Report

Archibald Lake
Phase 1 - Lake Study

Scope ID: 00A017

Archibald Lake Association

March 2002

Foth & Van Dyke
consultants · engineers · scientists

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Prepared for
Archibald Lake Association

Prepared by
Foth & Van Dyke and Associates Inc.

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2737 S. Ridge Road, P.O. Box 19012, Green Bay, Wisconsin 54304, 920/497-2500, FAX: 920/497-8516

Executive Summary

Foth & Van Dyke was retained by the Archibald Lake Association to conduct a water quality evaluation of Archibald Lake. The Lake Association received a Lake Management Planning Grant from the Wisconsin Department of Natural Resources (WDNR) which provided funding of up to $10,000 for this project. In-kind services and matching funds of 25% have been provided by the lake association.

This evaluation and report focuses on evaluating the current trophic status of the lake, water quality data generation, an evaluation of the recharge/discharge relationship of Archibald Lake with the surrounding groundwater system, the relationship between land use practices in the Archibald Lake watershed and the water quality of the lake, and the impacts of waterfowl on the water quality of the lake.

Water Quality

A sampling program was implemented to determine the lake's water quality and trophic status. Archibald Lake can be described as a mesotrophic lake based on the lack of oxygen below the stratification in summer and winter period. Other parameters such as phosphorus cycling, increasing chlorophyl a and decreasing water clarity are also typical of mesotrophic lakes.

This water quality study represents a single year or a single point in time for Archibald Lake. The rate at which the lake is aging could be a more significant issue and one that needs to be addressed.

Groundwater Recharge/Discharge

A sand point (shallow groundwater well designed to evaluate groundwater elevation) and staff gauge (surface water rod designed to evaluate the elevation of the lake) were installed in each basin of Archibald Lake to determine the hydraulic relationship between the lake and groundwater system (does water move from the groundwater system to the lake or from the lake to the groundwater system). The data collected, at the two monitoring points, showed there is no or very little groundwater input into the lake. Data from the two monitoring points indicate that surface water is flowing out of the lake and into the surrounding groundwater system. Thus, Archibald Lake is a seepage lake acting as a source of recharge to surrounding groundwater. The groundwater and lake elevation measurements provided data at only two points around the edge of the lake and thus do not definitively exclude a groundwater contribution to the lake in a more localized area. In fact, water quality data (hardness) indicate that there is likely a localized groundwater contribution to the lake.

Watershed Analysis

Forested land use is the largest category in the watershed and makes up 60% of the total land use. Rural residential land use makes up 18%. Wetland areas comprise 5% of the total watershed.

Agricultural land use totals 0.5% of the total watershed. Archibald Lake is 16% of the total watershed. The watershed to Archibald Lake is approximately 2,491 acres.

Waterfowl Impacts

A number of resident and migratory waterfowl use Archibald Lake for resting and nesting. Peak populations of over 49 Giant Canada Geese reside at the lake. This results in approximately 1 ton of fecal matter, including over approximately 44 pounds of phosphorus being added each year by waterfowl. The impact from waterfowl, along with the impact of other possible human sources, may be significant enough to impact water quality.

Recommendations

It is recommended that the Archibald Lake Association proceed with the following:

- Evaluate potential areas of localized groundwater input to the lake and possible correlations to failing septic systems.
- Evaluate methods of reducing phosphorus loading to Archibald Lake
- Evaluate methods of reducing waterfowl impact on Archibald Lake
- Complete a Lake Management Plan directed toward maintaining and protecting the water quality of Archibald Lake.

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1 Introduction

Archibald Lake is located in the Section 1, 2, and 3, T32N, R15E in the Town of Townsend, Oconto County, Wisconsin. The lake covers an area of 430 acres as referenced on the website *www.dnr.state.wi.us/org/water/fhp/lakes/lakemap/oconto.htm*, with approximately 10% of the lake area less than 3-ft in depth and approximately 42% of the lake area exhibiting a depth of over 20-ft. The maximum depth of the lake is approximately 50-ft. The lake has 7.47 miles of shore line.

In April 2000, the Archibald Lake Association was awarded a Lake Management Planning Grant from the Wisconsin Department of Natural Resources (WDNR) to conduct a study of the water quality in Archibald Lake.

1.1 Authorization

The Archibald Lake Association authorized Foth & Van Dyke and Associates Inc. to complete the Phase I study for Archibald Lake, and to prepare a report identifying the results. The study was completed through a collaborative effort between Foth & Van Dyke, the Archibald Lake Association volunteers, and WDNR personnel.

1.2 Purpose

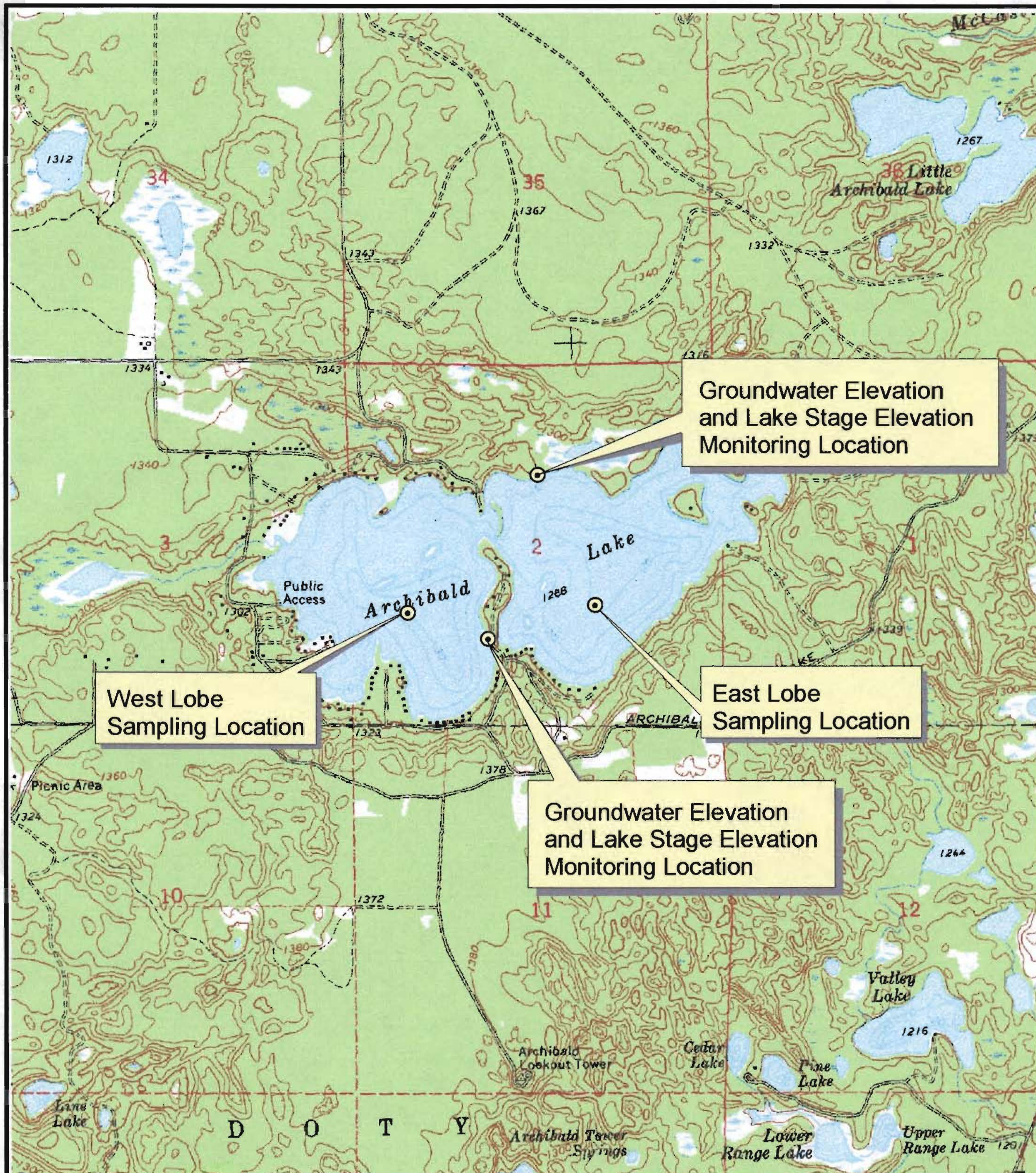
The purpose of the Phase I lake study was to address the following areas.

- Obtain water quality data to establish the existing water quality of both basins of Archibald Lake.
- Evaluate groundwater levels at two points around the lake to assess if groundwater is an important contributing source of water to the lake.
- Complete an analysis of the land use and associated phosphorus runoff in the immediate watershed of Archibald Lake.
- Determine the extent to which the waterfowl population impacts the lake.

The results of this study will be used to provide the Archibald Lake Association with an understanding of the water quality of Archibald Lake and the potential sources of nutrients. This report may be used as a basis for a Phase II study which, if implemented, will evaluate options for protecting the water quality in Archibald Lake.

1.3 Project Study Area

Figure 1-1 illustrates the project study area, including the water quality sampling locations.



This drawing is neither a legally recorded map nor a survey and is not intended to be used as one. This drawing is a compilation of records, information and data used for reference purposes only.

Source: U.S.G.S. 7.5-minute topographic quadrangle. Townsend (1972) - Oconto County, Wisconsin

N

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0 1000 2000 3000 4000 5000 Feet

M:\00a017\apr\townsend.apr February 6, 2002

ARCHIBALD LAKE

FIGURE 1-1

LAKE LOCATION MAP

Scale: AS SHOWN		Date: FEBRUARY 6, 2002	
Drawn By: PEP1	Checked By: SDJ		Scope: 00A017

2 Water Quality

The water quality of a lake is dependent upon a number of factors and lake characteristics. Every lake possesses a unique set of physical and chemical characteristics that may change over time. The chemical changes occur on a daily basis, while physical changes (such as plant and algae growth) occur on a seasonal basis. Seasonal changes in the physical characteristics of a lake are common because factors such as surface runoff, groundwater inflow, precipitation, temperature and sunlight are variable. A lake's water quality will vary with the seasonal changes, therefore data must be gathered over a period of time to accurately determine if a lake is experiencing significant changes in water quality and to distinguish between natural variability and impacts due to human activity.

To determine the water quality and trophic status of Archibald Lake, a sampling program was devised which included testing numerous characteristics of the lake over a one year time period. The following section explains the sampling program and its components, presents the results and analysis of the collected data, and provides conclusions about the water quality of the lake. First, however, it is important to identify the natural aging process experienced by lakes (eutrophication), and the source of the lake's water supply as this contributes to the resulting water quality of the lake. In addition, identification of the water source allows for sound management practices to be selected consistent with the specific characteristics of the lake.

2.1 Eutrophication - The Aging Process

The process of eutrophication is a natural aging process which occurs in all lakes whereby a lake progresses from a more oligotrophic (young lake) to a more eutrophic (old age) state. When nutrients such as phosphorus and nitrogen enter a lake with stormwater, by soil erosion, or by incoming tributaries and groundwater, they fertilize the lake and encourage algae and larger plants to grow. As the plants and the animals that feed on the plants die and decompose, the organic material accumulates on the lake bottom as organic sediments. After hundreds or thousands of years of plant growth and decomposition, the character of a lake may more closely resemble a marsh or a bog.

Lakes also obtain nutrients from various human activities which can accelerate the eutrophication (aging) process. This accelerated transition is commonly termed "cultural eutrophication", whereby changes that would normally take centuries may occur over/within one person's lifetime. Nutrients from agriculture, stormwater runoff, urban development, lawn and garden fertilizers, failing septic systems, land clearing, construction site runoff, municipal and industrial wastewater, and recreational activities contribute to the accelerated eutrophication or enrichment of lakes.

The practices which attract and hold waterfowl in this area can also be considered a cultural activity which can be directly linked to "cultural eutrophication."

