An Evaluation of the Impacts Septic Systems have on the Groundwater and Surface Water Quality of Minocqua Lake, Wisconsin

by
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Cathy - could you please copy this and return to WRC? - Thanks, Bob

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INTRODUCTION

Lake Minocqua is located in the north central portion of Onedia County, Wisconsin. The 1360 acre lake virtually surrounds the city of Minocqua. This drainage lake has inlets on the east end of the lake from the Minocqua and Tomahawk Thoroughfares and exits the lake on the west side into Kawaguesaga Lake. 96 percent of the Lake Minocqua shoreline is privately owned. The remaining 4 percent is publicly owned and located mostly on the far east end of the lake. Of the 96 percent that is privately owned, approximately 42 percent is served by city sanitary sewer and water. This leaves 58 percent using private sewage disposal systems and private wells.

Due to the great number of on-site sewage disposal systems around the lake, there is a concern about the effects these systems have on the lake and the groundwater. Because of the presence of high groundwater tables and highly permeable sand soils in lake frontage communities, the probability for incomplete on-site wastewater treatment and thus, the impact of groundwater and surface water are of great concern. Generally septic systems in these cases are adequate for the treatment and removal of bacteria and viruses found in wastewater, but may not be adequate for the removal of many of the chemical constituents found in wastewater. Some important chemical constituents found in wastewater that adversely affect surface and/or groundwater are nitrogen, phosphorous, sodium and chloride, as well as some trace organic chemicals, which are used in the home.

In most studies conducted on conventional septic systems, it has been demonstrated that nitrogen is not substantially removed (Postma et. 1992) (Shaw and Turyk 1994). Two forms of nitrogen are major concerns related to groundwater and surface water contamination. These forms are ammonium and nitrate. Most nitrogen in septic tank effluent is in the ammonium form, however, as this wastewater percolates the soil beneath a properly positioned and functioning drain field, ammonium is rapidly converted to nitrate (Canter and Knox 1985). Nitrates are formed in this fashion due to nitrification, which involves ammonium ions being converted to nitrite and then to nitrate under aerobic conditions. Therefore, in order for nitrification to take place, aerobic conditions must exist beneath drain fields, which is indicative of a properly functioning drain field. However, if a drain field is not functioning in this manner, there is a possibility for contamination of groundwater by ammonium. Anaerobic conditions seldom exist directly beneath an absorption system, unless the water table is near the bottom of the absorption system or in the saturated soil. Absorption systems placed too close to the water table can create a continuous anaerobic zone, in effect creating a conduit for ammonium movement to groundwater (Canter and Knox 1985). However, ammonium has a strong affinity to soil particles which initial prevents groundwater and surface water contamination. The amount of ammonium that the soil will attenuate is dependent on the soil properties, such as cation exchange capacity, which is dependant on the amount of clay and organic matter in the soil. Over time this cation exchange capacity of the soil may be exceeded causing ammonium to move deeper in the soil until eventually reaching groundwater and surface water.

Chloride is another chemical common in wastewater that is not effectively removed by septic systems. Concentrations of chloride in septic tank effluent range from approximately 40 to 100 mg/L with higher values found when water softeners are used (Canter and Knox 1985). Although chloride in drinking water does not pose a serious health problem and in surface water, at this range, does not cause serious problems, chloride in the dissolved phase is extremely mobile. For this reason, chloride can be a useful tracer of septic system pollution when background chloride levels are low. However, sodium, which is often associated with chloride, can pose a health risk to those on a low sodium diet.

In many cases, because it is not toxic, phosphorus is not a problem when contamination of groundwater is the concern. Phosphorus has a high affinity for soil particles, therefore, many times phosphorus is attenuated in the soil before reaching the groundwater. However, in sandy soils, like those found in northern Wisconsin, there is a potential for phosphorus to significantly contaminate groundwater (Postma et al. 1995). Due to the high affinity phosphorus has for soil particles long term loading is important. Fixation capabilities of soils are limited, and when these capabilities are exceeded phosphorus moves deeper in the soil eventually reaching groundwater then surface water. When phosphorus reaches surface water it aggravates problems of eutrophication more so than nitrogen due to the fact that phosphorus is normally the limiting nutrient in water communities (Honachefsky 1991). This means that only a small amount of phosphorus is needed to causes excessive algae growth in lakes. Increased eutrophication occurs in the presence of as little as 0.010 mg/L phosphorus.

OBJECTIVES

PHASE I

1. Determine the current status of septic systems around Lake Minocqua.

2. Determine areas of groundwater inflow or outflow by the use of mini piezometers.

3. Investigate impact on lake water quality.

4. Make observations of aquatic plant characteristics near areas of septic system inflow.

PHASE II

1. Assess groundwater quality using private wells located around Lake Minocqua.

2. Investigate impacts of septic systems on groundwater quality.

METHODS AND MATERIALS

SITE SURVEY

In order to determine the current status of septic systems surrounding Minocqua Lake, it was necessary to administer a door to door survey. Participation in this survey was on a strict voluntary basis. The questions contained in the survey were to determine age, usage and care of the system. In addition to the questions asked, Measurements were made with a 100 foot tape to determine if the system meets current codes. Such measurements included the distance of both the septic tank and drain field to the lake, occupied building, lot line, basement, and the well. Observations of the vent pipe and the area surrounding the septic system were also made to help determine if the system was failing hydraulically. These observations included presence or absence of standing water in the vent pipe as well as the presence of absence of ponding on the surface around the drain field. Elevation of the drain field above the lake level was also measured using a clinometer or a laser level and stadia rod. The clinometer was used to determine differences in elevation of over 12 feet. Those less than 12 feet were measured with the laser level and stadia rod. At differences in elevation of less than 10 feet, a well was installed using a bucket auger. A 1.25 inch (inside diameter) PVC well casing was then installed in the hole. The bottom two feet of the casing was screened with 0.010 inch wide slots. The depth to groundwater in the well was then measured using a 100 foot tape with a brass popper on the end. However, this procedure proved to be used rarely, due to the steep elevations around most of the lake. The third step in the initial investigation was to insert a mini piezometer into the lake bottom perpendicular to the drain field. The piezometer is then used to determine groundwater flow direction and to take samples for on site chemical analysis. A mini piezometer is constructed of a 6 foot length of 4 millimeter inside diameter polypropylene tubing. The piezometer is screened 1 inch from the bottom by perforating the tubing the entire way around and 1 inch in length with a small diameter needle. The bottom is then capped and a pipette tip is placed over the bottom of the tube acting as a well point. To insert the piezometer into the lakebed, a 7 foot metal rod is placed inside the piezometer to make the piezometer rigid so it can be pushed into the lake bottom. In some cases, due to the course underlying material, a hole was first made with a rigid steel rod and the piezometer was inserted in this hole. Piezometers were inserted approximately 2 feet from the shore and, at all time, at least 2 feet into the lake bottom to avoid surface water being drawn into the piezometer. The piezometer was then developed by drawing water up through the piezometer using a 60 milliliter syringe. Pumping of the well continued until the water in the piezometer was clear. At this point, the syringe was removed and the water in the piezometer was allowed to reach equilibrium. The difference in the level of water in the piezometer and the lake surface was then measured. This measurement determined if groundwater was flowing into the lake or away from the lake. If the level in the piezometer is above the level of the lake, it was concluded that groundwater is flowing into the lake. If the level in the piezometer is below the lake level then groundwater is flowing away from the lake at this particular point.

In addition to determining groundwater flow direction, samples were also taken from the piezometer to determine groundwater quality at the groundwater surface water interface. At this time, field tests were conducted to assist in determining which sites should be investigated further. Field tests included temperature, conductivity, nitrate and chloride. The field nitrate test used was a nitrate Hach kit where "Nitra vari V" was added to the sample, which developed an amber color in the presence of nitrate. The concentration of nitrate was then quantified by comparing the sample color to a calibrated color chart. The chloride test conducted in the field was the addition of one drop of .05 M $AgNO_3$ to the sample. In the presence of chloride, a white precipitate is formed. This method is not a calibrated quantitative method but with increased concentrations of chloride there is an increase in the amount of white precipitate. Relative amounts of precipitate ranging from slight to heavy were then noted.

SAMPLE SITE SELECTION

Sample sites were chosen for additional investigation of groundwater quality at the groundwater surface water interface based on the data collected during the on site survey. Parameters taken into account were distance the septic system was from the lake, the age of the system, the elevation of the system, the amount the system was used during the year and chemical data. Systems most likely to impact groundwater and the lake are those nearest to the lake where elevations are low and the water table is high. Age and usage also affect the probability of the system impacting the water resources. Older systems have had more time for the contaminants to infiltrate and saturate the soil that is under the system as well as having more effluent pass through the system. One other parameter that was considered was hydraulic head determined by using mini piezometers. Sites with negative hydraulic head (groundwater flowing away from the lake) were not sampled further due to the impossibility of the septic system impacting the lake at these sites.

Control samples were also taken to compare unimpacted areas to potentially impacted areas. Some samples were taken in the sewered areas around the lake and others were taken at vacant lots in the unsewered area of the lake. This was done to avoid finding contamination caused be septic systems in order to determine the chemistry of the groundwater entering the lake when not effected by septic systems. However, these samples may still be impacted by other land uses around the lake.

MINI PIEZOMETER SAMPLING

Samples were taken using mini piezometers in the same fashion as samples taken for field analysis during the site survey. However, due to the fact that septic system plumes can be very narrow, piezometers were inserted every 3 feet along the expected path of the plume. The field chloride test was again run to determine if the plume was intercepted. When high chloride was detected, it was assumed this was a septic system plume, and samples for lab analysis were then taken.

All samples taken were first filtered in the field with a 0.45 um filter using a millipore filter, sidearm flask and a hand pump. Sample was then distributed into one 250 ml unpreserved low density polyethylene bottle and one 125 ml bottle preserved with 5ml sulfuric acid per liter of sample. Between samples all equipment was decontaminated by rinsing with distilled water. Samples were then transported in a cooler, on ice to the Environmental Task Force Laboratory located at the University of Wisconsin - Stevens Point. All analysis was performed by methods listed in table 1. In addition to the analysis of the samples, quality control measures were performed on ten percent of the samples. These measures included duplicate analysis for measuring lab precision and check standards and spikes for measuring lab accuracy.

SURFACE WATER SAMPLING

Surface water samples were taken at some of the sites where piezometer sampling took place. This was done so water quality data from the analysis of the groundwater could be compared with that of the surface water. Samples were taken in the immediate area of the piezometer being used for sampling. Again, a 250 ml unpreserved sample and a 125 ml preserved sample was taken.

PRIVATE WELL SAMPLING

Drinking water sample bottles were distributed during the annual Minocqua Area Lakes Association meeting. A news release was published in the Lakeland Times notifying the public of the meeting and the opportunity for Minocqua Lake residents in the unsewerd areas, to have their drinking water tested. However, due to a low turn out at the meeting, only ten homeowners eligible to participate in the sampling received bottles. Because of the low turn out, the remaining ninety bottles had to be distributed house to house. Each homeowner was given two bottles, one sterile 200ml and one sulfuric acid preserved 125ml bottle. With these sample bottles, three instruction sheets, referring to sampling procedures, were also included and explained. The first side of the first sheet contained questions about the well, such as, well installation date, well depth and well location. On the backside of this sheet were the instructions about how to take the sample in the sterile 200ml bottle. The second sheet contained the instructions for taking the 125ml preserved sample needed for the analysis of nitrogen and phosphorus. On the backside of the second sheet, were the instructions on where and when the sample was to be dropped off in order for analysis of the sample to take place. All samples received at this location at the date and times indicated were delivered, on ice, to the Environmental Task Force Laboratory where test for coliform bacteria, pH, conductivity, total hardness, alkalinity, chloride, nitrate nitrogen, ammonium nitrogen, reactive phosphorus and fluorescence were carried out. Any samples dropped off after this scheduled drop off date were delivered to the Environmental Task Force Laboratory where all of the same analysis was conducted except for bacteria. Coliform bacteria were not tested for in these samples due to the time limitations for coliform bacteria analysis.

Table 1. Analytical method and method detection limits for analysis.

