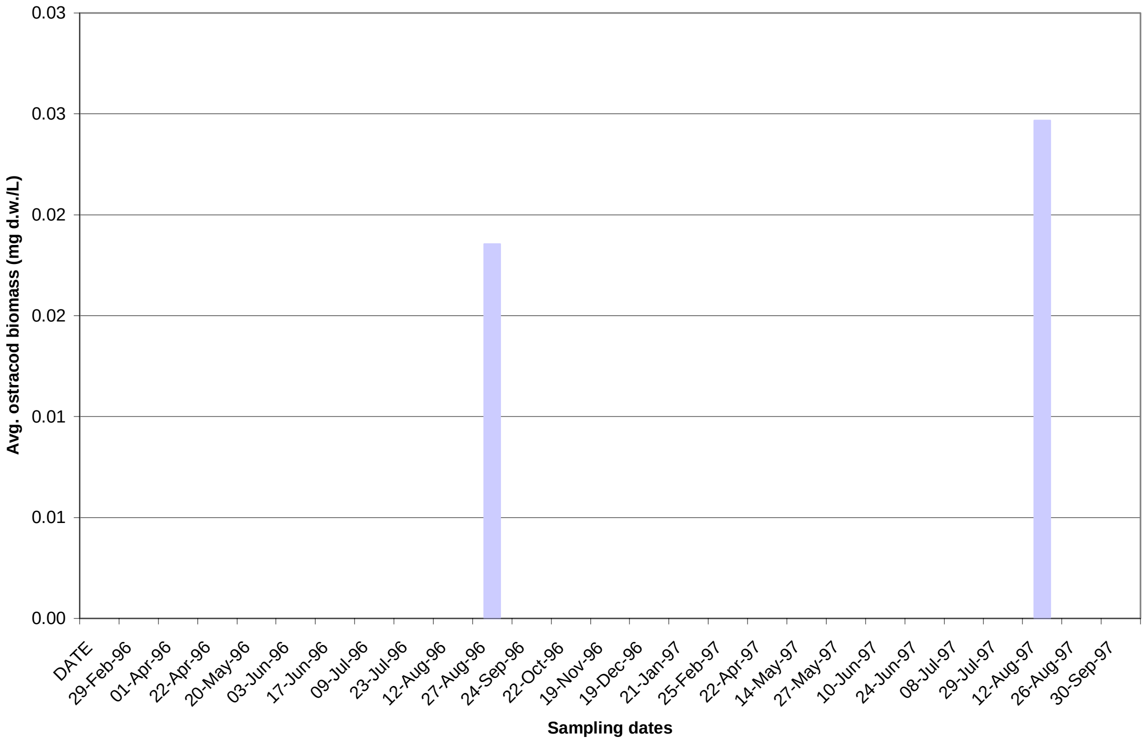

Figure 12 Average Ostracod biomass

Zooplankton community organization as percentage composition

Cladoceran community: Cladocerans experienced many changes in species dominance and exhibited a clear successional pattern. *Bosmina longirostris* was the most prevalent cladoceran between April and June of 1996, *Diaphanosoma brachyurum* was dominant from mid-June through August, and *Daphnia pulex* was dominant in October, and was co-dominant with *Daphnia laevis* until May of 1997 (**Fig. 13**). In June through September of 1997, *Diaphanosoma birgei* was very prominent with the exception of one sampling date. Because of its large size, *D. pulex* contributed heavily to cladoceran biomass for most of the study (**Fig. 14**). During the summer of 1997, when *D. pulex* was rarely found, *Daphnia laevis* had the greatest biomass. The exotic cladoceran *Daphnia lumholtzi* was never found in more than three sampling dates in any station. It was usually found in either late July or early August and at very low abundances.

