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SEWRPC Staff Memorandum

WATER QUALITY SAMPLE EVALUATION FOR SILVER LAKE, WAUKESHA COUNTY

INTRODUCTION

Silver Lake is a 222-acre lake located in the Town of Summit in Waukesha County. It is a seepage lake, meaning that it has no defined inlet or outlet, and that its water is supplied primarily by groundwater inputs (through springs), as well as, to a lesser extent, by direct precipitation on the Lake's surface and on the surrounding lands. Silver Lake lies within the larger Oconomowoc River drainage area and is within easy reach of both the Oconomowoc and Milwaukee metropolitan areas. The Lake community has adequate public access provided through a WDNR-owned public recreational boating access site and is the focal point for water-based recreation in a lake-oriented residential community.

Water quality has been an ongoing concern by the Lake's residents and the Silver Lake Management District. This is evidenced not only by controversy that has historically taken place in and around the Lake with relation to potential pollution sources,[1] but also by the fact that the Town encouraged the installation of a public sanitary sewerage system, operated by the City of Oconomowoc,[2] for the specific purpose of protecting the Lake from phosphorous pollution. As a result of this concern about water quality, the Silver Lake Management District has been engaged in Citizen Lake Monitoring since 1990, thereby providing nearly 25 years of water quality data for the Lake, with a brief break in data between 2000 and 2005. This data has provided the opportunity to understand how the management and land use changes that have been made in and around the Lake have impacted the Lake's "health."

In addition to the Citizen Lake Monitoring efforts, which focus on monitoring the surface water quality directly above the deepest part of Lake, the Silver Lake Management District received a WDNR Small Scale Lake Management Grant in 2010 for the specific purpose of monitoring the water quality of drainage pipes and other areas of concern, which were flowing directly into the Lake, generally after rain events. The study was undertaken to identify specific sources of pollution and to quantify the influence they could have on the Lake's overall water quality.

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[1] *"Relief Seen For Drainage Problem,"* Enterprise, *Oconomowoc, Wisconsin, June 13, 1974; "Town Board Authorizes Legal Action," January 13 1975; and "Legal Move Asked on Golf Course–Summit Wisconsin,"* Sentinel–*Waukesha Bureau, April 7, 1979.*

[2] *SEWRPC Community Assistance Planning Report No. 17, 2nd Edition,* Sanitary Sewer Service Area for the City of Oconomowoc and Environs, Waukesha County, Wisconsin*, September 1999, as amended.*

This report seeks to summarize the water quality data that was collected, from 2011 to 2013, as a part of this monitoring effort, and seeks to compare the values found with current and historic water quality values within the Lake. In addition to summarizing this data, this report provides recommendations for "next steps" in terms of further monitoring, management of the water quality in Silver Lake, and identifying potential future issues of concern.

PROJECT DESCRIPTION AND GOALS

The objectives of this study, as described in the grant proposal, were:

1. To quantify the extent of any existing water quality problems being experienced in the Lake, and determine current water quality status based upon (volunteer) physical-chemical monitoring data (i.e., use monitoring efforts to determine the current "health" of the Lake); and

2. To quantify the extent and possible nature of the contaminants entering the Lake from the unnamed tributary that enters Silver Lake via the Paganica Golf Course and neighboring residential developments.

While the first objective was completed as described above, the second objective was altered upon implementation of the monitoring efforts. More specifically, two other areas of concern, in addition to the Paganica golf course tributary, were added to the monitoring efforts as potential sources of pollution. These areas include a drainage pipe entering the Lake along the eastern shore of the Lake, which was identified as a potential source of commercial development runoff, and a drainage pipe entering the Lake in the southeastern corner of the Lake, which was identified as a potential source of urban pollutants resulting from the upstream highway system. These changes are reflected in this report and therefore change the scope of this study to, not only quantifying contaminants entering the Lake from the Paganica golf course, but also quantifying potential contamination entering from the eastern shore of the Lake.

METHODOLOGY

The monitoring study discussed in this report focused on three specific areas, featuring a total of eight sampling sites, including an in-lake site, as shown in Map 1. Each sample site was chosen to represent a particular area of concern and therefore reflect the different sources of water runoff and potential sources of pollution. The eight sites, as well as which runoff sources they represent, are shown in Appendix A and include: three sites downstream from the Paganica golf course; two sites at a tributary just north of the Summit town hall and two sites on the tributary entering the Lake at the southeast corner.

Water samples from the various sites were collected on seven different field days, including April 25 and August 9, 2011, March 25 and May 6, 2012, and May 4, June 16, and July 16, 2013. The collected samples were then analyzed by the Water and Environmental Analysis Laboratory of the University of Wisconsin-Stevens Point using standard protocols and methods. Chlorides, conductivity, nitrogen fractions, phosphorous fractions and total suspended solids were measured in all of the samples, while alkalinity, color, turbidity, pH, potassium, sulfate, sodium, and total and calcium hardness were analyzed only for the "In-Lake Deep Hole" site. Table 1 shows what samples were taken and what they were tested for. It may be noted that not all of the sites were sampled at each field day; this is due to the fact that the two wetland sites were not added to the site list until the summer of 2012, and due to the fact that only some of sample sites were flowing on some of the field days.

Map 1

LOCATION OF SAMPLING SITES IN SILVER LAKE, WAUKESHA COUNTY

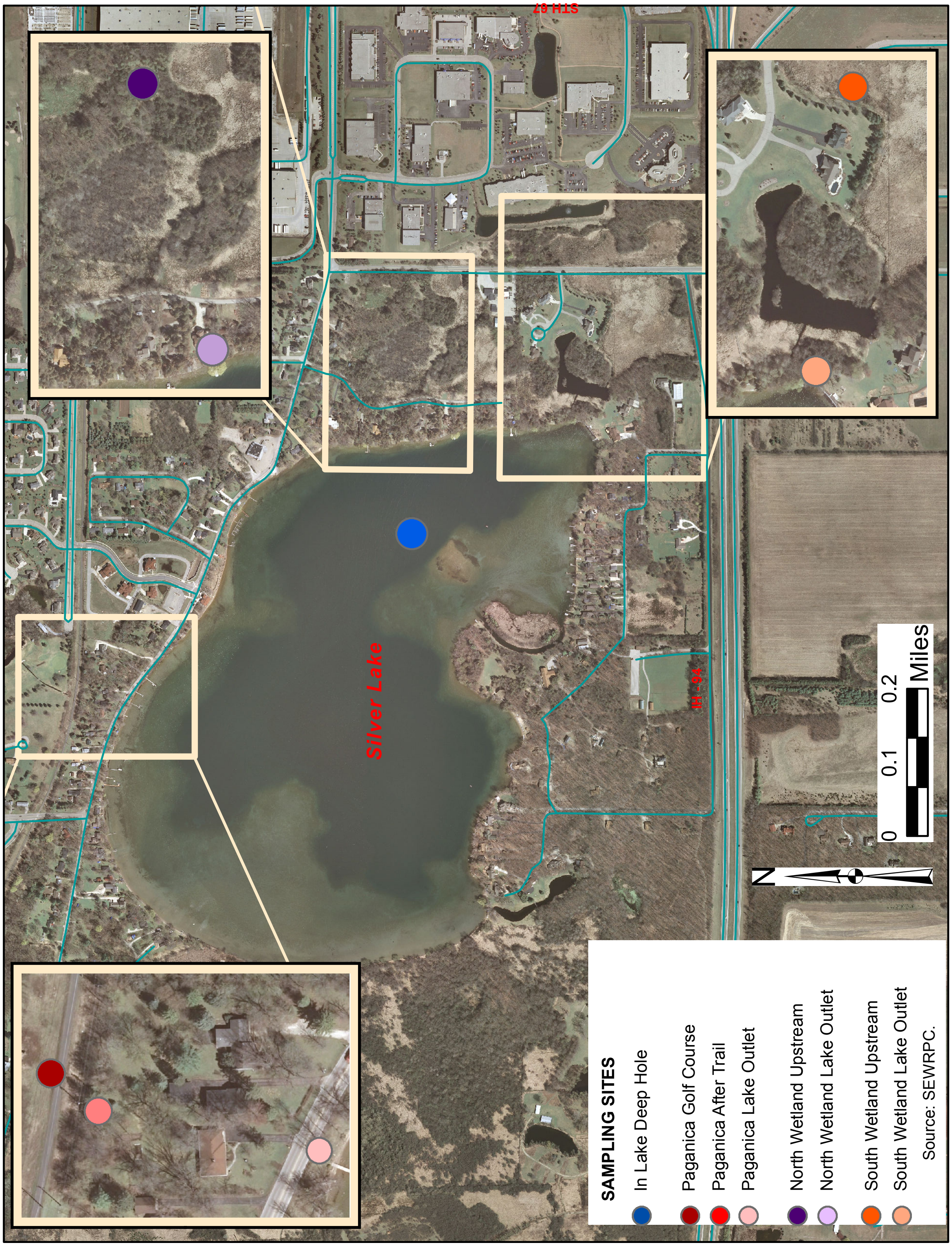

Table 1

PARAMETERS MEASURED AT SILVER LAKE SAMPLING SITE FOR EACH FIELD DAY

Site	04/25/11	08/09/11	03/25/12	05/06/12	05/04/13	06/16/13	07/16/13
Deep Hole	Alk, NH_4^+, CH, Cl^-, Color, Cond., N, pH, K^+, SRP, Na+, TH, TKN, TP	NH_4^+, CH, Color, Cond., N, Na+, SO_4^{2-}, TH	Alk, NH_4^+, CH, Cl^-, Color, Cond., N, pH, K^+, SRP, Na+, SO_4^{2-}, TH, TKN, TP, Turb.	NH_4^+,Cl^-, Cond., N, SRP, TKN, TP, TSS	NH_4^+, CH, Cond., K^+, TH, TKN, TP	NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS	NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS
Paganica Golf Course	NH_4^+, Cl^-, N, SRP, TKN, TP, TSS	NH_4^+	NH_4^+, Cl^-, N, SRP, TKN, TP	NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS	NH_4^+, CH, Cond., K+, TH, TKN, TP	NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS	NH_4^+, Cl^-, Cond., N, K+, TKN, TP, TSS
Paganica after Trail	NH_4^+, Cl^-, N, SRP, TKN, TP, TSS		NH_4^+, Cl^-, N, SRP, TKN, TP	NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS	NH_4^+, CH, N, K+, TH, TKN, TP	NH_4^+, Cl^-, Cond., N, K+, TKN, TP, TSS	NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS
Paganica Lake Outlet	NH_4^+, Cl^-, N, SRP, TKN, TP, TSS	NH_4^+	NH_4^+, Cl^-, N, SRP, TKN, TP	NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS	NH_4^+, CH, Cond., K+, TH, TKN, TP	NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS	NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS
Northwest Wetland Upstream				NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS		NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS	NH_4^+, Cl^-, Cond., N, SRP, TP, TSS
Northwest Wetland Lake Outlet				NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS		NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS	NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS
Southeast Wetland Upstream				NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS		NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS	NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS
Southeast Wetland Lake Outlet				NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS		NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS	NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS

NOTE: The following abbreviations have been used:

Alk = Alkalinity
NH_4^+ = Ammonium
Cl^- = Chloride
CH = Calcium Hardness
Cond. = Conductivity
N = Nitrate + Nitrite
pH = pH (S.U.)
K^+ = Potassium
SRP = Reactive Phosphorus
Na^+ = Sodium
SO_4^{2-} = Sulfate
TH = Total Hardness
TKN = Total Kjeldahl Nitrogen
TP = Total Phosphorus
TSS = Total Suspended Solids
Turb. = Turbidity (NTU)

Source: SEWRPC.

RESULTS AND DISCUSSION

As mentioned above, the purpose of this study is to evaluate the conditions in Silver Lake, identify potential issues of concern, and evaluate potential contamination sources. The results of this study are therefore organized into two sections. The first relates to evaluating the water quality and chemistry of the Lake itself and determining the general condition of the Lake as well as if there are any issues that should be deemed a concern. This will be important in order to provide a context for understanding the data that was collected at the "areas of concern." The second relates to the evaluation of the three areas of concern in comparison to the corresponding In-lake measurements in order to determine if any of these sites could be sources of pollution.

In Lake Data

As mentioned in the introduction, there is water quality data dating back to the late 1960s in Silver Lake, including a sampling period between 1968 and1974, a sampling period of 1990 to 2000, and an ongoing sampling period from 2005 to today. In addition, in lake monitoring was conducted on each of the field dates included in this study. Through examining this data, it is possible to determine:

1. The characteristics of Silver Lake;

2. The overall water quality of the Lake; and

3. How water quality has changed over time (indicating how effective management efforts have been).

This section seeks to complete these determinations by evaluating the historic Lake data as well as the samples found during this study.

Natural Lake Chemistry

There are several parameters that provide insight into the natural state of a lake. In particular, this means that, barring extensive human interference, there are types of measurements that tend to remain fairly constant over time. This is due to the fact that certain characteristics are primarily influenced by the source of the water contributing to the lake, rather the biological components in the lake. A lake which is naturally, surrounded by calcium carbonate (a specific type of rock), or is fed by groundwater coming from a calcium carbonate aquifer, for example, will naturally contain a higher amount of calcium carbonate deposits which in turn can influence pH, alkalinity, calcium, hardness and, to an extent, color. These parameters therefore depend more on the natural conditions than human influence, and can therefore provide insight into lake types and characteristics. These parameters, as well as the findings for each of them within Silver Lake, are further discussed below.

Total Hardness

Total Hardness is a measure of combined concentrations of calcium, magnesium, and various metals dissolved in lake water. Generally hardness of water is often highly influenced by the soils and bedrock of the lake's watershed and the aquifers beneath it. In the southeastern Wisconsin region, lakes traditionally have high hardness due to the limestone and dolomite deposits (rocks containing both magnesium and calcium) which make up much of the underlying bedrock in this area.[3] High levels of hardness can cause scaling in boilers and other equipment as well as increase soap or detergent requirements for washing[3]. Generally lakes with harder water produce more fish and plants than those with softer water.

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[3] *H.S. Garn, D.M. Robertson, W.J. Rose, G.L. Goddard, and J.A. Horwatich,* Water Quality, Hydrology, and Response to Changes in Phosphorus Loading of Nagawicka Lake, A Calcareous Lake in Waukesha County, Wisconsin, 2006, *U.S. Geological Survey Scientific Investigations Report 2006-5273*.

General guidelines for classifications of water hardness are: 0 to 60 mg/L is considered soft, 61 to 120 mg/L is moderately hard, 121 to 181 mg/L is hard, and more than 180 mg/L is very hard.[4] Total hardness was measured at the Deep Hole site on April 25, 2011 and March 25, 2012. 240 mg/L were found on both dates indicating the Lake is "very hard." This is expected due to groundwater being the major water source to the Lake. These levels are slightly higher than the historic average of 231.7mg/L which was found in the late 1970s. However, the value is within the historic range of 155 to 297mg/L.

pH

pH is the measure of the acidity or basicity of water; ranging from 0-14 where 7 is neutral, below 7 is acidic, and above 7 is basic. Natural waterbodies generally have a pH in the range of 6.0 to 8.5 with southeastern Wisconsin region lakes generally staying above 7.0. pH is important because it affects the chemical and biological components of the system. Lakes becoming more acidic from acid rain deposition (the most common reason for lake pH changes), for example, can cause heavy metals to more readily dissolve from surrounding sediments and rocks thereby causing in-lake metal concentrations to rise. Very high heavy metal concentration can then become toxic to plants and animals that live in and around the lake, thereby destroying the lake's natural ecosystem. Biologically speaking, pH also affects plant growth due to the fact that the availability of nutrients for organisms is dependent on the pH level; 6.5 to 8.0 is the productive range for most organisms.[5]

The pH of the "In-Lake Deep Hole" site was measured on April 25, 2011 and March 25, 2012 at 8.2 and 8.37 respectively. These basic values are very consistent with the historical average for the Lake of 8.3. This indicates that the Lake is not being affected by acid rain.

Alkalinity

Alkalinity, sometimes termed as "buffering capacity," is the ability of a lake to absorb and neutralize acidic loadings, or resist changes in pH with the addition of acid (most commonly deposited in the form of acid rain). Like with hardness, a lake's alkalinity is often highly influenced by the soils and bedrock of the lake's watershed causing the southeastern Wisconsin region lakes to traditionally have high alkalinity, averaging around 173 mg/L. A few low-alkalinity lakes do, however, exist in the northern regions of Wisconsin.

Alkalinity was measured on two different dates in the "In-Lake Deep Hole" sample site only. A value of 204 mg/L was found on April 25, 2011, indicating low sensitivity to acid rain and a value of 176mg/L was found on March 25th, 2012 indicating moderate sensitivity to acid rain. These numbers are slightly better than the average for the region, which is likely due to groundwater being the primary source of water in this Lake, thereby increasing the amount of deposits in the Lake water. These values are also slightly higher than historic number values. This could be due to an increased proportion of the water supply to the Lake being restricted to groundwater inputs. Considering the amount of detention basins that have been placed around the Lake since the 1970s (see Appendix B), this is likely the case.

Calcium

Calcium levels (calcium ions dissolved in the lake water) are highly correlated to hardness and alkalinity of water. This is due to the fact that dissolved calcium is found in calcium carbonate (the main mineral which is responsible for hard and alkaline lakes). Dissolved calcium is important to lakes as it has been shown to be influential on the life cycle of a microscopic crustacean called Daphnia. Commonly known as "water fleas" due to their quick and

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[4] *SEWRPC Technical Report No. 39,* Water Quality Conditions and Sources of Pollution in the Greater Milwaukee Watersheds*, November 2011.*

[5] *H. Perlman*, pH - Water properties, *U.S. Department of the Interior/U.S. Geological Survey, March 2014.*

sporadic swimming motion, Daphnia are important to lakes like Silver Lake because they eat algae. In general, calcium concentrations of at least 10mg/L need to be present for Daphnia to complete their lifecycles.[6]

Calcium levels were measured at the deep-hole site on March 25 2012. They were found to be 35.4 mg/L which was well within the historical ranges of 30-57 found in the 1970s and just above the ranges found in the 1990s to the 2000s (30-34). This value is also most definitely high enough to support daphnia.

Color

Color is an important characteristic which can provide information about a lake and affect water transparency. The color of lake water is due to dissolved and suspended materials in the water, similar to color variation of different types of tea. Highly colored water limits the depth to which light penetrates and reduces water clarity, having significant negative effects on aquatic plant and therefore the entire lake ecosystem. Transparent water with low dissolved and suspended materials appears blue. Dissolved organic material such as leaves, roots and plant remains can produce a yellow or brown color such as is common in northern Wisconsin lakes. Water rich in plankton and other algae often appears green but can occasionally be other colors due to chemicals produced by the algae. Soil runoff can also produce a variety of yellow, red, brown or gray colors depending on the soil material.

It is important to note that color is not necessarily associated with pollution; in contrast, water color is often more correlated with the area the water came from and how long the water has been in contact with soils and/or organic material, e.g. leaves and grass clippings, in general. In fact, color and cleanliness can sometimes even have an inverse relationship between color and water quality (i.e., the darker the water gets the cleaner it is). Water which sits in a detention basin or a wetland, for example, will have constant and long term contact with organic material and high amounts of decomposing materials. These organic materials, such as plants, will then naturally use up nutrients and other pollutants, thereby making long-term contact with these materials extremely beneficial in terms of water quality. However, this long-term contact will then cause water to get even darker in color (like leaving a teabag in the cup too long) thereby making the darker water "cleaner."

