LPL-1028-05

An Evaluation of Water Quality in Wilson Lake, Waushara County, Wisconsin

Prepared for:

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Introduction

Wilson Lake is located in the forested hills near the town of Wild Rose in Waushara County (**Figures 1 and 2**). It is an 81-acre seepage lake comprised of two basins. The west basin has a maximum depth of 16 feet and an average depth of 6 feet. The east basin has a maximum depth of 5 feet and an average depth of 3 feet. There is a small outlet creek on the north end of the lake, which eventually drains into the Pine River. Wilson Lake supports a fishery of northern pike, largemouth bass, walleye and panfish (WDNR, 2005).

Wilson Lake is heavily developed with summer cottages and permanent residences. The Kusel, Wilson, Round Lakes Protection and Rehabilitation District governs Wilson Lake and represents the interests of property owners and other lake users.

Recent Management

A lake aeration system has been operating in Wilson Lake since 1988. It was originally installed to prevent winter fish kills and to accelerate the decomposition of organic sediments.

Since 1999, the primary management concern for residents of Wilson Lake has been the control of exotic plant species, namely Eurasian watermilfoil (*Myriophyllum spicatum*) and curly leaf pondweed (*Potamogeton crispus*). Both quickly reached nuisance levels in the lake significantly reducing aesthetic values, recreational uses, and ecological health. The report entitled *Management of aquatic plants in Wilson Lake 2001-2006* outlined a course of action for controlling Eurasian watermilfoil in Wilson Lake. The management plan recommended aggressively treating Eurasian watermilfoil throughout the lake. Later as curly-leaf pondweed became more problematic, it too was targeted by treatments. Following a number of herbicide treatments, both milfoil and curly-leaf pondweed levels were drastically reduced to sub-nuisance levels. **Table 1** presents the history of herbicide treatments in the past six years.

Figure 1. Wilson Lake and the surrounding area, Waushara County, Wisconsin.

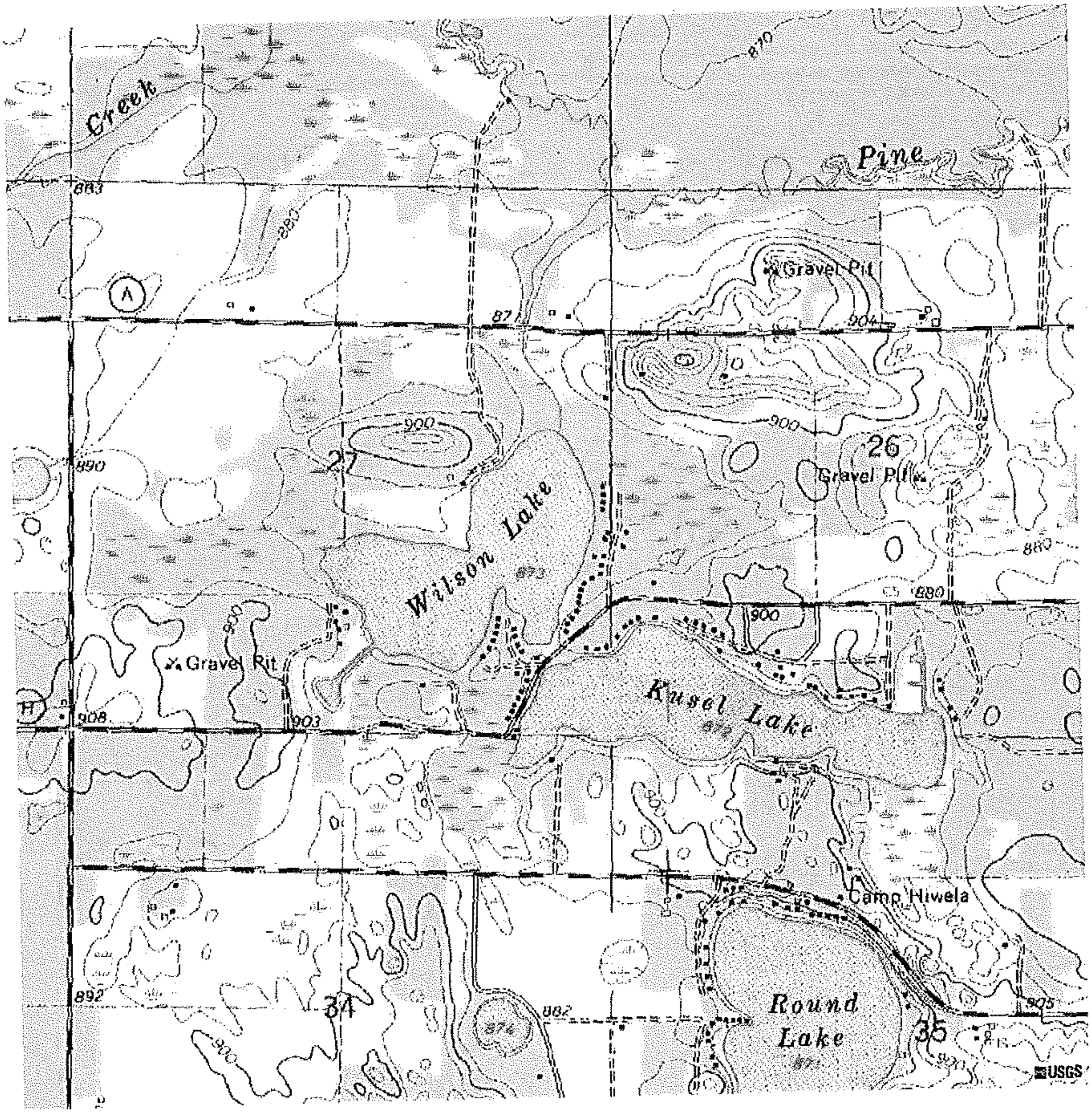


Figure 2. Wilson Lake, Waushara County Wisconsin

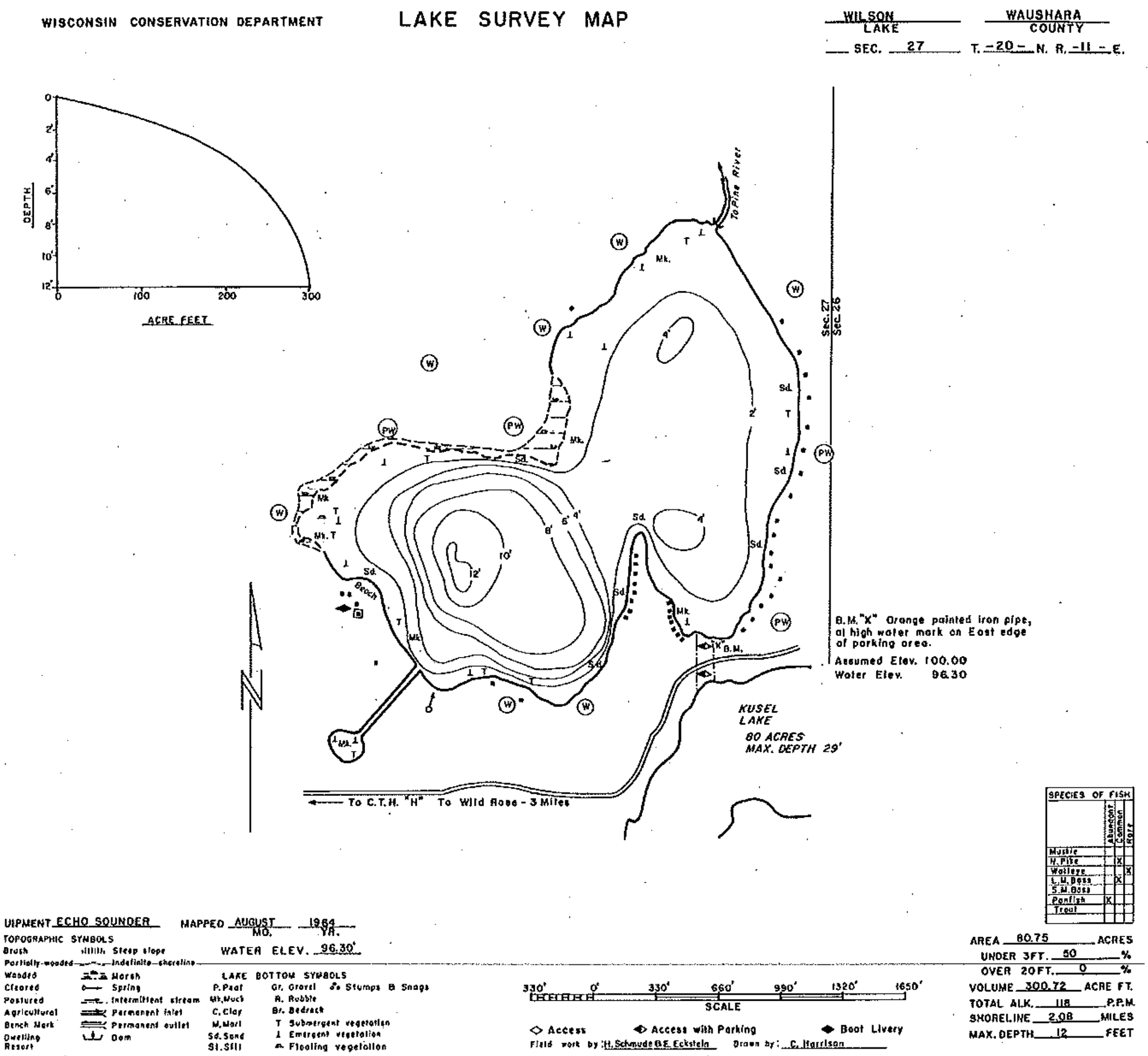


Table 1. Herbicide treatments conducted on Wilson Lake, Waushara County

Date	Acreage	Target Species	Product*	Amount
6/2000	7.75	Eurasian watermilfoil	Navigate®	775 lbs
7/2001	10.2	Eurasian watermilfoil	Navigate®	1020 lbs
7/2002	9.3	Eurasian watermilfoil	Navigate®	950 lbs
7/2003	16.8	Curly-leaf pondweed	Aquathol K®	100 gal
5/2004	16.8	Curly-leaf pondweed	Aquathol K®	100 gal
5/2005	16.8	Curly-leaf pondweed	Aquathol K®	100 gal

* Navigate® is granular 2,4-D, Aquathol K® is liquid dipotassium salt of endothall

Within the past few years, Wilson Lake has experienced heavy planktonic algae blooms and high levels of turbidity. This was previously attributed indirectly to high concentrations of exotic plant species cycling large amounts of nutrient from the bottom sediments. However, after Eurasian watermilfoil and curly leaf pondweed had all but been eliminated from Wilson Lake, heavy algae blooms continued.

Further investigation into the sources of nutrients and causes of impairment to the water quality of Wilson Lake was needed. Specific elements for monitoring in this study included water chemistry sampling in both basins of the lake, analysis of groundwater, and stream flow rates with associated nutrient inputs, and a thorough watershed assessment.

