SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION
W239 N1812 ROCKWOOD DRIVE • PO BOX 1607 • WAUKESHA, WI 53187-1607• TELEPHONE (262) 547-6721
FAX (262) 547-1103

Serving the Counties of: KENOSHA
MILWAUKEE
OZAUKEE
RACINE
WALWORTH
WASHINGTON
WAUKESHA

SEWRPC Staff Memorandum

WATER QUALITY SAMPLE EVALUATION FOR SILVER LAKE, WAUKESHA COUNTY

INTRODUCTION

Silver Lake is a 222-acre lake, with a maximum depth of 30 feet, 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 watershed 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 the Lake is the focal point for water-based recreation in a lake-oriented residential community.

Water quality has been an ongoing concern of 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 the existing public sanitary sewerage system, which is operated by the City of Oconomowoc,[2] for the specific purpose of protecting the Lake from phosphorus pollution. As a result of this concern about water quality, the Silver Lake Management District has been engaged in Citizen Lake Monitoring since 1990, with a brief break in data from 2000 through 2005, thereby providing nearly 20 years of water quality data for the Lake. 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 the 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 stormwater 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.

---

[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 memorandum summarizes the water quality data that was collected from 2011 to 2013 as a part of this monitoring effort, and compares that data with current and historical water quality data for the Lake. In addition to summarizing this data, this memorandum provides recommendations for "next steps" for further monitoring, managing 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 stormwater drainage pipe entering the Lake along the eastern shore of the Lake, which was identified as a potential source of runoff from commercial development, and a stormwater drainage pipe entering the Lake in the southeastern corner of the Lake, which was identified as a potential source of urban pollutants from the upstream highway system. Thus, this study quantifies contaminants entering the Lake from the Paganica Golf Course and from the eastern shore of the Lake.

METHODOLOGY

The monitoring study discussed in this memorandum focused on three specific areas, featuring a total of eight sampling sites, including an in-lake site, as shown on Map 1. Each sample site was chosen to represent a particular area of concern and, therefore, reflect the different sources of stormwater runoff and potential sources of pollution. The eight sites, and the general areas contributing runoff to them, are shown in Appendix A. They include: three sites downstream from the Paganica Golf Course; two sites at a tributary just north of the Summit Village Hall; and two sites on the tributary entering the Lake at the southeast corner.

Water samples from the various sites were collected by volunteers on seven different 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 analyzed by the Water and Environmental Analysis Laboratory of the University of Wisconsin-Stevens Point using standard protocols and methods. Chloride, conductivity, nitrogen fraction, phosphorus fraction, and total suspended solid measurements were obtained for all of the sites, while alkalinity, color, turbidity, pH, potassium, sulfate, sodium, and total hardness measurements were obtained only for the "In-Lake Deep Hole" site. Table 1 shows what samples were taken and what they were tested for. Not all of the sites were sampled on each field day because: 1) the two wetland sites were not added to the site list until the summer of 2012; and 2) only some of sample sites were flowing on some of the field sampling days.

RESULTS AND DISCUSSION

As mentioned above, the objectives of this study are to evaluate the water quality 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 section relates to evaluating the water quality and chemistry of the

Map 1

LOCATION OF SAMPLING SITES IN AND NEAR SILVER LAKE, WAUKESHA COUNTY

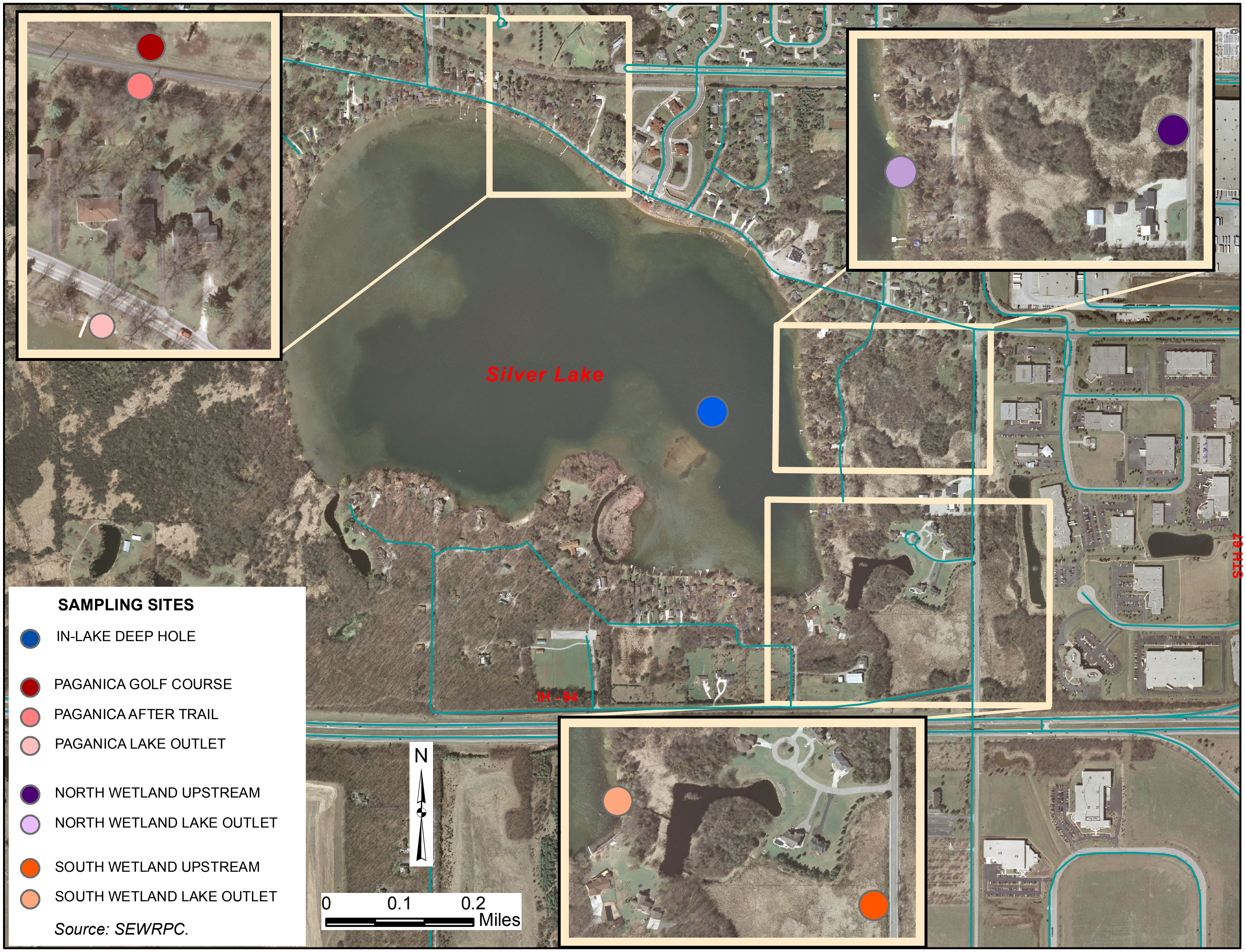


Table 1

PARAMETERS MEASURED AT SILVER LAKE SAMPLING SITE

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^+, Cl^-, Color, Cond., N, pH, K^+, SRP, Na+, TH, TKN, TP	NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS	Alk, NH_4^+, 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^+, Cl^-, N, SRP, TKN, TP, TSS	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^+, Cl^-, N, SRP, TKN, TP	NH_4^+,Cl^-, Cond., N, SRP, TKN, TP, TSS	NH_4^+, Cl^-, N, SRP, TKN, TP, TSS	NH_4^+, Cl^-, Cond., N, SRP, TKN, TP, TSS	NH_4^+, Cl^-, Cond., N, SRP, 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^+, Cl^-, N, SRP, TKN, TP, TSS	NH_4^+, Cl^-, Cond., N, SRP, 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^+, Cl^-, N, SRP, TKN, TP	NH_4^+,Cl^-, Cond., N, SRP, TKN, TP, TSS	NH_4^+, Cl^-, N, SRP, TKN, TP, TSS	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, TKN, 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
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.

Lake 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 terms of providing a context for understanding the data that was collected at the "areas of concern." The second section relates to the evaluation of the three areas of concern in comparison to the corresponding in-lake measurements to determine if any of the areas contributing runoff to these sites could be significant sources of pollution.

In-Lake Data

As mentioned in the introduction, there is water quality data dating back to the 1970s in Silver Lake, including a sampling period from 1973 through 1980, a sampling period from 1990 through 2000, and an ongoing sampling period from 2005 to today. In addition, in-lake monitoring was conducted on each of the field sampling 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 evaluates these factors using both the historical data available for the Lake and the samples collected during this study.

Natural Lake Chemistry

There are several parameters that provide insight into the natural state of a lake. This means that, barring extensive human interference, there are types of measurements that tend to remain fairly constant over time. This is because certain characteristics are primarily influenced by the source of the water contributing to the lake, rather than biological components in the lake. A lake which is surrounded by rock formations containing calcium carbonate, or is fed by groundwater coming from a calcium carbonate aquifer, for example, will naturally contain a higher amount of calcium carbonate deposits which can influence pH, alkalinity, calcium, hardness and, to an extent, water color. These parameters, therefore, depend more on the natural conditions in and around the lake than human influence, and, thereby, provide insight into lake types and characteristics. These parameters, as well as the findings for each of them within Silver Lake, are discussed further 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 greatly 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 total hardness due to the dolomite (limestone) deposits (rocks containing both magnesium and calcium) which make up much of the underlying bedrock in this area.[3] High levels of total hardness can cause scaling in boilers and other equipment, as well as increase soap or detergent requirements for washing. Generally lakes with harder water produce more fish and plants than those with softer water due to the need for calcium and magnesium when producing biomass.

General guidelines for classifications of water hardness are: 0 to 60 milligrams (mg)/liter (l), which is considered soft water; 61 to 120 mg/l, which is moderately hard; 121 to 181 mg/l which is hard; and more than 180 mg/l which is considered very hard.[4] Total hardness was measured at the Deep Hole site on April 25, 2011, and

---

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

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

March 25, 2012. A concentration of 240 mg/l was 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 historical average of 231.7 mg/l which was measured in the late 1970s. However, the value is within the historical range of 155 to 297 mg/l.

pH

pH is the measure of the acidity or basicity of water, ranging from 0 to14, 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 lakes, often staying above 7.0. The 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 concentrations can be toxic to plants and animals that live in and around the lake, potentially destroying the lake's natural ecosystem. Biologically speaking, pH also affects plant growth because the availability of nutrients within the water column for organisms is dependent on the pH level. The productive pH range for most organisms is 6.5 to 8.0.[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 (as opposed to acidic) 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). As with hardness, a lake's alkalinity is often greatly influenced by the soils and bedrock of the lake's watershed. The southeastern Wisconsin lakes traditionally have high alkalinity, averaging around 173 mg/l.

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 176 mg/l was found on March 25, 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 carbonate deposits in the Lake water. These values are also slightly higher than historical values. This could be due to an increased proportion of the water supply to the Lake being restricted to groundwater inputs.

Calcium

Calcium levels (calcium ions dissolved in the lake water) are highly correlated to hardness and alkalinity of water. This is because dissolved calcium is found in calcium carbonate; the main mineral which is responsible for hard and alkaline lakes, due to the limestone composition of the bedrock of Southeastern Wisconsin. The regional average concentration of calcium in lakes is 36 mg/l.[6]

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 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.[7]

---

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

[6] *R.A. Lillie and J.W. Mason, Wisconsin Department of Natural Resources Technical Bulletin No. 138,* op. cit.

[7] *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.*

Calcium levels were measured at the Deep-Hole site on March 25, 2012. The measured concentration of 35.4 mg/l is well within the historical range of 30 to57 measured in the 1970s and just above the ranges found in the 1990s to the 2000s (30 to 34). This value is 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 growth 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 fact, water color is often correlated with the area the water came from, and how long the water has been in contact with soils and/or organic materials such as leaves and grass clippings. Color and water quality can sometimes even have an inverse relationship (i.e., the darker the water gets, the cleaner it is). Water 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, naturally use up nutrients and other pollutants, making long-term contact with these materials beneficial to water quality. However, this long-term contact causes water to get darker in color (like leaving a teabag in the cup too long) as it becomes cleaner. This is not to say, however, that darker water is always "clean." Water can also become colored due to algae or suspended soil particles from eroded soil.

Several color scales have been developed 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 between 1966 and 1979.[8] The color of Silver Lake was recorded as very clear with values of less than 5 and 7.2 determined on April 25, 2011, and March 25, 2012, respectively. These colors were further corroborated with color recordings that have been made through the citizen lake monitoring activities. These records indicate that the water in Silver Lake is almost always blue, with some recordings of green during high growth seasons. These observations indicate Silver Lake has high quality water that supports a productive aquatic plant population.

Dissolved Oxygen
Dissolved oxygen is a critical factor for a lake's living organisms, specifically fish and aquatic insects. In general, dissolved oxygen levels are higher at the surface of a lake where wind action, the atmospheric interchange with the water, and plant photosynthesis are available to add oxygen to the lake.[9] Dissolved oxygen is affected by several factors, the most critical of which is stratification and mixing, as discussed below.

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 with colder temperatures than the water above it (i.e., the deep water stays the same

---

[8]*R.A. Lillie and J.W. Mason, Wisconsin Department of Natural Resources Technical Bulletin No. 138,* op. cit.

[9]Ibid.

temperature while the top waters get warmed). This process can sometimes be detected physically 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 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 together (the layer of water separating these layers being called the metalimnion, or thermocline). Overall, 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 waterbody 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 the wind is strong, the lake waters can mix, pushing surface waters to the bottom, and resulting in a lake of relatively constant temperature from the surface to the bottom. Ice cover can make this type of mixing impossible in the winter, thereby making stratification in the winter more common in upper Midwest lakes with ice cover.

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 solar radiation are reduced during these times (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 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.

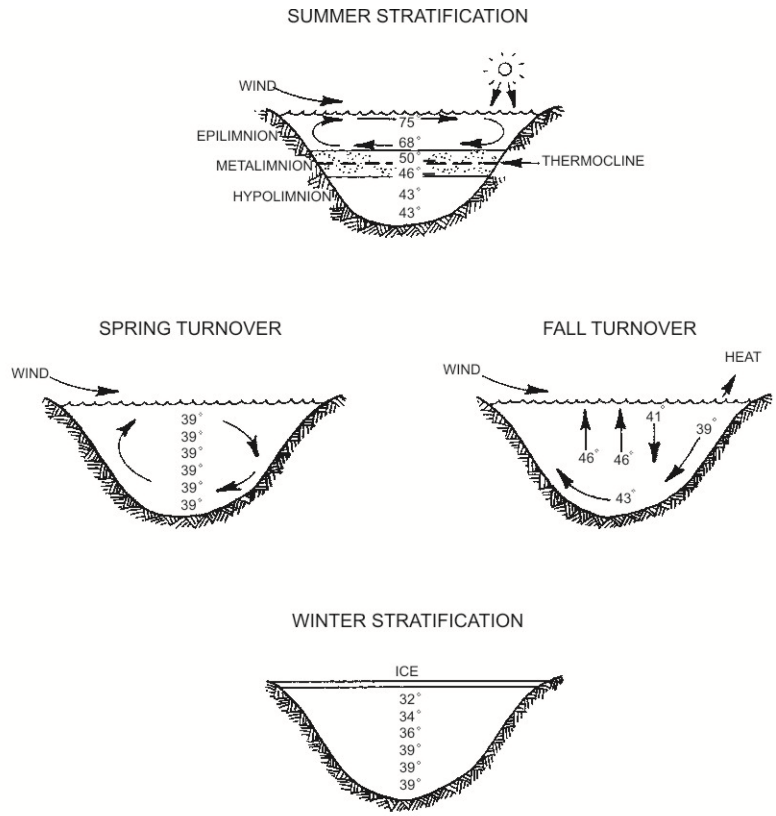
When a lake stratifies, the formation of a metalimnion creates a barrier that prevents mixing between the upper and lower layers. This barrier not only prevents water from moving between different depths, but also prevents the dissolved gases and nutrients in that water from moving through the layers as well. When a lake is well mixed, the oxygen from the air, and the oxygen being formed by aquatic plants, is present throughout the entire depth of the lake. However, when the barrier forms, this prevents the oxygen from getting to the deeper parts of the lake. This is a particular issue because much oxygen is used at the bottom of a lake for the decomposition of plants and debris which collect at 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 bottom becomes anoxic.

High amounts of stratification may make it difficult to support some kinds of fish, such as trout, which require both oxygen and cold temperatures to live. Additionally, if the anoxic part of the lake becomes too large, making the entire lake anoxic, this can cause fish kills. 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 (byproducts of anaerobic decomposition) to accumulate at the bottom of the lake. These chemicals can then rise to surface during spring and fall mixing periods ("turnovers") resulting in a particularly unpleasant "rotten egg" odor.

Stratification can be confirmed by taking measurements of water temperature and dissolved oxygen concentrations at various depths in the lake, creating a depth profile. In stratified lakes, this profile, when looked at graphically, will show a drastic decrease in temperature at a particular depth (the thermocline). This same

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.

decrease will also likely be found in the dissolved oxygen profile. Given that insufficient dissolved oxygen supply can cause fish and other organisms to become stressed (generally at concentrations below 5.0 mg/l) and/or cause fish kills (if levels drop below 2.0 mg/l), it is important to monitor the Lake's surface, and the vertical extent of the anoxic layer, to prevent these issues.

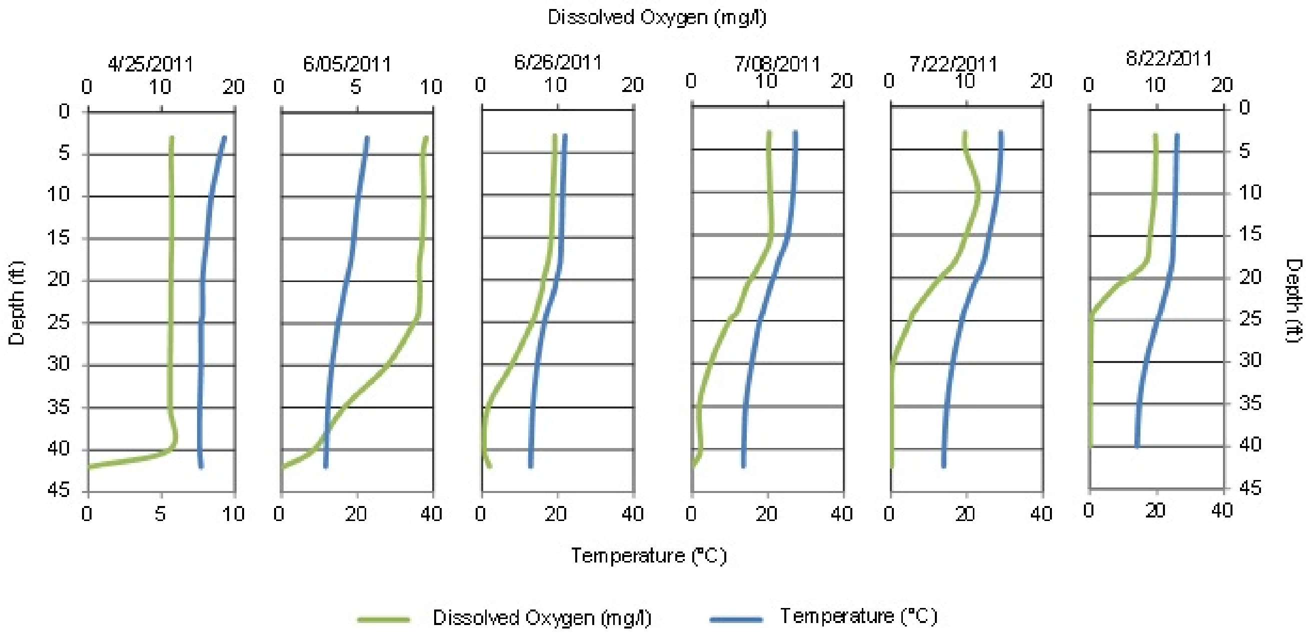
Temperature and dissolved oxygen profiles have been collected 38 times in Silver Lake since 2006. As can be seen in Figure 2, it can be definitively concluded that Silver Lake is stratified and exhibits mixing periods in the spring. However, with no reports of fish kills, it is unlikely that the whole Lake has become anoxic. This is further confirmed by the surface water dissolved oxygen measurements which were taken as a part of the profiles taken since 2006. With a mean concentration of 9.26 mg/l, and levels never dipping below 8 mg/l, Silver Lake has appears to have healthy levels of dissolved oxygen at the surface.