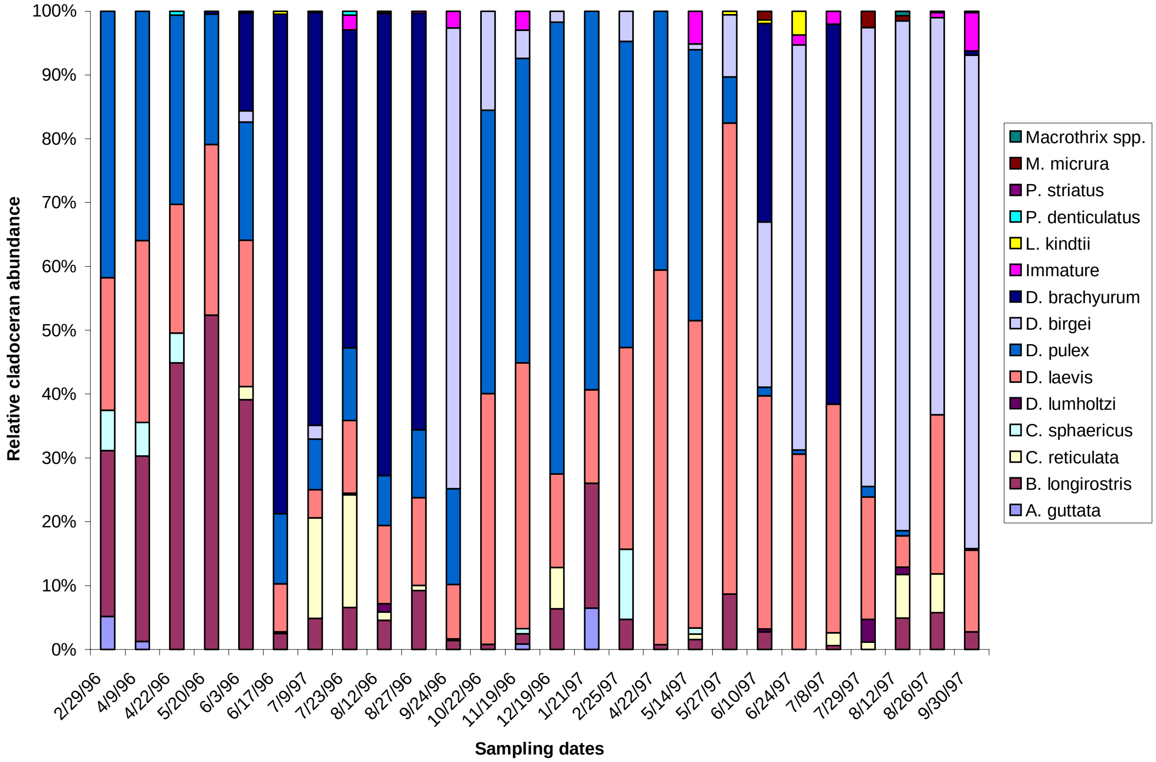

Figure 13 Relative Cladoceran abundance

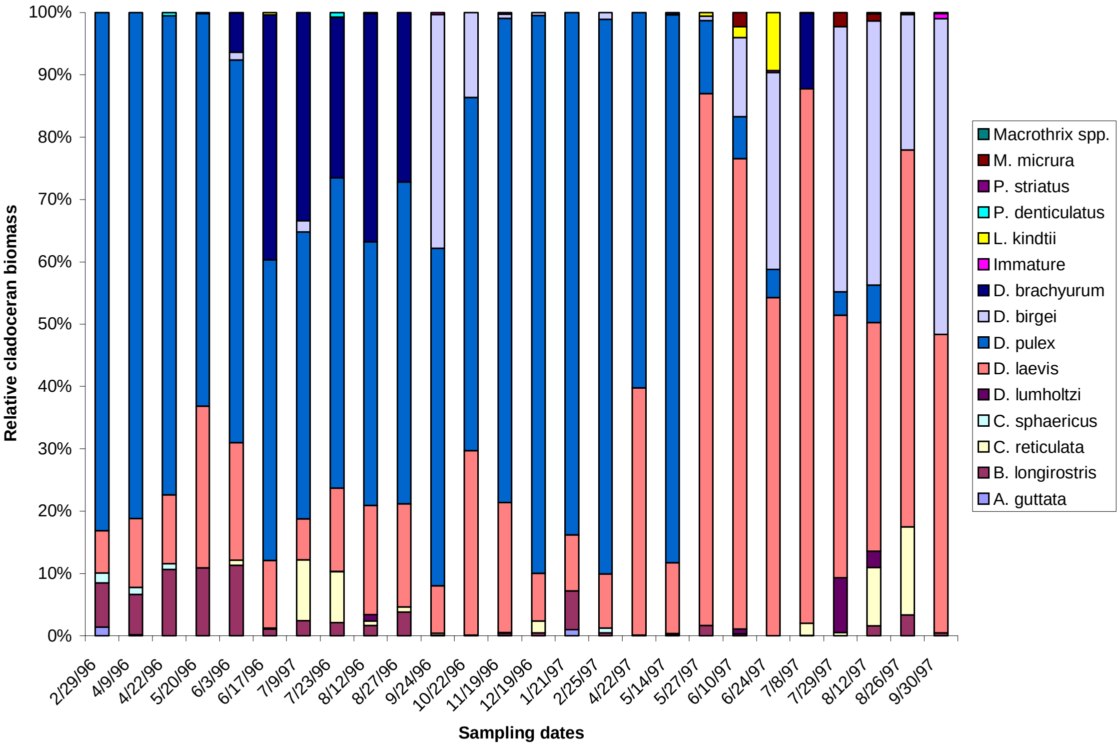

Figure 14 Relative Cladoceran biomass

<u>Copepod community:</u> Calanoid and cyclopoid copepodites numerically dominated the copepod community throughout the study period (**Fig. 15**). *Skistodiaptomus mississippiensis* was always present but occurred in the greatest proportion from February to September of 1996. Subsequently, *Leptodiaptomus connexus* and *Skistodiaptomus mississippiensis* co-dominated. A similar pattern was observed in copepod biomass (**Fig. 16**).