Methods

Water Quality

Seasonal water chemistry and limnology analyses were conducted six times in 2005-2006: April (spring turnover), June, July, August, November (fall turnover) and January (mid-winter). Seasonal analyses included:

- Total phosphorus
- Nitrate + nitrite as N
- Chlorophyll *a*
- pH
- Dissolved oxygen profile
- Temperature profile
- Secchi depth

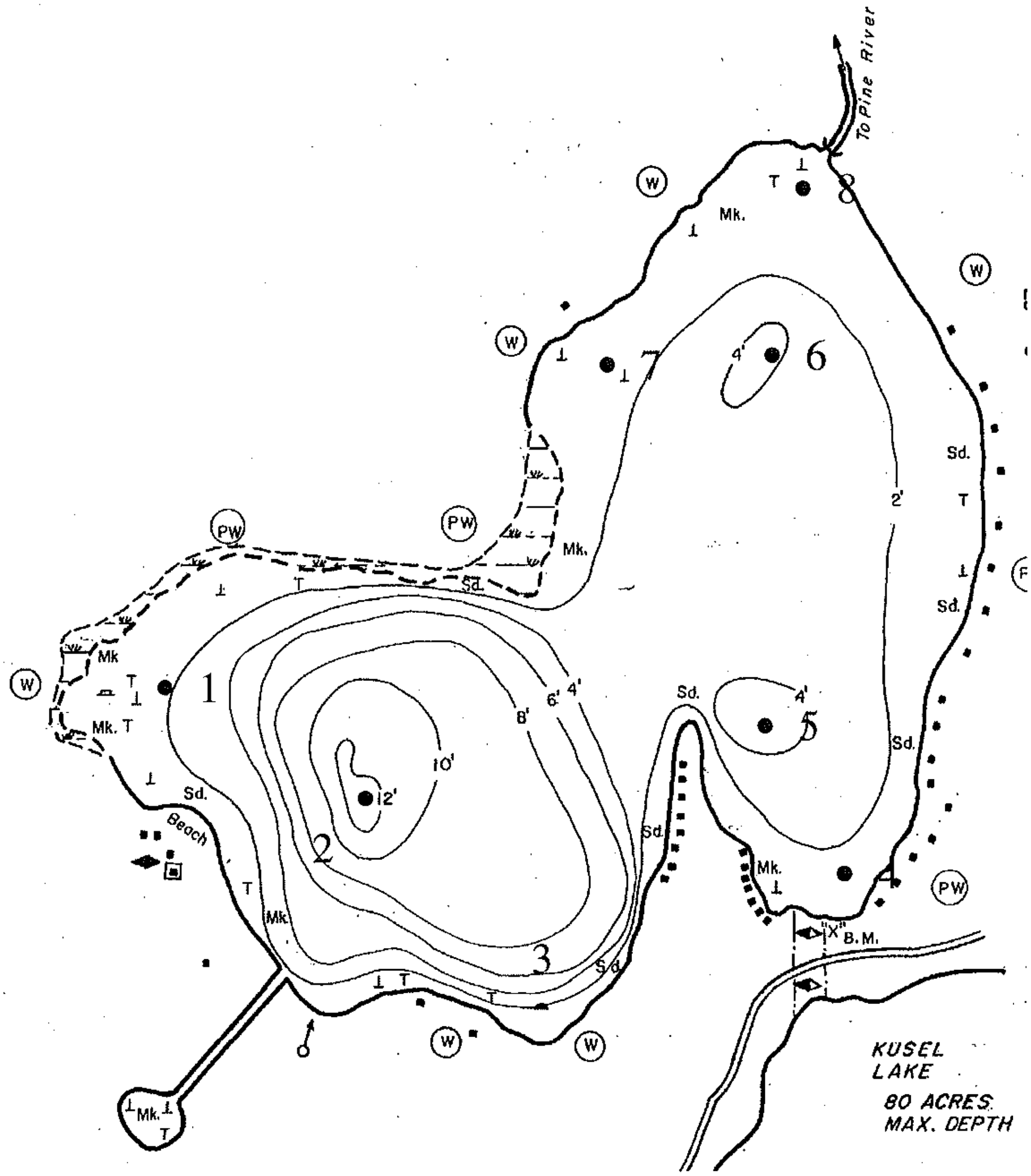
Numerous locations were sampled on each of the seasonal sampling dates (**Figure 3**). These included composite samples in each of the basins, plus two groundwater samples and one outlet sample. Each composite sample was taken by collecting water from one foot below the surface at numerous locations throughout a basin. These samples were then combined to form one composite sample, which was thoroughly mixed and sent to the State Lab of Hygiene for analysis.

For all sampling dates, dissolved oxygen, temperature, pH and water clarity were analyzed in the field. These four parameters were separately monitored at numerous locations throughout the lake (**Figure 3**). Measurements of pH were made using a Hach Kit (titration method) in April 2005 and with a portable Hach HQ20 Dissolved Oxygen/pH meter for the remaining dates. Dissolved oxygen and temperature profile data were collected with a YSI 55 dissolved oxygen meter in April and with the Hach HQ20 meter for the remaining dates. Water clarity was measured using a standard 8-inch, black and white Secchi disc. Additional samples were collected and analyzed for nutrients and pH. These included one groundwater sample, one sample from the channel leading to the spring pond to the southwest and one outlet sample. Finally, the January sampling event focused only on dissolved oxygen, temperature, pH, and Secchi depth.

A more thorough or "complete" water chemistry and limnology analysis was conducted in August and included:

- pH
- Dissolved (ortho) phosphorus
- Total phosphorus
- Total Kjeldahl nitrogen
- Nitrate + nitrite as N
- Ammonia as N
- Chloride
- Chlorophyll *a*
- Suspended solids
- Total dissolved solids
- Conductivity
- Alkalinity
- Dissolved oxygen profile
- Temperature profile
- Secchi depth

Figure 3. Locations of seasonal water quality, assessment of temperature, dissolved oxygen, pH and Secchi depth on Wilson Lake, Waushara County Wisconsin.



Composite samples were again collected in the two lake basins. Complete water chemistry samples were taken one foot below the surface and one foot above the lakebed at the deepest point of the lake for all analyses except Chlorophyll *a,* which were collected at the surface only. Groundwater samples were analyzed for all nutrients, pH, conductivity and chloride only. Outlet samples were analyzed for all nutrients and pH only.

Basic water quality data collected in April and June 2002 and August 2004 were also reviewed and compared to the data collected in 2005

Hydrological and Nutrient Budgets

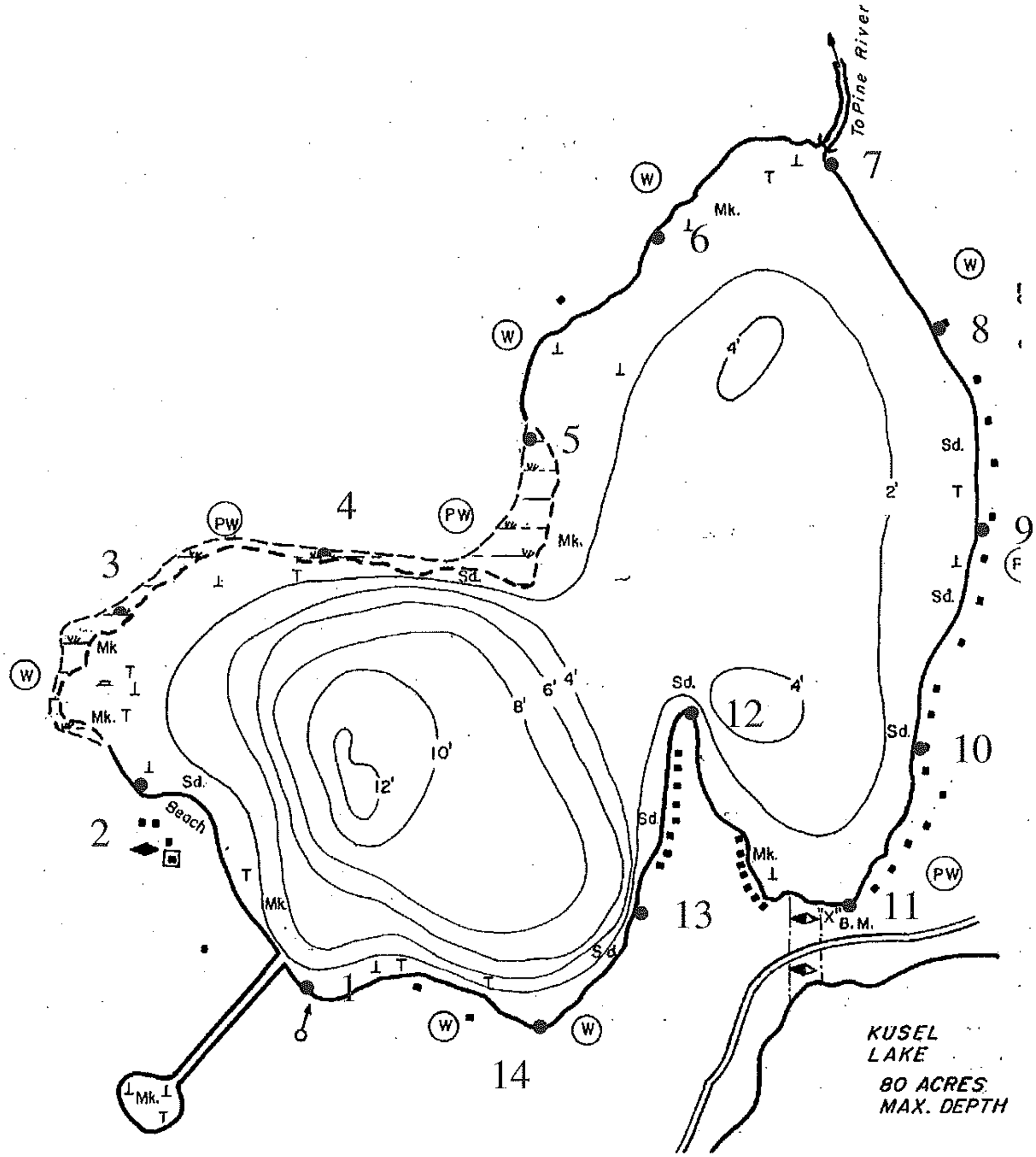
In order to develop a hydrological (water) budget for Wilson Lake, inflow and outflow sources of water were identified and quantified. During each of the six water-sampling periods, water flow rates were calculated with a flow meter at the head of the outlet creek. Also estimates of precipitation, evaporation, and groundwater contributions were estimated. Data collected was used to develop a seasonal picture of the lake hydrology and its relationship to water quality. Similarly, phosphorus data collected throughout the lake were used in conjunction with the hydrological data collected to estimate internal and external loads for each nutrient.

In April, 14 groundwater-monitoring devices called mini-piezometers were placed around the shoreline of Wilson Lake (**Figure 4**). The mini-piezometers were used to determine the relative strength and direction of groundwater. Findings were used to map patterns of groundwater flow around the lake. Data were used to correlate water movement in and around Wilson Lake with the associated movement of nutrients.

Watershed Analysis

During the watershed survey, the boundary of Wilson Lake's watershed was delineated and its physical characteristics were examined using topographic maps, and field observations. Land use patterns and vegetative cover, surface runoff patterns, and potential nutrient loading sources (point and non-point) were further assessed by ground surveys. The potential impacts of these features were presented and discussed. A possible correlation between nutrient loading and water flow patterns (surface and ground) were investigated.

Figure 4. Locations of mini-piezometers for groundwater analysis on Wilson Lake, Waushara County Wisconsin.



Results and Discussion

Water Quality Analysis

Dissolved Oxygen and Temperature

Dissolved oxygen and temperature data collected for Wilson Lake is included in **Appendix A**. Because most of the eight sampling locations were relatively shallow, the dissolved oxygen concentrations and temperature did not vary significantly with depth. As a result, profile graphs for these sites are unnecessary. Instead, data for Site 2, located at the deepest point of the lake, were used to develop profile graphs for both oxygen and temperature for August 24, 2005 (**Figure 5**). These data were chosen because, by August, water temperatures were at their warmest and oxygen levels were found to be at their lowest.