Test	Method	Method Detection Limit
Alkalinity	Titration Method Standard Methods 2320B	4.0 mg/L
Ammonium(Nitrogen)	Automated Salicylate-Nitroprusside Method Quick Chem Method 10-107-06-2-C	0.02 mg/L
Chloride	Automated Ferricyanide Method Standard Methods 4500-Cl^- E	1.0 mg/L
Conductivity	Standard Methods 2510B	1.0 umho/cm
Fluorescence		relative fluorescence
Nitrate + Nitrite (Nitrogen)	Automated Cadmium Reduction Standard Methods 4500-NO_3^- F	0.2 mg/L
pH	Electometric Method Standard Methods 4500-H^+ B	0.05 s.u.
ReactivePhosphorus	Automated Asorbic Acid Reduction Method 4500-P F	0.002 mg/L
Total Hardness	EDTA Titrimetric Method Standard Methods 2340 C	4.0 mg/L

RESULTS AND DISCUSION

SURVEY

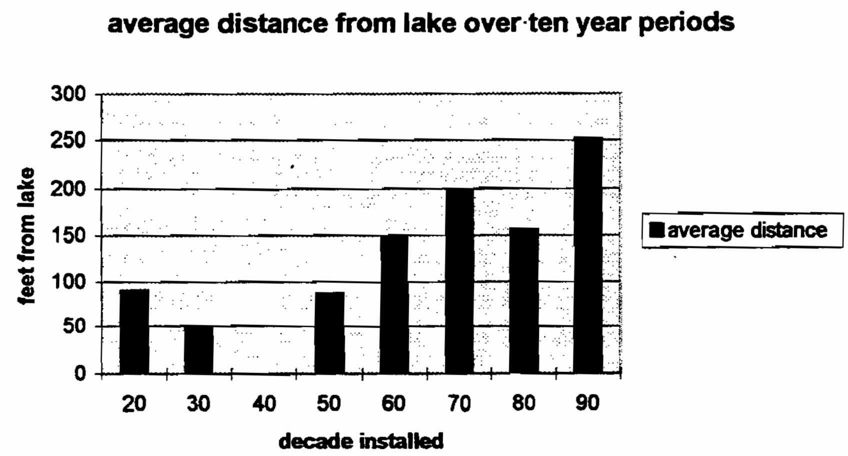
The site survey focused on the 160 homes on Lake Minocqua that currently have on site sewage disposal systems. Of these 160 homes, 82 of the owners gave us permission to conduct our survey. 40 decided that they did not want to be part study, and gave various reasons, if any at all. The most common reason given was the fear of being forced to upgrade their septic system if problems or code violations were found even though the owner believed there were no problems. The remaining 38 home owners could not be contacted, possible due to the fact that many of these homes are vacation homes and used so infrequently that we were not able to contact them when they were there.

Table 2. Septic system code violations found during the site survey of the 82 sites.

Absorption system 50 feet or less from lake	4
Absorption system 25 feet or less from occupied building	5
Absorption system 50 feet or less from well	3
Absorption system 5 feet or less from lot line	3
Ponding over absorption system	0
6 inches or more standing water in vent pipe	9
Septic tank 5 feet or less from occupied building	2
Septic tank 25 feet or less from well	1
Septic tank 5 feet or less from lot line	0
Septic systems unable to locate	2

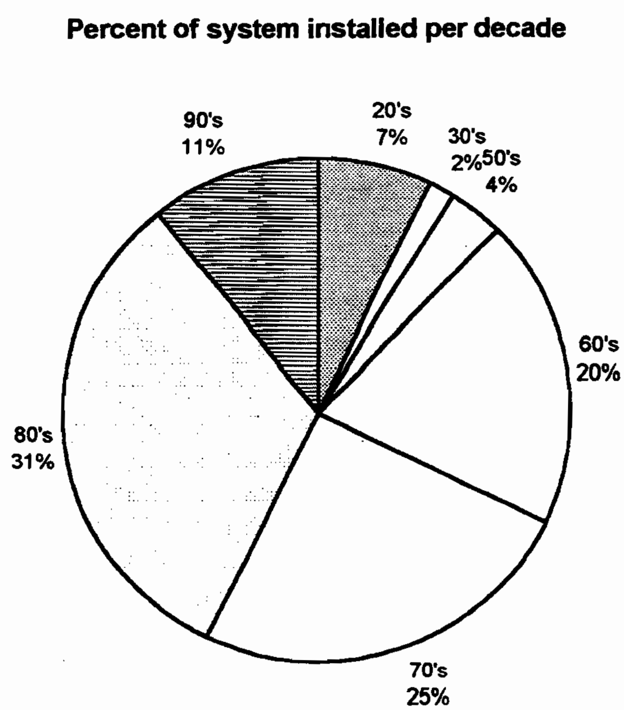
The four systems that were found to be less than the require 50 feet from the lake were all older systems, and due to grandfather clauses are most likely not in violation. However, these are systems of great concern for lake impacts. But the set back code is not always a good indicator of systems that may possibly impact groundwater and surface water. Any septic system in close proximity of groundwater or surface water has the potential of impacting both groundwater and surface water quality. The data collected shows that measures are being taken to further the distance of septic systems to Lake Minocqua. Figure 1 shows that on average, septic systems are being installed further from the lake as time goes by. This decreases the possibility of septic systems impacting surface water. As septic systems are installed further from lakes, not only is the distance from the lake increased but the distance to groundwater is also increased leaving longer travel distances and greater possibilities for attenuation of contaminants.

Figure 1. Average distance of absorption system to lake by decade installed.



It was also determined that of the sites surveyed, more than half of the systems on these sites were installed during the 70's and 80's. Figure 2 shows the percentage of septic systems installed in the corresponding decade. However, because participation in the survey was voluntary, some owners with older systems that may not meet many of the current codes or may be failing may have opted not to participate in the study.

Figure 2. Percent of septic systems installed by decade. (includes only septic systems that were inspected)



One objective of this study was to determine the number of systems that were failing hydraulically. The definition of a failing system, given in the Wisconsin Administrative Code, is any private sewage disposal system which causes or results in any of the following conditions: (a) the discharge of sewage into surface water or groundwater; (b) the introduction of sewage into zones of saturation which adversely affects the operation of a private sewage system; (c) the discharge of sewage to a drain tile or into zones of bedrock; (d) the discharge of sewage to the surface of the ground; (e) the failure to accept sewage discharges and back up of sewage into the structure served by the private sewage system.

Excessive standing water in a vent pipe is indicative of a septic system failing hydraulically. Water standing in a vent pipe shows that the septic tank effluent is not infiltrating the soil beneath the drain field as rapidly as the waste water is entering. This can eventually lead to sewage backing up in the house or ponding on the surface of the drain field. However, a system failing in this manner, may have less chance of impacting groundwater and surface water. Because the wastewater does not infiltrate the soil or infiltrates it much slower, there is less of a chance of wastewater rapidly reaching the groundwater. However, there are other problems associated with this type of failure. One is the back up of sewage in the house, the other is the potential for surface ponding which may impact surface water by over land flow. In addition to the eleven systems found to have greater than six inches of standing water in the vent pipe, there were fifteen systems that did not have vent pipes at all. So at these systems it could not be determined if there were saturated conditions associated with the drain field.

Another important factor when investigating septic systems is to be aware of how much the system is used and what types of wastewater enter the system. Of the properties includes in the survey it was determined that 39 percent of these homes were used 365 days per year. The remaining 61 percent of the homes were used anywhere from 270 to 30 days per year. To determine what goes into a septic system and the extent of use, we asked if garbage disposals, dishwashers, or cloths washers were installed in the house. Garbage disposals contribute increased solid to the septic tank, which may lead to more frequent pumping and increases in contaminant load in the wastewater. Clothes washers and dishwashers both put an increased hydraulic load on the septic system. But in addition to that they may also contribute to increased phosphorus contents in wastewater depending on the detergents used. Many automatic dishwashing detergents are very high in phosphorus, which can contribute significantly to the phosphorus load entering the septic system. Detergents for cloths also may contain fluorescent whiteners and brighteners. This increased amount of fluorescent compounds in the wastewater can then be helpful when trying to determine septic system plumes.

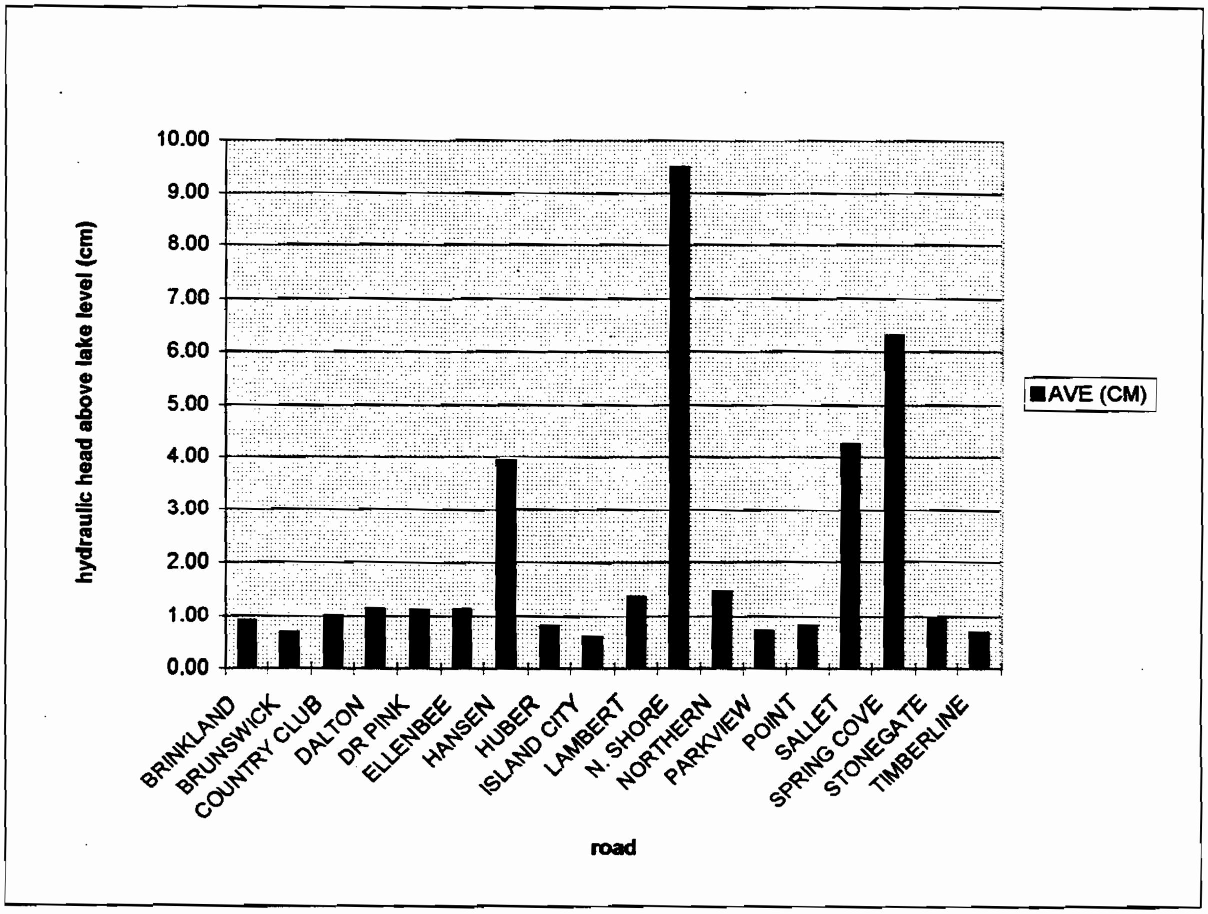
Table 3. Percentages of houses that contain household appliances that increase the amount of effluent and increase contaminants.

Dishwasher	82%
Clothes Washer	86%
Garbage Disposal	42%

HYDRALIC HEAD

At all sites that were surveyed there was some positive hydraulic head associated with groundwater flow. This means that groundwater is flowing into the lake to some degree at all sites investigated. The areas with the greatest hydraulic head were those in back bays. On average, the northern most bay of the lake had the highest hydraulic head. This can be seen in figure 3, where the average hydraulic head for each road is graphed. The four roads having the highest average hydraulic head, Hansen, North Shore, Sallet and Spring Cove, all are in the area of this northern most bay. All other average head values appear to be relatively close to one another. The sites where the lowest head values occurred were those site near the out let of Minocqua Lake where it flows into Kawaguesaga Lake.

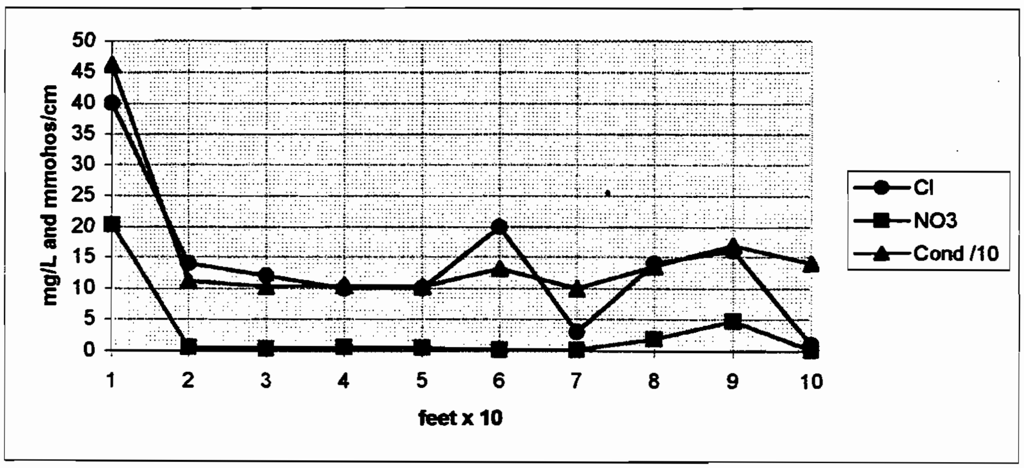
Figure 3. Average hydraulic head values above the lake level, corresponding to the road were the site is located.