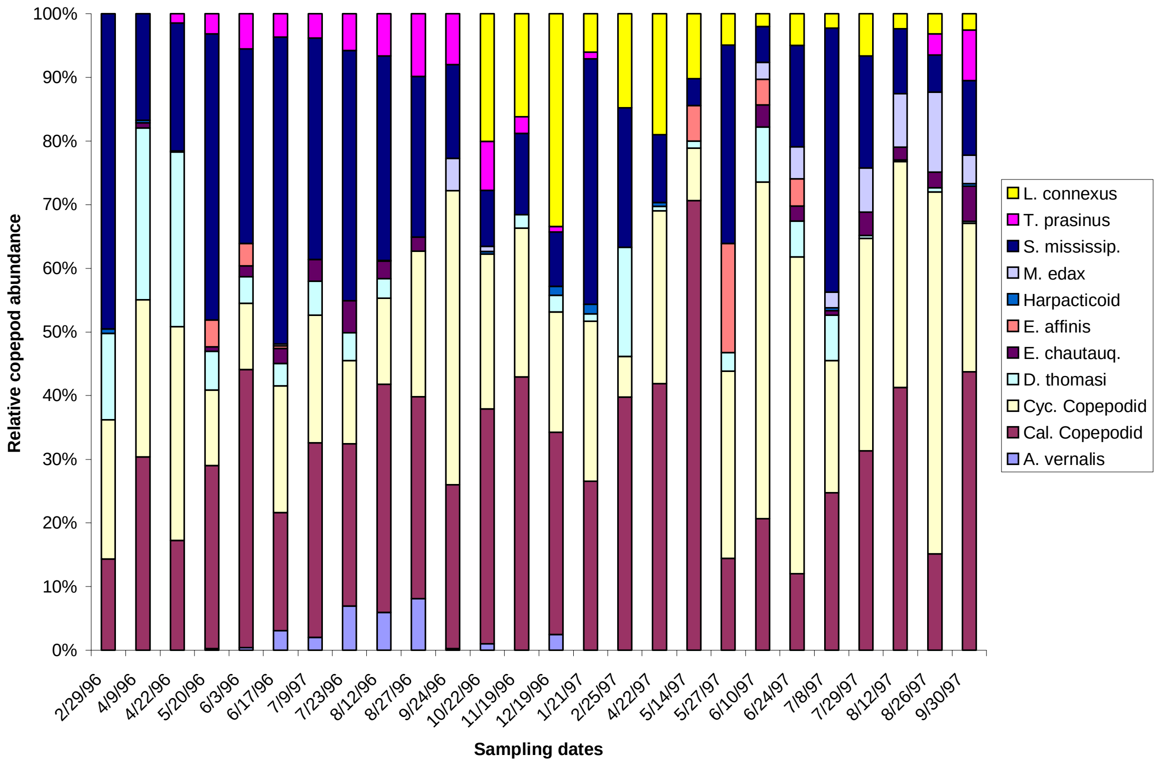

Figure 15 Relative Copepod abundance

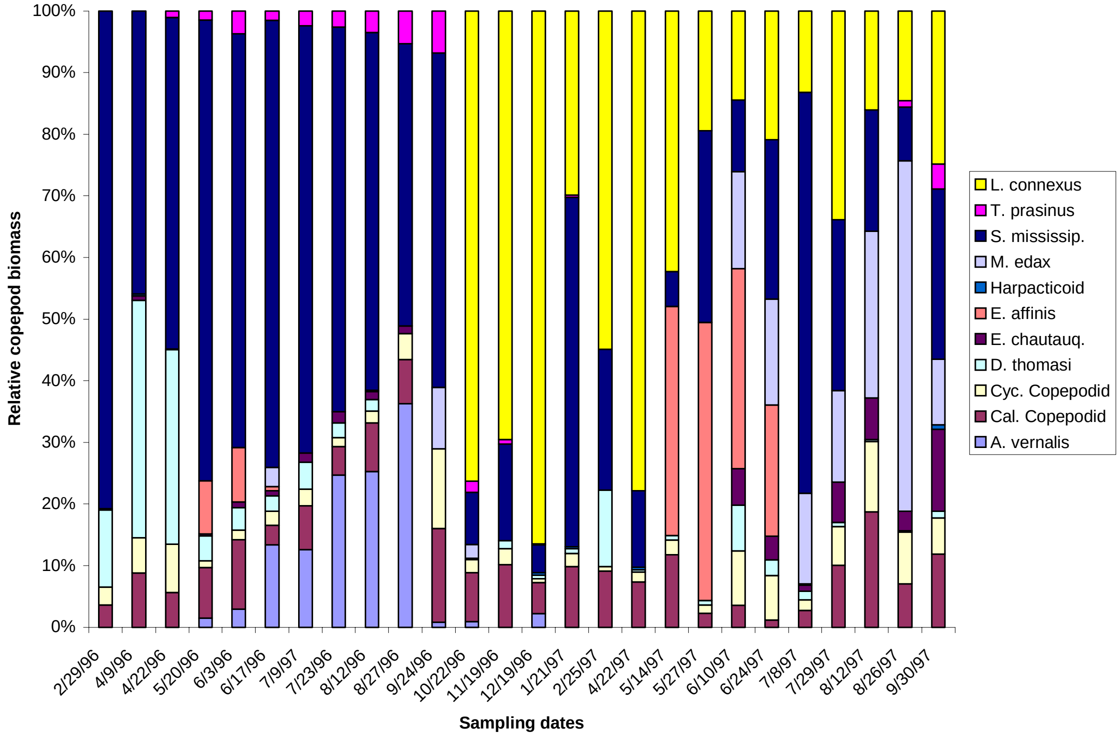

Figure 16 Relative Copepod biomass

Rotifer Community: As a taxonomic group, rotifer species diversity was greater than any other group. Three species dominated sporadically throughout the sampling period: *Conochilus unicornis, Gastropus hypotus,* and *Polyarthra vulgaris* (**Fig. 17**). In May of both years and August 1997, *C. unicornis* comprised more than 70 percent of rotifer abundance, although numerous species were found on each sampling date. *Asplanchna spp.* were typically not very abundant, but when present they accounted for the majority of the biomass (**Fig. 18**).