The dissolved oxygen data and profiles for Wilson Lake show that the aeration system continues to provide adequate oxygen throughout the lake. Surface levels of dissolved oxygen remained high throughout the season. **Figure 5** shows that even at the warmest times of the year (August 2005), oxygen is still present at the deepest part of the lake. The threshold level of oxygen needed for many fish species to survive and grow is approximately 5 mg/L. The abundance of oxygen throughout the lake is somewhat uncommon, but attributable to the aeration system. During the summer months, oxygen levels dropped off at a depth of approximately 12 feet but still remained above 5 mg/L. In many lakes, a greater decrease in oxygen is seen. These oxygen conditions are referred to as lake stratification. Although it is common in Wisconsin for lakes to become stratified, Wilson Lake is an exception. Because the aeration system physically circulates the lake water on a continuous basis, stratification as well as spring and fall turnover is not seen. A review of the data in **Appendix A** shows that occasionally the dissolved oxygen content fell below 5 mg/L. In particular, the January 2006 data contain concentrations below this point. However, these concentrations were measured deep in the lake and it is believed that these readings were in fact recorded within the sediment layer in the lake.

Some anomalies in the data exist though. To better understand these anomalies, it is important to first understand the relationship between dissolved oxygen and temperature. As a rule, colder water can hold more oxygen than warmer water. **Table 2** illustrates this point.

Figure 5. Dissolved oxygen and temperature profile graphs for August 2005, Wilson Lake, Waushara County, Wisconsin.

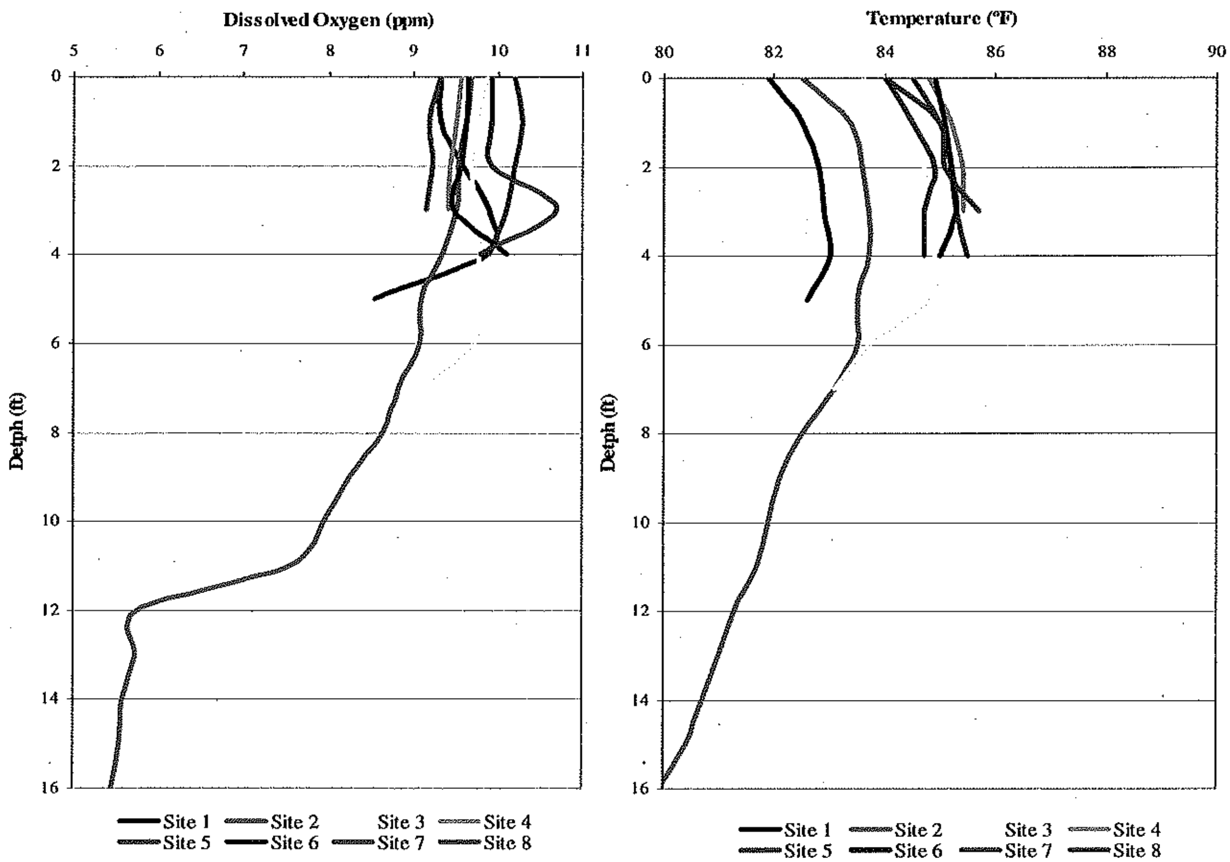


Table 2. Oxygen solubility in water at different temperatures.

Temperature °C	°F	Oxygen solubility (mg/L)
0	32	15
5	41	13
10	50	11
15	59	10
20	68	9
25	77	8

By utilizing this relationship the percent saturation of oxygen can be calculated at a given temperature. Data for percent saturation can also be found in **Appendix A**. A number of the readings taken throughout the year did not follow the solubility rules for oxygen and temperature. For these data the dissolved oxygen levels were higher than solubility levels at the corresponding temperatures and the percent saturation levels were above 100%. This is a condition referred to as supersaturation and is due to conditions in the lakes which produce elevated levels of oxygen.

The first and most obvious source of oxygen to the lake is the aeration system. This system provides a continuous supply of diffused air and exposes large quantities of water to the atmosphere where additional diffusion occurs. In addition, in lakes with high levels of algae, large amounts of oxygen can be produced through photosynthesis. Under warm sunny conditions in particular, oxygen levels in the lake can rise above the levels of solubility shown in **Table 2.** During the night when photosynthesis ceases and respiration takes over, oxygen levels can drop off significantly. Through respiration, oxygen is consumed leaving depleted levels in the lake. These wide fluctuations can be particularly stressful to many fish and invertebrate species. The daily fluctuations in oxygen levels in Wilson Lake are likely minimal because of the constant mixing and exposure to air provided by the aeration system.

Percent saturation values of 80-120% are considered to be excellent and values less than 60% or over 125% are considered to be poor. Data collected on June 21, and August 3, indicate high percent saturation levels. On June 21, many of the readings were above 150% saturation. This level of oxygen during the summer months may be having a negative impact on the quality of the water.

Temperature profiles in Wilson Lake show little change with depth, which is not surprising given the physical effects of the aeration system and the large portions of shallow water. During the warmest time of the year, water temperatures were between 80 and 86° F throughout the lake.

Seasonal trends in a number of water quality parameters for the period of April 2005 to January 2006 are shown in **Table 3**. Basic water quality data collected in April and June 2002 and August 2004 are presented in **Table 4.**

Table 3. Water quality data collect for Wilson Lake, April 2005-January 2006.

April 22, 2005	pH	Nitrogen (mg/l)	Phosphorus (mg/l)	Chlorophyll (µg/l)	Secchi (m)
Spring Pond	8.5	0.105	nd	--	--
West Basin	8.5	0.040	0.024	5.34	2.83
East Basin	8.5	0.029	0.015	4.43	na
Outlet	8.5	0.028	0.013	--	--
Groundwater	8.5	nd	0.185	--	--

June 21, 2005	pH	Nitrogen (mg/l)	Phosphorus (mg/l)	Chlorophyll (µg/l)	Secchi (m)
Spring Pond	8.74	nd	0.014	--	--
West Basin	8.97	nd	0.017	8.56	1.68
East Basin	8.80	nd	0.019	7.9	na
Outlet	8.94	nd	0.015	--	--
Groundwater	8.82	nd	0.187	--	--

August 3, 2005	pH	Nitrogen (mg/l)	Phosphorus (mg/l)	Chlorophyll (µg/l)	Secchi (m)
Spring Pond	8.78	0.059	0.016	--	--
West Basin	8.87	nd	0.033	8.9	1.17
East Basin	8.83	nd	0.034	12.8	0.97
Outlet	8.76	nd	0.050	--	--
Groundwater	7.71	0.137	0.121	--	--

August 24, 2005	pH	Nitrogen (mg/l)	Phosphorus (mg/l)	Chlorophyll (µg/l)	Secchi (m)
Spring Pond	7.90	0.060	0.010	--	--
West Basin	8.43	nd	0.042	na	0.98
East Basin	8.67	nd	0.033	na	1.07
Outlet	8.60	nd	0.029	--	--
Groundwater	na	nd	0.178	--	--

November 8, 2005	pH	Nitrogen (mg/l)	Phosphorus (mg/l)	Chlorophyll (µg/l)	Secchi (m)
Spring Pond	na	0.123	0.017	--	--
West Basin	8.61	nd	0.036	8.69	2.29
East Basin	8.81	nd	0.030	6.79	na
Outlet	na	nd	0.035	--	--
Groundwater	na	0.025	0.125	--	--

Table 3 cont.. Water quality data collect for Wilson Lake, April 2005-January 2006.

	Parameter				
January 13, 2006	pH	Nitrogen (mg/l)	Phosphorus (mg/l)	Chlorophyll (µg/l)	Secchi (m)
Spring Pond	--	--	--	--	--
West Basin	7.56	--	--	--	2.41
East Basin	7.84	--	--	--	na
Outlet	--	--	--	--	--
Groundwater	--	--	--	--	--

na = not available
nd = not detected; below detection limits
"--" = analysis not performed

Table 4. Water quality data collect for Wilson Lake, 2002 and 2004.

	Parameter				
April 15, 2002	pH	Nitrogen (mg/l)	Phosphorus (mg/l)	Chlorophyll (µg/l)	Secchi (m)
West Basin - surface	8.4	0.060	0.010	<1	4.27
West Basin - bottom	--	0.075	0.021	--	--
June 7, 2002					
West Basin	8.4	--	--	--	2.44
August 4, 2004					
West Basin	8.5	--	0.027	14.7	1.01

"--" = analysis not performed

pH

pH is a measure of a lake's acid level. It is the negative log of the hydrogen ion concentration in the water. Many factors influence pH including geology, productivity, pollution, etc. pH levels between 7.5 and 8.5 are common in lakes of central Wisconsin. Increased photosynthetic activity can increase pH. With a few exceptions, pH data for Wilson Lake fell between 7.5 and 9.0. This may be an indication of slightly elevated levels of productivity.

Nitrogen

Much of the samples tested for nitrogen (as nitrates and nitrites) were undetectable. Generally speaking when nitrogen was detected, it was from the samples collected from the spring pond adjacent to the west basin and from the groundwater sample collected from the east basin. Concentrations were consistently less than 0.15 mg/L from these sources. Water naturally contains less than 1 mg/L of nitrogen. Levels of as low as 0.3 mg/L are sufficient to support high levels of algae production.

Phosphorus
Total phosphorus is one of the most important water quality indicators. Phosphorus levels determine the amount of plant and algae growth in a lake. Phosphorus can come from external sources within the watershed (fertilizers, livestock) or to a lesser extent, from groundwater (septic systems). Phosphorus can also come from within the lake. Internal loading occurs when plants and chemical reactions release phosphorus from the lake sediments into the water column.

Phosphorus data in Wilson Lake followed similar trends as the nitrogen data. The average phosphorus concentration for natural lakes in Wisconsin is 0.025 mg/L. Values over 0.05 mg/l are indicative of poor water quality. Phosphorus concentrations throughout Wilson Lake with the exception of the groundwater samples were consistently below 0.05 mg/L in 2005. Groundwater samples ranged between 0.1 and 0.2 mg/L.

