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# Acid Rain Potential in East Texas Reservoirs

Field Operations Division

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TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

# Acid Rain Potential in East Texas Reservoirs

Prepared by
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Field Operations Division
Region 5, Tyler

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# Contents

# Figures

# ABSTRACT

Acid rain has detrimentally affected aquatic communities in large areas of the Eastern United States and Canada. The concern exists that this may occur in East Texas because of large industrial sources that contribute sulfate deposition across the region. To evaluate this concern, reservoirs within the Piney Woods (Ecoregion 35) and Prairie-Savanna regions (Ecoregions 32 and 33) of East Texas were evaluated for acid rain deposition or acidification. Intensive sampling of 20 reservoirs was carried out during the winter of 2002-2003. In addition, a subsample of 15 reservoirs within this study group was analyzed for trends in key parameters. Finally, two years of continuous monitoring data from two stations on Caddo Lake were reviewed for pH concentrations versus Texas Surface Water Quality Standards for Segment 0401 (Caddo Lake).

None of the reservoirs surveyed showed the classic acid rain trends over time: increasing sulfate, decreasing acid neutralizing capacity (ANC), and decreasing pH concentrations. Without consistent trends throughout the area in these key parameters, it was concluded that acid rain does not appear to be a current regional concern.

Caddo Lake had somewhat lower pH concentrations than other lakes in the region. This was evidenced by data from the intensive survey during the winter of 2002-2003, in the 30-year historical record, and in data from continuous monitoring stations on the lake during 2003-2005. Over 27,000 hourly pH readings from two continuous monitoring stations on Caddo Lake were compared to the water quality standards for Segment 0401 (pH 6.0-8.5 s.u.). Continuous monitoring stations on Caddo Lake were below the pH standard for a limited time: <5% at the upper midlake station and <0.1% at the midlake station. The upper midlake station was twice as likely to have pH reading in the range of 6.0 to 6.5 s.u. than was the midlake station. Flow levels from major streams in the Caddo Lake watershed appear to affect pH concentrations--particularly in the upper midlake area.

# ACKNOWLEDGMENTS

Special thanks go to Roger Miranda of the Total Maximum Daily Load (TMDL) team for his help in the statistical analysis of this data. Allison Woodall with the Clean Rivers Program helped with Excel software questions. And Christine Kolbe of the Surface Water Quality Monitoring (SWQM) team helped in formatting this manuscript for publication. Thanks also to those individuals from the TCEQ who reviewed this paper: Karen Holligan (Modeling Team), Patricia Wise (Clean Rivers Program), Michele Blair (SWQM Team), and Jim Davenport (Standards Team).

# INTRODUCTION

Acid rain has long been identified as an environmental concern in the eastern United States and Canada. Changes in aquatic communities including mayflies, crayfish, mollusks, and fish have been documented as a result of declining pH concentrations (Glick, 2001). To deal with growing acid rain concerns in the Northeast, amendments to the Clean Air Act were passed in 1990. Limits were placed on sulfur dioxide ($SO_2$) and nitrous oxide ($NO_x$) emissions from coal-fired generating plants, the major contributor of $SO_2$ to the environment (U.S. EPA, 2004). $SO_2$ discharges interact in the atmosphere and then fall with precipitation as sulfate ($SO_4$) where it is able to be monitored at over 200 sites across the United States (NADP, 2002). Nationwide decreases in $SO_4$ deposition were apparent after the passage of this legislation as is seen in Figure 1 where air monitoring stations in Western Pennsylvania (PA29) and the Finger Lakes region of New York (NY20) have shown steady declines in $SO_4$ over the years.

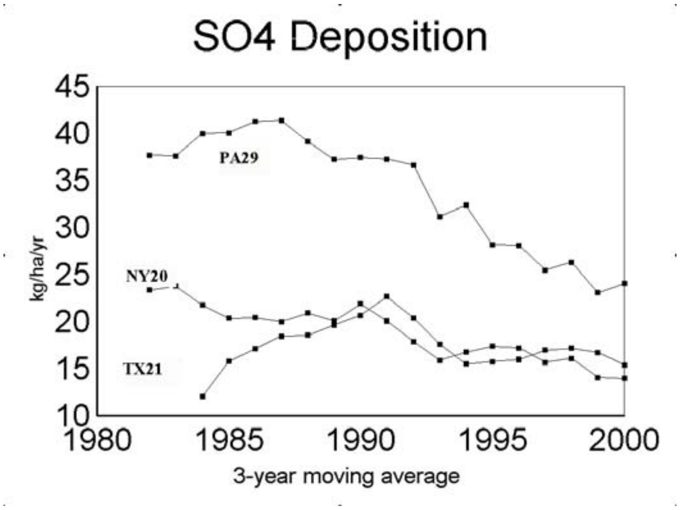

**Figure 1. $SO_4$ wet deposition at selected air monitoring stations.**

East Texas has a well established seam of lignite coal that runs in a northwest to southeast direction for several hundred miles. Several major coal-fired generating plants are located in this region (Figure 2), including the three largest $SO_2$ and $NO_x$ generating facilities in the state: Texas Utilities Big Brown, Monticello, and Martin Creek Lake (EPA, 2004). These three power plants came on line during the 1970s: Big Brown (1971-72), Monticello (1974-78), and Martin Creek Lake (1978-79) (Gary Spicer, Personal Communication). Currently there are nine active acid-rain monitoring stations in Texas (NADP, 2002). The Gregg County Regional Airport (TX21) has been the site of an acid-rain monitoring station since 1982. TX21 routinely has the highest recorded $SO_4$ deposition rates in Texas--concentrations that approximate areas of New York (NY20) and to a lesser degree areas of Pennsylvania (PA29) (NADP, 2002) that both exhibit low pH effects in their area lakes (Figure 1). The Gregg County site is the only monitoring station in Texas with $SO_4$ depositions routinely above 11-14 kg/ha/year, values considered high by Nichols (1990). These concentrations, however, are similar to those found at numerous air deposition stations in southern states east to the Atlantic (NADP, 2002).

Sulfate deposition is believed to have a much greater effect on the acidification of lakes than nitrate deposition since nitrate is rapidly taken up by both the aquatic and terrestrial biota.

All lakes have a natural buffering capacity against acidification that is referred to as alkalinity or acid neutralizing capacity (ANC). The ANC of any lake is a function of the geology and hydrology of its watershed. Water and carbon dioxide react to form carbonic acid which in turn causes weathering of local minerals (*e.g*. carbonate, feldspars, and mica) releasing bicarbonates ($HCO_3$), the main component of alkalinity or ANC. Approximately equal amounts (on an equivalent weight basis) of base cations: calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K) and $HCO_3$ are produced during weathering (Nichols, 1990). Since acid deposition removes some ANC, lakes that are subject to acid deposition should have a lower ANC:cation than lakes that are not subject to acid deposition (Nichols, 1990).

Acid deposition is a regional concern. Lakes within broad geographical areas will share similar concentrations of low pH and ANC and high sulfate values if acid deposition is a problem within the region. The historical record should be able to identify trends in these three key parameters.

The local geology of East Texas changes dramatically as you move west from the sandy soils of the Piney Woods (Ecoregion 35) to the clay-rich areas of the Post Oak Savanna (Ecoregion33) and Blackland Prairies (Ecoregion 32) (Griffith *et. al.*, 2004). ANC follows this same trend. ANC is much higher in lakes with most of their drainage in the clayey soils of the Blackland Prairie. Lakes located in the Piney Woods of East Texas have less buffering capacity and are therefore more susceptible to acid deposition. This study was initiated as a result of concerns that a local environmental group, the Caddo Lake Institute, had concerning recent low pH trends at monitoring sites on Caddo Lake.

# STUDY OBJECTIVES

This three-part study was designed to identify East Texas reservoirs that may be susceptible to the influence of acid deposition by:

- Identifying trends from historical data spanning a 10–30 year period of record from 15 East Texas lakes;
- Sampling 20 East Texas lakes during the winter of 2002–03 for parameters indicative of acid deposition;
- Evaluating continuous monitoring data from Caddo Lake for any periods when pH values were below designated water quality standards.

# METHODS

## Historical Review

A number of lakes in the study area have been sampled since the 1970s. Data from 1973–2003 for selected lakes were examined for trends that might indicate acidification: increasing $SO_4$, decreasing ANC, or decreasing pH. Deep water stations were selected to reduce the effects of photosynthesis and runoff that would be more apparent in shallower sites and sites closer to river inflow.

The lowest instantaneous pH reading for the calendar year in the mixed surface layer was selected for graphing purposes. Standards for pH apply only in the mixed surface layer, which is defined as the zone extending from the water surface to a depth at which the water temperature has decreased more than 0.5° C from that of the surface. Generally, the pH drops dramatically below this level.

Median surface ANC and sulfate concentrations for the calendar year were selected for analysis. Medians were selected rather than means because this eliminated much of the difficulty with handling censored data as well as occasional data outliers from non-normally distributed data. During the mid 1980s to the mid 1990s, several of the 20 lakes evaluated were sampled only once a year during the summer. Since these data were probably not representative of the low pH of the year or of median ANC values, these data were not included.

### *Winter Survey of 20 Lakes*

Surface measurements (0.3m depth) and samples from deep water areas unaffected by runoff were collected at a single station on 20 lakes (Figure 2) monthly during December 2002-February 2003 consistent with routine SWQM procedures (TCEQ, 2003) and included field pH, alkalinity, and $SO_4$. Samples for dissolved cations (Ca, Mg, Na, and K) were collected according to clean-metals sampling procedures (TCEQ, 2003). Routine wet chemistry samples were sent to the TCEQ-Houston lab. Since pH is defined as the negative log of the hydrogen ion concentration, it is inappropriate to graph pH on a linear scale or average pH values. All pH values were converted to their actual hydrogen ion concentration for comparison. A statistical software package (Minitab, 2000) was used to evaluate the data.

## Study Area

Ten lakes were selected that had most of their watersheds within Ecoregion 35 (South Central Plains), hereafter referred to as the Piney Woods:

- Lake O'the Pines (Station 10296)*
- Caddo Lake (Station 10283)*
- Lake Bob Sandlin (Station 17059)
- Martin Creek Reservoir (Station13601)
- Murvaul Lake (Station 10444)*
- Lake Cherokee (Station 15514)
- Lake Palestine (Stations 16159) (10593 and 16346)*
- Lake Tyler/Lake Tyler East (Station 10638)*
- Sam Rayburn Reservoir (Station 10612)*
- Toledo Bend Reservoir (Station 10404)*

Ten lakes were selected that had most of their watersheds within Ecoregion 32 (Texas Blackland Prairie) or Ecoregion 33 (East Central Texas Plains and Post Oak Savanna)–hereafter jointly referred to as the Prairie-Savanna:

- Lake Livingston (Station 10899)*
- Lake Limestone (Station 12123)*
- Richland-Chambers Reservoir (Station 15169)*
- Lake Tawakoni (Station 10434)*
- Lake Fork Reservoir (Station 10458)*
- Cedar Creek Reservoir (Station 13845)
- Cooper Lake (Station 15211)
- Wright Patman Lake (Stations 16859) (16859 and 10213)*
- Pat Mayse Lake (Stations 16343) (16343 and 10138)*
- Lake Conroe (Station 11342)*

In addition, stations with an asterisk (*) were also selected for historical review.