SAMPLING METHOD

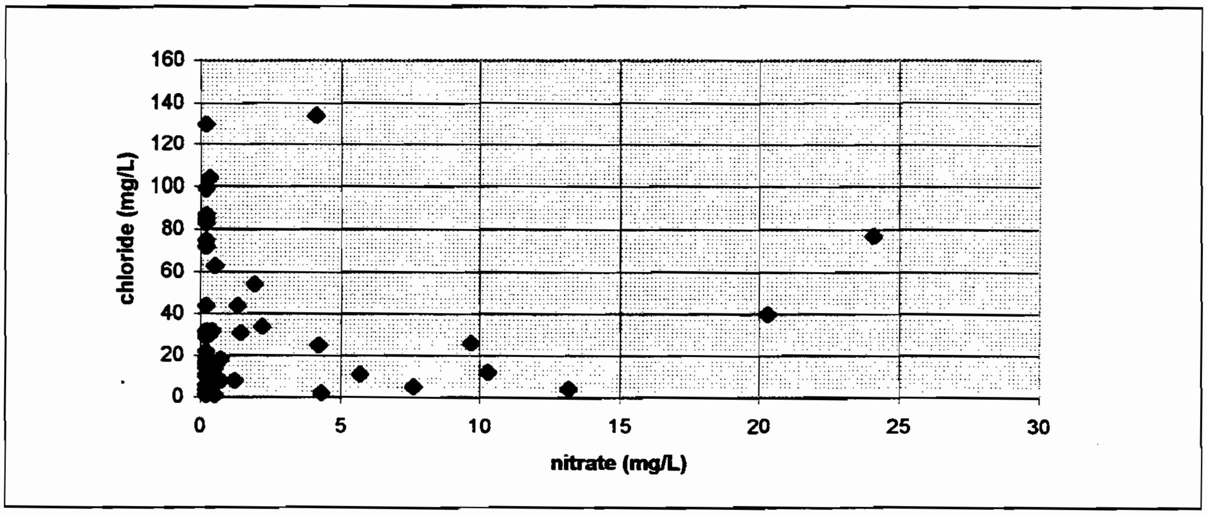
In past studies it has been determined that septic system plumes entering surface water bodies may be very narrow and therefore difficult to locate. This was also found to be the case in this study. To demonstrate this, a residence that is used year round with a septic system that meets all current codes was chosen. Samples were taken every 10 feet along the entire 100 feet of frontage. These samples were then analyzed to determine if any intersected a septic system plume. From figure 4 it can be seen that sample one intersected a septic system plume. Nitrate, chloride and conductivity data show the location of the plume very well. The location is characterized by high levels of nitrate and chloride. In this case nitrate levels in the plume are approximately 20 mg/L and chloride is 40 mg/L. The other samples along this shore show little to no nitrate with the exception of position nine. This site shows a small elevation in nitrate and chloride, which suggests that this to, may also be a septic system plume. Conductivity also shows the position of the plume very well. With increases in dissolved ions in groundwater such as nitrates, chlorides and phosphates, conductivity will also increase depending on the amount of dissolved ions. Figure 4 shows a significant difference in the conductivity found at site 1 and those found at the other nine sites. It can also be seen that the conductivity graph follows a similar trend as that of the nitrate and chloride. This shows that the change in conductivity is related to these ions which are indicative of septic system plumes.

Figure 4. Chloride, nitrate and conductivity in samples taken every ten feet along 100 feet of lake frontage.



As seen in figure 4, chloride is generally a good indicator of septic system plumes. Septic tank effluent contains anywhere from 40 to 100 mg/L chloride (Canter and Knox 1985). In an area such as northern Wisconsin, where background chloride levels are low, chloride seemed to be a good parameter to identify septic system plumes in order to sample sites further. However, as figure 5 shows, there are two trends in the piezometer data. One is where the chloride and the nitrate values relate well with one another. Finding both high chloride and high nitrate suggests the presence of a septic system plume. There is also a trend in the data where chloride and nitrate do not relate well with one another. In this case high chloride levels were detected but very little nitrate was found. When samples were taken chloride was used to determine the presence of a septic system plume. However, upon further analysis, it was determined that the sites that contained high levels of chloride but low levels of nitrate are most likely contaminant plumes due to road salting during the winter and not septic systems.

Figure 5. Scatter plot of chloride verses nitrate found in mini piezometer samples at groundwater surface water interface.



CONTROL SAMPLES

Control samples were taken at two different times during the course of sampling. The first sampling period took place on June 6, 1996. This was the beginning sample date for all samples taken on the lake. The other control samples, taken at the same locations were taken on August 8, 1996 to determine if changes occurred over the time period when sampling took place. Some changes did take place in water chemistry over the summer months. These changes can be explained considering changes in nutrient uptake by plants over the course of the summer or by considering land use practices that take place in the watershed during the summer months.

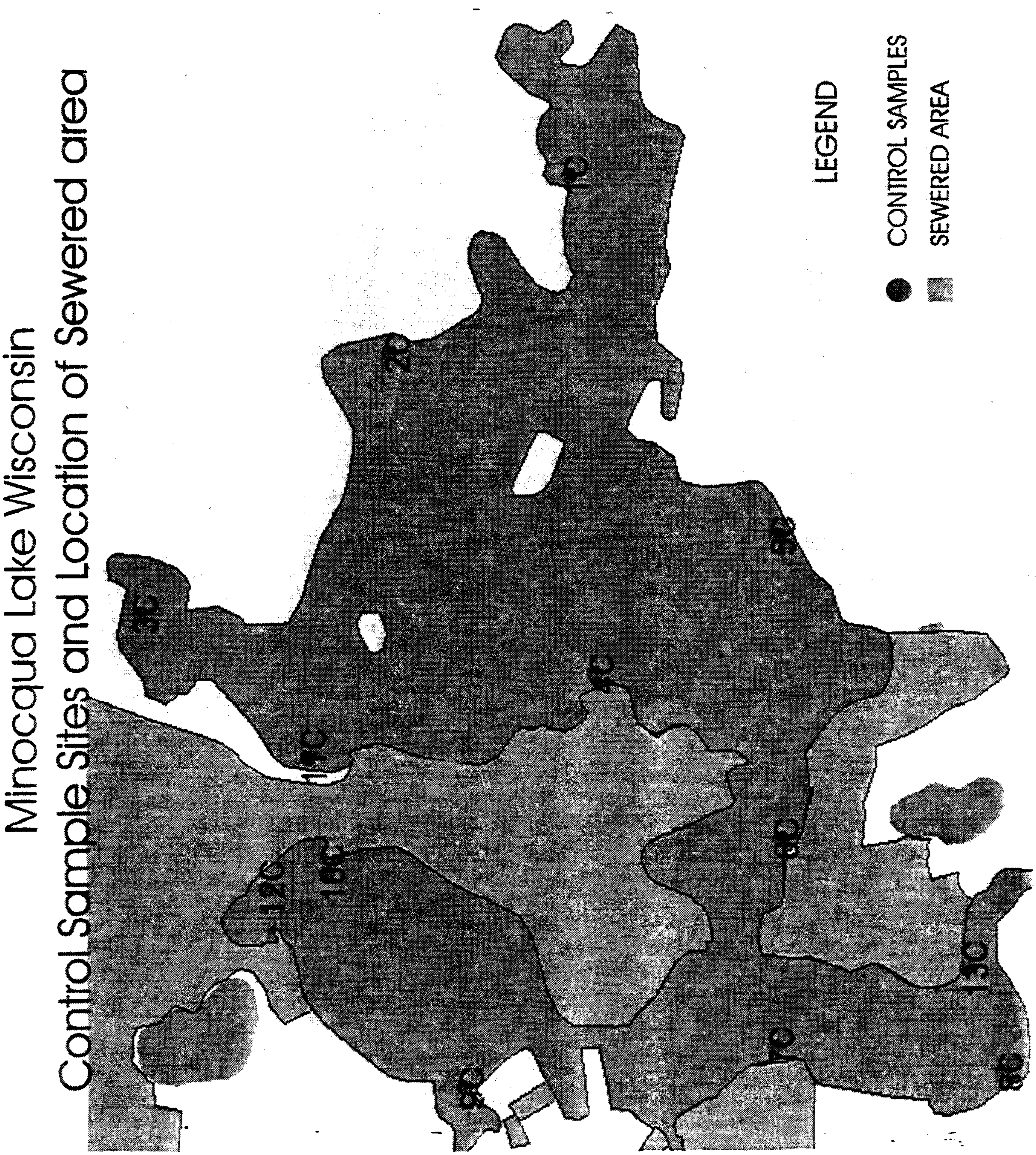
Because the samples were taken in areas that were assumed to be unimpacted by septic systems, the primary goal of the control samples was to determine levels of chemicals used to indicate septic system pollution. Many of the chemicals used to determine the presence or absence of septic system pollution could also originate from other sources. For example, chloride levels indicative of septic systems may also originate from road salt, elevated levels of nitrate may be a cause of over fertilizing, and elevated levels of both ammonium and phosphorus may be effects of natural processes taking place in the lake or around it. For these reasons average levels of chemical constituents were calculated from the control samples collected to determine average back ground levels in the lake. Table 4 contains the chemical data collected form the control samples as well as the average back ground levels of the constituents and Figure 6 shows the location of these sample sites.

Table 4

Control samples

Site	pH	Conductivity	Alkalinity	T. Hardness	Chloride	Fluorescence	NO3+NO2 (N)	Ammonium	Reactive P	Total P
6/6/96		umhos/cm	mg/L	mg/L	mg/L	.	mg/L	mg/L	mg/L	mg/L
1C	6.30	52.6	24	24	1	71.5	< 0.2	0.92	3.220	3.540
2C	6.15	124.0	12	36	20	14.0	1.4	< 0.01	0.066	0.096
3C	6.07	341.0	24	96	71	17.2	3.6	0.06	0.073	0.120
4C	6.52	228.0	96	116	3	62.6	< 0.2	0.96	0.364	0.559
5C	6.86	89.4	28	36	< 1	24.0	< 0.2	0.05	0.027	0.034
6C	6.40	115.0	32	36	13	81.2	< 0.2	0.15	< 0.002	0.370
7C	6.87	201.0	72	92	8	52.9	< 0.2	0.23	0.364	0.581
8C	6.50	110.0	52	52	5	27.9	< 0.2	0.44	0.361	0.420
9C	7.12	164.0	96	96	< 1	88.0	< 0.2	< 0.01	0.220	0.241
10C	7.45	143.0	80	80	< 1	24.5	< 0.2	0.19	0.198	0.251
8/18/96										
1C	6.32	150	64	48	3	44.6	0.03	3.94	1.510	
2C	6.30	91	12	28	10	15.0	0.71	< 0.01	0.036	0.050
3C	6.47	200	16	40	33	17.6	2.47	0.02	0.010	0.014
4C	6.63	163	76	68	4	63.0	< 0.02	0.86	0.038	0.039
5C	6.72	137	28	44	< 1	77.0	< 0.02	0.28	0.261	0.337
6C	6.60	157	20	40	21	17.0	0.28	< 0.01	0.014	0.016
7C	6.86	247	56	96	21	63.4	0.02	0.51	0.020	0.023
8C	6.87	161	68	64	7	48.4	< 0.02	0.27	0.013	0.125
9C	7.29	198	104	96	< 1	139.8	0.06	0.01	0.094	0.095
10C	6.72	453	132	140	37	52.2	< 0.02	0.14	0.298	
11C	7.12	137	60	56	6	62.0	< 0.2	0.64	0.427	
12C	6.69	440	44	88	106	32.0	0.2	0.74	0.206	
13C	7.01	85	40	36	< 1	47.4	< 0.2	0.26	0.212	
Average	6.67	186	54	67	22	49.8	0.97	0.58	0.372	0.384
Standard deviation	0.36	104	34	32	28	31.0	1.28	0.90	0.729	0.809
Maximum	7.45	453	132	140	106	139.8	3.60	3.94	3.220	3.540

Figure 6


Minocqua Lake Wisconsin
Control Sample Sites and Location of Sewered area
3C
12C
10C
7C
13C
LEGEND
CONTROL SAMPLES
SEWERED AREA

PIEZOMETER SAMPLES

In not all cases was a septic system plume found when sampling groundwater at the groundwater surface water interface. However, many areas of high nutrient inflow indicative of septic system plumes were located, which is one reason for the excessive aquatic plant growth found in may parts of the lake. Chemical parameters from the analysis of the mini piezometer samples were used to determine if a septic system plume had been intersected entering the lake. Some important chemicals considered were nitrate + nitrite nitrogen, ammonium nitrogen, phosphorus, chloride and fluorescence. Any single one of these chemistries cannot solely indicate the presence or absence of septic system impact, but when all are considered together septic system pollution can be more readily verified. Of the 68 different mini piezometer sample locations on the lake 45 were found to have elevated concentration of nitrate, ammonium, phosphorus or chloride. The location of these sample sites is illustrated in figure 7. Table 5 contains the chemical data of these 45 sites which is separated into the chemical constituent which is of concern.