2.2 Trophic Status Indicators

The trophic state of a water body is an indicator of the nutrient levels and water clarity in a lake. Lakes can be divided into three categories based on their trophic state which include oligotrophic, mesotrophic, and eutrophic. The following provides a description of each trophic state:

Oligotrophic: Young lakes with low productivity which are generally clear, cold, deep, and free of weeds or large algae blooms. Oligotrophic lakes are low in nutrients and therefore do not support plant growth or large fish populations, however are capable of sustaining a desirable fishery.

Mesotrophic: These lakes are in an intermediate stage between the oligotrophic and eutrophic stages. They are moderately productive, supporting a diverse community of native aquatic plants. The bottoms of mesotrophic lakes lack oxygen in late summer months or winter periods which limits cold water fish and causes phosphorus cycling from sediments. Overall however, mesotrophic lakes support good fisheries.

Eutrophic: Lakes which are high in nutrients and support a large biomass are categorized as eutrophic. These old age lakes are usually weedy and/or experience large algae blooms. Most often they support large fish populations, however, they are also susceptible to oxygen depletion which limits fishery diversity. Rough fish are common in eutrophic lakes.

The trophic state of a lake can be determined by observing three lake characteristics including total phosphorus concentration (Total-P) which indicates the amount of nutrients present which are necessary for algae growth, Chlorophyll *a* concentration which is a measure of the amount of algae actually present, and Secchi disc readings which is an indicator of water clarity. As expected, low levels of Total P are related to low levels of Chlorophyll *a*, which are related to high Secchi disc readings.

To determine the trophic state of the lake, the Wisconsin Trophic State Index (WTSI) can be applied to each of the above noted factors. The WTSI converts the actual measurement into a value which is representative of one of the trophic states. Values less than or equal to 39 indicate oligotrophic conditions, values from 40-49 indicate mesotrophic conditions, and values equal to or greater than 50 represent eutrophic conditions.

2.3 General Characteristics of Archibald Lake

Archibald Lake is classified a seepage lake: a seepage lake is a lake without a significant inlet or outlet, is fed by rainfall and may be fed by groundwater. Seepage lakes lose water through evaporation and water moving out of the lake over a portion or entire basin of the lake. Runoff is also a source of water to the lake. Seepage lake water quality is most influenced by runoff which is impacted by the drainage basin, the land use in that basin, and use of land on the shoreline.

Concentrated populations of livestock or waterfowl within the drainage basin may also impact the water quality of a seepage lake.

Archibald covers an area of 430 acres, with approximately 10% of the lake area under 3 ft of water and approximately 42% over a depth of 20 ft. The maximum depth of the lake is about 50 ft. The lake has 7.47 miles of shore line. The watershed associated with the Archibald Lake, which was delineated by Wisconsin Department of Natural Resources and Foth & Van Dyke, covers approximately 2491 acres, with the majority of the watershed being of forested land.

2.4 Sampling Program

Bi-weekly groundwater measurements were collected by Archibald Lake Association members at two sandpoint locations from December 2000 through October 2001. A lake gauge was installed near the sandpoints in April 2001. Bi-weekly measurements of the lake stage were taken from April 2001 through October 2001.

The sampling program used to evaluate the water quality of Archibald Lake was conducted over approximately a seven month time period, beginning in February of 2001, and concluding in August 2001. This sampling program provided information to evaluate the current water quality of the lake. Sampling was conducted on five separate occasions including:

- February 2001 (ice-on)
- April 2001
- June 2001
- July 2001
- August 2001

Archibald Lake Association members and Foth & Van Dyke personnel performed the water quality sampling, while laboratory analysis of the samples was completed by the State Laboratory of Hygiene. An important aspect of the sampling plan was to collect samples with ice on, and in summer months to assess seasonal changes which can affect water quality.

Numerous parameters were included in the sampling program, including:

Dissolved Oxygen (D.O.)
Total Phosphorus
Ammonia Nitrogen
Total Kjeldahl Nitrogen (organic plus ammonia)
Total Suspended Solids
Manganese
Potassium
Volatile Organic Solids

Temperature
Ortho-phosphate (dissolved/ reactive)
Nitrate plus Nitrite Nitrogen
Secchi Disc readings
Calcium
Magnesium
Specific Conductivity

Chlorophyll *a*
pH
BOD
Sulfate
Iron
Sodium
Redox

These parameters were measured at a single sample location in each basin. Temperature , D.O., pH, redox, and specific conductivity were measured at various depths in the lake in each basin ranging from surface to lake bottom. As the primary objective of this study was to determine the trophic status of Archibald Lake, the parameters which contribute to making this determination were sampled more frequently than most other parameters. These parameters include total phosphorus (Total P), Chlorophyll *a*, and Secchi Disc readings. For the purposes of this study, dissolved oxygen, pH, temperature, specific conductivity, and redox were also sampled on all sample dates. Table 2-1 summarizes the sampling program that was collected in the Phase 1 Lake Grant Study and data that was used in this study and collected by the self-help monitoring program.

The August 2001 monitoring event was to include sampling above and below the stratification in both lobes for the entire list of parameters. Although these samples were collected, they were not analyzed by the State Laboratory of Hygiene. Therefore, only April 2001 monitoring event included the expanded list.

The following section provides the results of the sampling program, highlighting the those factors which contribute to the determination of the lake's trophic state,

2.5 Results and Analysis

The complete results of the sampling program conducted on Archibald Lake are displayed in Appendix B. The following section provides a more detailed discussion of the sampling results of groundwater/surface water elevation measurements, temperature, dissolved oxygen levels, and trophic status indicators including total phosphorous concentrations, Chlorophyll *a* concentrations, and Secchi disc readings.

2.5.1 Groundwater and Surface Water Elevations

Two shallow groundwater wells or sandpoints were installed above the ordinary high water line. One well was installed near the west lobe, the other near the east lobe. Also, two corresponding lake gauges were installed in the lake bed near the two groundwater wells. the two measurement points were used to assess if water is flowing from the lake to the groundwater system or from the groundwater system to the lake.

The data collected indicates that Archibald Lake is a seepage type lake where lake water discharges to the groundwater system at the two points measured. This data can be found in Appendix A.

However, it should be noted that hardness calculations and field specific conductivity readings indicate Archibald Lake may receive a localized influx of groundwater. These two parameters, which are elevated in the lake relative to what would be expected in normal rainfall, suggest that there is some groundwater discharge to the lake. Hardness calculations and specific conductivity can be found in Appendix B.

Table 2-1

Archibald Lake - Oconto County
Data Collection Program

Phase 1 Lake Grant Study

Month	December		January		February		March		April		May		June		July		August		September		October	
Water Elevations																						
Water levels on wells	Bi-weekly		Bi-weekly		Bi-weekly		Bi-weekly		Bi-weekly		Bi-weekly		Bi-weekly		Bi-weekly		Bi-weekly		Bi-weekly		Bi-weekly	
Surface water levels									Bi-weekly		Bi-weekly		Bi-weekly		Bi-weekly		Bi-weekly		Bi-weekly		Bi-weekly	
Water Quality	east	west	east	west	east	west	east	west	east	west	east	west	east	west	east	west	east	west	east	west	east	west
Field Readings					1	1			1	1			1	1	1	1	1	1				
Secchi Disc					1	1			1	1			1	1	1	1	1	1				
Total Phosphorus					1	1			1	1			1	1	1	1	2	2				
Chlorophyl *a*					1	1			1	1			1	1	1	1	2	2				
BOD_5					1	1			1	1			1	1	1	1	2	2				
Ammonia Nitrogen									1	1												
TKN									1	1												
NO2+NO3-N									1	1												
TSS									1	1												
ortho-Phosphate									1	1												
Sulfate									1	1												
Sodium									1	1												
Potassium									1	1												
Volatile Organic Solids									1	1												
Manganese									1	1												
Magnesium									1	1												
Calcium									1	1												
Iron									1	1												
Goose Census									weekly		weekly		weekly		weekly		weekly		weekly		weekly	

Self Help Monitoring Data Used

	May		June		July		August		September		October	
	east	west	east	west	east	west	east	west	east	west	east	west
Secchi Disc	1	1	1	1	1	1	1	1	1	1		
Total Phosphorus			1		1		1		1			
Chlorophyl *a*			1		1				1			

2.5.2 Temperature

Temperature exerts a major influence on biological activity and growth. To a point, the higher the water temperature, the greater the biological activity. Temperature also governs the kinds of organisms that can live in a lake. Fish, insects, zooplankton, phytoplankton, and other aquatic species all have a preferred temperature range. As temperatures get too far above or below a preferred range, the survival of individual species may be limited or eliminated.

Temperature is also important because of its influence on water chemistry. The rate of chemical reactions generally increases at higher temperature, which in turn affects biological activity. An important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water, so it is more difficult to maintain enough oxygen in warm water for survival of aquatic life.

Stratification is a layering effect produced by the warming of the surface waters in many lakes in the summer, during which time lake water separates into layers of distinctly different temperature. Upper waters are progressively warmed by the sun and are less dense than the deeper waters which remain cold. Because of the resulting differences in water density, the upper and lower layers of the lake don't mix. As a result, they develop different physical and chemical characteristics, often resembling two different lakes. For example, oxygen in the bottom waters may become depleted. In autumn, as the upper waters cool to about the same temperature as the lower water, the density difference in the water and associated stratification is lost and the whole lake mixes. This process is defined as fall turnover. Stratification also exists in winter. However, in the winter the warmer water is near the bottom. Water exhibits it's greatest density at approximately 4°C. Therefore, during the winter months, the water temperature in most lakes will be near 4°C at the bottom and near 0°C at the surface. In spring, as ice melts, the water temperatures once again equalize and mixing occurs, a process defined as spring turnover. As summer progresses, the temperature difference (and density difference) between surface and bottom water becomes more distinct, as mentioned previously. Most lakes form three stratified layers. The upper layer, the epilimnion, is characterized by warmer (less dense) water and is the zone of light penetration, where the bulk of productivity or biological growth occurs. The next layer, the metalimnion or thermocline, is a narrow band where the transition from warmer surface waters goes to the cooler bottom layer. This transition zone helps to prevent mixing between the upper and lower layers. The bottom layer, the hypolimnion, has much colder water. Plant material either decays or sinks to the bottom and accumulates in this isolated layer.

A shallow lake, however, is more likely to be homogeneous from top to bottom. The water is well-mixed by the wind and current, and physical characteristics such as temperature and oxygen vary little with depth. Because sunlight reaches all the way to the bottom, photosynthesis and growth occur throughout the water column. As in a deep lake, decomposition in a shallow lake is higher near the bottom than the top simply due to the fact that when plants and animals die they sink. It is also likely that a larger portion of the water in a shallow lake is influenced by sunlight, and that photosynthesis and plant growth are proportionately higher.

2.5.2.1 Temperature Profile of Archibald Lake

Temperature profiles of each basin on Archibald Lake were taken at a single locations. The data collected shows that the lake experiences stratification in each basin during the summer and winter months. From June through early August, the temperature variation within the lake was as large as 17.2°C (63°F) variation.

2.5.3 Dissolved Oxygen (D.O.) Concentration

The presence of oxygen in lake water determines where organisms such as fish and zooplankton are found. When water is well-mixed, such as in spring, oxygen is usually present at all depths, thus organisms may be distributed throughout the lake. However, under stratified conditions, little or no oxygen may be produced in or introduced to the hypolimnion. Available oxygen may be consumed through decomposition of plant and animal material, and oxygen levels may become too low for fish which then must move to the top layer, or epilimnion. If these conditions are prolonged and the upper waters become too warm, cold-water fish such as trout may become stressed and eventually die. In the fall, the lake layers break down and turnover replenishes oxygen to the bottom waters. During the winter the formation of an ice cap on the water reduces the supply of oxygen to the lake from the overlying air. The extent to which oxygen is depleted is dependent on the amount of organic matter decaying in the lake and the amount of snow cover on the ice which prevents sunlight from penetrating the water column, thus inhibiting photosynthesis and oxygen generation. If oxygen levels fall too low as a result of ice and snow cover, fish and other aquatic life may die of a condition termed winter kill. Winter kill conditions occur in many eutrophic lakes.