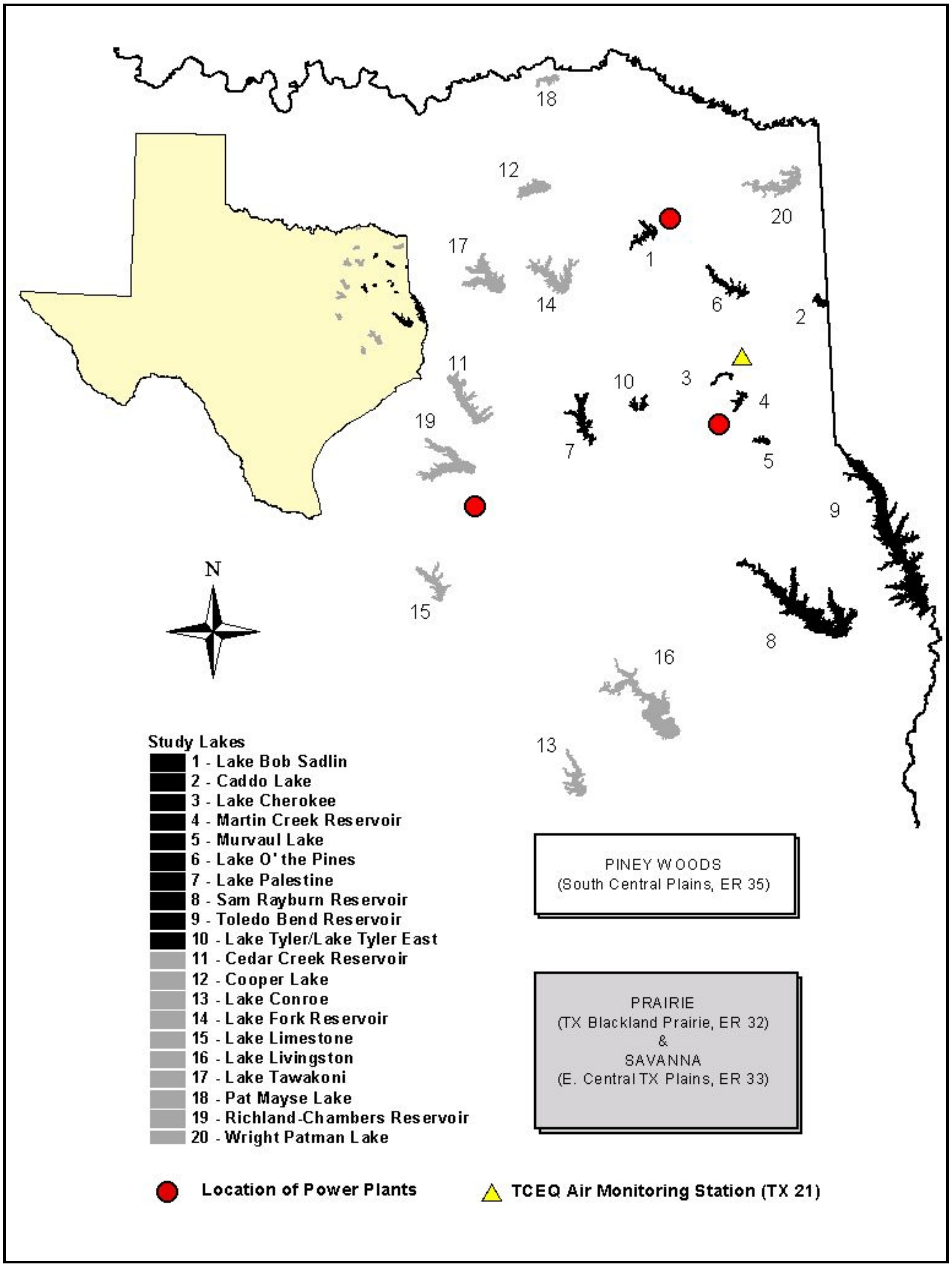

**Figure 2.** **Survey of 20 lakes with watersheds within the Piney Woods and Prairie-Savanna regions of East Texas.**

# Continuous Monitoring on Caddo Lake

Samples collected by the TCEQ and cooperating partners have typically been on a quarterly basis, in some cases monthly. This results in a snapshot view of the water quality at a particular moment. Some parameters, such as pH, change throughout the day. Without the benefit of continuous monitoring stations, it can only be assumed that these snapshot samples are representative of conditions throughout the period in which they are collected. Therefore, additional emphasis should be placed on data from sites with continuous monitors due to the large data sets they represent.

In October, 2003, two Greenspan continuous monitoring multiprobe instruments (Model CS4-1200) were installed on Caddo Lake. Temperature, pH, conductivity and dissolved oxygen data are collected on a real-time, continuous basis. The effect is to have hundreds of measurements throughout the day compared to only a few over a whole season. Both sites are relatively shallow. The midlake site is approximately 3m deep, while the upper midlake site is 1.0 to 1.5m deep. Although located within Caddo Lake proper, the upper midlake site is more influenced by discharge from Big Cypress Bayou than the midlake site (Figure 3).

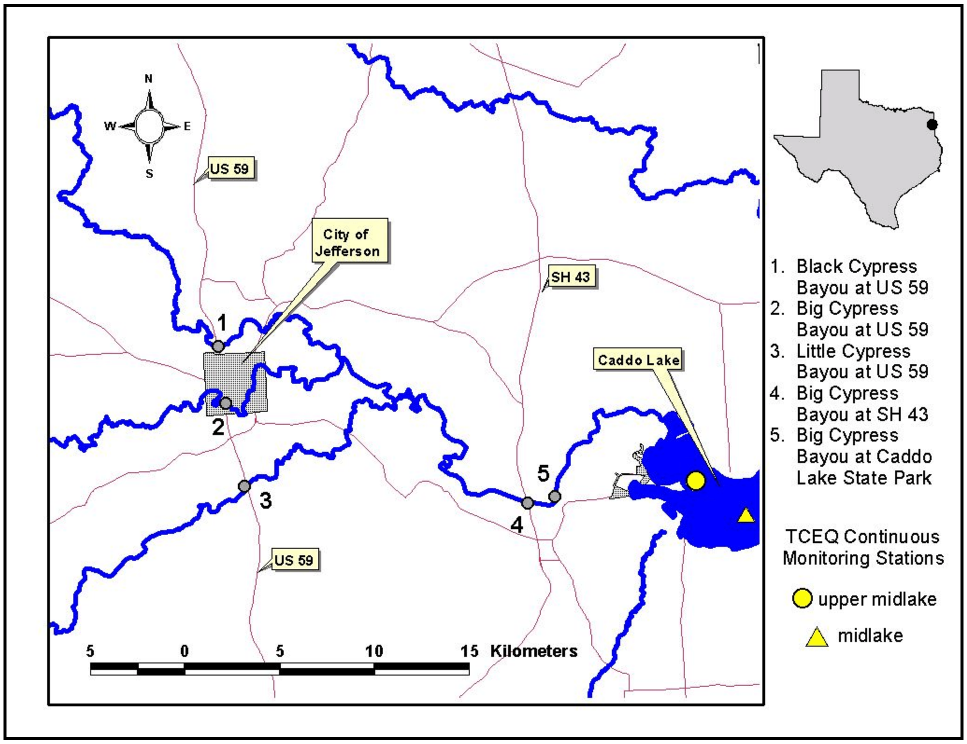

**Figure 3. Continuous monitoring stations on Caddo Lake and upstream stations.**

# RESULTS

## *Historical Review of 15 Lakes*

None of the lakes analyzed had a downward trend in pH concentration (Appendix A). Only Caddo Lake had pH concentrations that were below 6.0 s.u. Low pH readings in Caddo Lake seem as common in the 1970-80's as they were in 1990-2000's. There appears to be a downward trend in pH in Caddo Lake beginning around 1990; but this is not supported when viewed over the 30-year period of record.

With the exception of Lake Fork Reservoir and Richland-Chambers Reservoir, none of the lakes analyzed had any downward trends in ANC. None of the lakes had any visual upward trend in sulfate.

### Winter Survey of 20 Lakes

The data for hydrogen ion concentration, alkalinity, and ANC:cation were tested for normality using a modified Shapiro-Wilk test ($\propto = 0.1$). The data, except for the ANC:cation for the Prairie-Savanna lakes, were not normally distributed which supports the use of medians versus means.

### Hydrogen Ion Concentration—Piney Woods vs. Prairie-Savanna

The medians were tested between the two groups of lakes using a Wilcoxon-Mann-Whitney rank-sum test ($\propto=0.05$). The median hydrogen ion concentration of Piney Woods lakes was significantly greater ($P = 0.0011$) than that for Prairie-Savanna lakes, thus Piney Woods lakes overall had lower pH (more acidic) values. However, a boxplot (Figure 4) of the hydrogen ion concentrations shows that there is some overlap of the interquartile ranges. The January value at Caddo Lake appears as an outlier within the Piney Woods group of lakes. A high hydrogen ion concentration corresponds to a low pH (in this case, $H+$ of 50 mg/L = pH 6.3 s.u.). Therefore, Caddo Lake had a one-time pH reading during the winter of 2002-03 that was lower than other lakes in the region.

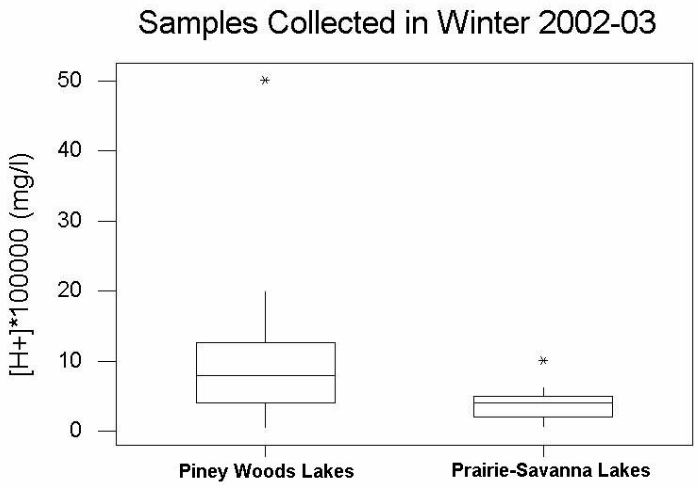

**Figure 4. Boxplots of hydrogen ion concentrations.**
**N = 10 within each region. (* = statistical outliers**)

### ANC:Cation—Piney Woods vs. Prairie-Savanna

The data for ANC:cation showed unexpected results. Nichols (1990) suggested that both $HCO_3$ (ANC) and cations are produced in relatively similar amounts. Therefore, ratios should be similar regardless of local geology. This was not the case in the data collected from across Texas. Differences were apparent in the boxplot of ANC:cation (Figure 5), where both medians and interquartile ranges are well separated. The medians were tested between the two groups of lakes using a Wilcoxon-Mann-Whitney rank-sum test ($\propto$=0.05). There was a statistically significant difference (P =0.0002) between the medians of the two ecoregions. This either indicates that Piney Woods lakes are subject to effects of acid deposition, or that this ratio is not as useful as suggested. The preponderance of other evidence suggests the later.

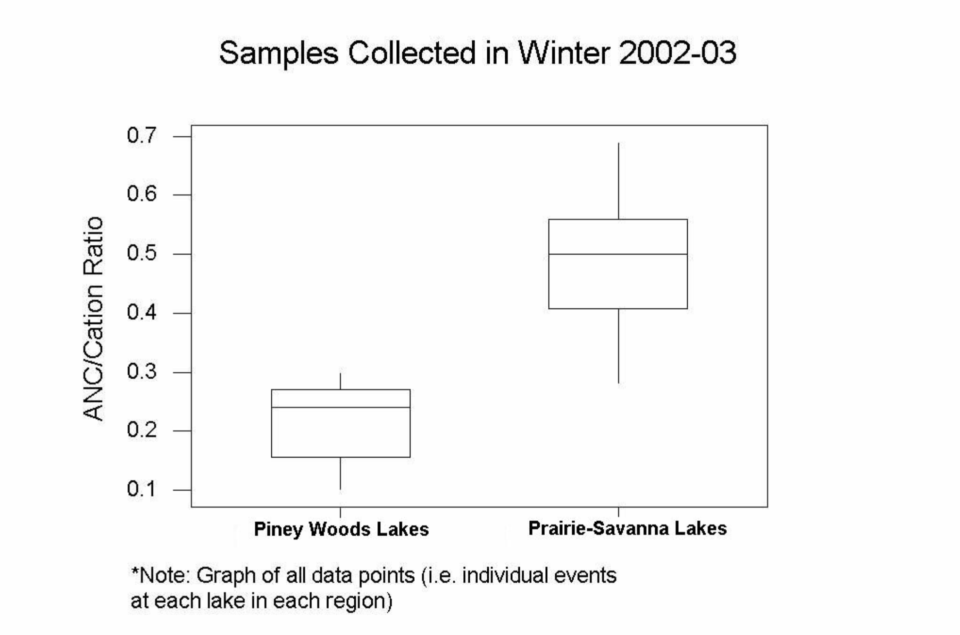

**Figure 5. Boxplots of ANC:cation ratio.**
**N = 10 within each region**.

## ANC—Piney Woods vs. Prairie-Savanna

The boxplot for ANC (Figure 6) shows similar information as the one for ANC:cation (Figure 5). The medians were tested between the two groups of lakes using a Wilcoxon-Mann-Whitney rank-sum test ($\propto$=0.05). Piney Woods lakes had statistically lower (P = 0.0001) median ANC than the Prairie-Savanna lakes. The two outliers at the lower end of the Prairie-Savanna lake boxplot are for Lake Fork Reservoir. This lake is geographically located between the two regions. Based on these data, Lake Fork Reservoir better fits into the Piney Woods category than into the Prairie-Savanna category. The two outliers at the upper end of the boxplot are for Richland-Chambers Reservoir. The high ANC values for this reservoir can either be explained by local geological conditions or by the fact that this is still a relatively young reservoir–it was completed in 1987.