This is not to say that darker water is always clean. Water can also become colored due to algae or suspended soil particles, i.e., erosion; however, it should be noted that sometimes brown water coming into the Lake is not a bad thing. This will help put some of the discussion in the "sample sites" section into perspective.

Several color scales have been developed over the years to measure and compare the color of lake water. The most commonly used scale in the United States uses platinum units with values ranging from 0 units for very clear lakes to 300 units for heavily stained, organic rich, wetland water. Lakes in the southeastern Wisconsin region average 46 units, based on data collected statewide between 1966 and 1979.[7] The color of Silver Lake was recorded as very clear with a value of less than 5 and 7.2 found on April 25, 2011 and March 25, 2012 respectively. This indicated a very healthy lake with excellent water clarity. These colors were further corroborated with color recording that have been made through the citizen lake monitoring activities. These records indicate that the water is almost always blue, with some recordings of green during high growth seasons. This indicates Silver Lake has high quality water that supports a productive aquatic plant population.

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[6]*D.O. Hessen, N.E.W. Alstad, and l. Skardal, "Calcium limitation in Daphnia magna."* Journal of Plankton Research*, Volume 22, 2000, pp. 553-568.*

[7]*R.A. Lillie and J.W. Mason, Wisconsin Department of Natural Resources Technical Bulletin No. 138,* Limnological Characteristics of Wisconsin Lakes, *1983.*

Stratification and Mixing

In the summer, lakes sometimes develop different temperatures at different depths. This generally happens because sun rays and warm air temperatures can only reach down to a certain depth of the lake, thereby leaving the water below that depth to have colder temperatures than the water above it (i.e., the deep water stays the same temperature while the top waters get warmed). This process can sometimes be felt when swimming in the deep end of lakes in the summer (i.e., your feet and legs go into a cold area while your upper body is still in the warm area). Incidentally, this process can also happen in the winter due to air temperatures and ice being colder than the water below it, thereby causing the opposite pattern (i.e., deep water staying the same and the surface water getting colder).

Once this process occurs the different water temperatures cause different water densities (i.e., the warm water becomes less "compact" than the colder waters). These different densities then cause the water at the surface of the lake and the deeper waters to form a physical separation from each other, i.e., the warm surface layer (the epilimnion) and the cold deep layer (hypolimnion) layers do not mix. Over all this process is called stratification.

Stratification, however, does not occur in all lakes. In fact its presence in a lake is highly dependent on two factors:

1. The depth of the lake; when the sun rays and air temperatures are able to reach down to the bottom of the lake the entire water body is warmed (causing there to be no difference between the surface and the deep water); and

2. Wind speed/ the amount of area and length of the lake the wind comes in contact with; when a lake has a large surface area, and/or wind is strong, this can cause a "mixing" of waters, i.e., pushing of surface waters to the bottom, thereby preventing the stratification process. Ice cover can actually make this type of mixing impossible in the winter thereby making stratification in the winter more common in northern lakes (where ice cover occurs).

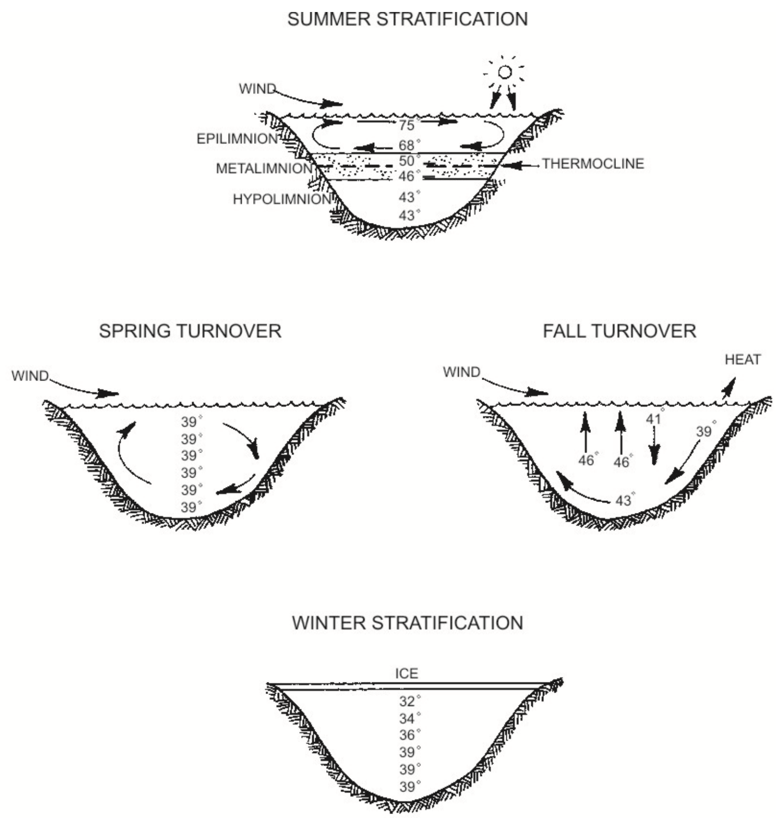
When the stratification process does occur in a lake, it is generally followed by a natural mixing period in the fall and the spring. This is either because: 1) The air temperatures and sun ray contact reduces during this time (in the fall and spring), thereby reducing the surface water temperature and density differences between the two layers and allowing the waters to mix again; or 2) the ice melting in the spring allows for wind to contact the water again causing the water to move more and in turn mix. The overall stratification process is shown in Figure 1.

It is important to know if a lake stratifies due to the barrier which forms. This barrier not only prevents water from moving between different depths, but also prevents the dissolved gases and nutrients in that water from moving through the layers as well. When a lake is well mixed, for example, this allows the oxygen from the air, as well as the oxygen being formed by aquatic plants, to be present throughout the entire depth of the lake. However, when the barrier forms, this prevents the oxygen from getting to the deep depths. This is a particular issue because a lot of oxygen is used at the bottom of a lake for the decomposition of plants and debris which fall to the bottom of the lake. With no oxygen to replenish this supply, oxygen is used up and no longer available at the bottom of the lake, i.e., the lake becomes anoxic.

As some fish, like trout, require both oxygen and cold temperatures to live, high amounts of stratification may make it difficult to support some kinds of fish. Additionally, if the anoxic part of the lake becomes too large and making the entire lake anoxic this can cause fish kills. Additionally, these conditions also spur anaerobic decomposition, i.e., bacteria decompose dead plant material without the use of oxygen, thereby causing high amounts of ammonium (nutrients) and sulfates to accumulate at the bottom of the lake. These chemicals, which cause that "rotten egg" smell, can then rise to surface during spring and fall mixing periods ("turnovers") making the lake particularly unpleasant.

Figure1

ILLUSTRATION OF LAKE MIXING PERIODS



Most deep lakes have a degree of what is called stratification in the summer, i.e. separation of the water column into chemical and temperature barriers due to heating of the surface of the lake with the deep waters remaining cool. This separation often causes nutrients and chemicals to get stuck deep at the bottom of the lake. These periods are normally followed by mixing in the periods in the spring and fall which cause the bottom water to mix with the top. Peak nutrient values can therefore be found during mixing periods.

Source: University of Wisconsin-Extension and SEWRPC.

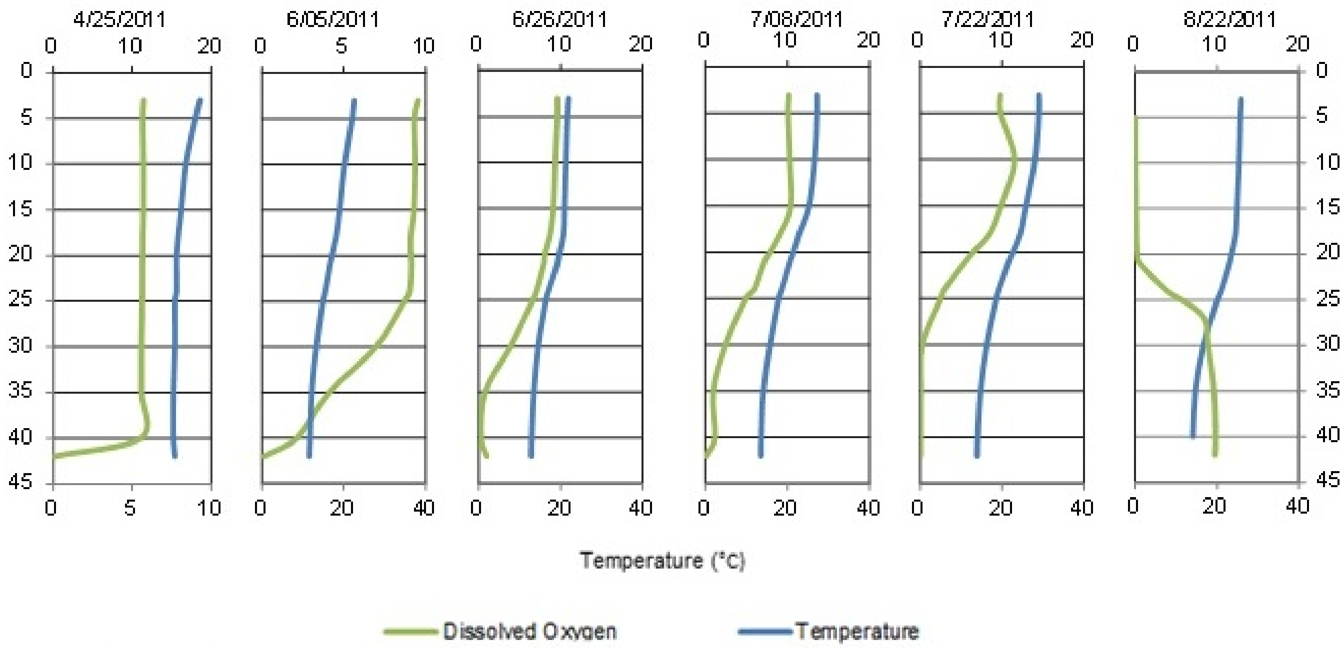
Stratification can be confirmed by taking measurements, namely oxygen and temperature, at various depths in the lake, creating what is known as a depth profile. In stratified lakes, this profile, when looked at graphically, will show a drastic decrease in temperature at a particular depth (known as the thermocline). This same decrease will also likely be found in the dissolved oxygen profile. When taking these measurements it is important to monitor how high the anoxic layer is getting in order to prevent possible fish kills.

Temperature and dissolved oxygen profiles have been consistently collected in Silver Lake since 2006. Consequently, as can be seen in Figure 2, it can be definitively concluded that Silver Lake is stratified and exhibits mixing periods in the spring.

Trophic Status (biological productivity)
Another component of understanding the state of a lake is through examining its trophic status. This status essentially refers to the amount of biological activity a lake can sustain and are generally used to describe the

Figure 2

STRATIFICATION IN SILVER LAKE



Source: SEWRPC.

"quality" or "cleanliness" of water. There are three major trophic categories each representing a different level of biological productivity, including:

1. Oligotrophic, which are lakes low in nutrients and therefore unable to support extensive biological activity both in terms of plants and animals (generally characterized as "high-quality water");

2. Mesotrophic, which are lakes with a moderate amount of nutrients which can maintain a good amount of biological activity (generally characterized as "high- to medium-quality water"); and

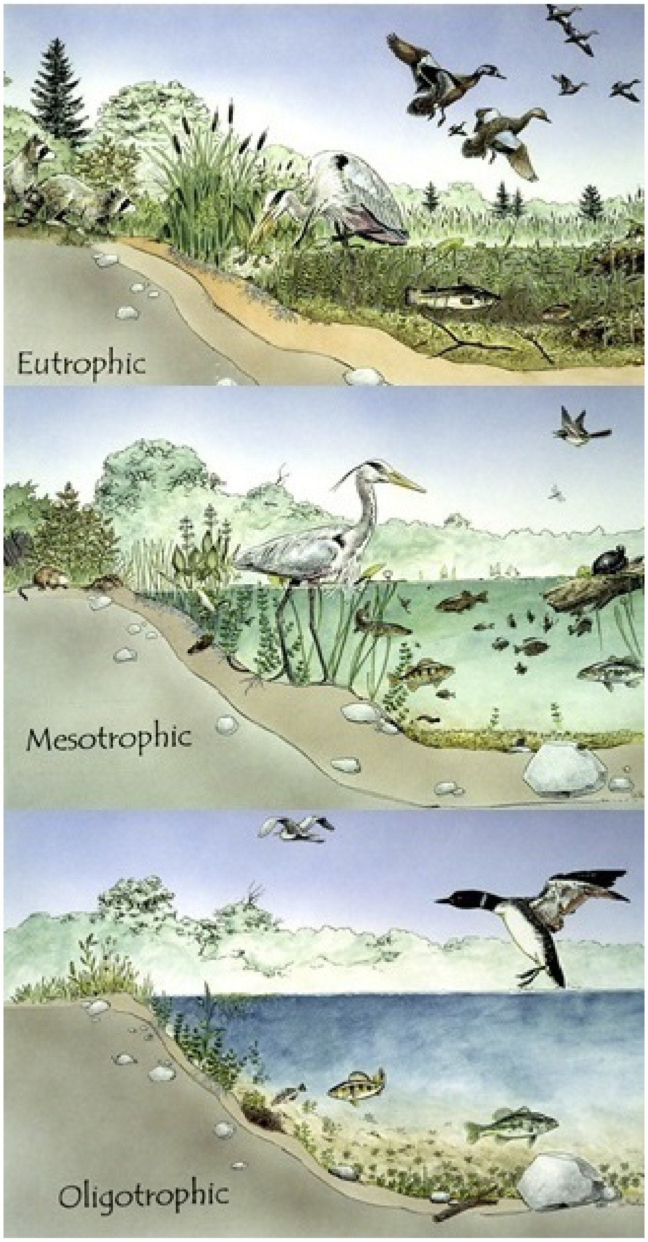
3. Eutrophic, which means that the lakes has high amount of nutrients and can support an extensive amount of plant and wildlife (generally characterized as medium- to low-quality water).

Figure 3 illustrates the biological difference between these characterizations.

As can be seen in the description of the trophic statuses, the major differing component is the presence of nutrients within the lake. This is due to the fact that plants and algae, which serve as habitat and food for wildlife, need nutrients in order to grow. Therefore, when high amounts of nutrients are present, plants grow more thereby creating a more biologically productive lake. Lakes can naturally be any of these three trophic statuses depending on the age of the lake (see Figure 4) and on conditions in and around the lake. For example, a lake which is generally in a marsh and/or a wetland with high organic material may naturally be eutrophic thereby resulting in a lake that may be covered by plants which then in turn supports an active fishery and wildlife hotspot. In contrast an area with little natural nutrient sources and very clear waters, for example a seepage lake like Silver Lake, would likely naturally be considered oligotrophic or in the low range of mesotrophic, as it would likely not have

Figure 3

ILLUSTRATION OF TROPHIC STATES



Source: DH Environmental Consulting, 1995.

natural sources of nutrients. These kinds of lakes would then by incapable of supporting extensive wildlife. Generally, eutrophic lakes are really good fishing lakes due to high amount of plant based fish habitat, while oligotrophic lakes are good recreational boating lakes due to low amounts of plant based navigational hazards.

Though trophic statuses happen naturally, human interference can cause shifts in trophic levels. This normally occurs when unnatural nutrient inputs such as phosphorous and nitrogen containing fertilizers, erosional deposits (i.e., increasing nutrient filled soils which get into the lake through poor land use), septic contamination, and pet waste enter the lake. This input of nutrients can then cause a lake to be more productive (go from oligotrophic to eutrophic) or even cause a lake to become "hyper-eutrophic." A hyper eutrophic lake (see Figure 5) is a lake which has so many nutrients that the plants and algae (particularly single cellular algae) grow so quickly that they cause biological problems. For example, the biomass of plants and algae can get so high that decomposition of plant material at the bottom of the lake takes up all of the oxygen in the lake. As fish depend on oxygen, this occurrence would result in fish kills. Hyper-eutrophic status does not happen naturally and is an indication of poor land use and practices in the land area surrounding the lake.

Trophic Status Indicators

Three parameters are commonly used as indicators of trophic status and water quality in general; water clarity, phosphorous levels and chlorophyll-*a* levels. Each of these parameters, as well as their interpretation, is further discussed below.

Water Clarity

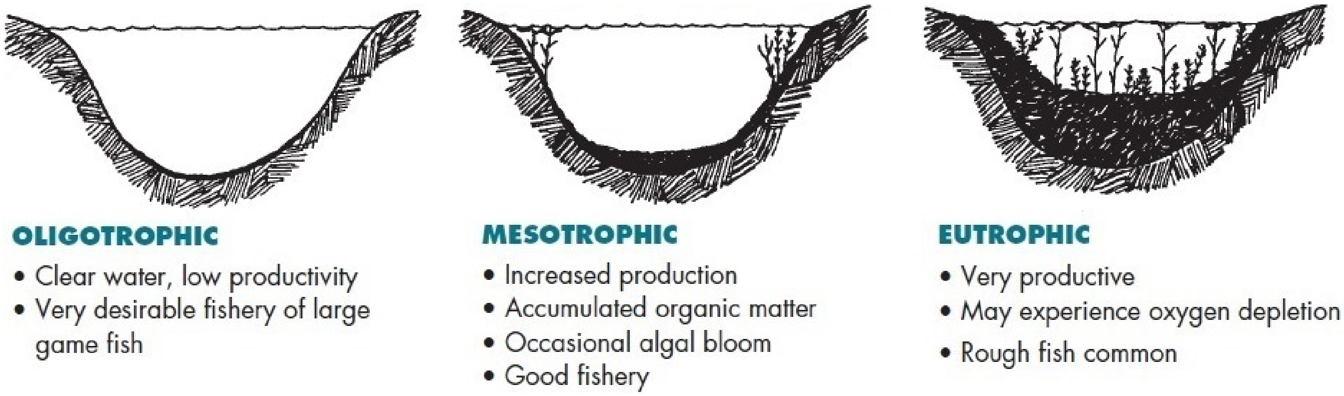
Water clarity is measured by lowering a black and white disk called a Secchi disk into the lake at the deepest point of the lake and recording when the disk is no longer visible. This measurement is an indicator of water quality due to the fact that water clarity can be affected by pollution and high algae growth, things that are generally present in "impaired lakes." As can be seen in Figure 6, the Secchi disk measurements (i.e., water clarity) has been increasing over time, with the most recent measurements ranging from two feet to 10.5 feet. This not only indicates current, good water quality but also that the water quality in the Lake has generally been getting better.

Phosphorous

As mentioned above, nutrients, specifically nitrogen and phosphorous, are needed to spur plant and algae growth. It is important to note, however, that one of these nutrients will be what is considered a "limiting factor" meaning

Figure 4

ILLUSTRATION OF AGING AFFECTING TROPHIC STATUS



Source: Wisconsin Department of Natural Resources.

that this is the nutrient which is least available in the lake and therefore is the factor preventing further growth of plants in the lake. In Silver Lake, and in most lakes in Wisconsin, this limiting nutrient is phosphorous. This means that whenever phosphorous enters the lake, it is quickly used by plants to grow and reproduce. Due to this connection, phosphorous can also be used as a barometer for trophic statuses as it is highly correlated to the amount of plant growth on the lake. This relationship is also the reason that increases in unnatural phosphorous loads to the lake cause major problems. The WDNR cutoff for determining a phosphorous impaired lake is 30 µg/L (0.03 mg/L) in stratified lakes during the spring mixing period; however, a concentration of 20 µg/L is recommended in order to prevent nuisance algal blooms.[8] The reason the standard is set in the mixing period is due to the fact that phosphorous can accumulate at the bottom of the lake during stratification and only come to surface during the mixing period (see "Stratification and mixing" and Figure 1).

