# ASSESSMENT RESULTS AND MANAGEMENT OPTIONS FOR CLEAR AND LOON LAKES

2016

**Establishing a management plan for the Waseca Lakes**

An initiative of the City of Waseca and Waseca County in partnership with Waseca-area residents and the Water Resources Center at Minnesota State University, Mankato to identify community goals, evaluate lake and watershed conditions, determine the magnitude of nutrient reductions needed, and survey options to improve the overall health of Clear Lake and Loon Lake.

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# Assessment Results and Management Options for Clear and Loon Lakes

*Establishing a management plan for the Waseca Lakes*

## EXECUTIVE SUMMARY


Clear and Loon lakes have long been a focal point for Waseca-area residents and the city of Waseca has made significant efforts to protect and improve these important resources. Historically, these once popular swimming and fishing lakes, exhibited abundant native vegetation and good water clarity. Changing watershed uses, development of shoreline habitats, water level management issues, and the introduction of invasive species have all contributed to accelerated nutrient loading and a now punctuated internal cycling of total phosphorous (TP).

Nutrient enrichment (primarily TP) has catalyzed lake conditions viewed unfavorably by elected officials and residents alike. Survey participants identified water quality as an area of concern, primarily because of excessive vegetation, odor, and high algal levels that degraded their lake experiences and raise concerns about the current and future health and utility of the lakes. Residents identified trail activities, fishing, use of local parks, aesthetics, and water recreation as important lake uses – all of which would be improved with better lake conditions. Therefore, the plan objectives were to establish community-based goals that address citizen-perceived challenges for Clear and Loon lakes, and to evaluate those goals through an assessment of water quality and watershed behaviors.

Based on available data, models calculated the annual TP load in Clear Lake at **78 to 91% higher** than would be expected under relatively natural conditions. Proportionally, 53% of the TP entered the lake from the watershed and 47% was annually recycled from sediments and plants within the lake (internal loading). During the 2-year monitoring period, internal loading was the single most significant TP source. Gaiter Lake and the Maplewood subwatersheds were also significant contributors of externally loaded TP. To meet the 65 µg/L TP state water quality standard, **Clear Lake annual TP load needs to be reduced by 32 to 43%.**

Loon Lake models indicated TP loading of **308 to 520% higher** than anticipated. An estimated 66% of the annual TP load came from internal loading. The remaining 34% of the annual TP load originated from the Alum Treatment and Hwy 14 Subsheds. To meet the 90 µg/L TP shallow lake water quality standard the **Loon Lake TP load needs to be reduced by 70 to 82%.**

Internal TP loading, as anticipated, is a significant TP challenge for the Waseca Lakes. Therefore, lake improvement strategies must address the internal loading factor; however, reductions in external loading is often a necessary prerequisite to effective internal load management. Expenditures to manage internal loading will be most effective and sustainable after external loading is reduced.

There are numerous potential approaches to address the problems identified by elected officials, citizens, and scientists in the Waseca Lakes. We should clarify, however, that excessive algae, odor, and other perceived problems are merely symptoms of the real underlying issue of excessive TP. Therefore, implementation of options to improve lake conditions should heavily focus on TP reduction and control. The lake improvement game plan must be multi-faceted and aggressive! The big challenges of TP reduction will need to be addressed with big strategies!

Based on the evaluation conducted here and demonstrated efforts on other lakes, citizen involvement in decision-making, incentives for good lake stewardship, and steadfast enforcement of existing rules and ordinances are needed. In addition, increased street cleaning, consideration of snow storage sites, on-going monitoring, use of groins to stabilize shorelines, and strengthening lake protections are also very important. Complex watershed challenges that will need to be addressed before targeting internal loading include TP loading from Gaiter Lake, individual septic systems, and unbuffered surface water flows (e.g., open-tile intakes). Managing internal loading will be a significant challenge, however, implementation of variable-level water management, including drawdowns to stabilize sediments and enhance shoreline vegetation growth, potential harvest of invasive aquatic plants, sediment removal, and phosphorous binding options (e.g., alum) need to remain on the table.

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# 1.0 PROJECT BACKGROUND

Lakes within and adjacent to municipal boundaries are typically a valuable community resource. Urban lakes, however, tend to be quite different from rural lakes due to differential watershed pressures and elevated citizen scrutiny. Urban lakes are often shallow, have more artificial structures in place, and are high in nutrients. Although urban lakes are valued, our knowledge on their ecology and management is weak.

Urban lakes are usually managed by local government staff that are often not equipped to address the ecological demands of maintaining a healthy lake ecosystem. Urban watershed and shoreline management is driven by planning processes that are often based on policies to provide what is best for the people using the lake, but not necessarily the lake itself. Birch and McCaskie (1999) found lake function understanding lacking in most municipal management approaches – and that incorrect management can be a contributing factor to water quality decline.

The City of Waseca, Waseca County and other organizations, such as the Waseca Lakes Association (WLA), are concerned about the future of Waseca's lakes – and they have all expressed dedicated interest in protecting and enhancing these important resources. Stakeholder interests vary, but the value of natural features is often a significant factor in local and regional communities. Leggett and Bookstael (2000) documented positive impacts on local and regional communities when surface water quality was good. Property values have also frequently been linked to lake protection measures (e.g., David 1968).

The Waseca Area Tourism and Visitors Bureau reflects a "value" on the Waseca lakes, by referring to them as "Crown Jewels" of the community and that Waseca is the gateway to a recreation-rich chain of southern Minnesota lakes (www.discoverwaseca.com). To maintain and realize the value of lake resources, a community must rally around a common mission to improve lake conditions and embrace diverse perspectives regarding lake use and management. The community needs to commit to a plan of action that embraces the philosophy that significant lake challenges can only be solved with significant solutions – and that successes will depend on strong collaboration and compromise.

The objectives of this plan are to establish community-based goals that address citizen-perceived challenges for Clear and Loon lakes, and to refine those goals through an assessment of water quality and watershed behaviors. As part of this process, we intend to provide evidence about the largest nutrient sources impacting the Waseca lakes, and to then outline management alternatives that will guide future decisions and priorities.

To facilitate the development of strategies to improve Clear and Loon Lakes, this report includes several major sections, including:

- History and Background Information,
- Problem Identification and Goals,
- Watershed and Lake Assessment,
- Nutrient Analyses and Reductions,
- Implementation Alternatives, and
- Management Recommendations.

> *"The health of our waters is the principle measure of how we live on the land."*
>
> - Luna Leopold

### *1.1 Changing Landscapes – Changing Waters*

Waseca County spans 433 square miles of south-central Minnesota that was historically rolling prairie and savannah habitats. The name Waseca is from the Dakota Sioux language meaning "rich" and was used correctly in reference to the fertile soils of the area. The productivity of the land, combined with abundant wildlife and water resources, made the area attractive to settlers. Waseca County was established in 1857 and by 1870, 2,601 people had taken up residence, of which 21% lived in the City of Waseca (Figure 1). By 2010, the Waseca County population had grown to 19,136 people, with 49% of the residents living in the City of Waseca (USCB 2010).

Although the population density in Waseca County is low by national standards, the conversion of land from perennial vegetation to agricultural production and urban landscapes has inevitably impacted surface waters. The density, distribution, and composition of vegetative cover influences hydrology (Sanders 1986). By 2007, 90% of the land in Waseca County was in agricultural production (USDA 2007). Runoff curve numbers that factor into models that estimate water loss from the landscape for various soil groupings in southern Minnesota have increased on average by148%, 190%, and 142% for lands in row-crop agriculture, with high proportions of impervious surfaces, and for turf grass (USSCS 1986).

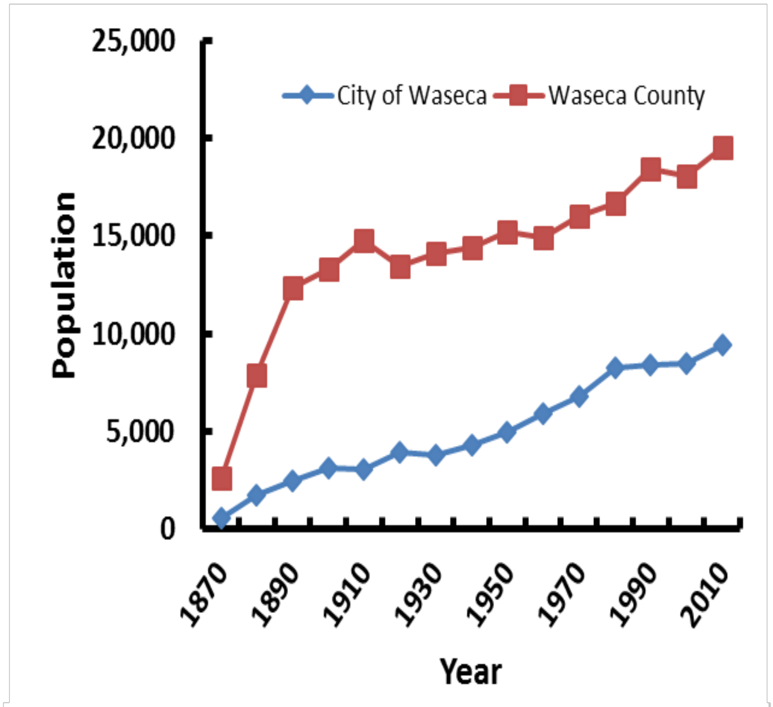



**Figure 1.** Human population estimates based on available Census data from 1870-2010 for the City of Waseca and Waseca County. (U.S. Census Bureau)

The lakes in and adjacent to the City of Waseca have long been a focal point for local residents. Historically, the lakes exhibited abundant native vegetation, maintained good water clarity, and were popular swimming and fishing destinations in the early 1900s. A detailed review of historical data was completed by Bolton and Menk (2003) and suggested that Clear Lake had been significantly altered from its original state since the late 1800s – the same timeframe in which human population was growing and land conversion was accelerating. As the watershed experienced anthropogenic modifications, the lakes also changed. As nutrient loading increased, the natural aging process for lakes, called eutrophication, was accelerated.