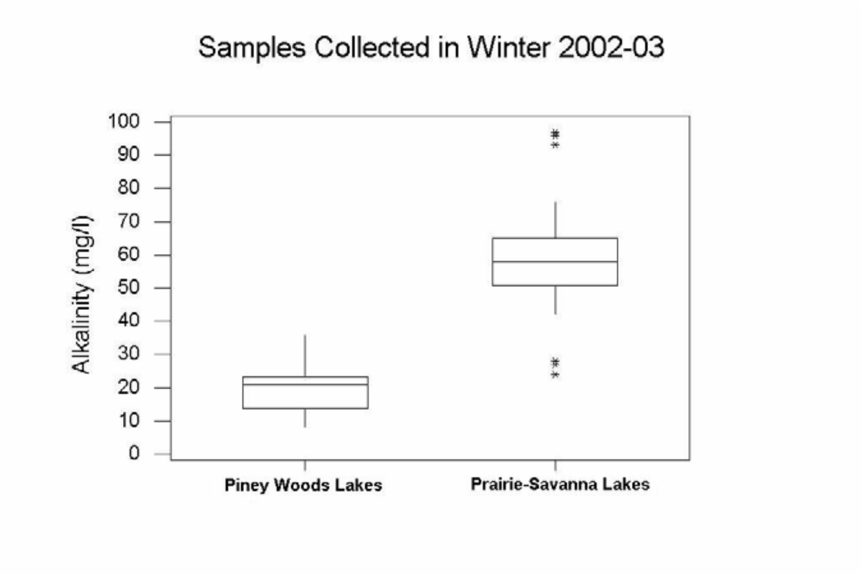

**Figure 6. Boxplots of alkalinities.**
**N = 10 within each region. (* = outliers)**

## *Continuous Monitoring Data on Caddo Lake*

Over 27,000 hourly pH values were compared to the Texas Surface Water Quality Standards for pH on Caddo Lake (Segment 0401) during the period October 2003–September 2005. The pH standard for Segment 0401 is 6.0-8.5 s.u. (TCEQ, 2003). During the period, both continuous monitoring stations had pH values less than the 6.5 s.u. for a relatively large percentage of the time. The upper midlake station recorded pH values from 6.0 to 6.5 s.u. approximately 60% of the time and the midlake station approximately 30% of the time. Long-term stream sites on Big Cypress Bayou at SH43 and Caddo Lake State Park, Little Cypress Bayou at US 59, and Black Cypress Bayou at US 59 (Figure 3) had similar instantaneous pH reading (pH 6.0-6.5 s.u. ~50% of the time) during the 1972–2005 period.

There were five separate periods in which pH concentration fell below segment standards (pH 6.0  s.u.) for extended periods at the upper midlake station: 9-15 June, 2004; 5-9 July, 2004; 6-22 December 2004; 2-10 January, 2005; and 17-25 February, 2005. Four of the five events can be associated with periods of high flow into Caddo Lake from upstream sources: Big Cypress, Little Cypress, and Black Cypress Bayous. The June 2004 event is of interest because it can be traced to a particular rise in flow after an extended dry period and abnormally low flows well below the long-term mean flow. Little Cypress Bayou began a sharp rise in flow on 6 June (Figure 7) and the upper midlake station began a corresponding drop in pH on 7 June (Figure 8). Other periods of pH exceedances can not be associated with particular rises in flow from any of the streams entering into Caddo Lake. However, the three sets of exceedances between December 2004 and February 2005 are during periods of relatively high inflow. For the period October 2003 to September 2005, the upper midlake site had pH values less than 6.0 s.u. less than 5% of the time; the midlake site had pH values less than 6.0 s.u. less than 0.1% of the time.

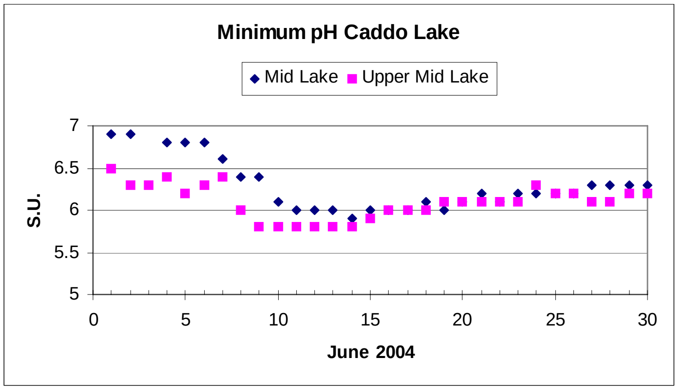

**Figure 7. Daily pH minima at continuous monitoring stations in Caddo Lake during June 2004.**

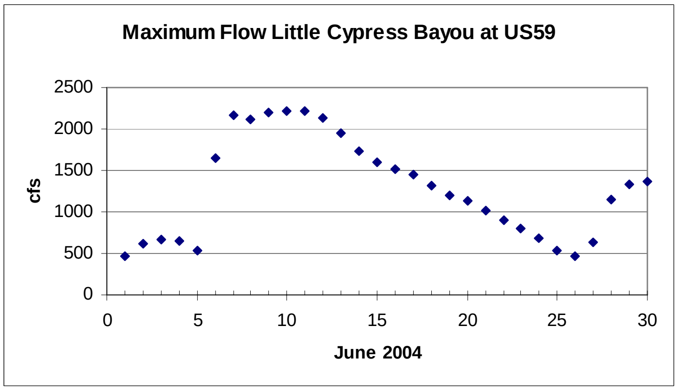

**Figure 8. Maximum flow in feet$^3$/second (cfs) at Little Cypress Bayou at US 59 during June 2004.**

# DISCUSSION

None of the lakes surveyed appear to be at risk for acidification based on trends in historical data, samples collected during 2002-03, or from continuous monitoring data from Caddo Lake during 2003-05. If acid rain were a concern, many lakes within the region would be negatively affected. This was not apparent. None of the lakes showed the classic acid rain trends: increasing sulfate concentrations, decreasing ANC, and decreasing pH.

Caddo Lake appears to be slightly different from other lakes in the Piney Woods region of Texas. Among lakes with an approximate 30-year period of record, only Caddo Lake had pH readings commonly below segment standards. However, there was no downward trend in pH or ANC at Caddo Lake, nor was there an upward trend in sulfate concentration over time. Low pH values affect the upper areas of the lake much more than the middle of the lake and are probably associated with high flow periods from the major streams within the watershed. Current pH standards for Little Cypress Bayou (5.5-8.5 s.u.) and proposed standards for Black Cypress Bayou (5.5-8.5 s.u.) are lower than pH standards for Caddo Lake. These same low pH values within the Black Cypress Creek watershed support high to exceptional aquatic life uses (Crowe A. and C. W. Bayer, 2005). If low pH on Caddo Lake remains a regulatory concern, a review of segment standards may be in order.

The ANC:cation did not provide any additional insight for acid deposition potential. Since alkalinity (or ANC) seems to provide the same information as ANC:cation, there does not appear to be any benefit to collecting this additional cation information. ANC remains a good way to group lakes within an ecoregion.

The steady downward trend in ANC at Lake Fork Reservoir is of interest. The dam on Lake Fork Reservoir was completed in 1980, but the first water samples were not collected until 1985. New lakes are known to undergo an initial few years of high primary productivity followed by a rapid decrease in productivity. Primary production is positively correlated with carbonate concentration, which is a component of alkalinity or ANC. The decreasing trend in ANC on Lake Fork Reservoir appears to be the result of natural lake aging and a decrease in productivity. A somewhat similar, but less dramatic trend is apparent from ANC concentrations on Richland-Chambers Reservoir which is also a relatively new lake.

Without multiple samples in a given year, evaluation of trends are difficult to ascertain. Year-round sampling should be maintained at stations with a long-term historical record in order to facilitate similar future studies.