Total phosphorous levels were measured on all of the field days. The average for the sample period was 17 µg/L, with the highest values being recorded at 34 and 28µg/L in the two samples taken in the spring of 2012. It is suspected that these measurements fell within the mixing period of the Lake; therefore, this study shows that the Lake periodically exceeds recommended standards. However, in 2011 and 2013 the Lake stayed well below these levels. Additionally, despite this periodic rise above WDNR standards, the total phosphorous levels have decreased dramatically since the late 1960s, as shown in Figure 7. This change was likely due to the extensive efforts to reduce phosphorous loading caused by septic system contamination through the installation of a sanitary sewer as well as the elimination of agricultural land use, a major contributor of phosphorous pollution in the watershed, in 1995 (see Appendix B).

*Chlorophyll-*a

Chlorophyll-*a* is a major component needed for photosynthesis and is found in all plants and algae and, when found in lake water, is an indicator of the amount of single cellular algae in the water. Since algae grow rapidly in eutrophic lakes this parameter can also be an indicator of water quality. Chlorophyll-*a* was not sampled as a part of this study, but was frequently sampled as a part of the citizen lake monitoring efforts that have occurred since

[8]*B. Shaw, C. Mechenich and L. Klessig,* Understanding Lake Data, *G3582, University of Wisconsin Extension, March 2004*.

Figure 5

PHOTOGRAPH OF A HYPER-EUTROPHIC LAKE

Source: University of Minnesota, College of Natural Resources, 2003.

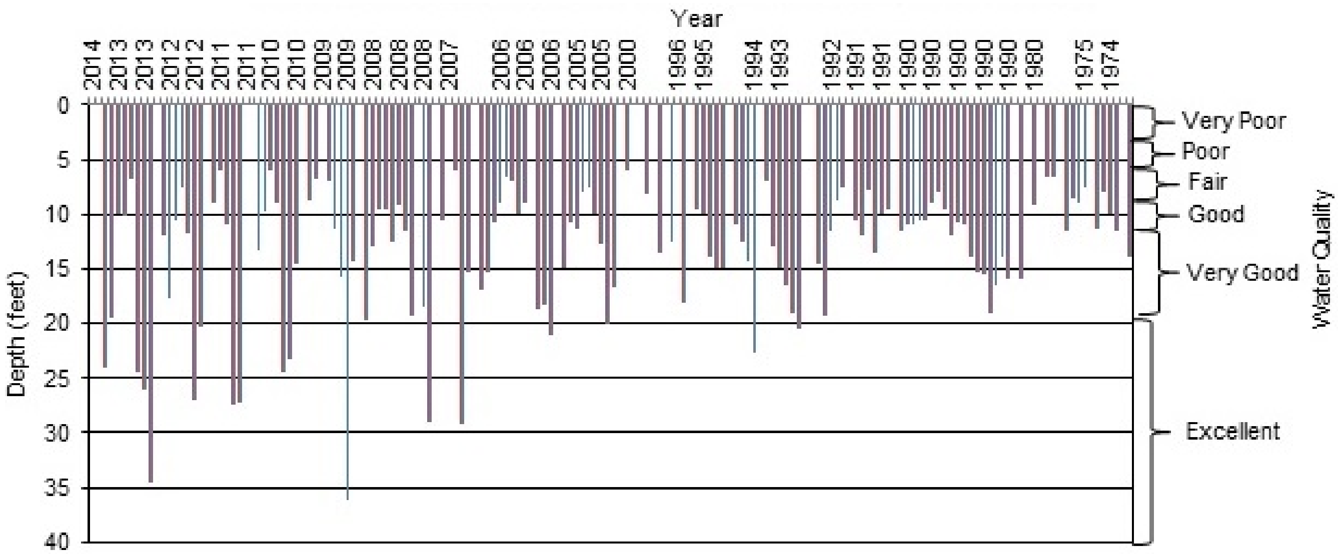
2005 with values ranging from 0.6 mg/L - 6.5 mg/L. Chlorophyll-*a* was only measured a total of five times before the year 2000 thereby making it difficult to provide a historical comparison. The values did, however, fall within the most recently recorded ranges.

Trophic Status Index

Though water clarity, phosphorous, and chlorophyll-*a* can each be used as an indicator for trophic status, it is more useful to use them in combination. However, since these values measure different things, they need to be converted to numbers that are comparable. To do this a scientist in 1977 developed what is called the Trophic Status Index or TSI which is a series of equations which convert Secchi disk, phosphorous, and chlorophyll-*a* data into comparable numbers. These numbers can then be looked at on one chart to determine trophic status. Generally, values below 40 are considered oligotrophic, values between 40 and 50 are considered mesotrophic and values over 50 are eutrophic. Figure 8 shows the TSI values for Silver Lake over time, indicating that the Lake should primarily be considered mesotrophic.

Figure 6

TIME SERIES OF SECCHI DEPTH MEASUREMENTS IN SILVER LAKE



Source: SEWRPC.

Nutrient Concentrations

Although total phosphorous levels, as discussed above, are good indicators of water quality, it is of value to monitor other nutrient components when trying to determine and identify issues of concern. This section presents the nutrient components that have also been monitored on the Lake including: reactive phosphorus, which is a component that is included in total phosphorous measurements; combined nitrates and nitrites, which are inorganic components of nitrogen pollution; ammonium, which is a form of nitrogen that is produced during decomposition; total kjeldahl nitrogen, which is a combination of ammonium and organic nitrogen (i.e., nitrogen held in biological materials found in the water); and total inorganic nitrogen, which is a combination of nitrite, nitrate, and ammonium. Details of each of these parameters are shown below.

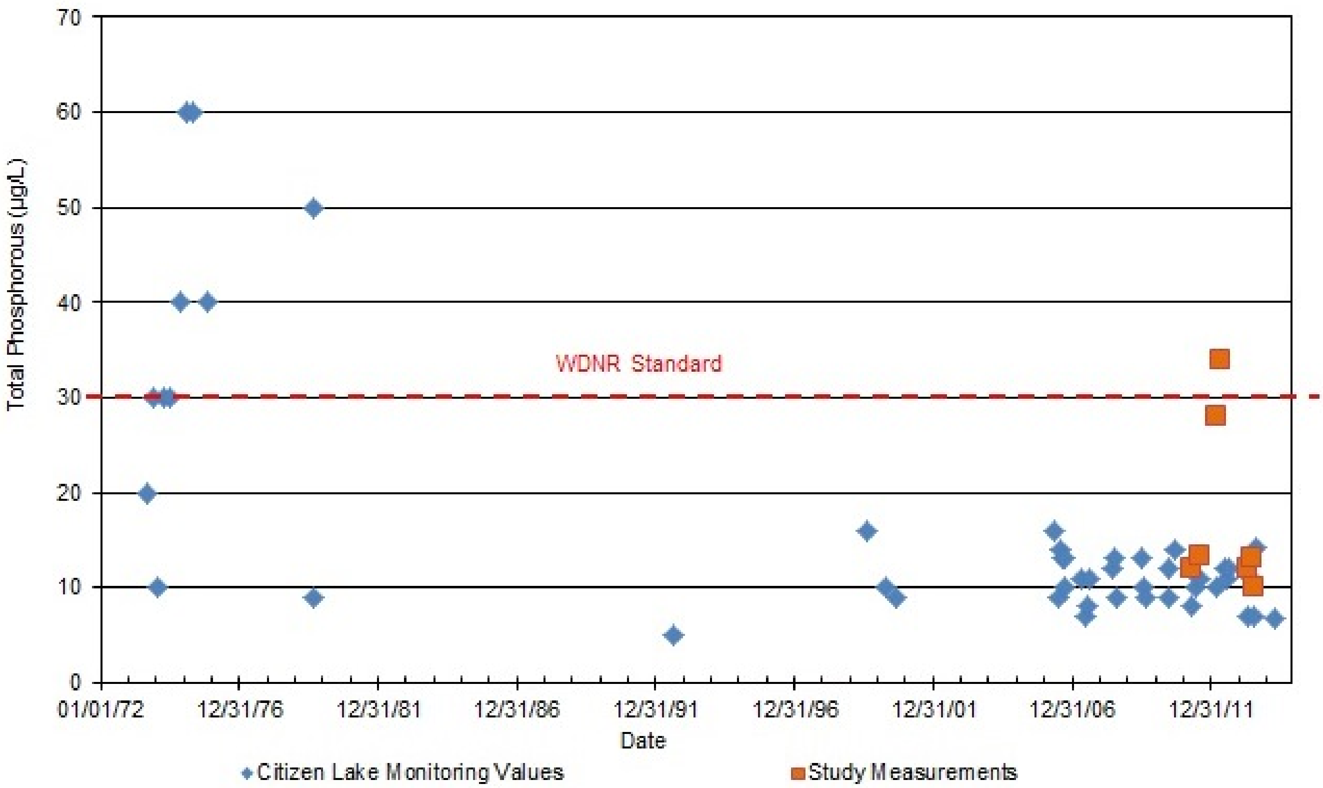
Reactive Phosphorus

Total phosphorous includes all of the phosphorous present in the water sample. This measurement, however, has several components, one of which is reactive phosphorus, which refers to the phosphorous which is immediately available for uptake (i.e., in the correct chemical form for plant and algae use). Generally, because reactive phosphorous is used up quickly, concentrations tend to vary throughout the season depending on how plants and algae absorb and release it. Though total phosphorus is considered a better indicator of a lake's nutrient status because its concentrations remain more stable than soluble reactive phosphorus, elevated reactive phosphorous levels (above 0.01 mg/L) are a strong indicator of nutrient problems in a lake.[9] In phosphorus limited situations (like in Silver Lake), the concentration of reactive phosphorous should be very low to undetectable (less than

[9] Interpreting Your Lake's Water Quality Data*, Lake County Health Department and Community Health Center, Waukegan, IL.*

Figure 7

TIME SERIES OF PHOSPHOROUS LEVELS IN SILVER LAKE INCLUDING STUDY MEASUREMENTS



Source: SEWRPC.

0.005 mg/L) during the growth season. As concentrations of reactive phosphorous increase, it can be inferred that phosphorus is either not needed by the algae (i.e., the lake has shifted to a nitrogen limited lake) or that phosphorous is being supplied at rates faster than it can be taken up by the biota.[10]

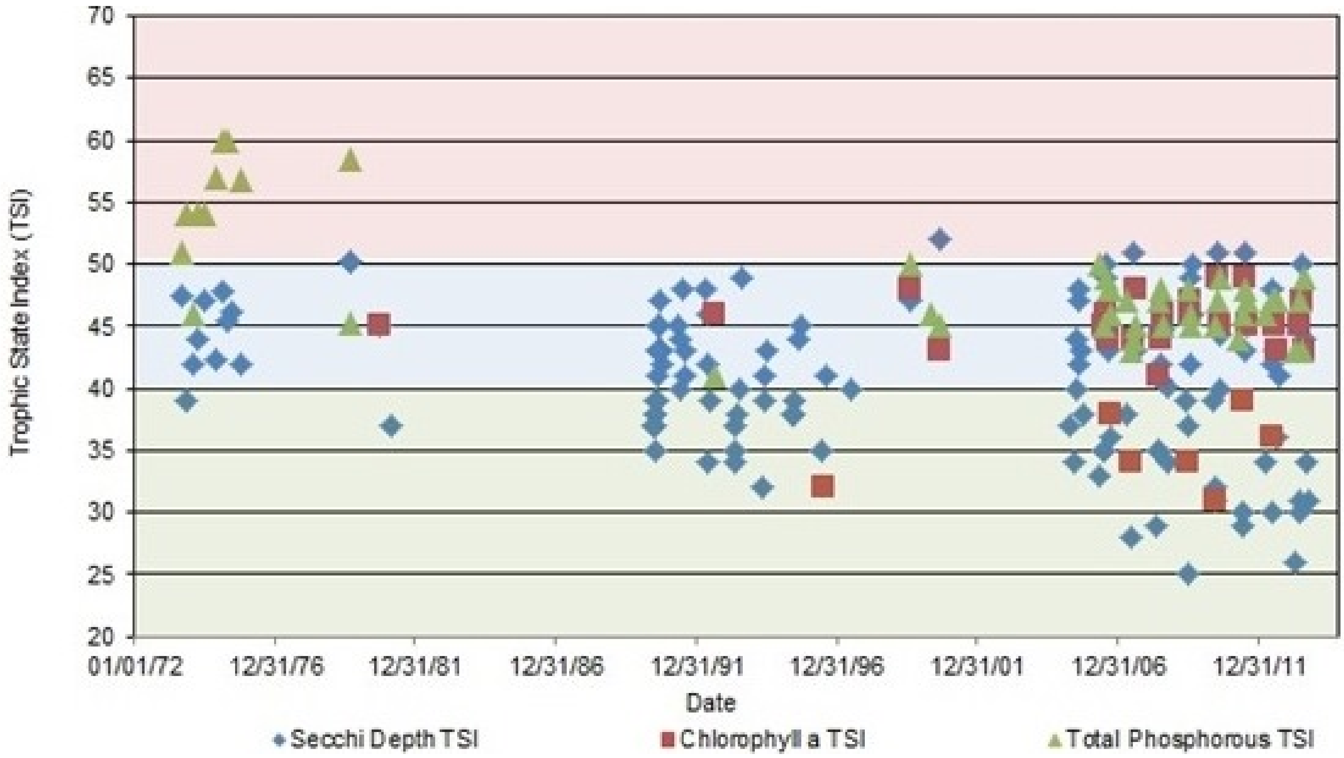
The in-lake reactive phosphorous was measured for all of the seven field days. The highest level of 0.117, as expected, was found in the sample that was taken at the end of the growing season (early August 2011).The rest of the samples ranged from 0.002-0.016mg/L and averaged 0.008mg/L. Only two samples were taken during the high growth season of mid-summer which included samples taken on Jun 16 and July 16, 2013. These had values of 0.005 and 0.002mg/L respectively, which fall within the expected range. Historical measurements had a mean value of 0.011; however, most of these values were measured outside of the growing season and are therefore not reliable indicators of water quality.

Nitrogen (NO_2 + NO_3)
Though not a "limiting factor", nitrogen values in a lake can still act as an indicator of pollution. This is due to the fact that nitrogen is contained in fertilizers which can sometimes contain harmful phosphorous and salts (pollutants which can cause excessive plant growth and stress to fish). Nitrogen occurs in various forms in water. Nitrate (NO_3) and nitrite (NO_2) are inorganic forms which are common and support algal growth, though are

[10]*R.E. Carlson, and J. Simpson,* A Coordinator's Guide to Volunteer Lake Monitoring Methods, *North American Lake Management Society,96 pp, 1996.*

Figure 8

TIME SERIES OF COMBINED TROPHIC STATUS INDEX LEVELS IN SILVER LAKE



Source: SEWRPC.

slightly harder for plants to use than ammonium (NH_4), ammonia (NH_3) or organic nitrogen.[11] Natural levels of ammonia or nitrate in lakes are typically lower than 1.0 mg/L. Nitrogen can become toxic to warm blooded animals, such as fish, at concentrations higher than 10 mg/L.[12]

The combined nitrite and nitrate levels were measured in the Lake on all field days. The highest value found, taken in April 2011, was 0.25mg/L, while most of the other measurements were 0.1mg/L or less. These values are similar to historic values found in 1999 and 2000 and lower than many of the values found during the late 60s which rarely went below 0.18. This lowering of nitrogen values is likely the result of increasing urbanization of the watershed which lowers fertilizer pollution from agricultural sources. In general, none of these values exceeded those that would be found in an unimpaired natural lake.

Ammonium (NO_4)
Ammonia is a gaseous biological byproduct of decomposing nitrogenous organic matter. When ammonia mixes with water it reacts and produces ammonium. Ammonium in low concentrations is common in most lakes aerobic surface waters (i.e., water which contain sufficient amounts of oxygen). Depending on the species, lethal

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[11] *SEWRPC Technical Report No. 39,* op. cit.

[12] *U.S. Environmental Protection Agency,* Water: Monitoring & Assessment, *March 2012.*

Table 2

TOTAL INORGANIC NITROGEN IN SILVER LAKE SAMPLING SITES

Date	In Lake Surface at Deep Hole	Paganica Golf Course	Paganica after Trail	Paganica Lake Outlet	North Wetland Upstream	North Wetland Lake Outlet	South Wetland Upstream	South Wetland Lake Outlet
04/25/11	**0.66**[a]	0.28	0.18	0.24	0.00	0.00	0.00	0.00
08/09/11	0.13		0.00	0.00	0.00	0.00	0.00	0.00
03/25/12	**0.34**[a]	0.09	**0.31**[a]	**0.63**[a]	0.00	0.00	0.00	0.00
05/06/12	**0.33**[a]	0.29	**0.30**[a]	**0.49**[a]	0.30	0.15	0.12	0.26
05/04/13	0.19	0.20	0.19	0.23	0.00	0.00	0.00	0.00
06/16/13	0.18	0.18	0.18	0.21	0.17	0.24	0.16	0.17
07/16/13	0.11	0.24	0.25	0.27	0.44	0.46	0.11	0.11

NOTE: Values greater than 0.3 can lead to algal blooms.

Source: SEWRPC.

concentrations of ammonium range from 0.2 to 2.0 mg/l; however, 0.2 mg/l can still have physiological affects to the more tolerant species.[13]

Ammonium was measured in the Lake on all of the field days. The values ranged from less than 0.01mg/L in fall of 2013 to 0.41 in April of 2011. In general, high ammonium levels indicate high amounts of decomposition which is often associated with high plant and algae growth in combination with very stagnant waters. The mean value of ammonium (0.15) was found to be slightly above the historic average of 0.14 mg/L, both being well below dangerous levels. However, the high value of 0.41mg/L, found during the mixing period of 2011, may indicate that there was a source of pollution or that stratification caused excessive decomposition in the deep part of the Lake over that particular winter. Monitoring of this parameter may, therefore be necessary.

Total Inorganic Nitrogen

Total inorganic nitrogen can be found by adding nitrate, nitrite, and ammonium. If the values found are over 0.3mg/L, this indicates a sufficient amount of nitrogen for summer algal blooms (if reactive phosphorous is available).[14] Table 2 shows the inorganic nitrogen values for the seven field dates. Inorganic nitrogen was above 0.3mg/L on three of those days, each coinciding with mixing periods (spring of 2011 and 2012). This indicates that nitrogen pollution, which results from fertilizers and animal waste, could potentially be an issue of concern for the Lake

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen is a combined measure of ammonia and organic nitrogen. It takes into account the plants in the water column and can be combined with the inorganic nitrogen values to determine the total amount of nitrogen. This total nitrogen can be used as an indicator of nitrogen pollution from animal waste or fertilizers.