NITROGEN

Two forms of nitrogen are of concern when contamination of groundwater and surface water by septic systems is the issue. These forms are nitrate and ammonium. Figure 8 shows that the elevation at which the septic system is installed is important to what form of nitrogen is present in groundwater flowing to the lake. Where septic systems are located at an elevation of ten feet or less above the lake level, the major form of nitrogen entering the lake was ammonium. This is because at lower elevations groundwater is closer to the land surface, which in turn puts the absorption system closer to the water table. This leaves less soil between the two for the aerobic conversion of ammonium to nitrate to take place. However, with systems at greater elevations, the conversion from ammonium to nitrate does take place due to the greater amount of unsaturated soil below the absorption field where aerobic conditions prevail. Therefore when identifying septic system plumes it is important to investigate both forms of nitrogen due to the effects depth to groundwater has on septic tank effluent.

A similar trend exists when nitrate and ammonium data is compared to the setback distance of the septic system from the lakeshore. This trend is generally true because the further from the lake the greater the depth to groundwater. In figure 9 it is shown that the major source of nitrogen at distances less than 100 feet from the lakeshore is ammonium. At distances greater than that nitrate level show a significant increase. However, this is not always the case. There are some relatively high levels of ammonium, which enter the lake in areas where the septic systems are greater than 100 feet from the lake. This discrepancy in the trend could be caused because more important than distance to the lake is distance to groundwater. In the case of some of these sites the setback may be of adequate distance but because of gentle sloping topography or low spots in the topography the distance to groundwater is not adequate to convert ammonium to nitrate.

Figure 7

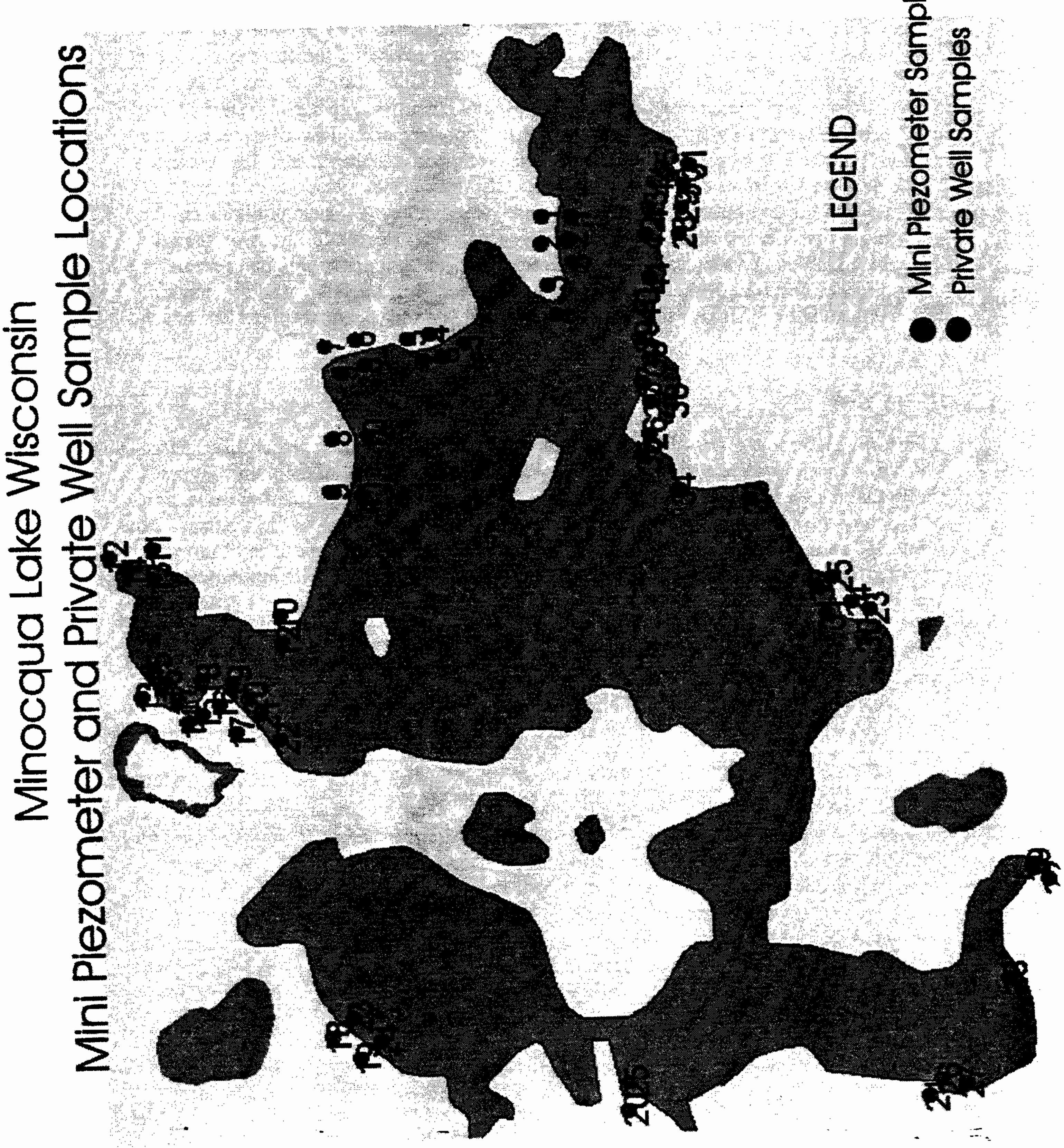

Minocqua Lake Wisconsin
Mini Piezometer and Private Well Sample Locations
LEGEND
Mini Piezometer Samples
Private Well Samples

Table 5

Piezometers with nitrate greater than 1.0 mg/L

SITE	pH	cond.	T. Hard.	Alk.	NO3+NO2	NH4	Cl-	React. P	Fluor.	ft from lake (ST)	AGE	ft from lake (AS)	elevation	# days/year
43	5.78	535.0	72	16	24.1	0.09	77	0.009	39.5	52	32		12	365
5	6.38	462.0	112	36	20.3	0.01	40	0.007	4.0	160	26	182	17	365
1	6.19	173.0	72	16	13.2	0.14	4	3.300	35.2	127	9	180	8	365
3	5.88	178.0	64	16	10.3	0.21	12	0.012	18.6			124	10	
25	6.57	236.0	84	24	9.7	0.03	26	0.021	24.5	131	19	212	15	240
7	6.75	164.0	68	36	7.6	0.03	5	0.051	18.7		37	131	22	180
28	7.08	208.0	40	52	5.7	0.01	11	0.021	25.1					
27	6.84	111.0	32	28	4.3	0.01	2	0.057	20.0		47			60
8	6.37	182.0	64	20	4.2	0.02	25	0.013	14.0	117	18	188	15	180
24	6.18	599.0	60	20	4.1	0.01	134	0.011	30.5	134	12	159	8	365
9	6.40	192.0	48	20	2.2	0.01	34	0.077	22.3	235	19	300		365
16	6.14	280.0	72	20	1.9	0.01	54	0.011	12.5		27	108	8	90
14	6.30	179.0	32	24	1.4	0.01	31	0.017	16.0	203		230	17	365
13	6.69	189.0	36	16	1.3	0.01	44	0.015	17.8	174	7	241	22	365
44	6.97	135.0	56	48	1.2	0.01	8	0.009	14.0	115	42	98	24	90

Piezometers with greater than 0.5 mg/L ammonium

SITE	pH	cond.	T. Hard.	Alk.	NO3+NO2	NH4	Cl-	React. P	Fluor.	ft from lake (ST)	AGE	ft from lake (AS)	elevation	# days/year
11	6.99	584.0	28	216	0.4	34.8	32	0.180	160.0	50	77	45	4	90
33	6.79	172.0	48	80	0.2	5.72	4	1.070						
26	6.44	121.0	48	32	0.2	3.84	10	0.055		50	67	50	12	30
2	7.24	53.0	8	20	0.2	1.67	1	1.200	18.1	130	21	140	7	240
21	6.59	245.0	40	52	0.2	1.53	31	0.011	57.5	65	33	117	5	120
38	6.70	161.0	80	84	0.2	1.35	1	0.096	52.0					
4	6.34	83.0	40	36	0.2	1.16	2	0.550	41.5	66	33	103	10	120
42	6.04	370.0	72	36	0.2	1.06	87	0.013	35.2	45		50		
41	6.29	144.0	64	76	0.2	0.83	1	0.117		45	11	80	7	270
23	5.69	44.9	20	20	0.2	0.80	1	0.059	123.0	122	25	201	5	42
20	6.65	109.0	48	56	0.2	0.78	2	0.750	50.3					
10	6.12	95.5	24	16	0.2	0.70	16	0.234	17.9	282	17	387	9	365
19	6.33	413.0	40	32	0.3	0.67	104	0.196	24.3	120	17	66	10	150

Piezometers with greater than 20 mg/L chloride

SITE	pH	cond.	T. Hard.	Alk.	NO3+NO2	NH4	Cl-	React. P	Fluor.	ft from lake (ST)	AGE	ft from lake (AS)	elevation	# days/year
24	6.18	599.0	60	20	4.1	0.01	134	0.011	30.5	134	12	159	8	365
6	5.48	549.0	180	8	0.2	0.02	130	0.010	27.0	185	3	337		365
19	6.33	413.0	40	32	0.3	0.67	104	0.196	24.3	120	17	66	10	150
22	6.70	442.0	28	40	0.2	0.03	99	0.010	65.5	170		315	10	
42	6.04	370.0	72	36	0.2	1.06	87	0.013	35.2	45		50		
45	6.16	381.0	36	24	0.2	0.05	85	0.012		137	15	108	10	300
39	7.57	693.0	196	224	0.2	0.16	83	0.176	33.0					
43	5.78	535.0	72	16	24.1	0.09	77	0.009	39.5	52	32		12	365
15	6.15	299.0	44	20	0.2	0.11	75	0.004						
40	5.88	306.0	40	20	0.2	0.01	72	0.008	27.0					
17	6.21	267.0	32	16	0.5	0.01	63	0.061	28.0	97	21	82	12	120
16	6.14	280.0	72	20	1.9	0.01	54	0.011	12.5		27	108	8	90
18	5.94	248.0	72	32	0.2	0.41	44	0.021	30.4	75	39	75	15	100
13	6.69	189.0	36	16	1.3	0.01	44	0.015	17.8	174	7	241	22	365
5	6.38	462.0	112	36	20.3	0.01	40	0.007	4.0	160	26	182	17	365
9	6.40	192.0	48	20	2.2	0.01	34	0.077	22.3	235	19	300		365
11	6.99	584.0	28	216	0.4	34.8	32	0.180	160.0	50	77	45	4	90
31	7.42	412.0	184	160	0.2	0.24	32	0.012		93	28	138	3	365
21	6.59	245.0	40	52	0.2	1.53	31	0.011	57.5	65	33	117	5	120
14	6.30	179.0	32	24	1.4	0.01	31	0.017	16.0	203		230	17	365
29	7.59	274.0	120	92	0.3	0.01	30	0.147	19.8	160	16	180	23	32
35	6.73	444.0	192	76	0.2	0.46	29	0.019	37.2	110	17	104	8	365
25	6.57	236.0	84	24	9.7	0.03	26	0.021	24.5	131	19	212	15	240
8	6.37	182.0	64	20	4.2	0.02	25	0.013	14.0	117	18	188	15	180
30	5.65	5.0	4	8	0.2	0.14	22	0.019					3	365

Piezometers with greater than 0.1 mg/L reactive phosphorus

SITE	pH	cond.	T. Hard.	Alk.	NO3+NO2	NH4	Cl-	React. P	Fluor.	ft from lake (ST)	AGE	ft from lake (AS)	elevation	# days/year
1	6.19	173.0	72	16	13.2	0.14	4	3.300	35.2	127	9	180	8	365
2	7.24	53.0	8	20	0.2	1.67	1	1.200	18.1	130	21	140	7	240
33	6.79	172.0	48	80	0.2	5.72	4	1.070						
20	6.65	109.0	48	56	0.2	0.78	2	0.750	50.3					
34	6.83	93.8	36	52	0.2	0.30	1	0.581	61.0					
4	6.34	83.0	40	36	0.2	1.16	2	0.550	41.5	66	33	103	10	120
36	6.82	74.1	28	24	0.2	0.03	1	0.251	37.0	136	15	188	22	365
10	6.12	95.5	24	16	0.2	0.70	16	0.234	17.9	282	17	387	9	365
12	6.56	167.0	80	56	0.2	0.28	14	0.214	65.5	201	11	254	14	365
19	6.33	413.0	40	32	0.3	0.67	104	0.196	24.3	120	17	66	10	150
11	6.99	584.0	28	216	0.4	34.8	32	0.180	160.0	50	77	45	4	90
37	7.00	158.0	72	80	0.2	0.23	3	0.178	30.5	88	21	96	17	365
39	7.57	693.0	196	224	0.2	0.16	83	0.176	33.0					
29	7.59	274.0	120	92	0.3	0.01	30	0.147	19.8	160	16	180	23	32
32	6.63	60.0	28	28	0.2	0.36	1	0.129	49.2	112	3	133	6	365
41	6.29	144.0	64	76	0.2	0.83	1	0.117		45	11	80	7	270

Figure 8. Concentrations of nitrate and ammonium found in piezometer samples verses the difference in elevation between the lake and the absorption system.