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# Appendix A

# Graphs of pH, ANC, and $SO_4$ Versus Time

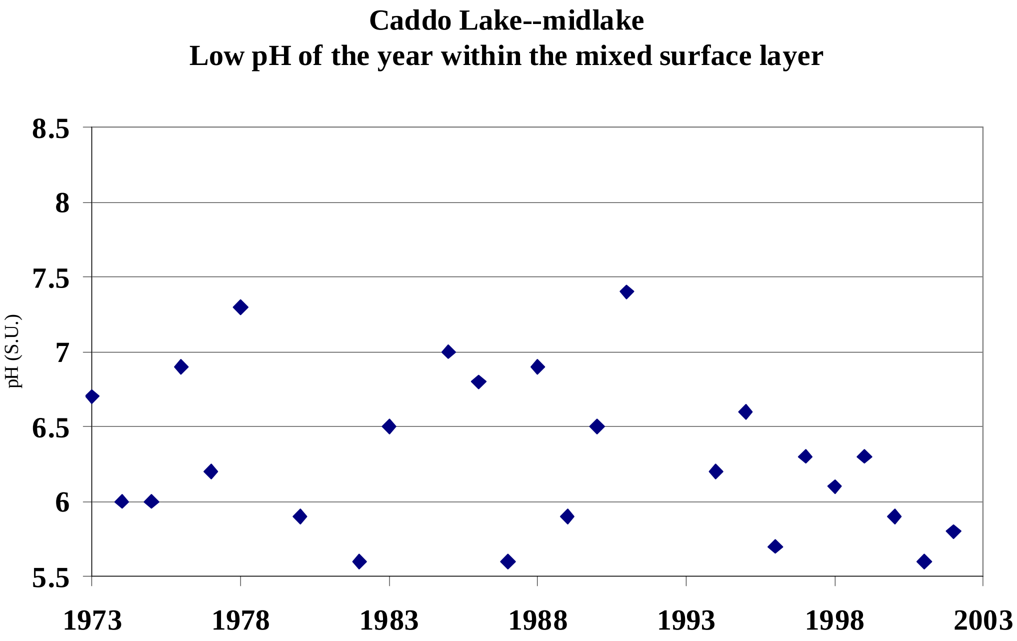

**Figure A-1.** Low pH of the year within the mixed surface layer—Caddo Lake.

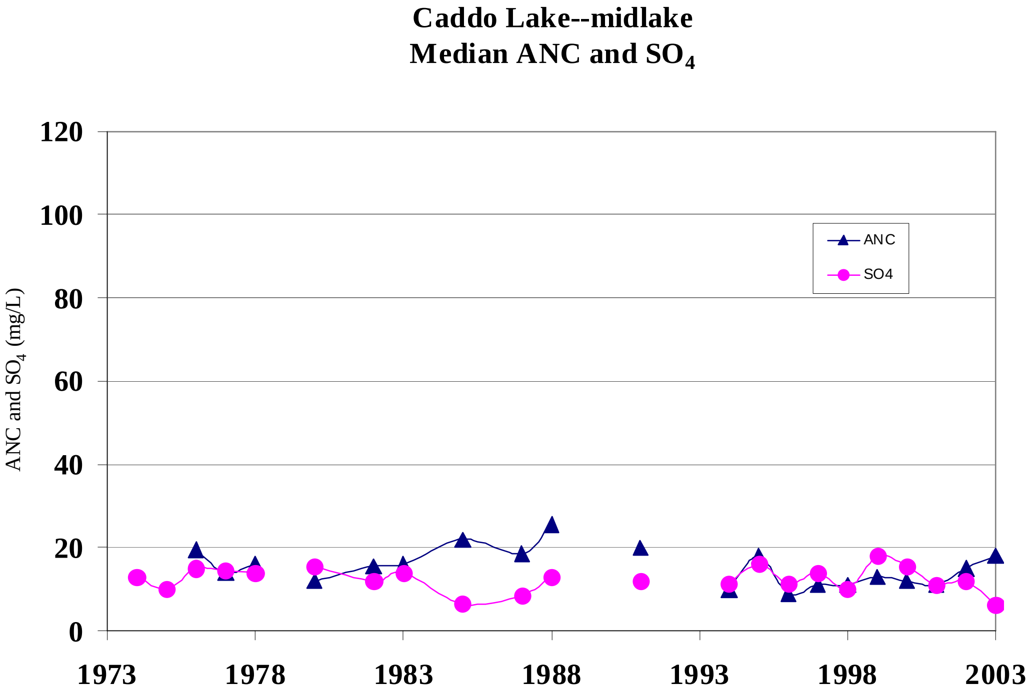

**Figure A-2.** Median ANC and $SO_4$—Caddo Lake

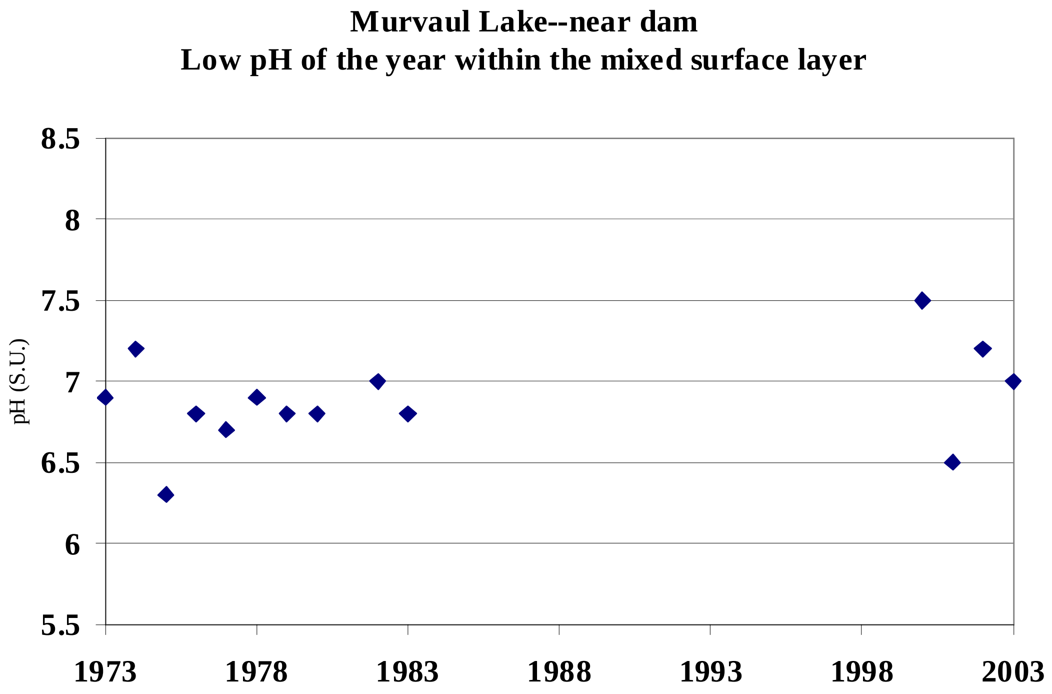

**Figure A-3.** Low pH of the year within the mixed surface layer—Murvaul Lake.

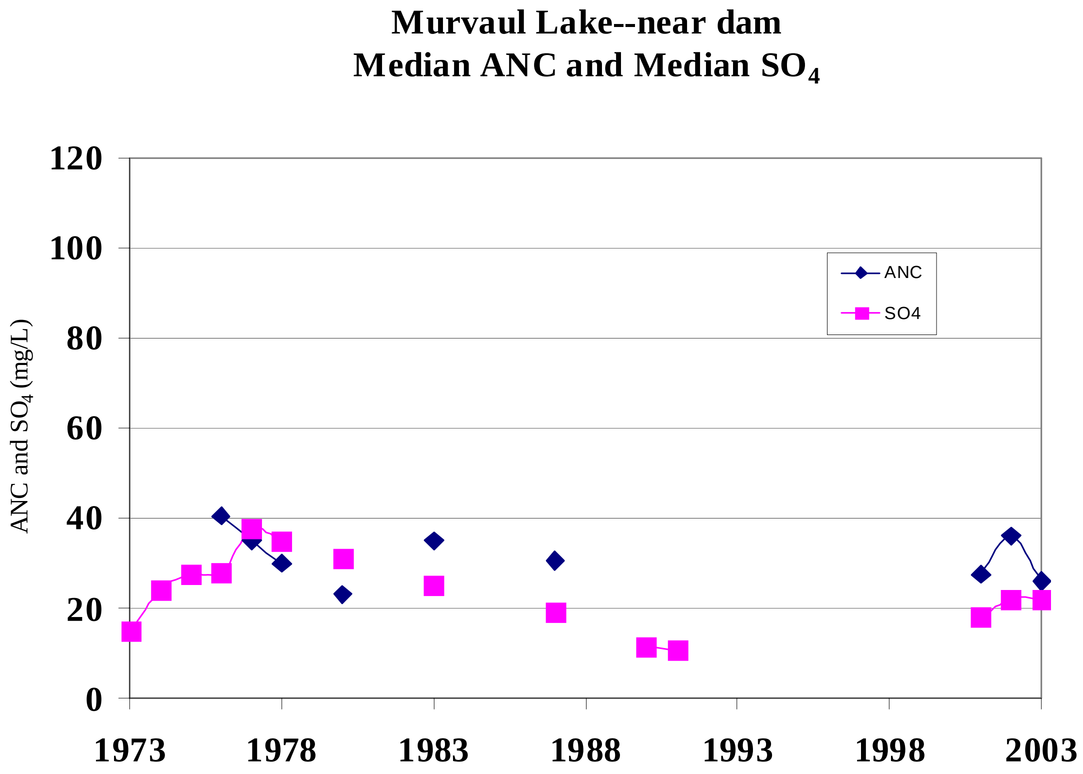

**Figure A-4.** Median ANC and $SO_4$—Murvaul Lake.

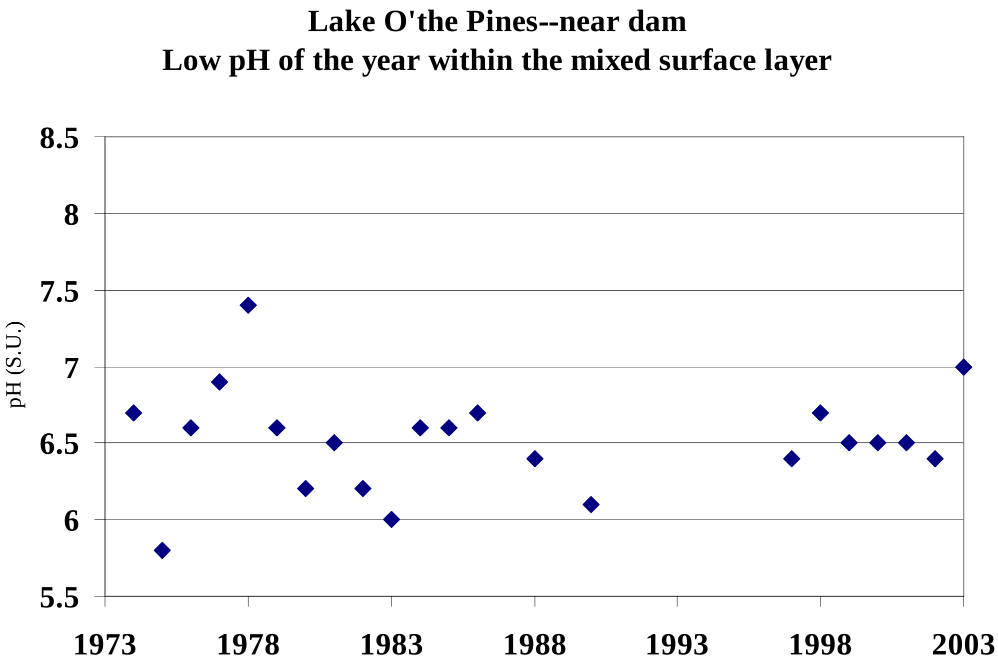

**Figure A-5.** Low pH of the year within the mixed surface layer—Lake O' the Pines.

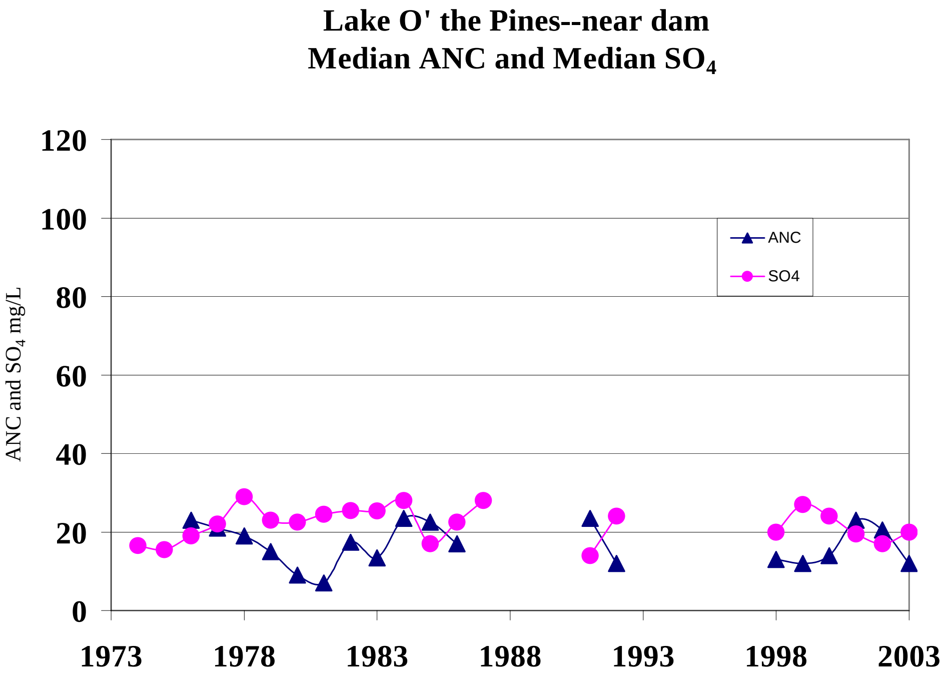

**Figure A-6.** Median ANC and $SO_4$—Lake O' the Pines.

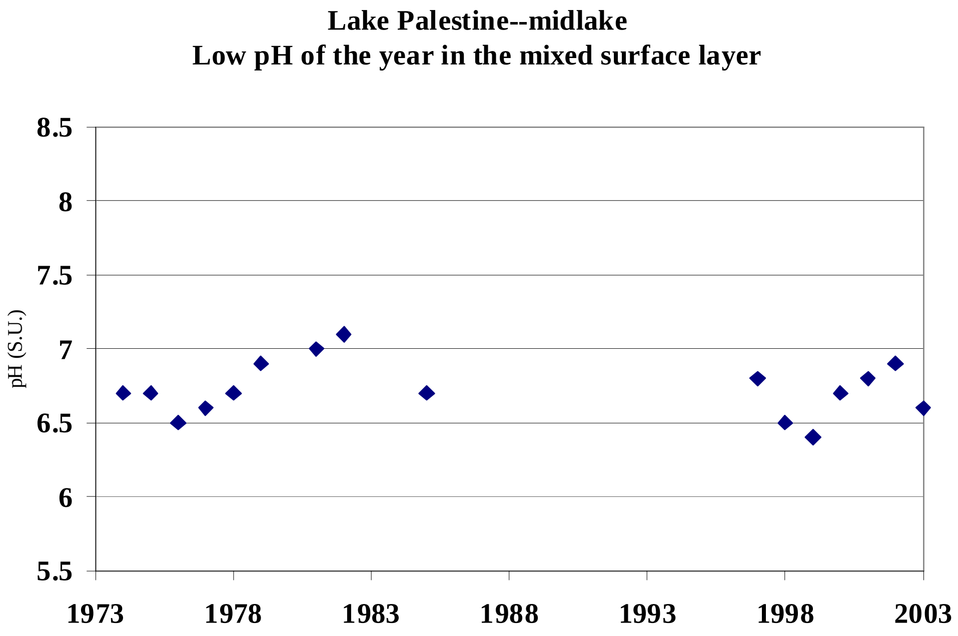
Lake Palestine--midlake
Low pH of the year in the mixed surface layer

Figure A-7. Low pH of the year within the mixed surface layer—Lake Palestine.

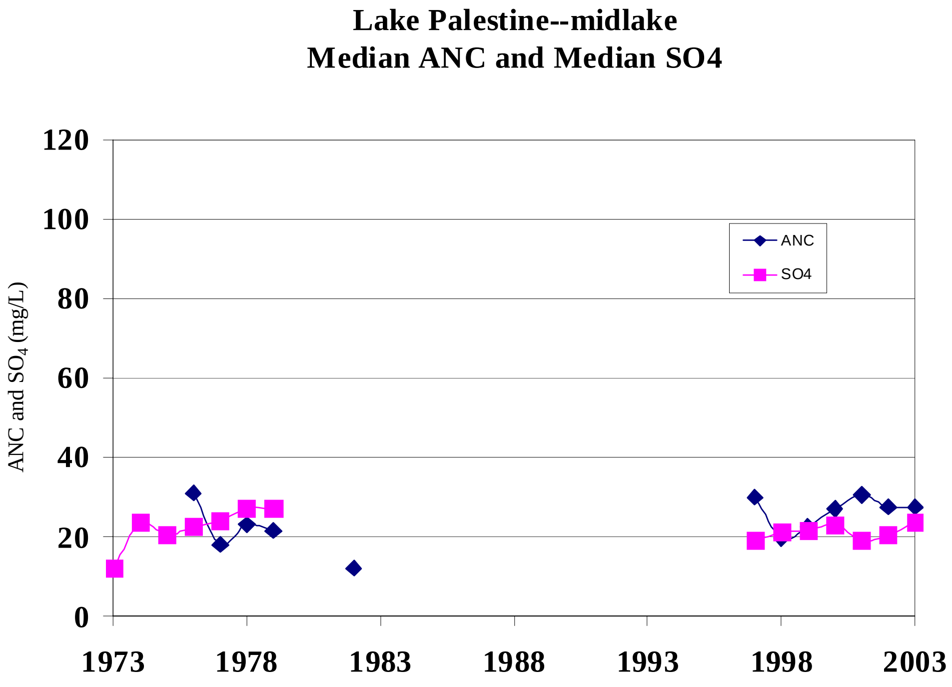
Lake Palestine--midlake
Median ANC and Median SO4

Figure A-8. Median ANC and $SO_4$—Lake Palestine.