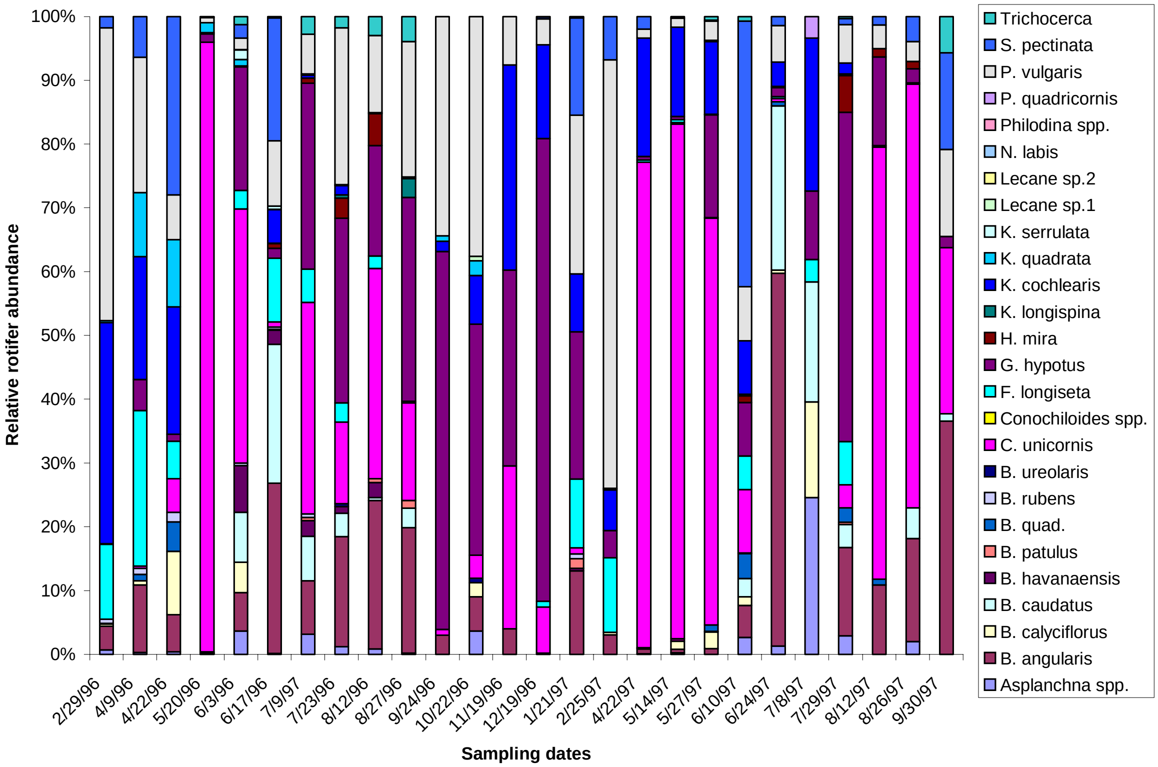

Figure 17 Relative rotifer abundance

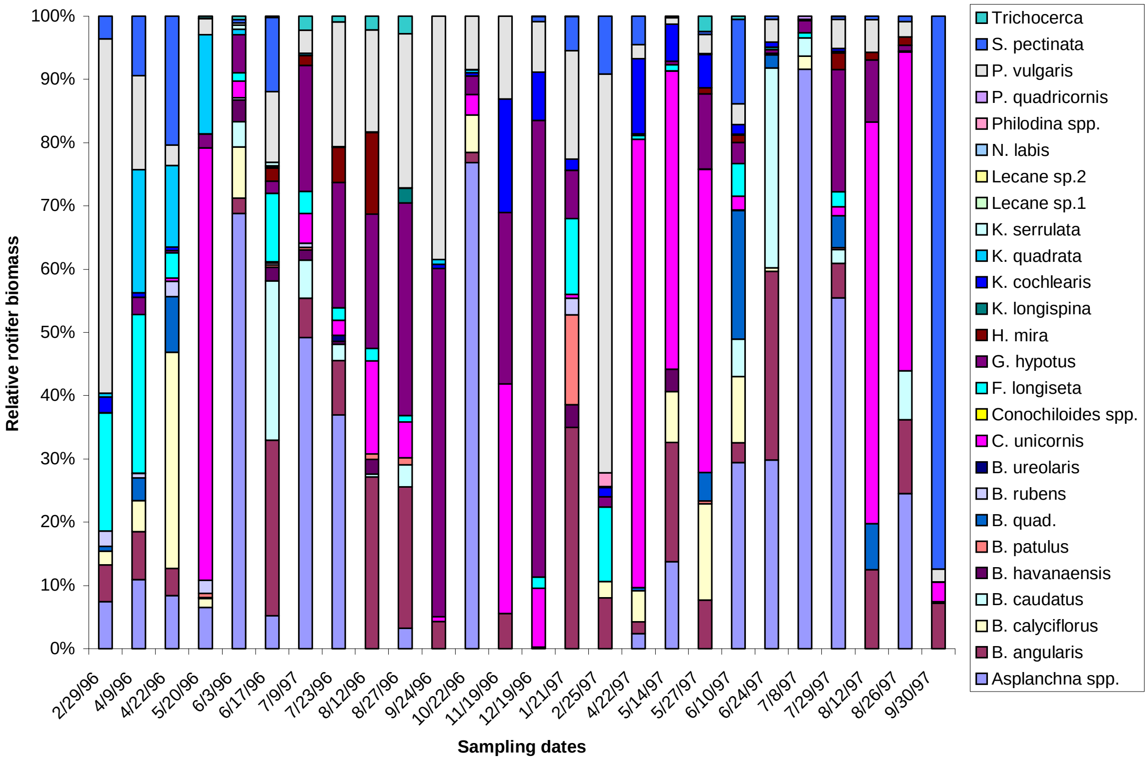

Figure 18 Relative rotifer biomass

Zooplankton community differences relative to some physio-chemical parameters

Based on physio-chemical parameters, the five sites displayed variable trophic states. Stations 1-3 were less eutrophic than the other sites, station 4 was more nutrient-rich, and station 5 was in the hypereutrophic range (**based on Carlson's 1977 Trophic State Index**).

Zooplankton abundance was generally reflected by the trophic status of the stations. Chlorophyll a (Chl a) and total phosphorus (TP) were lowest at station 1, which also had the least amount of zooplankton in all four groups (cladocerans, copepods, nauplii, and rotifers) (**Table 1**). There was a trend toward increasing levels of Chl a and TP from station 1 through station 5. Abundances were greatest at station 5, with cladocerans, nauplii, and rotifers approximately twice the densities at station 1. Zooplankton were more abundant at stations 2, 3, and 4 than at station 1, and similar densities occurred within the individual groups of zooplankton with the exception of a lower number of rotifers at station 3. Transparency showed an inverse trend. In general, transparency decreased from 61 cm in the first station until visibility decreased to 30 cm. Total nitrogen concentrations were similar among the five sites.

Zooplankton biomass did not parallel the trends in abundance. Sites 2 and 3 remained similar to each other in all groups, but station 4 had the highest total zooplankton biomass (**Table 1**). Copepod, nauplii, and rotifer biomass was highest at station 5, although total zooplankton biomass was less at site 5 than site 4 due to the differences in cladoceran biomass. Station 5, the most eutrophic based on water quality parameters, also had the greatest abundance and biomass of *Asplanchna*, *Bosmina*, and *Brachionus* (**Table X-2**). The biomass of these taxa at station 5 were all significantly higher than at the other stations.

Table 1. Mean abundance and biomass of major zooplankton groups by station, and select water quality variables in Arcadia Lake during the study period

Abundance (# ind./L)

Station	Cladocerans	Copepods	Nauplii	Rotifers	Total zooplankton
1	17.70	27.02	50.87	63.47	159.06
2	21.12	35.57	79.74	124.81	261.25
3	20.94	39.42	71.02	86.20	217.58
4	25.67	38.22	87.79	107.16	258.84
5	32.62	38.46	101.99	138.41	311.53

Biomass (ug d.w./L)

Station	Cladocerans	Copepods	Nauplii	Rotifers	Total zooplankton
1	60.56	63.59	44.11	1.16	169.42
2	78.22	87.14	67.88	2.88	236.11
3	72.00	87.96	61.10	1.68	222.74
4	103.93	97.67	77.13	2.80	281.52
5	68.61	98.69	88.15	4.65	260.11

Physio-chemical parameters

Station	Secchi depth (cm)	Chl a (ug/L)	TN (mg/L)	TP (ug/L)
1	60.24	12.10	0.888	0.053
2	47.65	12.68	0.805	0.056
3	53.66	12.78	0.772	0.054
4	35.62	14.12	0.834	0.079
5	23.30	21.37	0.979	0.115

Table 2. Mean abundance of select zooplankton genera by station in Arcadia Lake during the study period.

(*,** significantly different from the other stations)

	Asplanchna		***Brachionus***		***Bosmina***	
Site	Abundance (#ind./L)	Biomass (ug d.w./L)	Abundance (#ind./L)	Biomass (ug d.w./L)	Abundance (#ind./L)	Biomass (ug d.w./L)
1	6.24	3.27	165.15	5.4	74.23	53.74
2	15.48	19.56	468.78	16.7	62.79	50.03
3	12.21	8.11	218.55	7.16	52.21	32.91
4	27.17	21.08	234.52	12.98	71.75	49.69
5	47.59	*62.99	659.27	**65.81	145.11	**126.33

* = $p<0.10$ (Significance determined using Student-Newman-Keuls Test);** = $p<0.05$

Zooplankton correlations with the physical and chemical lake components

In general, most zooplankton components were correlated only moderately to poorly with environmental/limnological variables. Temperature was positively, moderately ($p<0.01$) correlated with cladoceran, copepod, and nauplii densities and with copepod, nauplii, and total zooplankton biomass; rotifer biomass was negatively, weakly ($p<0.05$) correlated (**Tables 3 and 4**).

Rotifer biomass was the only group positively correlated with pH. Specific conductivity was positively correlated with rotifer abundance and biomass, and with total zooplankton density. Dissolved oxygen was negatively, moderately correlated with cladoceran and nauplii densities and biomass, copepod abundance, and total zooplankton biomass.

The correlations between zooplankton components and measures of algal biomass do not suggest a strong cause and effect relationship. Transparency was positively, moderately correlated with nauplii abundance. Turbidity was only positively, moderately correlated with cladoceran biomass. Chlorophyll-*a* was positively, moderately correlated with ostracod density and biomass, and copepod abundance; and was positively correlated with nauplii density and biomass. Pheophytin-*a* was only positively, moderately correlated with copepod densities.

Total nitrogen was positively, moderately correlated with nauplii abundance and biomass, and copepod abundance, and weakly, positively correlated with cladoceran density and total zooplankton biomass. Total phosphorus was only weakly, negatively correlated with rotifer density and biomass.

Table 3. Correlations among the abundancies of select limnological variables in Arcadia Lake during the study period. Correlations are Pearson product-moment type.