### *1.2 The Waseca Lakes – Clear and Loon*

**Clear Lake** is located in the north central portion of Waseca County, Minnesota (Figure 2). At approximately 678 acres, Clear Lake is the 12th largest lake (out of 26 lakes) within the Cannon River watershed. Approximately 1,914 acres drain into Clear Lake from areas with dominant land uses of agricultural and the developed lands that make up the City of Waseca. The watershed-to-lake ratio is approximately 2.9:1. Clear Lake has been actively managed to various degrees since the early 1900s and local conservation concerns for the lake catalyzed protective legislation as early as 1873, when local authorities banned gravel and sand mining from the lake bed. Historical events have been documented by the WLA (http://wasecalakes.org/pages/photos.php) and were further summarized in Bolton and Menk (2003; Appendix A).

**Loon Lake** is also located in the north central portion of Waseca County, Minnesota (Figure 2). At 1238 acres, Loon Lake represents one of the smaller lakes found within the Cannon River system. The Loon Lake watershed include approximately 331 acres that is primarily within the developed area of the City of Waseca. The watershed-to-lake ratio for Loon Lake is 2.6:1. Lakes with watershed-to-lake ratios less than 10:1 have more potential for success when attempting restoration efforts (Hoyman et al. 2012). The historical accounts for Loon Lake are not as well documented as those for Clear Lake; however, that is not to say that Waseca-area residents and governmental units have ignored this resource. Loon Lake has been the subject of multiple rehabilitation efforts, aeration, and shoreland enhancements, including an alum-treatment facility. Documentation that could be located was compiled and can be found in Appendix B.

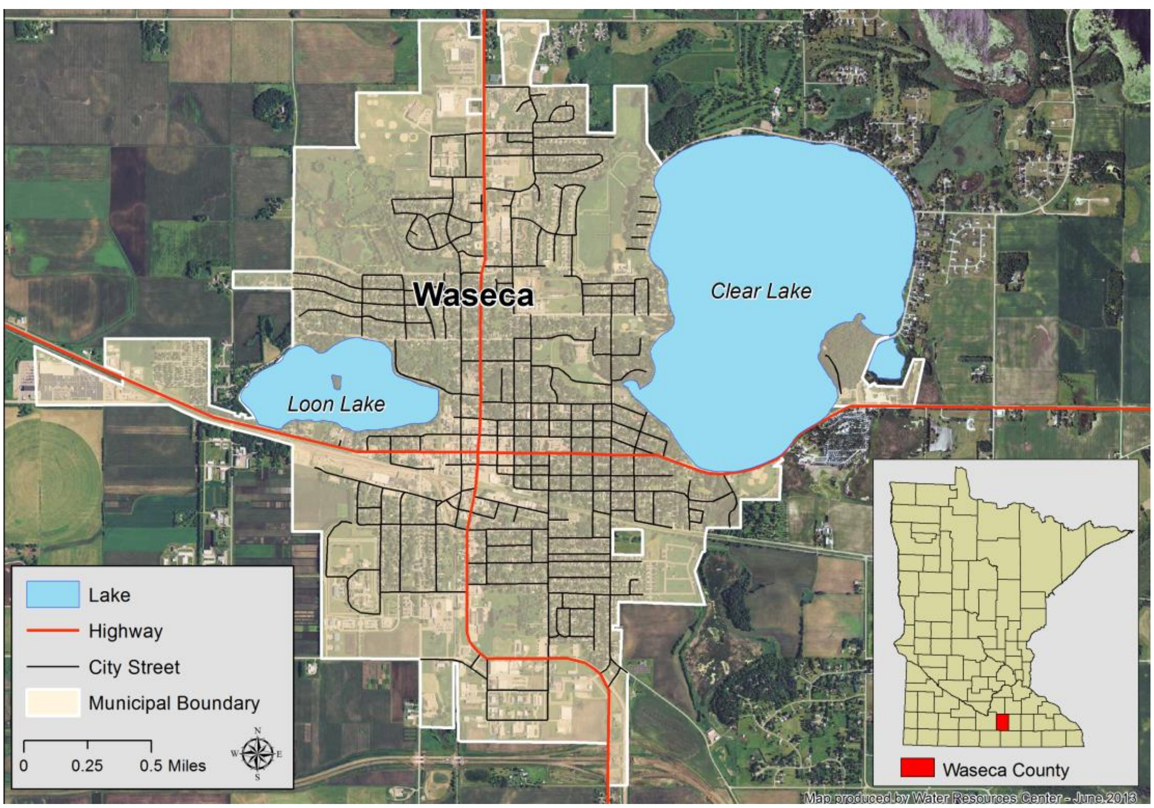



***Figure 2. Map of Clear Lake and Loon Lake in the context of the City of Waseca, Waseca County, and the State of Minnesota. The map includes the municipal boundary and is bisected north-south by Minnesota State Highway 13 and east-west by Minnesota State Highway 14.***

### *1.3 The Decline of Clear Lake*

The first recorded water quality problems in Clear Lake date back to the early 1930s, when algae blooms were documented on hot, calm days (Bolton and Menk 2003). As the local population grew during the early 1900s, sanitary sewage systems were inadequate and contributed untreated sewage from developing neighborhoods directly into Clear Lake. Based on documentation from James Groebner (former Regional Fisheries Biologist), Clear Lake had good fishing and abundant native vegetation until some point between 1940 and 1944.

Correspondence among interested stakeholders from the 1940s indicated that water quality and fishing began to decline dramatically. Historical information maintained by the WLA (http://www.wasecalakes.org/pages/photos.php) include notes that in 1951, heavy rains raised the level of Clear Lake by 3 feet. Locals often refer to this event as the beginning of Clear Lake's decline due to losses of shoreline vegetation combined with high waters that allowed common carp to invade. By 1963, James Groebner documented that carp had become extremely abundant, submerged vegetation was very sparse, only a small area of bulrush persisted, and the algae had become extremely dense. He went on to comment that the bluegill and bass fishing were greatly depreciated and pike and crappie fishing were also declining.

During the 1970s and 1980s, numerous management efforts were underway to improve the water quality and fish community of Clear Lake. Historical data suggest that the lake was beginning to respond to these efforts; however, by the mid-1990s, nutrient loads had again increased and water quality was poor, particularly in comparison to other area lakes. Across the United States during the mid-portion of the last century, surface water quality declined similarly to what was observed in Clear Lake. As a result, the 1972 Clean Water Act (CWA) for restoring and protecting the ecological integrity of America's waters was established. As part of the CWA requirements, Minnesota has been assessing waters to identify, list, and work towards restoring "impaired waters."

In 2002, Clear Lake (DOW# 81-0014) was proposed for listing on the 303(d) list of impaired waters and remains on that list as of 2012 (MPCA 2013). Based on water quality data, Clear Lake has been deemed impaired for aquatic recreation due to unfavorable observations of *Nutrient/Eutrophication Biological Indicators* caused by excess nutrients (MPCA 2011, 2013). Loon Lake (DOW# 81-0015) would almost certainly be classified as impaired as well; however, there have been insufficient water quality data to propose its listing (as of 2012).

In 2003, Bolton and Menk, Inc. completed a Clear Lake Assessment. The 2003 assessment utilized available methodology at the time to assess nutrient loading from various sources; however, approaches to data collection, assessment, and interpretation have been modified substantially over the past decade. The 2003 data are still useful, but should be placed in the context of substantially evolved in-lake nutrient cycling models, the techniques used to address septic systems, and tightened up monitoring requirements for flow measurements and pollutant sampling.

In terms of nutrient loading from the watershed, Bolton and Menk (2003) implicated County Ditch 15-1 as one of the largest sources of phosphorus to Clear Lake and recommended that the ditch should be abandoned and re-routed. In 2010, it was determined that a portion of County Ditch 15-1 was either blocked or collapsed (Personal Communication, Russ Stammer, Former Waseca City Engineer and also reported in Hager 2011); resulting in substantially reduced flows and elimination of a potentially large nutrient sources. Clear Lake was scheduled for a total maximum daily load study (TMDL) to begin in 2008; however, the study was postponed due to uncertainties associated with the Gaiter Lake Diversion Project. The TMDL study was to be completed as part of the overall Cannon River Watershed Assessment scheduled to begin in 2015.

# 2.0 PROBLEM IDENTIFICATION AND ESTABLISHING GOALS

Problem identification can be a complicated process of balancing differences of opinion in what constitutes a "problem," managing perceptions about assumed problems, and verification of perceived problems with scientific research. Regardless of the challenges associated with problem identification, the main outcome is to establish community, and in some cases, legal priorities that guide future management actions, investment of resources, and data acquisition. Problem identification is important to better frame constructive discussions, allow the community members to ask better questions, and aid in decision-making. This section summarizes the results of input from Waseca-area citizens regarding their lake use, as well as their lake-related concerns and goals.

## *2.1 Identification and Prioritization of Stakeholder Concerns*

Communities are based on the collective thoughts and actions of individuals; however, as individuals in a free society, we develop strong opinions about the aspects of our environment that we find favorable, and those aspects that we find unfavorable. What may be identified as a problem to one resident may in fact be viewed as a benefit to another. To move forward as a community, the collective conscience must be assessed and considered as the Waseca Lakes region prioritizes issues, and decides how to move forward.

### Public Information Meeting

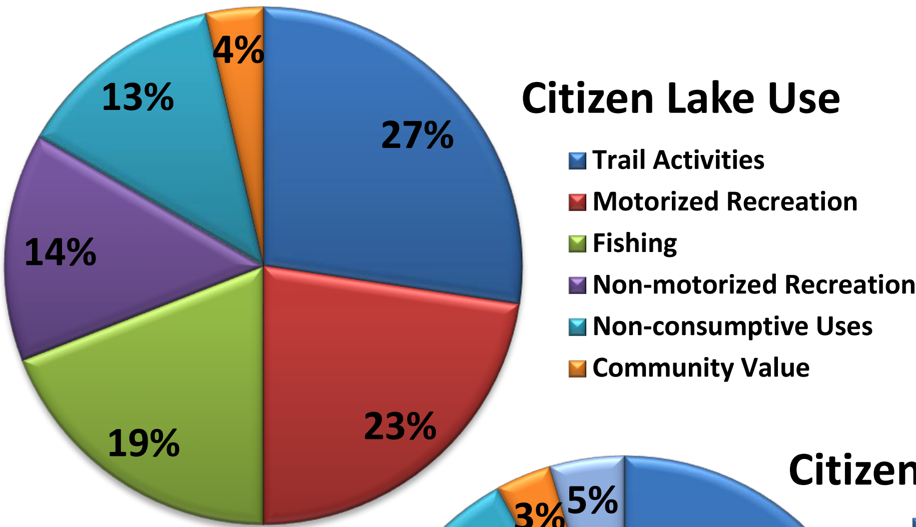
In the spring of 2012, Waseca area residents were invited to a public information meeting about Clear and Loon Lakes. The intent of this public meeting was to inform the public about the water quality monitoring and planning process that was underway, gather input about lake concerns, discuss a future vision for Clear and Loon lakes to meet public desires, and give residents a chance to ask questions about the lakes (Appendix C).