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[13]*U.S. Environmental Protection Agency, PB-263 943,* Quality Criteria for Water*, Washington D.C., 1976.*

[14]*B. Shaw, C. Mechanich and L. Klessig,* op.cit.

In the Lake, total kjeldahl nitrogen was sampled on all seven field days. The mean value found was 1.06mg/L. This number was slightly over the average found in the Lake 1960s for the Lake of 0.94. The largest value, and the only value outside of historical levels, was found in June of 2013 with measurement of 1.91mg/L. No standards related to kjeldahl nitrogen exist in Wisconsin; however, values above 0.5mg/L are considered excessive in New Hampshire. Though this is not a good standard due to geographical location, it is still indicates that this parameter, as with inorganic nitrogen, may be one to be concerned about.

Other Possible Pollutants

There are other pollutants which can enter a lake in addition to nutrients. These pollutants can have an effect on specific lake species as well as the general biology overall. This section seeks to explain the effect these other pollutants could have on the lake and highlights whether or not they are issues within Silver Lake.

Chlorides

Chloride is natural in lakes if found in small quantities due to the fact that some chlorides originate from natural weathering, soil and bedrock. When concentrations are found to be higher than the range of 20-30mg/L, however, it normally stems from pollution sources like road salt, run off of chloride containing fertilizers, and salt discharged from water softeners and sewage. In general, a major issue with chlorides is that they are not used up over time and so they can continue to concentrate in a lake over time resulting in the lake becoming progressively more saline. This increased concentration can then eventually negatively affect plant growth and threaten aquatic organisms. Negative effects can be seen starting at concentrations around 250 mg/l and are considered severe in excess of 1,000 mg/l. Wisconsin has two standards set in place as it relates to chlorides, including: 757 mg/l as the acute toxicity level for fish and 395 mg/l as the chronic toxicity for fish and other aquatic life.[15] It has also been found that Eurasian Water Milfoil is more tolerant of chlorides than native plants; therefore, keeping chloride concentration in check can prevent further issues associated with this invasive species.

In 1983, the median chloride concentration for the Southeastern Wisconsin regions was 16 mg/l[16]; however, chloride concentrations throughout the region have been rising steadily. Chloride levels within Silver Lake were recorded on all seven sampling days revealing an average of 111.4 mg/L. This level is much higher than historic levels which were found in late 1960s (between 15 and 27 with an average of 19.4). Though these values have not yet hit the levels where negative effects are seen on fish and plant populations (i.e., 250mg/L), chlorides have obviously been increasing greatly over the past 40 years, as shown in Figure 9. This indicates that chlorides from direct runoff should be addressed as soon as possible. Additionally, as chlorides can also pollute groundwater, it may be necessary to test groundwater sites for chloride contamination.

Conductivity

Conductivity is the measure of the water’s resistance to electrical flow or the ability to carry electrical current. As the number of ions, for example sodium ions, dissolve into water, the water’s ability to conduct electricity will also increase. Consequently, lakes that are more saline have higher conductivity. In general, freshwater lakes can vary from 10 to 1,000 micro-Siemens/cm (µS/cm). Lakes in the southeastern Wisconsin region range from 500 to 600 µS/cm.[17]

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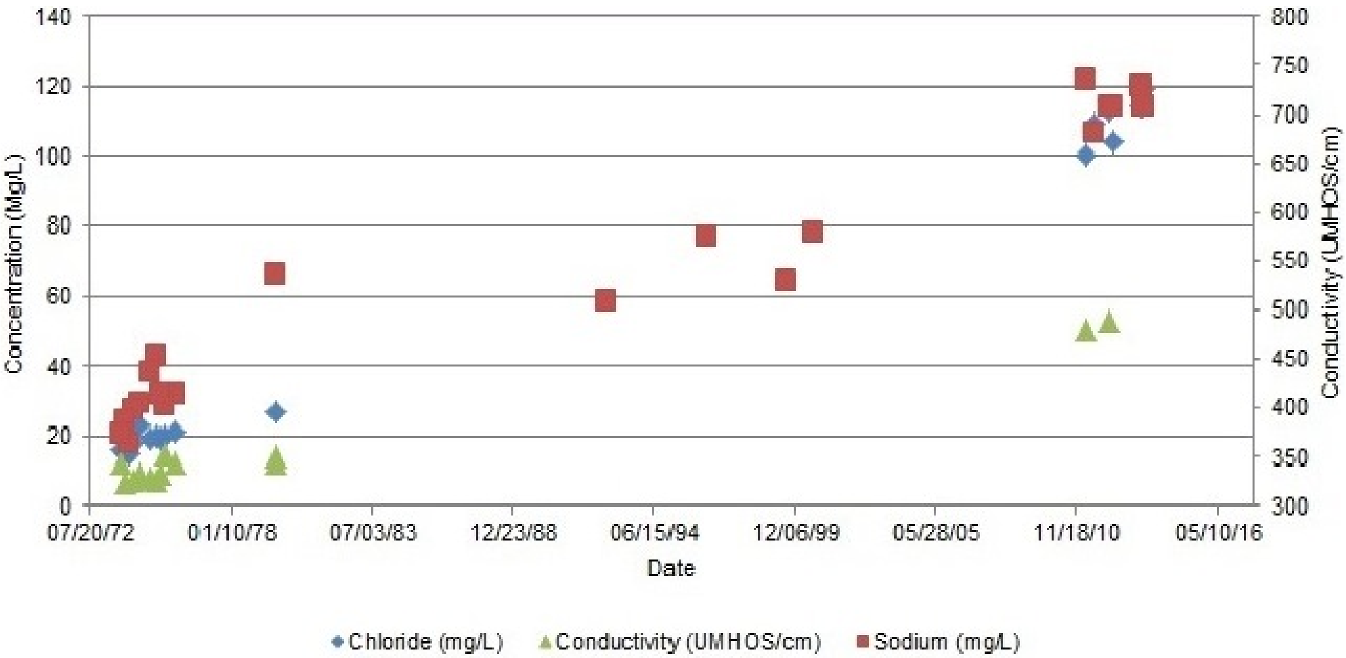
[15]*SEWRPC Technical Report No. 39,* op.cit.

[16]*R.A. Lillie and J.W. Mason,* op. cit.

[17]Ibid.

Figure 9

TIME SERIES OF CHLORIDE, SODIUM AND CONDUCTIVITY IN SILVER LAKE



Source: SEWRPC.

Conductivity was recorded on all field days with the exception of May 4, 2013 and resulted in a mean conductivity of 711 µS/cm . This is quite a bit higher than both the average for the region (600 µS/cm) and the historic average of 451 µS/cm. In fact, as can be seen in Figure 9, conductivity has been steadily increasing over time the same way sodium and chlorides have. This further emphasizes the need to take action about these pollutants entering the Lake.

Sodium

Sodium concentrations are of interest because of their close association with chloride in the solid form of salt. Sodium, like chloride, is found in low concentrations in natural lakes. However, concentrations of sodium and chloride have been increasing in lakes across the country due to human activities, such as de-icing runoff, discharge of water softeners and treated sewage effluent. Sodium concentrations in Lake Nagawicka, Waukesha County, Wisconsin, for example, were seen to approximately double from 10 mg/L in 1973 to over 20 mg/L in 2003.[18]

Sodium levels also have strong links to the growth of cyanobacteria, historically termed blue-green algae. Cyanobacteria is among the most studied of all planktonic groups, and has been growing in populations due to its ability to survive zebra and quagga mussel filtering unlike most other algae. Toxic byproducts of cyanobacteria have well documented adverse effects on freshwater lakes, especially those with enriched or eutrophic conditions.

[18] *H.S. Garn, D.M. Robertson, W.J. Rose, G.L. Goddard, and J.A. Horwatich,* op. cit.

Sodium levels were recorded in Silver Lake on April 25, 2011 and March 25, 2012 at 50 and 53 mg/L respect-tively. This is well above the historic range of 7.0-20 mg/L and historic average of 11 mg/L which indicates that sodium levels have been accumulating in the Lake over time. This is consistent with what was found in the previously discussed chloride analysis (see Figure 9). The fact that toxic Cyanobacteria (blue green algae) have been recorded in Silver Lake in the past five years further emphasizes the need to reduce sodium loads entering into the Lake. It is very possible that the occurrence of Cyanobacteria could be related to sodium level increases in the Lake, consequently sodium chloride concentrations should be considered an issue of concern.

Potassium
Potassium, as with sodium, has strong links to the growth of cyanobacteria. Also, like sodium, potassium ions in soil and water are very low meaning that their presence may indicate lake pollution caused by human activities. Potassium is the key component of commonly used potash fertilizer, and is abundant in animal waste. Though potassium can accumulate in soils, thereby making it a problematic indicator of pollution, increasing potassium values over time can mean there are long-term effects caused by pollution. Although not normally toxic themselves, these compounds strongly indicate possible contamination from more damaging compounds, such as the chlorides which are also found in potash containing fertilizers.

Potassium levels were recorded on April 25, 2011 and March 25, 2012 at 2.6 and 3.3 mg/L respectively. This is within the historic range of 0.7-5.6 and right at the historic average of 3mg/L. This indicates that potassium levels do not seem to be increasing over time and therefore are not a concern at this time.

Sulfate
Sulfate is a form of sulfur and is an important nutrient for aquatic life. Sulfur occurs naturally from rocks and fertilizers; as well as unnaturally from anthropogenic sources like the burning of fossil fuels associated with industrial regions. While sulfate is an important nutrient in lakes, in high concentrations it can further the eutrophication process which can be detrimental to plant life. Due to the vast industrialization of southeastern Wisconsin, lakes here have high sulfate concentrations ranging from 20 to 40 mg/L.[19]

Sulfates were recorded in the Lake at 22.5mg/L. This is within the historic range and slightly below the historic average for Silver Lake (26.8mg/L). In general, this indicates that sulfur contamination has not increased over time, which is consistent with the changes in national policy regarding fossil fuel (coal) burning.

Turbidity
Turbidity is the measure of relative clarity or transparency of a liquid. Specifically, it is an expression of the amount of light that is scattered by dissolved particles when a light is shined through the water sample. Turbidity is caused by suspended particles in lake water such as clay, silt, fine inorganic and organic matter, soluble colored compounds, algae, plankton, and other microscopic organisms, which can result from erosion of soil, high river flows, and disturbance of lake Bottom sediments. Additionally, many poorly soluble organic toxins, such as PCBs, PAHs, pesticides, organic nitrogen and phosphorus, metals and pathogens can adsorb, or attach to particles suspended in the water and increase their distribution. The southeast region of Wisconsin historically has the highest turbidity measurements in the state, based on data collected between 1966 and 1979.[20]

Turbidity was measured on March 25, 2012 as 1.3 NTU's. This is below the historic average of 2, thereby indicating that sediment kick-up and other causes of turbidity are not a major factor in Silver Lake.

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[19] *R.A. Lillie and J.W. Mason,* op. cit.

[20] Ibid.

Table 3

SUMMARY OF IN-LAKE WATER QUALITY FINDINGS

Parameter (in mg/L unless otherwise noted)	Current				Historic (1970s)		Standards for Comparison
	Dates	Range	Mean	Number of Samples	Range	Mean	
Alkalinity	2011-2012	176-204	190	2	160-180	172	173[b]
Ammonium	2011-2013	0.01-0.41	0.15	7	0.11-0.19	0.14	0.20[c]
Calcium	2012	35.4[a]	35.4	1	30-57	39	36[b]
Calcium Hardness	2011	114[a]	114	1	- -	- -	- -
Chloride	2011-2013	100-121	111.429	7	15-27	19.4	250[c]
Color (units)	2011-2012	5-7.2	6.1	2	- -	- -	46[b]
Conductivity (µS/cm)	2011-2013	681-736	711.333	6	373-537	416.8	500-600[b]
NO2+NO3	2011-2013	0.01-0.25	0.127	7	0.046-0.469	0.187	10[c]
pH (S.U.)	2011-2012	8.2-8.37	8.285	2	7.9-8.5	8.3	8.1 [b]
Potassium	2011-2012	2.9-3.3	3.1	2	0.7-5.6	3	- -
Reactive Phosphorus	2011-2013	0.002-0.117	0.02371	7	0-0.033	0.0111	0.01[c]
Sodium	2011-2012	50-53	51.5	2	7.0-20.0	11	- -
Sulfate	2012	22.5[a]	22.5	1	21-32	26.8	20-40[b]
Total Hardness	2011-2012	240[a]	240	2	155-297	231.7	- -
Total Inorganic Nitrogen	2011-2013	0.11-0.66	0.277	7	- -	- -	0.3[c]
Total Kjeldahl Nitrogen	2011-2013	0.67-1.91	1.05857	7	0.59-1.18	0.94	- -
Total Phosphorus	2011-2013	0.01-0.034	0.01747	7	9.0-60	.0345	0.03[c]
Total Suspended Solids	2011-2013	2-4	2.6	5	- -	- -	- -
Turbidity (NTU)	2012	1.3[a]	1.3	1	0.9-3	1.84	- -

NOTE: Red Font = Significantly higher than historical average; Red Cell = Ranges that exceed standard amount

[a]*Only one sample taken for this parameter.*

[b]*Southeastern Wisconsin regional average.*

[c]*Established "maximum level" standards.*

Source: SEWRPC.

Total Suspended Solids

Total Suspended Solids include materials like sand, silt, clay, plant material, fine organic and inorganic debris. These materials are suspended in the water column from the energy (or velocity) of the water's movement; the greater the velocity the higher concentrations and the larger and denser particles can be suspended. High levels of total suspended solids can result from algae blooms, sediment re-suspension, and/or the inflow of turbid water, and are typically associated with low water clarity and high phosphorus concentrations in many lakes in Lake County. High total suspended solids can also result in damage to fish populations through the clogging of gills.

In Silver Lake total suspended solids was low (ranging from negligible to 4mg/L) on all of the field days and was not measured historically. In general, this indicated that activities which cause high total suspended samples, i.e., motor boat activities in shallow areas and carp, are not factors in Silver Lake.

Summary of In Lake Data

As summarized in Table 3, the monitoring of the in lake sample site, through this study and citizen lake monitoring efforts, revealed that Silver Lake has generally good water quality, with clear waters and good nutrient balances, and can be classified as mesotrophic. Additionally, it was revealed, as suspected, that the Lake is basic, highly alkaline and contains high amounts calcium. This means that the Lake is well buffered to changes in pH or acidity.

The analysis also revealed that phosphorous in the Lake has decreased dramatically since the late 1960s thereby indicating that the installation of the sanitary sewer and the transition to residential land use in the watershed had a significant impact on phosphorous contamination of the Lake. However, it was also noted that phosphorus concentrations do periodically go above the WDNR standards in the Lake thereby indicating that phosphorus prevention may still be deemed an issue in the future if loading continues.

In contrast, chlorides and sodium have been steadily increasing over the past 40 years, thereby indicating that the reduction of chlorides should be made a priority in the future. Additionally, nitrogen levels, though found to have decreased over time, are still periodically showing values which indicate potential for algal blooms. Reducing nitrogen pollution should therefore be considered a priority.

Finally, it was found that sulfates, total suspended solids, turbidity, potassium and reactive phosphorous do not appear to be issues of concern.

Sample Site Water Quality

As it has been established that, though Silver Lake has primarily good water quality, chlorides and total phosphorous, and to a lesser extent nitrogen, are issues of concern, it is important to now evaluate potential sources of these pollutants. As mentioned in the project description, a major component of this study was to determine the extent of pollution entering the Lake from designated "areas of concern." These areas of concern included:

1. The Paganica Golf Course tributary (Map 1; North end of the Lake)
   There has historically been extensive controversy surrounding the water draining into the Lake from the Paganica golf course, which is located just north of the Lake.[21] This controversy, particularly the worry that human harming micro-organisms were entering the Lake, spurred a bio-assessment published by WDNR. The study found no evidence of organisms that could harm humans,[22] however, largely due to the fact that the water coming from the Paganica pipe was brown (unlike the Lake water), Lake residents continued to be concerned with this source of runoff. In fact, the Golf Course was declared a public nuisance in 1974,[23] though the cease and desist order was not completely enforced.

   Concern about this site continues to be an issue, again largely because the water running off the golf course, as well as the water running into the Lake, is such a drastically different color than the Lake water itself. As discussed in the "Color" section of the "In Lake Results", color does not, however, always equate to pollution. Brown color is generally just an indication of the amount of organic

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[21] *"Relief Seen for Drainage Problem,"* Enterprise*, Summit, Wisconsin, June 13, 1974.*

[22] *J. Bode and T. Moe,* Report of Biological Analysis of Water Samples Collected from the Paganica Golf Course Water Hazard Discharge to Silver Lake Waukesha County*, Wisconsin Department of Natural Resources, June 7, 1974.*

[23] *"Town Board Authorizes Legal Action," January 13 1975; and "Legal Move Asked on Golf Course–Summit Wisconsin,"* Sentinel*–Waukesha Bureau, April 7, 1979.*

material the water has come into contact with. However, as golf courses are none-the-less a well known source of pollution, it was still deemed necessary to investigate the water coming from this site. Consequently, this area was deemed the primary “area of concern” in this study.

It is important to note that the runoff along this tributary includes contributions from potential pollution sources other than the golf course. In fact, the tributary goes through a series of underground pipes, as illustrated in Map 2, which includes a downstream stormwater drain. This drain collects runoff and flood water from shoreline properties which could also be adding pollution to the runoff which is occurring from the golf course. In order to accommodate this fact, and ensure that our samples were accurately recording the runoff from the golf course, as well as from other sources, three sites were chosen along the tributary, beginning directly after the golf course and then traveling downstream. These sites, as well as the runoff sources they represent, are as follows:

a. The “Paganica Golf Course” site, found directly downstream from the Paganica Golf course located on the northern end of the Lake. This site represents overflow water coming from a detention basin located on the golf course. This basin likely includes runoff from the golf course as well as runoff from the residential area directly adjacent to the golf course on the east side (see Appendix A for a photo of the site) It is important to note that this detention basin, though it was not sampled, is likely full of organic material of which the water in question would remain in contact with for an extended period of time. This could account for the brown color of the water (the water essentially gets “dyed”).

b. The “Paganica After Trail” site, which was taken at the drainage pipe located directly across from the Paganica Golf Course after the water has flown under the Lake Country Trail. This site essentially captured water flowing into the pipe from a “pooled area” which should represent the runoff found in the “Paganica Golf Course” site in combination with the water that drains from the roads and residential regions directly east and west of the site (see Appendix A for photo of site). If there are increases in pollution at this site, this would most likely be from the sources of pollution other than the golf course.

c. The “Paganica Lake Outlet” site, located at the pipe outlet to the Lake. This site should include pollutants which drain from the two other Paganica sites as well as pollution from the land plots which enter through the stormwater drain (see Map 2).