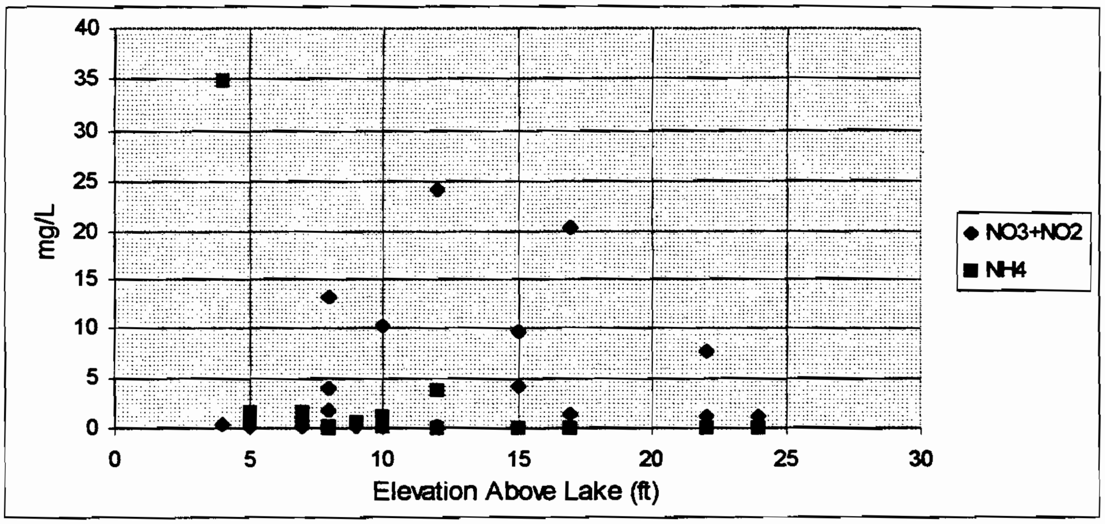
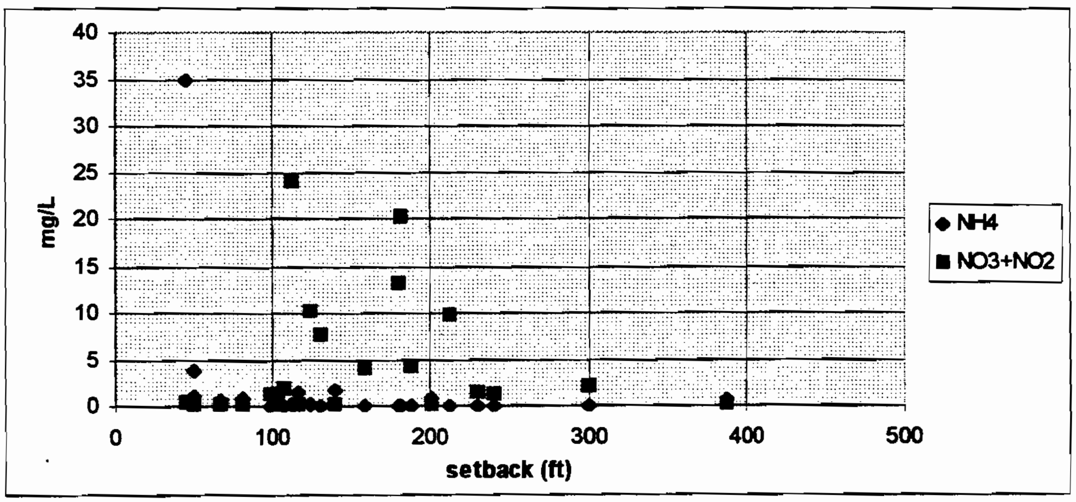


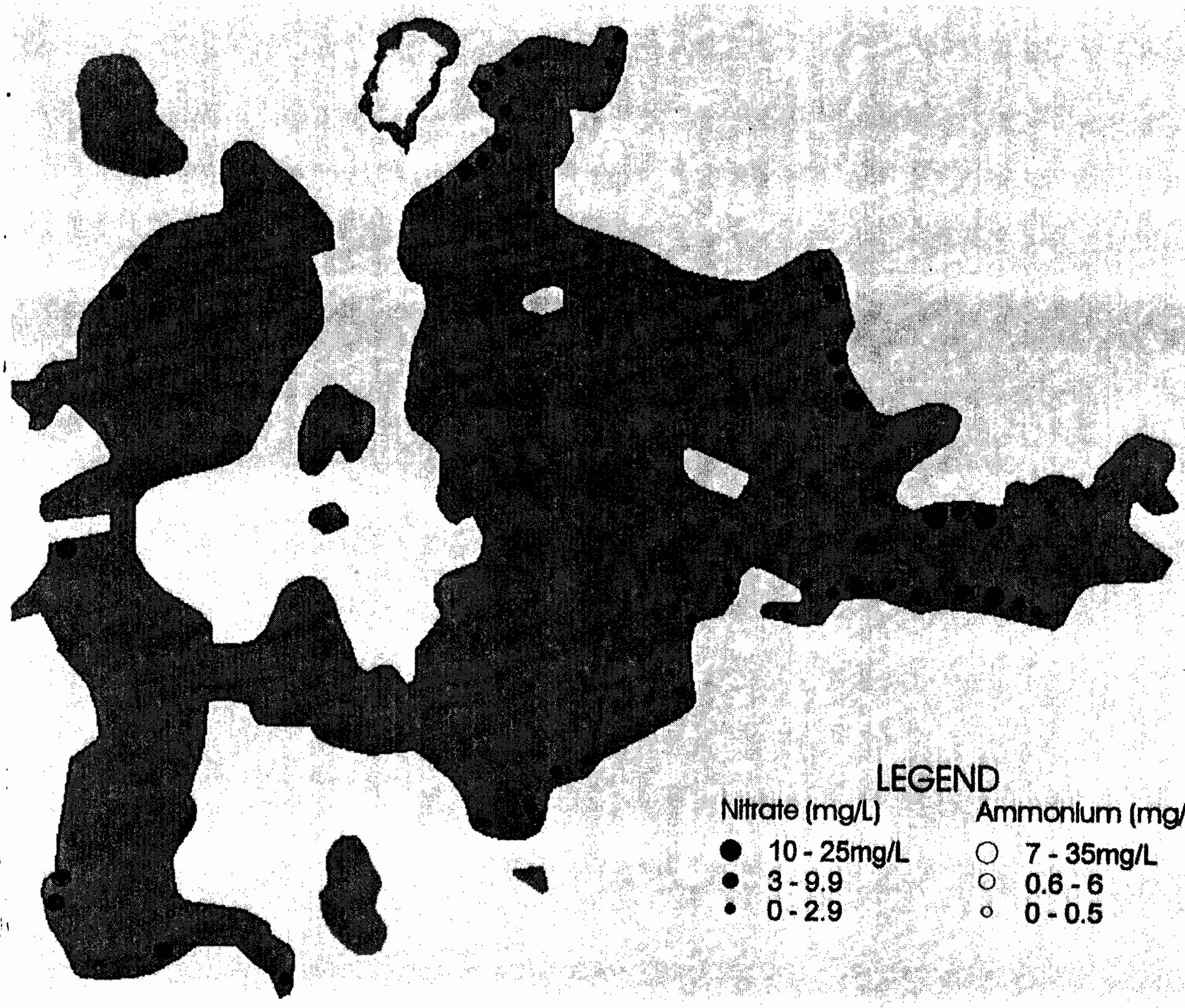
Figure 9. Concentrations of nitrate and ammonium found in piezometer samples verses distance of septic system setback.



This same inverse relationship can be observed on the map showing the relationship between nitrate and ammonium (figure 10). Those sites with relatively high concentrations of nitrate are coupled with relatively low concentrations of ammonium. This suggests that the major source of nitrogen in wastewater (ammonium) is being converted to nitrate at those sites where aerobic conditions are present and not being converted to nitrate at those sites where anaerobic conditions prevail. This is the primary reason that both ammonium and nitrate contamination was found entering Minocqua Lake. Of the samples taken, 15 exceeded 1.0 mg/L nitrate with about half of these samples exceeding 5.0 mg/L. The highest concentration of nitrate found entering the

Figure 10

Minocqua Lake Wisconsin
Relationship Between Nitrate and Ammonium Concentrations



lake was 24.1 mg/L nitrate. 13 of the samples exceeded 0.5 mg/L ammonium with more that half of these sites having greater than 1.0 mg/L ammonium. The highest concentration of ammonium found was 34.8 mg/L ammonium which was thought to be unreasonable high so a duplicate sample at this site was taken. The duplicate sample showed similar results proving this was the concentration of ammonium entering the lake at this site. Research has shown that only 0.3 mg/L of inorganic nitrogen is needed to support excessive algae growth. Other research has shown that nitrogen in lake sediments is important in determining the amount of aquatic plant growth in an area. With the amounts of nitrogen entering Lake Minocqua problems with excessive aquatic plant growth and algae blooms are expected in many parts of the lake if not already present.

PHOSPHORUS

Phosphorus moves through the subsurface in a much different manner than ammonium. Both have a high affinity for soil particles, but ammonium movement is dependent on the cation exchange capacity of the soil where as phosphorus movement is dependent on the absorption capacity of the soil. Ammonium is adsorbed by clay and organic matter and moves through the soil as it exceeds the soils exchange capacity. Phosphorus, on the other hand, is largely retained by the iron and aluminum coatings found on sand particles. Another difference between the movement of ammonium and phosphorus is that ammonium will only be present in the absence of oxygen. In the presence of oxygen ammonium will undergo nitrification and be converted to nitrate. However, phosphorus can exist and move through the subsurface under both conditions. Because loading rates are important for both ammonium and phosphorus there is some correlation between the relative concentrations of both. In figure 11 it is apparent that at some of the sample sites phosphorus relates to elevation in the same why that ammonium does. However there are some sites that elevation and concentration do not relate in the way expected. This is also true when a graph of phosphorus verses ammonium (figure 12) is looked at. Some of the data points appear to relate well with one another and create a straight line, however there are others that do not follow this expected trend.

This relationship is also evident when it is illustrated in a map form like that found in figure 13. From this map it becomes clearer that the relative concentrations of phosphorus and ammonium entering the lake relate to one another in most cases. Those with relatively high concentrations of ammonium are often coupled with high levels of phosphorus.

Figure 11. Concentrations of reactive phosphorus and ammonium verses the difference in elevation between the lake and the absorption system.