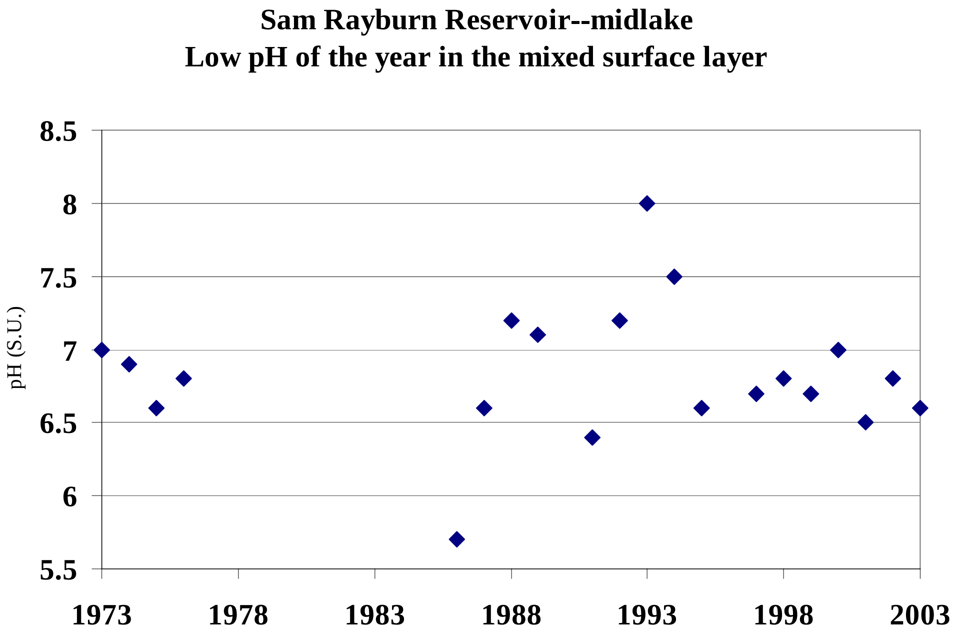

Figure A-9. Low pH of the year within the mixed surface layer—Sam Rayburn Reservoir.

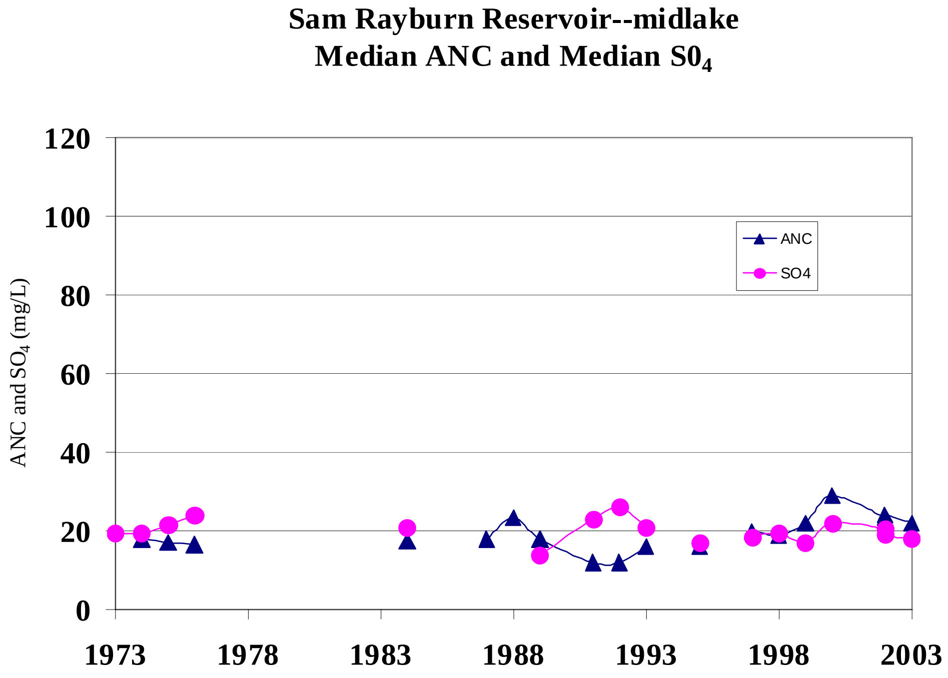

Figure A-10. Median ANC and $SO_4$—Sam Rayburn Reservoir.

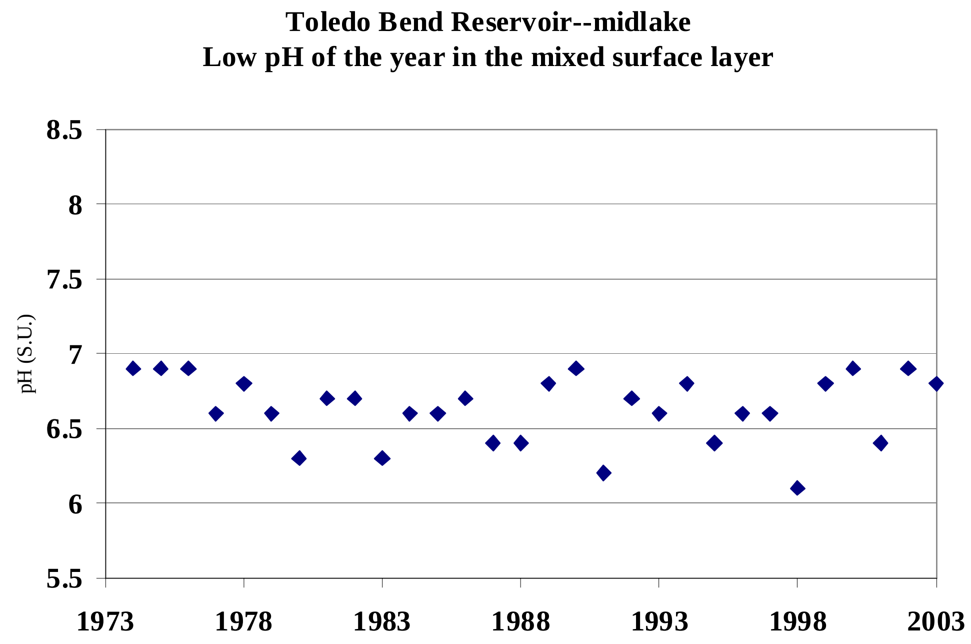

Figure A-11. Low pH of the year within the mixed surface layer—Toledo Bend Reservoir.

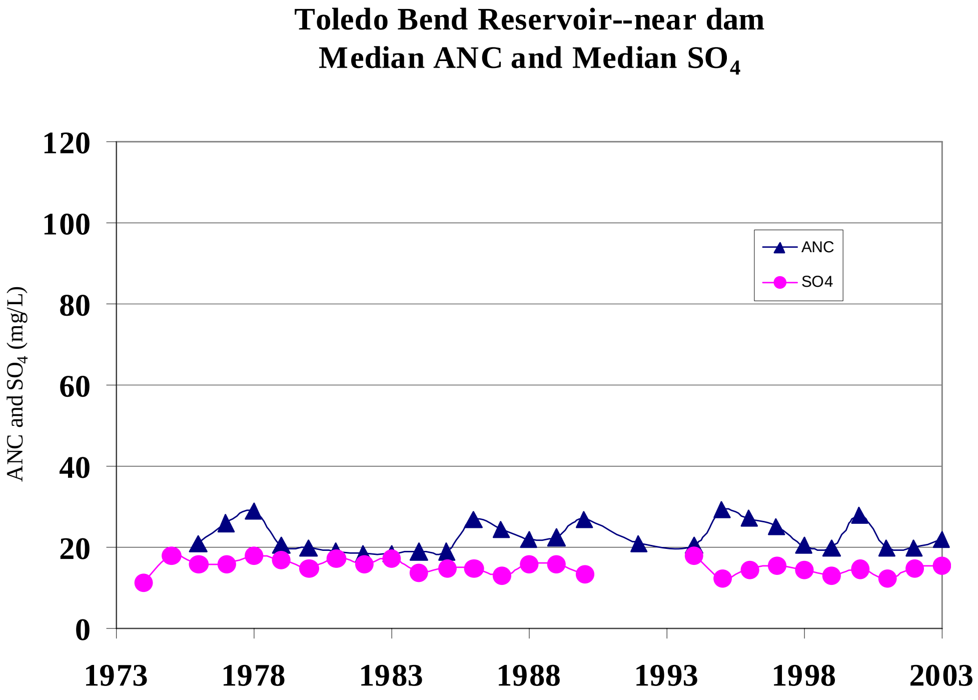

Figure A-12. Median ANC and $SO_4$—Toledo Bend Reservoir.

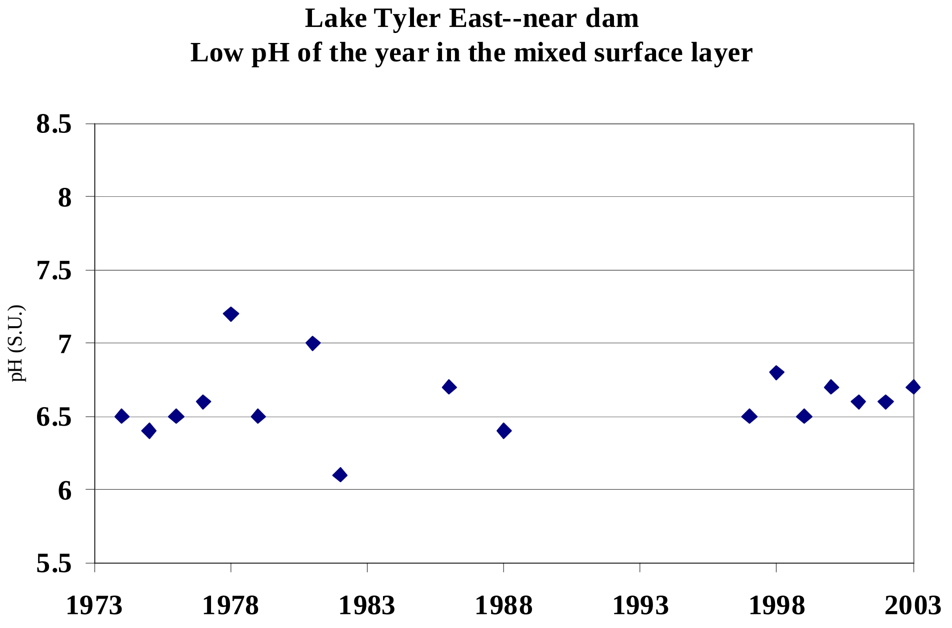

Figure A-13. Low pH of the year within the mixed surface layer—Lake Tyler East.

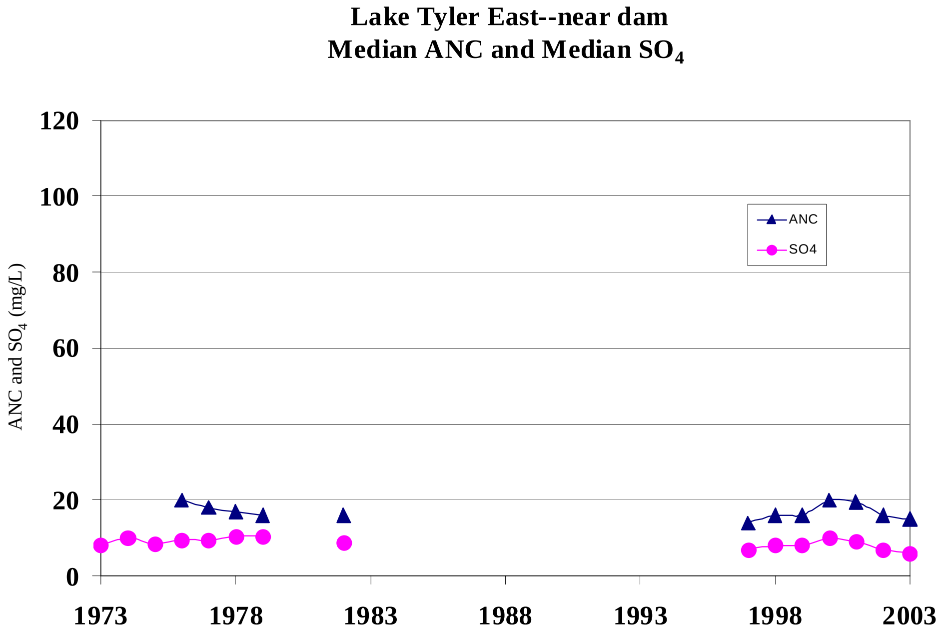

Figure A-14. Median ANC and $SO_4$—Lake Tyler East.

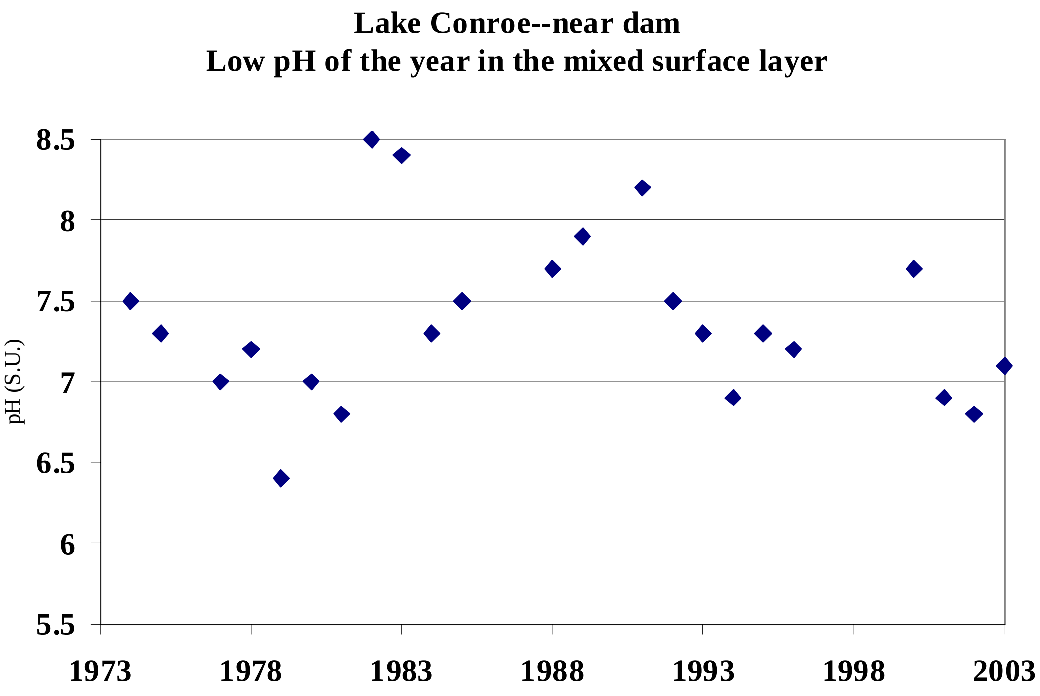

Figure A-15. Low pH of the year within the mixed surface layer—Lake Conroe.