The concentration of dissolved oxygen (D.O.) present in a lake is important as it supports aquatic life. The solubility of oxygen depends on the temperature of the water - colder water holds more oxygen than warmer water. The amount of D.O. present in lakes at different times of the day, and at different depths, is largely determined by the processes of photosynthesis and respiration. Oxygen is produced when green plants grow (photosynthesis), and is consumed through respiration. Therefore, D.O. levels tend to be higher during daylight hours (when photosynthesis occurs), and lower at night/early morning. In addition, lake depths which are below the reach of sunlight may experience oxygen depletion. Oxygen depletion is especially apparent in winter months where snow cover prevents sunlight from penetrating the water, stopping photosynthesis.

In warm water, the water quality standard for D.O. is 5 mg/l, which represents the minimum amount needed for the survival and growth of warm water fish species. D.O. concentrations between 8 mg/l and 12 mg/l indicate oxygen saturation.

2.5.3.1 Dissolved Oxygen Results

The D.O. levels in the lake vary among the varying sample dates and depths ranging from approximately 0.1 mg/l to 11.5 mg/l in each lobe. In the shallower west lobe the upper 20 ft had consistently higher D.O. levels in the open water samples. In the deeper east lobe the upper

33 ft had consistently higher D.O. levels in open water samples. During spring turnover, the D.O. concentrations were found to be uniform throughout the water column in west lobe. In the east lobe, the D.O. levels were somewhat reduced at depth during the April sampling event indicating the onset of stratification. During the spring turnover, the D.O. levels were not near saturation levels for the temperatures measured. During the summer months the oxygen levels become depleted at depths greater than about 15 to 20 ft.

When the lake is ice covered, D.O. concentrations were higher, above 15 ft of the water in the west lobe, while in the east lobe the D.O. levels were higher above 25 ft. In both lobes, D.O. levels drop below 1.0 mg/l in the lower depths. The low D.O. concentrations prevent fish from surviving in this part of the lake and impact other aquatic organisms as well. A graphic illustration of the D.O. and temperature stratification along with other field measured parameters is shown in Appendix B.

2.5.4 Trophic Status Indicators

2.5.4.1 Total Phosphorus Concentration (Total P)

Phosphorus is the key nutrient which influences plant growth in over 80% of the lakes throughout Wisconsin. Excess phosphorus promotes excessive aquatic plant growth. In most lakes, phosphorus is the least available nutrient, so it's abundance, or scarcity, controls the extent of algae growth. For that reason, phosphorus is typically referred to as the limiting nutrient. If more phosphorus is added to the lake from septic tanks, urban or farmland runoff, lawn or garden fertilizers, sewage treatment plants, or even if it is released from phosphorus-rich lake bottom sediments, that limitation is taken away and more weeds and algae will grow. Under certain conditions, especially when oxygen is absent from bottom waters, phosphorus is released from bottom sediments into the overlying water which upon lake turnover can precipitate algae blooms.

Algae and weeds are a source of food and energy for fish and other lake organisms, and are a vital part of all lakes. However, excessive amounts or nuisance types of algae or weeds can interfere with lake uses by inhibiting the growth of other plants by clouding the water so that it shades them, contributing - as they decay - to oxygen depletion and fish kills, and causing taste and odor problems in water and fish. In addition, algae can interfere with the aesthetic environment of the lake causing unsightly blooms which float on the lake surface forming scums. The regular occurrence of visible algal blooms often indicates that nutrient levels, especially phosphorus, are too high.

Aquatic plants may also limit many lake uses. Although aquatic plants (macrophytes) serve a vital function for the lake by providing cover, habitat, and even food for fish and other wildlife, an overabundance of rooted and floating plants can limit swimming, fishing, skiing, sailing, and boating activities, and aesthetic appreciation. Excessive plant growth can physically prevent mixing of oxygen through the water.

Two types of phosphorus analyses can be conducted which include soluble reactive phosphorus (orthophosphate) and total phosphorus. Total phosphorus is often a better indicator of the nutrient status of a lake because its levels remain more stable. The concentrations of Total P detected at the sample points and the corresponding Wisconsin Trophic Status Index (WTSI) values are presented in Table 2-2.

Table 2-2

Average Total Phosphorus Levels
Archibald Lake
(February 2001 - September 2001) [1]

	East Lobe	West Lobe
Average Total P ug/l	14.5	13.4
Range Total P ug/l	1-50	10-19
Average WTSI [2]	43	42

1 See Appendix B
2 WTSI < 40 = Oligatrophic, 40< WTSI <50 = Mesotrophic, WTSI >50 = Eutrophic

The total phosphorus data indicates that the Archibald Lake is a mesotrophic lake.

The WDNR guide Understanding Lake Data shows that an average total phosphorus concentration for natural lakes is 25 ug/l. This guide also states that total phosphorus should be maintained below 20 ug/l for natural lakes in order to prevent nuisance algae blooms. As indicated in Table 2-2 and Appendix B, the total P concentrations in the lake exceeded 30 ug/l in the east lobe of the lake on one occasion. The total phosphorus concentrations in the Archibald Lake indicate the potential for problematic phosphorus levels on a seasonal basis.

2.5.4.2 Chlorophyll *a* Concentration

Chlorophyll *a* is a green pigment which is present in all plant life and is necessary for photosynthesis. The amount of chlorophyll *a* present in a lake is dependent upon the amount of algae present, and is therefore used as a common indicator of water quality. It is also one of three characteristics used to determine the trophic state of a lake. Table 2-3 identifies the concentration of Chlorophyll *a* detected in Archibald Lake and the corresponding WTSI status.

Table 2-3

Chlorophyll *a* Levels
Archibald Lake
(February 2001 - September 2001) [1]

	East Lobe	West Lobe
Average Chl. a - ug/l	1.87	2.72
Range Chl. a - ug/l	1.0-3.0	1.0-6.0
Average WTSI [2]	37	40

[1] See Appendix B
[2] WTSI < 40 = Oligatrophic, 40< WTSI <50 = Mesotrophic, WTSI >50 = Eutrophic

Based on the results of the Chlorophyll *a* samples, the trophic status of Archibald Lake was identified as being mesotrophic in the West Lobe and oligotrophic in the East Lobe. However, some of the Chlorophyll *a* samples would tend to identify the East Lobe as mesotrophic also.

2.5.4.3 Secchi Disc Reading

A Secchi disc reading is a measure of water clarity; it is not a direct measure of water quality. However, water clarity is often indicative of a lake's overall water quality, especially the amount of algae present. Secchi disc readings are taken by lowering into the water an 8-in disc of alternating colors of black and white, and recording the average depth where the disc disappears from sight and where it becomes visible again when raised. The Secchi disc reading is used to determine the trophic state of a lake. Table 2-4 shows the average Secchi disc readings in the main lake and the corresponding WTSI status.

Table 2-4

Secchi Depth
Archibald Lake
(February 2001 - September 2001) [1]

	East Lobe	West Lobe
Average Secchi Depth - Ft.	17	14
Range Secchi Depth - Ft.	14-31	12-25
Average WTSI [2]	36	39

[1] See Appendix B
[2] WTSI < 40 = Oligatrophic, 40< WTSI <50 = Mesotrophic, WTSI >50 = Eutrophic

These readings also indicate the Archibald Lake water quality is nearing a mesothrophic trophic status in the West Lobe and oligotrophic in the East Lobe. However, some of the Secchi depth readings would tend to identify the East Lobe as mesotrophic on a seasonal basis.

2.5.5 Non-Trophic Status Indicators

2.5.5.1 Nitrogen

Nitrogen is an important plant nutrient. While phosphorus is typically the limiting nutrient for algae growth, nitrogen can be limiting under some circumstances. Inorganic and organic nitrogen compounds are present in lake. The inorganic forms are ammonia and nitrite/nitrate (NO_2 + NO_3) which are forms that are available to plants for growth. The organic form is included in Total Kjeldahl Nitrogen. Organic nitrogen is associated with plant and animal tissues.

The data collected in the April 2001 sample shows relatively low values for inorganic nitrogen. The value for ammonia was 0.063 mg/l. The value for nitrite/nitrate (NO_2 + NO_3) was 0.057mg/l. Ammonia can be toxic to aquatic organisms in concentrations exceeding 5 mg/l. Also toxicity of total ammonia solutions was greater at higher pH values and decreasing oxygen levels. Due to problems with the State Laboratory of Hygiene, a comparison sample that was collected in August 2001 sampling event was analyzed.

2.6 Water Quality Conclusions

2.6.1 Temperature

The lake does have a strong stratification characteristic and has demonstrated varying temperatures for most of the year, meaning that the temperatures vary greatly from the top to the bottom of the lake. Because the lake remains stratified, oxygen is not distributed evenly during the winter and summer months throughout the lake for most of the year, as seen from the D.O. readings.

2.6.2 Dissolved Oxygen

Typical of mesotrophic lakes, D.O. concentrations were lower at the bottom of the lake in summer and winter. The D.O. was depleted at depths greater than 20 ft in the west lobe and 33 ft in the east lobe during the summer stratification months. During the winter stratification months the depleted of oxygen depths rose higher in the water column, 15 ft for the west lobe and 25 ft for the east lobe. These reduced D.O. concentrations are not adequate for survival of fish and other aerobic aquatic organisms.

2.6.3 Total Phosphorus

Concentrations of Total P were consistently in the mesotrophic range. This was in complete agreement to the Chlorophyll *a* and Secchi disk readings which were also in the mesotrophic range.

2.6.4 Chlorophyll *a*

Measurements of chlorophyll *a* were in the mesotrophic range.

2.6.5 Secchi Disc

The Secchi disc measurements were also reviewing the mesotrophic range. Water clarity decreases with an increase in algae growth. As the water clarity decreases, so does the size of the litoral zone, that area of a lake where the light penetration reaches the bottom. The litoral zone is the area that can support rooted macrophytes, an important component of the aquatic ecosystem.

2.6.6 Nitrogen

Ammonia concentrations from most recent sampling event indicate low levels of ammonia in both lobes of the lake during non-stratification period or spring turnover. The low levels of ammonia do not appear to be causing toxicity to aquatic organisms.