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 is generally used to describe the

Figure 2

STRATIFICATION IN SILVER LAKE



Source: SEWRPC.

"quality" or "cleanliness" of water. There are three major trophic categories for lakes (as illustrated in Figure 3) with 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");

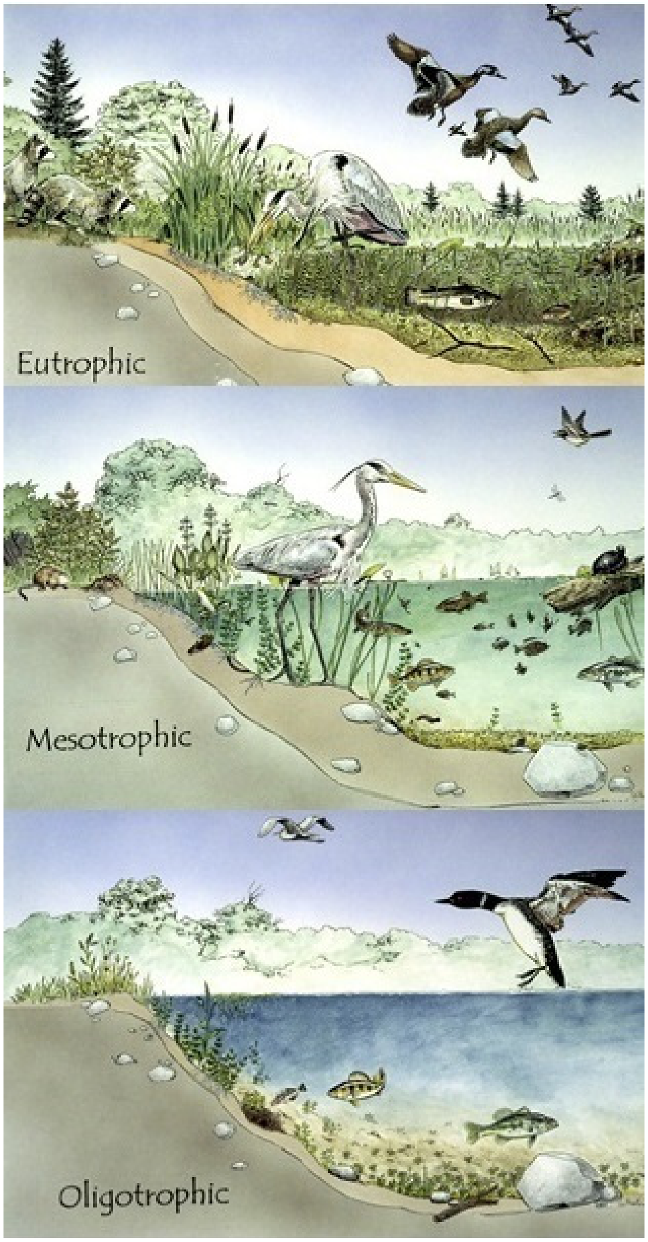
2. Mesotrophic, which are lakes with a moderate amount of nutrients which can maintain a good amount of biological activity (generally characterized as "high to medium quality water"); and

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

As can be seen in the description of the trophic statuses, the major differing component is the level of nutrients present within the lake. This is because plants and algae, which serve as habitat and food for wildlife, need nutrients to grow. Therefore, when large amounts of nutrients are present, plant growth is accelerated, and more animals are attracted to the lake, thereby creating a more biologically productive lake. Lakes can naturally attain any of the three trophic statuses, depending on the age of the lake (see Figure 4 for illustration of the natural aging process of lakes) 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. Such a lake may be covered by plants which support an active fishery, making the lake a wildlife hotspot. In contrast a lake with little natural nutrient sources and very clear waters, for example a seepage lake, like Silver Lake, could naturally be oligotrophic or in the low range of mesotrophic, as it would likely not have natural sources of nutrients. These kinds of lakes would be incapable of supporting extensive wildlife due to lack of food and habitat. Generally, eutrophic lakes are very 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.

Figure 3

ILLUSTRATION OF TROPHIC STATES



Source: DH Environmental Consulting, 1995.

Though trophic statuses happen naturally, human interference can cause shifts in trophic levels. This normally occurs when unnatural nutrient inputs such as phosphorus- and nitrogen-containing fertilizers, erosional deposits (i.e., nutrient-rich soils transported from areas of agricultural or urban development which do not have adequate stormwater controls), septic system contamination, and pet waste enter the lake. These inputs of nutrients can then cause a lake to be more productive (e.g., to change 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. The biomass of plants and algae can get so extensive that the decomposition of plant material at the bottom of the lake takes up all of the oxygen in the lake. As fish depend on oxygen (as discussed above), this occurrence would then result in fish kills. A hyper-eutrophic status does not occur naturally and is an indication of poor land management practices contaminating the water in the lake.

Trophic Status Indicators

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

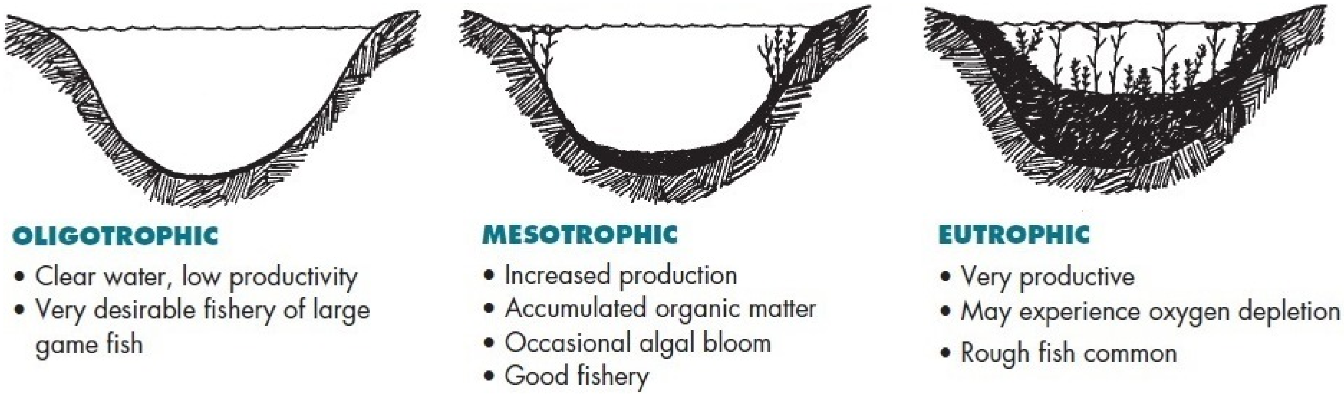
Water Clarity

Water clarity is measured by lowering a black and white disk called a Secchi disk into the deepest point of the lake and recording when the disk is no longer visible. This measurement is an indicator of water quality because water clarity can be affected by pollution and high algae growth, which are generally present in "impaired lakes." As can be seen in Figure 6, the measured Secchi depths have been increasing over time in Silver Lake, with the most recent measurements ranging from seven feet to 27 feet. These numbers generally indicate good water quality.

It is important to note that zebra mussels were reported in Silver Lake in 2004. Zebra mussels are an invasive species (i.e., a species which thrives, once introduced, due to the absence of natural predators) which can significantly influence a lake's ecosystem by excessively eating suspended microscopic plants, animals, and debris within the water column (causing food shortages for other species). As this process often increases water clarity, it is possible that the improvements in water clarity, since 2004, are due to zebra mussels, and not improved water quality. Consequently, it is necessary to look at other indicators to determine the Lake's health.

Figure 4

ILLUSTRATION OF AGING AFFECTING TROPHIC STATUS



Source: Wisconsin Department of Natural Resources.

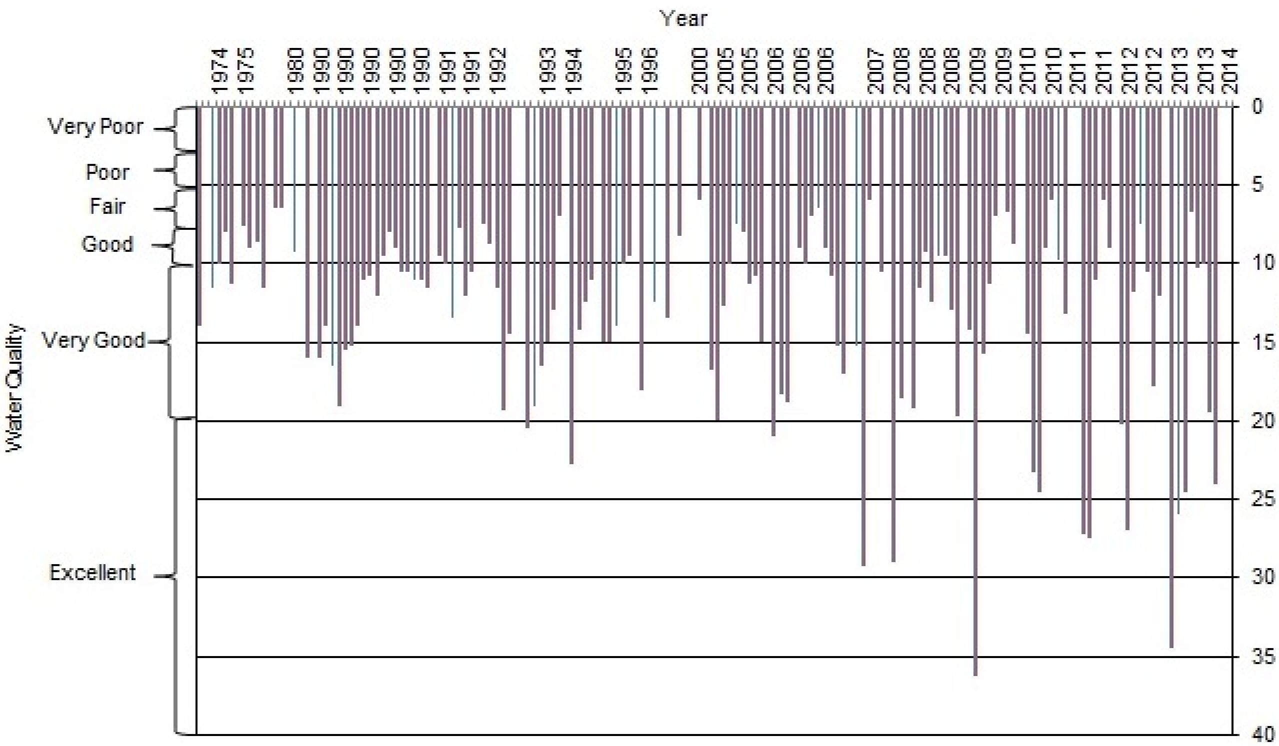
Figure 5

PHOTOGRAPH OF A HYPER-EUTROPHIC LAKE

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

Figure 6

SECCHI DEPTH MEASUREMENTS IN SILVER LAKE



Source: SEWRPC.

Phosphorus

As mentioned in the "Trophic Status" section, nutrients (specifically nitrogen and phosphorus) are needed for plant and algae growth. It is important to note that one of these nutrients will be what is considered a "limiting factor;" meaning that this is the nutrient which is least available in the lake and, therefore, is the factor limiting further growth of plants. In Silver Lake, and in most lakes in Wisconsin, this limiting nutrient is phosphorus. This means that when phosphorus enters the lake it is quickly used by plants and algae to grow and reproduce. Due to this connection with plant and algal growth, phosphorus can also be used as a barometer of a lake's trophic status. This relationship is also the reason that increases in phosphorus loads to a lake cause major problems. The WDNR threshold for determining a phosphorus impaired lake is 30 micrograms (µg)/liter (l) (i.e., 0.03 mg/l) in stratified lakes during the spring mixing period; however, a concentration of 20 µg/l is recommended in the regional water quality plan[10] and is often needed to prevent nuisance algal blooms.[11] The reason the standard is set in the mixing period is because phosphorus can accumulate at the bottom of the lake during stratification and only come to the surface during the mixing period (see the "Stratification and Mixing" section of this memorandum and Figure 1 for more information).

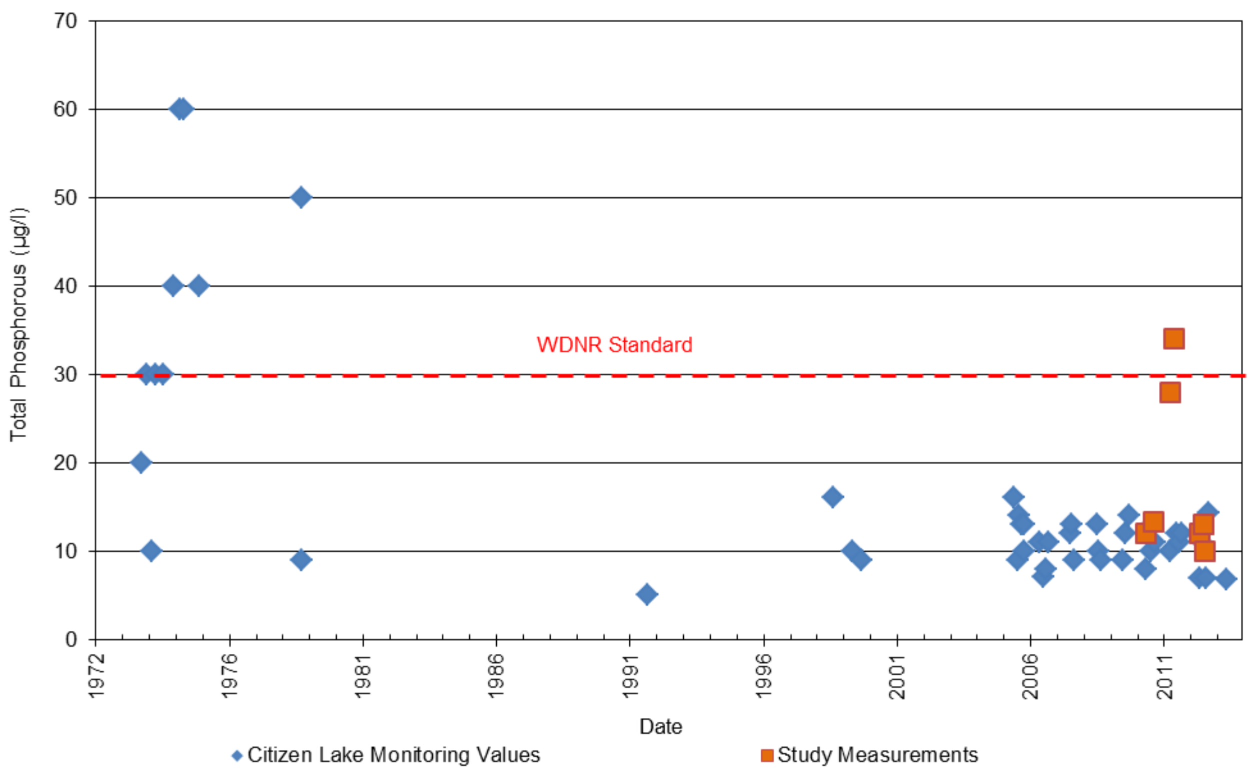
---

[10]*SEWRPC Planning Report No. 30,* A Regional Water Quality Management Plan for Southeastern Wisconsin—2000*, 1979.*

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

Figure 7

PHOSPHORUS LEVELS IN SILVER LAKE INCLUDING STUDY MEASUREMENTS



Source: SEWRPC.

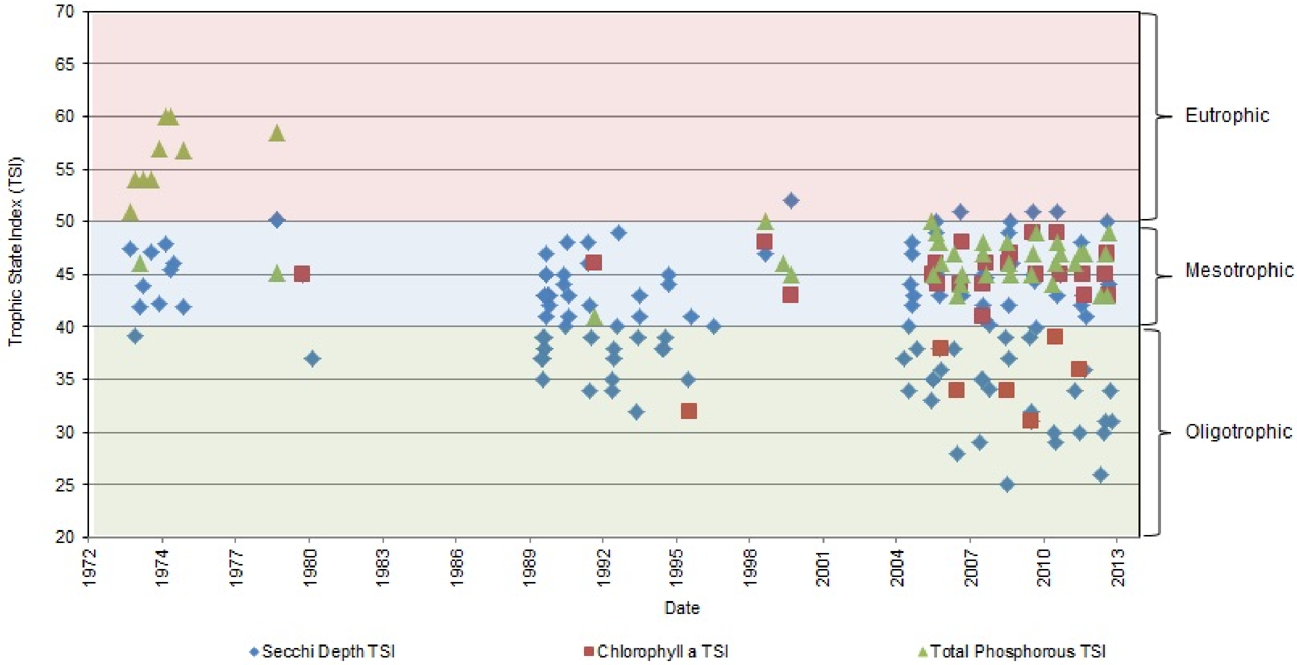
Total phosphorus levels were measured in the Lake under this study. The average total phosphorus concentration for the sample period was 17 µg/l, with the highest values being 28 and 34 µg/l in the two samples taken in the spring of 2012. It is suspected that these measurements fell within the mixing period of the Lake; therefore, this study shows that the Lake periodically exceeds recommended standards. However, in 2011 and 2013 phosphorus concentrations in the Lake stayed well below these levels. Additionally, despite this periodic rise above the WDNR standard, the total phosphorus levels have decreased dramatically since the 1970s, as shown in Figure 7. This change was likely due to the provision of sanitary sewer service to reduce phosphorus loading caused by septic system contamination. However, the significant reduction of agricultural land use over time (see Appendix B), may also have been a factor in reducing pollution from phosphorous-based fertilizer that is washed off the land surface.

*Chlorophyll-*a

Chlorophyll-*a* is needed for photosynthesis, and is found in all plants and algae. Consequently, when found in lake water, chlorophyll-*a* is considered an indicator of the amount of single cellular algae in the water column. Since algae rapidly grow in eutrophic lakes, this parameter can also be an indicator of water quality. Chlorophyll-*a* was not sampled under this study, but was frequently sampled as a part of the citizen lake monitoring efforts that have occurred since 2005, with concentrations ranging from 0.6 to 6.5 mg/l. These values indicate good water quality. Chlorophyll-*a* was only measured a total of five times before the year 2000, thereby making it difficult to provide a historical comparison. The historical values did, however, fall within the most-recently recorded ranges, indicating similar algal levels.