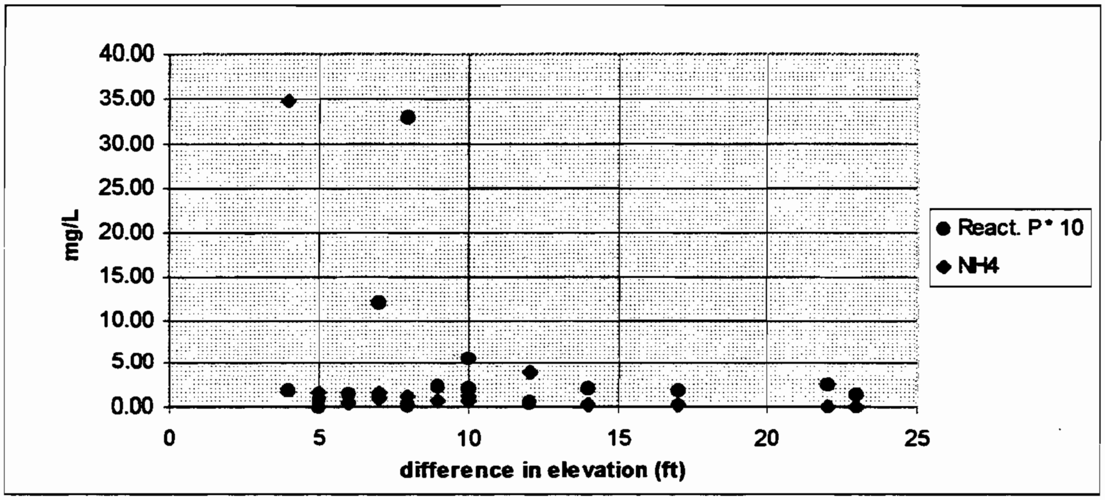
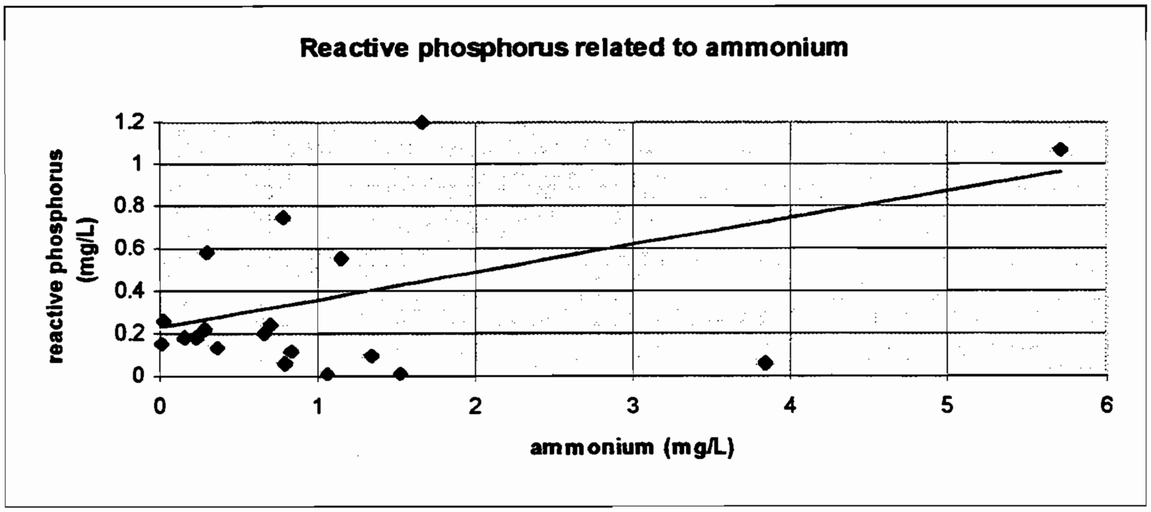


Figure 12. Linear relationship between reactive phosphorus and ammonium at the same sites.



Reasons for the discrepancies may simply be that these areas of relatively high nutrient inflow are not caused by septic systems, which may be the case on the east shoreline of the northern most bay. In this area relatively high concentrations of ammonium was found in both the mini piezometer samples and the private well samples, suggesting that the contamination may be coming from the wetland area to the north west. Both phosphorus and ammonium are released during the natural process of decomposition as in the case of swampy areas with extensive weed growth.

Figure 13

Minocqua Lake Wisconsin
Relationship Between Reactive Phosphorus and Ammonium Concentrations

However it may be that different septic system emit different amounts of phosphorus relative to the amount of ammonium produced. This could be true considering what goes into the septic system. Phosphorus in septic tank effluent originates mainly from human waste and cleaning detergents. However due to the restriction put on phosphate based laundry detergents, a decrease in phosphates entering septic systems is probable. Nonetheless, many other household detergents and cleaners other than laundry detergents still contain phosphates (VanRyswyk 1996). The most likely explanation of the discrepancies found in the data between ammonium and reactive phosphorus is that the elevation of the septic system. In figure 8 it shows that the points that do not have ammonium associated with them are those where the elevation may be great enough that ammonium is being converted to nitrate while phosphorus still moves through the subsurface contaminating groundwater and eventually entering the lake.

16 of the sites sampled exceeded 0.1 mg/L reactive phosphorus with the highest concentration found to be entering the lake at 3.3 mg/L reactive phosphorus. These amounts of phosphorus entering the lake are well above those needed to create problems with excessive aquatic plant growth, algae blooms and accelerated eutrophication when it is considered that only 0.01 mg/L reactive phosphorus is needed to support excessive growth of algae.

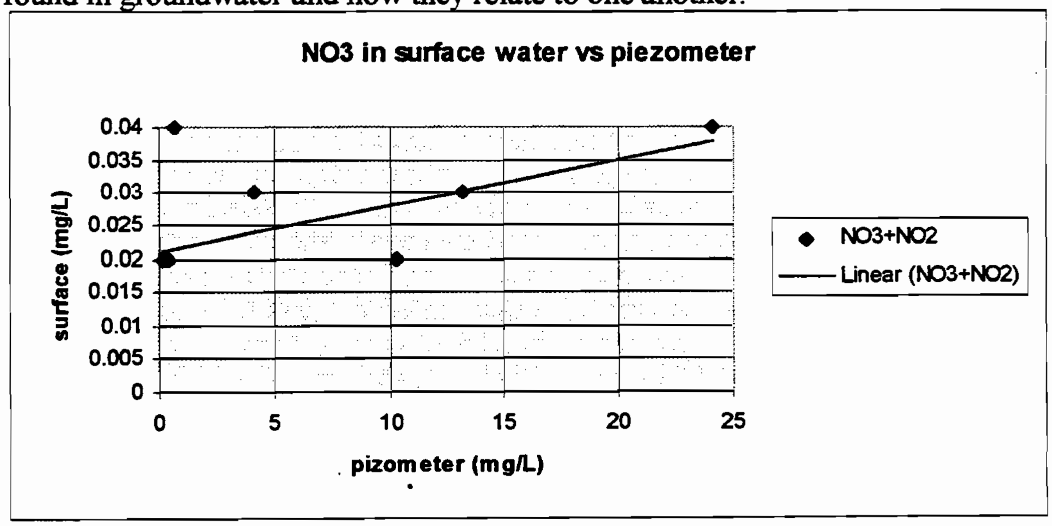
CHLORIDE

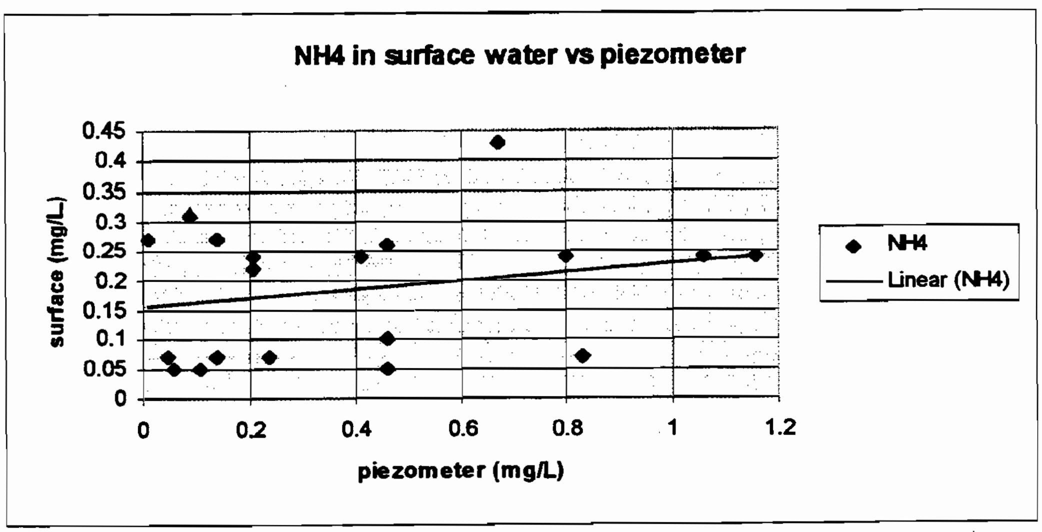
Chloride greater than 20 mg/L was found in groundwater associated with all septic system elevations as well as at all setback distances and ages. One reason for this is the fact that chloride was the chemical parameter used in the field to determine if a sample site was a potential area of septic system impact. However, a reason why relatively high chloride levels were found in many of the areas sampled is because chloride readily leaches into the groundwater which eventually reaches receiving bodies of water regardless of the contaminant source. The city of Minocqua uses a sand salt mix on the roads of Minocqua. The mixture consists of approximately only 7 percent sodium chloride but during an average winter 210 tons of sodium chloride is used. In addition to the city roads, the county highways are also treated with salt during the winter by the county highway department. These highways, such as highway 51, highway 70 and county highway J likely receive heavier salting than the city roads but all roads around Minocqua Lake receive some degree of salt during the winter. Because heavy road salting occurs in this area during the winter months, chloride can not be used exclusively to determine the presence of septic system plumes. However, when additional chemical data such as nitrogen and phosphorus, are coupled with the chloride data, distinctions can then be made between contamination from deicing salt and contamination from septic systems.

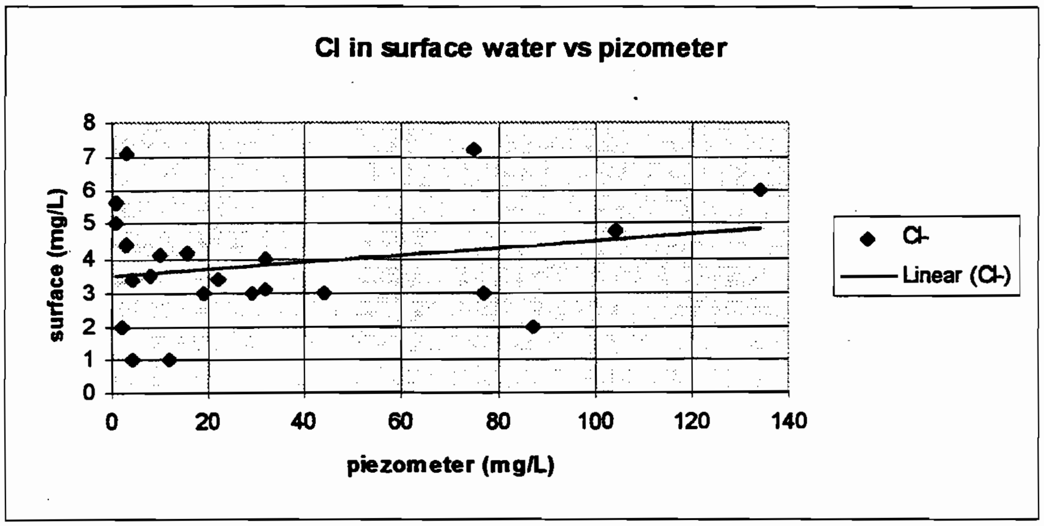
SURFACE WATER SAMPLES

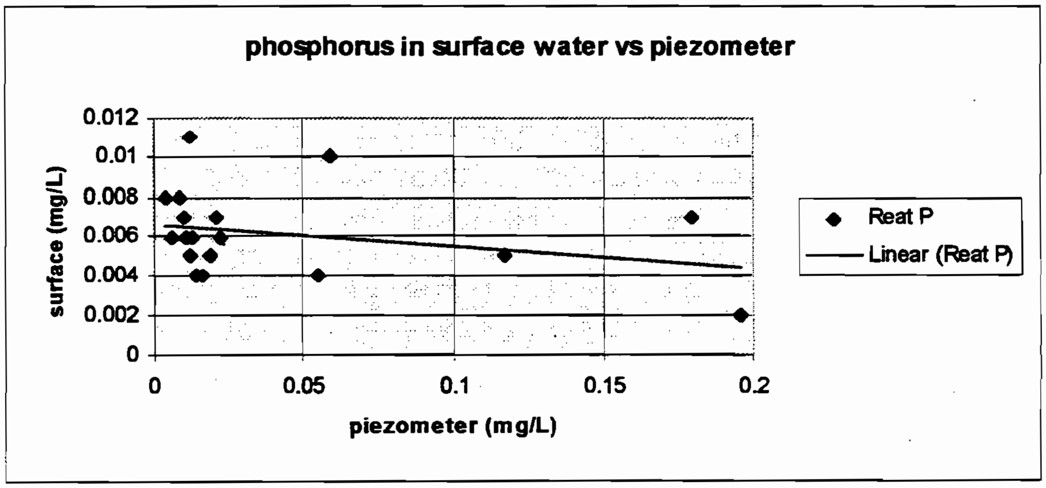
Surface water samples were taken to compare the groundwater flowing into the lake with the water in the lake. Because dilution and mixing with lake water occurs when groundwater flows into the lake contaminate levels in the lake were relatively low compared to that of groundwater samples taken from the piezometers. Another reason for the lower levels of nutrients in the surface water compared to that of the groundwater samples is the fact that the aquatic plants in the area are using these nutrients during the summer months when sampling took place. However, somewhat of a trend still exists between some chemical parameters found in groundwater and that found in surface water. Figure 14 shows the relationship between some chemical parameters found in surface water and how the relate to the piezometer data at the same sample site. The trends are not statistically significant but this may be explained by the vast amount of dilution and mixing that takes place as the groundwater enters the lake. It can also be explained considering the fact that aquatic plants area using the nutrients in the groundwater entering the lake, which also varies around the lake.