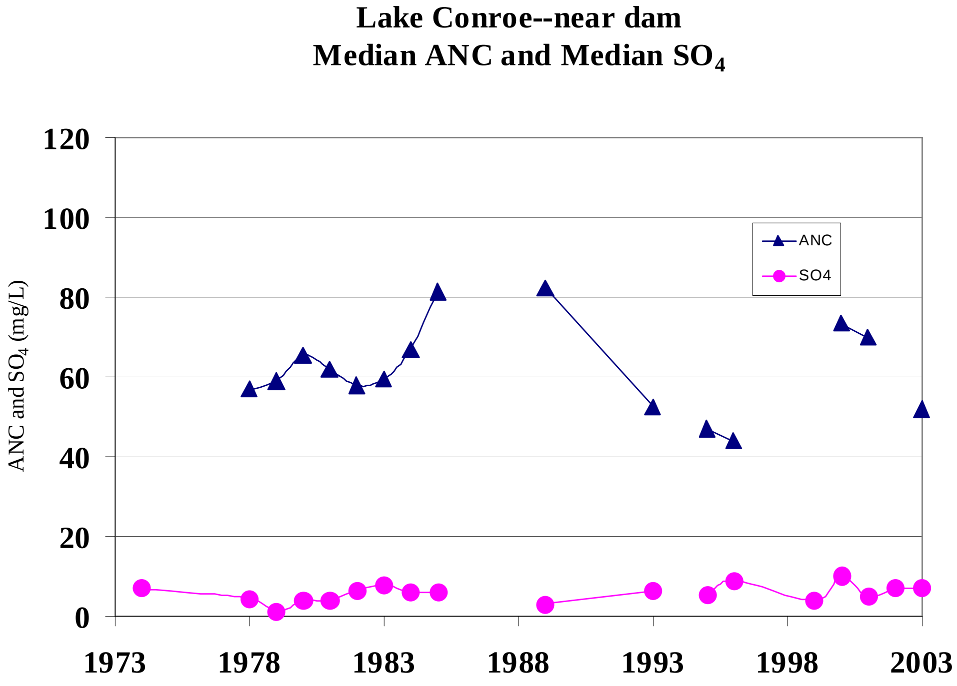

**Figure A-16. Median ANC and $SO_4$—Lake Conroe.**

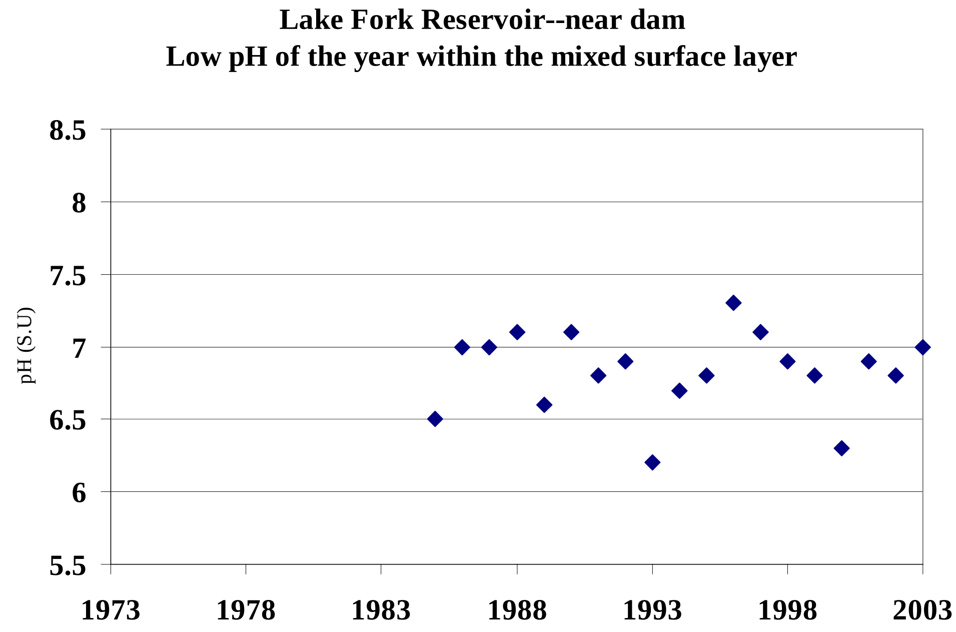

Figure A-17. Low pH of the year within the mixed surface layer—Lake Fork Reservoir.

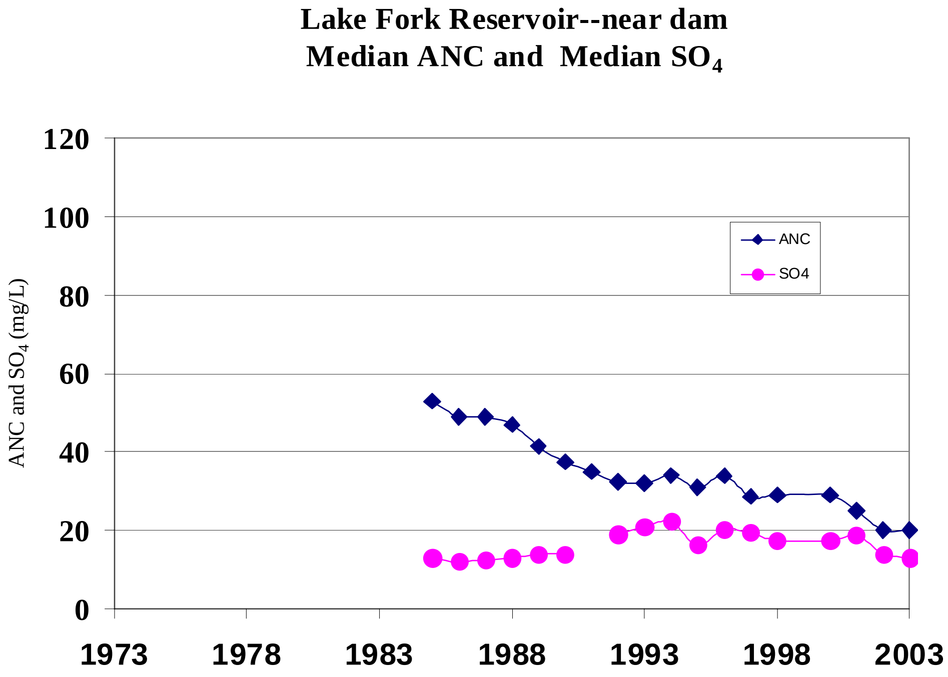

Figure A-18. Median ANC and $SO_4$—Lake Fork Reservoir.