	Cladocerans	Ostracods	Copepods	Nauplii	Rotifers	Total zooplankton
Temperature	0.691**	0.212	0.726**	0.738**	-0.170	0.229
pH	-0.088	0.369	0.150	0.072	0.102	0.134
SpCond	-0.031	-0.322	-0.369	-0.087	0.644**	0.505**
DO	-0.644**	-0.184	-0.641**	-0.615**	0.152	-0.196
Secchi	0.291	0.384*	0.258	0.597**	-0.212	0.039
Turbidity	0.276	-0.349	-0.023	-0.174	0.059	0.049
Chlorophyll-a	0.074	0.674**	0.494**	0.385*	-0.328	-0.117
Pheo-a	0.332	0.135	0.565**	0.309	-0.296	-0.057
Total N	-0.387*	-0.181	-0.578**	-0.638**	-0.026	-0.330
Total P	0.231	-0.178	0.088	-0.131	-0.415*	-0.368

positively correlated; **negatively correlated**; **** = p<0.05***; ***** = p< 0.01***

Table 4. Correlations among the biomasses of zooplankton components and select limnological variables in Arcadia Lake during the study period. Correlations are Pearson product-moment type.

	Cladocerans	Ostracods	Copepods	Nauplii	Rotifers	Total zooplankton
Temperature	0.371	0.212	0.432*	0.753**	-0.382*	0.670**
pH	-0.085	0.369	0.264	0.160	0.420*	0.159
SpCond	0.338	-0.322	-0.042	-0.119	0.529**	0.153
DO	-0.511**	-0.184	-0.366	-0.620**	0.272	-0.649**
Secchi	-0.045	0.279	-0.002	0.602**	-0.231	0.146
Turbidity	0.505**	-0.350	-0.012	-0.225	-0.069	0.217
Chlorophyll-a	-0.296	0.746**	0.182	0.464*	-0.272	0.050
Pheo-a	-0.025	0.116	0.319	0.316	-0.116	0.240
Total N	-0.213	-0.168	-0.229	-0.615**	0.113	-0.425*
Total P	0.143	-0.110	0.121	-0.108	-0.484*	0.087

positively correlated**;** **negatively correlated****;** * = $p<0.05$; ** = $p< 0.01$

Discussion

Possible Controlling Factors

Examination of trophic-level interactions has been an integral theme in limnology (**e.g., Nauwerck 1963, Brooks and Dodson 1965**). Zooplankton function as pivotal intermediaries between fish and lower trophic levels. Temporal and spatial alterations in plankton community structure have long been recognized as biological manifestations of eutrophication **(Shapiro et al.1975, Crisman and Beaver 1990**). Among the environmental factors potentially structuring zooplankton communities, abundance and composition of the phytoplankton and the intensity of predation by planktivorous fish are frequently important. Plankton dynamics are often attributed to abiotic (e. g. nutrients and transparency) and/or biotic (top-down forces) factors. It is likely that both types of factors are, to some degree, operant on the plankton community of Arcadia Lake. Furthermore, these influences can vary spatially and seasonally within a lake.

We suggest that food availability in Arcadia Lake is a strong controlling factor for zooplankton abundance, particularly for rotifers. The relationship between crustacean zooplankton components and trophic state variables was significant only during spring. This observation suggests that, although populations of adult crustaceans responded somewhat to increased food availability in the spring, other controlling factors were limiting their populations during other seasons. The seasonal abundance of adult crustaceans in Arcadia Lake may have been more strongly influenced grazing activities of planktivores.

Although increased phytoplankton biomass should support elevated zooplankton densities in general (**McCauley and Kalff, 1981**), the poor correlations observed in our study strongly suggests that this trophic link is only seasonally coupled in Arcadia Lake. Adult crustacean densities were greatest during the late fall and early spring but reached the lowest levels in summer densities coincident with peaks in algal biomass. During summer, the decline in large zooplankton in Arcadia Lake may have resulted from predation by fish. The importance of zooplankton as food for juvenile and adult fish (**Jones and Hoyer 1982, Guest et al. 1990**) and the ability of planktivorous fish to decimate larger-bodied zooplankton (**Nauwerck, 1963, Brooks and Dodson, 1965**) are well established. Detailed fish data for Arcadia Lake are lacking, but it is likely that the fish community is dominated by common carp (*Cyprinus carpio*). This omnivorous fish is considered typical of eutrophic habitats, feeding on both the plankton and the benthos (**Baker et al. 1993**).

Axler et al (**1988**) have demonstrated the clear relationship among phosphorus, primary productivity, various water quality variables, and fisheries. However, nutrient enrichment or reduction, respectively, does not necessary translate into a one-to-one increase or decrease in zooplankton abundance. Phytoplankton responses to modest nutrient enrichment may include an increase in more favorable food items for herbivorous zooplankton (**McCauley and Kalff 1981, Elser and Goldman 1991**), but greater nutrient enrichment may increase the abundance of larger colonial and filamentous cyanophytes which are less desirable for herbivorous crustacean zooplankton (**Porter 1977**). We suggest that all components of the zooplankton community in Arcadia Lake responded positively to increased algal biomass, but rotifer populations peaked in summer only when competition from more efficient filter-feeding cladocerans and copepods was reduced by planktivory from fish (**Brooks and Dodson 1965**).

When viewed as a group, cladoceran seasonality was more pronounced than copepods. However, within the cladocerans a definite species succession representing a progressive increase in the size of the dominant species occurred each year of the study (*Bosmina, Diaphanosoma, Daphnia*). The small-bodied *Bosmina* dominated the cladoceran community in early spring while the large bodied *Daphnia pulex* reached its annual maximum during early fall. During summer *Daphnia* were at very low densities while the small-bodied *Bosmina* and rotifers dominated the zooplankton community.

The effects of increased nutrients on phytoplankton in aquatic systems have been well documented. The fact that station 5 had the highest density of cladocerans yet station 4 had the highest biomass suggests that there were zooplankton compositional differences among the sites. Station 5 had the lowest percentage of the large-bodied cladoceran *D. pulex*, as well as the highest percentage of the small-bodied, *B. longirostris*. Furthermore, station 5 was the only site where *Bosmina* abundance exceeded *D. pulex*. Such a difference between areas could indicate, either an increase in predation on the larger bodied crustacean by planktivores, or a more nutrient rich environment, where small-bodied cladocerans often fare better (**Gannon and Stemberger 1978**). Increased grazing pressure from visual feeding predators does not seem likely since the transparency was the lowest at the Deep Fork arm of the lake. However, due to the higher concentration of TP, it is possible that *Bosmina* were more prevalent in that site, due to their high reproductive rates, which allow a more rapid response to the high nutrient levels (**Allan 1976, Hofmann 1996**). *Bosmina longirostris* is also a typical eutrophic species (**Gannon & Stemberger 1978**) and has been shown to exhibit strong selectivity for green algae and diatoms, especially during summer blooms of cyanophytes (**Mason & Abdul-Hussein 1991**). Because *Bosmina* has a preferred filtering range for small particles (1-5 :m), they may be able to survive on alternate food material such as small detrital particles and bacterioplankton.

Rotifers were also the most abundant in the nutrient rich arm of the lake when compared to the other lake sites. The relationship rotifer abundance and percentage composition of the zooplankton community and lake/seasonal trophic state is well established (**e.g., Bays and Crisman 1983**).