2.6.7 Water Quality Summary

The water quality parameters showed that Archibald Lake is to be classified as a mesotrophic water body for phosphorus and other parameters measuring algae growth. The phosphorus concentrations in both lobes are high enough to encourage algae growth in the lake. The D.O. is adequate for fish survival and other aquatic life requiring an aerobic environment

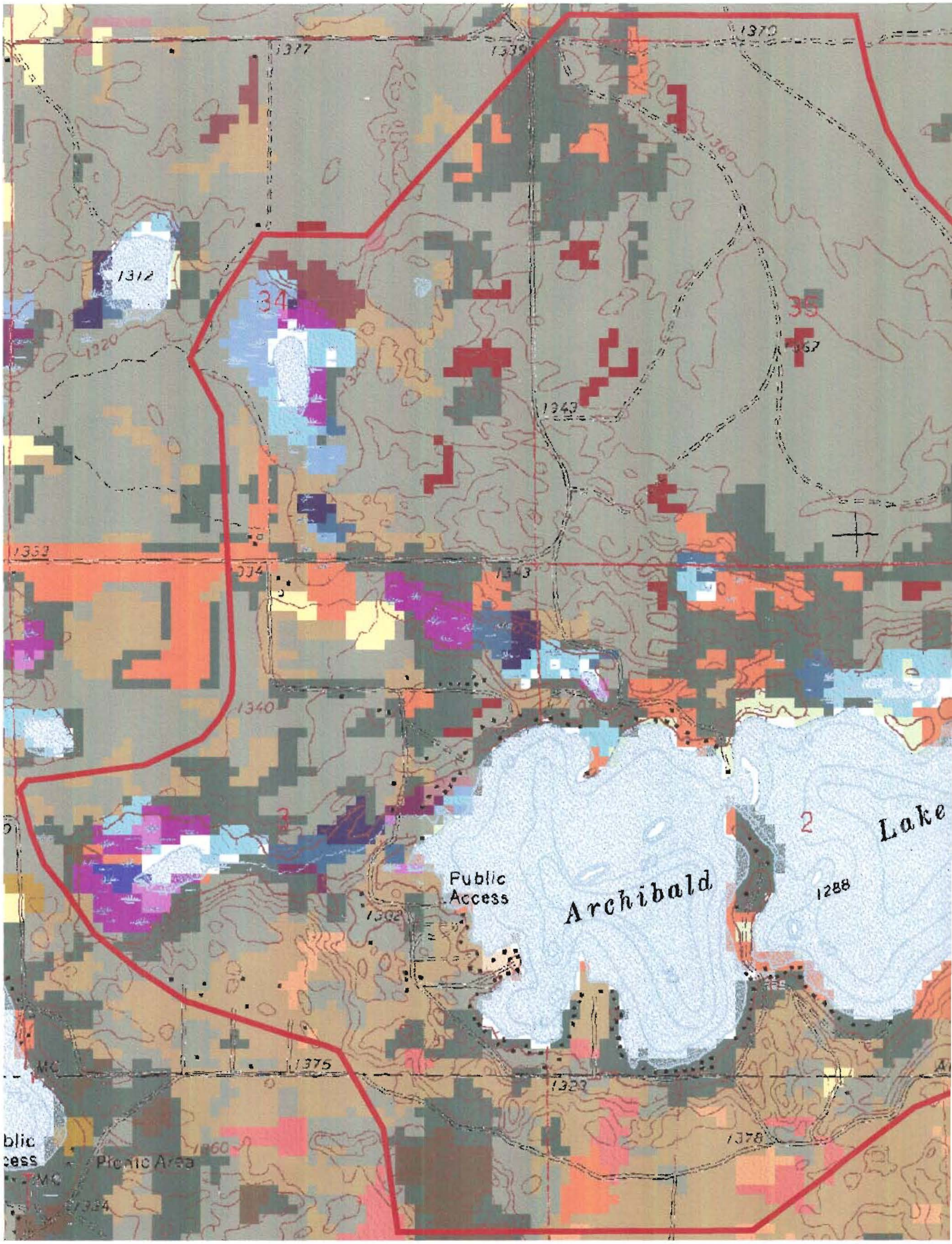
3 Watershed Analysis

A watershed is an area of land in which water drains to a common point, such as a stream, lake or wetland. A lake reflects its watershed because the watershed contributes both the water required to maintain a lake, and the majority of constituents which enter the lake. Therefore, effective lake management programs must include watershed management practices, as lake problems generally cannot be solved without controlling the sources in the watershed. Managing the watershed to control nonpoint pollutants such as nutrients, soil, and other substances which originate over a relatively broad area is essential to protecting water quality. Water running over the land picks up these materials and transports them to the lake, either directly in runoff or through a tributary stream, drainage system, or groundwater. Water running off a lawn or driveway during a heavy rain is an example of nonpoint source runoff. Land uses such as agriculture, construction, and roadways contribute higher nonpoint pollutant loads than other land uses such as forests. Controlling nonpoint pollution sources can usually be achieved by implementing best management practices. However, it must be noted that nonpoint pollution sources are harder to identify, isolate, and control than point sources (distinct sources such as an end of pipe discharge from a wastewater treatment plant or an industrial facility). Controlling the water that runs from the land's surface into a lake is important as lakes receive water directly from drainage of the surrounding land (watershed) and precipitation.

The watershed, or land area, which drains ***into*** the Archibald Lake was delineated by Foth & Van Dyke, and is illustrated on Figure 3-1. The map was prepared using LandSat imagery which is made available by the WDNR. Figure 3-2 summarizes the land use classifications within the watershed and the total acreage and percentage of land use each comprises. The straight lines that were delineated are between contour breaks on the USGS quadrangle.

The Archibald Lake Watershed is relatively small, and is situated within the North Branch Oconto River Watershed, in Oconto County, Wisconsin. The watershed of Archibald Lake comprises a land area of approximately 2491 acres while the lake itself comprises approximately 430 acres of surface water. Therefore, the watershed to lake area ratio is about 5.8:1. The larger the ratio, the more the watershed will have an impact on the lake through nutrient, pesticide, and soil runoff. A watershed to lake area ratio of 5.8:1 is small and the watershed has a proportionately small impact on the lake. In general, a seepage type lake has a small watershed to lake area ratio. This watershed to lake ratio is described in the publication "Understanding Lake Data" (G3582) by the UW-Extension.

Not all areas of the watershed are equal nutrient or pollutant contributors. By identifying those critical areas that contribute excessive amounts of soil and nutrients to the lake, the most effective controls can be developed. For example, agricultural runoff carrying animal wastes, soil, and nutrients can be a critical pollutant contributor. Urban runoff from lawns, gardens, streets, and rooftops may be significant sources of sediment, oils and greases, nutrients, and heavy metals to lakes. Construction and forestry activities can provide significant quantities of sediments, especially during rainstorms. In small watersheds, lakeside activities may be more critical pollutant contributors. However, in large watersheds, the contributions from urban, forestry, and agricultural areas are generally more significant than those from lakeshore homes.


1377
1339
1370
1360
1312
1320
34
35
1367
1343
1353
1334
1343
1340
3
2
Lake
Public
Access
Archibald
1288
1302
1375
1323
1378
1360
Picnic Area

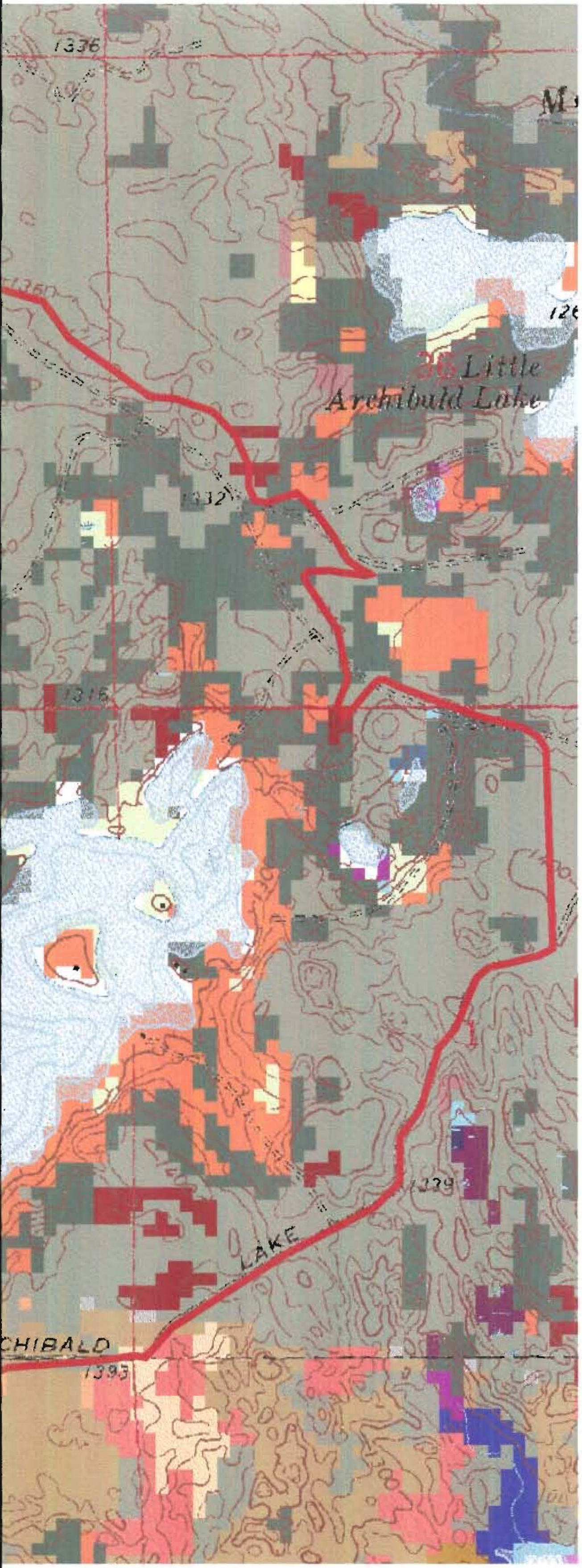


FIGURE 3.1
LAND COVER AND U.S.G.S. QUADRANGLE
Town of Townsend
Oconto County, Wisconsin

State of Wisconsin

AGRICULTURE
- Herbaceous/Field Crops
- Forage Crops
- Grassland

FOREST
- Red Pine
- White Spruce
- Mixed/Other Coniferous
- Aspen
- Oak
- Northern Pin Oak
- Red Oak
- Maple
- Sugar Maple
- Mixed/Other Broad-leaved Deciduous
- Mixed Deciduous/Coniferous

WETLAND
- Emergent/Wet Meadow
- Lowland Shrub
- Lowland Shrub: Broad-leaved Deciduous
- Lowland Shrub: Broad-leaved Evergreen
- Lowland Shrub: Needle-leaved
- Forested: Broad-leaved Deciduous
- Forested: Coniferous
- Forested: Mixed Deciduous/Coniferous
- Barren
- Delineated Watershed Boundary

N

0 800 1600 2400 3200 4000 Feet

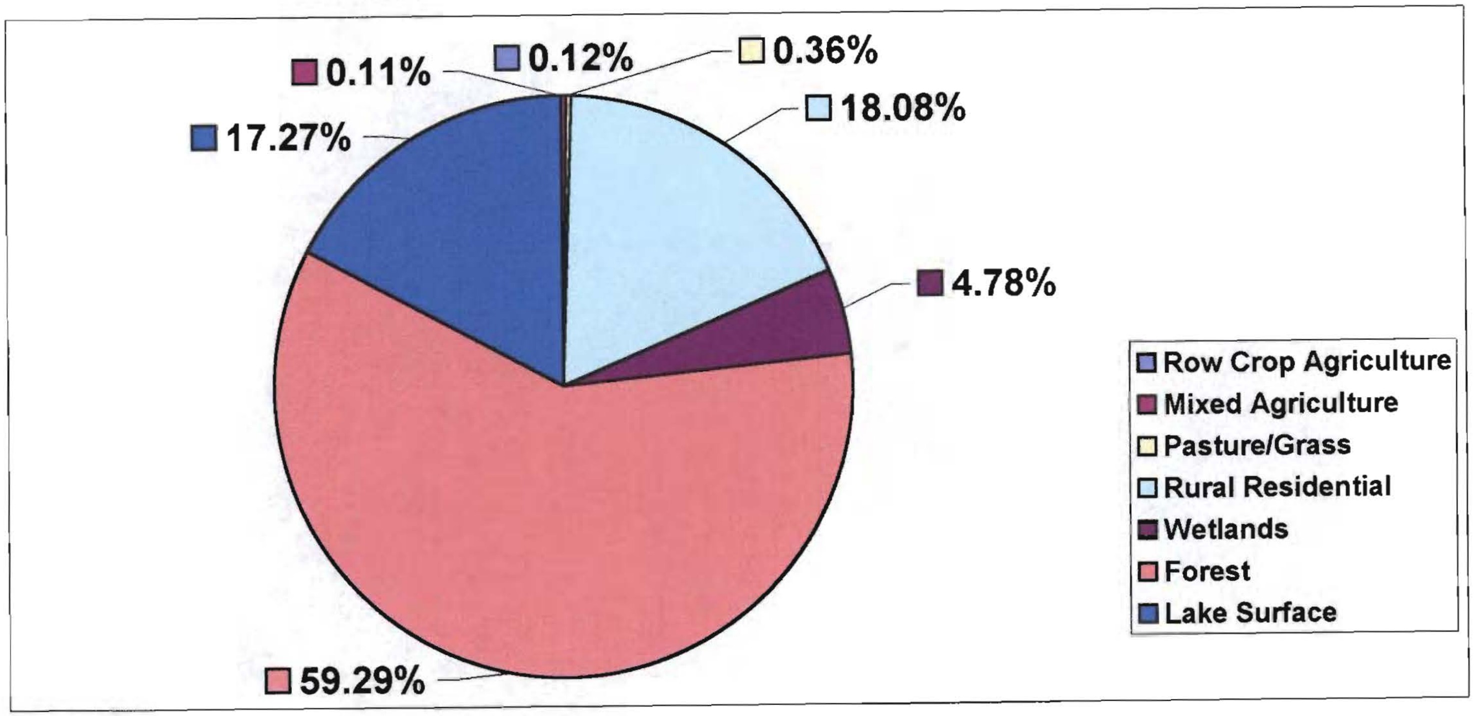
Foth & Van Dyke
consultants · engineers · scientists