Figure 8

COMBINED TROPHIC STATES INDEX LEVELS IN SILVER LAKE



Source: SEWRPC.

Trophic State Index
Though water clarity, phosphorus, and chlorophyll-*a* can each be used as an indicator for lake health, it is more useful to use them in combination to determine a trophic status. 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 State Index or TSI. This index is a series of equations which convert Secchi disk, phosphorus, and chlorophyll-*a* data into numbers that can be compared to each other, and can be looked at together to determine trophic status. Generally, TSI 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 (especially since zebra mussels are affecting the Secchi depth measurements). This means that Silver Lake has moderate nutrient levels, high to medium quality water, and is capable of supporting good levels of biodiversity.

Other Nutrient Concentrations
Although total phosphorus levels, as discussed previously, are good indicators of general water quality, it is of value to monitor other nutrients when trying to identify issues and areas of concern. This section presents information on the other nutrients that have been monitored in the Lake, including reactive phosphorus, which is a component that is included in total phosphorus 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 discussed below.

Reactive Phosphorus
Total phosphorus includes all of the phosphorus present in the water sample. This measurement, however, has several components, one of which is reactive phosphorus, which refers to the phosphorus which is immediately available for biological uptake (i.e., in the correct chemical form for plant and algal use). Generally, because reactive phosphorus is used up quickly, concentrations tend to vary throughout the growing 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 phosphorus levels (above 0.01 mg/l) are a strong indicator of nutrient pollution problems in a lake.[12] In phosphorus limited situations (as in Silver Lake), the concentration of reactive phosphorus should be very low to undetectable (less than 0.005 mg/l) during the growing season. As concentrations of reactive phosphorus 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 phosphorus is being supplied at rates faster than it can be taken up by the biota.[13]

The in-Lake reactive phosphorus was measured on all seven days when field data were collected under this study. The highest level of 0.117 mg/l was found in the sample that was taken at the end of the growing season (early August 2011), as expected. The rest of the samples ranged from 0.002-0.016 mg/l and averaged 0.008 mg/l. Two samples were taken on June 16 and July 16, 2013, during the high-growth season of mid-summer. These had values of 0.005 and 0.002 mg/l respectively, which fall within the expected range (meaning that the reactive phosphorous levels are not indicating nutrient pollution issues). 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 numbers to use for comparative purposes, nor are they reliable indicators of nutrient pollution. Consequently, they were not used in this analysis.

Nitrogen (NO_2 + NO_3)
Though not a "limiting factor," nitrogen concentrations in a lake can still act as an indicator of pollution. This is because nitrogen is contained in fertilizers which can sometimes also contain phosphorus and salts (pollutants which can cause excessive plant growth and stress to fish). Nitrogen occurs in various forms. Nitrate (NO_3) and nitrite (NO_2) are inorganic forms, which support algal growth but are slightly harder for plants to use than ammonium (NH_4), ammonia (NH_3) or organic nitrogen.[14] Natural levels of nitrite and nitrate in lakes are typically lower than 1.0 mg/l; concentrations higher than 10 mg/l can become toxic to warm blooded animals, including humans.[15] The combined nitrite and nitrate levels were measured in the Lake on all field days. The highest value recorded, taken in April 2011, was 0.25 mg/l, while most of the other measured concentrations were 0.1 mg/l or less. These values are similar to historical values found in 1999 and 2000 and lower than many of the values found during the late 1960s, which rarely went below 0.18 mg/l. This reduction in nitrogen concentrations is likely the result of decreasing agricultural sources of nitrogen pollution as the watershed has urbanized. In general, none of these concentrations 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 lake surface

---

[12]*Interpreting Your Lake's Water Quality Data,* Lake County Health Department and Community Health Center, Waukegan, IL. 2005.

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

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

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

Table 2

TOTAL INORGANIC NITROGEN IN SILVER LAKE SAMPLING SITES

	Concentrations in mg/l							
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**	0.28	0.18	0.24	- -	- -	- -	- -
08/09/11	0.13	- -	- -	- -	- -	- -	- -	- -
03/25/12	**0.34**	0.09	**0.31**	**0.63**	- -	- -	- -	- -
05/06/12	**0.33**	0.29	**0.30**	**0.49**	0.30	0.15	0.12	0.26
05/04/13	0.19	0.20	0.19	0.23	- -	- -	- -	- -
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: **Red font =** Concentrations greater than 0.3 mg/l that can lead to algal blooms.

Source: SEWRPC.

waters. However, depending on the affected species, lethal concentrations of ammonium range from 0.2 to 2.0 mg/l; where 0.2 mg/l can have physiological effects on more tolerant species.[16]

Ammonium was measured in the Lake on all of the field days. The values ranged from less than 0.01 mg/l in fall of 2013 to 0.41 mg/L in April of 2011. In general, high ammonium levels indicate high amounts of decomposition which is often associated with excessive plant and algae growth, in combination with very stagnant waters. The mean value of ammonium (0.15) based on measurements made during the course of this study was slightly above the historical average of 0.14 mg/l, with both being well below dangerous levels. However, the high value of 0.41 mg/l, 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 the winter. Continued monitoring of this parameter may, therefore, be warranted.

Total Inorganic Nitrogen

Total inorganic nitrogen concentration can be determined by adding nitrate, nitrite, and ammonium concentrations. If the values found are over 0.3 mg/l, this indicates a sufficient amount of nitrogen for summer algal blooms (if reactive phosphorus is available).[17] Table 2 shows the in-lake inorganic nitrogen values for the seven field dates. Levels above 0.3 mg/l were found on three of those days, each coinciding with mixing periods (spring of 2011 and 2012). This indicates that nitrogen pollution, resulting in spring algal blooms, could potentially be an issue of concern.

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. Total nitrogen can be used as an indicator of nitrogen pollution from animal waste or fertilizers. In the

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

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

Lake, total Kjeldahl nitrogen was sampled on all seven field days. The mean value was 1.06 mg/l. This concentration was only slightly higher than the average measured in the Lake in the 1960s (0.94 mg/l). The largest total Kjeldahl nitrogen concentration value, and the only value outside of historical levels, was the June 2013 measurement of 1.91 mg/l. Wisconsin has no adopted standard for Kjeldahl nitrogen; however, values above 0.5 mg/l are considered excessive in New Hampshire. Though this is not directly applicable due to geographical location, it still indicates that this parameter, as with inorganic nitrogen, may be an issue of concern.

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 ecosystem overall. This section seeks to explain the effect these other pollutants could have on a lake, and highlights whether or not they are issues within Silver Lake.

Chlorides
Chloride naturally occurs in small quantities in lakes, because some chlorides originate from natural weathering, soil, and bedrock. When concentrations are found to be higher than the range of 20-30 mg/l, however, it normally stems from pollution sources such as road salt, runoff of chloride-containing fertilizers, and salt discharged from water softeners and treated wastewater. In general, a major issue with chlorides is that they are a conservative pollutant that persists in the environment 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 in lakes at concentrations around 250 mg/l and are considered severe in excess of 1,000 mg/l. Wisconsin has two standards related to chlorides. A concentration of 757 mg/l is the acute toxicity level for fish and 395 mg/l is the chronic toxicity level for fish and other aquatic life.[18] It has also been found that Eurasian Water Milfoil is more tolerant of chlorides than native plants; therefore, keeping chloride concentration in check can mitigate the growth and spread of this invasive plant.

In 1983, the median chloride concentration in lakes in southeastern Wisconsin was 16 mg/l;[19] however, chloride concentrations throughout the Region have been rising steadily. Chloride levels within Silver Lake were recorded on all seven sampling days with the average being 111.4 mg/l. This level is much higher than historical levels recorded in the mid to late 1970s (between 15 and 27 mg/l with an average of 19.4 mg/l). Although these values have not yet hit the levels where negative effects are seen on fish and plant populations (i.e., 250 mg/l), chloride concentrations in the Lake have increased significantly since the late 1970s, as shown in Figure 9. This indicates that chlorides from direct runoff should be addressed. Additionally, as chlorides can also pollute groundwater, it may be necessary to test groundwater for chloride contamination.

Conductivity
Conductivity is the measure of water's ability to carry electrical current. As the number of ions, for example sodium ions, dissolved in water increases, 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 (µS)/centimeter (cm). Conductivity in lakes in the Southeastern Wisconsin Region range from 500 to 600 µS/cm.[20]

---

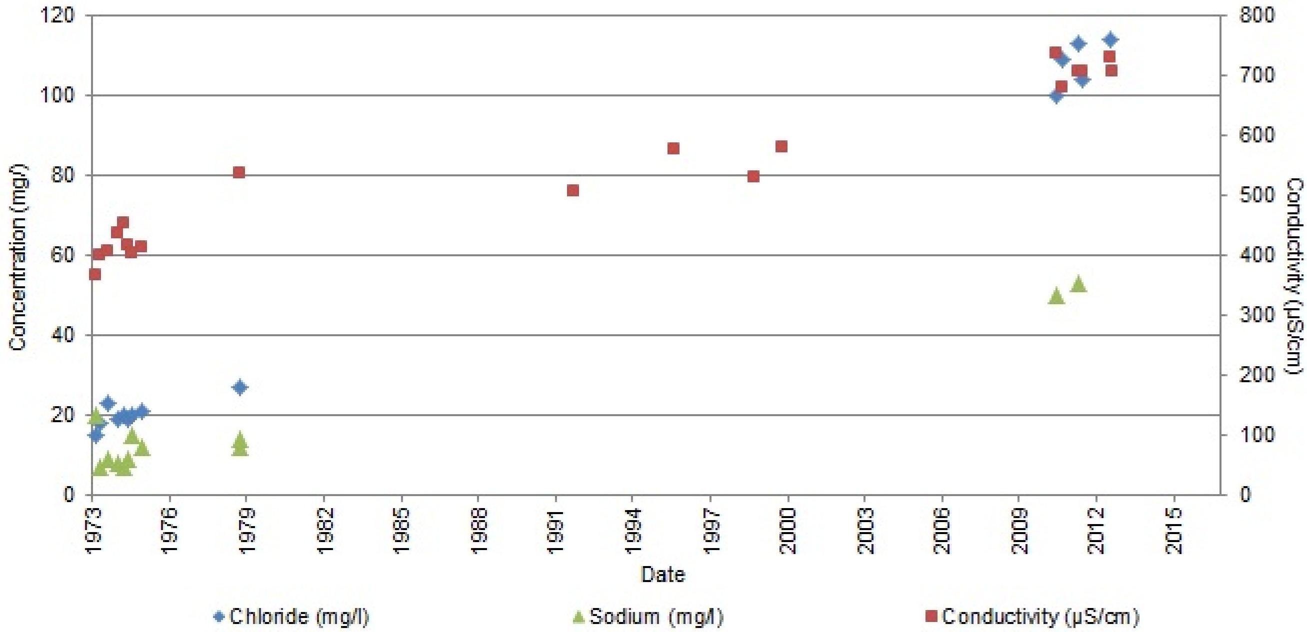
[18]*SEWRPC Technical Report No. 39,* op. cit.

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

[20]Ibid.

Figure 9

CHLORIDE AND SODIUM CONCENTRATIONS AND CONDUCTIVITY IN SILVER LAKE



Source: SEWRPC.

Conductivity was recorded on all field days with the exception of May 4, 2013. The mean value of the conductivity measurements is 711 µS/cm. This is higher than both the average for the Region (600 µS/cm) and the historical average of 451 µS/cm. In fact, as can be seen in Figure 9, conductivity has increased over time, similar to chloride concentrations. This further emphasizes the need to prevent these pollutants from 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 runoff from de-icing activities, discharge of water softeners, and treated wastewater .

Sodium levels also have strong links to the growth of cyanobacteria, or blue-green algae. Cyanobacteria are among the most studied of all planktonic groups, and have been growing in population due to their ability to survive filtering by zebra and quagga mussels, unlike most other algae. There are both nontoxic and toxic types of cyanobacteria. The toxic types have well documented adverse effects on freshwater lakes, especially those with enriched or eutrophic conditions.

Sodium levels were recorded in Silver Lake on April 25, 2011 and March 25, 2012 at 50 and 53 mg/l, respectively. This is well above the historical range of 7.0-20 mg/l and the historical average of 11 mg/l, indicating that sodium has been accumulating in the Lake over time. This is consistent with the previously discussed chloride analysis (see Figure 9). Additionally, it is very possible that the recent occurrence of *nontoxic* cyanobacteria in Silver Lake[21] could be related to sodium level increases. Though the toxic type of cyanobacteria has yet to be detected in the Lake, measures should be taken to prevent further sodium contamination to reduce potential cyanobacteria growth.

Potassium
Potassium, as with sodium, has strong links to the growth of cyanobacteria, both toxic and nontoxic. Also, like sodium, potassium ions are naturally found in only small amounts in soil and water, 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. Additionally, increasing potassium values over time can mean there are long-term effects caused by pollution.[22]

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

Sulfate
Sulfate, a form of sulfur, is an important nutrient for aquatic life. Sulfur occurs naturally in rocks and soils; as well as unnaturally from anthropogenic sources like the burning of fossil fuels associated with industry. While sulfate is an important nutrient in lakes, in high concentrations it can accelerate the eutrophication process which can be detrimental to a lake. The presence of industries in southeastern Wisconsin contributes to high sulfate concentrations in lakes, ranging from 20 to 40 mg/l.[23]

A sulfate concentration of 22.5 mg/l was recorded in the Lake. This is within the historical range, and slightly below the historical average for Silver Lake (26.8 mg/l). In general, this indicates that sulfur contamination has not increased over time, which is consistent with the reductions in burning of coal by power plants and industries.

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 in a 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 be introduced through 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, thereby increasing their distribution. The southeastern Wisconsin historically had the highest turbidity measurements in the State, based on data collected between 1966 and 1979.[24]

---

[21]*Silver Lake Management District members detected algae "balls" within the Lake in the summer of 2008. Samples were collected and later identified as "Scytonema" and "Tolypothrix;" two nontoxic strains of blue-green algae.*

[22]*B. Shaw, C. Mechenich and L. Klessig, op cit.*

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

[24]Ibid.

Turbidity was measured on March 25, 2012, as 1.3 Nephelometric Turbidity Units (NTUs). This is below the historical average of 2, thereby indicating that sediment resuspension and other causes of turbidity were not major factors in Silver Lake at the time of sampling. However, as turbidity was only measured in March, a date when boating activity is low on the Lake, it is possible that boating activity may still be an issue of concern relative to turbidity. This is further supported by the fact that stirring up of sediments in the littoral zone (i.e., nearshore area) of the Lake was documented as an issue of concern in Silver Lake's most recent Lake Protection Plan which was completed in 1993. In this plan a recommendation was made to reduce high speed boating access in areas where significant ecological damage could occur, namely the clam beds along the western shore, the extensive wetland plant communities of the western embayment, and the aquatic plant communities on the southeastern shore at the "inlet" of the Lake.[25] It is important to note that boat traffic may affect the deep-hole turbidity measurements less than near shore areas. Consequently, it may be necessary to periodically monitor turbidity in nearshore areas.

Total Suspended Solids
Total suspended solids (TSS) include materials like sand, silt, clay, fine organic and inorganic debris, and plant material. These materials are suspended in the water column. The potential for suspension, or resuspension of solids increases with the velocity of the water, and higher water velocities enable suspension of larger and denser particles. High TSS concentrations can result from algae blooms, sediment re-suspension (which can occur with boating activity), and/or the inflow of turbid water. Additionally, they are typically associated with low water clarity and high phosphorus concentrations in lakes. High TSS concentrations can also damage fish populations through the clogging of gills.

In Silver Lake, TSS concentrations were low (ranging from negligible to 4 mg/l) on all of the field days. There are no historical measurements available. However, as mentioned in the "Turbidity" subsection of this memorandum, the 1993 report for Silver Lake did identify boating activity in the littoral zone as an issue.[26] In general, this indicates that activities which cause high total suspended solid concentrations, i.e., motor boat activities in shallow areas, may be a factor in Silver Lake, thereby indicating that TSS should be periodically monitored.

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 indicated, 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 phosphorus concentrations in the Lake have decreased dramatically since the late 1960s, thereby indicating that the provision of sanitary sewer service, and the transition to residential land use within the watershed, had a significant impact on phosphorus loads to the Lake. However, it was also noted that phosphorus concentrations in the Lake do periodically go above the WDNR standards, indicating that phosphorus pollution prevention may still be an issue of concern in the future, if loading continues.

In contrast, chloride and sodium concentrations have increased over the past 40 years, indicating that the reduction of chlorides should be made a priority. Additionally, nitrogen levels, though found to have decreased over time, still periodically reach levels that indicate potential for algal blooms. Reducing nitrogen pollution should, therefore, be considered a priority.

---

[25]*SEWRPC Memorandum Report No. 82,* A Lake Protection Plan for Silver Lake, *July 1993.*

[26]Ibid.

Table 3

SUMMARY OF IN-LAKE WATER QUALITY FINDINGS

Parameter (in mg/l unless otherwise noted)	Current (2005 to 2013)				Historic (1970s)		Standards or Other Bases for Comparison
	Dates	Range	Mean	Number of Samples	Range	Mean	
Alkalinity	2011-2012	176-204	190	2	160-180	172	173[b]
Ammonium (N)	2011-2013	0.01-0.41	0.15	7	0.07-0.20	0.136	0.20[c]
Calcium	2012	35.4[a]	35.4	1	26-57	39.42	36[b]
Chloride	2011-2013	100-121	111.429	7	15-27	19.36	250[c]
Color	2011-2012	5-7.2	6.1	2	- -	- -	46[b]
Conductivity	2011-2013	681-736	711.333	6	365-537	416.82	500-600[b]
NO2+NO3(N)	2011-2013	0.07-0.25	0.127	7	0.046-0.469	0.187	10[c]
pH (S.U.)	2011-2012	8.2-8.37	8.285	2	- -	- -	8.1[b]
Potassium	2011-2012	2.9-3.3	3.1	2	0.7-5.6	3	- -
Reactive Phosphorus	2011-2013	.002-0.117	0.02371	7	0-0.033	0.011	0.01[c]
Sodium	2011-2012	50-53	51.5	2	6.6-20.0	11	- -
Sulfate	2012	22.5[a]	22.5	1	21-32	26.8	20-40[b]
Total Hardness	2011-2012	240	240	2	155.5-323.5	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	- -	- -	- -
Total Phosphorus	2011-2013	0.01-0.034	0.01747	7	9.0-60	.035	0.03[c]
TSS	2011-2013	2-4	2.6	5	- -	- -	- -
Turbidity (NTU)	2012	1.3[a]	1.3	1	0.9-3	1.83	- -

NOTE: **Red Font** = Values significantly higher than historical average; [red box] = Ranges that periodically exceed standard or regional averages.

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

[b]*Southeastern Wisconsin Regional average.*

[c]*Established "maximum level" standards as discuss throughout this memorandum.*

Source: SEWRPC.

Finally, it was found that sulfates, TSS, turbidity, potassium, and reactive phosphorus do not appear to be issues of concern in the deep-hole area. However, as turbidity was only measured during a time of low boat traffic, further monitoring may be necessary. Additionally, monitoring of TSS and turbidity in the littoral zone may also be necessary given that boating activity in this area, which re-suspends sediments and affects nearshore biota, has been a documented issue of concern.

Sample Site Water Quality

As has been discussed thus far in this memorandum, chlorides, total phosphorus, and, to a lesser extent, nitrogen, are issues of concern, despite the fact that Silver Lake generally has good water quality. It is, therefore, important to evaluate the potential sources of these pollutants for the purpose of forming strategies aimed at preventing any future water quality issues in the Lake.