Secchi Transparency
Water clarity is often used as a quick and easy test for a lake's overall water quality, especially in relation to the amount of algae present. Because of the shallowness of the east basin of Wilson Lake, accurate transparency readings were not possible most of the year. On almost every occasion the Secchi disc could be seen sitting on the lake bottom is this portion of the lake. As the season progressed, the water clarity in the west basin of Wilson Lake decreased. This is common for lakes in Wisconsin and is often due to high levels of algae and other particulate matter in the water column. As expected the lowest transparency readings were collected in August.

Chlorophyll *a*
Chlorophyll is the pigment found in all green plants including algae that give them their green color. It is the site in plants where photosynthesis occurs. Chlorophyll absorbs sunlight to convert carbon dioxide and water to oxygen and sugars. Chlorophyll data is collected because this green pigment is found in algae and can be used to estimate how much phytoplankton (algae) there is in the lake. Generally speaking, the more nutrients there are in the water and the warmer the water, the higher the production of algae and consequently chlorophyll.

Chlorophyll concentrations below 10 μg/l are most desirable for lakes. The only sample that had chlorophyll concentrations above this level was collected from the east basin on August 3, 2005. The August 2004 sample also had a concentration of chlorophyll above 10 μg/l.

Trophic State
There is a strong relationship between levels of phosphorus and chlorophyll *a* and water clarity in lakes. As a response to rising levels of phosphorus, chlorophyll *a* levels increase and transparency values often decrease.

Lakes can be categorized by their productivity or trophic state. When productivity is discussed, it is normally a reflection of the amount of plant and animal biomass a lake produces or has the potential to produce. The most significant and often detrimental result is elevated levels of algae and nuisance aquatic plants. Lakes can be categorized into three trophic levels:

- oligotrophic - low productivity, high water quality
- mesotrophic - medium productivity and water quality
- eutrophic - high productivity, low water quality

These trophic levels form a spectrum of water quality conditions. Oligotrophic lakes are typically deep and clear with exposed rock bottoms and limited plant growth. Eutrophic lakes are often shallow and marsh-like, typically having heavy layers of organic silt and abundant plant growth. Mesotrophic lakes are typically deeper than eutrophic lakes with significant plant growth, and areas of exposed sand, gravel or cobble bottom substrates.

Lakes can naturally become more eutrophic with time, however the trophic state of a lake is more influenced by nutrient inputs than by time. When humans negatively influence the trophic state of a lake the process is called *cultural eutrophication.* A sudden influx of available nutrients may cause a rapid change in a lake's ecology. Opportunistic plants such as algae and nuisance plant species are able to out-compete other more desirable species of macrophytes. The resultant appearance is typical of poor water quality.

Total phosphorus, chlorophyll *a* and Secchi depth are often used as indicators of the water quality and productivity (trophic state) in lakes. Values measured for these parameters can be used to calculate Trophic State Index (TSI) values (Carlson 1977). The formulas for calculating the TSI values for Secchi disk, chlorophyll *a*, and total phosphorus are as follows:

$$\text{TSI} = 60 - 14.41 \ln \text{Secchi disk (meters)}$$

$$\text{TSI} = 9.81 \ln \text{Chlorophyll } a\ (\mu\text{g/L}) + 30.6$$

$$\text{TSI} = 14.42 \ln \text{Total phosphorus } (\mu\text{g/L}) + 4.15$$

The higher the TSI calculated for a lake, the more eutrophic it is (**Figure 6**). Eutrophic lakes have TSI values starting around 50 to 55. Values calculated from the Wilson Lake water quality data for 2005 reached above 50 during the summer months (**Tables 5 and 6**). As expected levels were lower during the rest of the year when cold weather and shorted day lengths cause chlorophyll concentrations to drop and clarity to increase. TSI values calculated for the non-summer months were generally in the mid to upper 40's.

Water quality measurements taken in August 2004 and 2005 placed Wilson Lake at the lower boundaries of classic eutrophy. Wilson Lake has many other characteristics of a eutrophic lake: shallowness, dense aquatic plant growth and heavy accumulation of organic sediments.

Figure 6. Relationship between trophic state in lakes and parameters including Secchi transparency, chlorophyll *a*, and total phosphorus.

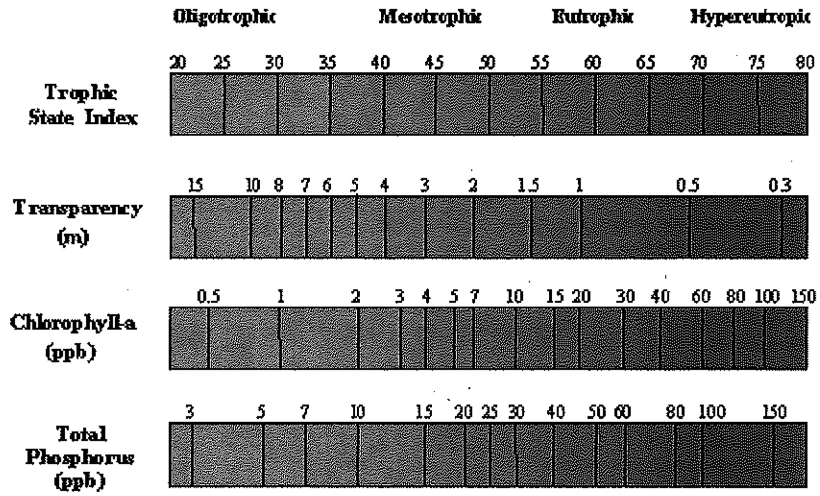


Table 5. 2005 Trophic State Index values calculated for Wilson Lake, Waushara County, Wisconsin

	Parameter			
April 22, 2005	*Phosphorus TSI*	*Chlorophyll TSI*	*Secchi TSI*	*Average TSI*
West Basin	*49.98*	*47.03*	*44.99*	*47.33*
East Basin	*43.20*	*45.20*	--	*44.20*
June 21, 2005				
West Basin	*45.00*	*51.66*	*52.56*	*49.74*
East Basin	*46.61*	*50.88*	--	*48.74*
August 3, 2005				
West Basin	*54.57*	*52.05*	*57.69*	*54.77*
East Basin	*55.00*	*55.61*	*60.47*	*57.03*
August 23, 2005				
West Basin	*58.05*	--	*60.36*	*59.20*
East Basin	*54.57*	--	*59.07*	*56.82*
November 8, 2005				
West Basin	*55.82*	*51.81*	*48.09*	*51.91*
East Basin	*53.20*	*49.39*	--	*51.29*
January 13, 2006				
West Basin	--	--	*47.34*	*47.34*
East Basin	--	--	--	--

Table 6. 2002 and 2004 Trophic State Index values calculated for Wilson Lake, Waushara County, Wisconsin

	Parameter			
April 15, 2002	*Phosphorus TSI*	*Chlorophyll TSI*	*Secchi TSI*	*Average TSI*
West Basin	*37.35*	--	*39.08*	*38.22*
June 7, 2002				
West Basin	--	--	*47.15*	*47.15*
August 4, 2004				
West Basin	*51.68*	*56.97*	*59.86*	*56.17*

Table 7 presents the results of the water quality analysis conducted in August of 2005.

Table 7. August 2005 water chemistry results for Wilson Lake, Waushara County, Wisconsin.

Parameter	Units	Spring Pond	West Basin - surface	West Basin - bottom	East Basin - surface	Ground-water	Outlet
pH	SU	7.9	8.43	8.6	8.67	8.03	8.6
Alkalinity	mg/L	145	115	115	--	122	--
Chloride	mg/L	6.5	3.9	3.8	--	4.8	--
Conductivity	μMhos/cm	319	244	245	--	249	--
Suspended solids	mg/L	--	12	11	--	--	--
Total dissolved solids	mg/L	--	156	144	--	--	--
Total phosphorus	mg/L	0.01	0.042	0.047	0.033	0.178	0.029
Dissolved (ortho) phosphorus	mg/L	0.024	0.008	0.006	0.006	0.037	0.005
Total Kjeldahl nitrogen	mg/L	0.16	1.1	1.11	0.84	1.49	0.92
Nitrate + nitrite as N	mg/L	0.06	nd	nd	nd	nd	nd
Ammonia as N	mg/L	0.033	nd	nd	nd	0.3	nd
Chlorophyll a	μg/L	--	na	--	na	--	--

na = not available (lab error in chlorophyll a sample analysis)

nd = not detected/ below detection limits

"--" = test not requested

Alkalinity

Alkalinity is a measure of the acid buffering capacity of a lake and is expressed in mg/L of calcium carbonate. A higher alkalinity value means a higher buffering capacity for a given a lake. Alkalinity values above 25 mg/L are indicative of an aquatic system with a very high buffering capacity. pH values above 8 and alkalinity levels well above 25 mg/L in Wilson Lake reflect not only an increase in productivity but are also indicative of a hard water system able to withstand acidic rain conditions.

Chloride

Chloride is not commonly a concern for lakes in Wisconsin. Naturally occurring concentrations of chloride, in central Wisconsin, range from approximately 3-10 mg/L. Wilson Lake levels in August were well within this range.

Conductivity

Conductivity is the measure of the ions in a body of water by determining how well an electrical current is carried through the water sample. This has a direct correlation to the amount of salts in the water. The recommended value for conductivity in lake samples is below 300 μMhos/cm. Values in Wilson Lake with the exception of the spring pond were below this level.

Nutrients

Concentrations of phosphorus and nitrogen were measured in August 2005 at the surface and bottom of Wilson Lake's west basin. Relatively low levels of nitrogen and phosphorus were found in these samples. The results of these tests also show that the concentrations of nutrients were very similar between the upper and lower samples. Nutrients such as ammonia or dissolved phosphorus are often found in higher concentrations deeper in a lake. For example, ammonia, which is produced under anaerobic conditions, was only found in the groundwater and spring pond samples. The consistency seen in the concentrations of nutrients in Wilson Lake are a direct result of the aeration system. This system has served to reduce lakebed sediments as a source of nutrient loading. Adequate oxygenation from the aeration system has prevented anoxic release of phosphorus and nitrogen from bottom sediments.

Solids

Total suspended solids (TSS) concentrations indicate the amount of solids suspended in the water, whether mineral (e.g., soil particles) or organic (e.g., algae, plankton). More productive lakes and those with soils susceptible to erosion tend to have higher concentrations of suspended solids. TSS concentrations below 5 mg/L are preferable for lakes. Values for Wilson Lake were between 11 and 12 mg/L for August. High concentrations of solids negatively affect light penetration and habitat quality. Particles also provide attachment places for other pollutants, notably metals and nutrients.

Boat traffic can cause an increase in suspended solids especially in shallow areas of lakes (Hill, 2004). Studies have shown that maximum increases in turbidity occurred between 2 and 24 hours following boating activities. The full effects of heavy boating depend upon a number of factors including propeller size, boat speed, draft, and sediment characteristics (Asplund, 1996). Silty sediments tend to have the highest susceptibility to resuspension and the highest potential for the reintroduction of nutrients into the water column. Studies have also focused on algae (chlorophyll a) concentrations but found no significant changes following boating activity. This is due primarily to an indeterminate time lag which occurs between the release of nutrients and the subsequent increase in algal growth. It has also been suggested that disturbances to the native plant communities due to watercraft use can accelerate the spread of opportunistic exotic plant species such as Eurasian watermilfoil and curly leaf pondweed (Asplund and Cook, 1997).