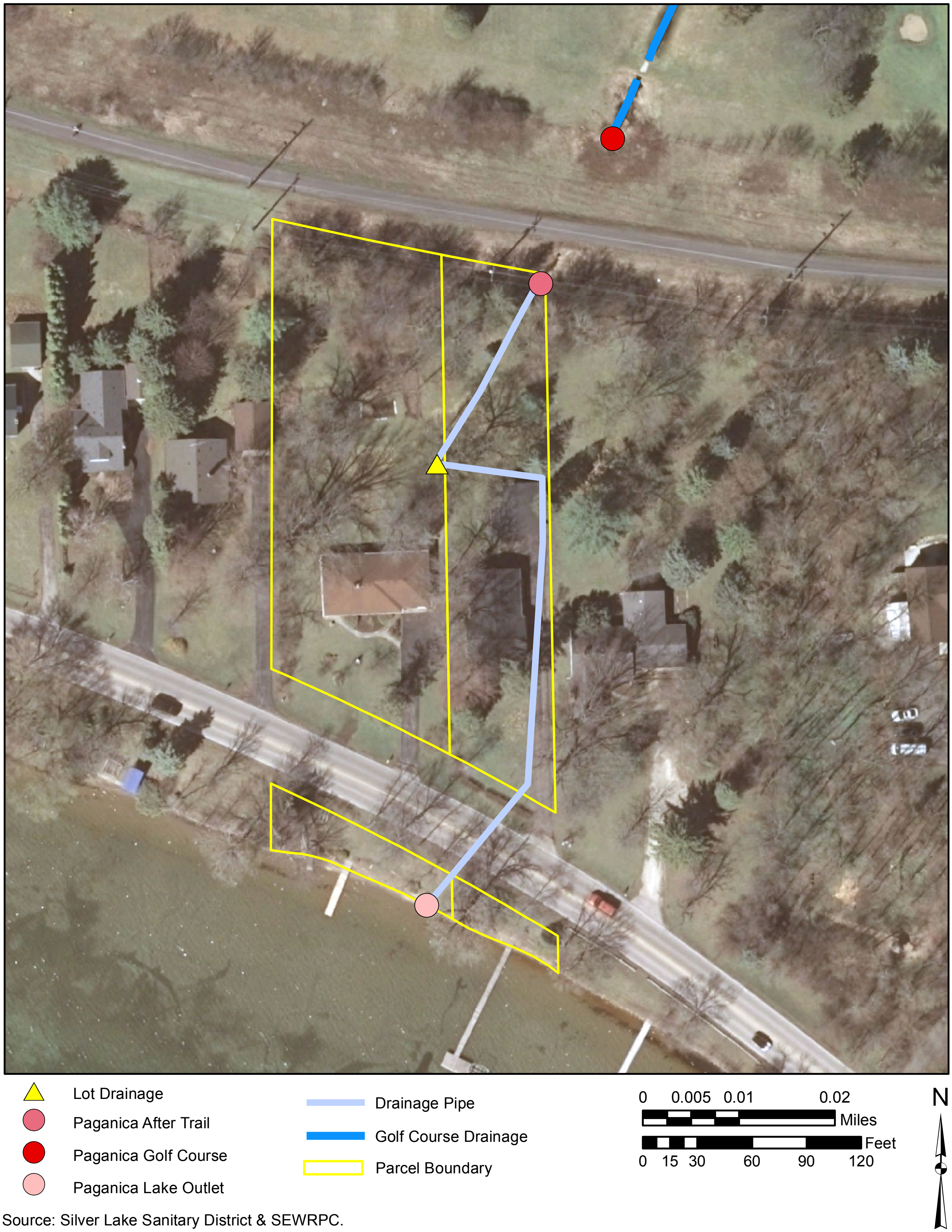
2. The “North Wetland” runoff area (see Map 1: Eastern shore north of the Summit Town Hall)
Though this area does not have the same level of controversy as the Paganica site, it was identified as an issue of concern for a similar reason, specifically, the fact that the water entering the Lake from this drainage pipe is brown. This area was also targeted due to its proximity to commercial parking lots and landscaping areas. Two sites were chosen along this tributary, including:

a. The “North Wetland Upstream” site, located on the western side of North Dousman Road just north of the Summit Town Hall. This site likely represents the water draining from the commercial parking lot and lawn across North Dousman Road, direct runoff from North Dousman Road, and potential overflows from the commercial detention basin located east of North Dousman. As with the Paganica Golf Course, this detention basin and the amount of organic material within it may be the reason for brown water being visible at this site.

b. The “North Wetland In-Lake Outlet” site, located in the pipe draining into the eastern side of the Lake, directly west of the “North Wetland Upstream” site. This site would include runoff from the “North Wetland Upstream” site, as well as runoff from the Summit Town Hall parking lot and potential runoff from the adjacent residential areas. It is important to note that the

Map 2

LOCATION OF DRAINAGE PIPES COMING FROM THE PAGANICIA GOLF COURSE



Source: Silver Lake Sanitary District & SEWRPC.

waters entering the Lake from this site first drain through an adjacent wetland. Wetlands and bogs frequently dye water brown, and yet serve to filter out pollution. This could also account for the brown color that was of concern.

3. The Southeastern corner of the Lake (see Map 1; Most southern site)

   As with the North Wetland site, this area was also chosen due to the brown color of the runoff. Additionally, it was chosen due to its proximity to Interstate 94 and two detention basins (one residential and one commercial. Two sites were chosen in this area, including:

   a. The "South Wetland Upstream" site, located on the west side of North Dousman Road just south of Silver Knoll Court. This region likely receives overflow from the stormwater detention system located just east of the site (which may account for the brown color). This area may also receive runoff directly from North Dousman Road and overflow from the detention basin on the other side of the IH 94 (through a culvert under the highway).

   b. The "South Wetland In-Lake Outlet" site, located in the southeast corner of the Lake. This area is likely receiving the runoff from the "South Wetland Upstream" site, runoff from IH 94 (and potentially the aforementioned detention basin on the other side of the highway), and potentially overflow from the adjacent residential stormwater detention basin (which is filled with residential runoff). The water entering this site goes through a wetland prior to entering the Lake (potentially accounting for some of the brown color).

Map 1 shows where each of the aforementioned sites are in relation to the Lake, while maps of the runoff sources which are flowing to each of these sites are shown in Appendix A. This section presents the data that was found at these seven sites, compares that data to levels in the Lake and to WDNR standards, and highlights particular areas that should be considered a concern.

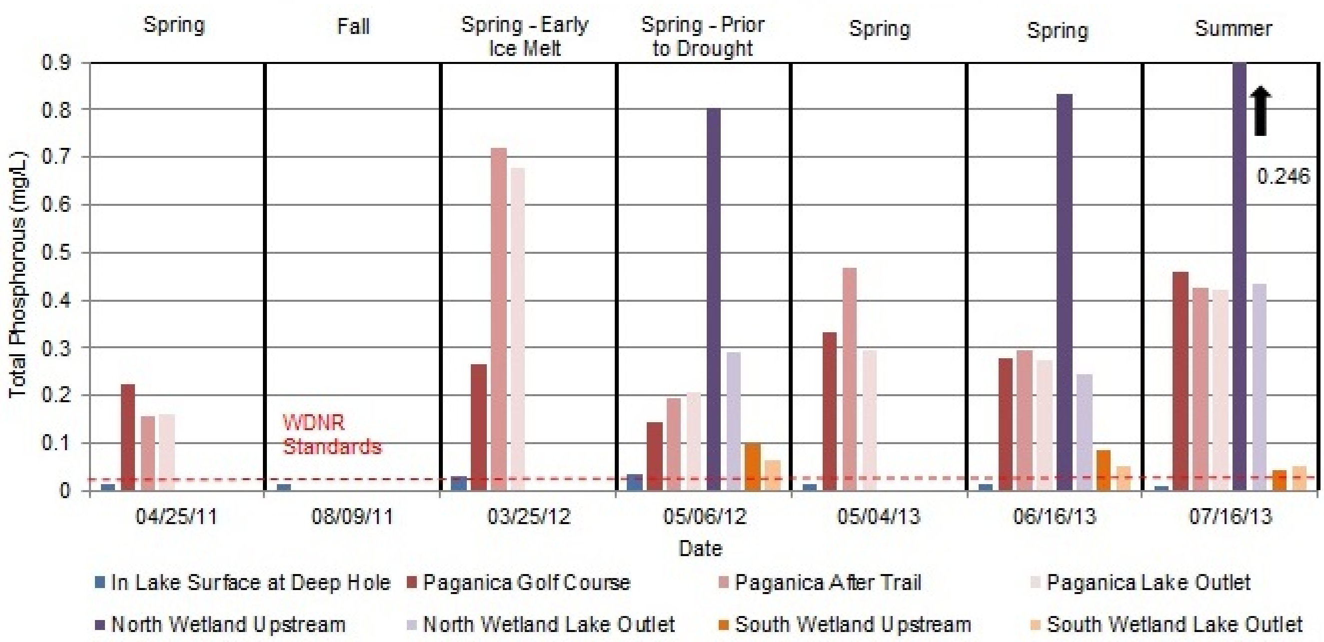
Nutrient Pollutants
As both phosphorous and nitrogen were deemed pollutants of concern with regards to the in-lake data, this section seeks to determine potential sources of the various nutrient components.

Total Phosphorous
Total phosphorus levels were measured in the three Paganica sites on all of the field days with the exception of August 9, 2011. They were also measured in the north and south wetland sites on May 6, 2012, June 16, 2013 and July 16, 2013. As can be seen in Figure 10, the phosphorous levels for all of the samples taken were much higher than the Lake water itself. Additionally, all of the samples exceed WDNR standards for phosphorous levels. Consequently, actions should be taken to ensure that the phosphorous fertilizer ban on turfed lawns is being well enforced throughout the watershed, with a focus on the areas draining to these sites (see Appendix A). Additionally, phosphorous containing fertilizers should be discouraged on gardens and pet waste should be cleaned up immediately. Additionally, if any individual meets the exemption to the 2010 phosphorous fertilizer ban, they should be taught how to use fertilizers in a conservative manner in order to avoid runoff.

It is important to note however, that phosphorous levels are particularly high in the North Wetland upstream site, potentially indicating an unexpected source of contamination coming from the adjacent commercial property. This source should therefore potentially be investigated. It is also important to note that, though high, phosphorous concentrations coming directly out of the golf course are actually lower than the phosphorous levels found just across the trail, i.e., the levels actually increase after going under the trail. In fact, in March 2012 phosphorous levels almost doubled once the water left the golf course). This pattern indicates there is a significant source of phosphorous contributing to this tributary aside from the golf course. Considering this source seemed to increase during the spring runoff, it is possible this may be pet waste accumulation from the winter draining towards the Lake from the residential area to the west of the site. This may, however, need to be further investigated.

Figure 10

TOTAL PHOSPHOROUS LEVELS FOR SILVER LAKE SAMPLING SITES



Source: SEWRPC.

Reactive Phosphorous

Reactive phosphorous levels were measured in the three Paganica sites on all of the field days with the exception of August 9, 2011. They were also measured in the north and south wetland sites on May 6, 2012, June 16, 2013 and July 16, 2013. As can be seen in Figure 11, the reactive phosphorous levels in all of the sample sites were higher than levels in the Lake. This is common due to the fact that plants will use this form of phosphorous up as quickly as possible once it enters the Lake. It is interesting to note however, that the reactive phosphorous remained fairly consistent throughout the Paganica sites, thereby indicating this form of phosphorous is primarily coming from the golf course detention basin. Additionally, the highest values recorded were collected from the wetland upstream sites, prior to the wetland, thereby indicating that this form of phosphorous got used up fairly quickly when draining through these wetlands.

Nitrite and Nitrate

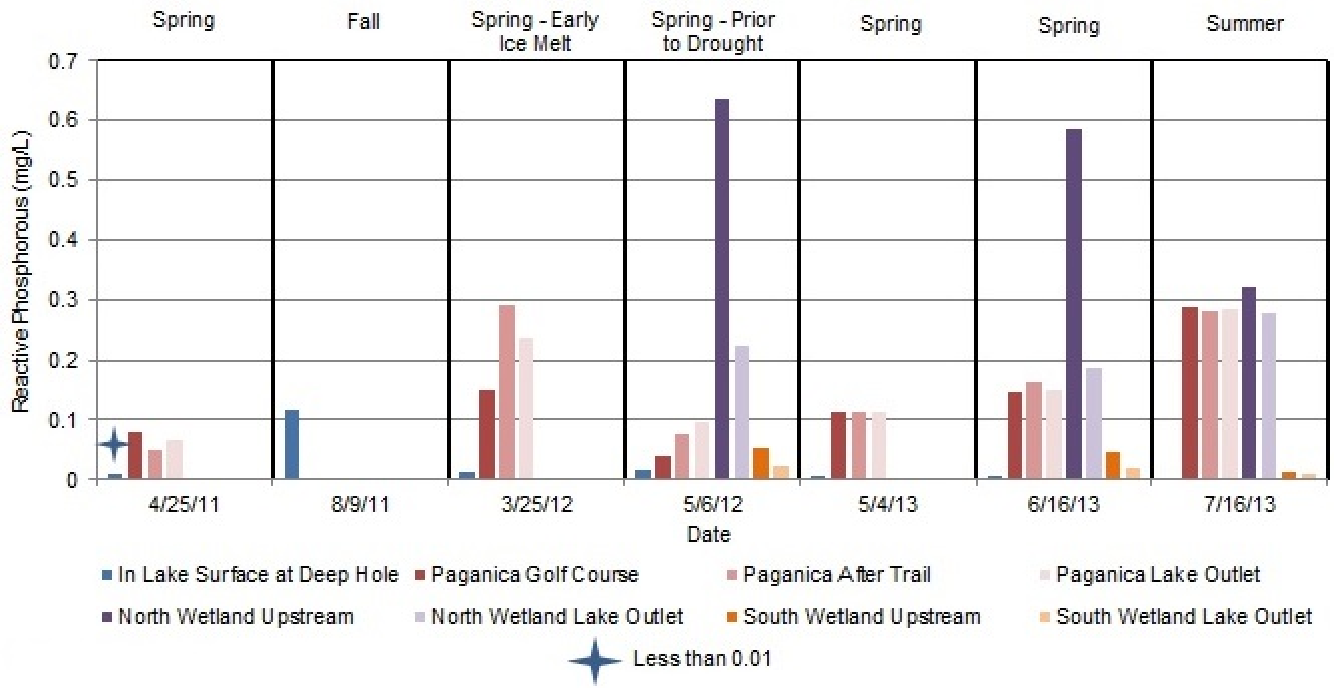
Combined nitrite and nitrates were measured in the three Paganica sites on all of the field days with the exception of August 9, 2011. They were also measured in the north and south wetland sites on May 6, 2012, June 16, 2013 and July 16, 2013. As can be seen in Figure 12, out of the sites sampled, the highest values were found on the Paganica sites, with the four "wetland" sites recording as nearly negligible across the board. The numbers found in these areas, however, were the same if not less than the in-lake concentrations, thereby indicating that the Paganica golf course is not a significant contributor of this kind of pollution.

Ammonium

Ammonium levels were measured in the three Paganica sites on all of the field days with the exception of August 9, 2011. They were also measured in the north and south wetland sites on May 6, 2012, June 16, 2013 and July 16, 2013. As can be seen in Figure 13, the highest values were found at the Paganica Lake Outlet site (the

Figure 11

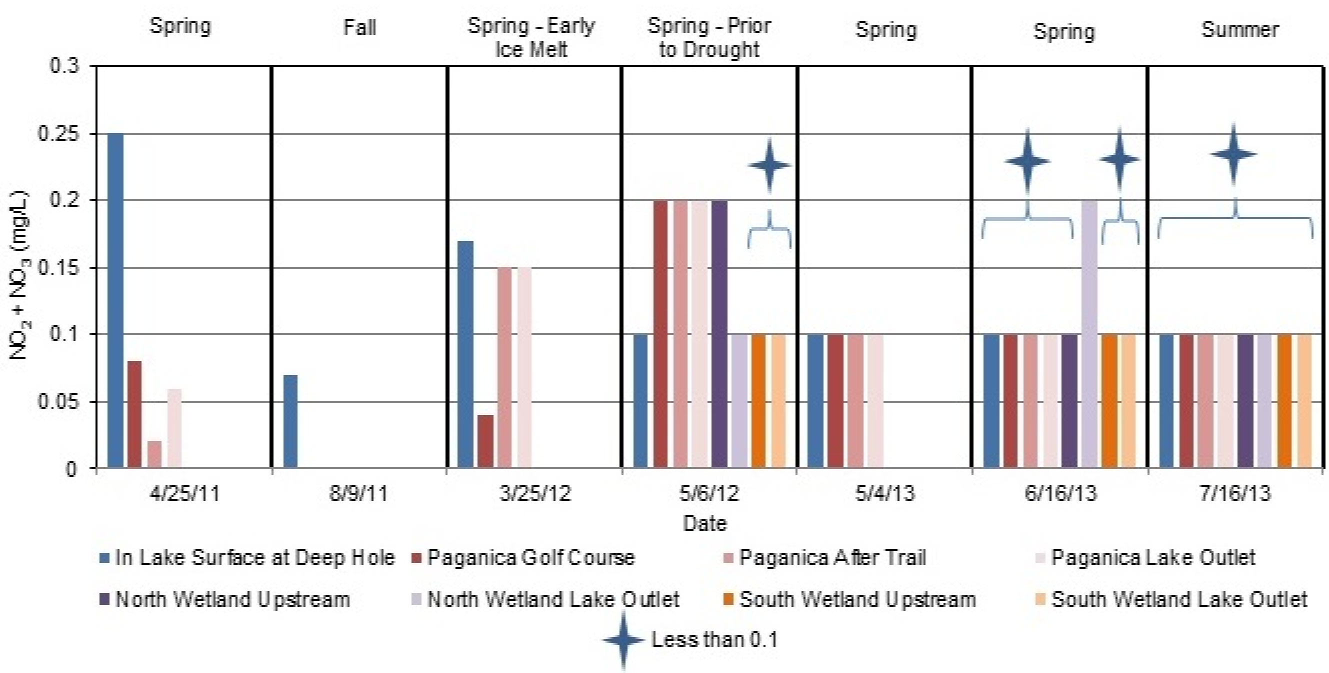
REACTIVE PHOSPHOROUS LEVELS FOR SILVER LAKE SAMPLING SITES



Source: SEWRPC.