Sample Sites

As mentioned in the "Project Description and Goals" section of this memorandum, a major component of this study was to determine the extent of pollution entering the Lake from designated "areas of concern," namely the Paganica Golf Course and neighboring residential developments. Accordingly, seven monitoring sites were chosen for the project with the specific purpose of identifying sources of pollution. Map 1 indicates where each of the sites is in relation to the Lake, while maps of the runoff sources which are flowing to each of these sites, as confirmed by interpreting two foot contours elevations and through on-foot investigations, are shown in Appendix A. These areas of concern include:

1. The Paganica Golf Course tributary (see 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 located within the northern portion of the watershed.[27] This controversy spurred a bio-assessment completed by WDNR in 1974 which found no evidence of organisms that could harm humans in the golf course discharge.[28] Despite these results, the runoff coming from the golf course has continued to be an issue of concern primarily because the runoff water is such a drastically different color than the Lake water itself. However, as discussed in the "Color" subsection earlier in this memorandum, color does not always equate to pollution. In fact, a brown color in the water is generally just an indication of the amount of organic material the water has come into contact with. However, since golf courses may be sources 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 pipe which drains part of the golf course and discharges to the Lake, also drains other areas of the watershed. In fact, this "tributary," as illustrated on Map 2, includes a downstream stormwater drain. This drain collects runoff from shoreline properties which could also be contributing pollution to the discharged water. To distinguish between the runoff from the golf course and from the other sources, three sites were monitored along the discharge water's pathway to the Lake, 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 is located directly downstream from the Paganica Golf course near the northern end of the Lake. This site represents water discharging from a detention basin located on the golf course. This basin likely collects runoff from the golf course and a small portion of the residential area directly adjacent to the golf course on the east side. The detention basin, though it was not sampled, is likely full of organic material which would remain in contact with the water in with the basin for an extended period of time. This could account for the brown color of the water which drains from the basin (due to the water essentially being "dyed").

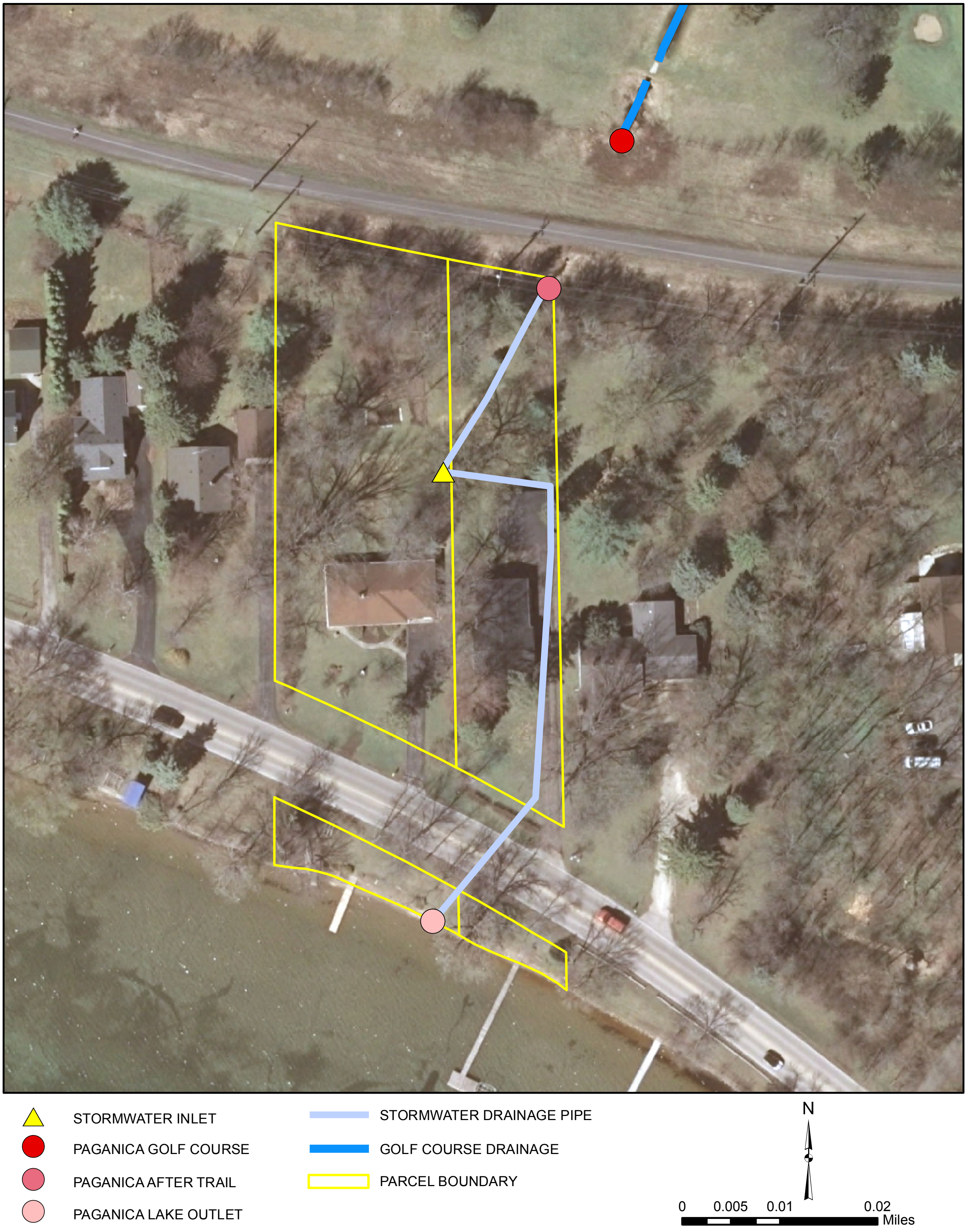
   b. The "Paganica After Trail" site, which is located at the drainage pipe on the south side of the Lake Country trail and downstream from the Paganica Golf Course. This site includes the runoff from the "Paganica Golf Course" site" that flowed under the Lake Country trail. This

[27] *"Relief Seen for Drainage Problem,"* Enterprise, *Summit, 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.*

[28] *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.*

Map 2

LOCATION OF STORMWATER DRAINAGE PIPES COMING FROM THE PAGANICIA GOLF COURSE



Source: Silver Lake Sanitary District and SEWRPC.

site also includes water that drains from the Lake County Trail west of the sites and the residential region directly west of the site. If there are increases in pollution at this site in comparison to the “Paganica Golf Course” site, these two regions 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 upstream Paganica sites, and runoff/pollution from the surrounding residential lots which enter through the stormwater inlet located upstream to prevent residential flooding (see Map 2). Any differences at this site in comparison to the “Paganica After Trail” site would be attributed to contributions from those properties.

2. The “North Wetland” runoff area (see Map 1, eastern shore north of the Summit Village 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 the associated stormwater drainage pipe is brown. This area was also targeted because of its proximity to commercial parking lots and landscaping areas. Two sites were monitored along this tributary, including:

a. The “North Wetland Upstream” site, located on the western side of North Dousman Road just north of the Summit Village Hall. Based on ground elevation data and site investigation, water quality conditions at this sampling site likely reflect direct runoff from North Dousman Road and runoff from the forested area and hillside directly east of the road. It was originally suspected that this site might receive water from the commercial area east of North Dousman Road, however, further investigation of the drainage pathways from the commercial parking lots indicated that these areas drain to the retention basins located on site which are intended to store runoff from most storms. Consequently, pollution detected at this site should only reflect pollution from the aforementioned road and eastern hillside.

b. The “North Wetland 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, runoff from the Summit Village Hall parking lot, and potential runoff from the adjacent residential areas. Any increase in pollution at this site in comparison to the “North Wetland Upstream Site” would, therefore, be coming from these additional sources. It is important to note that the waters entering the Lake from this site drain through an adjacent wetland. Wetlands and bogs frequently contain humic material which can dye water brown, and yet still serve to filter out pollution, consequently, the presence of the wetland could also account for the brown color that was of concern at this site.

3. The “South Wetland” runoff area (see Map 1, southernmost sites)
As with the North Wetland site, this area was also chosen due to the brown color of water entering the Lake. Additionally, it was chosen due to its proximity to IH 94 and two detention basins (one residential and one commercial). Two sites were monitored in this area of concern, including:

a. The “South Wetland Upstream” site, located on the west side of North Dousman Road just south of Silver Knoll Court. This area receives runoff from North Dousman Road, runoff from the hillside area east of North Dousman, outflow from the detention basin on the south side of IH 94 (through a culvert under the highway), and runoff directly from the IH 94 overpass (see Figure 10). It was also noted that an area on the south side of IH 94 is periodically home to a large population of geese, however, as direct drainage towards the Lake could not be detected through an onsite investigation, and as geese have only been found to be a major contributor of nutrients in small, shallow lakes,[29] this pollution source is considered negligible.

b. The "South Wetland Lake Outlet" site, located in the southeast corner of the Lake. This area is receiving the outflow from the adjacent residential stormwater detention basin. This basin collects runoff from the adjacent residential properties, and may also receive flow from North Dousman Road, Forest Drive (located south of the Lake), and the "South Wetland Upstream" site. As with the "Paganica Golf Course Site" the water coming from the detention basin is likely in contact with organic material, potentially accounting for the discharge color. Additionally, as with the "North Wetland In-Lake Outlet" site, some of the water entering this site goes through a wetland, which could also account for the brown color.

Detention Basins
It is important to note that the Paganica and South Wetland sites receive outflow from two detention basins. Though it may seem intuitive to think the water accumulating in these basins are the cause of water quality issues, this is actually generally not the case. In fact, detention basins are designed to have a positive impact on the quality of the water draining into a lake by allowing the runoff to detained and treated in the pond. While the water is detained, sedimentation occurs, allowing the removal of particulates, organic matter, and metals that otherwise would have been deposited in the Lake itself. Nutrients and dissolved metals are also removed through biological uptake.[30] Therefore, properly maintained detention basins improve water quality. Though these basins may likely be the cause of the dark colored water entering the Lake, as discussed above, they actually play a significant role in removing pollutants prior to their entering the Lake and should be considered an asset to the maintenance of water quality.

Eastern Commercial Properties
It was suspected in the original design of the project that some runoff from the retention basin located just east of the wetland sites was entering the sites through a surface water connection or through overflow in rain events. If this were the case, it would have been possible to evaluate flow entering the Lake from the commercial site located on the eastern side of the watershed (i.e., the area which drains to this retention basin). However, an onsite investigation revealed that the retention basin would only contribute surface flow to the sampling sites in the largest of rain events, given the lack of a constructed outlet topography surrounding the basin (see Appendix A "Drainage for Eastern Commercial Area Near Silver Lake, Waukesha County"). Consequently, with the exception of the commercial property at the northwest corner of the area just south of Valley Road (see Appendix A "North Wetland Upstream" site map), there is likely no consistent runoff source from these commercial properties to the Lake.

It is important to note, however, that water in this retention basin, and the others within the commercial areas both south and north of Valley Road, likely infiltrates into the groundwater. Given, that groundwater flows from east to west,[31] any pollution entering these areas are likely to contribute to the groundwater supplying Silver Lake, and may contribute to chloride and, to smaller extent, phosphorus (given natural filtration processes)

[29]*Scott Hygnstrom, Canada Goose Management Website. University of Nebraska-Lincoln, NRES 348 Wildlife Damage Management class, Spring Semester,* http://icwdm.org/handbook/Birds/CanadadGeese/Default.aspx*, 2010.*

[30]*U.S. Environmental Protection Agency, Office of Water, Washington, D.C., Storm Water Technology Fact Sheet Wet Detention Ponds, EPA 832-F-99-048, September 1999.*

[31]*The direction of groundwater flow was determined using groundwater table elevation data for the watershed.*

Figure 10

DRAINAGE FROM IH 94 OVERPASS

Source: Nate Rice, Silver Lake Management District.

pollution. Consequently, even though these sites will not be included in the sample site analysis, recommendations with regard to monitoring and reducing chloride and phosphorus pollution from these properties is included in this memorandum.

Sample Site Data

This section presents the water quality data that was collected at the seven sites and compares that data to WDNR standards, as well as to concentrations in the Lake (as discussed in the "In-Lake Data" section). This information is then used to determine the tributary areas that should be considered a concern, and the strategies that should be undertaken in those areas to reduce the risk of further contamination of the Lake.

Nutrient Pollutants

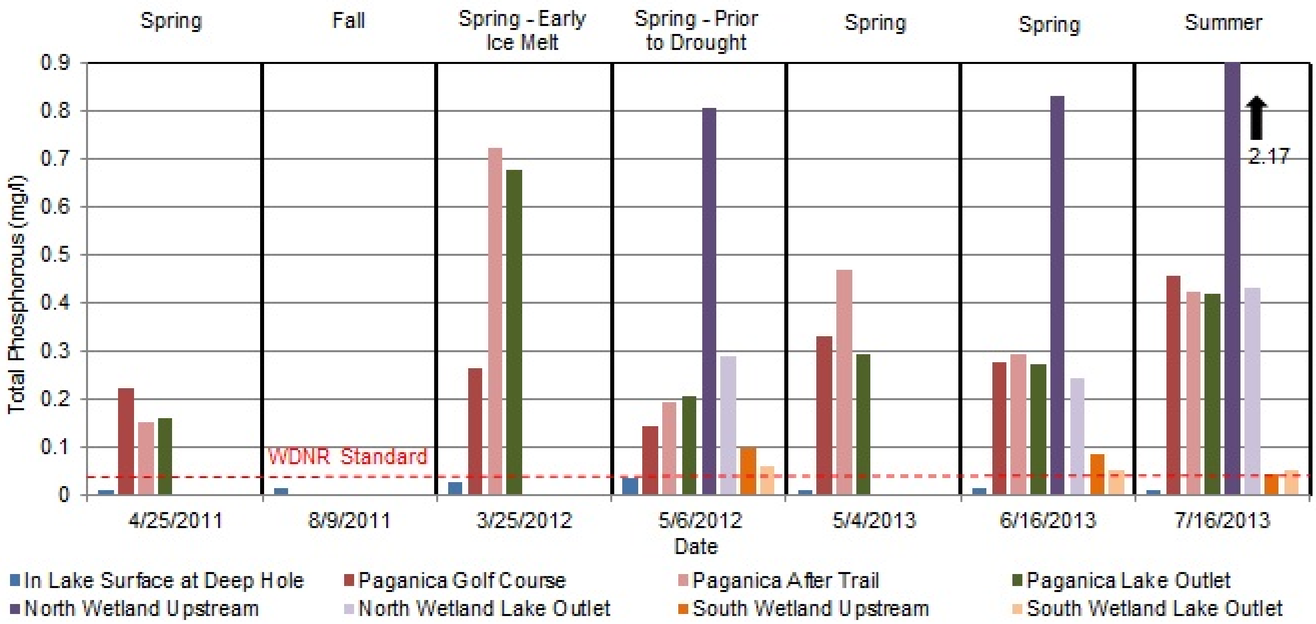
This section seeks to identify potential sources of the various nutrients. As both phosphorus and nitrogen were deemed pollutants of concern with regards to the in-Lake data, the information presented in this section will help inform the recommendations with respect to phosphorous and nitrogen pollution prevention.

Total Phosphorus

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 11, the phosphorus levels for all of the samples taken were much higher than the Lake water itself. Though this is common in flowing water since plants and algae are unable to use up the phosphorus the way they can in Lakes and the water volume is considerably less than in a lake, resulting in higher constituent concentrations, these high numbers should still be considered an issue of concern, since in-lake phosphorous levels were deemed an issue earlier in this memorandum. Consequently, actions should be taken to ensure that the phosphorus fertilizer ban on turf lawns is being well enforced throughout the watershed and these fertilizers are discouraged on gardens, with a focus on the areas draining to these sites (as shown in Appendix A). Additionally, if any individual meets the exemptions to the 2010 phosphorus fertilizer ban, they should be taught how to use fertilizers in a conservative manner to minimize the amount of fertilizer in runoff. Finally, pet waste, which contains phosphorous and can accumulate over the winter months, should be cleaned up immediately wherever possible.

Figure 11

TOTAL PHOSPHORUS CONCENTRATIONS FOR SILVER LAKE SAMPLING SITES



Source: SEWRPC.

It is important to note that, though phosphorous concentrations are high at all of the sites, they were particularly high in the North Wetland upstream site, potentially indicating an unexpected source of contamination may be coming from the contributing residential and commercial property north of the site (see Appendix A "North Wetland Upstream Site"). Though it is possible that natural leaf matter from the wooded area located adjacent to these properties is contributing to phosphorus loads, these sources should be investigated to ensure phosphorous containing fertilizers are not being used. At this site and the south wetland site, it should also be noted that the sample concentrations downstream from the wetlands were much lower than upstream from the wetlands, indicating that the wetlands themselves, as well as the detention basin located at the south wetland site, are efficiently removing phosphorus pollution. Consequently, the following actions should be considered a priority: 1) preserving of these wetlands and preventing invasion of invasive species (which limit wetland effectiveness), such as purple loosestrife (see Figure 12); and 2) ensuring the continued maintenance of the detention basin located east of the "South Wetland Lake Outlet" site.

Another interesting result is that, though still high, phosphorus concentrations coming directly out of the golf course are generally lower than the phosphorus levels found just across the trail, i.e., in most instances the levels increase at the site downstream from the golf course. In March 2012 phosphorus levels almost doubled once the water left the golf course. This pattern indicates there is a significant source of phosphorus contributing to the Paganica discharge pipe aside from the golf course. Considering this source seemed to increase during the spring runoff, it is possible this other source may be pet waste accumulation from the winter which is draining towards the Lake from the residential area and the recreational trail to the west of the site. This would need to be investigated further.

Figure 12

PHOTOGRAPH OF PURPLE LOOSESTRIFE

Source: Leslie Mehrhoff, Invasive Plant Atlas of New England.

Finally, though not represented in the data collected under this study, a final, potential future source of phosphorus to the Lake may be future construction on STH 67. Detention basins are located near STH 67 and without proper measures in place to control erosion these basins will fill in from sedimentation, possibly making them less effective in reducing run-off pollution and, in turn, affecting the water quality of the Lake. Consequently, this construction project, along with any other construction within the water-shed, especially on the Lake Country trail (which would run directly into the Lake), should be monitored, and erosion control measures should be enforced, to reduce future phosphorus loads to the Lake.

Reactive Phosphorus

Reactive 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 13, the reactive phosphorus levels in all of the sample sites were higher than levels in the Lake. This is to be expected because plants will use this form of phosphorus up as quickly as possible once it enters the Lake, and because the large Lake volume relative to the volume of water passing the sampling sites dilutes the reactive phosphorus.

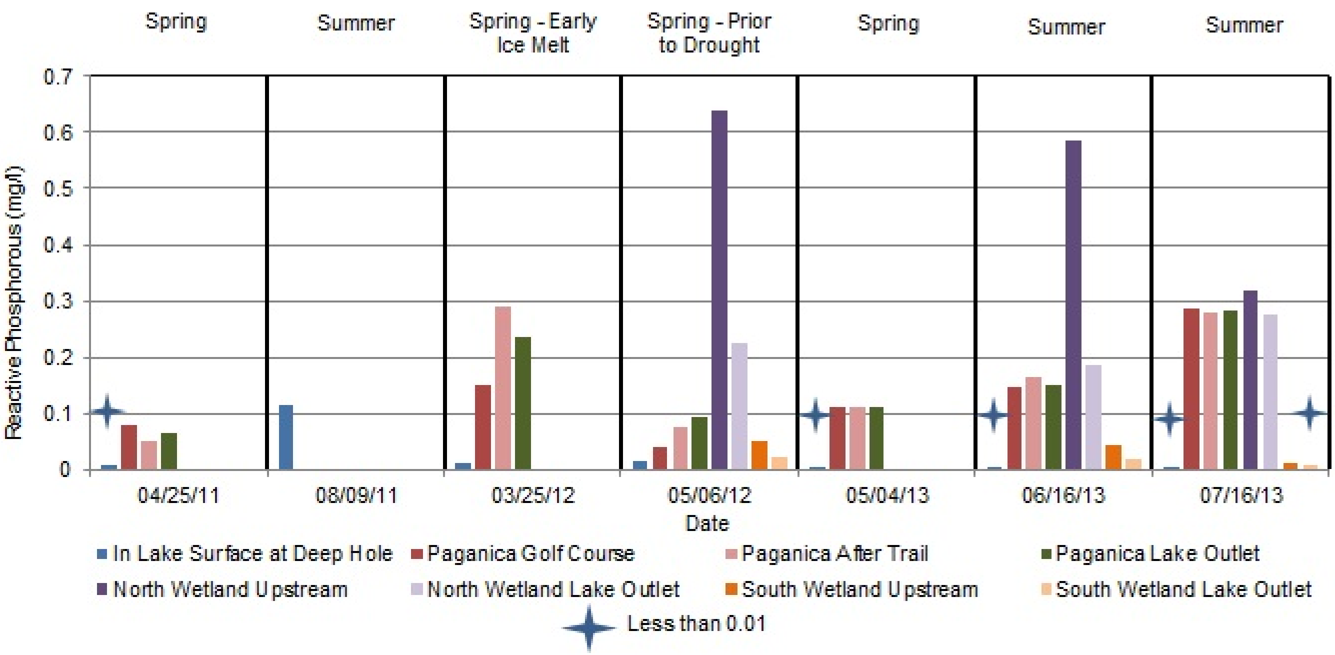
The highest reactive phosphorus levels were found in the North Wetland Upstream site, further emphasizing the presence of an unknown source of phosphorus. However, for the two pairs of wetland sampling sites (north wetland upstream and north wetland lake outlet; south wetland upstream and south wetland lake outlet), the highest concentrations were recorded for the upstream sites, indicating that significant amounts of this form of phosphorus were removed as the water traveled through the wetlands.