Wisconsin statutes require boaters to maintain no-wake speeds within 100 feet of shorelines, other boats, or fixed structures, including boat docks and swimming platforms. However, it is difficult to enforce such regulations and even slow boat traffic can have a negative impact on sediments and plant communities in shallow areas. In the case of the east basin of Wilson Lake, shallow waters extend well past this mandatory no-wake zone. It is evident that some damage due to watercrafts has occurred in Wilson

Lake. In particular disturbances from motor boats were noted in the shallow sandy areas of the lake. This not only has a negative impact to the lake but can also damage boats.

Pollution or general human activities usually result in higher TSS concentrations or turbidity. Previous studies have found that boat propellers can disturb lake sediments as deep as 10 feet. As this disturbance occurs, turbidity and nutrient concentrations in the water, specifically phosphorus, increase. These increases can then lead to further impairments to the lake. It is important to note that because water clarity can be affected by a number of contributing factors, it is difficult to directly attribute decreases in water quality to just one factor such as watercraft use.

Dissolved solids are a measure of dissolved organic compounds present in water. The most common source of dissolved solids is decomposing plant matter. Water having high concentrations of dissolved solids limits the depth at which photosynthesis can take place. Thus it is an important parameter that can affect lake ecosystems. The relatively high concentrations of dissolved solids found in Wilson Lake likely limit the aquatic plant community in deeper waters.

Hydrological and Nutrient Budgets

Table 8 presents the rates and volume of flow for the outlet creek on Wilson Lake.

Table 8. Hydrologic data for the outlet creek on Wilson Lake, Waushara County, Wisconsin.

Outlet Stream			
	ft^3/sec	gal/day	acre-ft/day
April 22, 2005	4.09	2,644,123	8.11
June 21, 2005	0.24	157,453	0.48
August 3, 2005	0.89	576,422	1.77
August 24, 2005	0.53	340,657	1.05
November 8, 2005	0.19	122,162	0.37
January 11, 2006	0.42	272,285	0.84

The average flow rate based on the above data is 1.33 acre-feet per day. With the current lake volume of nearly 400 acre-feet, the estimated residence time for Wilson Lake is 295 days.

The hydrologic budget for a lake can be viewed in terms of the following equation:

$$PPT + SW_i + DR + GW_i = EVAP + SW_o + GW_o$$

where:

PPT = precipitation
SW_i = surface water inflow
DR = direct runoff
GW_i = groundwater inflow
$EVAP$ = evaporation
SW_o = surface water inflow
GW_o = groundwater inflow

Table 9 presents the estimations for the above variables for the period from April 22, 2005 to January 11, 2006. Rainfall data available for Waushara County show that in 2005, the total rainfall was 5 inches below normal. Total precipitation for this period was estimated at 23.3 inches. Direct runoff was estimated at an average rate of 4 inches per year for the entire watershed. Pan evaporation rates were obtained from the Campus Climatological Observatory in Saint Paul, MN. The average annual evaporation from 2000-2205 was 35.1 inches. Groundwater rates were not measured directly; values are estimates of net flow in the system.

Because it is nearly impossible to account for all variables affecting the flow of water into and out of a lake, and because flow rates from the spring pond were below detectable levels, certain assumptions and estimations were made as follows:

1) Water flow from the outlet creek was estimated to occur for the entire 265 days of the study.
2) The dam at the outlet keeps the lake volume stable
3) Because there is no inlet creek, the net contribution of water via groundwater (including water from the spring pond) is equal to the amount of water leaving the system through the outlet creek.

Table 9. Water budget data for Wilson Lake, Waushara County.

Water Inputs	Volume (acre-feet)
precipitation	156.8
surface flow	0
direct runoff	303.9
groundwater, spring pond flow	126.4
Total	587.1

Water outputs	Volume (acre-feet)
evaporation	236.2
surface flow	350.9
groundwater*	--
Total	587.1

*groundwater rates were not measured, spring pond flow was too low to measure -- values are estimates of net flow in the system.

Mass balance modeling
By utilizing the hydrologic budget and the empirical data collected for phosphorus over the timeframe of this study, a mass balance model can be created. This model can be used to identify the sources and movement of nutrients throughout the Wilson Lake system. The external loading of runoff pollutants, namely phosphorus, into Wilson Lake can be approximated by utilizing general *export coefficients* for total phosphorus. Export coefficients are available for a number of land use types as kilograms of pollutant per hectare per year. Coefficients for total phosphorus are given in **Table 10.**

Table 10. General Export Coefficients for total phosphorus or the Eastern U.S.

Land Use	Export Coefficients* (kg/ha/yr)
	TP
Urban	1.0
Rural/Agriculture	0.5
Forest	0.05

*From Rast and Lee (1978).

Using the water budget estimates for the outlet creek and groundwater flow with the nutrient data found in **Table 3**, the following results were obtained for the period between April 22 and November 8, 2005:

Total input P load from precipitation: **3.0 lbs P**
Total input P load from direct runoff **79.9 lbs P**
Total input P load from groundwater: **54.6 lbs P**

Total output P load from outlet: **15.8 lbs P**

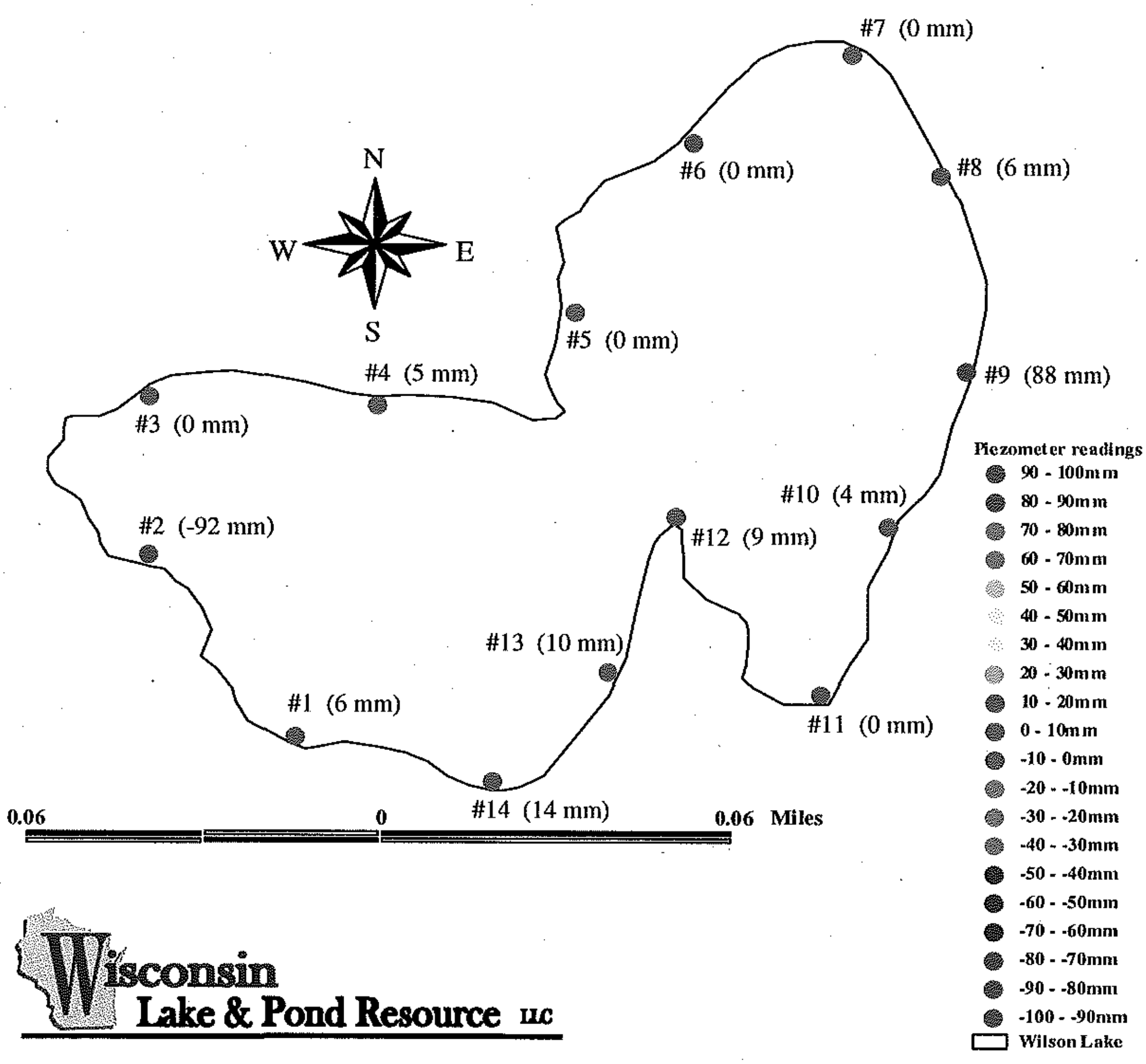
Contributions from precipitation were determined assuming 23.3 inches of rainfall with a total phosphorus concentration of 0.007 mg/L (Robertson and Rose, 2000). Phosphorus concentrations collected from the spring pond and groundwater samples were averaged to calculate groundwater contributions.

As is evident, phosphorus imports exceed exports. The data presented above show that Wilson Lake acts as a nutrient sink. Nutrients enter the lakes faster than they are removed. The data also show that the primary sources of phosphorus to Wilson Lake is direct runoff, and groundwater. In order to reverse this process, nutrients from these sources would have to be reduced significantly. In doing so, the model shows that the response would be a shift toward the removal of more phosphorus from the system at a rate higher than it is imported.

Another sources of phosphorus would include internal cycling (Holdren, 2001). Because the aeration system keeps the deepest portions of the lake from becoming anoxic, internal nutrient cycling is kept at a minimum. In addition, septic systems are known to contribute nutrients to a lake. Each home can contribute up to 2 lbs of phosphorus annually. As was previously discussed motorboat activity can suspend sediments and increase nutrient concentrations in the water column. It will be important to control major sources of nutrients before a significant improvement in the quality of Wilson Lake will be seen.

Figure 7 presents the results of groundwater flow monitoring in Wilson Lake. Positive piezometers readings indicate groundwater movement into the lake and negative readings indicate movement out of the lake. A majority of the sampling locations showed little or no movement of groundwater (±15 mm). Two readings are particularly important. Site 2 was the location of the most significant groundwater outflow (-92 mm) and Site 9 showed relatively high inflow (88 mm). As a result, Site 9 became the location of groundwater monitoring for the remainder of the study. These results indicate that at the time of monitoring, the groundwater was moving in a westerly direction. However, this movement appears localized and confined to specific portions of the lake.