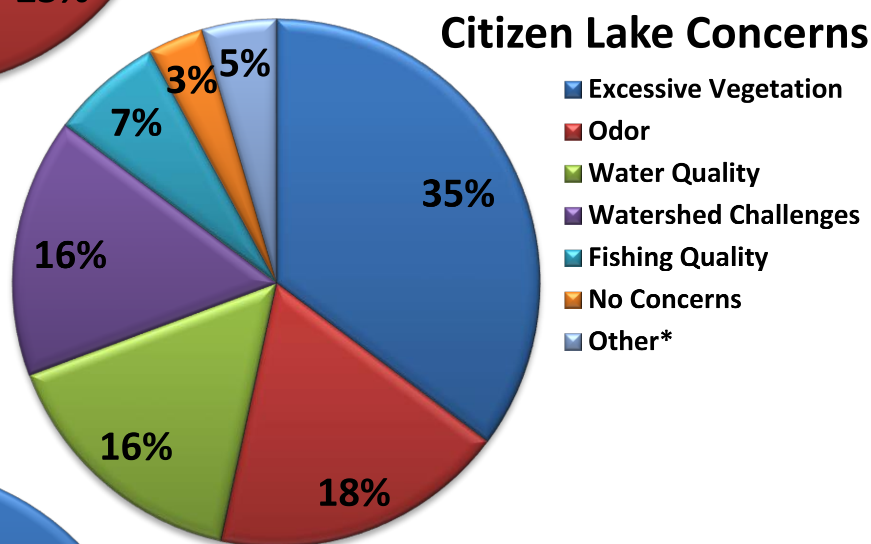
The Waseca Lakes Public Information Meeting was held on May 9, 2012 with 28 people in attendance. Attendees represented the City of Waseca, Waseca County, WLA, Waseca-area residents, local educational staff, and the Minnesota Department of Natural Resources (MDNR). Staff completed an overview of the collaboration among the City of Waseca, Waseca County, and the Water Resources Center, explaining that the impetus for the initiative was to develop a plan to improve the Waseca Lakes.

As part of the process to identify and prioritize citizen concerns about Clear and Loon lakes, participants were asked to identify up to three of each of the following:

- *Values and uses they had for the Waseca Lakes,*
- *Concerns they have about the observed changes and current status of the Waseca Lakes, and*
- *Goals, dreams, and/or vision for the Waseca Lakes' future.*

Fishing, boating, walking/jogging, and viewing the lakes were among the most common activities reported (Figure 3). In total, there were 18 different activities identified. The diversity of activities speaks to the range of values Waseca residents place on these. One woman mentioned that these lakes were a part of how Waseca residents define themselves. The general consensus among the group was that swimming on Clear Lake/Loon Lake has definitely decreased in the past 20-30 years. Residents indicated that the decline is partially attributed to increased use of the water parks; however, poor water quality has also made the natural beaches less appealing.




***Other concerns included water depth management, carp populations, sewage overflow, Gaiter Lake, and shoreland erosion.**

***Other goals included modified water depth management, pollutant identification, shoreline improvements, and enhanced swimming beach areas.**

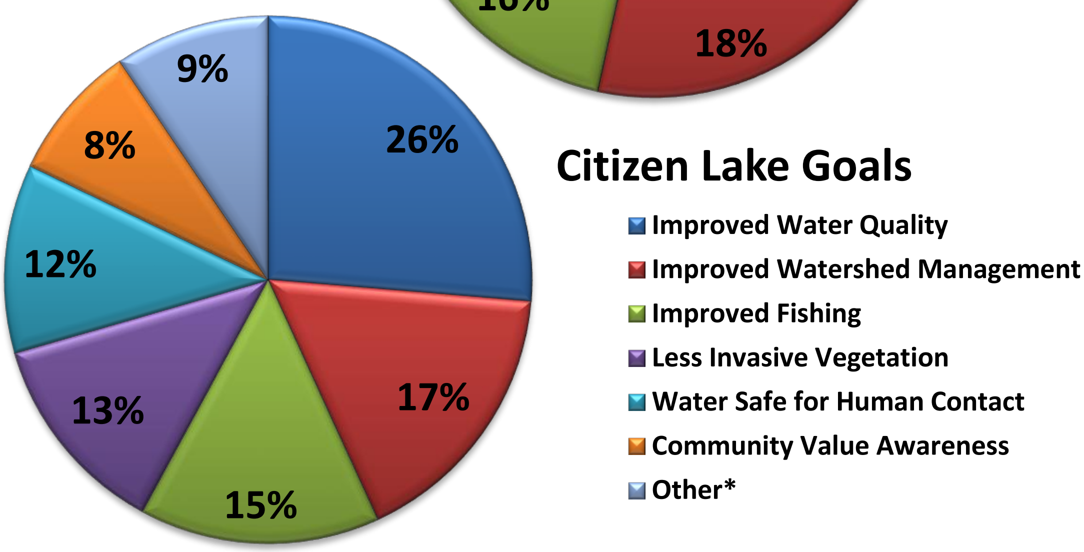



***Figure 3. The six most identified uses of, concerns for, and goals regarding the Waseca Lakes (Clear and Loon) among 28 Waseca area citizens at a public informational meeting held May 9, 2012. Participants were asked to identify three uses/values, concerns, and goals/desires for the Waseca Lakes. The values indicate the proportion of 84 responses in each category provided by the participants.***

After discussing the activities Waseca residents enjoyed most, attendees were asked to list some of their concerns for Clear Lake/Loon Lake – and to be as specific as possible. The most common concerns were water quality (which participants further defined as green water with a strong odor), weeds, water depth, and storm water management. The floor was opened for discussion of the concerns. A resident indicated that he believed the lake was lowered when the outlet structure was fixed following the completion of the trail in 2008. In contrast, participants acknowledged that there have also been complaints about high water levels over the years.

Various causes for water level fluctuation were discussed; however, staff attempted to point out that water level fluctuations are a natural, and healthy, process for lakes here in southern Minnesota. Many potential mechanisms to address water levels were offered by the participants; however, additional review would be needed to determine the ordinary high water levels and how lake levels had evolved.

A Waseca resident that also works for the MDNR indicated that he continues to believe that stormwater management is the major concern that needs to be addressed. Many of the Waseca residents agreed with this mindset. Most agreed that this was an area where work can and should be done. As a result of the stormwater discussion, a few residents inquired about rain gardens and shoreland plantings.

The staff discussed the benefits and challenges of rain gardens and rain barrel and asked that anyone with an interest in putting one of these best management practices on their property to contact the Water Resources Center and we would review possible grant opportunities to help them with the funding. The Kuchenbecker's rain garden was provided as an example of a best management practice that could help incrementally address stormwater issues.

*Citizens generally agree that Clear Lake is a valuable resource to the community and surrounding area; however, there is a broad spectrum of understanding about the various challenges that Clear Lake faces, including fish kills, invasive vegetation, and nutrient levels that catalyze algal blooms (depicted).*

The meeting concluded with the participants identifying their goals for Clear Lake and Loon Lake – particularly regarding what they would like to see in 10-15 years. The most common responses included improved water quality (again to address green water and odor), a reduction in algae during the late summer, and fewer weeds (particularly during the spring and early summer. It appeared to be well understood by those in attendance that attaining genuine lake improvements would require a long term commitment by residents, the city and county, and other entities. *Citizens also generally agree that something should be done to improve the Waseca Lakes, but again there exists broad opinions about lake goals and what actions should be taken.*

## Citizen Interviews

The public information meeting included important feedback from representative of the WLA, the City of Waseca, and local natural resource agencies; however, broader citizen representation needed supplementation. Therefore, we conducted individual and group interviews to gain additional insight about the uses, concerns, and goals that people have regarding Clear Lake and Loon Lake. We completed 147 interviews representing a range of citizens with a potential stake in the Waseca Lakes Plan. Survey participant demographics included Caucasian (81%), Latino (16%), and Black (3%), with 83 men and 64 women – 72% of which were from the City of Waseca and Waseca County, but with another 21% from Steele County (Table 1).

After a brief explanation about the initiative by the City of Waseca and Waseca County to develop a Waseca Lakes Plan, participants were asked to identify their primary county of residence. Those that stated "Waseca" were then asked if they lived in the City of Waseca. Residency information, age (if provided), and ethnicity were recorded. If age was not specifically given, each participant was placed into the most likely age category, based on appearance (Table 1). Each participant was then asked three basic questions about Clear Lake and Loon Lake:

- *In what ways do you primarily use, enjoy, or value Clear/Loon Lake?*
- *What concerns do you have about the current conditions of Clear/Loon Lake?*
- *What goals are important to you for the future management of Clear/Loon Lake?*

As a point of clarification, participants were allowed to provide multiple responses to each question. Therefore, if an individual indicated that he/she uses the lake for fishing and camping (two separate categories); he/she would be counted as a respondent in each category. The number of people that provided a response in each category and the number of overall responses in each category are reported as frequencies (percent of the total). For example, if 77 of 147 people interviewed indicated "Trail Activities" was a primary lake use, the frequency of trail users would be 52%.

Because many of those interviewed provided multiple responses, the frequency of "Trail Activities" in the total responses will, in most cases, differ from the frequency of trail users. Sample size (N) for the number of people interviewed was 147, and applies to all categories for both lakes. The number of responses, however, varied substantially between the two lakes and among the questions. For example, the number of responses regarding Clear Lake uses (N=314) was substantially greater than responses about Loon Lake uses (N=162).

Table 1. Age distribution and ethnicity summary for 147 people interviewed between September 2012 and August 2013 in association with the Waseca Lakes study. For each parameter, the number of participants (and % of the total participants) is noted. The number of male (M) and female (F) participants in each ethnic group, a summary of interview collection locations, and participant residency data are also reported.