It is also interesting to note, that, with the exception of the March 25, 2012 samples, the reactive phosphorus concentrations generally remained fairly consistent throughout the Paganica sites, indicating this form of phosphorus is primarily coming from the golf course.

Given that reactive phosphorus is included in total phosphorous measurements, and that the highest reactive phosphorous levels are filtered out in the northern and southern wetlands, the prevention measures discussed in the "Total Phosphorus" subsection above, including those referring to the protection of the wetlands, and ensuring reductions of phosphorus containing fertilizers, should be sufficient to control most of the reactive phosphorus loading to the Lake. Consequently, those recommendations are reiterated.

Figure 13

REACTIVE PHOSPHORUS CONCENTRATIONS FOR SILVER LAKE SAMPLING SITES



Source: SEWRPC.

Nitrite and Nitrate

Combined nitrite and nitrate concentrations were measured at 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 14, nitrogen levels from the samples only exceeded Lake levels on May 6, 2012, where all three Paganica sites and the North Upstream Site were 0.1mg/l higher than the Lake, and on June 16, 2014, where the North Wetland Lake Outlet site was 0.1mg/l higher. In general, these concentrations are not high enough to indicate any issues of concern.

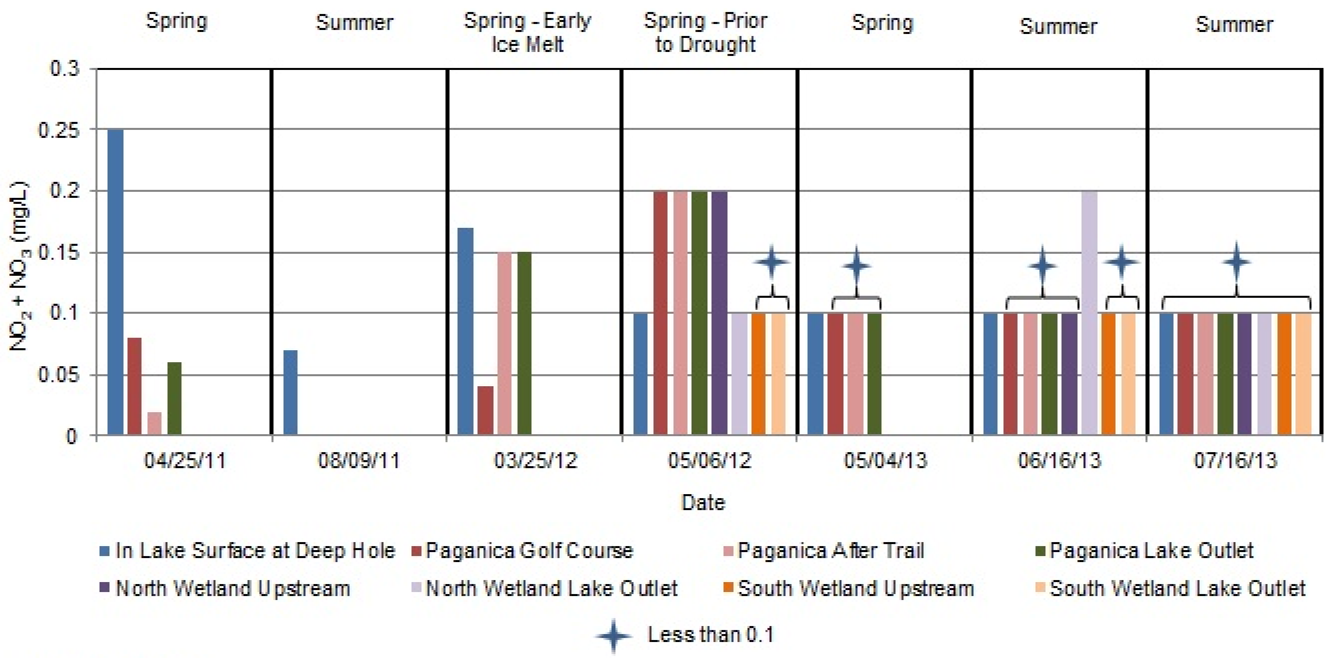
Ammonium

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 15, on March 25, 2012, and May 6, 2012, the highest values were found at the "Paganica Lake Outlet" site (the 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 that the ammonium found in this sample came from the residential areas which discharge to this pipe through a stormwater inlet. As this area has a tendency to flood, it is possible that the ammonium values are from fertilizer runoff and leaf debris which enter the drainage pipe and then decompose underground. Maintenance of the surrounding properties should, therefore, potentially be considered a priority.

High ammonium values were also found at the north wetland sites during July 2013. A possible cause of these levels could be natural decomposition occurring in the wetland area, or fertilizers entering the sample site area. Consequently, the measures discussed in the "Total Phosphorus" subsection above, with respect to reducing fertilizer use where possible, are reiterated.

Figure 14

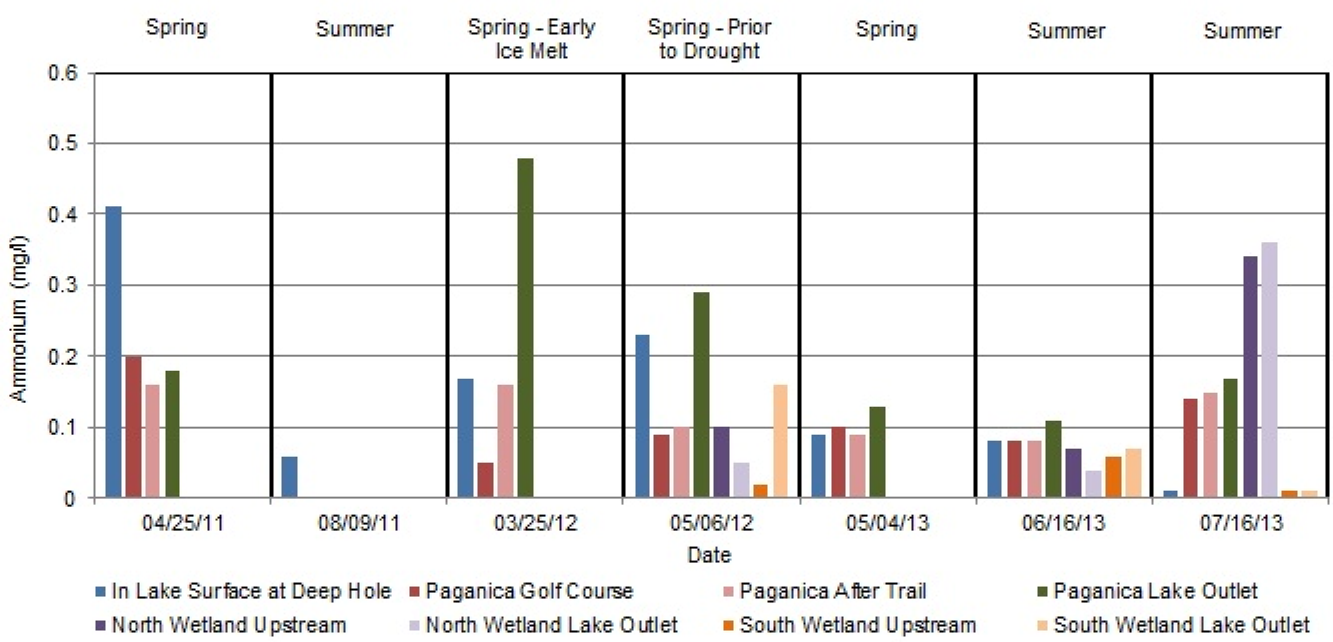
COMBINED NITRATE AND NITRITE CONCENTRATIONS FOR SILVER LAKE SAMPLING SITES



Source: SEWRPC.

Figure 15

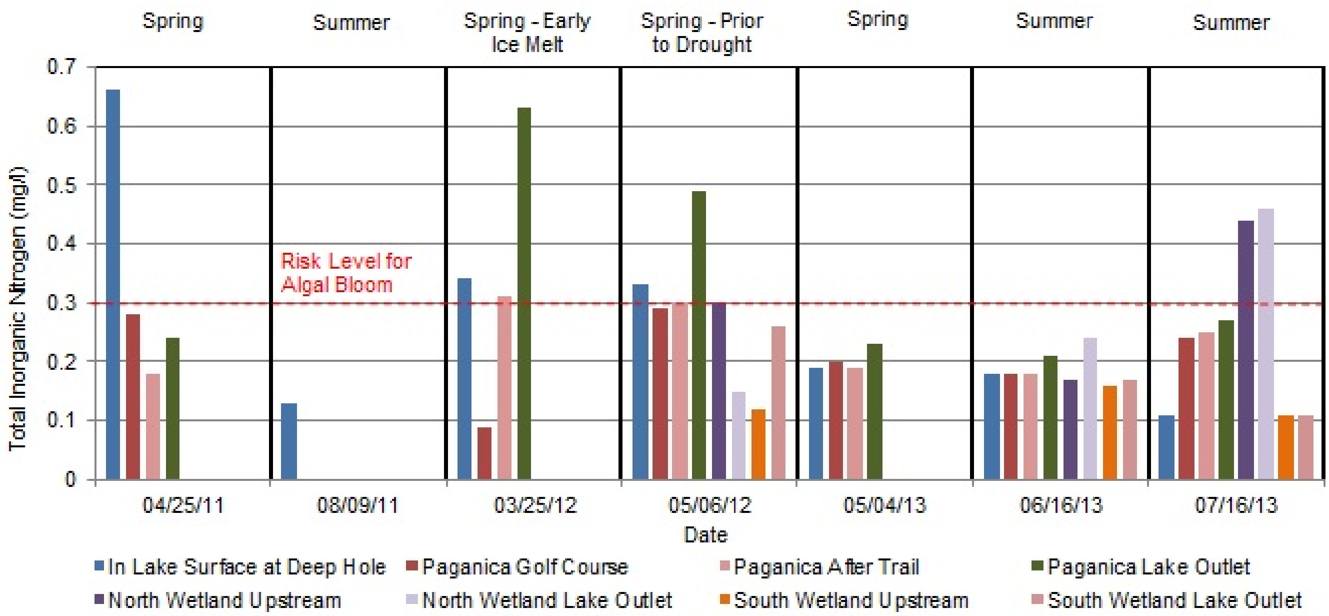
AMMONIUM CONCENTRATIONS FOR SILVER LAKE SAMPLING SITES



Source: SEWRPC.

Figure 16

TOTAL INORGANIC NITROGEN IN SILVER LAKE SAMPLING SITES



Source: SEWRPC.

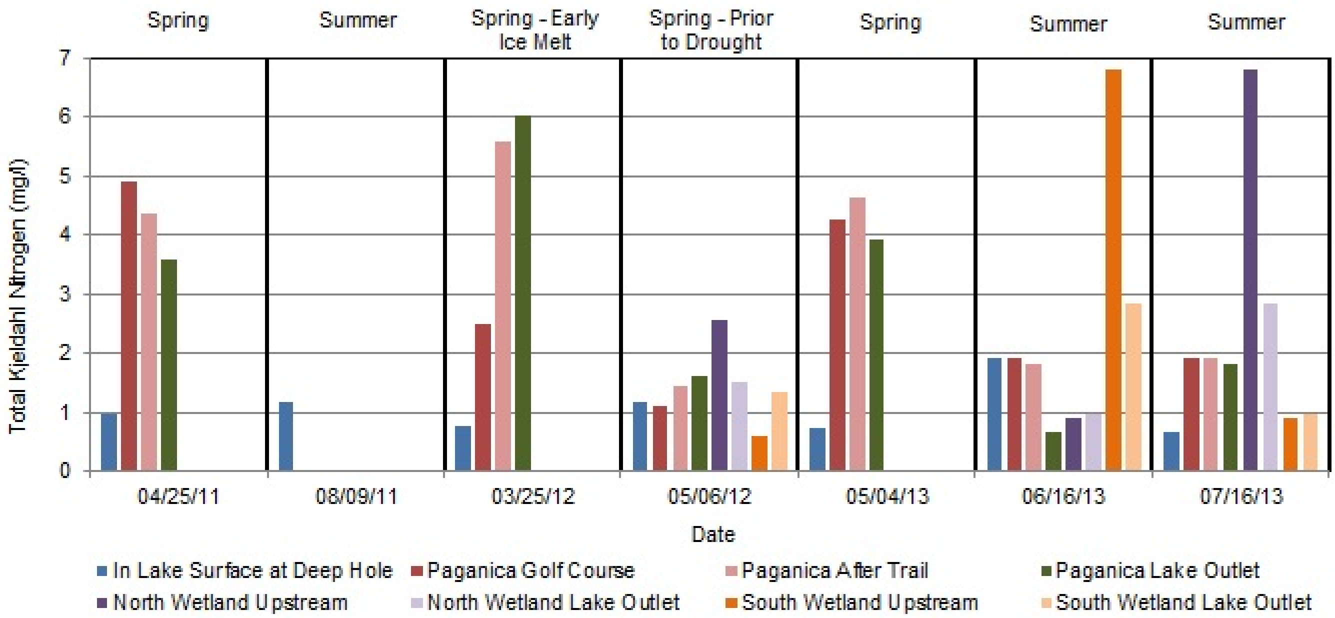
Total Inorganic Nitrogen
Total inorganic nitrogen (nitrite, nitrate and ammonium) were also calculated for all of the relevant sites. As shown in Figure 16, the "In-Lake Paganica Outlet" site on March and May of 2012 exceeded the 0.3 mg/l threshold for summer algal blooms, indicating a need for management of runoff in the area tributary to the stormwater drain. The north wetland sites had high values on July 16, 2013, indicating a need to investigate potential fertilizer use for the aforementioned residential and commercial area located north of the site (see Appendix A for location of these sources).

Total Kjeldahl Nitrogen
Kjeldahl nitrogen concentrations were measured at the three Paganica sites on all of the field days with the exception of August 9, 2011. They were also measured at the north and south wetland sites on May 6, 2012, June 16, 2013, and July 16, 2013. As can be seen in Figure 17, the three Paganica sites had Kjeldahl nitrogen values above those found in the Lake on all sample days with the exception of March 2012 when the golf course concentration was slightly less than in-Lake values and June 2013 when concentrations were at or below those in the Lake. Additionally, the nitrogen values were fairly consistent throughout all three Paganica sites with only one instance (March 2012) of a significant nitrogen input to the tributary after the golf course. A likely source of these pollutants is, therefore, fertilizers from the golf course and potentially the small southwestern portion of the residential area east of the golf course.

The highest concentrations (over 6.5 mg/l), however, were measured in the wetland samples (on June 16, 2013, for the south wetland and on July 16, 2013, for the north wetland), with levels being greatly reduced after passing through the wetlands (and the detention basin in the case of the south wetland site). It is likely that high concentrations are due to fertilizer application and/or leaf and grass accumulation. To reduce nitrogen loads, it is, therefore, recommended that residents of the surrounding residential areas be encouraged to reduce fertilizer use

Figure 17

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



Source: SEWRPC.

and that the detention basin be properly maintained. Additionally, the maintenance and protection of the wetlands should also be considered a priority with respect to nitrogen pollution abatement.

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 Silver Lake. This section identifies potential sources of chlorides which should be addressed. Additionally, as discussed previously, though total suspended solids (TSS) were not an issue in the Lake samples that were collected for this study, TSS were a documented issue identified in the 1993 SEWRPC report.[32] Consequently, they were measured for each of the sites. The data from this analysis is also presented in this section.

Chlorides

Chlorides were measured at 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 18, the highest chloride values were found the Lake deep hole site and the four wetland sites, with the highest amounts for the wetland sites being measured on June 16, 2013 and July 16, 2013. The values on these days ranged from 69 mg/l at the “North Wetland Upstream” site to 234 mg/l at the “South Wetland Upstream” site, with an average of 145 mg/l. Given the steady increase in in-Lake chloride values, the areas draining to the wetland sites (see Appendix A) should be targeted for chloride reduction efforts.

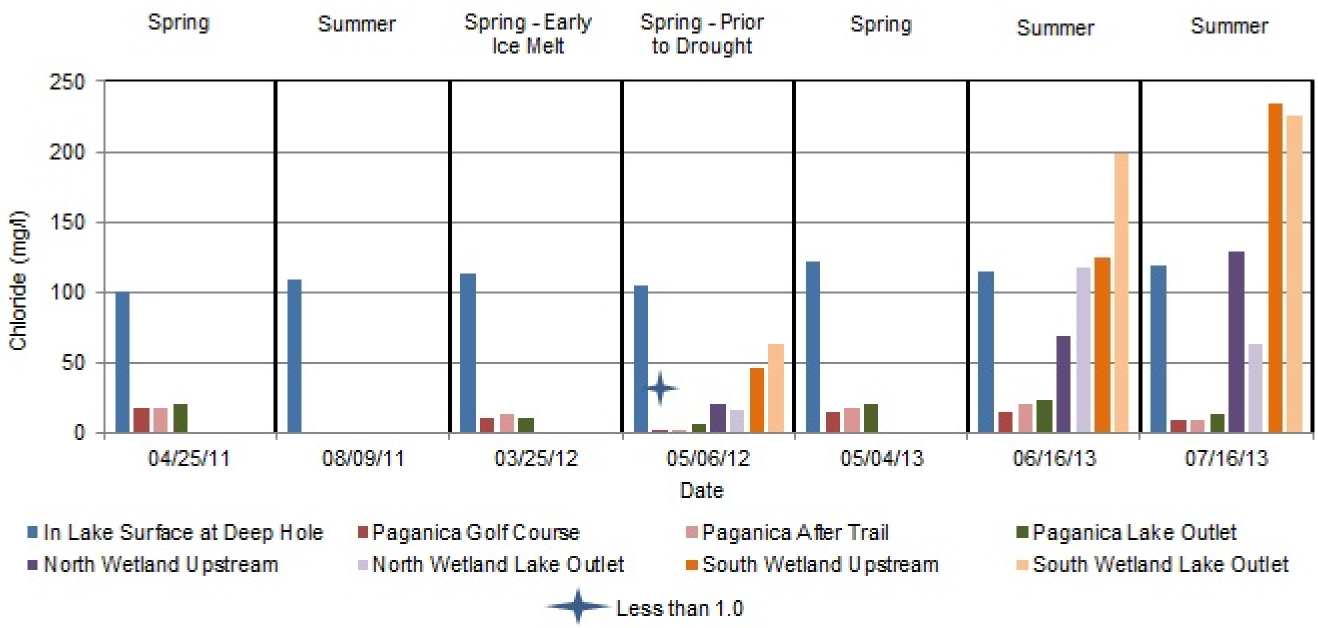
Given these high chloride numbers in the wetland sites, and the fact that these samples were taken in the summer it is possible that the sources of chlorides which supply these sites are as follows: 1) road salt, persisting after

---

[32]*SEWRPC Memorandum Report No. 82,* op cit.