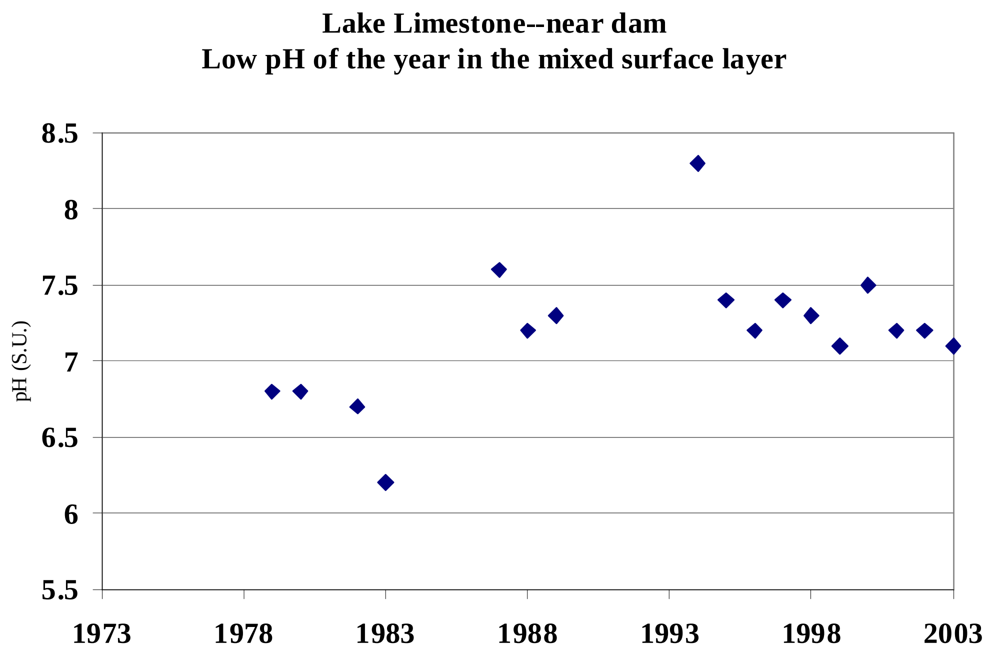

**Figure A-19.** Low pH of the year within the mixed surface layer—Lake Limestone.

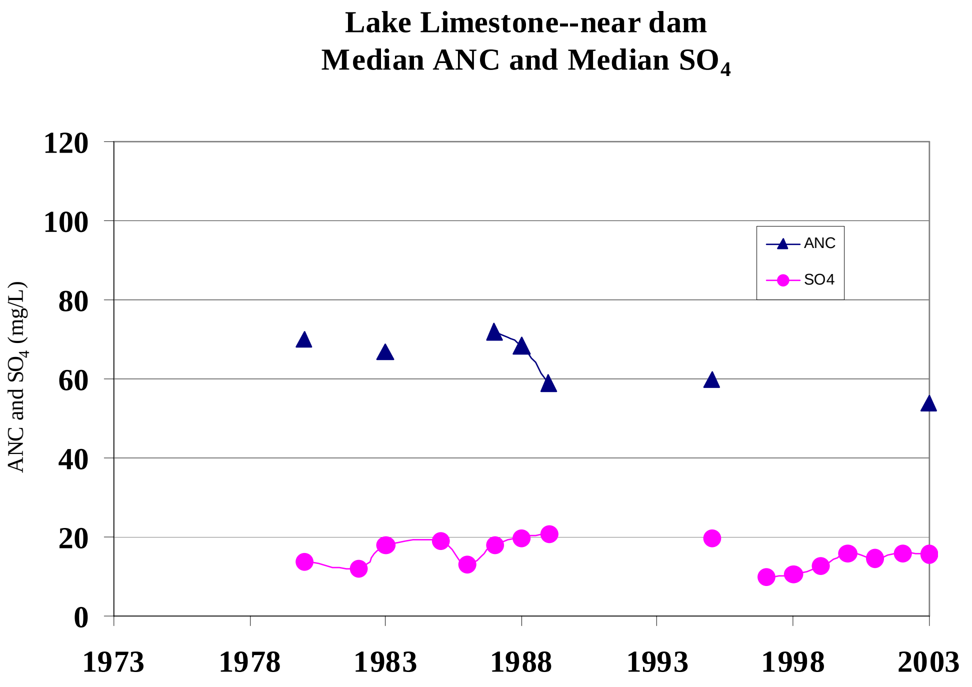

**Figure A-20.** Median ANC and $SO_4$—Lake Limestone.

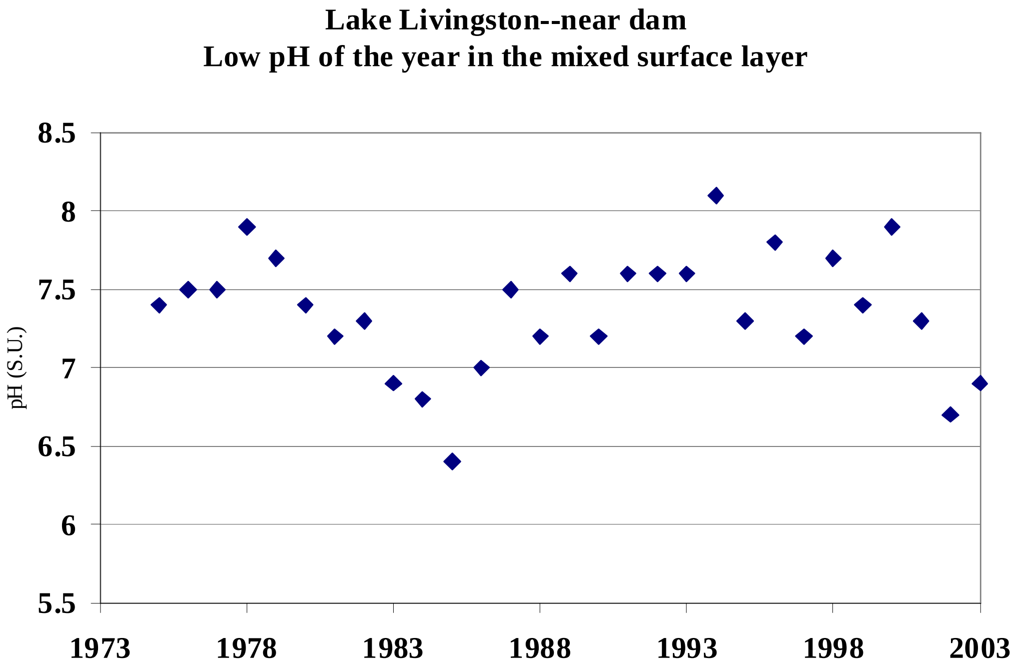

**Figure A-21.** **Low pH of the year within the mixed surface layer—Lake Livingstone.**

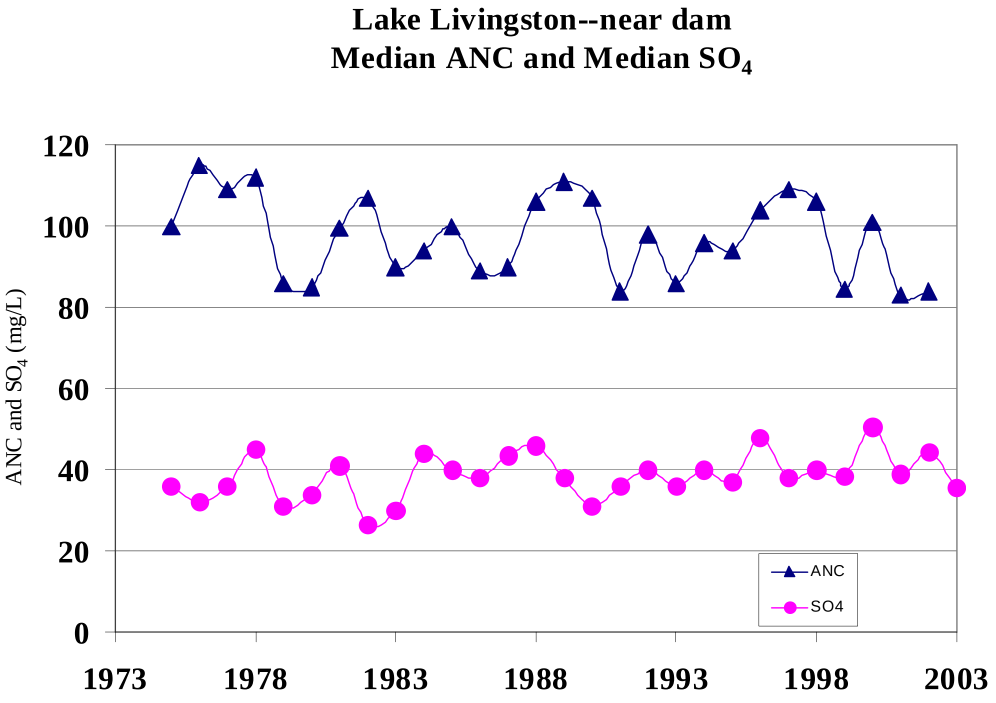

**Figure A-22.** **Median ANC and $SO_4$—Lake Livingstone.**

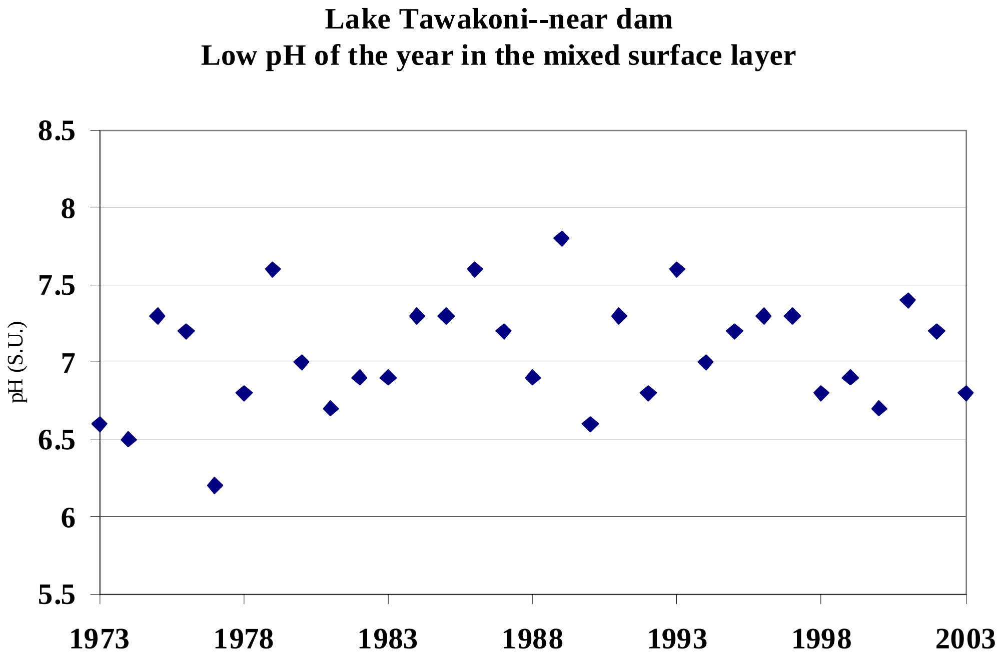

Figure A-23. Low pH of the year within the mixed surface layer—Lake Tawakoni.

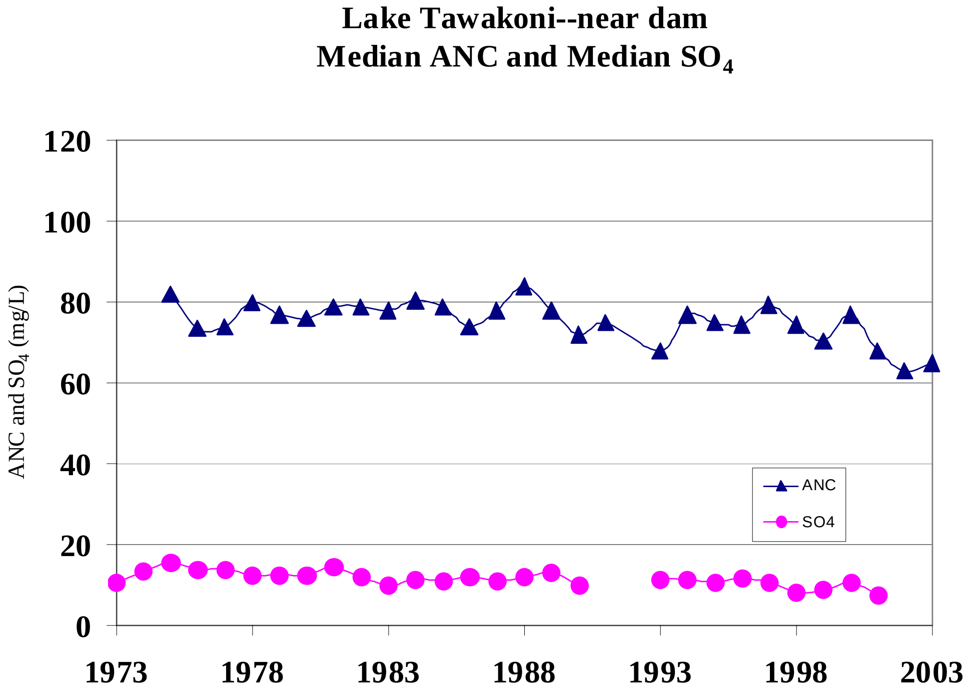

Figure A-24. Median ANC and $SO_4$—Lake Tawakoni.

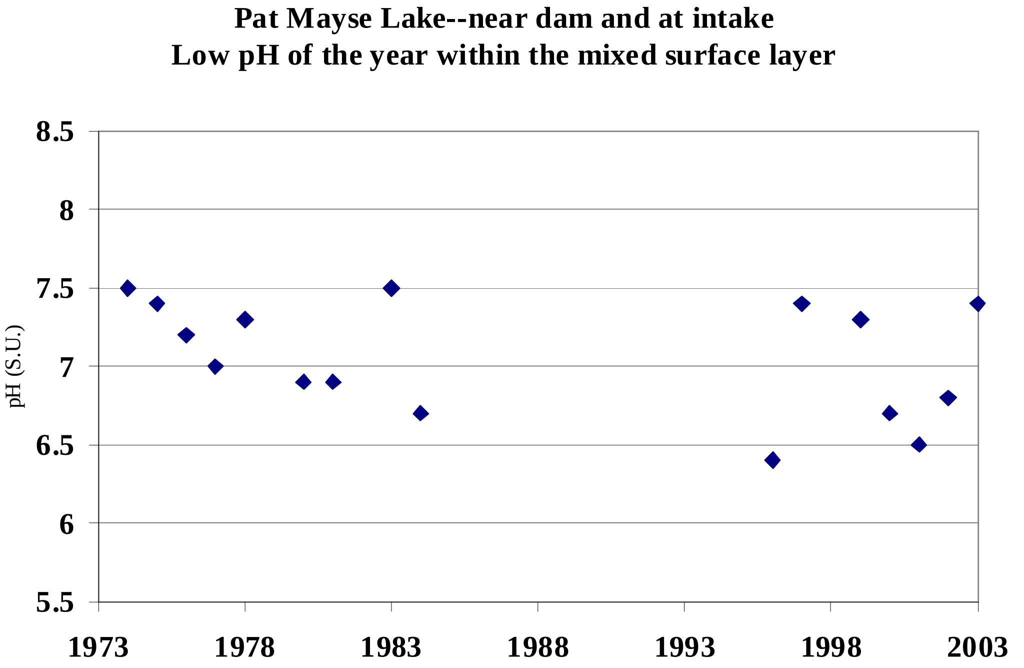

**Figure A-23.** **Low pH of the year within the mixed surface layer—Pat Mayse Lake.**

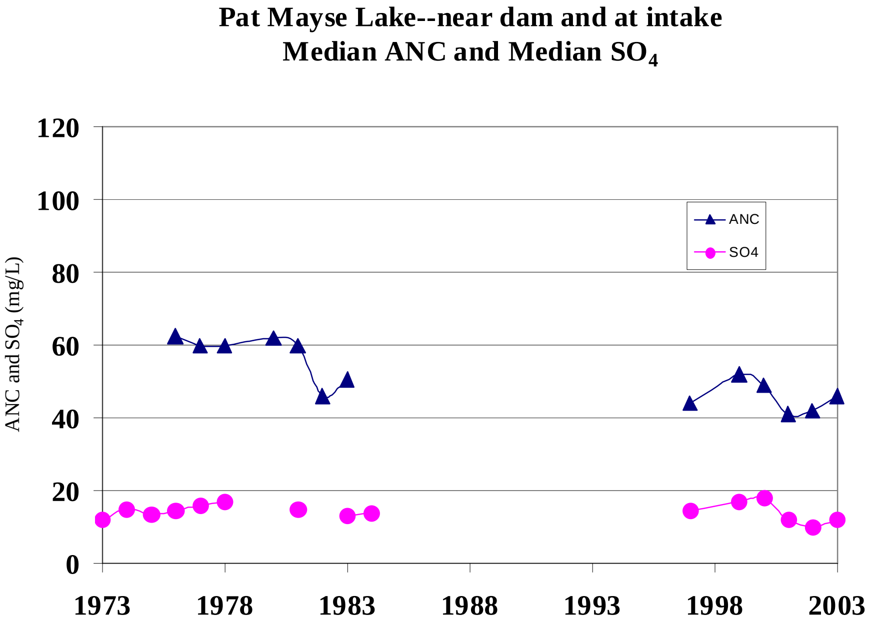

**Figure A-24.** **Median ANC and $SO_4$—Pat Mayse Lake.**

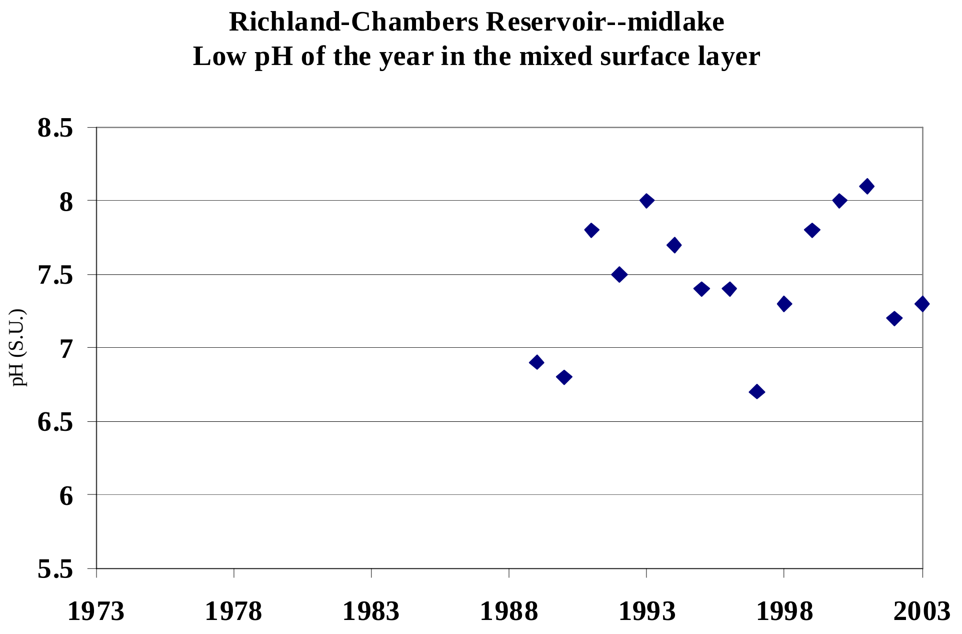

Figure A-25. Low pH of the year within the mixed surface layer—Richland Chambers Reservoir.