**Participant Age Distribution**

| Age (years) | Participants (%) |
|---|---|
| 12*-19 | 22 (15) |
| 20-29 | 13 ( 9) |
| 30-39 | 19 (13) |
| 40-49 | 22 (15) |
| 50-59 | 32 (22) |
| 60-69 | 21 (14) |
| >69 | 18 (12) |

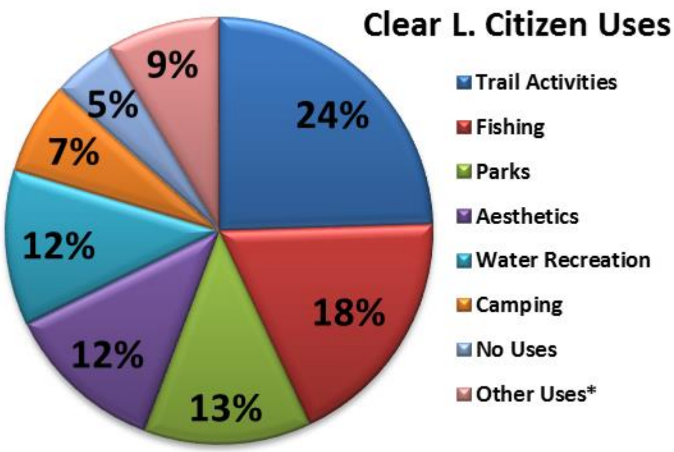
| Ethnicity | Participants (%) | Sex (M/F) |
|---|---|---|
| Caucasian | 119 (81) | 63/56 |
| Latino | 23 (16) | 15/8 |
| Black | 5 (3) | 5/0 |
| | *Overall* | *83/64* |

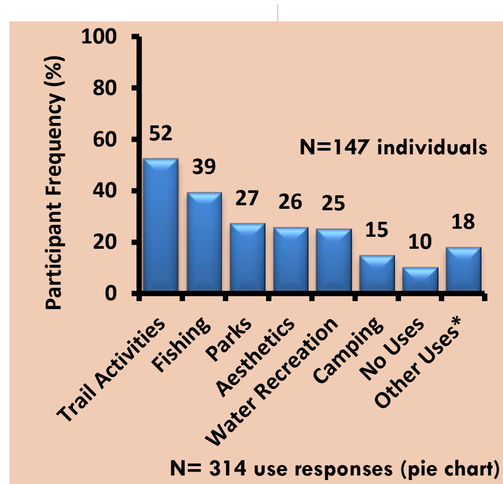
| Self-Identified Residency (%) | |
|---|---|
| City of Waseca | 57 (39) |
| Waseca County | 49 (33) |
| Steele County | 31 (21) |
| Other Counties/States** | 10 ( 7) |

| Summary of Interview Locations | |
|---|---|
| Retail Outlets | 32 |
| 2013 County Fair | 31 |
| Rotary Club Meeting | 26 |
| Clear Lake Landings/Trail | 24 |
| Waseca City Parks (lake locations) | 16 |
| Waseca Lakes Association Meetings | 12 |
| Other/Parks Board | 6 |
| *Total Interviews* | *147* |

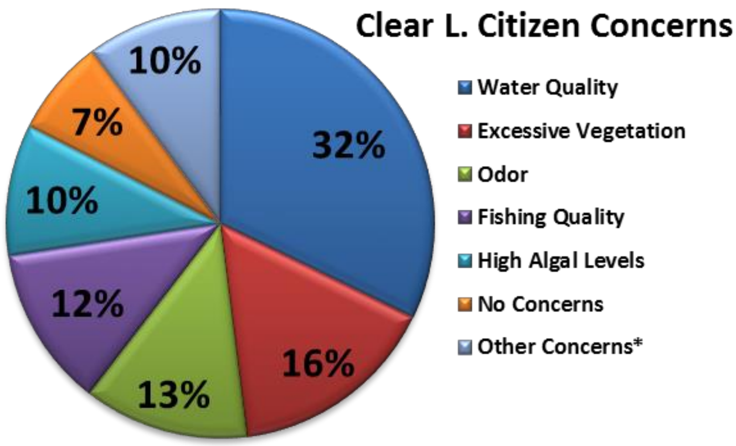
**Individuals <age 12 were not knowingly approached or interviewed due to policies associated with the use of human subjects in research.*
*** Other participants included residents of Iowa (2) and other Minnesota Counties: Blue Earth (3), Rice (3), and Le Sueur (2)*

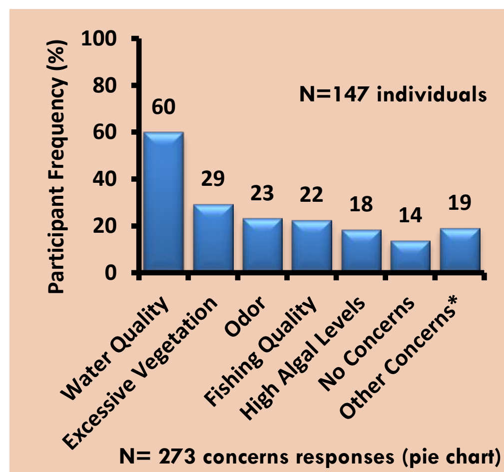
As anticipated, interview results were starkly different between Waseca and Loon Lakes. The nature of those differences, however, was less about differential uses, concerns, and goals, and more about lack of awareness or interest of any type in Loon Lake. Fifteen participants (10%) expressed that they did not use or have other specific values for Clear Lake, as compared with 101 participants (69%) who indicated no use of or values about Loon Lake (Figures 4 and 5). Twelve of the 147 people interviewed (8%) specifically indicated they did not know where Loon Lake was located. Of the total use responses provided, the frequency of "no use/value" for Loon Lake was 63%, whereas, Clear Lake "no use/value" responses was 5% overall (Figures 4 and 5).



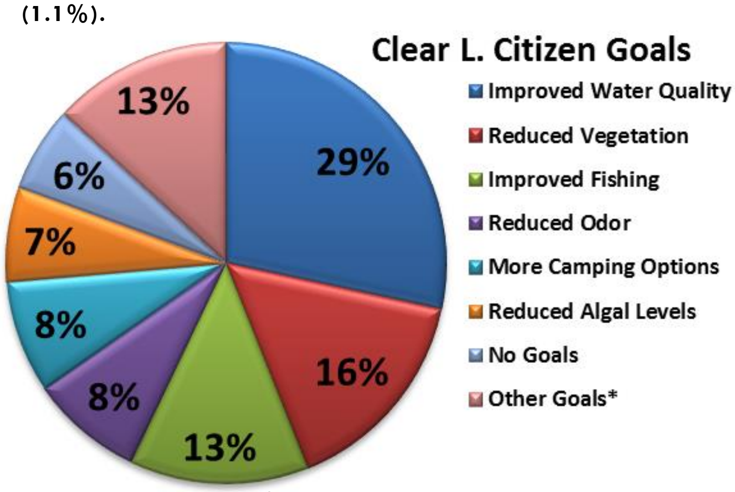



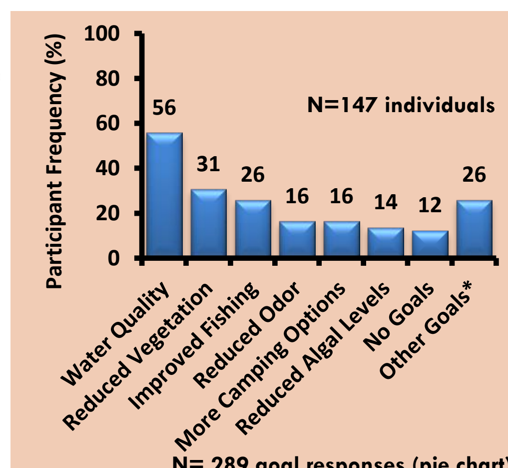

*Other Uses included value as a community asset (3.5%), residential setting (3.2%), and swimming (1.9%).



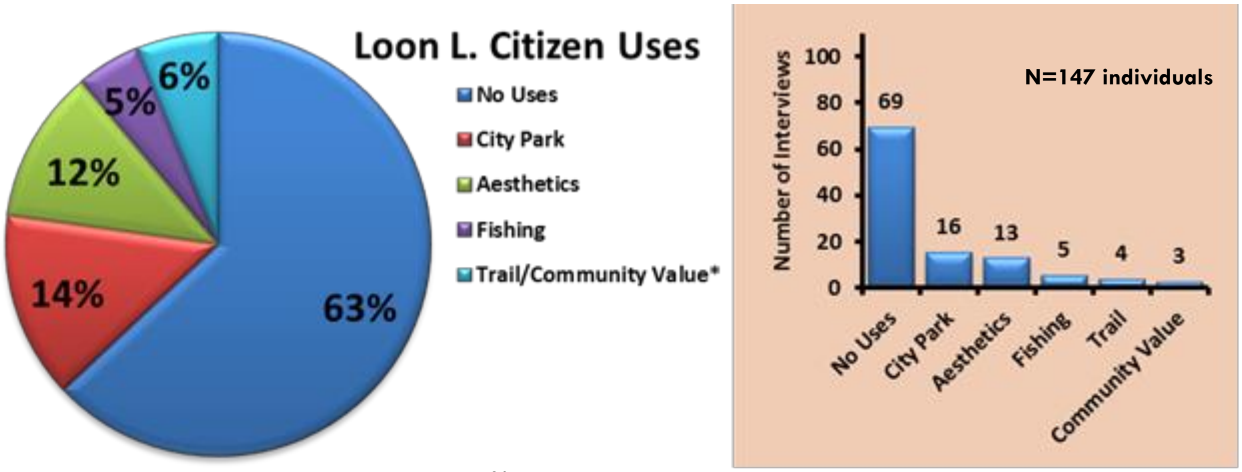

*Other concerns included swimming safety (3.7%), water recreation limitations (2.1%), park conditions and safety (1.8%), lack of community value (1.5%), and excessive stormwater (1.1%).