Figure 18

CHLORIDE CONCENTRATIONS IN SILVER LAKE SAMPLING SITES



Source: SEWRPC.

winter application, on impervious surfaces and in the detention basin located along North Dousman Road just south of IH 94, 2) dissolved road salt that was infiltrated into the groundwater and may be entering surface waters and wetlands as baseflow, 3) runoff from poorly stored salt bags left outside after the winter; or 4) runoff from the use of fertilizers containing potassium chlorides (known as potash). Efforts to determine which of these are the cause should therefore be undertaken through on-site investigations and management efforts should be employed to reduce the sources that are found.

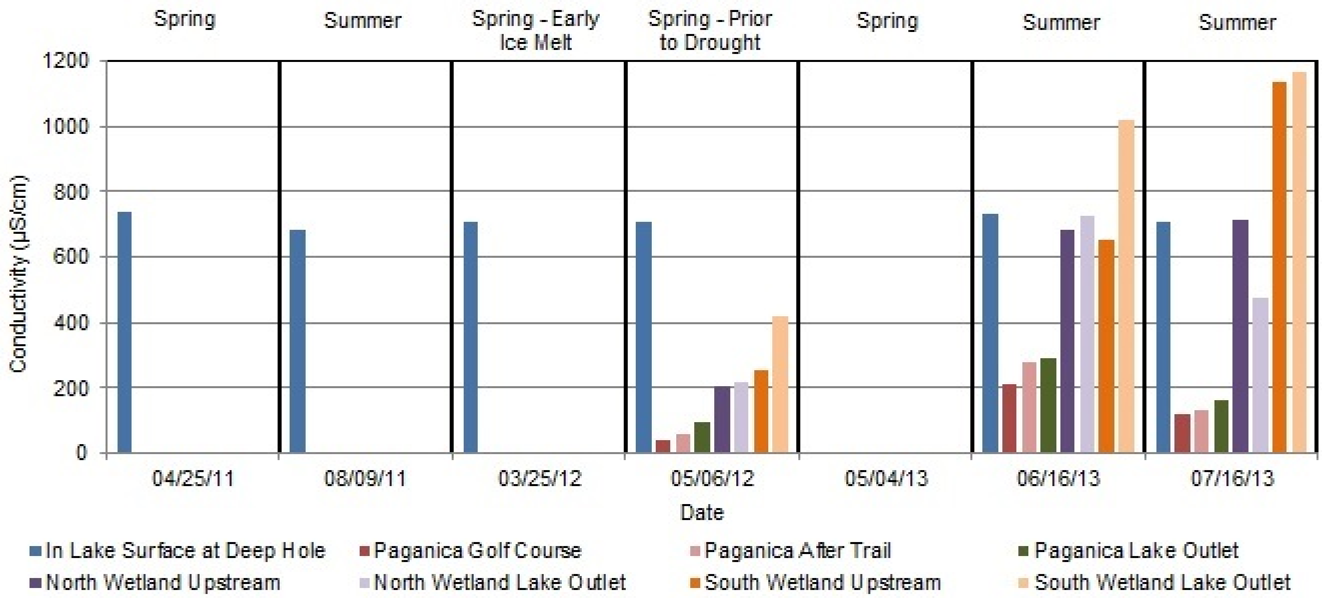
Conductivity
Conductivity measurements were taken at the seven nonLake sample sites on May 6, 2012, June 16, 2013 and July 16, 2013. As shown in Figure 19, these values seem to largely correlate with the chloride concentrations on these dates in the Lake, with the highest values being found at the "wetland" sites. These observations support the recommendation to reduce source of chlorides delivered to the Lake.

Total Suspended Solids
Total suspended solids were measured at 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 20, total suspended solids were relatively low for all of the samples, with the exception of the north wetland upstream site which had a value of 127 mg/l. This value may have been caused by land disturbance and resultant soil erosion in the areas draining to this site. However, since it was an outlier in the data, it is possible that it was due to an isolated incident, and is not indicative of a long-term increasing trend at that location. Additional measurements would be needed to verify that conclusion.

Future construction on STH 67 was previously identified in the "Total Phosphorus" subsection of this memorandum as a possible source of phosphorus loads to the Lake. That construction could also increase sediment loadings, affecting the total suspended solids in the north and south wetland areas of concern, and in the Lake

Figure 19

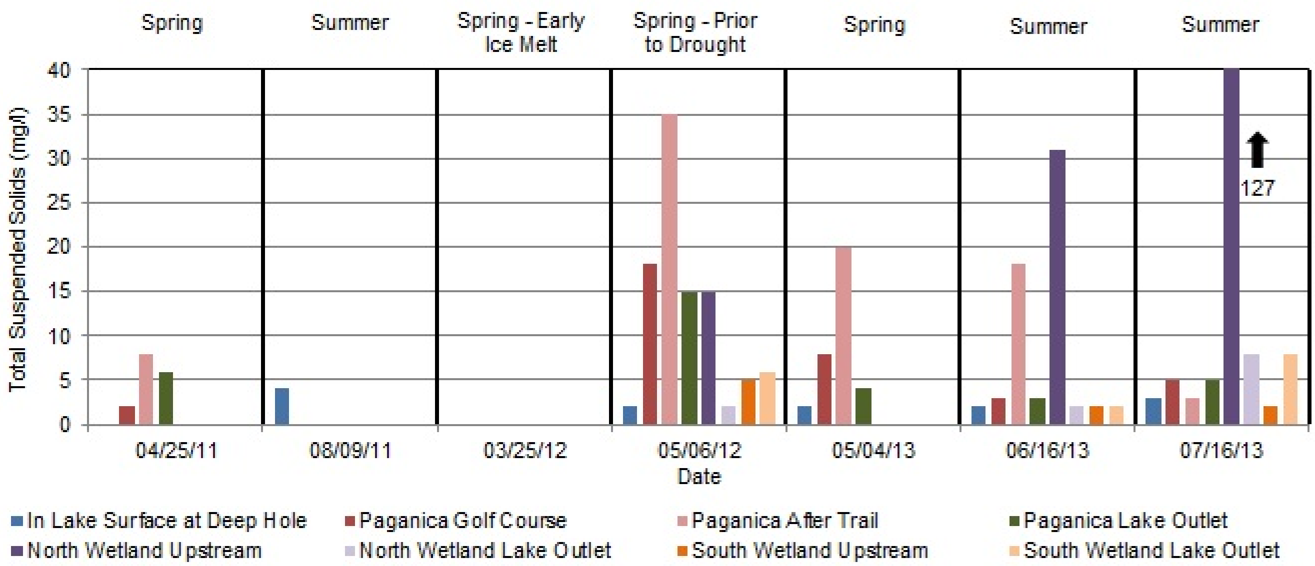
CONDUCTIVITY IN SILVER LAKE SAMPLING SITES



Source: SEWRPC.

Figure 20

TOTAL SUSPENDED SOLIDS CONCENTRATIONS FOR SILVER LAKE SAMPLING SITES



Source: SEWRPC.

itself. Consequently, efforts to monitor and enforce erosion control measures on construction sites within the watershed is reiterated.

Summary of Sample Site Results

An overall summary of the individual site analysis is shown in Table 4. Relatively high phosphorus concentrations were detected at all of the sample sites, indicating that the sources of these pollutants should be identified and loads should be reduced. Efforts to investigate and reduce the sources should target the areas draining to each site (see Appendix A) and should focus on protecting the wetlands and identifying and working with users of phosphorus containing fertilizers[33] and pet owners (to reduce pet waste). Phosphorus concentrations from the golf course were similar to those at the other sites where flow enters the Lake. In fact, the values directly off the golf course were similar to, or lower than those measured just across the trail, except on April, 25, 2011. This indicates that residential runoff may be a more productive target for management than the golf course (which already has measures in place to reduce its runoff). Finally, future construction, as a potential source of phosphorus, should be monitored and effective erosion control measures should be installed.

Nitrate plus nitrite concentrations were low at all of the sites, indicating that nitrate plus nitrite concentrations are not a concern. Ammonium and total inorganic nitrogen pollution sources of concern are most likely coming from the residential areas which contribute runoff to the Paganica drainage pipe downstream at the stormwater inlet, with some pollution also potentially coming from areas draining to the "North Wetland Upstream" site. As the phosphorus recommendations double as nitrogen reduction measures (reduction of fertilizer use, leaf litter pick up, etc.), efforts to reduce the sources of the above nitrogen sources should be combined with phosphorus reduction efforts.

High total Kjeldahl nitrogen concentrations were measured from all three of the areas of concern, with the most consistently high values coming from the Paganica Golf Course sites. Consequently, the Paganica Golf Course and southwest corner of the residential area just east of the golf course, should be targeted for nitrogen reduction activities wherever possible, the most important of which would be the continued maintenance of the detention ponds located in these regions. Total suspended solids concentrations were relatively low for all of the sites, however, should be considered more of a concern when future construction takes place.

Chloride concentrations were elevated at the four wetland sites, indicating that the outflow from the detention basin south of IH 94, the runoff coming from the highway and North Dousman Road, and the outflow from the detention basin at the southeast corner of the Lake, should be monitored to better evaluate the extent of chloride pollution. Additionally, an investigation should be made to determine if potash fertilizers are being used in the regions draining to the wetlands. Finally, concentrated efforts should be made to reduce chloride use (road salts and potash fertilizers) in the residential areas and roads adjacent to these sites, recognizing that some levels of winter road anti-icing and de-icing operations are necessary for public safety.

RECOMMENDATIONS

Two types of recommendations are discussed in this section:

1. Recommendations related to further investigation into the sources of phosphorus (by association nitrogen) and chloride; and

2. Recommendations which seek to address likely sources of these pollutants to the Lake.

---

[33] *Applied consistent with State regulations.*

Table 4

SUMMARY OF SAMPLE SITE WATER QUALITY FINDINGS

Site	Concentrations in mg/l								
	Date	RP	TP	N	NH_4^+	TIN	TKN[a]	Cl^-	TSS[a]
Pagancia Golf Course	04/25/11	0.079	0.224	0.08	0.20	0.28	4.90	16.8	2
	03/25/12	0.151	0.264	0.04	0.05	0.09	2.49	9.8	- -
	05/06/12	0.041	0.142	0.20	0.09	0.29	1.12	0.7	18
	05/04/13	0.113	0.333	0.10	0.10	0.20	4.25	14.9	8
	06/16/13	0.147	0.279	0.10	0.08	0.18	1.92	14.5	3
	07/16/13	0.286	0.457	0.10	0.14	0.24	1.91	8.8	5
Pagancia After Trail	04/25/11	0.05	0.154	0.02	0.16	0.18	4.37	16.8	8
	03/25/12	0.29	0.721	0.15	0.16	0.31	5.58	13.0	- -
	05/06/12	0.075	0.194	0.20	0.10	0.30	1.44	1.7	35
	05/04/13	0.113	0.468	0.10	0.09	0.19	4.64	17.4	20
	06/16/13	0.165	0.295	0.10	0.08	0.18	1.82	20.1	18
	07/16/13	0.279	0.424	0.10	0.15	0.25	1.92	9.2	3
Pagancia Lake Outlet	04/25/11	0.066	0.159	0.06	0.18	0.24	3.58	20.6	6
	03/25/12	0.238	0.679	0.15	0.48	0.63	6.01	10.1	- -
	05/06/12	0.095	0.208	0.20	0.29	0.49	1.61	5.7	15
	05/04/13	0.112	0.293	0.10	0.13	0.23	3.91	19.9	4
	06/16/13	0.151	0.273	0.10	0.11	0.21	0.67	24.0	3
	07/16/13	0.283	0.419	0.10	0.17	0.27	1.82	13.8	5
Northwest Wetland Upstream	05/06/12	0.637	0.805	0.20	0.10	0.30	2.57	20.7	15
	06/16/13	0.586	0.833	0.10	0.07	0.17	0.89	69.0	31
	07/16/13	0.32	2.17	0.10	0.34	0.44	6.80	129.0	127
Northwest Wetland Lake Outlet	05/06/12	0.224	0.289	0.10	0.05	0.15	1.50	15.7	2
	06/16/13	0.186	0.246	0.20	0.04	0.24	0.97	117.0	2
	07/16/13	0.276	0.433	0.10	0.36	0.46	2.84	63.4	8
Southeast Wetland Upstream	05/06/12	0.053	0.098	0.10	0.02	0.12	0.60	46.6	5
	06/16/13	0.045	0.086	0.10	0.06	0.16	6.80	124.0	2
	07/16/13	0.011	0.044	0.10	0.01	0.11	0.89	234.0	2
Southeast Wetland Lake Outlet	05/06/12	0.022	0.062	0.10	0.16	0.26	1.33	63.1	6
	06/16/13	0.018	0.052	0.10	0.07	0.17	2.84	198.0	2
	07/16/13	0.008	0.053	0.10	0.01	0.11	0.97	226.0	8
Standard for Comparison		**0.01**	**0.03**	**10**	**0.20**	**0.30**	**- -**	**250**	**- -**

NOTES: RP=Reactive Phosphorus, TP=Total Phosphorus, N=Nitrate + Nitrite, NH_4^+=Ammonium, TIN=Total Inorganic Nitrogen, TKN=Total Kjeldahl Nitrogen, Cl^-=Chloride, TSS=Total Suspended Solids; Standards as discussed in text.

(yellow) = Approaching Standard (red) = At or Above Standard

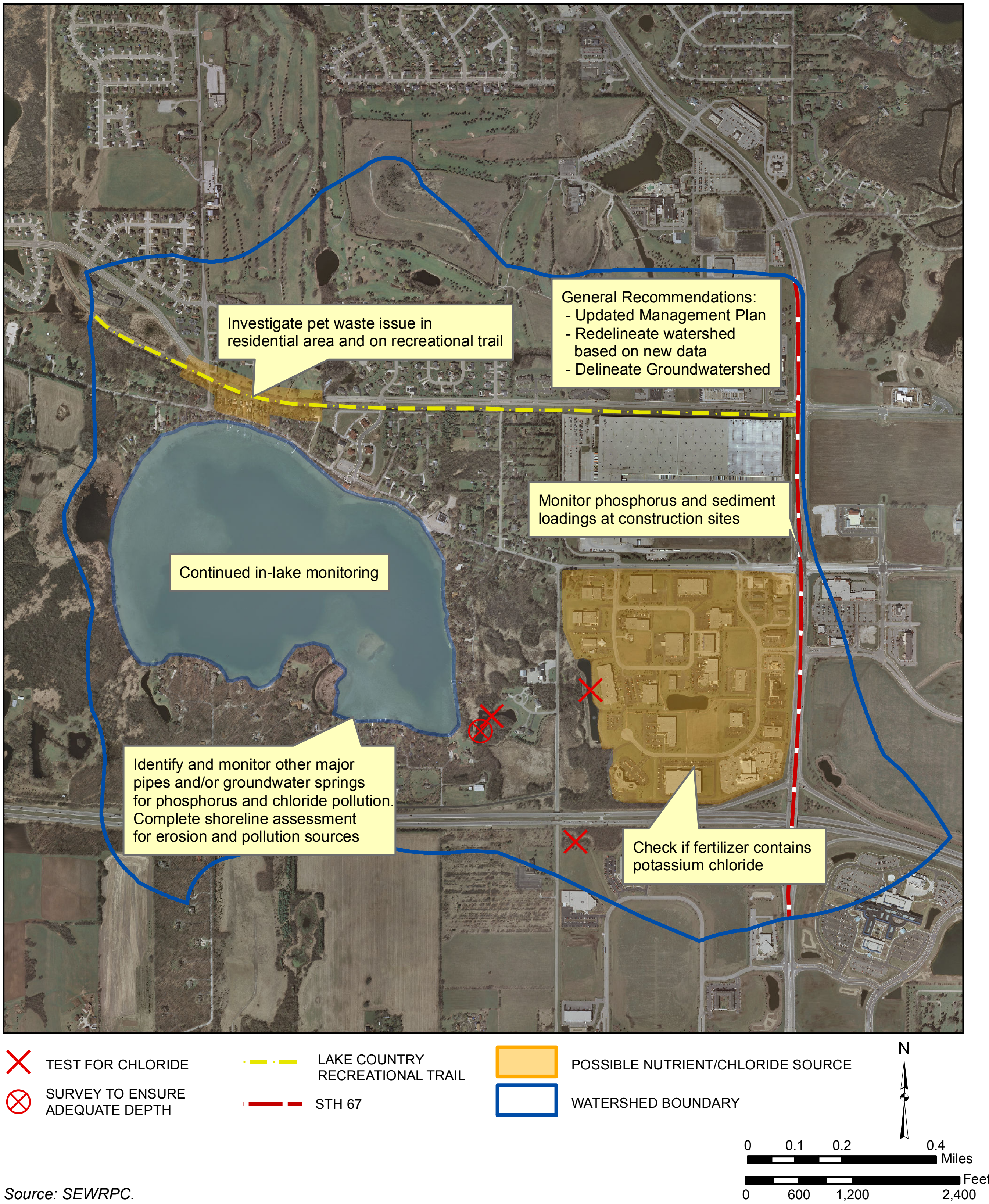
[a]*TKN and TSS do not have local standards to which to compare the current concentrations.*

Source: SEWRPC.

The first set of recommendations, informed by the analyses discussed in this memorandum, not only seek to identify causes of pollution consistent with the concentrations that were measured under this study, but also calls for further investigation to get a better grasp on the other sources which could also be contributing to pollutant loadings. Essentially, these recommendations, as represented on Map 3, relate to further investigation of what is not currently known. They are as follows:

Map 3

SILVER LAKE MONITORING AND INVESTIGATION RECOMMENDATION MAP



Source: SEWRPC.

1. Test for chlorides in the detention basins draining to the South Wetland sites to determine if the areas draining to the basins are the sources of the chloride concentrations that were measured at the sampling sites.

2. Investigate if fertilizers containing potassium chloride (otherwise known as potash) as a main ingredient are used on the turf at the commercial site located on the eastern side of the Lake (as this area contributes to groundwater) and on the residential areas which drain to the wetland sites. This compound can be a source of chlorides in addition to road salts. This investigation does not currently need to be repeated at the Paganica Golf Course as the course does not currently appear to be a major source of chlorides.

3. Encourage periodic surveying of the detention basins which drain to the Lake to ensure they still have adequate depth to properly treat runoff and store sediment.

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 as well as on the trail itself, as it is a popular dog walking trail. This will help better determine if this is the source of phosphorus which was increasing the phosphorus concentrations at this sampling location.

5. Develop a list of other major potential pollution sources to the Lake, with a particular emphasis on stormwater drainage pipes which discharge to the Lake more often than the sites examined in this study. Such sites should be monitored for chloride and phosphorus concentrations, and streamflow should also be measured to enable determination of pollutant volumes. Though the concentrations may be more diluted in these areas, they could potentially contribute more frequently and consistently, resulting in a significant volume of chloride and phosphorus reaching the Lake.

6. The next time that lake planning is undertaken, develop an updated watershed boundary using two-foot contours. The watershed which was used in the most recent Silver Lake Protection Plan was done using 10 foot contour data. Completing this watershed delineation, along with delineation of subwatershed boundaries within the overall watershed, would help to better target pollution reduction efforts.

7. Complete a shoreline assessment to determine if there are areas which should be targeted for shoreline restoration or buffer development to reduce runoff from residential areas.

8. Consider locating and testing springs and groundwater discharge areas in the Lake, or along tributary streams, for phosphorus and chloride pollution. This can be done using a variety of methods and would help determine if groundwater pollution is a major source of those pollutants.

9. If groundwater is deemed a source of phosphorus and chloride pollution through the investigation mentioned above, consider delineating the groundwatershed boundary.