Figure 7. 2005 groundwater flow intensity for Wilson Lake, Waushara County, WI



Watershed Analysis

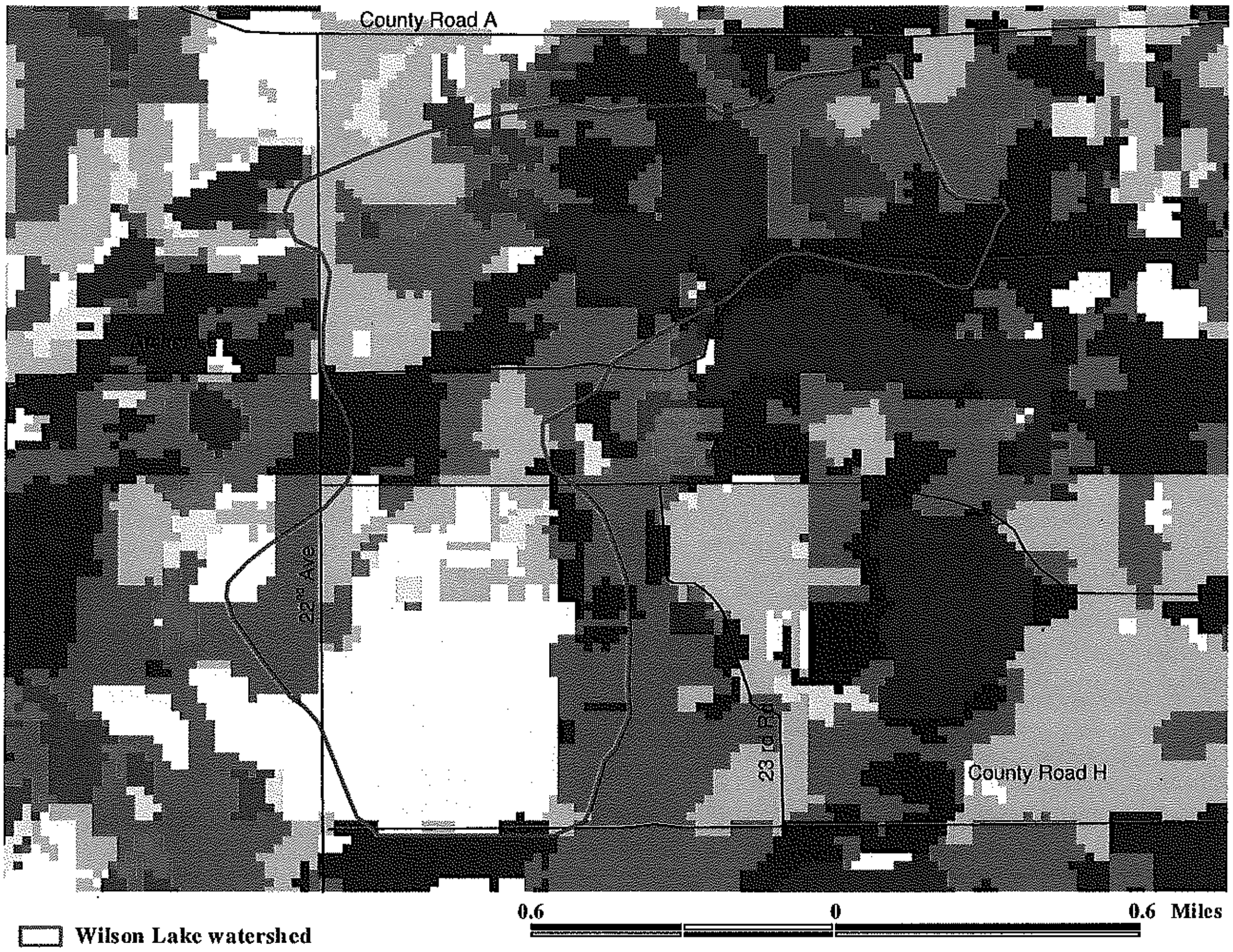
In June 2005, the watershed analysis was conducted. **Figure 8** shows the delineation of the Wilson Lake watershed and the land use types present. The steepest slopes in the watershed are found in areas closest to the lake. The east and south shores have the highest concentration of homes and septic systems. For this reason, it is those areas closest to the lakes which have the greatest influence on water quality.

The survey and resulting analysis found that the watershed of Wilson Lake is approximately 921 acres (1.44 mi^2) in size. It is dominated by forests (47.5%), agriculture (38.2%), and wetlands (14.2%). Much of the forested areas are pine plantations with scattered homes. The agricultural areas of the watershed are concentrated to the south and include crop fields such as corn and cucumbers.

A concern was raised regarding the farm fields located to the south of Highway A (east of 22^{nd} Avenue) near Wilson Lake. In the past sewage/manure had frequently been applied to these fields. Homeowners were concerned that runoff from these fields may be causing water quality impairments to Wilson Lake. Portions of these fields lie both within and outside the watershed for Wilson Lake. Those sections outside the watershed drain to the north towards the Pine River. Materials applied to the fields within the watershed have the potential to reach the lake and have negative impacts to water quality. Groundwater measurements taken along the northwest shore of Wilson Lake indicate little exchange of water in that area. As a result, nutrients that may seep into the ground from these fields do not appear to reach the lake.

The soils found in the Wilson Lake watershed are dominated sand (54.8%) and loamy sand (19.8%) soils (**Table 11**). The remaining watershed contains muck soils (11.5%) or water (8.1%). Sandy soils are well-drained soils with little water holding capacity. In addition, these soils are not ideal for farmland. Loamy sand soils have higher percentage of organic matter but are still primarily comprised of sand and generally do not make good farmland. Muck soils are highly organic, poorly drained (wet or *hydric*) soils and do not make good farmland unless drained.

Figure 8. Land use and watershed delineation for Wilson Lake, Waushara County, Wisconsin.



Wilson Lake watershed

Land use

AGRICULTURE

General Agriculture

Herbaceous/Field Crops

GRASSLAND

FOREST

Coniferous

Broad-leaved Deciduous

Mixed Deciduous/Conferous

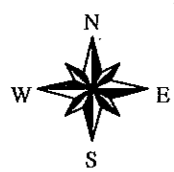
OPEN WATER

WETLAND

Emergent/Wet Meadow

Lowland Shrub

Forested



Wisconsin Lake & Pond Resource LLC

Table 11. Soil types found within the watershed of Wilson Lake, Waushara County, WI.

Soil type	Percent of Watershed	Description
Plainfield sand, 2 to 6 percent slopes	36.6	*Excessively drained sandy soil. Low available water capacity. This soil is not hydric. The maximum allowable erosion rate is 5 tons/acre/year. Not highly erodible. Not prime farmland.*
Coloma loamy sand, 2 to 6 percent slopes	12.4	*Excessively drained sandy soil. Low available water capacity. This soil is not hydric. The maximum allowable erosion rate is 5 tons/acre/year. Not highly erodible. Not prime farmland.*
Plainfield sand, 0 to 2 percent slopes	9.5	*Excessively drained sandy soil. Low available water capacity. This soil is not hydric. The maximum allowable erosion rate is 5 tons/acre/year. Not highly erodible. Not prime farmland.*
Adrian muck, 0 to 1 percent slopes	7.7	*Very poorly drained organic over sandy soil. Frequently ponded. Very high available water capacity. This soil is hydric. The maximum allowable erosion rate is 2 tons/acre/year. Not highly erodible. Not prime farmland.*
Plainfield sand, wet substratum, 0 to 3 percent slopes	7.4	*Moderately well drained sandy soil. Low available water capacity. This soil is not hydric. The maximum allowable erosion rate is 5 tons/acre/year. Not highly erodible. Not prime farmland.*
Meehan loamy sand, 0 to 3 percent slopes	5.1	*Somewhat poorly drained sandy soil. Low available water capacity. This soil is not hydric, but the map unit commonly contains hydric inclusions. The maximum allowable erosion rate is 5 tons/acre/year. Not highly erodible. Not prime farmland.*
Houghton muck, 0 to 1 percent slopes	3.3	*Very poorly drained organic soil. Frequently ponded. Very high available water capacity. This soil is hydric. The maximum allowable erosion rate is 3 tons/acre/year. Not highly erodible. Not prime farmland.*
Coloma loamy sand, 6 to 12 percent slopes	2.3	*Excessively drained sandy soil. Low available water capacity. This soil is not hydric. The maximum allowable erosion rate is 5 tons/acre/year. Potentially highly erodible. Not prime farmland.*
Richford loamy sand, 12 to 20 percent slopes	2.1	*Somewhat excessively and well drained sandy soil. Low available water capacity. This soil is not hydric. The maximum allowable erosion rate is 5 tons/acre/year. Potentially highly erodible. Not prime farmland.*
Fisk loamy sand, 0 to 3 percent slopes	1.7	*Somewhat poorly drained sandy over loamy soil. Moderate available water capacity. This soil is not hydric, but the map unit commonly contains hydric inclusions. The maximum allowable erosion rate is 5 tons/acre/year. Not highly erodible. Prime farmland where drained..*

Table 11 (cont.). Soil types found within the watershed of Wilson Lake, Waushara County, WI.

Plainfield sand, 6 to 12 percent slopes	1.3	*Excessively drained sandy soil. Low available water capacity. This soil is not hydric. The maximum allowable erosion rate is 5 tons/acre/year. Potentially highly erodible. Not prime farmland.*
Kingsville loamy sand, 0 to 2 percent slopes	1.1	*Poorly drained sandy soil. Frequently ponded. Low available water capacity. This soil is hydric. The maximum allowable erosion rate is 5 tons/acre/year. Not highly erodible. Not prime farmland..*
Plainfield sand, 12 to 30 percent slopes	1.1	*Excessively drained sandy soil. Low available water capacity. This soil is not hydric. The maximum allowable erosion rate is 5 tons/acre/year. Highly erodible. Not prime farmland.*
Houghton muck, ponded, 0 to 1 percent slopes	0.5	*Very poorly drained organic soil. Frequently ponded. Very high available water capacity. This soil is hydric. The maximum allowable erosion rate is 3 tons/acre/year. Not highly erodible. Not prime farmland.*
Water	8.1	--

Protecting Lake Water Quality

The most significant contributions of nutrients to Wilson Lake appear to be through groundwater and direct runoff from areas closest to the lake. Elevated nutrient inputs from human activities around Wilson Lake can have adverse affects on both water clarity and water quality. The following are options for water quality enhancement which both the District as a whole and individual lakefront property owners can undertake to improve Wilson Lake.

Nutrient Management Options

The first steps taken in managing nutrients in a lake should be to control external sources of nutrients. These can include: encouraging the use of phosphorus free fertilizers; improving agricultural practices, reducing run-off, and restoring vegetation buffers around waterways.

Lawn care practices
Mowed grass up to the water's edge is a poor choice for the well being of the lake. Studies show that a mowed lawn can cause 7 times the amount of phosphorus and 18 times the amount of sediment to enter a waterbody (Korth and Dudiak, 2003). Lawn grasses also tend to have shallow root systems that cannot protect the shoreline as well as deeper-rooted native vegetation (Henderson et al., 1998).

Landowners living in close proximity to the water should be discouraged from using lawn fertilizers. Fertilizers contain nutrients, including phosphorus and nitrogen can wash directly into the lake. While elevated levels of phosphorus can cause unsightly algae blooms, nitrogen inputs have been shown to increase weed growth. Landowners are encouraged to perform a soil test before fertilizing. A soil test will help determine if there is a need for fertilizer. The Waushara County UW-Extension office can assist in having soil tested. If there is a need to fertilize a lawn, a fertilizer that does not include phosphorus should be used. Most lawns in Wisconsin don't need additional phosphorus. The numbers on a bag of fertilizer are the percentages of available nitrogen, phosphorus and potassium found in the bag. Phosphorus free fertilizers will have a 0 for the middle number (e.g. 10-0-3).

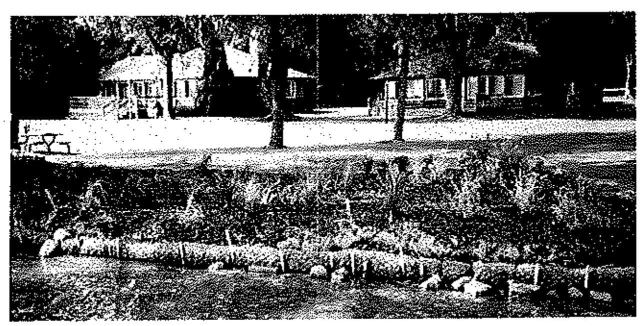
To further reduce nutrient loading, avoid raking twigs, leaves, and grass clippings into the lake. They contain both nitrogen and phosphorus. The best disposal for organic matter, like leaves and grass clippings is to compost them. Composted material can then be used for gardening.