m:\00a017\apr\archibald2.apr February 12, 2002 Drawn by: kpk1 Checked by:sdj

Figure 3-2
Archibald Lake - Oconto County
Land Use Classification

Non-Point Source Land Usage

Land Use	Acre	Perentage
Row Crop Agriculture	2.9	0.12%
Mixed Agriculture	2.7	0.11%
Pasture/Grass	8.9	0.36%
Rural Residential	450	18.08%
Wetlands	119	4.78%
Forest	1476	59.29%
Lake Surface	430	17.27%
Totals	2489.5	100.00%



An estimation of phosphorus loading to Archibald Lake was calculated based on the existing land uses illustrated in Figure 3-1. Unit area loads by land use type in lbs/acre/year for phosphorus were calculated by Foth & Van Dyke. The unit area load by land use type was then multiplied by the total acreage. The results of the calculation are identified in Table 3-1.

The land use impacts did not account for the waterfowl impacts. These were evaluated as a specific source.

Table 3-1

Existing Phosphorus Loading (lbs/yr)
Archibald Lake

Land Use Class	Acreage	Phosphorus (lbs/yr)	% of Total Phosphorus
Row Crop AG	2.9	4.4	7%
Mixed Ag	2.7	2.2	4%
Pasture/Grassland	8.9	2.2	4%
Rural Residential	450	39.7	66.5%
Emergent Wetland/Meadow	119	11	18.5%
Forested:	1476	0	0%
Total	2098.8	59.5	100%

Area Loads by Land Use (lbs/acre/year); Wilm's Program Foth & Van Dyke, 2001.

The table identifies the estimated existing phosphorus loadings for the Archibald Lake watershed. The rural residential development has the greatest land use impact on the lakes water quality based on the amount of phosphorus it contributes to the lake. As identified in the table, rural residential development uses contribute approximately 66.5% of the phosphorus associated with land use practices which enters the lake on an annual basis. There are some common "Best Management Practices" (BMP's) which can be used to help protect the lake's water quality from pollutants/nutrients. These BMP's (shore buffer areas and riparian management zones, lakeshore development, upgrade of septic systems, removal of non-conforming structures, building of access roads, etc.) are available from WDNR or local county extension offices.

4 Waterfowl Impacts

The resident and migratory waterfowl at Archibald Lake have a significant impact on water quality as a relatively moderate population of giant Canada geese and mallard ducks use the lake.

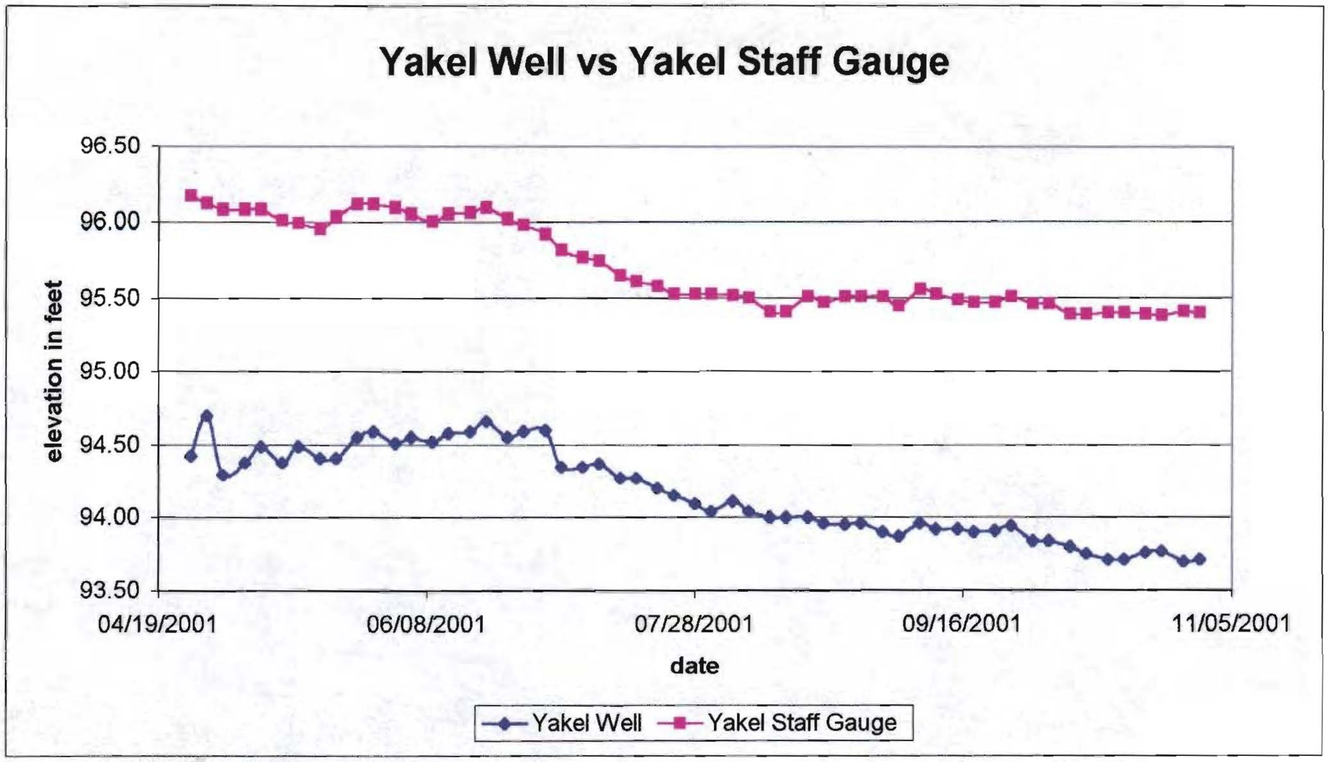
Appendix C contains the waterfowl counts and the impact from waterfowl defecation. Based on numbers from a 1994 paper by Manny et. al., calculations were made to determine phosphorous loading from waterfowl. In summary, waterfowl defecation totals 1 ton dry fecal matter each year. Included in that total is over 44 lbs phosphorus per year. When this value for phosphorus is compared to the estimated 59 lbs phosphorus per year from the watershed, it is clear that waterfowl are a significant contributor (over 47%) on the phosphorus loading to the lake.

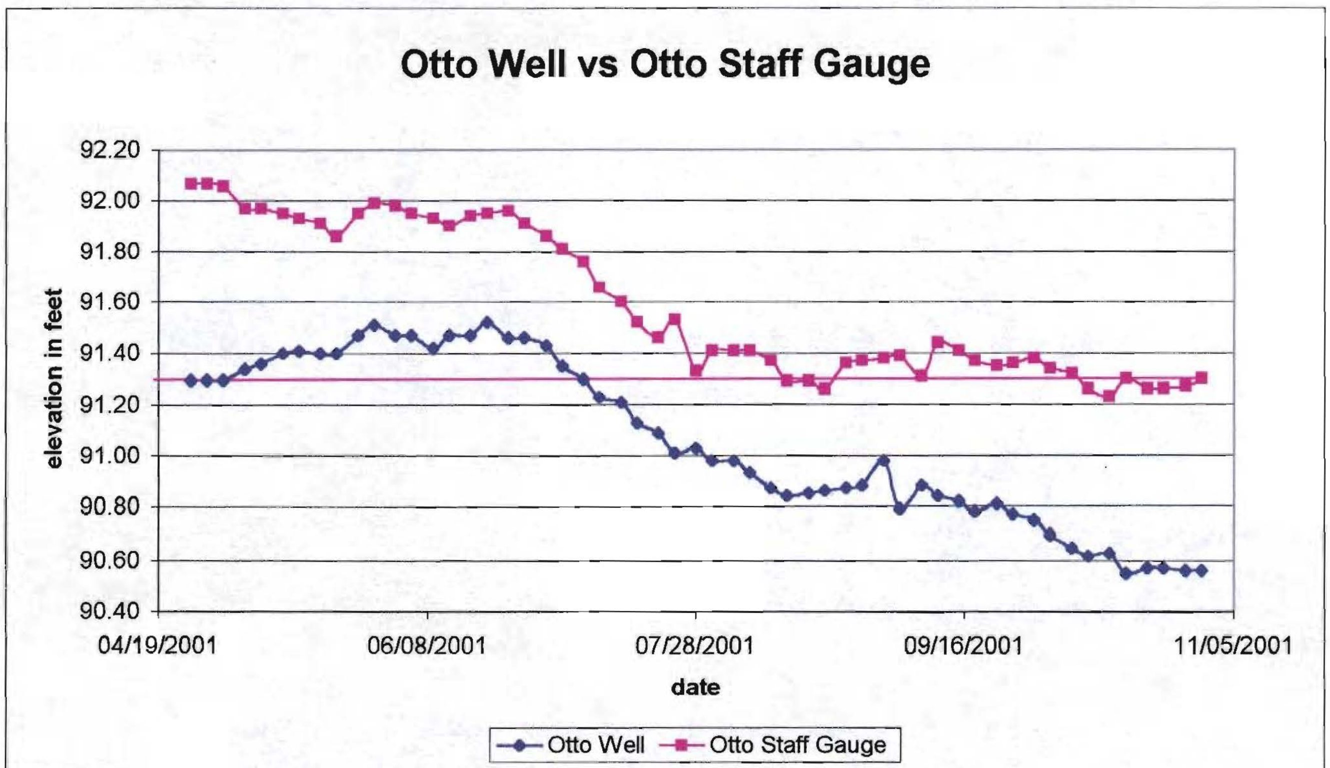
Waterfowl defecation also contributes organic compounds and nitrogen compounds to the lake. The organic compounds are degraded by microorganisms consuming oxygen in the process. During periods of time when the lake is stratified, the increased oxygen demand consumes most, if not all, the oxygen in the lower depths of the lake.

5 References

UW-Extension. *Understanding Lake Data*. Publication 63582.