10. Continue citizen lake monitoring efforts, adding periodic sampling of chlorides.

11. Monitor construction within the watershed for use of appropriate construction site erosion control techniques.

12. Finally, it is recommended that an update to the existing lake protection plan be prepared. This plan could be prepared by SEWRPC or a private sector contractor to summarize water quality data and incorporate any new monitoring data which results from the implementation of the recommendations within this plan. This plan could then provide further details on the specific actions that should be taken to help protect Silver Lake as the healthy ecosystem it is.

The second set of recommendations, informed by the analyses in this report, relates to action items to address potential pollution sources without further investigation. These recommendations include those which target the specific areas of concerns that were identified under this study as well as general recommendations which may be better targeted with more monitoring. These general recommendations are included because it may be more feasible and effective to begin action on them without further monitoring, especially given the small size of the watershed relative to the lake size. Each of the following pollution reduction recommendations is represented on Map 4:

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

2. Ensure the State law against phosphorus containing fertilizers is being properly enforced.

3. Encourage proper maintenance of the stormwater detention ponds adjacent to the Lake, including routine inspections, housekeeping maintenance, special inspection and repair, nuisance insect and plant control, and sediment removal.[34]

4. Discourage the use of salts in the winter in the local areas adjacent to the Lake (including the commercial areas given their connection to the groundwater) either through encouraging the use of brine mixtures or through using the salt early and sparingly. Also discourage kitty litter use or other phosphorus containing materials as a replacement for salt, since both chlorides and phosphorus are issues in the Lake.

5. Encourage homeowners to use phosphorus free fertilizers in their gardens or to use phosphorus fertilizers very sparingly.

6. Encourage pet waste pick up on residential lots, with initial targeting of the Lake Country recreational trail and properties west of the Paganica Golf Course. Ultimately, this effort should be expanded to cover the other residential areas in the watershed.

---

[34] *"Routine inspection and housekeeping maintenance [on wet detention basins] should be performed regularly and frequently. Housekeeping maintenance includes removal and disposal of litter from the landscaped areas and any materials floating on the surface, removal of any materials clogging inlets or outlets and maintenance of vegetated areas through reseeding damaged areas, mowing, and removal of tree seedlings.*

Special inspection and repairs should be conducted annually and after each significant runoff event. Inspect and repair any eroded or slumping areas on or around the embankment, emergency spillway, inlet and outlet. Inspect for excessive deposition and identify and correct the source area. Inspect all inlets and outlets for needed repairs or clogging and repair if necessary.

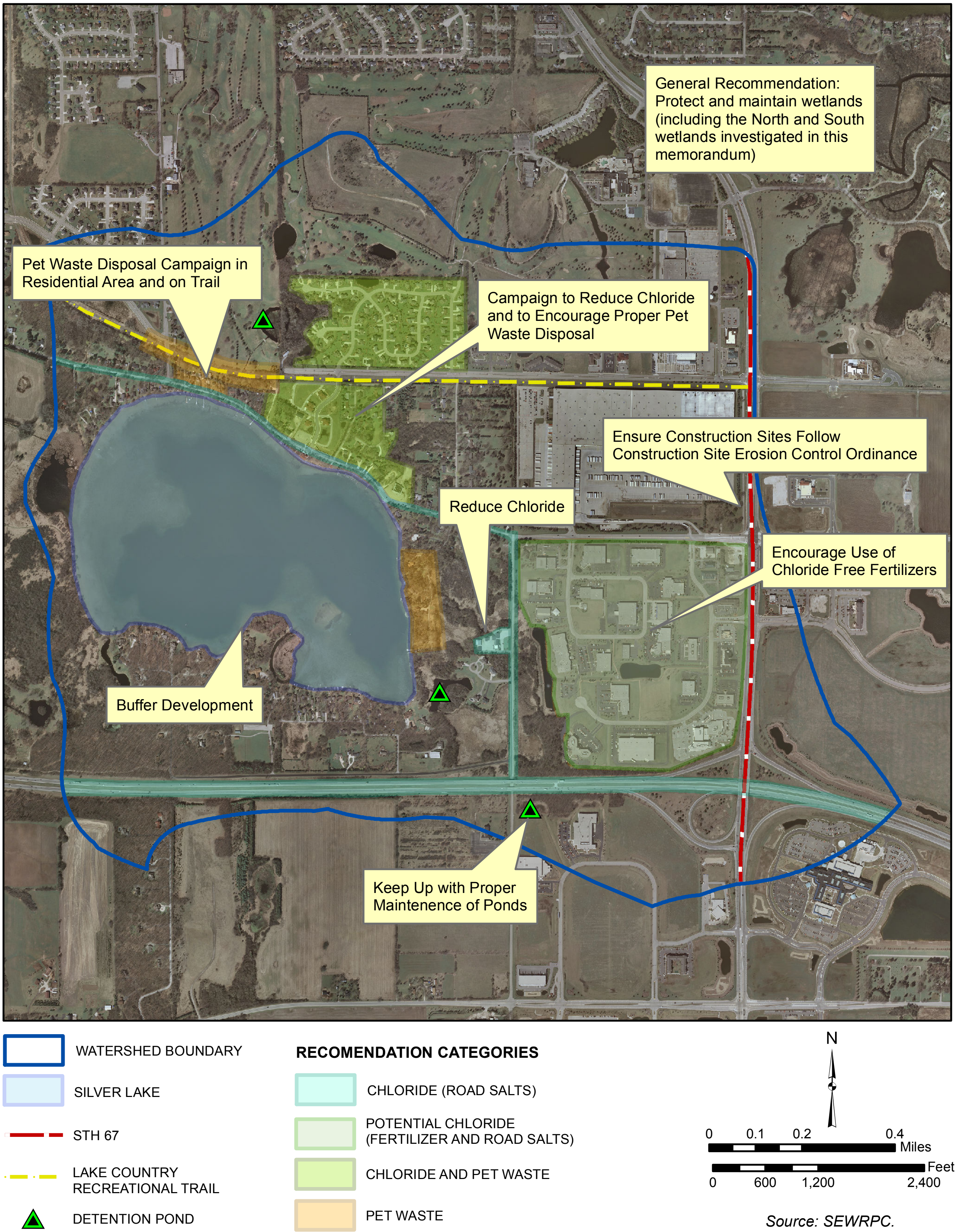
Control of nuisance aquatic plants and mosquitos is critical to public acceptance of detention basins. These activities should be conducted if a nuisance occurs or threatens. Mechanical controls should be used where feasible. Chemical control should be used sparingly and only if necessary.

Any maintenance plan must include provisions for sediment removal. Survey bottom elevations to determine permanent pool depth and sediment depths in the basin. Remove and safely dispose of sediment as need to maintain a minimum acceptable depth for sediment storage. If the basin has a forebay, frequent cleaning may be necessary to prolong the life of the basin."

– *The Wisconsin Storm Water Manual: Wet Detention Basins, University of Wisconsin Extension Publication No. G3691-4, 2000, p.11.*

Map 4

SILVER LAKE ACTION ITEM RECOMMENDATION MAP



Source: SEWRPC.

7. Consider developing an ordinance limiting uses of chlorides. Similar ordinances exist throughout the State.[35]

8. Encourage buffer establishment in areas where runoff could be entering the Lake directly (i.e., shoreline properties). This will prevent road salt and phosphorus in soils from getting into the Lake. A new "Healthy Lakes" grant has been developed by WDNR to provide partial funding to help with these kinds of projects. The Lake District should potentially consider applying for this funding, if interested homeowners can be found. Additionally, some of the many available "how to guides" should be distributed.

9. Stringently enforce compliance with Village of Summit Ordinance No. 285-08: An Ordinance for the Village of Summit relating to the Control of Construction Site Erosion Resulting from Land Disturbing Construction Activities.

10. Protect and maintain the health of the wetlands surrounding the Lake so they will continue to filter nutrients prior to their entering the Lake. This could include protecting these areas from development through easements, if necessary, and/or the removal of purple loosestrife and other invasive species if they are found.

CONCLUSIONS

Silver Lake in Waukesha County is a high quality lake that should be protected to the greatest extent possible. The Silver Lake Management District has thus far done an exemplary job of improving the Lake's water quality, as is evidenced by the vast improvements that have been seen since the 1970s. However, with new developments come new challenges as is the case with the new emerging issue of chloride contamination. The implementation of the recommendations set forth in this memorandum will help focus 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.

* * *

---

[35]*Some local government ordinances include regulations on the amount of salt used and/or when salt should not be used. This can be seen in the City of Ashland's ordinance on regulating salt use on streets and noted in the Town of Walworth's Snow Removal Policy, referenced respectively.*

- *Ordinance Regulating Salt Use on Streets in the City of Ashland, Ordinance No. 536*
- *Snow Removal Policy, Town of Walworth No. 05132014-2.*

Appendix A

DRAINAGE FOR SAMPLING SITES AROUND SILVER LAKE, WAUKESHA COUNTY

Map A-1

DRAINAGE FOR PAGANICA GOLF COURSE

DRAINAGE FLOW

DRAINAGE SOURCE

PAGANICA GOLF COURSE SAMPLING SITE

N

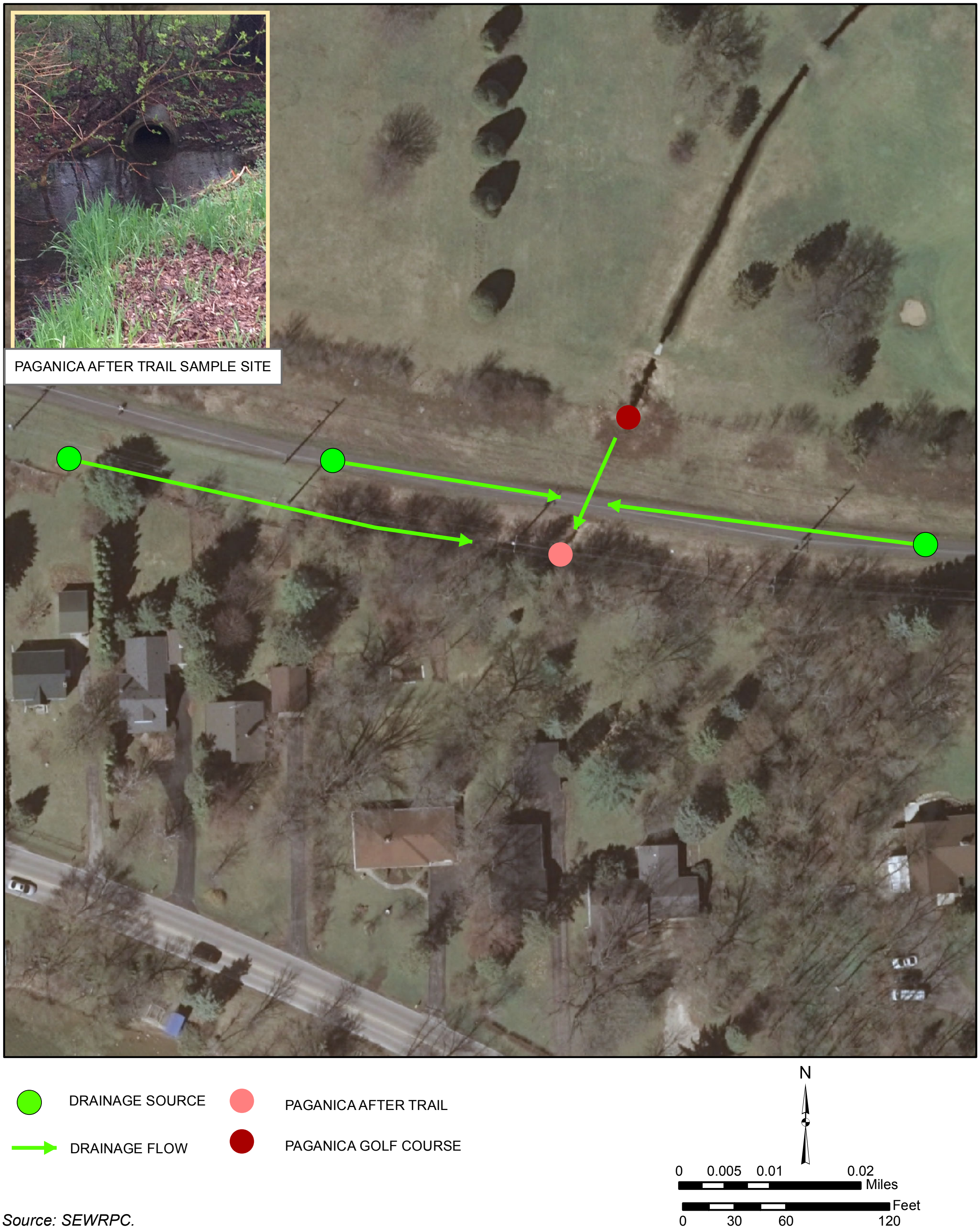
0 0.015 0.03 0.06 Miles

0 80 160 320 Feet

Source: SEWRPC.

Map A-2

DRAINAGE FOR PAGANICA AFTER TRAIL



Source: SEWRPC.

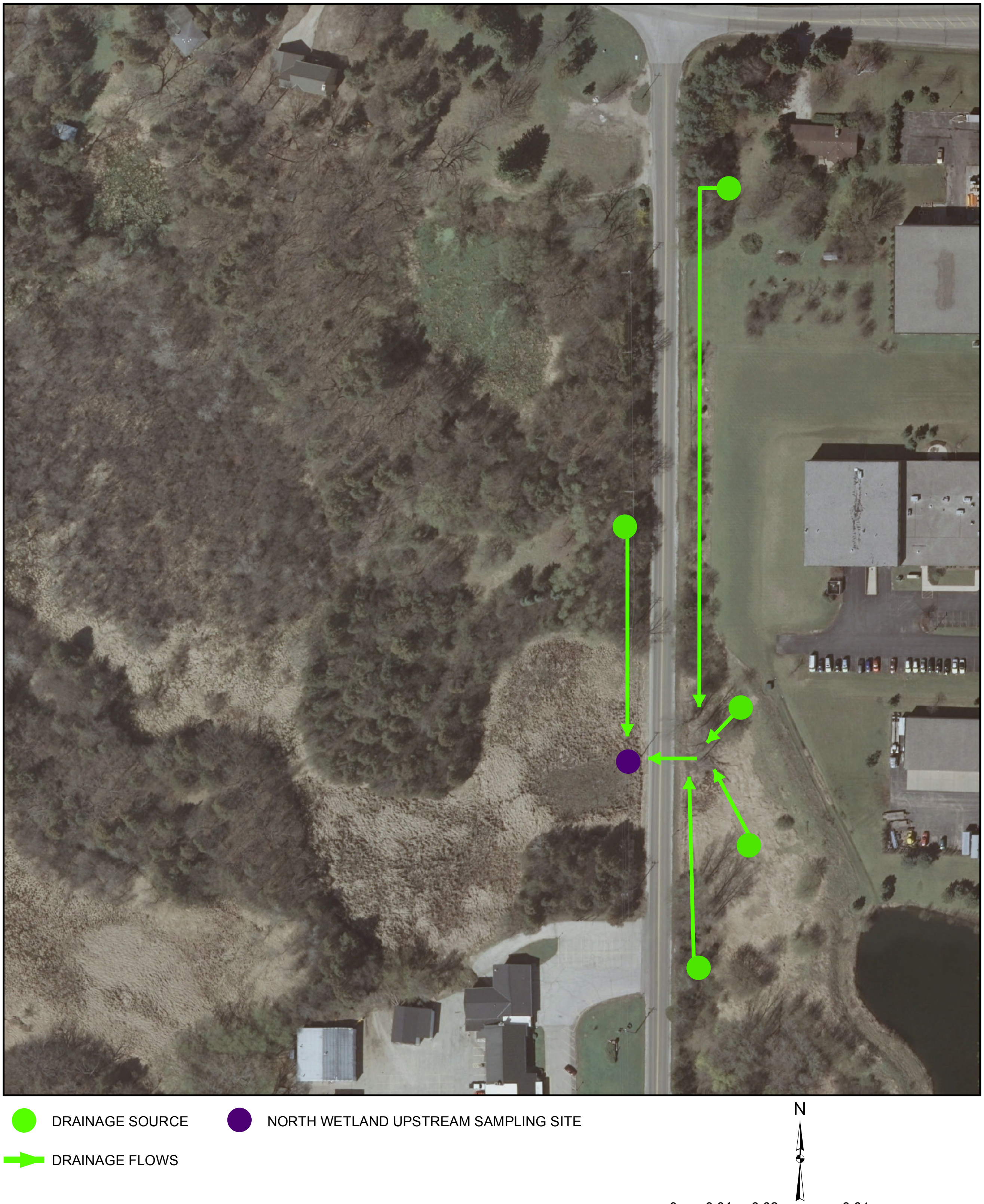
Map A-3

DRAINAGE FOR PAGANICA LAKE OUTLET

Source: SEWRPC.

Map A-4

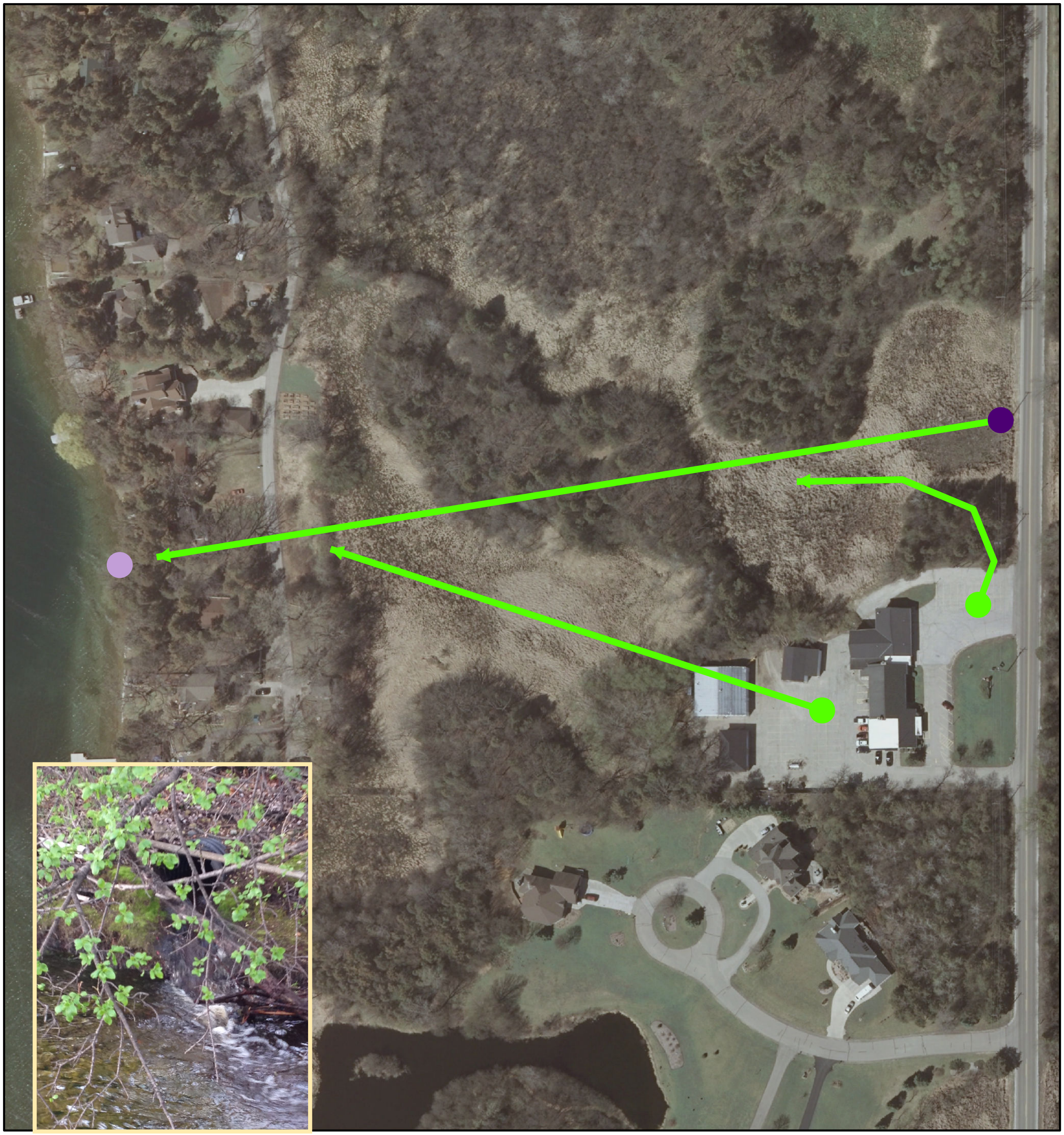
DRAINAGE FOR NORTH WETLAND UPSTREAM



Source: SEWRPC.