Vegetative buffer zones
There are beneficial alternatives to the traditional mowed lawn. The best alternative is to protect the natural shoreline and leave it undisturbed. If clearing is necessary to access and view the lake, consider very selective removal of vegetation. Restoring a vegetative buffer zone is also an important alternative.

A recommended buffer zone consists of native vegetation that may extend from 25 – 100 feet or more from the water's edge onto land, and 25 – 50 feet into the water. A buffer should cover at least 50%, and preferably 75% of the shoreline frontage (Henderson et al., 1998). In most cases this still allows plenty of room for a dock, swimming area, and lawn. Buffer zones are made up of a mixture of native trees, shrubs, and other upland and aquatic plants.

Shoreline vegetation serves as an important filter against nutrient loading and trapping loose sediment. A buffer provides excellent fish and wildlife habitat, including nesting sites for birds, and spawning habitat for fish. Properly vegetated shorelines also play a key role in bank stabilization. A number of resources are available to assist property owners in creating beneficial buffer zones. These include descriptions of native beneficial plant species and where they can be found locally.

Shoreline plant restoration



Shoreline vegetation can benefit lake ecology tremendously. A properly vegetated shoreline provides habitat for a variety of birds, furbearers, amphibians, and reptiles. Much of the shoreline and emergent vegetation in Wilson Lake appears to have been destroyed by lakefront development. Benefits to lake water quality, fishery and wildlife could be achieved by restoring shoreline plants in Wilson Lake. Lakefront habitat improvement is often done on a property-by-property basis. In recent years many new techniques have been developed for restoring lakefronts. This type of work often incorporates many attractive flowering plants and adds a great deal of aesthetic appeal to lakefronts as well.

Septic system maintenance

It is the responsibility of lakeshore property owners to ensure that septic systems are properly functioning. A failing septic system can contaminate both surface and ground water. If located in a groundwater discharge area, failing septic systems can be a major cause of nutrient loading in lakes. Systems should be professionally inspected every 3 years, and pumped every 2-5 years depending on operating circumstances (EPA, 2002). Avoid flushing toxic chemicals into the system. This can harm important bacteria that live in your tank and naturally break down wastes. Avoid planting trees, compacting soil, or directing additional surface runoff on top of the drain field.

Erosion control

Erosion is a natural process, but it's for the benefit of the landowner and health of the lake that erosion control practices be carried out to slow the process as much as possible. Sedimentation into the lake causes nutrient pollution, turbid water conditions, eliminates fish spawning habitat, and increases eutrophication. Shoreline owners are encouraged to leave existing vegetation, which is a great shore stabilizer. The placement of logs, brush mats, and rock riprap are also options against erosion. When riprap is used it is recommended that desirable shrubs and aquatic plants be planted within the riprap. The plantings serve as nutrient filters and habitat. Before any shoreline stabilization project is initiated, it is recommended that property owners contact the local DNR office for project approval and to obtain any necessary permits.

Because the watershed of Wilson Lake is approximately one-third agriculture, proper erosion control is particularly important. It is important that the District work with the local Soil Conservationist with the Natural Resource Conservation Service (NRCS) and the Waushara County Land Conservation Office to encourage improved farming practices within the watershed. In particular, the application of sewage and/or manure to agricultural fields within the watershed should be discouraged.

Aeration

By artificially introducing air into a lake, a number of benefits to Wilson Lake have been achieved. The most common result of aeration is an improvement in dissolved oxygen levels and the resulting benefits to fish and water quality. Under oxygenated conditions, nutrients otherwise available to fuel weed and algae growth are greatly reduced. As these nutrients become tied up in the sediments, nuisance plant growth slows and the general appearance and quality of the water increases. By properly maintaining the current aeration system in Wilson Lake, these benefits can continue.

Informational resources for property owners
The following list are a number of valuable references that property owners and the District can utilize to further explore options for water quality and shoreline habitat improvements.

Lakescaping for Wildlife and Water Quality. This 180-page booklet contains numerous color photos and diagrams. Many consider it the bible of shoreline restoration. It is available from the Minnesota Bookstore (651-297-3000) for $19.95.

The Living Shore. This video describes buffer zone construction and gives information on selecting and establishing plants. May be available at local library, or order from the Wisconsin Association of Lakes (800-542-LAKE) for $17.00.

A Fresh Look at Shoreland Restoration. A four-page pamphlet that describes shoreland restorations options. Available from UW Extension (#GWQ027) or WDNR (#DNR-FH-055).

What is a Shoreland Buffer? A pamphlet that discusses both ecological and legal issues pertaining to riparian buffer zones. Available from UW Extension (#GWQ028) or WDNR (#DNR-FH-223).

Life on the Edge…Owning Waterfront Property. A guide to maintaining shorelands for lakefront property owners. Available from UW Extension-Lakes Program, College of Natural Resources, University of Wisconsin, Stevens Point, WI 54481, for $4.50.

The Water's Edge. A guide to improving fish and wildlife habitat on your waterfront property. Available from WDNR (#PUB-FH-428-00).

District Involvement

Improved public awareness is one of the most important aspects of any lake management effort. By becoming knowledgeable about the condition of Wilson Lake, the District can learn what practices are necessary to reduce nutrient inputs and keep the lake healthy. There are a number of activities that District members can carry out to improve lake users' awareness of the problems facing Wilson Lake.

Self-Help Citizen Lake Monitoring
The Wisconsin DNR has established a volunteer lake monitoring program designed to collect water quality data, educate volunteers, and share data and knowledge. Volunteers measure water clarity, using at Secchi disk. This information is then used to determine the lake's trophic state. Volunteers may also collect chemistry, temperature, and dissolved oxygen data, as well as identify and map plants, and watch for the first appearance of exotic species.

The DNR provides all equipment to the volunteer. Training of the volunteers is provided by either DNR or University of Wisconsin - Extension staff. Volunteers provide their time, expertise, energy and a willingness to share information with their lake association or other lake residents. The information gathered by the volunteers is used by DNR lake biologists, fisheries experts and water regulation and zoning staff, as well as by the UW Extension, lake association and other interested individuals.

State grant programs
A number of State-funded grants are available to qualified lake organizations for a variety of lake management and improvement projects. Grants which the Kusel, Wilson, Round Lakes Protection and Rehabilitation District may benefit from include: Lake Management Planning and Protection grants, Aquatic Invasive Species Control grants, and the Recreational Boating Facilities grant.

Lake Management Planning Grants
This program has been established for the purpose of assisting with lake management. The District would again be eligible to apply for funding to collect and analyze information needed to protect Wilson Lake and develop an aquatic plant management plan. Small and large-scale grants are available. This program funds up to 75% of the cost of the project. Grant awards cannot exceed $10,000 per grant for large-scale projects and $3,000 per grant for small-scale projects.

Lake Management Protection Grants
The Lake Management Protection Grant program awards funds up to 75 percent of project costs with a maximum grant amount of $200,000. Eligible projects include the purchase of land or conservation easements, restoration of wetlands and shorelands, development of local regulations or ordinances to protect lakes, and lake management plan implementation projects.

Recreational Boating Facilities Grants
The DNR's Waterways Commission provides grant money for a variety of projects designed to improve recreation on Wisconsin lakes. The DNR provides cost sharing of up to 50 percent for eligible costs. Organizations can apply for funds to provide safe recreational boating facilities, conduct feasibility studies, purchase aquatic weed harvesting equipment, purchase navigation aids, dredge waterways, and chemically treat Eurasian watermilfoil.

Aquatic Invasive Species (AIS) Control Grants
This grant program is designed to assist management units in the control of aquatic invasive species. The WDNR awards cost-sharing grants for up to 50% of the costs of projects to control invasive species. These grants are awarded to projects that fall within three major categories:

1. Education, Prevention and Planning
2. Early Detection and Rapid Response
3. Controlling Established Infestations

These funds are currently available only to units of government including Lake Districts.

For more details on each of these and other grant programs, visit the DNR's grant program website at http://www.dnr.state.wi.us/org/caer/cfa/grants/index.html.

Conclusions and Recommendations

Water quality management

Results of this study show that the water quality in Wilson Lake is fair. It would appear that groundwater and direct runoff are the largest contributors of phosphorus to the lake. The aeration system has been shown to successfully manage nutrients. If maintained, this system should continue to benefit Wilson Lake. However, increased nutrient inputs will slow the process. As nutrients levels increase, plants and algae become more prolific. This in turns causes an increase in the biological demand for oxygen in the water. A higher the demand for oxygen causes a decline in the effectiveness of the aeration system. The greatest improvements to water quality would result from significantly decreasing the input of nutrients from the watershed.

Water quality may continue to be a concern for residents of Wilson Lake. Nutrients are annually introduced into the lake. It is vital that efforts to control nutrient inputs be undertaken for the future of Wilson Lake. Improvements can be made to land use practices within the watershed, including not only farming practices, but also improvements to individual lakeshore properties. Again, it is also recommended that the District work with the County Land Conservation Office and the local NRCS Soil Conservationist to further encourage best management practices throughout the watershed.

It appears that the greatest input of nutrients into Wilson Lake is from groundwater and from near-shore areas of the watershed. Specifically, septic systems are likely a significant source of nutrients to the lake. It would be wise for the District to install a sanitary sewer system to serve riparian properties. This system could serve not only properties around Wilson Lake, but also those around Round and Kusel Lakes as well. Other lakes in the county have benefited from such systems. Although it would be a costly project, it would greatly benefit the water quality and recreational uses of all three lakes. In addition, it is recommended that individual property owners take steps to improve water quality. By utilizing the information presented above under **Protecting Lake Water Quality**, individuals as well as the District as a whole can encourage improvements to Wilson Lake.

In addition to managing external sources, internal sources should also be addressed. The east basin of Wilson Lake, is relatively shallow and it is evident that boating occurs throughout the lake. It has also been shown that boating activities can cause damage to a lake through sediment suspension and the release of nutrients. As result it is recommended that the District take the necessary step to make the east basin of Wilson Lake a no wake zone. This will decrease the rates of sediment suspension and improve water quality and clarity.

The District is also encouraged to participate in the DNR's Self-Help Monitoring program to continue to monitor the water quality of Wilson Lake.

Aquatic Plant Management

Although the distribution of aquatic plants was not the focus of this study, continued monitoring of exotic plant species is highly recommended for any lake susceptible to infestation. To this end, lake property owners and in particular district board members should be well informed on the threat posed by these nuisance plants and how to readily identify them.

In addition to focusing on water quality in the near future, it is also recommended that the Management Plan for Wilson Lake be updated for 2007. This plan can address not only the aquatic plant community, but also other areas of lake management the District wishes to address such as changes to the aeration system, investigation into septic versus sewer options for the lakes, and further community involvement.