Beaver and Havens (**1996**) have underscored the importance of fish community structure in structuring the temporal and spatial distribution of zooplankton in a lake with widely ranging trophic conditions. Vertebrate predators are believed to be the primary determinants of crustacean zooplankton abundance and mean zooplankton body-size in a variety of North American lakes. It is likely that the abundance of small-bodied zooplankton (*Bosmina*, rotifers) in Arcadia Lake is most strongly controlled by food availability, while the abundance of large-bodied zooplankters (cladocerans, copepods) is primarily limited by predation from fish.

Daphnia lumholtzi

Another factor that could influence cladoceran community structure is the occurrence of *Daphnia lumholtzi*. This exotic cladoceran is a native of tropical and subtropical lakes in east Africa, east Australia, and the Asian subcontinent of India (**Havel and Hebert 1993**). It is distinguished by a long helmet and tail spines. The helmet is much larger than the native species and the tail spine is normally as long as the body length (up to 3.5mm). *D. lumholtzi* has been detected in 56 reservoirs in the southern and midwestern United States including waters leading into major river drainages such as the Arkansas, Cumberland, Illinois, Mississippi, Missouri, South Atlantic-Gulf, Tennessee, and Texas-Gulf. Occurrences of *D. lumholtzi* in the following states have been recorded: Alabama, Arkansas, Florida, Illinois, Kentucky, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, and Texas (**Havel et al. 1995**). The ecological impacts of this invader are unclear, but one study indicates it does not appear to be displacing other daphnia species (**Goulden et al. 1995**) as has been observed with zebra mussels. The abundance of *D. lumholtzi* in Arcadia Lake was never more than one percent of the total cladoceran abundance during the period of study, but further monitoring is suggested.

Biological indicators for Arcadia Lake Based on Zooplankton

Development of Biological indicators Using Zooplankton

Zooplankton communities of lakes and reservoirs are often good indicators of water quality (**e.g., Gannon and Stemberger, Bays and Crisman, 1983**). Given that herbivorous zooplankton may exert significant controls over the abundance, biomass, and composition of the phytoplankton community, and as a result determine water clarity and prevalence of nuisance algal species, they may be an important consideration in lake and reservoir management strategies. Development of bioassessment techniques to measure community condition based on regional expectations (i.e., ecoregion) would be desirable. Various biological components have been considered in developing biological indicators including fish, macroinvertebrate, zooplankton, and phytoplankton. The goal of such an approach would be to collect long-term information to refine knowledge of lake conditions (i.e., define baseline conditions, measure spatial and temporal variability of community attributes). Such a program would use representative multiple sampling of zooplankton populations and physical/chemical (limnological) variables to predict community condition. Presented below is a preliminary step towards developing a biological indicators approach for Oklahoma lakes and reservoirs based on the current study of the zooplankton of Arcadia Lake.

The relative abundance, biomass, and size structure of the major zooplankton groups and certain taxa at station 5 suggest that the poorer water quality characteristics were reflected in the zooplankton community. Although total cladocerans were higher at station 5, the biomass was very low because of the dominance by *Bosmina,* a small bodied, small particle specialist considered to be a good indicator of eutrophic conditions. Similarly, the rotifer community at station 5 had significantly higher biomasses of *Asplanchna* and *Brachionus*, rotifer species also considered indicative of eutrophic conditions (**Pejler 1983, Beaver and Crisman 1990**).

The increase in the abundance/biomass of *Bosmina* and *Brachionus* may be associated with increased availability of small particles, including detritus, which may have been more available at station 5. Because smaller-bodied zooplankton such as *Bosmina* and *Brachionus* have high intrinsic growth rates, they should respond concurrently to environmental changes and may be more sensitive indicators of water quality. If similar trends are observed in other lakes of the region, this approach may have some value in developing biological indicators based on zooplankton community structure for Oklahoma lakes and reservoirs.

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Appendix H

The following list of conservation and best management practices (BMP's) to reduce or eliminate nonpoint source water pollution problems has been compiled from the USDA.

1. **Access Road** - A road located and constructed to provide needed access, but built with soil conservation measures to prevent soil erosion caused by vehicular traffic or animal travel.

2. **Alternative Pesticides** - Pesticides other than chemical types traditionally used on a crop.

3. **Bedding** - Plowing, blading, or otherwise elevating the surface of flat land into a series of broad, low ridges separated by shallow, parallel channels.

4. **Biological Control Methods** - Use of organisms or biological materials to control crop pests. Integrated Pest Management (IPM) is an example of biological control that can reduce the amounts of chemical pesticides needed to grow a crop.

5. **Brush Management** - Management and manipulation of brush to improve or restore plant cover quality in reducing soil erosion.

6. **Chiseling and Subsoiling** - Loosening the soil to shatter compacted and restrictive layers to improve water quality, infiltration and root penetration, and reduce surface water runoff.

7. **Conservation Cropping** - Growing crops in combination with needed cultural and management measures to improve the soil and protect it during erosion periods. Practices include cover cropping and crop rotation, and providing vegetative cover between crop seasons.

8. **Conservation Cropping Sequence** - A sequence of crops designed to provide adequate organic residue to maintain and improve soil tilth.

9. **Conservation Tillage** - In producing a crop, limiting the number of cultural operations to reduce soil erosion, soil compaction, and energy use. Usually involves an increase in the use of herbicides.

10. **Contour Farming** - Farming sloped land on the contour to reduce erosion, control water flow, and increase infiltration.

11. **Contour Orchard and Other Fruit Areas** - Planting orchards vineyards, or small fruits, so all cultural operations are done on the contour.

12. **Correct Fertilizer Container Disposal** - Following accepted methods for fertilizer container disposal, keeping containers out of sinkholes, creeks, and other places adjacent to water to reduce the amount of fertilizer that reaches waterways.

13. **Correct Pesticide Container Disposal** - Following accepted methods for pesticide container disposal, keeping containers out of sinkholes, creeks, and other places adjacent to water to reduce the amount of pesticide that reaches waterways.

14. **Cover and Green Manure Crops -** Use of close-growing grasses, legumes, or small grain for seasonal soil protection and improvement.

15. **Critical Area Planting** - Planting vegetation to stabilize the soil and reduce erosion and runoff.

16. **Crop Residue Use** - Leaving plant residues after harvest to protect cultivated fields during critical erosion periods when the ground would otherwise be bare.

17. **Crop Rotation** - Planting different crops in successive seasons in the same field. Procedure can reduce pesticide loss significantly. There are some indirect costs if less profitable crops are alternated.

18. **Debris Basin** - A barrier or berm constructed across a water-course or at other suitable locations to act as a silt or sediment catchment basin.

19. **Deferred Grazing** - Postponing grazing for a prescribed period to improve vegetative conditions and reduce soil loss.