Figure 12

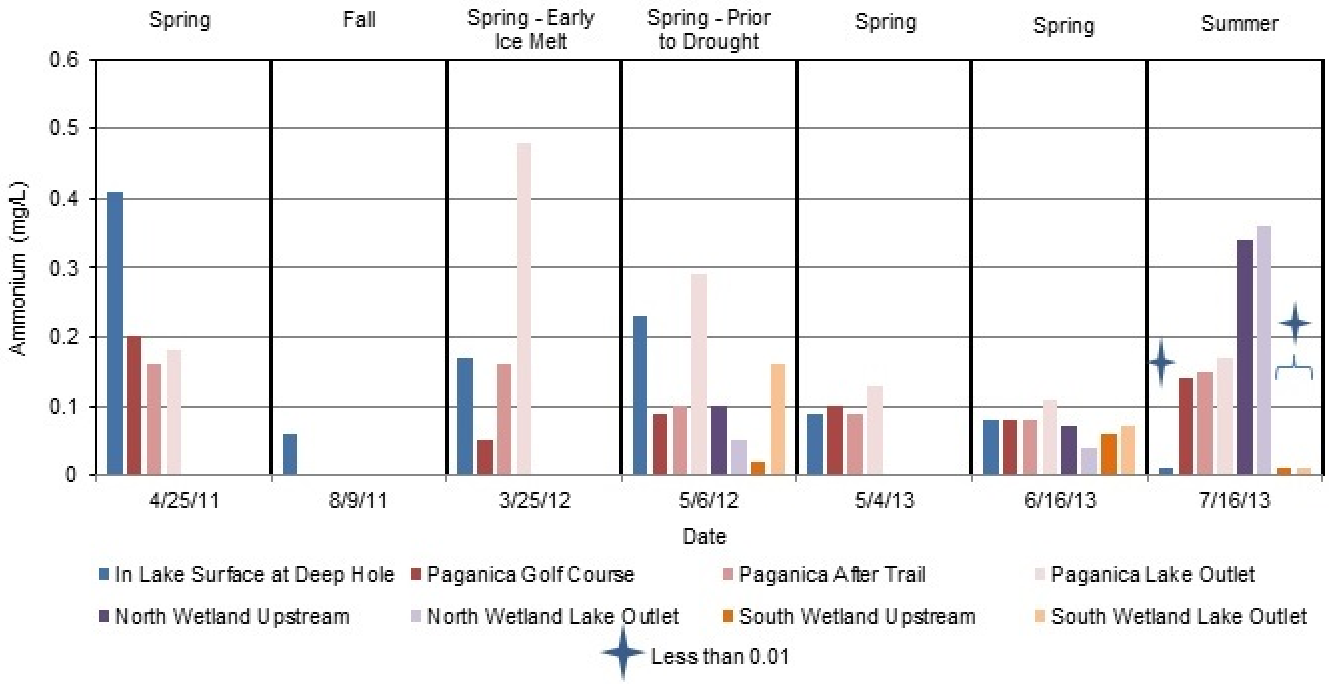
COMBINED NITRATE AND NITRITE MEASUREMENTS IN SILVER LAKE SAMPLING SITES



Source: SEWRPC.

Figure 13

AMMONIUM MEASUREMENTS IN SILVER LAKE SAMPLING SITES



Source: SEWRPC.

site downstream from the Golf course). Since these high values were found in samples downstream from the golf course but not at the site directly off the golf course or under the trail, it is most likely the ammonium found in this sample came from the residential areas which through the stormwater drain off of the private property. As this area has a tendency to flood, it is likely that the ammonium values we are seeing are from fertilizer runoff and leaf debris which enter the drainage pipe and then decompose underground. Maintenance of this property should therefore, potentially be considered a priority.

Somewhat high ammonium values were also found on at the north Wetland sites during July, 2013. A likely cause of this contamination would be fertilizer application and runoff from the lawns located in the adjacent commercial area.

Total Inorganic Nitrogen

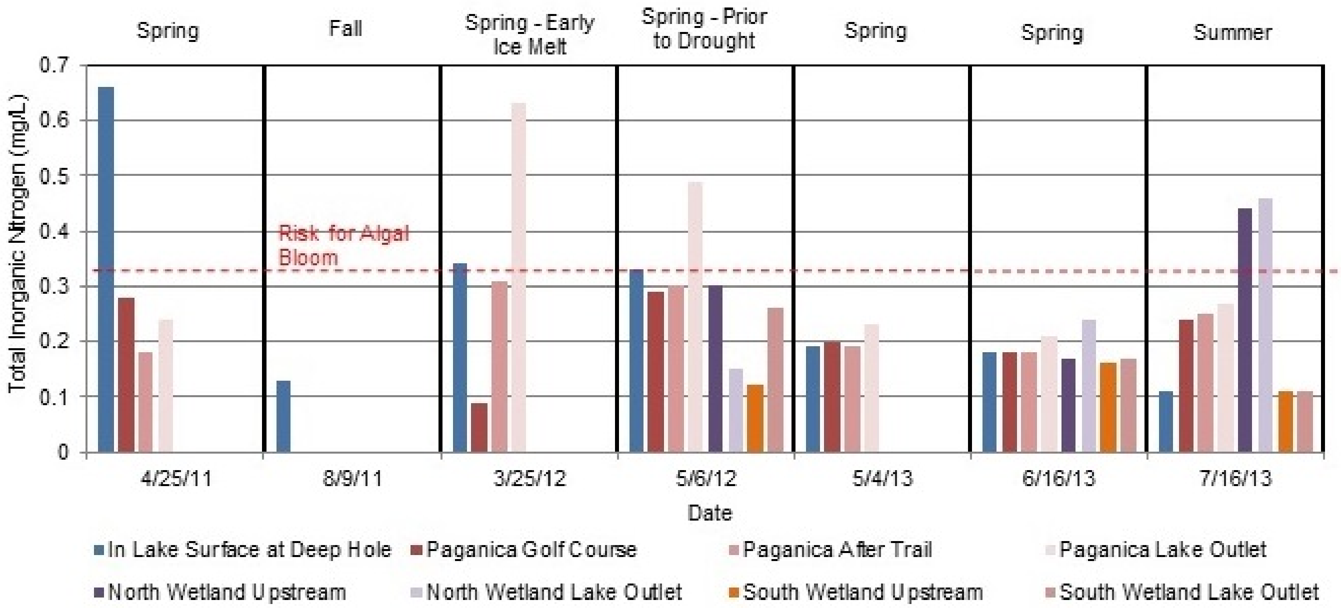
Total inorganic nitrogen (nitrite, nitrate and ammonium) were also calculated for all of the relevant sites. As shown in Figure 14, the "In Lake Paganica Outlet" site on March and May of 2012 exceeded the 0.3mg/L standard, further emphasizing the need for better land management in the area near the stormwater drain. Additionally, the north wetland sites also had high values on July 2013, further emphasizing the need to investigate the landscaping activities of the adjacent commercial area.

Total Kjeldahl Nitrogen

Kjeldahl nitrogen levels were measured in the three Paganica sites on all of the field days with the exception of August 9, 2011. They were also measured in the north and south wetland sites on May 6, 2012, June 16, 2013 and July 16, 2013. As can be seen in Figure 15, the three Paganica sites consistently had kjeldahl nitrogen values well above those found in the Lake (ranging from 1.12 to 4.9 mg/L). Additionally, the nitrogen values were fairly

Figure 14

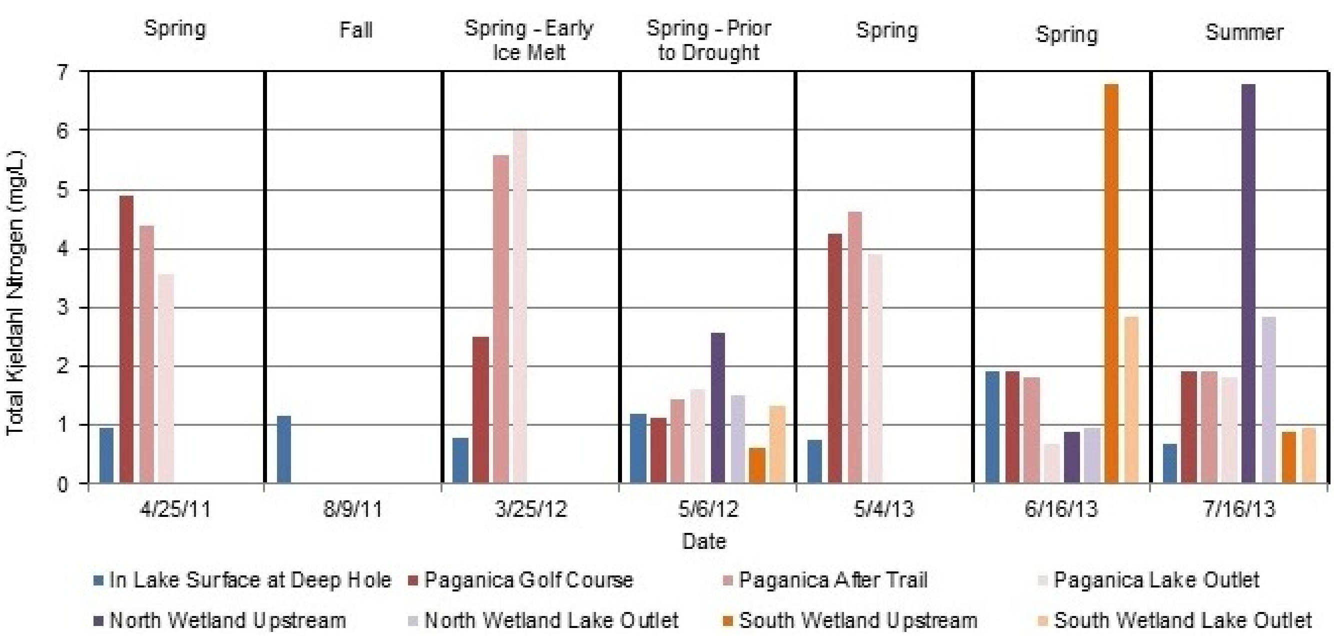
TOTAL INORGANIC NITROGEN IN SILVER LAKE SAMPLING SITES



Source: SEWRPC.

Figure 15

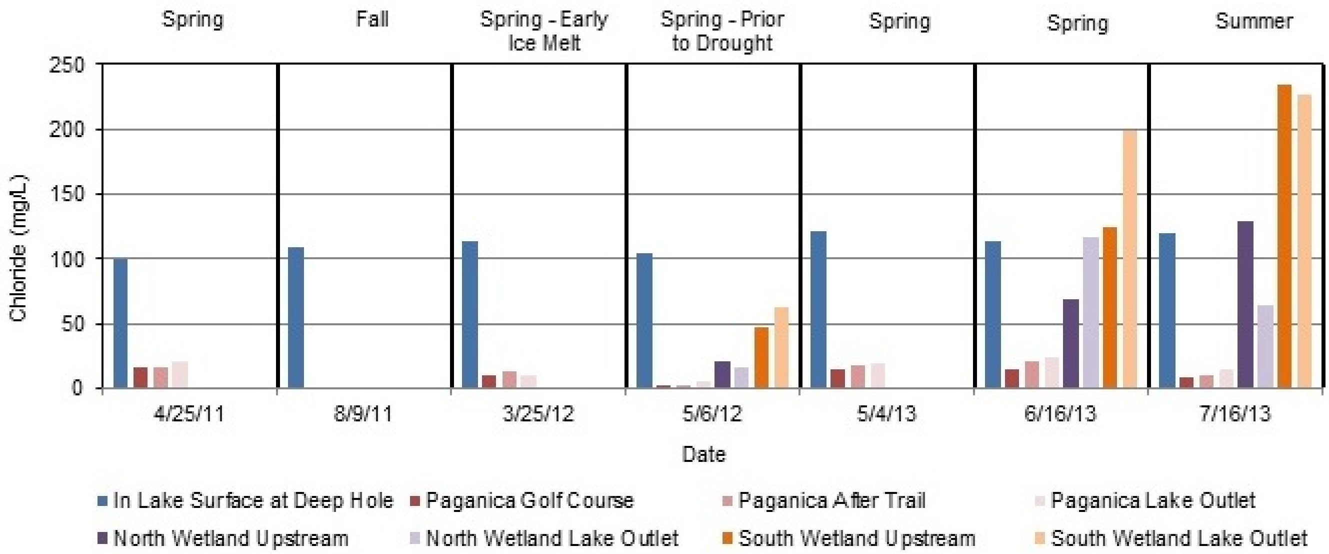
TOTAL KJELDAHL (ORGANIC AND AMMONIUM) NITROGEN IN SILVER LAKE SAMPLING SITES



Source: SEWRPC.

Figure 16

CHLORIDE CONCENTRATIONS IN SILVER LAKE SAMPLING SITES



Source: SEWRPC.

consistent throughout all three Paganica sites with only one instance of the nitrogen entering the tributary after the golf course (in March 2012). The most likely source of these pollutants is therefore fertilizers from the golf course and/or the upstream residential area.

The highest values (over 6.5mg/L), however, were periodically found in the Wetland samples. It is likely that these sources are due to fertilizer application and potential overflow of organic nitrogen accumulation in the adjacent stormwater ponds. To prevent these pollutants, it should be encouraged that surrounding areas reduce fertilizer use to only those times when absolutely necessary and that the detention basins be properly maintained.

Salt Pollution and Suspended Particles

As was noted in the in-lake data analysis, chlorides (which are correlated with conductivity) are an issue of concern in the Lake. This section seeks to identify the potential sources which should be addressed. Additionally, though total suspended solids were not an issue in the Lake, they were measured for each of the sites. The data from this analysis is also presented here.

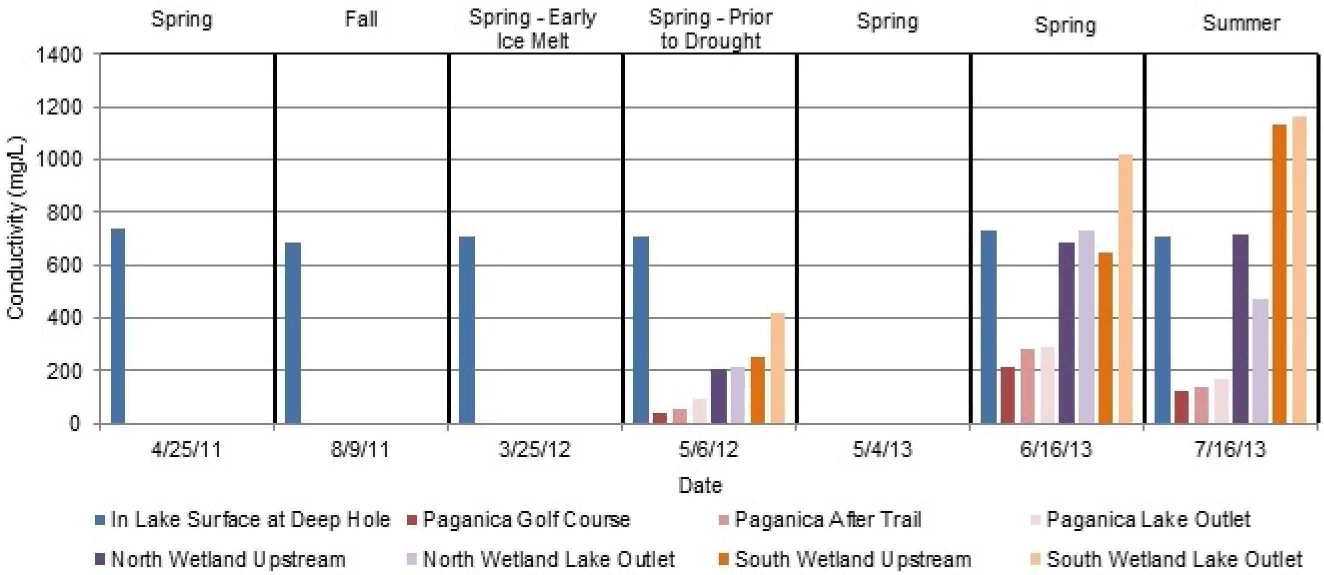
Chloride

Chlorides were measured in the three Paganica sites on all of the field days with the exception of August 9, 2011. Chlorides were also measured in the north and south wetland sites on May 6, 2012, June 16, 2013 and July 16, 2013. As can be seen in Figure 16, out of the sites sampled, the highest chloride values were found in the four wetland sites, with the highest amounts coming from the four “wetland” sites on June 16, 2013 and July 16, 2013. The values on these days ranged from 69mg/L at the “North Wetland Upstream” site to 234 mg/L at the “South Wetland Upstream” site, with an average of 145mg/L. An average of 111 mg/L was measured in the Lake; these numbers indicate that these Wetland Upstream sites should be targeted for chloride reduction efforts.

Given these high chloride numbers, and the fact that these samples were taken in the summer (after direct runoff from the roads would have carried road salts), it is believed that the sources of chlorides which supply these sites

Figure 17

CONDUCTIVITY IN SILVER LAKE SAMPLING SITES



Source: SEWRPC.

are as follows: 1) road salt accumulation in detention basins which enter the lake during over flow scenarios; 2) runoff from either the brine solutions in water softeners or from poorly stored salt bags left over from winter in adjacent residential areas; or 3) runoff from the use of fertilizers containing potassium chlorides (known as potash) which are draining either directly into the Lake or accumulating in the detention ponds which enter the lake during overflow events. Future efforts to reduce chloride concentrations should therefore target these activities.

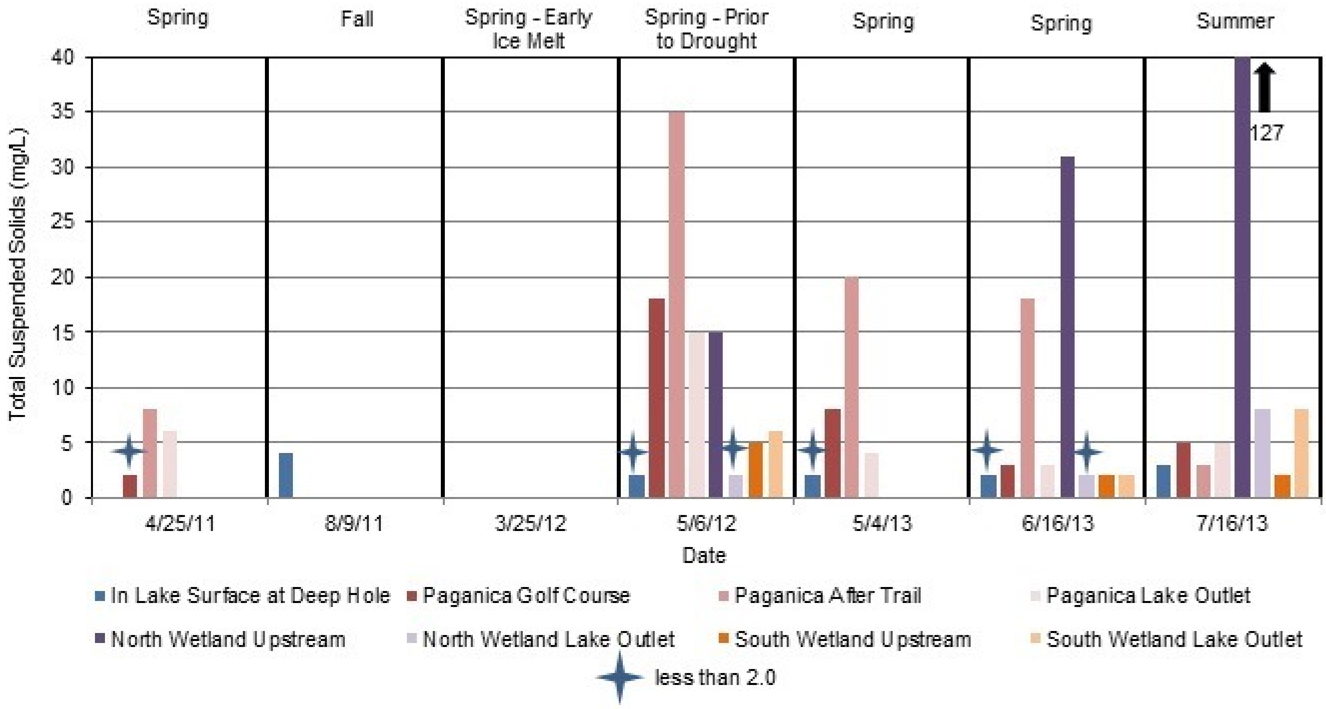
Conductivity
Conductivity values were taken at the other seven sample sites on May 6, 2012, June 16, 2013 and July 16, 2013. As shown in Figure 17, these values seem to largely correlate with the chloride values also found on these dates in the Lake, with the highest values being found at the “wetland” sites. Consequently, actions to address chlorides should be sufficient to reduce these numbers.