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Appendix A

- Wilson Lake dissolved oxygen and temperature data – April 2005-January 2006
- Wilson Lake groundwater flow data, April 2005

Wilson Lake Site 1

Depth	April 22, 2005			June 21, 2005			August 3, 2005		
(ft)	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.
0	60.3	11.99	120	83.5	12.1	>150	81.9	9.32	122.8
1	59.9	11.94	119	83.9	12.1	>150	82.5	9.33	123.1
2	60.1	11.48	114	83.4	12.9	>150	82.8	9.60	127.2
3				82.1	14.2	>150	82.9	9.89	131.4
4				81.4	13.9	>150	83.0	9.87	131.1
5							82.6	8.55	113.0
6									

Depth	August 24, 2005			November 8, 2005			January 11, 2006		
(ft)	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.
0	73.3	8.73	100	50.3	10.10	92.7	33.4	7.35	53.9
1	73.3	8.76	101	49.9	10.10	91.7	34.6	10.20	79.2
2	73.7	8.56	99	49.2	10.00	90.5	35.4	11.10	82.9
3				48.8	9.69	87.0	35.7	10.30	77.3
4							37.9	0.40	3.1
5									
6									

Wilson Lake Site 2

Depth (ft)	April 22, 2005 Temp (°F)	D.O. (mg/l)	% Sat.	June 21, 2005 Temp (°F)	D.O. (mg/l)	% Sat.	August 3, 2005 Temp (°F)	D.O. (mg/l)	% Sat.
0	59.5	11.42	113	82.3	11.9	149	82.5	9.69	128.7
1	59.5	11.32	112	82.4	12.0	>150	83.4	9.62	128.2
2	59.5	11.11	110	82.5	12.0	>150	83.6	9.54	127.7
3	59.5	10.76	107	81.9	12.2	>150	83.7	9.51	127.1
4	59.4	10.62	105	81.1	12.3	>150	83.7	9.34	125.0
5	59.4	10.79	107	80.6	12.3	>150	83.5	9.10	121.5
6	59.4	10.81	107	79.6	12.4	>150	83.5	9.08	121.2
7	59.4	10.66	106	79.1	12.7	>150	83.1	8.82	117.2
8	59.4	10.64	106	78.8	12.8	>150	82.5	8.64	114.3
9	59.4	11.08	109	78.4	12.6	>150	82.1	8.26	108.9
10	59.2	11.00	100	78.2	12.5	>150	81.9	7.96	104.3
11	59.2	10.64	105	77.4	11.8	143	81.7	7.56	96.5
12				76.5	10.3	123	81.3	5.76	75.2
13				75.8	9.03	107	81.0	5.74	74.7
14				75.2	8.75	103	80.7	5.60	74.2
15				74.9	8.54	99	80.4	5.56	73.8
16				75.6	6.52	76	79.9	5.46	73.2

Depth (ft)	August 24, 2005 Temp (°F)	D.O. (mg/l)	% Sat.	November 8, 2005 Temp (°F)	D.O. (mg/l)	% Sat.	January 11, 2006 Temp (°F)	D.O. (mg/l)	% Sat.
0	73.2	8.73	101	48.5	10.3	92.4	35.3	11.3	84.9
1	73.2	8.69	100	48.3	10.4	92.6	35.3	11.3	84..9
2	73.2	8.68	100	48.2	10.4	92.6	35.5	11.3	84.7
3	73.2	8.63	99	48.2	10.4	92.6	35.7	11.3	84.5
4	73.3	8.67	99	48.3	10.3	92.2	35.5	11.3	84.7
5	73.2	8.35	96	48.2	10.4	92.3	35.5	11.3	84.7
6	72.8	7.89	99	48.1	10.4	92.3	35.5	11.3	84.7
7	72.7	7.96	92	48.0	10.4	92.4	35.6	11.3	84.4
8	72.6	7.96	92	48.0	10.4	92.4	35.6	11.3	84.5
9	72.5	7.97	93	48.3	10.3	92.0	35.6	11.3	84.5
10	72.3	7.96	89	48.2	10.3	91.8	35.7	11.3	84.7
11	72.3	8.00	93	48.1	10.3	91.9	35.5	11.3	84.9
12	72.3	7.71	88	48.1	10.3	92.0	37.6	0.23	1.7
13	72.3	7.53	86	48.0	10.4	92.0			
14				48.2	10.3	91.8			
15				48.4	10.1	90.6			
16									

Wilson Lake Site 3

Depth	April 22, 2005			June 21, 2005			August 3, 2005		
(ft)	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.
0	59.72	11.87	118	84.0	13.0	>150	83.6	9.87	131.8
1	59.72	11.46	113	83.3	12.8	>150	84.3	9.75	131.1
2	59.72	11.40	113	82.8	12.6	>150	84.7	9.69	130.8
3	59.72	10.30	102	82.1	12.5	>150	84.7	9.72	131.2
4				81.3	12.8	>150	84.9	9.79	132.6
5				80.6	12.9	>150	84.8	9.74	131.9
6				80.2	12.9	>150	83.7	9.72	130.1
7				79.3	12.3	>150	83.1	9.11	121.1

Depth	August 24, 2005			November 8, 2005			January 11, 2006		
(ft)	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.
0	73.3	8.97	103	56.0	9.03	89.0	31.1	11.3	83.9
1	73.5	8.85	102	50.0	10.2	93.5	34.8	11.5	85.2
2	73.4	8.80	100	49.4	10.4	93.8	35.6	11.3	84.8
3	73.4	8.70	99	49.0	10.4	94.0			
4	73.4	8.66	99	48.9	10.5	94.3			
5	73.4	8.55	98	48.7	10.6	95.1			
6	73.2	8.48	97	48.6	10.6	95.1			
7	73.2	8.06	93						

Wilson Lake Site 4

Depth	April 22, 2005			June 21, 2005			August 3, 2005		
(ft)	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.
0	59.0	10.90	107	86.1	11.0	144	84.8	9.57	129.5
1	59.2	10.89	107	86.5	11.0	145	85.2	9.52	129.3
2	59.2	10.73	106	86.7	10.9	145	85.4	9.43	128.1
3				85.9	11.3	138	85.4	9.42	128.1
4									

Depth	August 24, 2005			November 8, 2005			January 11, 2006		
(ft)	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.
0	71.9	9.25	105	48.0	10.5	93.3	34.5	12.2	89.7
1	71.8	9.31	105	47.9	10.6	94.1	35.6	12.1	90.5
2	71.5	9.55	107	47.3	10.8	95.3	36.4	11.9	90.5
3	70.9	9.54	107	47.3	10.7	93.9	36.6	12.1	91.6
4									

Wilson Lake Site 5

Depth (ft)	April 22, 2005			June 21, 2005			August 3, 2005		
	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.
0	59	11.41	113	84.1	10.8	140	84.5	10.2	137.5
1	58.82	11.02	108	84.3	10.9	142	85.0	10.3	139.1
2	58.82	10.68	105	84.4	10.9	142	85.2	10.2	138.1
3	58.82	10.76	106	84.4	11.1	143	85.3	10.1	137.0
4	58.82	9.14	90	84.2	8.15	105	85.5	9.89	134.8
5									

Depth (ft)	August 24, 2005			November 8, 2005			January 11, 2006		
	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.
0	71.7	9.71	108	48.5	10.7	95.4	33.9	12.1	88.4
1	71.8	9.78	110	48.3	10.7	95.7	34.4	12.0	87.9
2	72.0	9.60	108	48.0	10.8	96.2	35.8	11.9	89.7
3	72.1	9.97	112	47.8	10.9	96.3	36.7	11.9	90.5
4				47.7	10.9	96.6	39.2	12.6	99.3
5									

Wilson Lake Site 6

Depth (ft)	April 22, 2005			June 21, 2005			August 3, 2005		
	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.
0	59.9	11.08	110	84.9	11.4	147	84.9	9.64	130.5
1	59.72	10.98	110	84.8	12.0	>150	85.1	9.62	130.4
2	59.54	10.84	108	84.4	13.0	>150	85.2	9.57	129.9
3	59.54	10.71	107	84.0	12.8	>150	85.3	9.48	128.8
4	59.54	9.63	104	83.3	12.8	>150	85.0	10.11	137.1
5									

Depth (ft)	August 24, 2005			November 8, 2005			January 11, 2006		
	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.	Temp (°F)	D.O. (mg/l)	% Sat.
0	71.4	9.10	103	48.6	10.7	96.1	34.3	12.1	88.5
1	71.3	9.12	103	48.3	10.8	96.5	35.5	12.2	90.9
2	71.4	9.11	103	48.0	10.9	96.6	36.4	12.0	91.0
3	71.3	9.14	103	47.8	10.9	96.6	36.6	12.1	91.6
4	71.0	9.17	103	47.7	11.0	97.3	39.2	0.76	6.0
5									

Wilson Lake Site 7

Depth (ft)	April 22, 2005 Temp (°F)	D.O. (mg/l)	% Sat.	June 21, 2005 Temp (°F)	D.O. (mg/l)	% Sat.	August 3, 2005 Temp (°F)	D.O. (mg/l)	% Sat.
0	60.26	11.83	118	87.1	11.8	>150	84.0	9.93	133.6
1	59.18	11.35	112	84.9	12.1	147	84.5	9.93	134.0
2	59.18	10.70	106	84.5	12.2	>150	84.9	9.94	134.6
3				84.1	3.94	48	84.7	10.70	144.2
4							84.7	9.80	133.1
5									

Depth (ft)	August 24, 2005 Temp (°F)	D.O. (mg/l)	% Sat.	November 8, 2005 Temp (°F)	D.O. (mg/l)	% Sat.	January 11, 2006 Temp (°F)	D.O. (mg/l)	% Sat.
0	72.3	9.64	108	49.0	10.8	97.3	33.7	11.9	86.8
1	72.1	9.65	108	48.6	11.0	98.1	34.3	12.0	88.0
2	72.2	9.64	108	48.5	11.0	98.1	36.2	12.0	90.8
3	72.4	9.62	108	48.6	11.2	100.1	37.0	12.0	91.6
4									
5									

Wilson Lake Site 8

Depth (ft)	April 22, 2005 Temp (°F)	D.O. (mg/l)	% Sat.	June 21, 2005 Temp (°F)	D.O. (mg/l)	% Sat.	August 3, 2005 Temp (°F)	D.O. (mg/l)	% Sat.
0	58.64	10.91	108	86.2	14.10	>150	84.0	9.33	125.4
1	58.82	10.72	105	85.0	12.40	>150	85.0	9.19	124.5
2	58.82	10.94	108	85.0	12.20	>150	85.1	9.22	125.0
3							85.7	9.15	124.9
4									

Depth (ft)	August 24, 2005 Temp (°F)	D.O. (mg/l)	% Sat.	November 8, 2005 Temp (°F)	D.O. (mg/l)	% Sat.	January 11, 2006 Temp (°F)	D.O. (mg/l)	% Sat.
0	72.8	8.62	99	50.2	10.4	94.6	33.3	12.1	87.1
1	71.9	8.73	98	49.2	10.6	95.7	35.8	12.2	91.4
2	71.5	8.61	98	48.7	10.7	95.9	37.6	11.9	92.0
3	70.9	7.85	98	48.2	10.6	94.5			
4									

Wilson Lake groundwater flow data, April 2005

1	N44º 10.350'	W89º 10.624'	6
2	N44º 10.436'	W89º 10.733'	-92
3	N44º 10.501'	W89º 10.758'	0
4	N44º 10.530'	W89º 10.630'	5
5	N44º 10.543'	W89º 10.450'	0
6	N44º 10.655'	W89º 10.372	0
7	N44º 10.676'	W89º 10.238'	0
8	N44º 10.635'	W89º 10.194'	6
9	N44º 10.562'	W89º 10.168'	88
10	N44º 10.457'	W89º 10.226'	4
11	N44º 10.361'	W89º 10.273'	0
12	N44º 10.436'	W89º 10.378'	9
13	N44º 10.350'	W89º 10.434'	10
14	N44º 10.316'	W89º 10.497'	14