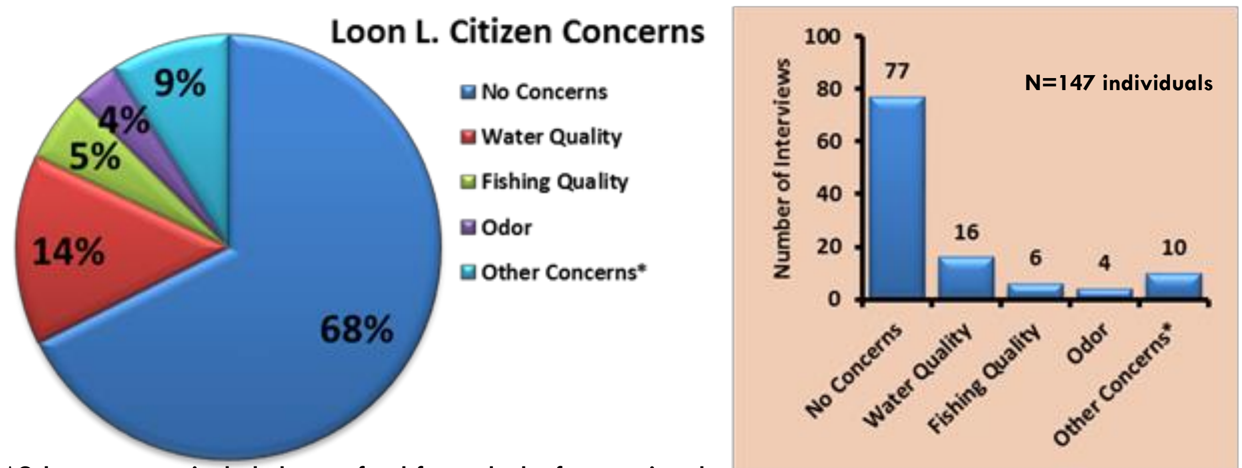

*Other Goals were safe swimming and increased community value (3.1% each), and aesthetic (2.8%), water recreation, and park improvements (2.1% each).

*Figure 4. The most identified uses of, concerns for, and goals for Clear Lake based on 147 citizen interviews conducted in 2012 and 2013. The pie charts indicate the frequency (%) of each category among all responses combined. The bar charts indicate the frequency (%) of participants that identified each category.*



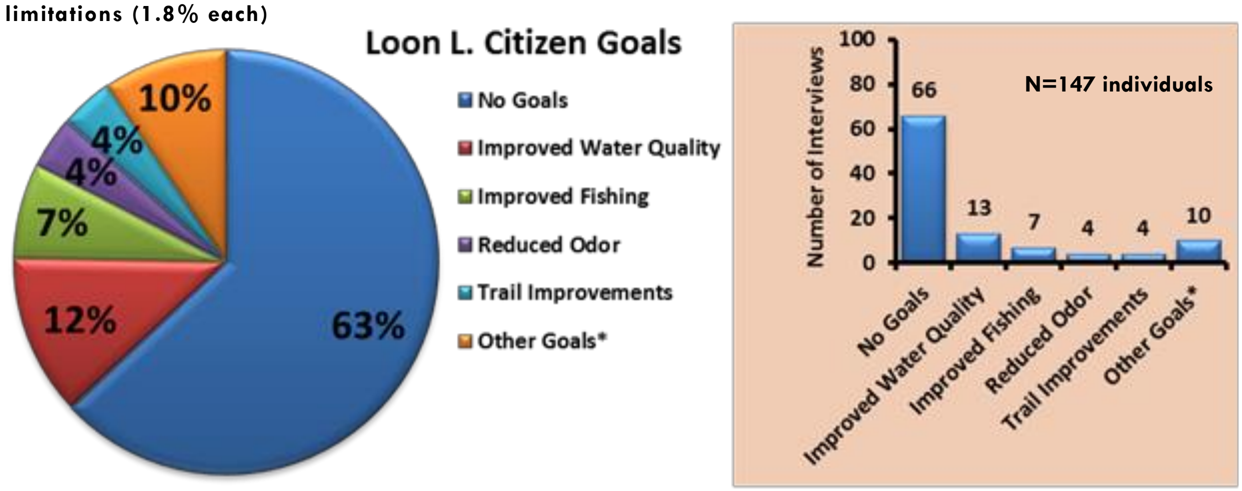

*Trail use and community value are each 3% of the total responses.

N= 167 use responses (pie chart)




*Other concerns included waterfowl feces, lack of recreational access, shallow lake conditions, high algal levels, and trail limitations (1.8% each)

N= 162 concerns responses (pie chart)




*Other goals included waterfowl reductions, improved recreational access, dredging, reduction of algal levels, and enhanced community value (1.9% each)

N= 154 goal responses (pie chart)

*Figure 5. The most identified uses of, concerns for, and goals for Loon Lake based on 147 citizen interviews conducted in 2012 and 2013. The pie charts indicate the frequency (%) of each category among all responses combined. The bar charts indicate the frequency (%) of participants that identified each category.*

## Clear Lake Stakeholder Uses, Concerns, and Goals

***Uses --*** The interview results revealed five primary groupings of uses, values, and reasons to enjoy Clear Lake identified by interview participants. The most prominent use category was "Trail Activities" that included biking, lake access, pet exercising, walking/jogging/running, and roller-blading; however, we did not differentiate among these uses in this report. The uses and values reported by at least 25% of those interviewed included:

- Trail Activities (52%),
- Fishing (39%),
- Park Activities (27%),
- Aesthetics (26%), and
- Water Recreation (25%) (Figure 4).

Other noteworthy uses and values included camping, value of the lake as a community asset, residential settings, and swimming. The category of "aesthetics" was interpreted as a value of the view and beauty the lake brings to people's lives while commuting, recreating, or enjoying some quiet time. The "fishing" category included those that indicated shore fishing, boat fishing, and ice fishing. It should be noted that "water recreation" does not include fishing, but collectively includes responses such as boating, personal watercraft use, skiing, and tubing. "Park activities" responses varied from use of play areas and athletic courts/fields, to a place to relax, socialize with friends and family, and sunbathing.

Overall, 132 of the 147 participants (90%) readily identified at least one use and/or value for Clear Lake. It was apparent that the trail is an important factor in connecting local residents with Clear Lake. If the users who only listed trail use were removed from the lake user frequency above, lake use drops from 90% to 62%. Additionally, at least 25 people (17%) indicated they knew very little about Clear Lake before they started using the trail – demonstrating added benefits of the trail.

*Heavy algal blooms, such as the one pictured here, have become common during the summer and fall on Loon Lake. Algal communities, under certain conditions, can include species capable of producing toxins that may be harmful to wildlife, pets, and potentially humans. Algal blooms are the result of nutrient inputs, disrupted vegetation communities, and the presence of sediment-stirring fish species.*

***Concerns*** **--** Overall, citizens readily offered up opinions about perceived problems and were quick to provide feedback about what they didn't like. There were, however, 21 participants (14%) that had no concerns about the current condition of Clear Lake. For those that provided concerns, the challenge was to summarize them into logical categories. For example, 60% of the interview participants identified water quality as an area of concern (Figure 4); however, to the researchers, water quality is about nutrients and suspended sediment. Therefore, we attempted to differentiate water quality from the three of the primary concerns identified as excessive vegetation, odor, and high algal levels (29, 23, and 18%, respectively).

Of the 273 concerns that participants provided, 32% were stated as "water quality" that we again interpreted as nutrient and suspended solids issues (Figure 4). The other individual and noteworthy response categories included excessive vegetation, odor, fishing quality and high algal levels (16, 13, 12, and 10%, respectively; Figure 4). Other concerns noted by participants included swimming safety, water recreation limitations, park conditions and safety, lack of community value, and excessive stormwater (1.5 to 3.7% each) – all of which tie back to the other issues as well.

Four of the top five concerns identified by the public are directly interconnected and contribute to each other; however, it is important to compartmentalize these issues, thereby revealing smaller and possibly more manageable challenges to address. The other concern identified by 22% of the participants was fishing quality (22%). Fishing quality can also be related to water quality, however, there are many other factors that also shape the fishery that are not necessarily tied directly to water quality challenges.

***Goals*** **--** Interview participants were more reserved and cautious about declaring what they thought should be the goals and priorities for the future of Clear Lake. In the end, however, 289 responses regarding potential goals and mission components were provided. As expected, the goals were largely a response to the concerns listed above. Water quality was again provided in a rather generic fashion by 56% of the participants (Figure 4), along with reducing vegetation (31%) and improved fishing (26%) also a high priority to at least 1 of every 4 survey participants. Other goals included finding ways to reduce lake odor, creating more camping options, and reducing algal levels (each making up at least 5% of all responses and identified by 14-16% of the participants).

Compared with uses and concerns, the responses regarding goals were considerably more diverse. Opinions ranged widely about future lake condition, what should be considered the highest priorities, and how we would possibly achieve those goals. There were 18 individuals who stated they had no goals or vision for the future of the lake. Many individuals commented about what they would like to see, but offered the caveat that they did not feel qualified to make decisions about future lake management actions. In addition to the goals and improvement targets listed above, participants also identified safer swimming conditions, increased community value, and aesthetic water recreation, and park improvements (2.1-3.1% each).

Nearly all of the goals identified in this study tie back to a few foundational challenges – nutrients, vegetation, and algae. If these foundational problems can be addressed, many of the other goals will be indirectly satisfied. Breaking each of the foundational issues down into manageable components will be critical to finding success – and using a progressive and methodical approach will require substantial perception management. As with any effort to achieve objectives and reach target goals, an educational component will need to be included in the overall plan.

## Loon Lake Stakeholder Uses, Concerns, and Goals

***Uses --*** The Loon Lake data were dominated by responses that indicated interview participants had little use for, placed limited value on, and/or knew very little about Loon Lake. Of all responses received regarding uses and value for Loon Lake, 63% were categories as "no uses" (Figure 5.) Of the uses that were identified, 16% of participants indicated they used the city park and another 13% appreciated the aesthetics of the area. A few individuals also listed fishing, use of the short trails, and community value. Because many of the participants only provided a single response to each question (N=167 use responses), the overall response frequencies closely align with the number of participants that responded in each category (N=147).

***Concerns --*** Given the lack of use and value placed on Loon Lake by interview participants, we anticipated some predominant concerns would be identified; however, empathy was the general rule, with 77% of the participants representing 68% of all responses indicating they had no concerns about Loon Lake. A majority of those that indicated no concerns also indicated they did not have substantial knowledge about Loon Lake. Given the limits on use by participants, many indicated they have not taken much of an interest in the lake's challenges. The concerns that were voiced were largely similar to those of Clear Lake, with water quality, fishing quality, and odor (16, 6, and 4% of participants, respectively) being the most noteworthy (Figure 5). Several individuals that appeared to be more familiar with Loon Lake also offered up concerns regarding waterfowl feces, lack of recreational access, shallow lake conditions, high algal levels, and trail limitations.