Archibald Lake -Oconto County
Groundwater - Surfacewater Comparison



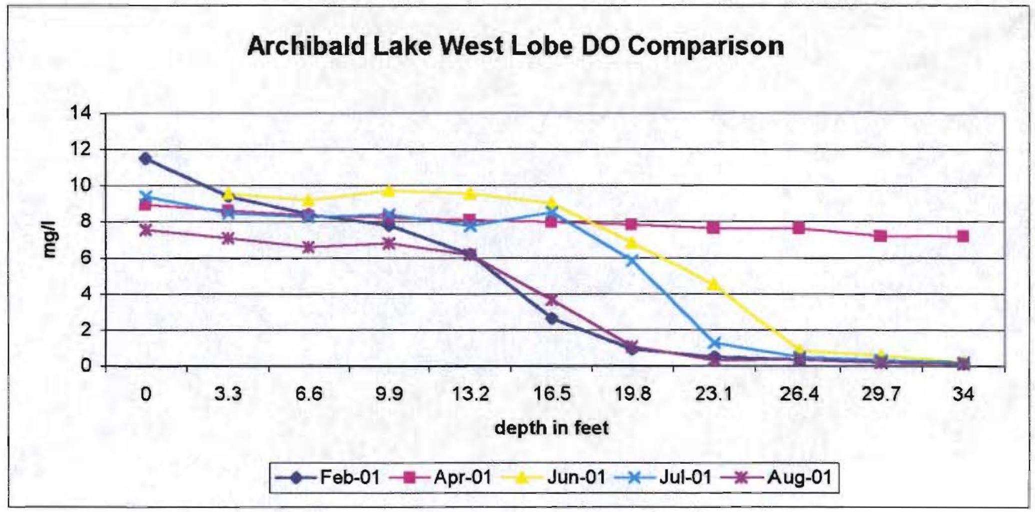


Appendix B

Water Quality Data

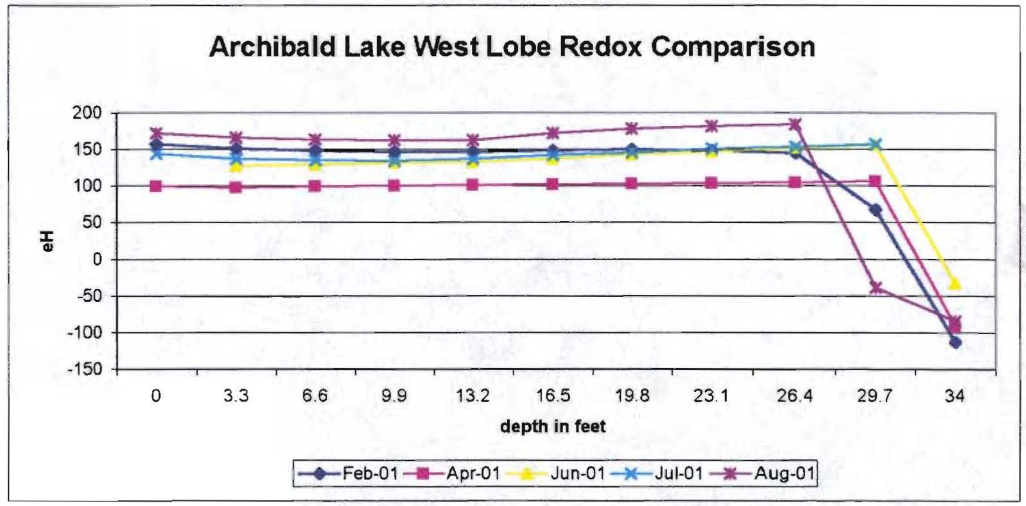
Dissolved Oxygen

Depth	Date 2/8/2001	4/25/2001	6/20/2001	7/14/2001	8/14/2001
0	11.51	8.94		9.4	7.55
3.3	9.41	8.62	9.53	8.49	7.1
6.6	8.41	8.33	9.19	8.27	6.58
9.9	7.81	8.23	9.72	8.42	6.81
13.2	6.19	8.09	9.53	7.77	6.18
16.5	2.65	7.97	9.02	8.51	3.66
19.8	0.91	7.83	6.84	5.86	1.07
23.1	0.49	7.62	4.52	1.3	0.33
26.4	0.34	7.62	0.86	0.51	0.36
29.7	0.25	7.19	0.58	0.31	0.17
34	0.15	7.19	0.25	0.22	0.11

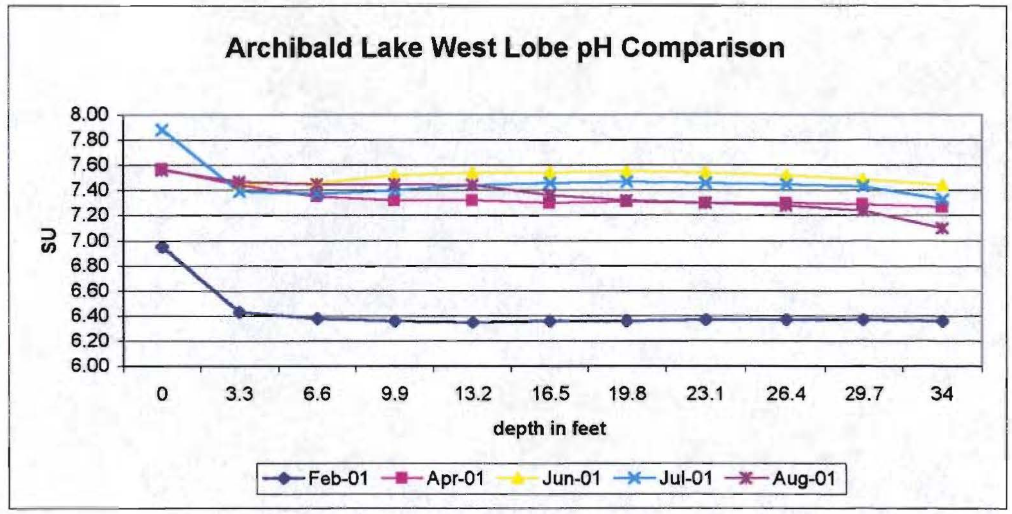


Redox

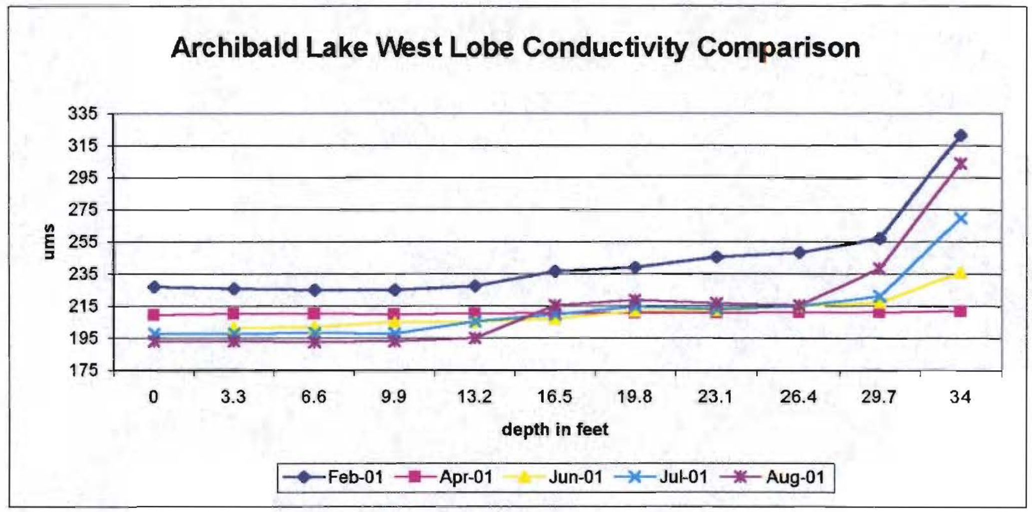
Depth	Date 2/8/2001	4/25/2001	6/20/2001	7/14/2001	8/14/2001
0	157	99		144	172
3.3	151	98	127	137	166
6.6	148	99	129	135	163
9.9	147	100	132	134	162
13.2	147	101	133	137	162
16.5	148	102	137	142	172
19.8	150	103	143	146	178
23.1	148	104	147	151	182
26.4	145	105	152	154	184
29.7	68	106	156	157	-39
34	-113	-91	-33	-84	-84



			pH		
	Date				
Depth	2/8/2001	4/25/2001	6/20/2001	7/14/2001	8/14/2001
0	6.95	7.57		7.88	7.56
3.3	6.43	7.44	7.45	7.39	7.47
6.6	6.38	7.35	7.46	7.37	7.45
9.9	6.36	7.32	7.52	7.40	7.45
13.2	6.35	7.32	7.54	7.44	7.44
16.5	6.36	7.30	7.54	7.46	7.36
19.8	6.36	7.31	7.55	7.47	7.32
23.1	6.37	7.30	7.54	7.46	7.30
26.4	6.37	7.30	7.52	7.45	7.28
29.7	6.37	7.29	7.49	7.43	7.24
34	6.36	7.27	7.44	7.33	7.10

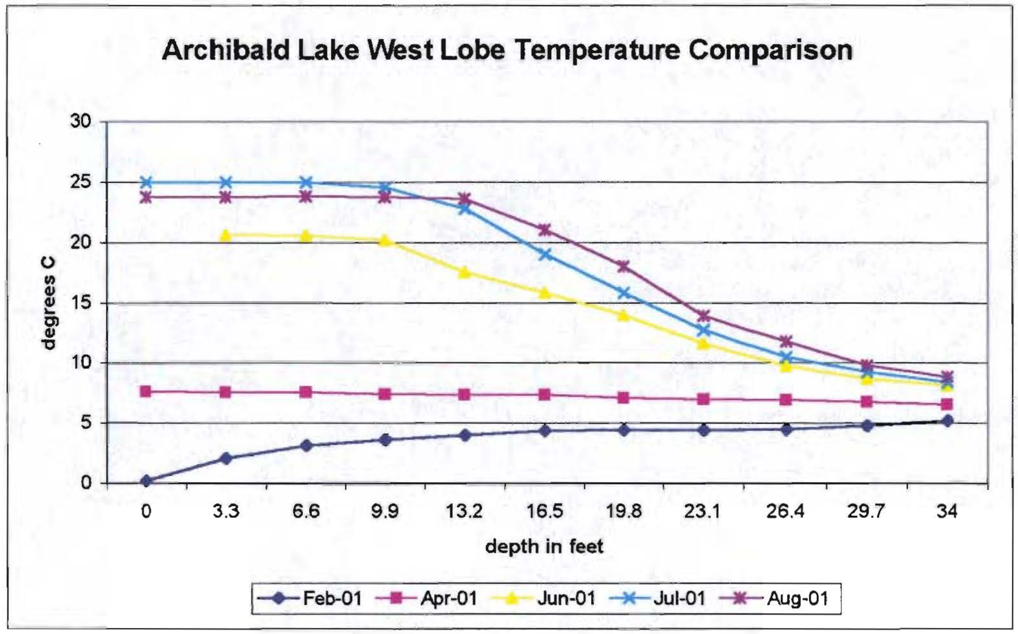


			Conductivity		
	Date				
Depth	2/8/2001	4/25/2001	6/20/2001	7/14/2001	8/14/2001
0	227.2	209.6		198	192.9
3.3	225.7	210.3	201.6	197.8	192.9
6.6	224.9	210.3	201.7	198.1	192.7
9.9	225	209.8	205.1	197.9	192.8
13.2	227.6	210.3	204.8	205.3	195.2
16.5	236.7	210.5	207	210	215.5
19.8	239.2	210.7	212	214.4	218.4
23.1	245.5	210.7	212.2	213.1	216.4
26.4	248.4	211.2	215.1	215	215.6
29.7	257	210.8	216.8	221	238.1
34	321.3	211.7	235.7	269.8	303.9