Figure 14. Scatter plots of various chemical parameters found in surface water verses that found in groundwater and how they relate to one another.









Nutrient concentrations found in the surface water of Minocqua Lake differ greatly around the lake. Table 6 summarizes the chemical data from the surface water sample sites that are illustrated in figure 15. In figure 16 it becomes evident that ammonium concentrations are highest in the back bay areas of the lake and where abundant aquatic plant growth is present. This is also true for concentrations of phosphorus found in the surface water of Minocqua Lake. Both reactive phosphorus and total phosphorus concentration are illustrated in figure 16. For the analysis of total phosphorus filtered samples were used so the concentration is not truly total phosphorus but total filtered phosphorus. Total phosphorus concentrations are slightly higher in most cases but it is assumed that these concentrations would be significantly higher if an unfiltered sample were analyzed.

PRIVATE WELL SAMPLES

Nitrate is the primary concern in drinking water supplies impacted by septic systems due to the health risks associated with elevated concentrations. Elevated concentrations of

Table 6

MINOCQUA SURFACE WATER SAMPLES

SITE	pH	cond.	T. Hard.	Alk.	NO3+NO2	NH4	Cl-	Reat P	Total P	Fluor.
1	7.75	98.4	72	48	0.03	0.27	1.0	0.012	0.016	24.0
2	7.56	96.6	44	44	0.02	0.24	1.0	0.011	0.019	22.2
23	7.45	94.7	44	40	0.04	0.31	3.0	0.008		18.8
20	7.61	100.0	48	48	0.02	0.26	3.0	0.005		17.0
10	7.68	112.0	48	44	0.02	0.24	5.0	0.010	0.017	18.4
11	7.50	113.0	44	44	0.03	0.27	6.0	0.006	0.014	16.9
4	7.99	98.2	48	40	0.02	0.22	3.0	0.007	0.016	17.1
9	8.09	102.0	48	44	0.02	0.24	3.0	0.007		17.2
3	7.80	97.5	48	44	0.02	0.24	2.0	0.006	0.016	19.0
22	7.50	94.1	44	44	0.02	0.24	2.0	0.006	0.017	17.5
5	7.63	100.0	44	44	0.02	0.16	4.0	0.007	0.008	16.0
6	7.90	102.0	44	44	0.04	0.07	3.5	0.006	0.027	3.0
13	8.61	116.0	44	48	0.02	0.10	7.1	0.006	0.012	3.5
16	7.48	265.0	116	88	0.02	0.07	3.4	0.005	0.009	3.0
14	7.84	104.0	48	52	0.02	0.05	4.1	0.004	0.004	3.5
12	8.05	106.0	44	52	0.02	0.05	4.4	0.004	0.006	3.0
8	8.17	105.0	44	52	0.02	0.43	4.8	0.002	0.042	3.0
21	8.42	111.0	44	48	0.02	0.07	5.6	0.005	0.013	3.5
15	7.96	107.0	44	48	0.02	0.05	4.2	0.004	0.004	3.5
19	7.94	101.0	44	48	0.02	0.04	3.4	0.006	0.006	4.0
7	7.94	113.0	44	48	0.02	0.05	7.2	0.008	0.010	3.5
18	7.94	102.0	44	48	0.02	0.07	3.1	0.005	0.018	3.0
17	7.87	100.0	44	48	0.02		3.3	0.005	0.005	3.5

Figure 15

MINOCQUA LAKE WISCONSIN
SURFACE WATER SAMPLE SITES

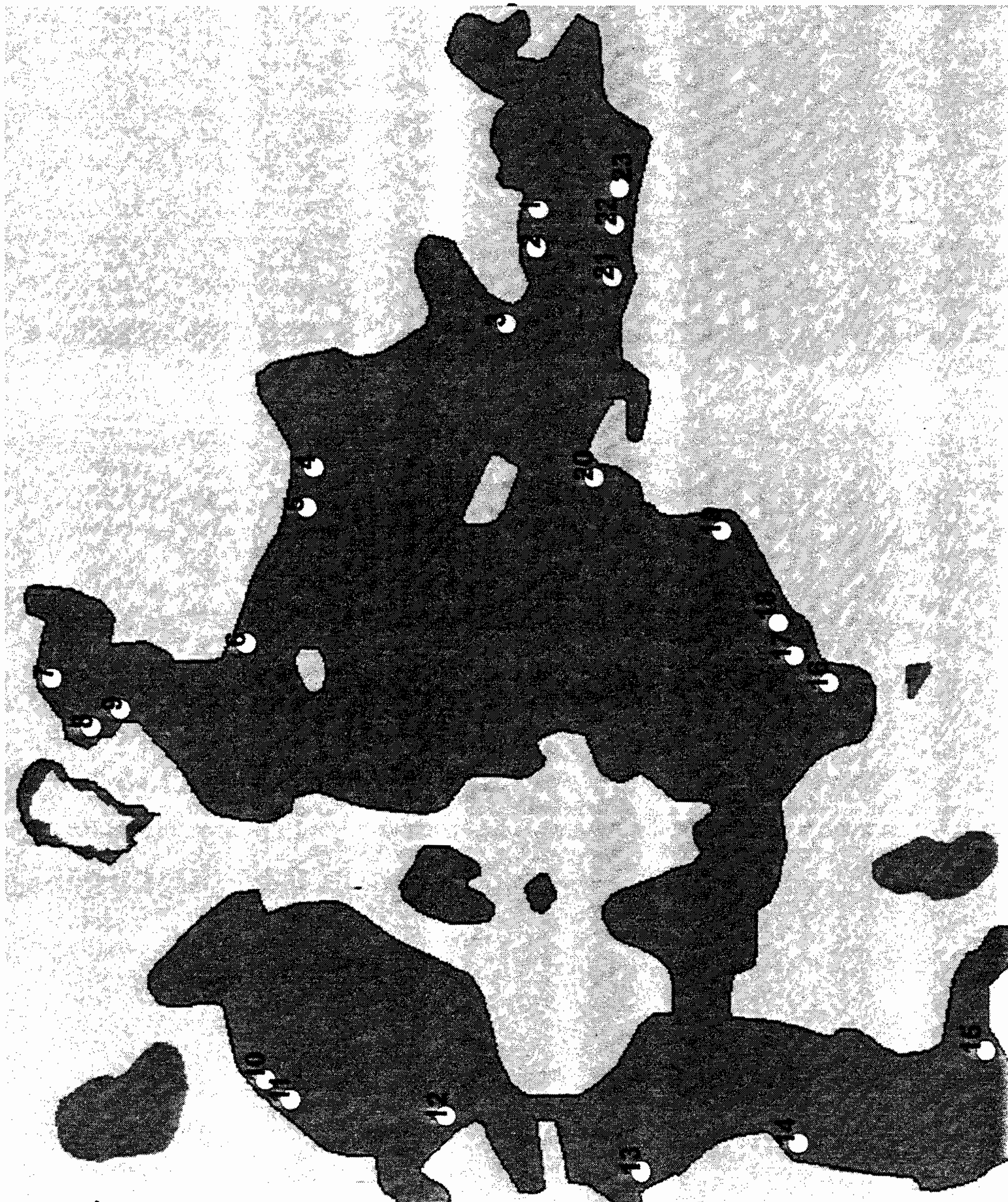
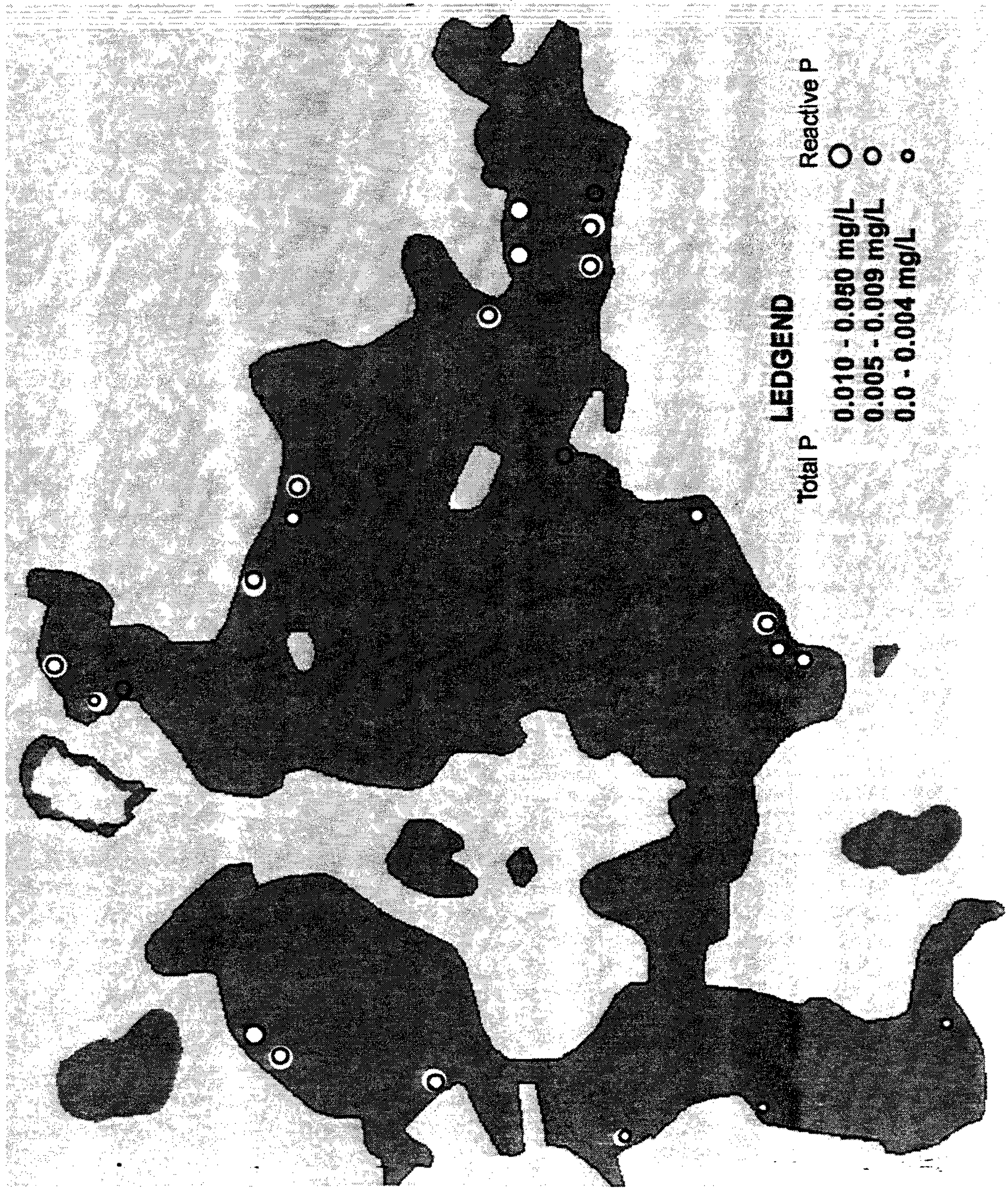


Figure 16

MINOCQUA LAKE WISCONSIN
AMMONIUM FOUND IN SURFACE WATER SAMPLES

Figure 17

MINOCQUA LAKE WISCONSIN
PHOSPHORUS FOUND IN SURFACE WATER SAMPLES



nitrates in drinking water have been associated with methemoglobinemin (Blue baby syndrome). Methemoglobinemin is of most concern in infants due to the relative high pH of an infant's stomach. Nitrate is converted to nitrite in the digestive system, which reacts with the hemoglobin in the blood converting it to methemoglobin. Methemoglobin in incapable of carrying oxygen like hemoglobin does which results in oxygen deprivation and possibly death. Due to this, the EPA issued an enforcement standard of 10 mg/L nitrate + nitrite nitrogen. Wisconsin also has a preventive action limit of 2 mg/L nitrate + nitrite nitrogen for drinking water supplies. Other health effects of excessive nitrate mentioned in the literature include birth defects and stomach cancer. Of the private wells sampled, only one exceeded the enforcement standard but others are approaching this level and exceed the preventive action limit.
Placement and depth of wells is critical to avoid contamination from septic systems. Because there is no regulation on whether wells are located up gradient or down gradient of septic systems, both situations were encountered around Lake Minocqua. Of the sites where the survey was conducted only 35 percent of the wells were found to be up gradient of the septic system serving the residence. This leaves 65 percent of the wells down gradient of septic systems, which increases the possibility of contaminated drinking water. Similar percentages were found of the wells that were sampled and analyzed. 33 percent of these wells were up gradient and 67 percent were down gradient. However, because the well is down gradient of the septic system does not mean that the well will be impacted by the septic system. Private well down gradient of septic systems stand a chance of not being contaminated for the same reasons problems exist when trying to locate septic system plumes at the lake shore. The well must be at the exact position and depth to intersect the septic system plume. This can be more clearly illustrated in figure 18. From this figure you can see that both wells A and B are down gradient of the septic system. However, well A is unimpacted by the septic system due to its depth, while well B is in the direct path of the septic system plume. This also shows that septic system contamination entering the lake does not always impact the well on the property. This is evident from the samples taken around the lake. Figure 19 is a map showing nitrate concentrations in both private well samples and mini piezometer samples. This shows that impact to the lake does not always show up in drinking water supplies.