***Goals --*** Following the same patterns as exhibited in the questions regarding uses and concerns, 66% of the participants and 63% of all responses indicated "no goals" for Loon Lake. A common response was again limited use of the lake left participants with limited knowledge of the system and no strong opinions about how the water body should be managed. Of those goals that were identified by participants, improving water quality, improved fishing, reduced odor, and trail improvements had support (13, 7, 4, and 4%, respectively). Also noted by a few participants were the goals of reducing waterfowl presence, improved recreational access, dredging, algal reduction, and enhancing community value.

Like the Clear Lake goals, the few concerns and goals identified for Loon Lake were related to at least a couple of the same foundational challenges – nutrients and algae. Although participants did not extensively connect waterfowl presence with their concerns or goals, it was frequently noted during the discussion of uses. Or when people were unsure of where Loon Lake was located, and I explained to them where it was, the body language and comments about "that place with all the geese" definitely had a negative tone. Overall, if efforts to address the foundational problems of Clear Lake are extended to Loon Lake, the goals would largely be met. With Loon Lake in particular, it appears an educational component will be very important.

### *2.2 Establishment of Plan Goals and Objectives*

#### Community-based Goals

Based on stakeholder input, four generalized goals were identified that would address many of the priority concerns and enhance many, if not all, of the identified uses. The bullets below list the proposed goal statements and the various concerns that each will potentially address. These goals are defined in greater detail after the watershed and lake assessment sections, to include specific progress measures and target goals.

Although there were many potential goals, the following five areas (listed in order of priority based on the areas of greatest concern and use) emerged:

1) **To improve water quality in the Waseca Lakes through both watershed and in-lake management strategies to a level that facilitates safe recreational opportunities and an improved lake experience.**

   Benefitting lake uses/values: All identified uses would benefit.

   Primary concerns addressed: Fishing quality, odor problems, algal levels, swimming safety, water recreation limitations, community value losses, excessive stormwater, nutrients, and erosion.

2) **To explore and implement strategies, including experimental and innovative efforts, to reduce invasive vegetation and algae in the Waseca Lakes.**

   Benefitting lake uses/values: Nearly all of the identified uses/values would benefit from invasive vegetation/algal reductions.

   Primary concerns addressed: Fishing quality, excessive vegetation, algal levels, internal nutrient loading, odor, water recreation limits, and community value limitations.

3) **To identify and implement management options that will enhance fishing opportunities and quality for anglers.**

   Benefitting lake uses/values: fishing, park use, camping, non-motorized recreation, community value, and residential setting.

   Primary concerns addressed: fishing quality, excessive vegetation, water quality, internal nutrient loading, algal levels, carp populations, and shoreland erosion.

4) **To elevate lake value to the community and surrounding region.**

   Benefitting lake uses/values: fishing, park/trail use, non-motorized and motorized water recreation, residential settings, and camping.

   Primary concerns addressed: watershed challenges, water quality, algal levels, and park conditions.

5) **To improve infrastructure, lake access, and recreational opportunities.**

Benefitting lake uses/values: These goals are outside of the scope of this project, however, we list them here and refer these matters to the City for consideration. Nearly all of the uses/values benefit from enhanced access and infrastructure – as it elevates use and awareness (e.g., trail use).

Primary concerns addressed: shoreland erosion, watershed challenges, trail limitations, access, improved community value, and park conditions and safety.

### Lake Improvement Plan Objectives

To further refine the community-based goals listed above, and to compartmentalize those goals into components that have the potential to be managed, we established the following basic objectives for this plan:

1) **Quantify, to the greatest extent possible, the watershed and in-lake nutrient cycles in Clear Lake and Loon Lake.**

2) **Determine if there are applicable standards for water quality standards and numeric targets that provide a foundation on which to establish data-driven goals.**

3) **In consideration of nutrient budget results above, watershed parameters, previous research, and any existing standards, identify nutrient reduction scenarios that would be required for Clear Lake and Loon Lake to meet water quality goals.**

4) **Overview a range of implantation options and/or other management strategies that, with proper scientific foundation, may catalyze improved conditions in Clear and Loon lakes.**

## *2.3 Primer on Nutrient Impairments and Applicable Standards*

### Why are the Waseca Lakes Impaired by Excess Nutrients?

Phosphorus (P) and nitrogen (N) are the primary nutrients that, in excess, pollute our lakes, streams, and wetlands (MPCA 2008). While both N and P are elements of the impaired waters listing, P tends to be the focus for southern Minnesota lakes, as it is nearly always the limiting nutrient. Phosphorus is an essential nutrient for plant and algal growth and development within a lake, as it is necessary for the conversion of sunlight into usable energy for cellular reproduction.

Two types of P are typically monitored, total phosphorus (TP) and orthophosphorus (OP). While OP is the form most readily used by plant life due to its chemical nature, TP values are more easily obtained, can be used to index bio-available P, and are also used in many models to predict lake behavior under different conditions. Nitrogen is also present in several different chemical forms that will influence its availability to plants and algae.

Historical research suggests that total N in lakes, when N:P ratios are less than 16:1, create conditions of N limitation that favor blue-green algae species that have the ability to fix N (Redfield 1958); however, Schindler (2012) indicated that the collective research still indicates P is the over-riding factor.

Changing land use often triggers the release and/or transport of sediment and nutrients from the watershed into surface waters. This process is known as "loading," and when left unchecked, leads to a decrease in water quality caused by suspended materials and algal production. We examine water clarity by measuring total suspended solids (TSS). The levels of TSS increase as the amount of suspended matter, usually algae and soil particles, increases in the water column – resulting in decreased clarity.

Over time, nutrients incorporate into the lake sediments; however, through the process of "internal loading," these materials can again mix with the water column. There are two basic mechanisms that cause P transfer from sediments back into the water column: 1) physical disturbance and 2) anoxia-driven chemical release. Physical disturbance includes bio-turbation, the physical disruption of sediments by animals, wind, and wave action. Chemical P release occurs when oxygen levels are depleted at the sediment-water interface, creating anoxic conditions. In the absence of oxygen, a series of chemical reactions occurs that facilitate the flow of P from the sediment, back into the water column.

Another measure of water quality that is commonly used to assess nutrient impairments is chlorophyll, or more specifically chlorophyll-a (Chl-a), a pigment produced by algae. The Chl-a data can be used to index algae concentrations, as components of several lake assessment tools, as input parameters to model water quality improvements.

Because Clear Lake has experienced substantive loading over the past century, internal loading has also increased. Water quality parameters have been assessed, and because many observed measurements exceeded state water quality standards, the lake was listed as impaired for excess nutrients. Loon Lake, although not officially declared at the time of this study, would meet impaired water criteria if a sufficient number of water quality observations are completed.

### What are the Applicable Minnesota Water Quality Standards?

Water quality standards are important for a variety of reasons; however, the Minnesota Pollution Control Agency (MPCA) cites four specific benefits of having and using standards:

1) Protect beneficial uses, such as healthy fish and plant communities, swimming and other water recreation, and fish consumption,
2) Evaluate monitoring data used to assess the quality of the state's water resources,
3) Identify waters that are polluted/impaired or in need of additional protection, and
4) Set effluent limits/treatment requirements for discharge permits and restoration.

There are many different water quality "standards" that could be applied to the Waseca Lakes, however, at the time of this study, MPCA proposed TP guidelines in conjunction with Carlson's Trophic State Index (TSI) to classify lake quality for aquatic recreation (Carlson 1977; Table 2). Because of regional diversity in lake and watershed characteristics, it was determined that a single TP value could not be adopted as a statewide criterion for lake protection in Minnesota (Heiskary et al. 1987, 2008). Therefore, gradients in TP were identified by ranking and categorizing characteristics, such as depth/lake morphometry, geographic setting, and reference lake conditions for lakes across Minnesota. By using ecoregion data, "natural" lake loading is taken into account, and lake quality is put into perspective based on natural landscape settings, local land use, and loading typical of the region. Clear and Loon lakes are Class “2b” waters, having cool to warmwater habitats that support aquatic life and recreation (Bouchard and Genet 2014).

The TSI is calculated using TP (ppb), Chl-a (ppb) and transparency (e.g., secchi disk). These three parameters are then placed on a set of scales as depicted in Figure 6. Clear Lake, because of its >15-ft maximum depth has a different set of standards compared to shallower Loon Lake (Table 2). The TSI serves as a reasonable, and easy to obtain, measure of progress as we move forward with this plan.

Table 2. Proposed target standards for aquatic recreational use (Class 2b waters) used in the determination of excess nutrients impairment classifications. For the sake of comparison, examples of standards from other ecoregions are included. The three measures include total phosphorous (TP), chlorophyll-a (Chl-a), and secchi transparency. Transparency is in meters (m) and TP and Chl-a are both measured in parts per billion (ppb).

| Ecoregion | TP (ppb) | Chl-a (ppb) | Transparency (m) |
|---|---|---|---|
| Northern Lakes & Forests | <30 | <9 | <2.0 |
| Central Hardwood Forest (>15 ft in depth) | <40 | <14 | >1.4 |
| Central Hardwood Forest (Shallow Lakes) | <60 | <20 | >1.0 |
| *Western Cornbelt Plains and Northern Glaciated Plains (>15 feet depth) | <65 | <22 | >0.9 |
| **Western Cornbelt Plains and Northern Glaciated Plains (Shallow Lakes) | <90 | <30 | >0.7 |

**The ecoregion category, and subsequent water quality standards, for Clear Lake.*
*** The ecoregion category, and subsequent water quality standards, for Loon Lake.*

### Why Use a Trophic State Index?

Indices are often easier to understand and can provide reasonable target values and success measures. Eutrophication is a complex process that links nutrients directly to observations; however, it is often a relationship that is difficult to interpret. The TSI can be used as an overall measure to index the influence of collective actions. The movement of a lake’s trophic status in the desired direction is relatively simple to track and serves as an easy point of reference and a good tool for communicating progress.