Total Suspended Solids
Total suspended solids were measured in the three Paganica sites on all of the field days with the exception of August 9, 2011. They were also measured in the north and south wetland sites on May 6, 2012, June 16, 2013 and July 16, 2013. As can be seen in Figure 18, total suspended solids were fairly low for all of the samples (particularly since these were moving water samples), with the exception of the north wetland upstream site which had a value of 127 NTUs. This could potentially be a sampling error or measurement error. Otherwise may be caused by disturbances upstream.

Summary of Sample Site Results
An overall summary of the site data is shown in Table 4. Phosphorous loads were detected in all of the sample sites indicating that the source of these pollutants should be identified and reduced. Efforts to investigate and reduce the sources should target the areas draining to each site (see Appendix A) and should focus on identifying

Figure 18

TOTAL SUSPENDED SOLIDS MEASUREMENTS FOR SILVER LAKE SAMPLING SITES



Source: SEWRPC.

and working with users of phosphorous containing fertilizers for gardens and pet owners (to reduce pet waste). Phosphorous from the golf course did not have values that were higher than any of the other sites. In fact, the values directly off the golf course were lower than those found just across the trail. This indicated that residential runoff may be a more productive target than the golf course.

Nitrite and nitrate concentrations were low in all of the sites, thereby indicating these sites are not issues of concern in terms of this parameter. Ammonium and total inorganic nitrogen pollution sources of concern are most likely coming from the residential areas which enter the Paganica drainage pipe downstream at the stormwater drain with some pollution also coming from the commercial landscaping activities occurring adjacent to the "North Wetland Upstream" site. Actions to address these sources should therefore be prioritized.

Total kjeldahl values were coming from all three of the areas of concern, with the most consistent values coming from the Paganica golf course sites. Paganica golf course and the upstream residential area just east of the golf course should therefore be targeted for nitrogen reduction activities wherever possible.

Chloride concentrations were very high in the four "wetland sites." This indicated that the detention basin adjacent to the highway, the runoff coming from the highway and north Dousman road, the runoff coming from the detention pond on the southeast corner of the Lake, and the use of potash containing fertilizers on the commercial property adjacent to the Lake, should be more stringently monitored and prevented to greatest extent practical. Total suspended solids were low for all of the sites.

Table 4

SUMMAY OF IN-LAKE WATER QUALITY FINDINGS

Site	Date	SRP	TP	N	NH_4^+	TIN	TKN	Cl^-
Pagancia Golf Course	04/25/11	0.079	0.224	0.08	0.20	0.28	4.900	16.8
	03/25/12	0.151	0.264	0.04	0.05	0.09	2.490	9.8
	05/06/12	0.041	0.142	0.20	0.09	0.29	1.120	0.7
	05/04/13	- -	0.333	- -	0.10	0.20	0.333	- -
	06/16/13	0.147	0.279	0.10	0.08	0.18	1.920	14.5
	07/16/13	- -	0.457	0.10	0.14	0.24	1.910	8.8
Pagancia After Trail	04/25/11	0.050	0.154	0.02	0.16	0.18	4.370	16.8
	03/25/12	0.290	0.721	0.15	0.16	0.31	5.580	13.0
	05/06/12	0.075	0.194	0.20	0.10	0.30	1.440	1.7
	05/04/13	- -	0.468	0.10	0.09	0.19	0.468	- -
	06/16/13	- -	0.295	0.10	0.08	0.18	1.820	20.1
	07/16/13	0.279	0.424	0.10	0.15	0.25	1.920	9.2
Pagancia Lake Outlet	04/25/11	0.066	0.159	0.06	0.18	0.24	3.580	20.6
	03/25/12	0.238	0.679	0.15	0.48	0.63	6.010	10.1
	05/06/12	0.095	0.208	0.20	0.29	0.49	1.610	5.7
	05/04/13	- -	0.293	- -	0.13	0.23	0.293	- -
	06/16/13	0.151	0.273	0.10	0.11	0.21	0.670	24.0
	07/16/13	0.283	0.419	0.10	0.17	0.27	1.820	13.8
Northwest Wetland Upstream	05/06/12	0.637	0.805	0.20	0.10	0.30	2.570	20.7
	06/16/13	0.586	0.833	0.10	0.07	0.17	0.890	69.0
	07/16/13	0.320	2.170	0.10	0.34	0.44	6.800	129.0
Northwest Wetland Lake Outlet	05/06/12	0.224	0.289	0.10	0.05	0.15	1.500	15.7
	06/16/13	0.186	0.246	0.20	0.04	0.24	0.970	117.0
	07/16/13	0.276	0.433	0.10	0.36	0.46	2.840	63.4
Southeast Wetland Upstream	05/06/12	0.053	0.098	0.10	0.02	0.12	0.600	46.6
	06/16/13	0.045	0.086	0.10	0.06	0.16	6.800	124.0
	07/16/13	0.011	0.044	0.10	0.01	0.11	0.890	234.0
Southeast Wetland Lake Outlet	05/06/12	0.022	0.062	0.10	0.16	0.26	1.330	63.1
	06/16/13	0.018	0.052	0.10	0.07	0.17	2.840	198.0
	07/16/13	0.008	0.053	0.10	0.01	0.11	0.970	226.0

NOTES: The following abbreviations were used:

SRP=Reactive Phosphorus
TP=Total Phosphorus
N=Nitrate + Nitrite
NH_4^+=Ammonium
TIN=Total Inorganic Nitrogen
TKN=Total Kjeldahl Nitrogen
Cl^-=Chloride

Green = Good (well below standards) Yellow = Risk (approaching standards) Red = High Risk (above standards)

Source: SEWRPC.

RECOMMENDATIONS

In order to further reduce phosphorus and chloride loading, it is important to identify where the loading is coming from so that efforts to reduce the loads can be correctly targeted. Consequently, there are two types of recommendations which are discussed in this report, including:

1. Recommendations related to better determining sources of phosphorous and chloride; and
2. Recommendations which seek to address likely sources of phosphorous and chloride.

The first set of recommendations not only seek to identify what is causing the numbers that were found in this study, but also seek to get a better grasp on the other sources which could also be contributing to pollutant loadings. Essentially, these recommendations relate to further investigation of what we do not currently know. These recommendations, which are represented on Map 3, include:

1. Test for chlorides in the detention basins located adjacent to the eastern shore sampling sites to determine if these are the sources of chlorides that were found at the sampling sites.
2. Test for phosphorous at the detention basins adjacent to the eastern shore sampling sites to determine if these are the sources of phosphorous found on the eastern shore.
3. Investigate if fertilizers are used and the types of fertilizers that are used on the turf at the commercial site located on the eastern side of the Lake. The goal of this investigation is to determine the chloride content. To do this check to see if the fertilizers contain Potassium Chloride (otherwise known as potash) as a main ingredient. This compound can be a source of chlorides in addition to water softeners and road salts. This investigation does not currently need to be repeated at the Paganica golf course as this does not currently appear to be a major source of chlorides.
4. Investigate if pet waste is a major issue in the watershed, particularly at the residential sites located just west of the "Paganica After Trail" site. This will help better determine if this is the source of phosphorous which was increasing the phosphorous concentrations in this sample.
5. Develop a list of other major potential pollution sources to the Lake, with a particular emphasis on drainage pipes which input to the Lake on a more consistent basis than the sites examined in this study. These sites should then be monitored periodically throughout the years to determine if there are peaks in concentrations. Though the concentrations may be more diluted in these areas, they could potentially contribute more frequently and consistently to the chloride and phosphorous concentrations.
6. Develop an updated watershed boundary using two-foot contours. The watershed which was used in the most recent Silver Lake Protection Plan completed in 1993 was done using 10 foot contour data obtained during the 50s, and, therefore is largely out of date (see Appendix B for the land use changes/land re-contouring which has occurred since 1941). Completing this watershed delineation would give a better idea of where to target pollution reduction efforts and a better indication of which land areas are contributing to which drainage pipe.
7. Complete a shoreline assessment to determine if there are areas which should be targeted for shoreline restoration or buffer development in order to prevent direct runoff from residential areas.

Map 3

SILVER LAKE MONITORING AND INVESTIGATION RECOMMENDATIONS

Source: SEWRPC.

8. Potentially complete a ground-watershed delineation, particularly if groundwater is deemed the primary source of phosphorous and chloride pollution through further investigation.

9. Continue citizen lake monitoring efforts with periodic sampling of chlorides.

10. Finally, it is recommended that a Lake Protection Plan update be completed. This plan could be completed by SEWRPC or another contractor to summarize all of the water quality data as well as incorporate any new monitoring data which results from the recommendations of this plan. This Lake Protection Plan could then further detail the specific actions that should be taken to help protect Silver Lake as the healthy ecosystem it is.

The second set of recommendations relate to action items meant to address potential pollution sources without further investigation. The first recommendations that are discussed relate to specific issues of concerns that were identified in this study. The later recommendations relate to general recommendations which seek to reduce phosphorous and chlorides in runoff. These efforts may be better allocated with more targeted monitoring, however, as the watershed is relatively small in comparison to the Lake size, it may be more feasible and effective to begin action as opposed to paying and waiting for further monitoring efforts. The recommendations, as represented on Map 4, include:

1. Encourage landscapers at the commercial site east of the Lake to use chloride free fertilizers.

2. Ensuring the Wisconsin Law against phosphorous containing fertilizers is being properly employed

3. Encourage proper maintenance of the stormwater detention ponds adjacent to the Lake.

4. Consider more stormwater detention basins along the IH 94 area to lower the amount of chloride runoff entering the Lake.

5. Discourage the use of salts for ice in the local areas adjacent to the Lake either through encouraging the use of brine mixtures or through better education of using the salt early and sparingly (more salt does NOT mean faster melting). When doing this also be sure to discourage kitty litter use or other phosphorous containing materials as a replacement to salt. Keep in mind chlorides and phosphorous are the issues.

6. Encourage homeowners to use phosphorous free fertilizers in their gardens or to use phosphorous fertilizers very sparely.

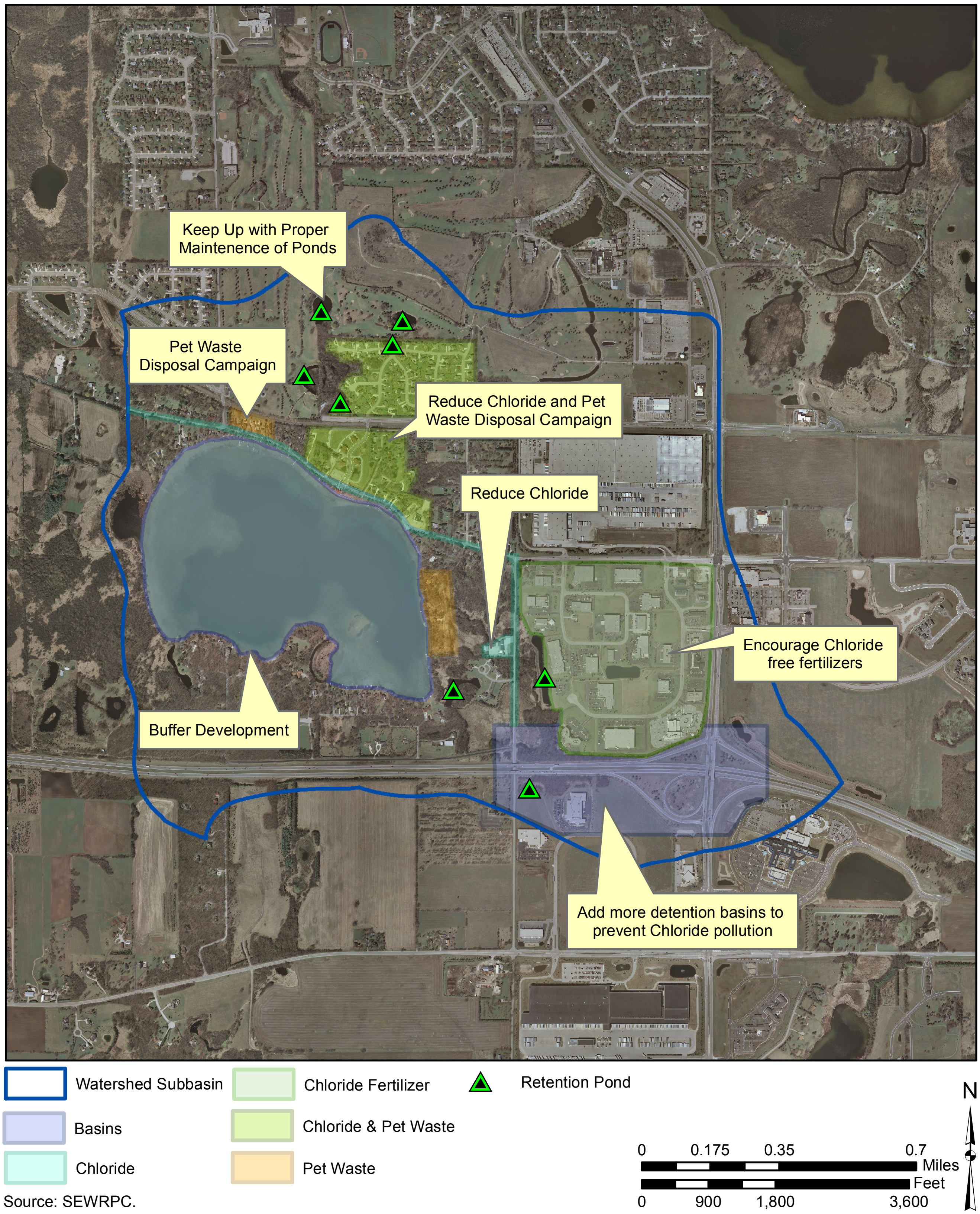
7. Encourage pet waste pick up on homeowner plots, with a specific target on the properties west of the Paganica Golf Course sites. This effort should then try to cover the other residential areas.

8. Consider developing an ordinance limiting uses of chlorides. Similar ordinance exist throughout the state.

9. Encourage buffer development in areas where direct runoff could be entering the Lake (i.e., shoreline properties. This will prevent road salts and phosphorous in soils from getting into the Lake. A new grant is being proposed by WDNR to provide partial funding to help with these kinds of projects. Additionally, many resources related to “how to guides” are available. These should be well communicated and distributed.

Map 4

SILVER LAKE ACTION ITEM RECOMMENDATIONS



Source: SEWRPC.

CONCLUSIONS

Silver Lake Waukesha is a high quality lake that should be protected to the greatest extent possible. Silver Lake Management District has thus far done an exemplary job thus far of improving the Lake quality as is evidenced by the vast improvements that have been seen since the late 1960s. However, with new developments come new challenges as is evidenced by the new emerging issue of chloride contamination. The implementation of the recommendations laid out in this report will help target future management efforts as well as reduce current threats to the Lake for the purpose of maintaining the Lake's water quality now and in the future.

* * *

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Appendix A

DRAINAGE FOR SAMPLING SITES AROUND SILVER LAKE, WAUKESHA COUNTY

Map A-1

DRAINAGE FOR PAGANICA GOLF COURSE

Picture of Paganica Golf Course sample site.

Source: SEWRPC.

Map A-2

DRAINAGE FOR PAGANICA AFTER TRAIL

Picture of Paganica After Trail sample site.

Drainage

Drainage Flow

Paganica After Trail

Paganica Golf Course

0 0.0075 0.015 0.03 Miles

0 50 100 200 Feet

N

Source: SEWRPC.

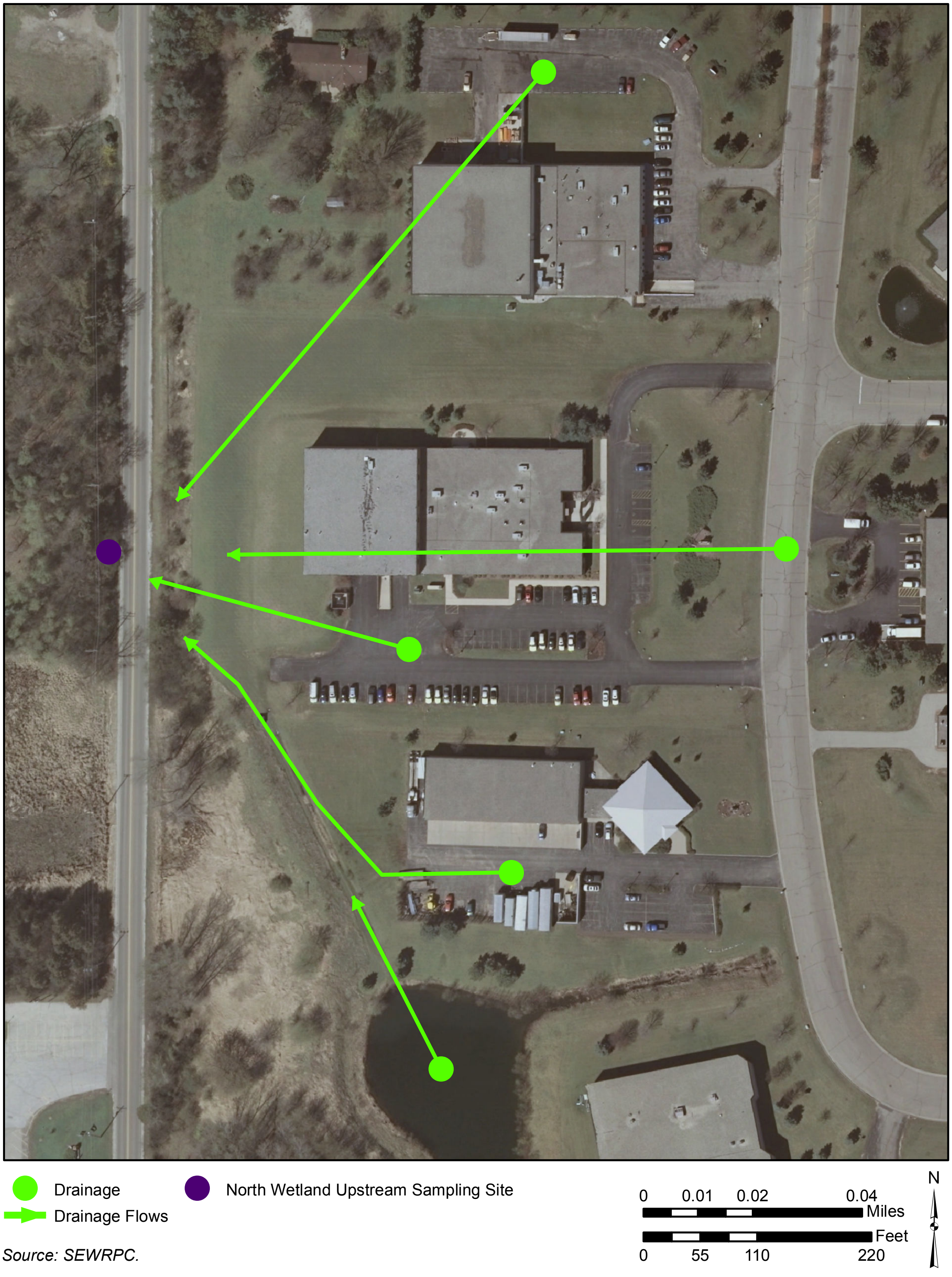
Map A-3

DRAINAGE FOR PAGANICA LAKE OUTLET

Source: SEWRPC.

Map A-4

DRAINAGE FOR NORTH WETLAND UPSTREAM



Source: SEWRPC.