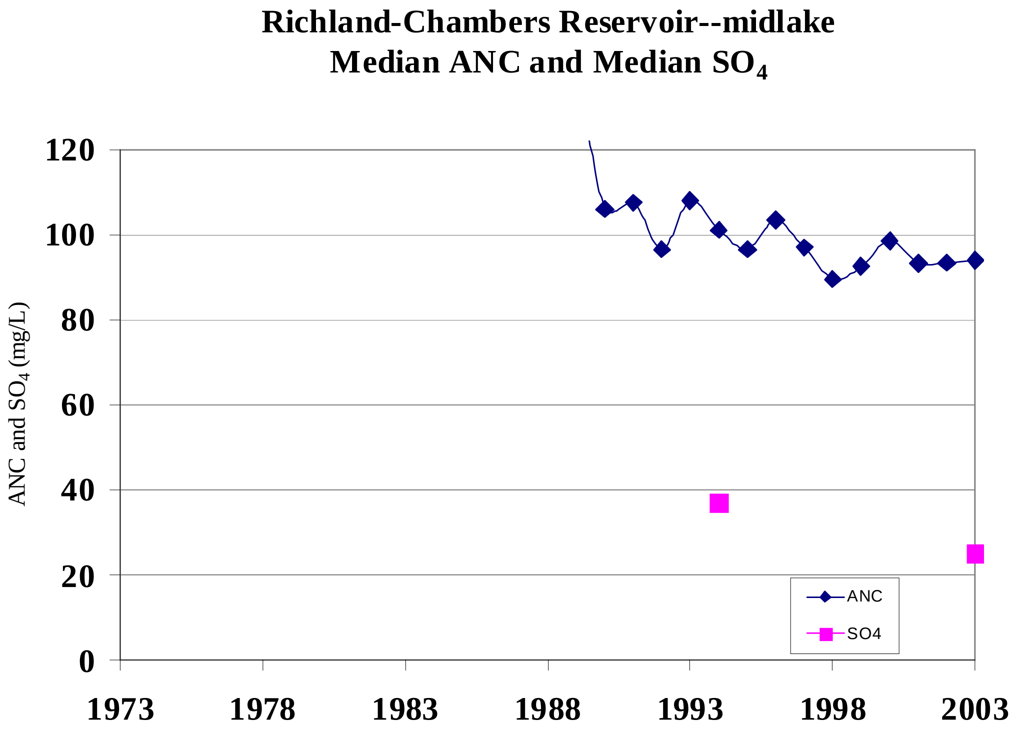

Figure A-26. Median ANC and $SO_4$—Richland Chambers Reservoir.

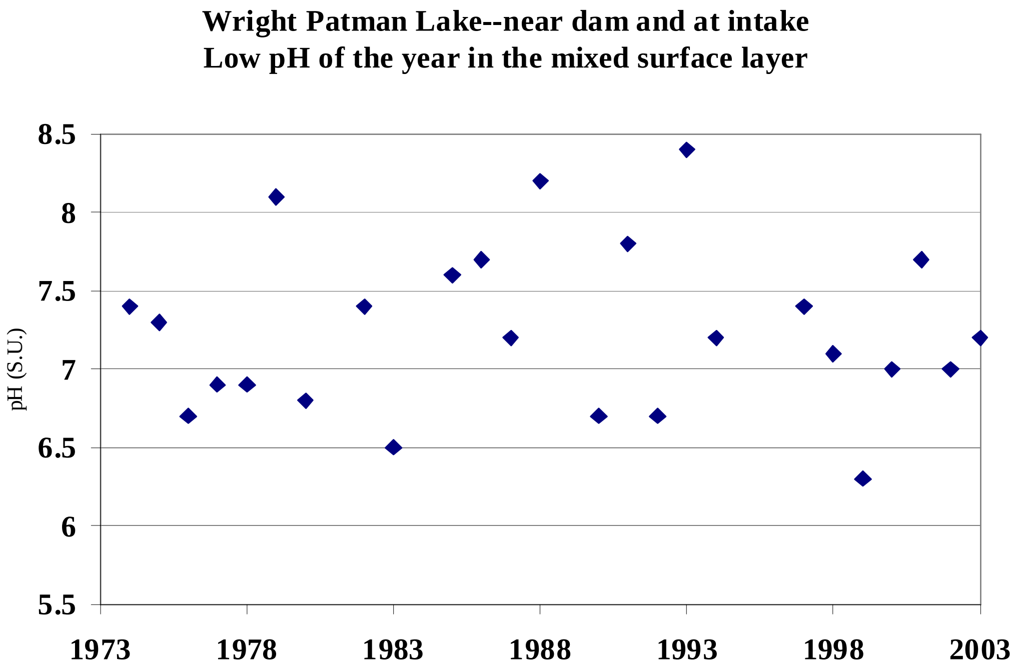

Figure A-27. Low pH of the year within the mixed surface layer—Wright Patman Lake.

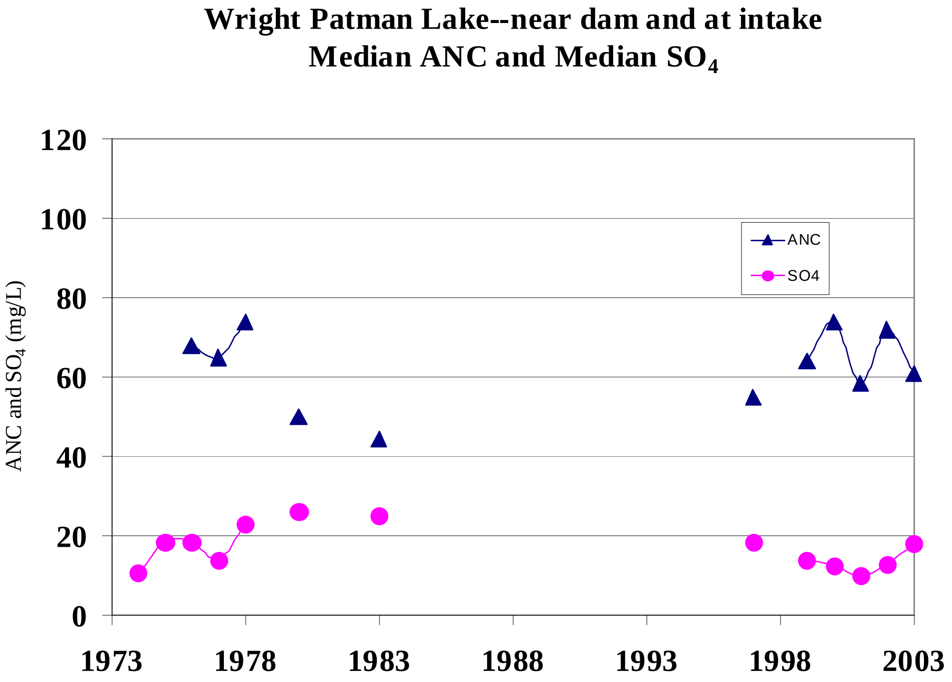

Figure A-28. Median ANC and $SO_4$—Wright Patman Lake.

# Appendix B

# Winter pH Values from Selected East Texas Reservoirs

## Appendix B. Winter pH values from selected East Texas reservoirs in the Piney Woods and Prairie-Savanna regions.

| Location | December 2002 | January 2003 | February 2003 |
|---|---|---|---|
| **Piney Woods** | | | |
| Lake O' the Pines | 7.4 | 7.2 | 6.8 |
| Caddo Lake | 7.1 | 6.3 | 6.9 |
| Murvaul Lake | 7.2 | 7.6 | 7.9 |
| Lake Palestine | 7.1 | 8.1 | 6.9 |
| Lake Tyler East | 6.7 | 7.0 | 6.9 |
| Sam Rayburn Reservoir | 7.0 | 8.4 | 6.8 |
| Toledo Bend Reservoir | 7.1 | 8.4 | 6.8 |
| Lake Bob Sandlin | 7.2 | 7.1 | 7.2 |
| Lake Cherokee | 7.2 | 7.2 | 7.0 |
| Martin Creek Reservoir | 7.0 | 7.5 | 7.4 |
| **Prairie Savanna** | | | |
| Lake Livingston | 7.4 | 7.4 | 7.7 |
| Lake Limestone | 7.2 | 7.4 | 7.3 |
| Richland-Chambers Reservoir | 7.8 | 7.3 | 7.3 |
| Lake Tawakoni | 8.3 | 7.8 | 7.9 |
| Lake Fork Reservoir | 7.3 | 7.5 | 7.5 |
| Wright Patman Lake | 7.7 | 7.3 | 7.7 |
| Pat Mayse Lake | 7.2 | 8.1 | 7.9 |
| Lake Conroe | 7.0 | 7.5 | 7.4 |
| Cooper Lake | 7.5 | 7.7 | 8.0 |
| Cedar Creek Reservoir | 7.3 | 7.0 | 7.3 |

# Appendix C

# Winter Acid Neutralizing Capacity (ANC) from Selected East Texas Reservoirs

## Appendix C. Winter Acid Neutralizing Capacity (ANC) values from selected East Texas reservoirs in the Piney Woods and Prairie-Savanna regions.

| Location | December 2002 | January 2003 | February 2003 |
|---|---|---|---|
| **Piney Woods** | | | |
| Lake O' the Pines | 21 | 14 | 12 |
| Caddo Lake | 15 | 10 | 8 |
| Murvaul Lake | 36 | 17 | 26 |
| Lake Palestine | 30 | 33 | 22 |
| Lake Tyler East | 16 | 17 | 13 |
| Sam Rayburn Reservoir | 21 | 21 | 22 |
| Toledo Bend Reservoir | 25 | 26 | 24 |
| Lake Bob Sandlin | 23 | 23 | 21 |
| Lake Cherokee | 23 | 11 | 11 |
| Martin Creek Reservoir | 14 | 11 | 14 |
| **Prairie Savanna** | | | |
| Lake Livingston | 76 | 64 | 62 |
| Lake Limestone | 58 | 58 | 50 |
| Richland-Chambers Reservoir | 93 | 96 | 97 |
| Lake Tawakoni | 62 | 65 | 63 |
| Lake Fork Reservoir | 28 | 27 | 24 |
| Wright Patman Lake | 75 | 61 | 60 |
| Pat Mayse Lake | 42 | 42 | 44 |
| Lake Conroe | 55 | 52 | 52 |
| Cooper Lake | 66 | 65 | 56 |
| Cedar Creek Reservoir | 55 | 51 | 51 |

# Appendix D

# Winter ANC:Cation from Selected East Texas Reservoirs

**Appendix D. ANC:cation from selected East Texas reservoirs in the Piney Woods and Prairie-Savanna regions. Values in parentheses are duplicates.**

| Location | December 2002 | January 2003 | February 2003 |
|---|---|---|---|
| **Piney Woods** | | | |
| Lake O' the Pines | 0.27 | 0.19 | 0.17 |
| Caddo Lake | 0.21 | 0.16 | 0.11 (0.12) |
| Murvaul Lake | 0.28 | 0.14 | 0.22 |
| Lake Palestine | 0.24 | 0.27 | 0.19 (0.21) |
| Lake Tyler East | 0.27 | 0.30 | 0.23 |
| Sam Rayburn Reservoir | 0.24 | 0.24 | 0.26 |
| Toledo Bend Reservoir | 0.28 | 0.29 | 0.28 |
| Lake Bob Sandlin | 0.26 | 0.27 (0.23) | 0.25 |
| Lake Cherokee | 0.26 | 0.14 | 0.14 |
| Martin Creek Reservoir | 0.12 | 0.10 | 0.13 |
| **Prairie Savanna** | | | |
| Lake Livingston | 0.40 | 0.36 | 0.28 |
| Lake Limestone | 0.39 | 0.43 (0.40) | 0.41 |
| Richland-Chambers Reservoir | 0.56 | 0.56 | 0.56 |
| Lake Tawakoni | 0.64 | 0.69 | 0.64 |
| Lake Fork Reservoir | 0.32 (0.32) | 0.32 | 0.28 |
| Wright Patman Lake | 0.60 | 0.52 | 0.51 |
| Pat Mayse Lake | 0.53 (0.52) | 0.54 | 0.54 |
| Lake Conroe | 0.49 | 0.48 | 0.49 |
| Cooper Lake | 0.66 | 0.63 | 0.54 |
| Cedar Creek Reservoir | 0.47 | 0.44 | 0.44 |