The TSI can also be used to generalize lake conditions at any given point in time – both past and present. Table 3 summarizes characteristics often associated with TSI values in a typical Midwest lake. Some characteristics, such as oxygen levels will vary by both latitude and altitude, and thus some traits shift among the TSI categories based on factors outside of TP, Chl-a, and secchi transparency. As a tool for tracking changes in a single lake, however, this chart is often quite accurate – and makes TSI a good tool for tracking trends over time. This information is provided as a point of reference for later discussions.

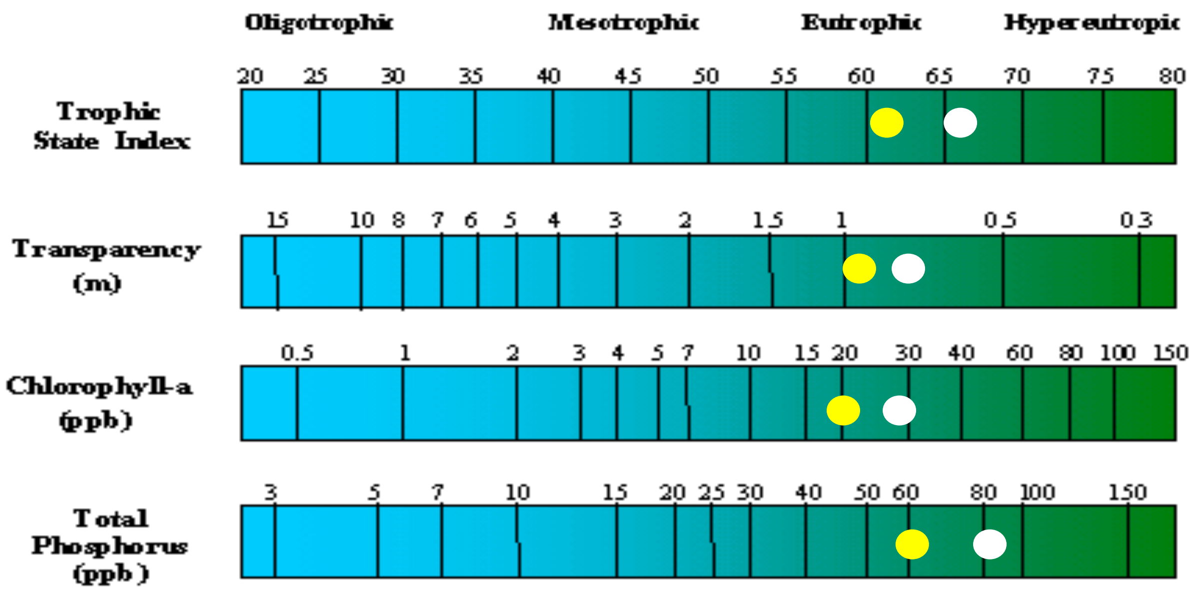



***Figure 6. The total phosphorous, chlorophyll-a, and secchi transparency maximum standards for the Western Cornbelt Plains and Northern Glaciated Plains depicted as part of the Trophic State Index (Carlson 1977). Deep lake standards are shown with yellow circles, and shallow lake standards are represented with white circles.***

Table 3. Common lake traits associated with various Trophic State Index (TSI) values in a north temperate lake. The parameters used to calculate TSI are listed, including total phosphorous (TP), chlorophyll-a (Chl-a), and secchi transparency (ST). Secchi transparency is measured in meters (m) and TP and Chl-a are both measured in parts per billion (ppb).

| TSI | Chl-a (ppb) | ST (m) | TP (ppb) | Attributes |
|---|---|---|---|---|
| **<30** | <0.95 | >8 | <6 | Oligotrophy: Clear water, oxygen throughout the year in the hypolimnion |
| **30-40** | 0.95-2.6 | 8-4 | 6-12 | Hypolimnia of shallower lakes may become anoxic |
| **40-50** | 2.6-7.3 | 4-2 | 12-24 | Mesotrophy: Water moderately clear; increasing probability of hypolimnetic anoxia during summer |
| **50-60** | 7.3-20 | 2-1 | 24-48 | Eutrophy: Anoxic hypolimnia, macrophyte problems possible |
| **60-70** | 20-56 | 0.5-1 | 48-96 | Blue-green algae dominate, algal scums and macrophyte problems |
| **70-80** | 56-155 | 0.25-0.5 | 96-192 | Hypereutrophy: (light limited productivity). Dense algae and macrophytes |
| **>80** | >155 | <0.25 | 192-384 | Algal scums, few macrophytes |

# 3.0 WATERSHED AND LAKE ASSESSMENTS

Clear and Loon Lakes are located in the north-central portion of Waseca County in south-central Minnesota within the Cannon River major watershed. Limnologists have long acknowledged that the watershed-to-lake ratios play a role in lake health. Fraterrigo and Downing (2008), however, documented a range of lake water quality parameters that correlated with watershed characteristics (e.g., soil types, land use, and slopes), but were only partially explained by watershed size. The Waseca Lakes area is located at the transitional point between the hardwood forest and prairie grassland ecotones, and therefore consideration of watershed factors is required.

The various sections below overview the data components utilized in the models and assessments.

## *3.1 Waseca Lakes Watershed Profile*

### Land Use

The Clear Lake watershed is 2,620 acres (25.9% of which is the lake itself). Developed property (39.0%) and row-crop agricultural (18.8%) are the two most predominant land uses (Table 4). A majority of the Clear Lake shoreline is developed (Figure 7). The remaining undeveloped land consists of a small forested area adjacent to Maplewood Park, the wetland acreage represented by Gaiter Lake, and the wetland complex adjacent to Memorial Park. There are also a number of wetlands and restorable wetland depressions throughout the watershed (Figure 8).

The Loon Lake watershed is 459 acres, of which 64.3% is developed land (Figure 7). Loon Lake itself represents about 28% of the watershed acreage (Table 4). Agricultural land uses are present, but represent only about 4.5% of the watershed. Wetlands comprise only 0.5% of the entire Loon Lake watershed and are predominantly small, seasonally flooded depressions (Figure 8).

*The watersheds of Clear and Loon lakes are relatively small; leaving room for optimism that progress can be made towards improving lake conditions. Watershed land use is varied, and is going to require strong collaboration and support among the various stakeholders to see improved water quality.*

Table 4. Land use summary for the watershed of Clear Lake and Loon Lake in Waseca County, Minnesota based on data from National Land Cover Dataset (Fry et al. 2011). The table includes land uses (sorted by category), the total acres present, and the proportion of the land use for each category. In addition, the watershed-to-lake ratios are noted.

| | Clear Lake | | Loon Lake | |
|---|---|---|---|---|
| **Land Use Category** | **Acres** | **%** | **Acres** | **%** |
| Open Water | 678.4 | 25.9 | 128.0 | 27.9 |
| Developed/Low Intensity | 931.6 | 35.6 | 200.4 | 43.7 |
| Developed/Med Intensity | 67.9 | 2.6 | 50.4 | 11.0 |
| Developed/High Intensity | 22.4 | 0.9 | 44.2 | 9.6 |
| Barren/Rock | 4.2 | 0.2 | 0.0 | 0.0 |
| Forest | 90.6 | 3.5 | 11.6 | 2.5 |
| Shrubland/Grassland | 148.6 | 5.7 | 1.1 | 0.2 |
| Hay/Pasture | 23.2 | 0.9 | 0.0 | 0.0 |
| Cultivated Crops | 493.8 | 18.8 | 20.6 | 4.5 |
| Wetlands | 159.5 | 6.1 | 2.3 | 0.5 |
| Total Acres | 2,620.2 | | 458.6 | |
| Watershed:Lake Surface Area Ratio | | 2.9:1 | | 2.6:1 |

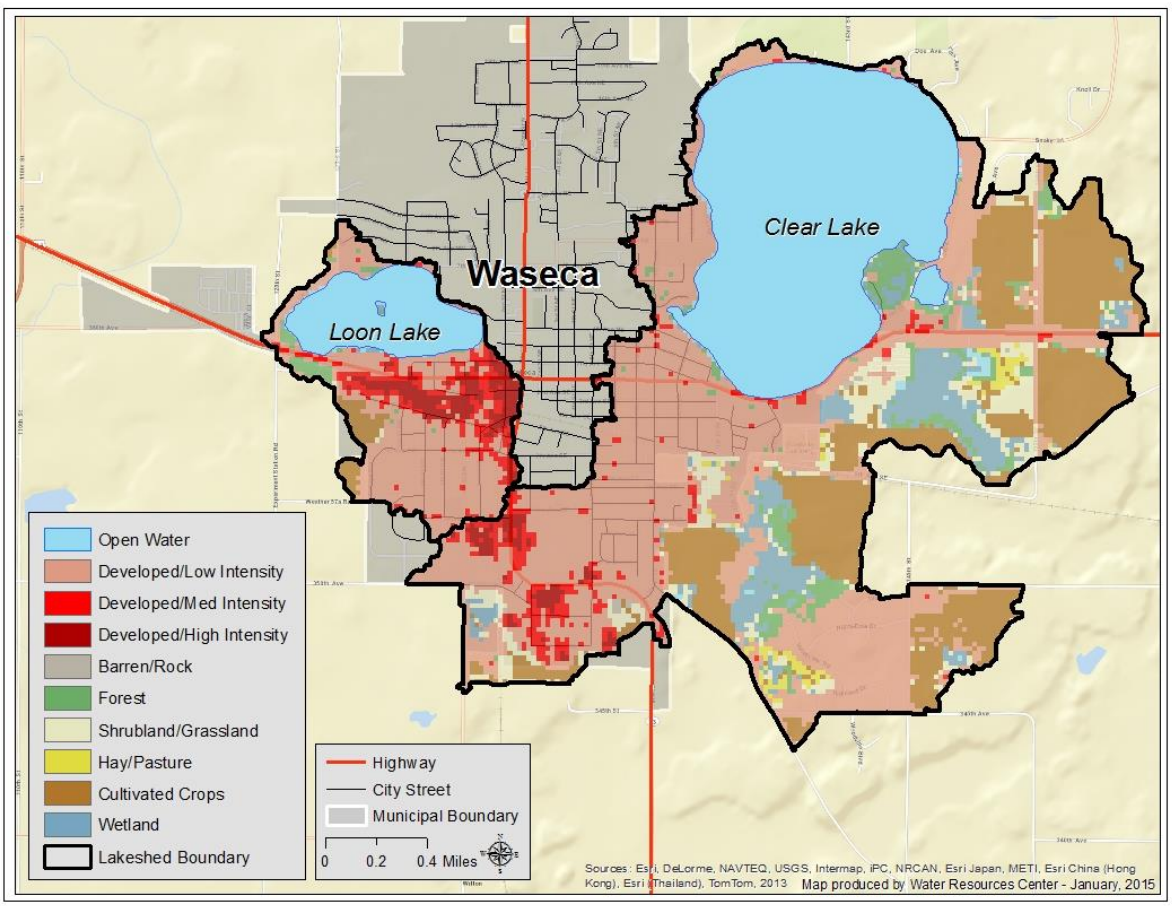



***Figure 7. Depictions of land use for the Loon Lake and Clear Lake watersheds in Waseca County, Minnesota. Lakeshed boundaries are outlined with a solid black line. Land use data are from Fry et al. (2011).***