20. **Diversion -** Channels constructed across a slope to divert runoff water and help control soil erosion, and having a mound or ridge along the lower side of the slope.

21. **Drainage Land Grading** - Reshaping the surface of land to improve surface drainage and/or water distribution.

22. **Emergency Tillage** - Roughening soil surfaces by methods, such as listing, ridging, duck-footing, or chiseling. Procedure is done as a temporary protection measure.

23. **Farmstead and Feedlot Windbreak** - A strip or belt of trees or shrubs, established next to a farmstead or feedlot to reduce wind speed and protect soil resources.

24. **Fencing** - Enclosing an environmentally sensitive area of land or water with fencing to control access of animals or people.

25. **Field Border** - A border or strip of permanent vegetation, established at field edges to control soil erosion and slow, reduce, or eliminate pollutants from entering an adjacent watercourse or water body.

26. **Field Windbreak** - A strip or belt of trees or shrubs, established in or adjacent to a field, to reduce wind speed and protect soil resources.

27. **Filter Strip** - A strip or section of land in permanent vegetation, established downslope of agricultural operations to control erosion and slow, reduce, or eliminate pollutants from entering an adjacent watercourse.

28. **Fishpond Management** - Developing or improving impounded water to produce fish for consumption or recreation.

29. **Grade Stabilization Structure** - A structure to stabilize a streambed or to control erosion in natural or constructed channels.

30. **Grasses or Legumes in Rotation** - A conservation cropping system that establishes and maintains grasses and/or legumes for a definite number of years.

31. **Grazing Land Mechanical Treatment** - Renovating, contouring, furrowing, pitting, or chiseling native grazing land by mechanical means to improve plant cover and water availability.

32. **Heavy-Use Area Protection** - Establishing vegetative cover or installing structures to stabilize heavily used areas.

33. **Hillside Ditch** - A channel constructed to control the water flow and erosion by diverting runoff to a protected outlet.

34. **Integrated Pest Management Program** - Use of organisms or biological materials for effective pest control with reduction in amounts of pesticides used. "Scouting" of insect pest populations is necessary to determine when pest management actions are necessary to reduce pests.

35. **Irrigation Field Ditch** - A permanently lined irrigation ditch that conveys water from a supply source to fields, preventing erosion, infiltration, or degradation of water quality.

36. **Irrigation Water Conveyance** - A pipeline or lined waterway constructed to prevent erosion and loss of water.

37. **Irrigation Water Management** - Determining and controlling the rate, amount, and timing of irrigation water applied to crops to minimize soil erosion, runoff, and fertilizer and pesticide movement.

38. **Land Absorption Areas and Use of Natural or Constructed Wetland Systems** - Providing adequate land absorption or wetland areas downstream from agricultural areas so that soil and plants receive and treat agricultural nonpoint source pollutants.

39. **Listing** - Plowing and planting done in the same operation. Plowed soil is pushed into ridges between rows, and seeds are planted in the furrows between the ridges.

40. **Livestock Exclusion -** Excluding livestock from environmentally sensitive areas to protect areas from induced damages. Also, excluding livestock from areas not intended for grazing.

41. **Precision Application Rates** - Within a particular field, applying precise amounts of fertilizer and pesticide according to the soil/plant needs in specific parts of the field. Generally, lower rates can be applied, especially where tests show residues are present from previous applications.

42. **Managing Aerial Pesticide Applications** - Having pesticides applied when winds are low and when they are in a direction away from watercourses and riparian areas. This can reduce contamination in these nontarget areas.

43. **Mechanical Weed Control Methods** - Using mechanical or biological, instead of chemical, weed control can reduce substantially the need for chemicals. Costs will have to be carefully computed to make the operation economically feasible.

44. **Minimizing Number of Irrigations** - Carefully monitoring crop water needs and soil water availability minimizes the number of irrigations necessary to produce a crop. This may yield higher profits at harvest and reduce water pollution and soil erosion.

45. **Mulching** - Applying plant residues or other suitable materials to the soil surface reduces evaporation, water runoff, and soil erosion. Plastic sheeting can increase runoff, but will reduce nutrient leaching.

46. **No-till or Zero-tillage** - Tilling the soil with minimal disturbance and utilizing a fluted colter or double-disk opener ahead of the planter shoe to cut through untilled residues of the previous crop.

47. **Optimizing Crop Planting Time** - Planting a crop at a time other than when the crop's specific pest enemies would be present can reduce the need for pesticides and lower costs.

48. **Optimizing Date of Application** - Changing a pesticide application date to avoid impending rain or winds can improve effectiveness of the pesticide application and avoid environmental problems. Application can only be done when pest control effectiveness is not adversely affected. Process involves little or no cost.

49. **Optimizing Pesticide Formulations** - Pesticides come in several formulations with different half-lives. If a formulation with a shorter half-life than one normally used by an individual is chosen, the pesticide will be less available to cause environmental damage. Also, some formulations require fewer applications for the same pest protection, so costs are reduced and less is available to the environment.

50. **Optimizing Pesticide Placement** - Direct application of a pesticide on the field and plants rather than aerial spraying is more effective, reduces costs, and protects nearby environments from accidental spraying.

51. **Optimizing Time of Day for Application** - Applying pesticide at times of low winds, often early and late in the day, can reduce amounts needed for the crop, reduce costs, and reduce pesticide that could adversely affect adjacent environments.

52. **Pasture and Hayland Management** - Proper treatment, including fertilizing, aerating, and harvesting can protect soil and reduce water loss.

53. **Phreatophyte Water Losses** - Elimination of nonbeneficial uses of water by phreatophytes (plants getting water from deep roots) not only lessens the concentration of salts through transpiration, but conserves water as well. Lowering the water table and

developing mechanical and chemical techniques for elimination of phreatophytes ensures more efficient water use and minimizes salt hazards.

54. **Planned Grazing Systems** - A system in which two or more grazing units are alternately grazed and rested from grazing in a planned sequence to improve forage production, maintain vegetative cover, retain animal wastes on the land, and protect animals from polluted waters.

55. **Plant Between Rows in Minimum Tillage** - Applicable only to row crops in nonplow-based tillage; may reduce amounts of pesticides necessary.

56. **Plow-Plant** - Crop is planted directly into plowed ground with secondary tillage. This system increases infiltration and water storage.

57. **Pond** - A water impoundment made by constructing a dam or embankment or by excavating a pit or "dugout."

58. **Pond Sealing or Lining** - Installing a fixed lining of impervious material or treating the soil in a pond to reduce or prevent excessive water loss.

59. **Precision Land Forming** - Reshaping the surface of land to planned grades to give effective and efficient water movement.

60. **Proper Fertilizer Applications** - Selecting the proper time and method of fertilizer application to reduce losses through leaching and soil erosion, and ensure adequate crop nutrition.

61. **Proper Grazing Use** - Having no more animal units than will allow grazing areas to maintain sufficiently healthy, productive vegetative cover to protect the soil from eroding and protect the water quality of adjacent watercourses.