Map A-5

DRAINAGE FOR NORTH WETLAND LAKE OUTLET



NORTH WETLAND LAKE OUTLET SAMPLING SITE

DRAINAGE SOURCE

DRAINAGE FLOW

NORTH WETLAND LAKE OUTLET SAMPLING SITE

NORTH WETLAND UPSTREAM SAMPLING SITE

N

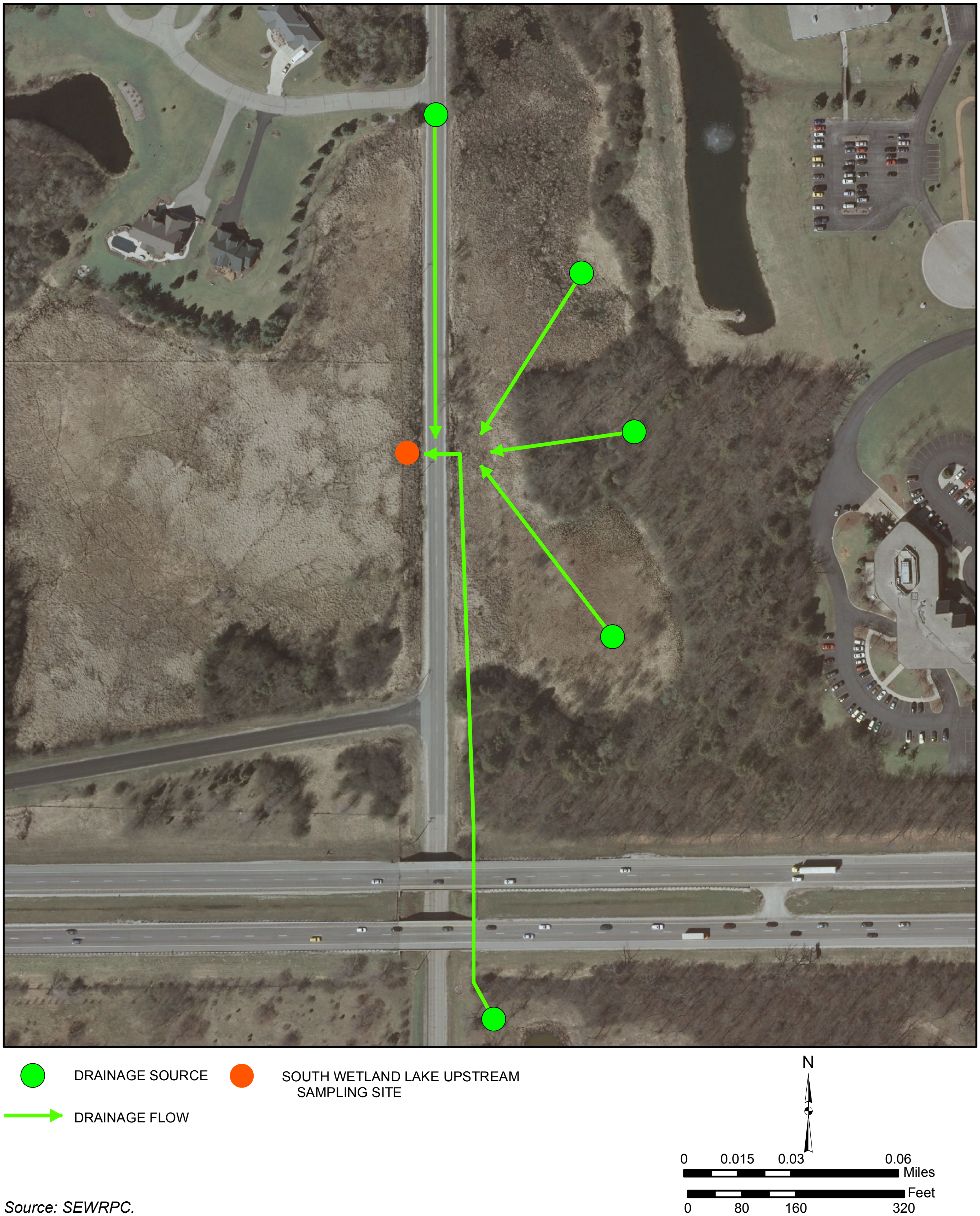
0 0.0125 0.025 0.05 Miles

0 70 140 280 Feet

Source: SEWRPC.

Map A-6

DRAINAGE FOR SOUTH WETLAND UPSTREAM SAMPLING SITE



Source: SEWRPC.

Map A-7

DRAINAGE FOR SOUTH WETLAND LAKE OUTLET

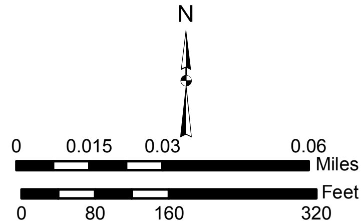
SOUTH WETLAND LAKE OUTLET SAMPLING SITE

DRAINAGE SOURCE

SOUTH WETLAND LAKE OUTLET SAMPLING SITE

DRAINAGE FLOW

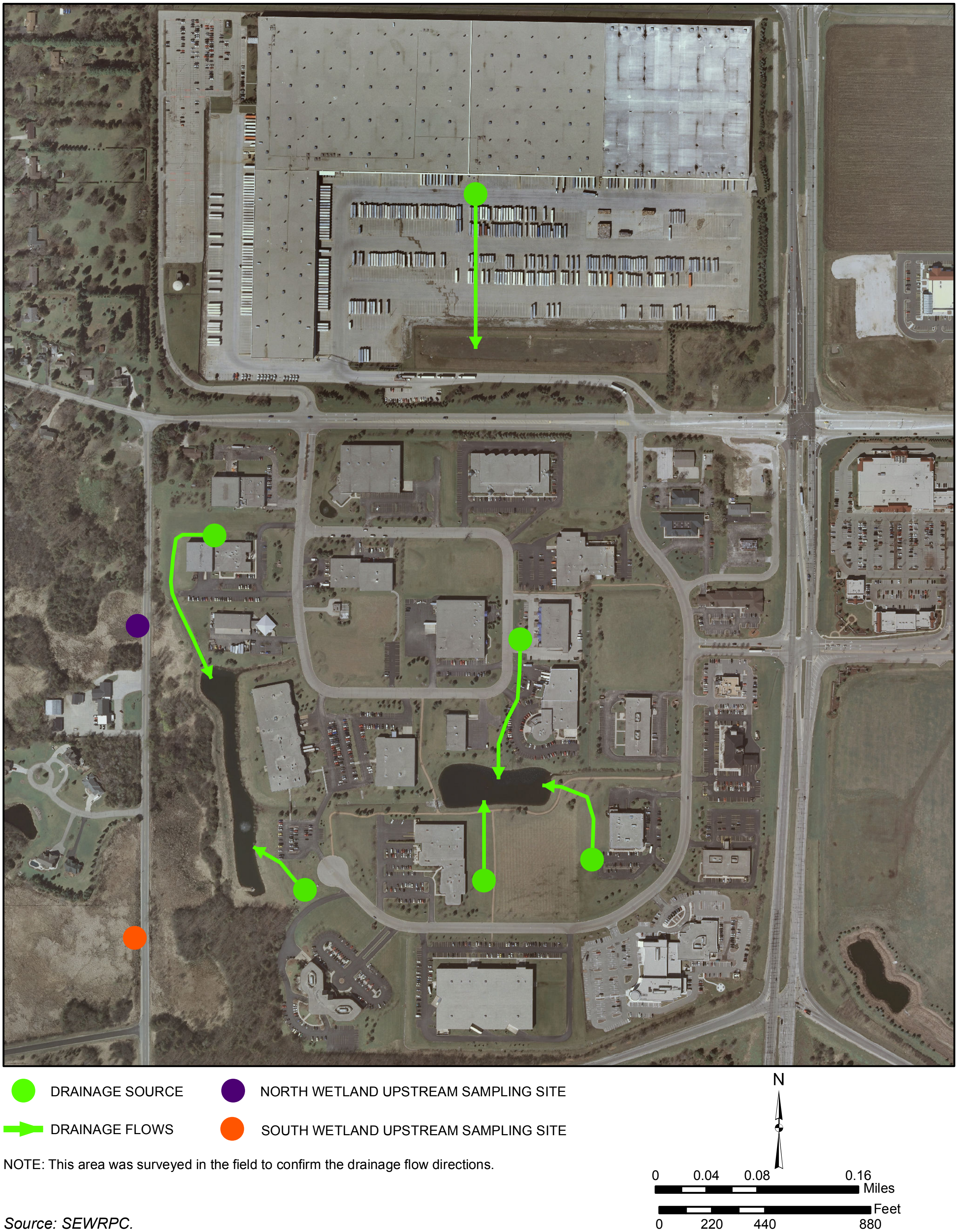
SOUTH WETLAND LAKE UPSTREAM SAMPLING SITE



Source: SEWRPC.

Map A-8

DRAINAGE FOR EASTERN COMMERCIAL AREA NEAR SILVER LAKE, WAUKESHA COUNTY



NOTE: This area was surveyed in the field to confirm the drainage flow directions.

Source: SEWRPC.

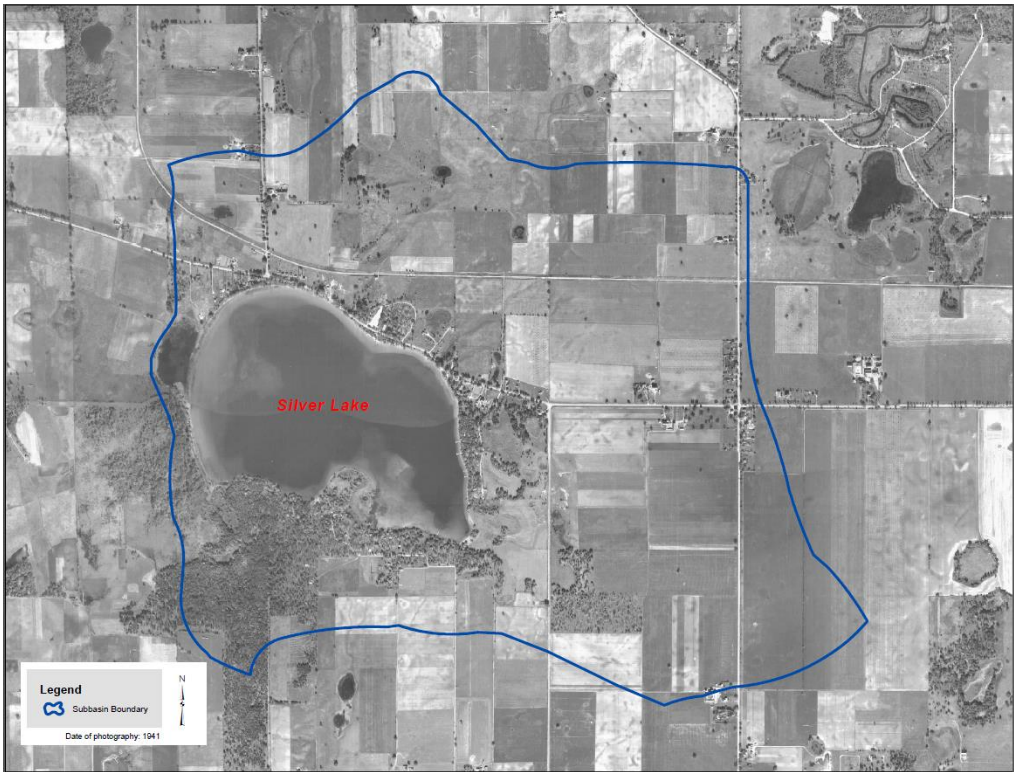
(This Page Left Blank Intentionally)

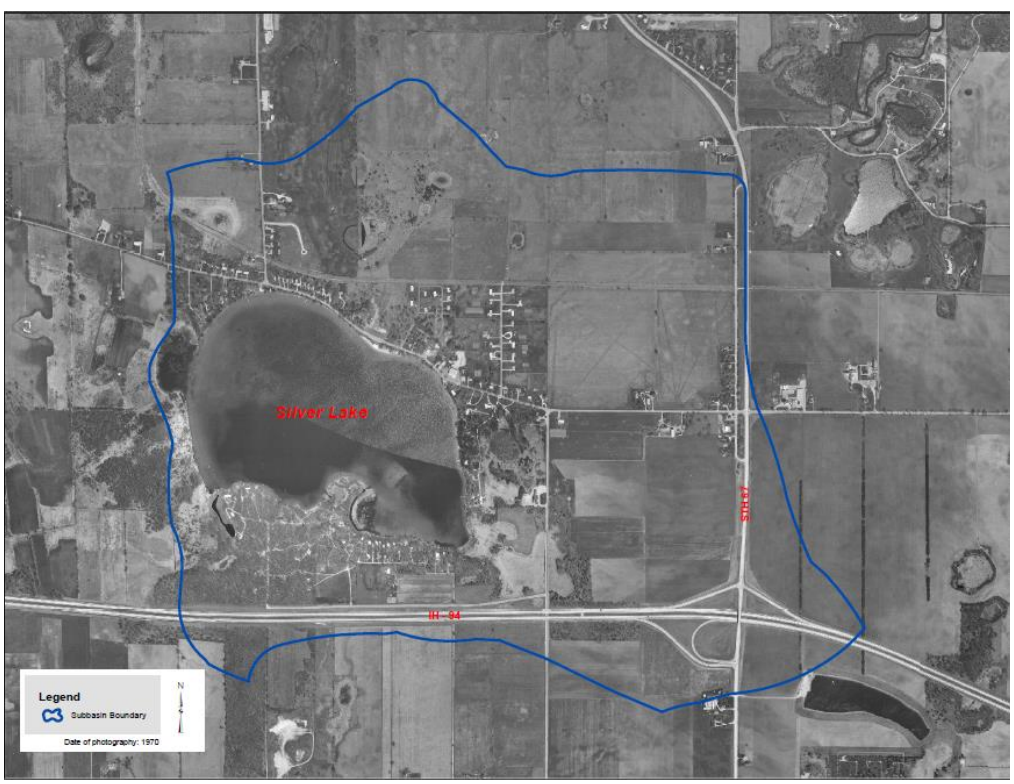
Appendix B

HISTORICAL AERIAL PHOTOGRAPHS OF SILVER LAKE WATERSHED

Map B-1

HISTORICAL AERIAL PHOTOGRAPHS OF SILVER LAKE WATERSHED: 1941 AND 1970

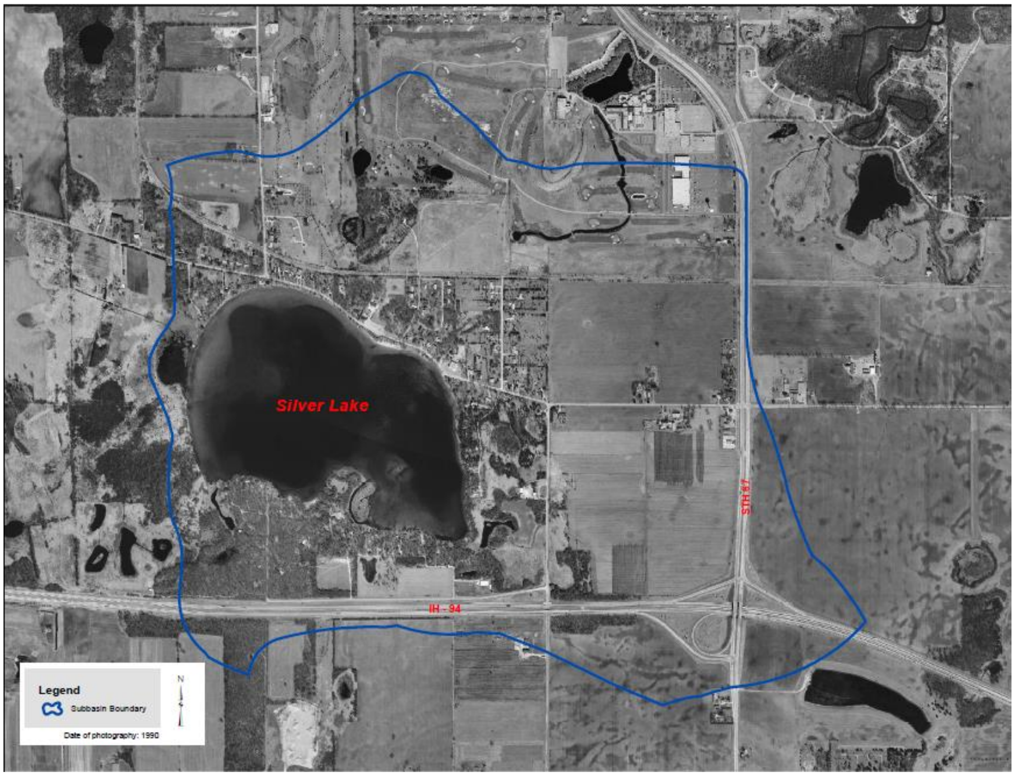


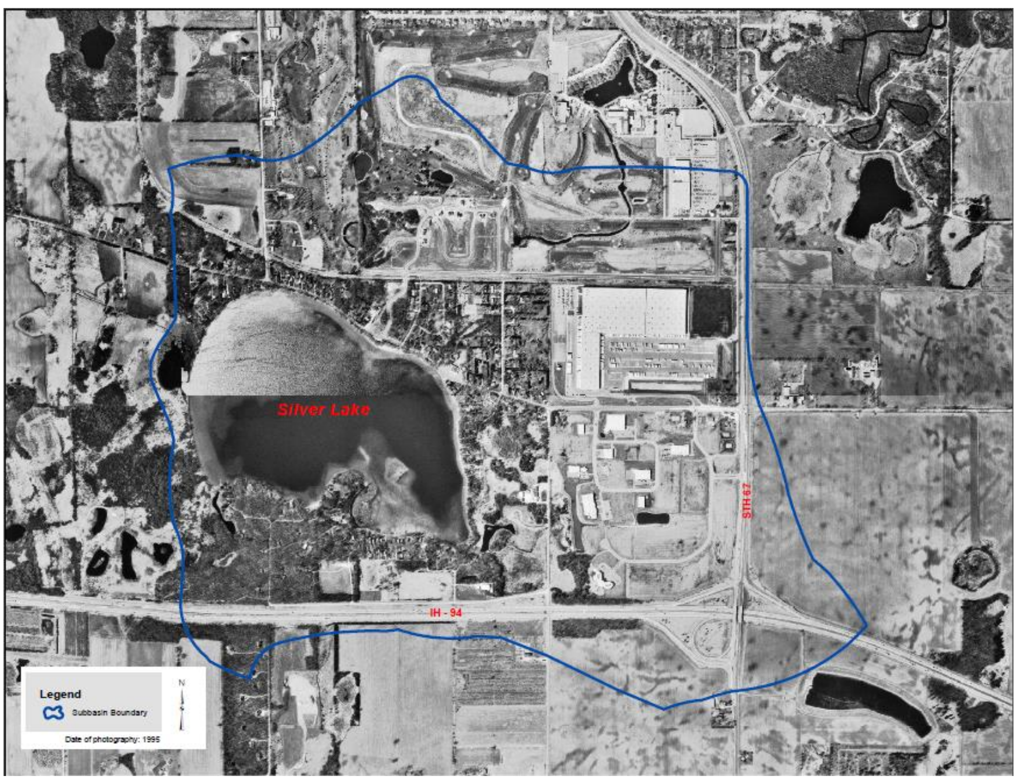


Source: SEWRPC.

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.