AQUATIC PLANT SURVEY

An informal plant survey was conducted at the same time mini piezometer samples were being taken around the lake. The survey was only a visual survey to determine if aquatic plant growth related to areas of septic system impact. In general, aquatic plant growth was minimal in sandy or gravelly sediments to a depth of approximately 1.5 meters. However, at greater depths in these same areas aquatic plant density increased dramatically. Back bay areas contained the greatest aquatic plant density and number of species. The sediments associated with the majority of these sites were organic sediments. From this survey it was not obvious if septic system impact was directly related to species or density of aquatic plant growth. To determine this more in depth studies are needed concerning species and density of aquatic plant and how they relate to the concentration of nutrients entering the lake through groundwater and the nutrients contained in the sediments.

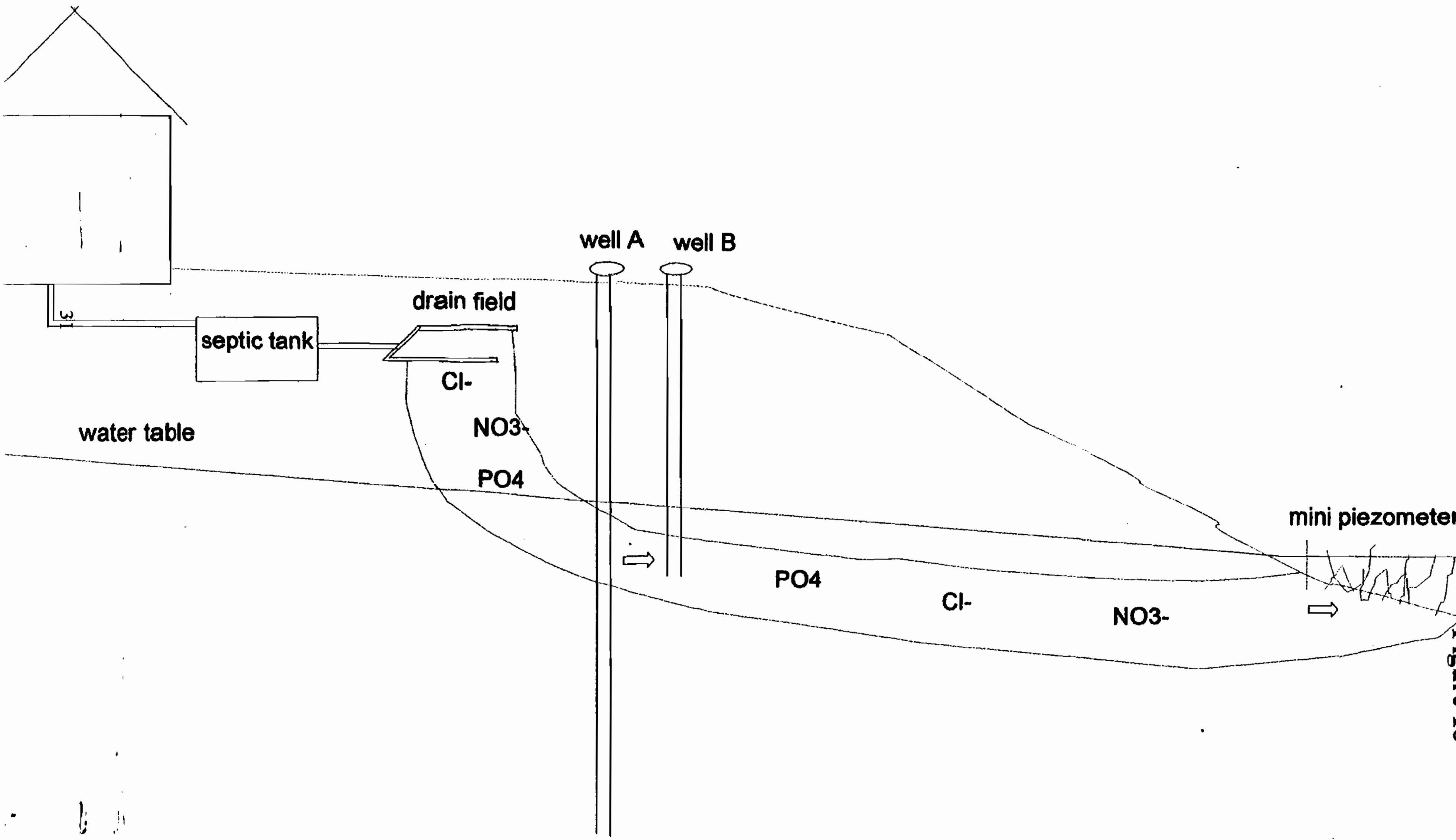
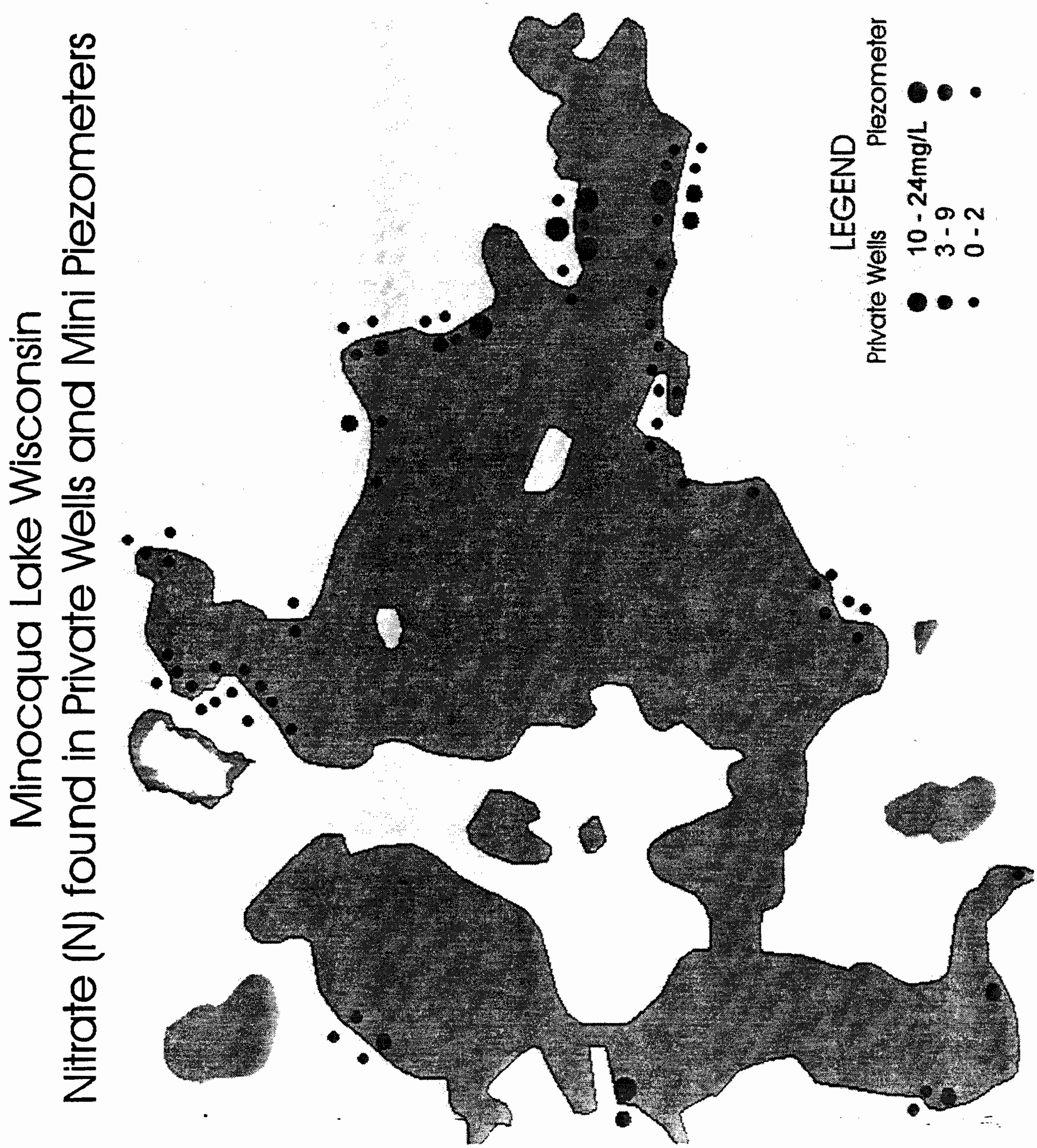

well A
well B
drain field
septic tank
Cl-
NO3-
water table
PO4
mini piezometer
PO4
Cl-
NO3-

Figure 18

Figure 19



Minocqua Lake Wisconsin
Nitrate (N) found in Private Wells and Mini Piezometers
LEGEND
Private Wells
Piezometer
10 - 24mg/L
3 - 9
0 - 2

CONCLUSIONS

It is difficult to quantify the amount of nutrients entering Minocqua Lake from septic systems. However, it is obvious from this study that increased amounts of nitrate, ammonium, phosphorus and chloride, which are indicative of septic system pollution, are entering the lake by groundwater flow. A number of sites investigated showed one or more nutrients to be in elevated concentrations in groundwater at the lake edge. Most of the sites showing these high concentrations could be associated with developed areas on septic systems. However, wetland seepage or urban areas where septic systems are not present may impact some sites. This is probable true in the area near the inlet to the lake and both east and west of highway 51 on the north of downtown Minocqua. Urban activity, storm water disposal and nutrient accumulation in wetlands with subsequent leaching are all potential impacts to groundwater and surface water that need to be considered in lake management. Therefore, it is possible that both septic systems and the natural processes going on around the lake and within the lake impact Minocqua Lake. It must also be taken into account the vast number of septic systems around Minocqua Lake. With the majority of these septic systems installed in the 70's and 80's the problems associated with septic system pollution will only become greater in the future. There are septic systems we surveyed that do not meet current codes, and most likely more that we were not allowed to investigate. However, it was shown in this study that a septic system meeting all current codes with no evidence of failure can contribute elevated concentrations of nutrients to the lake. Previous studies by WDNR demonstrated that the phosphorus load to the lake is only about 7 percent from septic systems. It is however important when looking at lake eutrophication to consider the nutrient inflow to the shallow water zone from groundwater as this is the area where most nucence growth of aquatic plants occur. This study shown elevated concentrations of nutrients entering the shallow zone. It is however, not clear as to whether there is significant negative impact on aquatic vegetation to warrant any action. As septic system drainfields are used for more years by more people the absorption sites will become saturated with nutrients leading to more transport to the lake.

To prevent septic systems from impacting the lake requires either greater set back of drainfields from the lake which allows more soil for the adsorption of nutrients, or the use of holding tanks or advanced on site treatment systems, or sewer collection systems. All of these options are expensive and have their own associated problems of where to dispose of the waste. Land may not be available for greater set back distances and holding tanks and sewer systems only divert the problem to other areas.

Lake residents need to decide if some increases in aquatic plant or algae growth from continued use of septic systems is more acceptable than the cost associated with alternative ways of disposing of human waste.

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