62. **Proper Timing of Irrigation Sprinklers** - Using irrigation equipment when plants need moisture, and controlling the amount of moisture delivered to the plants by avoiding over-irrigating to conserve water, protect soil from eroding, and protect the water quality of adjacent watercourses.

63. **Pumped Well Drain** - A well sunk into an aquifer to pump water to lower the prevailing water table.

64. **Pumping Plant for Water Control** - A pumping facility installed to transfer water for a conservation need.

65. **Range Seeding** - Establishing adapted plants on rangeland to reduce soil and water loss and produce more forage.

66. **Reducing Excessive Insecticide Treatment** - Applying exactly the correct amounts of insecticide recommended by the manufacturer for the crop and soil types. Refined predictive techniques required, such as computer forecasting.

67. **Reduction of Weed Growth** - Reducing number of weed plants to reduce water loss from evapotranspiration.

68. **Reduction or Elimination of Irrigation of Marginal Lands** - Taking irrigated marginally productive lands out of production to reduce water losses and salt pollution.

69. **Regulated Runoff Impoundment** - Retention or detention of water with infiltration prior to discharge to reduce runoff quantity, retain nutrients and pesticides, and prevent pollutants from reaching watercourses.

70. **Regulating Water in Drainage Systems** - The use of water-control structures to control the removal of surface runoff waters or subsurface flows.

71. **Reservoir Evaporation** - Controlling, through design or practices, the evaporation rate of water from reservoirs. If not controlled, evaporation tends to increase the salt content of the reservoir waters.

72. **Resistant Crop Varieties** - Use of plant varieties that are resistant to insects, nematodes, diseases, salt, etc.

73. **Return Flow Regulation** - Regulating the type and quantity of water return flows as a means of maintaining and improving irrigation water quality.

74. **Ridge Tillage** - Tillage producing a row configuration similar to listing, but planting is done on the ridges year after year with no seedbed preparation preceding planting.

75. **Rock Barrier** - A rock retaining wall, constructed across the slope, forming and supporting a bench terrace to control the flow of water on sloping land.

76. **Roof Runoff Management** - A facility for collecting, controlling, and disposing of rainfall/snowmelt runoff water from roofs. It keeps animal holding areas free of excess water and helps to maintain water quality of adjacent watercourses.

77. **Row Arrangement** - Establishing crop rows on planned grades and lengths to provide drainage and erosion control.

78. **Runoff Management System** - A system for controlling excess runoff from a development site during and after construction operations.

79. **Sediment Basin** - A basin constructed to collect and store sediment from runoff waters associated with nonpoint source pollutants.

80. **Slow Release Fertilizer** - Applying fertilizers that release nitrogen slowly to soil and plants, to minimize rapid nitrogen losses from soils prone to leaching.

81. **Soil Testing and Plant Analysis** - Testing soils and determining plant fertilizer requirements to avoid overfertilization and subsequent nutrient losses to runoff water.

82. **Split Applications of Nitrogen** - "Splitting" or dividing a set amount of fertilizer into two or more applications in the same season for the same crop.

83. **Spring Development** - Improving springs and water seeps by excavating, cleaning, capping, or providing collection and storage facilities for the water.

84. **Spring Nitrogen Fertilizer Application** - Applying nitrogen fertilizer in the spring, instead of autumn, to avoid fertilizer losses from heavy late winter and early spring runoff events.

85. **Streambank Protection** - By vegetative or structural means, stabilizing and protecting banks of watercourses, lakes, estuaries, or excavated channels against scour and erosion.

86. **Strip Tillage** - A narrow strip, tilled with a rototiller gang or other implement. Seed is planted in the same operation.

87. **Stripcropping** - Growing crops in a systematic arrangement of strips or bands to reduce water and wind erosion.

88. **Stripcropping, Contour** - Growing crops on the contour to reduce erosion and control water.

89. **Stripcropping, Field** - Planting large sections or entire fields in a systematic arrangement to help control erosion and runoff on sloping cropland where contour stripcropping is not a practical method.

90. **Structure for Water Control** - A structure to control the water stage, discharge, distribution, delivery, or direction of water flow in open channels or water use areas.

91. **Subsurface Drain** - A conduit, such as tile or plastic pipe, installed beneath the ground surface to control water levels for increased production. Net runoff and leaching are reduced, but nitrate concentrations may be increased.

92. **Surface Drainage** - A conduit, such as tile, pipe, or tubing, installed beneath the ground surface to collect and/or convey drainage water.

93. **Surface Roughening** - Roughening the soil surface by ridge or clod-forming tillage.

94. **Sweep Tillage** - Using a "sweep" on small-grain stubble to kill early fall weeds. The practice shatters and lifts the soil, thus enhancing infiltration while leaving residue in place.

95. **Terrace** - An earth embankment, channel, or a combination ridge and channel constructed across a slope to control runoff.

96. **Timing and Placement of Fertilizers** - Delaying timing or using proper placement of fertilizers for maximum utilization by plants and minimum fertilizer leaching or movement by surface runoff.

97. **Tree Planting** - To establish or reinforce a stand of trees to conserve soil and moisture and help protect water leaving agricultural areas by "filtering" pollutants from the water flow.

98. **Trickle Irrigation** - Using trickle irrigation equipment to deliver small quantities of water to irrigate crops.

99. **Trough or Tank** - Locating watering facilities a reasonable distance from watercourses and dispersing the facilities to encourage uniform grazing and to reduce livestock concentrations, particularly near watercourses.

100. **Underground Outlet** - A water outlet, placed underground to dispose of excess water without causing damage by erosion or flooding.

101. **Uniformity of Irrigation Water Quality** - Uniform irrigation water quality can be achieved through water flow regulation by controlling the release of water from storage reservoirs.

102. **Waste Management System** - A planned system to manage animal wastes in a manner that does not degrade air, soil, or water resources. Often wastes are collected in storage or treatment impoundments, such as ponds, lagoons, or stacking facilities.
103. **Waste Storage Pond** - An impoundment for temporary storage of animal or other agricultural waste.

104. **Waste Storage Structure** - A fabricated structure for the temporary storage of animal wastes or other organic agricultural wastes.

105. **Waste Treatment Lagoon** - An impoundment for biological treatment of animal or other agricultural waste.

106. **Waste Utilization** - Using wastes for fertilizer or other purposes in a manner which improves the soil and protects water resources. May also include recycling of waste solids for animal feed supplement.

107. **Water and Sediment Control Basin** - An earth embankment or a combination ridge and channel to form a sediment trap and a water detention basin to prevent soil erosion losses and improve water quality.

108. **Water Supply Dispersal** - A well which is constructed or improved to provide water for irrigation and livestock and which enhances natural livestock distribution or improved vegetative cover.

109. **Water Spreading** - Diverting or collecting runoff and spreading it over relatively flat areas.