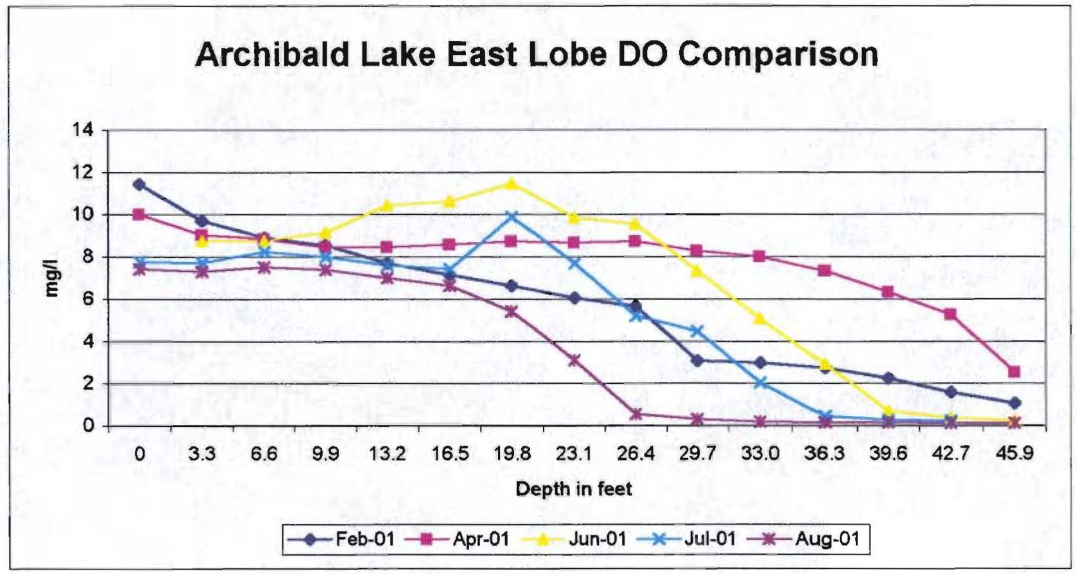
j:scopes\00a017\81401profile.xlsWest lobe Comparison

	Temperature				
	Date				
Depth	2/8/2001	4/25/2001	6/20/2001	7/14/2001	8/14/2001
0	0.23	7.62		24.99	23.78
3.3	2.1	7.56	20.64	24.99	23.79
6.6	3.14	7.57	20.58	25.01	23.8
9.9	3.64	7.39	20.21	24.56	23.79
13.2	3.99	7.35	17.51	22.78	23.61
16.5	4.38	7.34	15.85	19.03	21.03
19.8	4.41	7.08	13.95	15.85	17.99
23.1	4.44	7	11.64	12.72	13.9
26.4	4.49	6.94	9.73	10.52	11.79
29.7	4.77	6.79	8.69	9.26	9.78
34	5.22	6.56	8.14	8.43	8.85



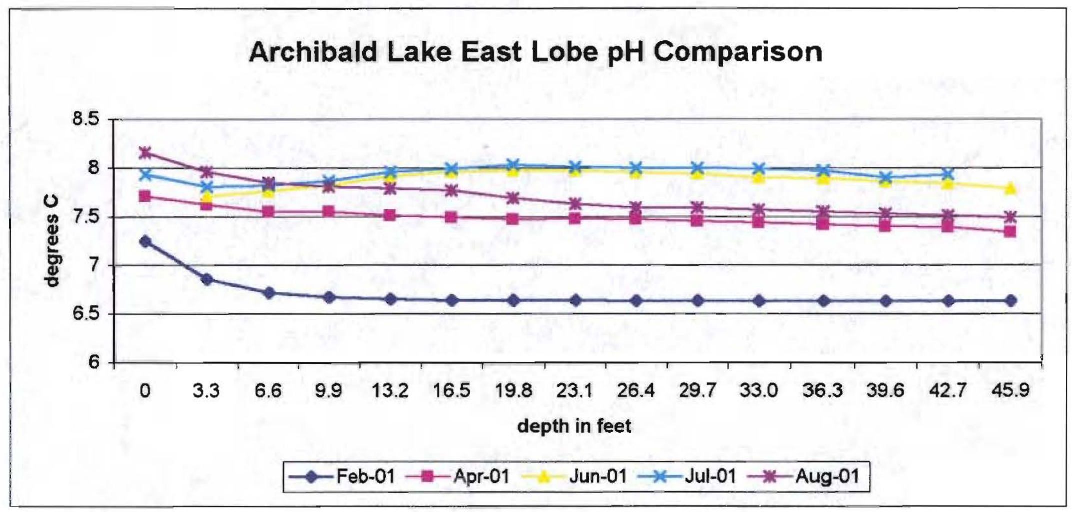
Dissolved Oxygen

Depth	Date 2/28/2001	4/25/2001	6/20/2001	7/18/2001	8/14/2001
0	11.45	10.02		7.77	7.42
3.3	9.72	9.04	8.78	7.73	7.3
6.6	8.91	8.86	8.77	8.24	7.53
9.9	8.56	8.46	9.15	8.01	7.39
13.2	7.71	8.46	10.43	7.61	6.99
16.5	7.14	8.57	10.62	7.44	6.63
19.8	6.63	8.74	11.46	9.9	5.41
23.1	6.05	8.68	9.86	7.7	3.09
26.4	5.65	8.73	9.55	5.19	0.54
29.7	3.08	8.28	7.33	4.46	0.31
33.0	2.99	7.99	5.07	2.04	0.19
36.3	2.74	7.34	2.92	0.45	0.15
39.6	2.24	6.32	0.7	0.28	0.14
42.7	1.59	5.27	0.36	0.23	0.13
45.9	1.07	2.53	0.23		0.11



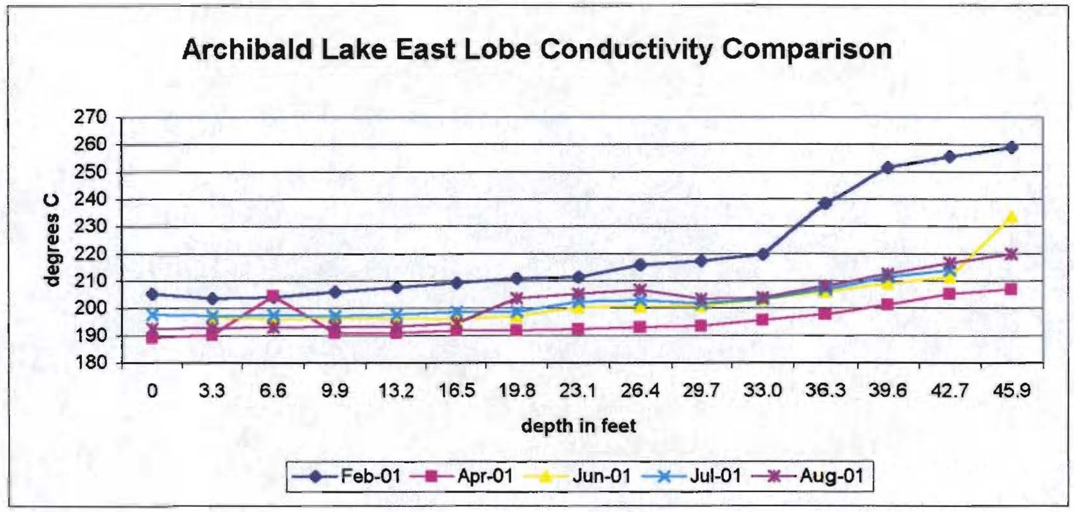
pH

Depth	2/28/2001	4/25/2001	6/20/2001	7/18/2001	8/14/2001
0	7.25	7.71		7.93	8.16
3.3	6.86	7.62	7.71	7.81	7.96
6.6	6.72	7.55	7.76	7.82	7.85
9.9	6.67	7.55	7.82	7.87	7.81
13.2	6.65	7.51	7.91	7.96	7.79
16.5	6.64	7.49	7.96	7.99	7.77
19.8	6.64	7.47	7.97	8.03	7.69
23.1	6.64	7.48	7.97	8.01	7.63
26.4	6.63	7.47	7.95	8.00	7.59
29.7	6.63	7.45	7.94	8	7.59
33.0	6.63	7.44	7.9	7.99	7.57
36.3	6.63	7.42	7.89	7.97	7.55
39.6	6.63	7.40	7.86	7.9	7.53
42.7	6.63	7.39	7.84	7.93	7.51
45.9	6.63	7.34	7.79		7.49



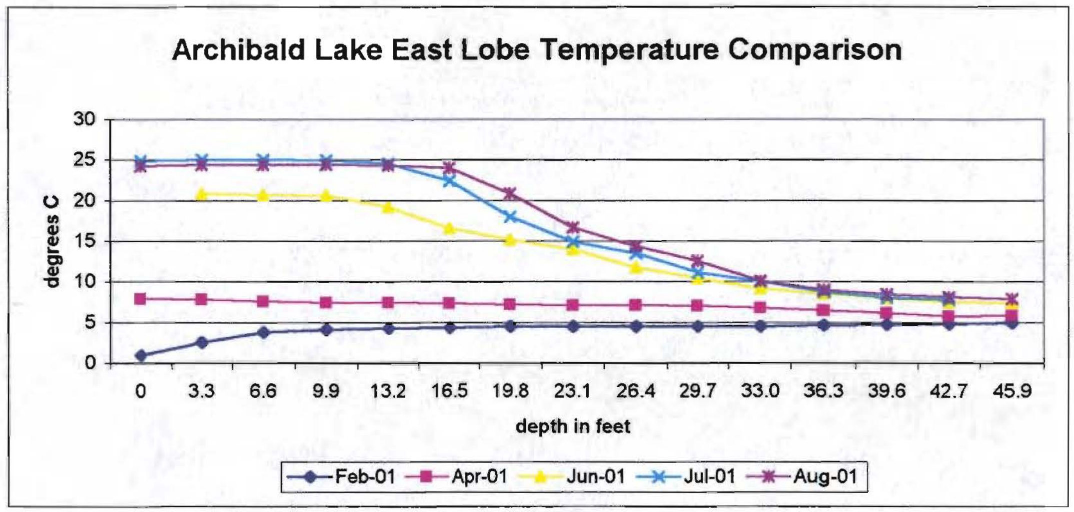
Conductivity

Depth	2/28/2001	4/25/2001	Date 6/20/2001	7/18/2001	8/14/2001
0	205.3	189.2		197.6	192.5
3.3	203.6	190.1	196.5	197.3	192.7
6.6	204.1	204.6	196.0	197.4	193.1
9.9	206.1	190.8	196.2	197.2	193.2
13.2	207.7	190.8	196.2	197.8	193.2
16.5	209.2	191.9	196.0	198.6	194.4
19.8	210.9	191.9	196.9	198.7	203.7
23.1	211.3	192.3	200.2	202.4	205.3
26.4	215.8	192.9	200.5	202.9	206.7
29.7	217.4	193.4	200.8	201.8	203.3
33.0	219.7	195.6	203.1	203.4	203.8
36.3	238.4	197.8	206.0	206.9	208.1
39.6	251.6	201.3	209.1	211.4	212.6
42.7	255.6	205.3	211.3	214	216.5
45.9	258.9	207.0	233.6		220.0