Map A-5

DRAINAGE FOR NORTH WETLAND LAKE OUTLET

Picture of North Wetland Lake Outlet Sampling Site

Drainage

Drainage Flow

North Wetland Lake Outlet Sampling Site

North Wetland Upstream Sampling Site

0 0.015 0.03 0.06 Miles

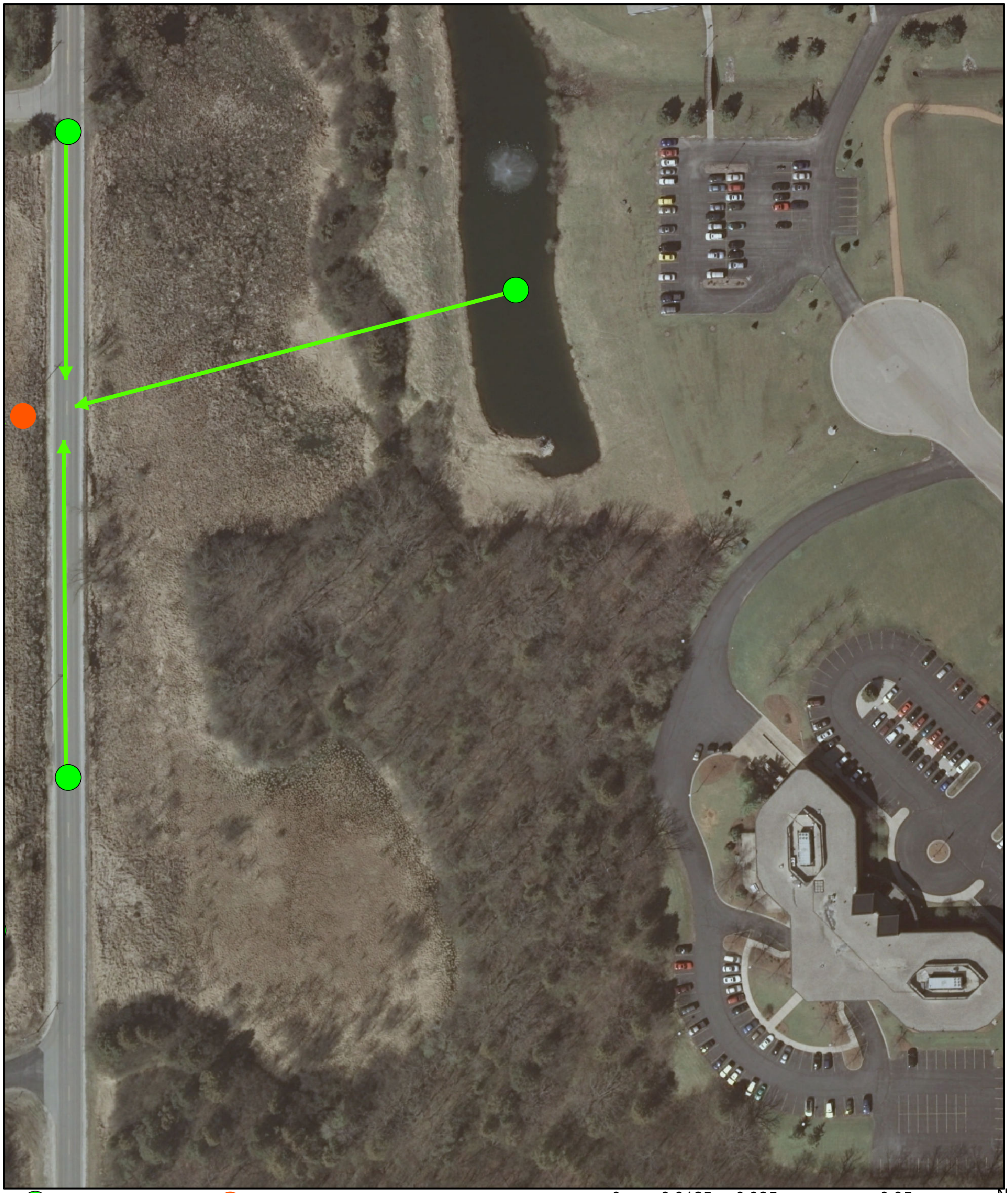
0 85 170 340 Feet

N

Source: SEWRPC.

Map A-6

DRAINAGE FOR SOUTH WETLAND UPSTREAM SAMPLING SITE



Drainage

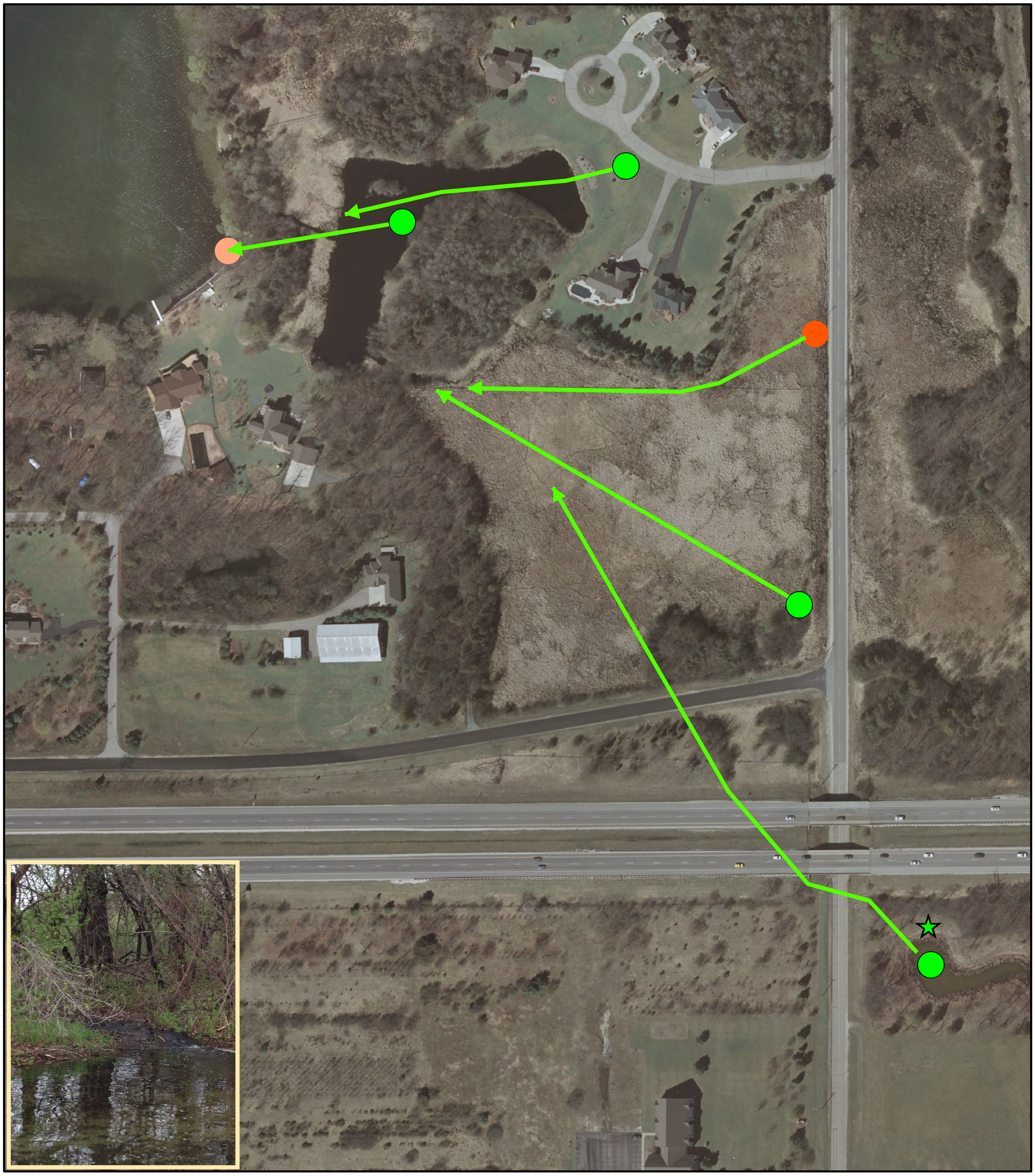
Drainage Flow

South Wetland Lake Upstream Sampling Site

Source: SEWRPC.

Map A-7

DRAINAGE FOR SOUTH WETLAND LAKE OUTLET



Picture of South Wetland Lake Outlet Sampling Site

Drainage Flow

Drainage

South Wetland Lake Outlet Sampling Site

South Wetland Lake Upstream Sampling Site

Potential Drainage to South Wetland Upstream

0 0.025 0.05 0.1 Miles

0 135 270 540 Feet

N

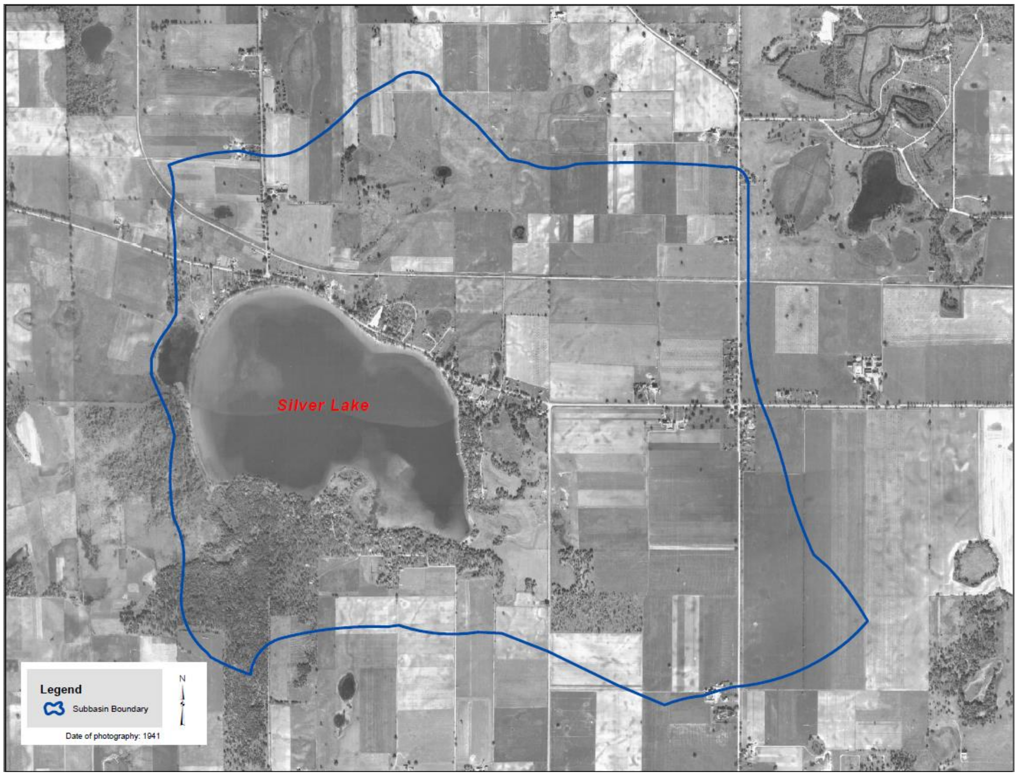
Source: SEWRPC.

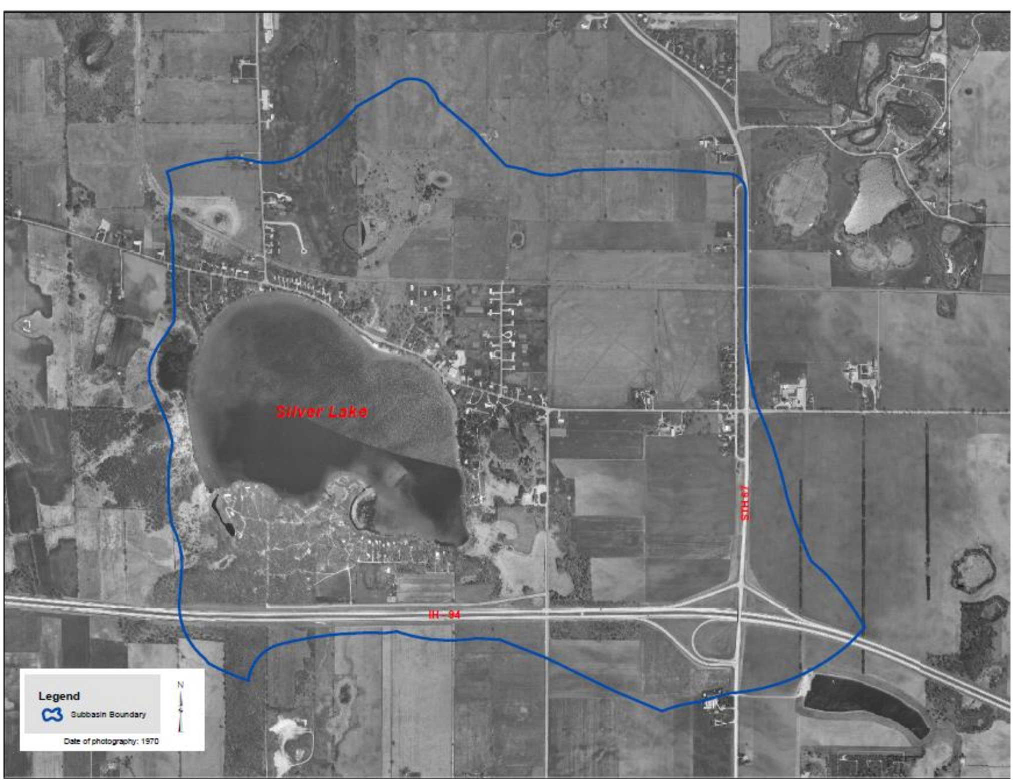
Appendix B

HISTORICAL AERIAL PHOTOGRAPHS OF SILVER LAKE WATERSHED

Map B-1

HISTORICAL AERIAL PHOTOGRAPHS OF SILVER LAKE WATERSHED: 1941 AND 1970

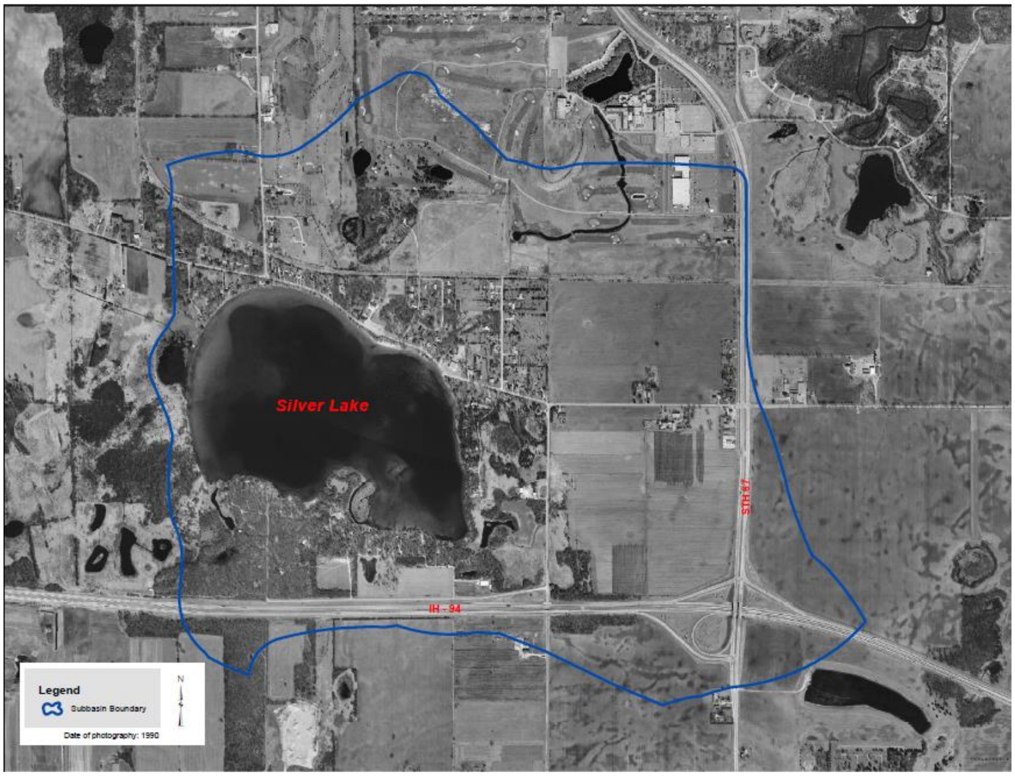


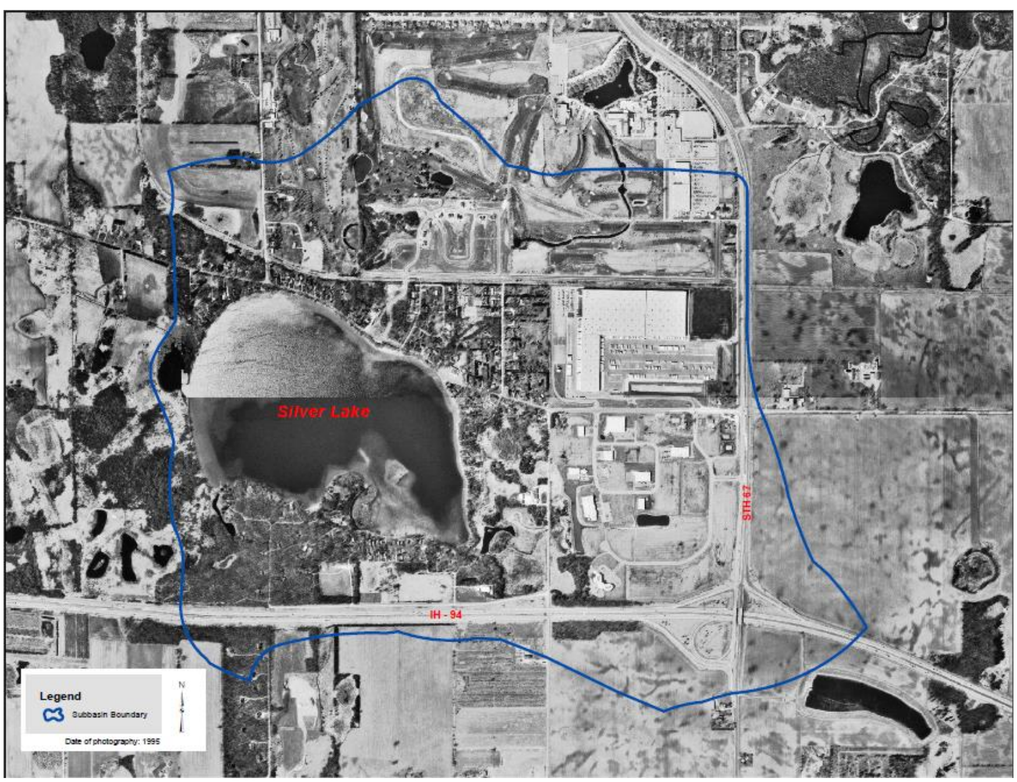


Source: SEWRPC.

Map B-2

HISTORICAL AERIAL PHOTOGRAPHS OF SILVER LAKE WATERSHED: 1990 AND 1995





Source: SEWRPC.

Map B-3

HISTORICAL AERIAL PHOTOGRAPHS OF SILVER LAKE WATERSHED: 2000 AND 2010

Source: SEWRPC.