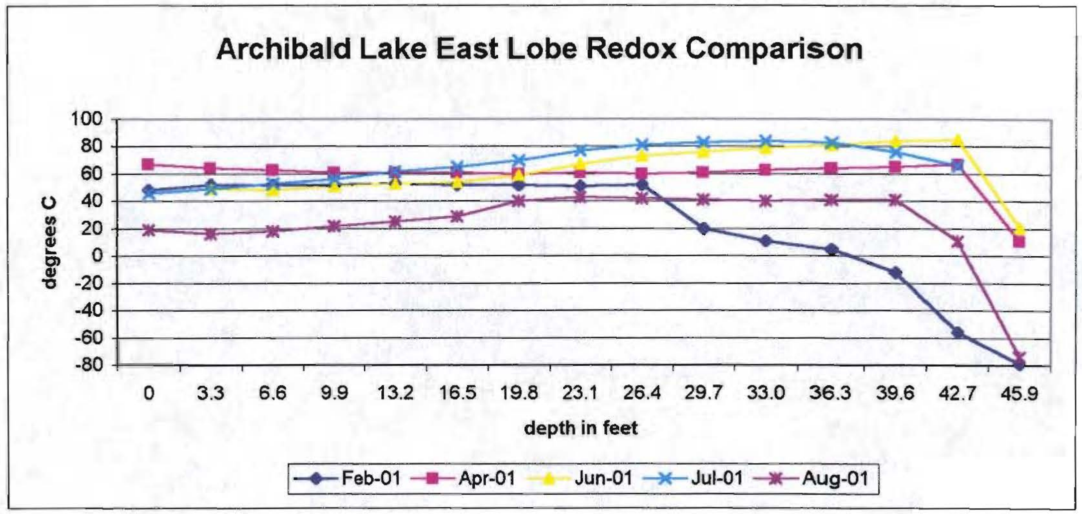
Temperature

Depth	2/28/2001	4/25/2001	Date 6/20/2001	7/18/2001	8/14/2001
0	0.91	7.93		24.88	24.26
3.3	2.55	7.8	20.83	24.99	24.41
6.6	3.81	7.57	20.68	25	24.37
9.9	4.10	7.45	20.64	24.92	24.38
13.2	4.30	7.45	19.15	24.53	24.33
16.5	4.36	7.31	16.61	22.45	24.01
19.8	4.48	7.22	15.17	17.99	20.82
23.1	4.47	7.12	13.94	14.93	16.63
26.4	4.50	7.12	11.79	13.52	14.34
29.7	4.52	7.01	10.41	11.16	12.58
33.0	4.52	6.82	9.13	10.06	10.12
36.3	4.67	6.51	8.5	8.76	9.02
39.6	4.76	6.15	7.98	8.07	8.48
42.7	4.85	5.8	7.50	7.81	8.11
45.9	4.98	5.82	7.45		7.86



j:scopes\OOa017\81401profile.xlsEast Lobe Comparison

			Redox		
			Date		
Depth	2/28/2001	4/25/2001	6/20/2001	7/18/2001	8/14/2001
0	48	67		46	19
3.3	52	64	49	49	16
6.6	52	63	48	53	18
9.9	52	61	51	56	22
13.2	53	61	53	62	25
16.5	52	61	54	65	29
19.8	52	60	59	70	40
23.1	51	61	67	77	43
26.4	52	60	73	81	42
29.7	20	61	76	83	41
33.0	11	63	79	84	40
36.3	5	64	81	83	41
39.6	-12	65	84	76	41
42.7	-56	67	85	66	11
45.9	-79	11	21		-74

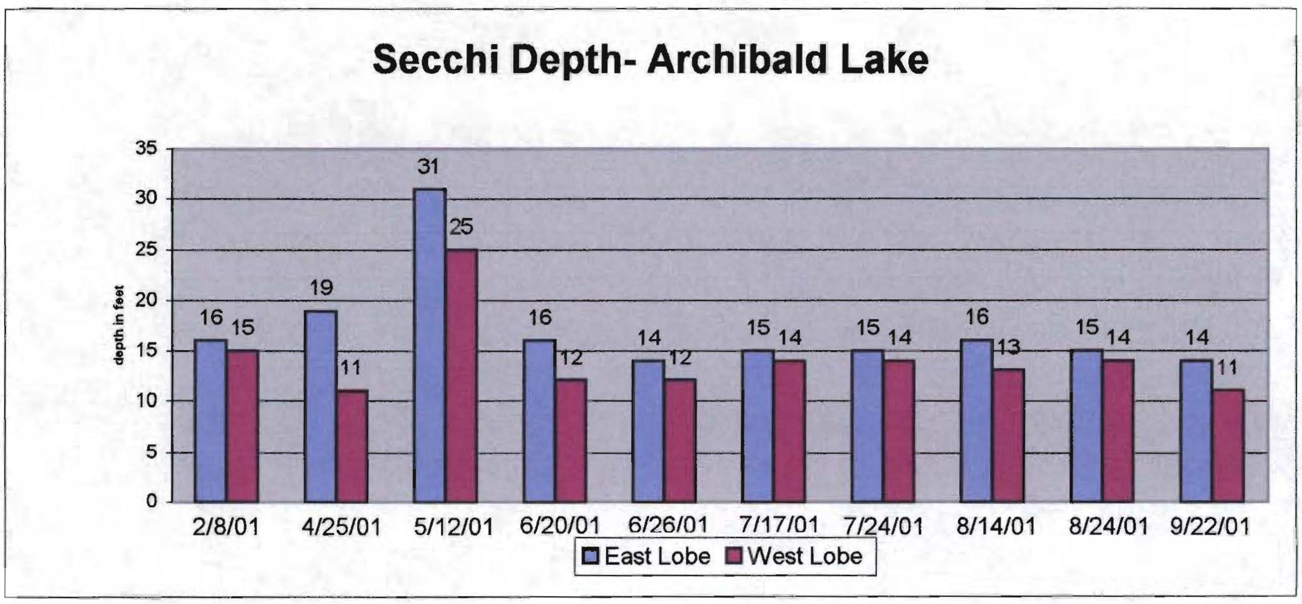


j:scopes\00a017\81401profile.xlsEast Lobe Comparison

Secchi Depth

Sample Point	Date	Result	Units	Sample Point	Date	Results	Units
East Lobe	2/8/2001	16	feet	West Lobe	2/8/2001	15	feet
East Lobe	4/25/2001	19	feet	West Lobe	4/25/2001	11	feet
East Lobe	5/12/2001	31	feet	West Lobe	5/12/2001	25	feet
East Lobe	6/20/2001	16	feet	West Lobe	6/20/2001	12	feet
East Lobe	6/26/2001	14	feet	West Lobe	6/26/2001	12	feet
East Lobe	7/17/2001	15	feet	West Lobe	7/17/2001	14	feet
East Lobe	7/24/2001	15	feet	West Lobe	7/24/2001	14	feet
East Lobe	8/14/2001	16	feet	West Lobe	8/14/2001	13	feet
East Lobe	8/24/2001	15	feet	West Lobe	8/24/2001	14	feet
East Lobe	9/22/2001	14	feet	West Lobe	9/22/2001	11	feet
	Total	171			Total	141	
	Average	17.1	feet		Average	14.1	feet
	0.3048	meters = 1 Foot					
	Average	5.2121	meters		Average	4.2977	Meters
Total Growing Season		105	feet	Total Growing Season		90	feet
Average Growing Season		15	feet	Average Growing Season		12.8571	feet
Average in meters		4.572		Average in meters		3.9189	meters

These calculations include readings from the self-help monitoring program
Growing Season is considered during summer months



Prepared By: SDJ
Checkedd By: DJL

Chlorophyl A

Sample Point	Date	Result	Units	Sample Point	Date	Results	Units
East Lobe	2/8/2001	1	ug/l	West Lobe	2/8/2001	1	ug/l
East Lobe	4/25/2001	1.2	ug/l	West Lobe	4/25/2001	2.5	ug/l
East Lobe	5/12/2001		ug/l	West Lobe	6/20/2001	6	ug/l
East Lobe	6/20/2001	3	ug/l	West Lobe	7/17/2001	2.1	ug/l
East Lobe	6/26/2001	1	ug/l	West Lobe	8/14/2001	2	ug/l
East Lobe	7/17/2001	2.1	ug/l				
East Lobe	7/24/2001	2.1	ug/l				
East Lobe	8/14/2001	2	ug/l				
East Lobe	8/24/2001		ug/l				
East Lobe	9/22/2001	2.6	ug/l				
	Total	15			Total	13.6	
	Average	1.875	ug/l		Average	2.72	ug/l
Total Growing Season		10.2		Total Growing Season		10.1	
Average Growing Season		2.04	ug/l	Average Growing Season		3.366667	ug/l

These calculations include readings from the self-help monitoring program
Growing Season is considered during summer months

Prepared By: SDJ
Checked By: DJL

Phosphorus

Sample Point	Date	Result	Units	Sample Point	Date	Results	Units
East Lobe	2/8/2001	9	ug/l	West Lobe	2/8/2001	10	ug/l
East Lobe	4/25/2001	7	ug/l	West Lobe	4/25/2001	12	ug/l
East Lobe	5/12/2001		ug/l	West Lobe	5/12/2001		ug/l
East Lobe	6/20/2001	10	ug/l	West Lobe	6/20/2001	13	ug/l
East Lobe	6/26/2001	50	ug/l	West Lobe	6/26/2001		ug/l
East Lobe	7/17/2001	12	ug/l	West Lobe	7/17/2001	19	ug/l
East Lobe	7/24/2001	11	ug/l	West Lobe	7/24/2001		ug/l
East Lobe	8/14/2001	10	ug/l	West Lobe	8/14/2001	13	ug/l
East Lobe	8/24/2001	12	ug/l	West Lobe	8/24/2001		ug/l
East Lobe	9/22/2001	10	ug/l	West Lobe	9/22/2001		ug/l
	Total	131			Total	67	
	Average	14.55556			Average	13.4	
Total Growing Season		115		Total Growing Season		45	
Average Growing Season		16.42857		Average Growing Season		15	

These calculations include readings from the self-help monitoring program
Growing Season is considered during summer months

Prepared By: SDJ
Checked By: DJL

Archibald Lake - Water Hardness Calculation
February 2001

		Concentrations mg/L		Hardness Equivalent mg/L $CaCO_3$	
Cation	Factor	West	East	West	East
Ca	2.497	28	26	69.916	64.922
Mg	4.116	11	11	45.276	45.276
Fe	1.792	0.05	0	0.0896	0
Mn	1.822	0.12	0.021	0.21864	0.038262
Hardness as $CaCO_3$				116	110

Appendix C

Waterfowl Counts and Impact Calculations

ARCHIBALD LAKE - OCONTO COUNTY

IMPACT OF GOOSE DEFECATION ON ARCHIBALD LAKE

A. 26,420 Goose-days/year

Based on counts from Bob Yakel

B. Assume that goose population uses both lake basins equally

17,614 Goose-days/year on Archibald Lake

C. Goose defecation

From 1994 paper by Manny et. al.
32.76 gr/day dry weight fecal matter
2560 gr/wild goose (5.6 lbs/bird)
1.28% fecal matter per body weight
The fecal matter is composed of by weight as follows:
76.00% carbon
4.80% nitrogen
1.50% phosphorus

Note this same paper cites other studies that found 2% to 4% fecal matter per body weight.

D. Convert values to Giant Canada Geese

13 lbs average giant Canada goose
1.28% fecal matter per body weight
0.166 lbs fecal matter per goose per day

E. Annual Totals of Goose Fecal Matter in Main Pond

2930 lbs fecal matter per year
1 tons dry fecal matter per year

2227 lbs carbon per year
141 lbs nitrogen per year
44 lbs phosphorus per year

F. Add Impact from Ducks
The lake is use by ducks is approximately equal in numbers to geese
Ducks weigh about 1/3 of a goose
Assume that defecation amount per body weight and concentrations are the same

4.3 lbs average duck
1.28% fecal matter per body weight
0.055 lbs fecal matter per duck per day

977 lbs fecal matter per year
0 tons dry fecal matter per year

742 lbs carbon per year
47 lbs nitrogen per year
15 lbs phosphorus per year

Total All Waterfowl

3907 lbs fecal matter per year
2 tons dry fecal matter per year

2969 lbs carbon per year
188 lbs nitrogen per year
59 lbs phosphorus per year

G. Convert to BOD

Laboratory testing done on fecal matter at Green Bay's Bay Beach Wildlife Sanctuary showed
0.145 lbs BOD per lb dry fecal matter

567 lbs BOD per year.

H. Oxygen Demand

DO for BOD removal =	1.8	lbs/lb BOD
DO for ammonia removal =	4.6	lbs/lb nitrogen
DO for BOD removal =	1020	lbs/yr
DO for ammonia removal =	863	lbs/yr
Total =	1882	lbs/yr

Maximum month = October with 23.70% of annual demand

Total for maximum month =	446.133	lbs/month
=	14.3914	lbs/day oxygen