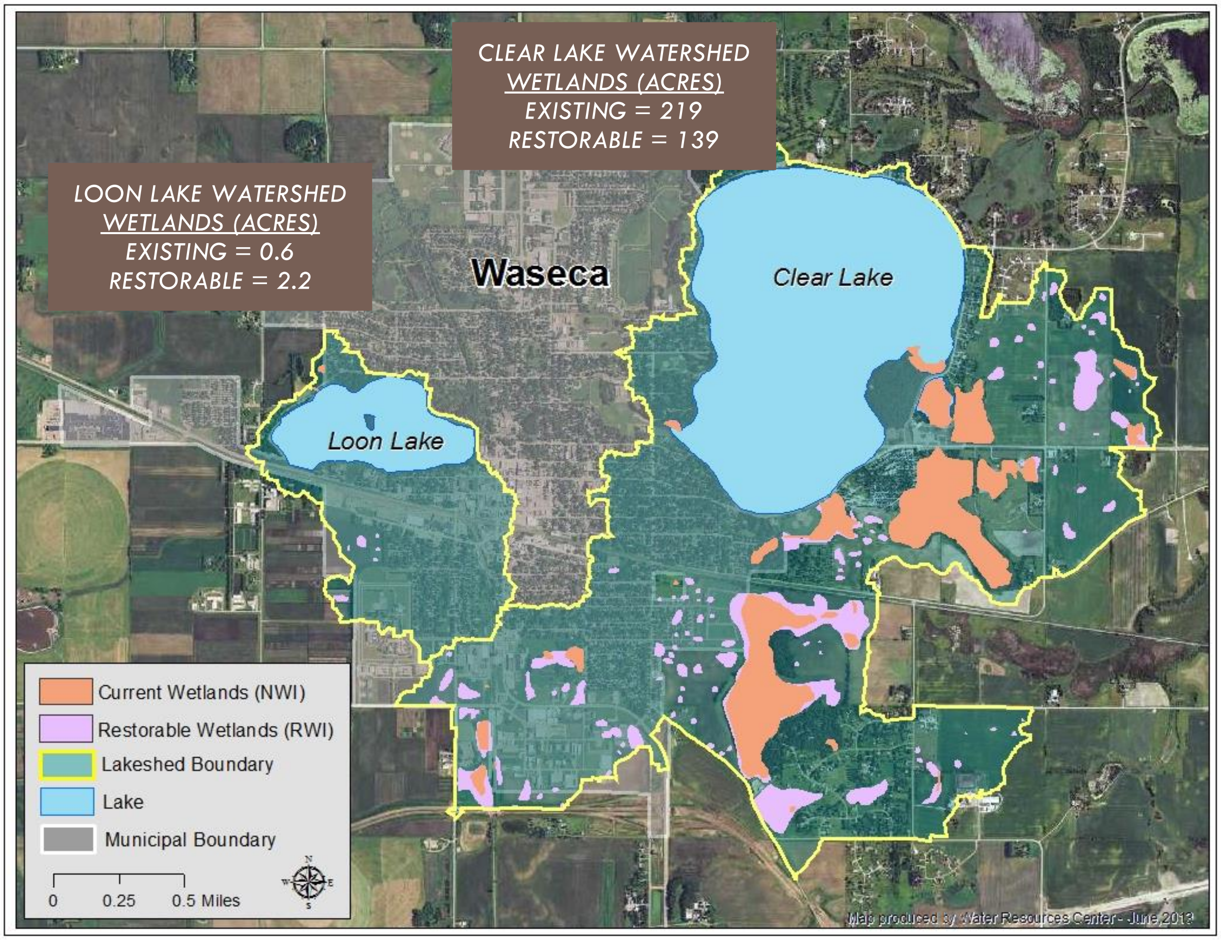



***Figure 8. Existing and potentially restorable wetland locations within the Loon Lake and Clear Lake watersheds in Waseca County, Minnesota (USFWS 2013). Lakeshed boundaries are outlined with a solid yellow line. The inset notes total existing and restorable wetlands in each watershed.***

## Geography, Geology, and Soils

A majority of the Waseca Lakes area lies within a Galena-Decorah-Platteville formation. The majority of the bedrock lies within the Galena stratum with the exception of the extreme northeastern portion of the watershed that is a mix of Decorah and Platteville strata (Figure 9). The formations present under the Waseca Lakes are all limestone based, and collectively may be more than 250 ft thick (USGS 2011). Limestone is a great buffer for acidic water conditions; however, acidification does not appear to be an area of concern for the Waseca Lakes and due to thick layers of glacial till (see soils section below), would not interact with surface waters.

The highest elevation within the Clear Lake watershed is 364 m (1,195 ft) above sea level and the lowest elevation is 341 m (1,119 ft). The elevation change of 76 ft in the Clear Lake watershed is significant in a watershed of this size. Depending on the location of the high points to the low points, there is likely enough slope to move water via surface run-off at a rapid pace. NRCS (2003) noted that the region is considered a level to rolling topography that forms circular and coalescing flat-topped hills with subdued relief with common depressions filled with organic deposits.

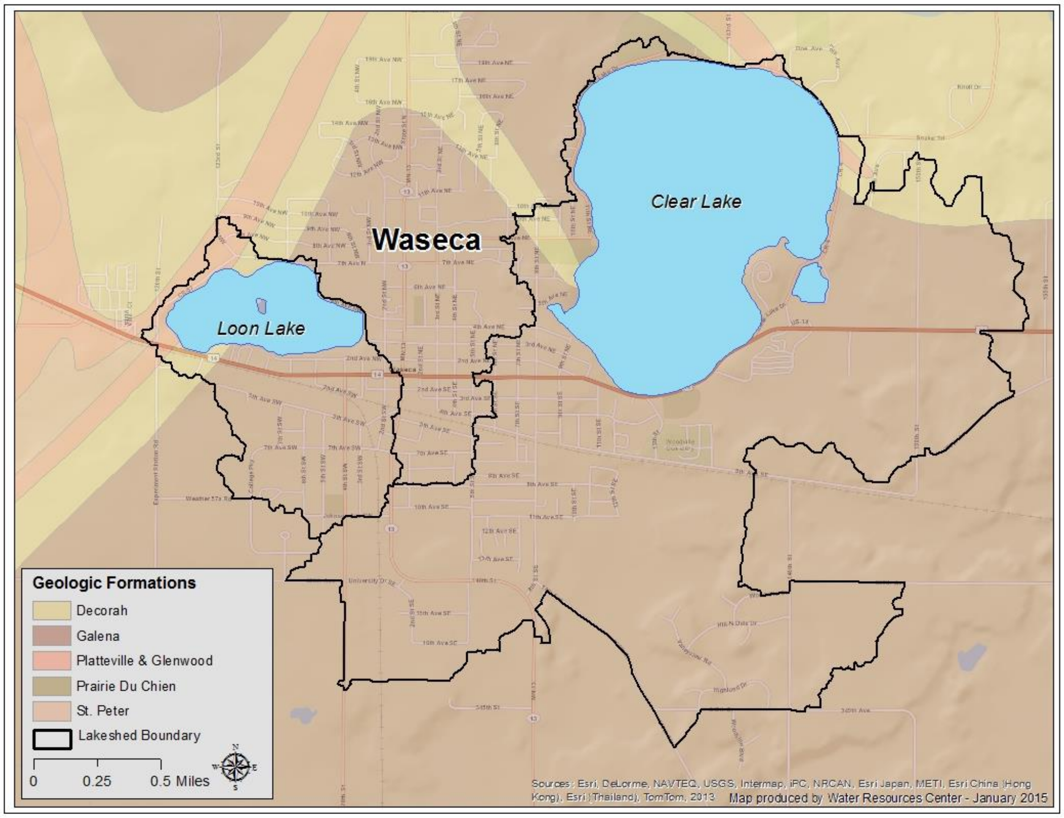



***Figure 9. Geologic formations found under Loon and Clear Lake watersheds in Waseca County, Minnesota (USGS 2011). Lakeshed boundaries are outlined with a solid black line.***

The highest elevations in the Loon lake watershed occur along the southwestern portion of the watershed at 355 m (1,165 ft) above sea level. The watershed slopes downwards to the north and east with the lowest elevations occurring at the surface of Loon Lake at 346 m (1,135 ft). Although the total drop in elevation is only 30 ft, the slope would be considered relatively substantial given the small size of the watershed.

The Waseca Lakes watersheds include five soil orders: 1) Alfisols, 2) Histosols, 3) Entisols, 4) Inceptisols and 5) Mollisols (Figure 10). It is important to place watershed behaviors into the context of soils. Soil productivity, drainage potential, and erosiveness can all play substantial roles in watershed processes and impact restoration efforts. A brief overview of the soil orders is summarized in Appendix D if more information is needed.

A soil orders breakdown reveals areas of Kilkenny and Le Sueur clay loams that are deep, rich, dark soils with moderate to poor natural drainage. Portions of the Clear Lake watershed are dominated by peat/muck soils and Dundas silt loams, particularly around Gaiter Lake, that are also characterized as deep, poorly drained soils. Eastern watershed portions hold fibric soils associated with the wetland complex adjacent to Maplewood Park. Where elevations rise in the watershed, Lester clay loams form the dominant matrix with interspersed areas of Kilkenny and Le Sueur clay loams. Lester clay loams are well drained, but are often surrounded by other loams that hold water. The Loon Lake watershed is largely Webster and Le Sueur clay loams, both of which are typically deep, rich, and poorly drained. (USDA 2011).

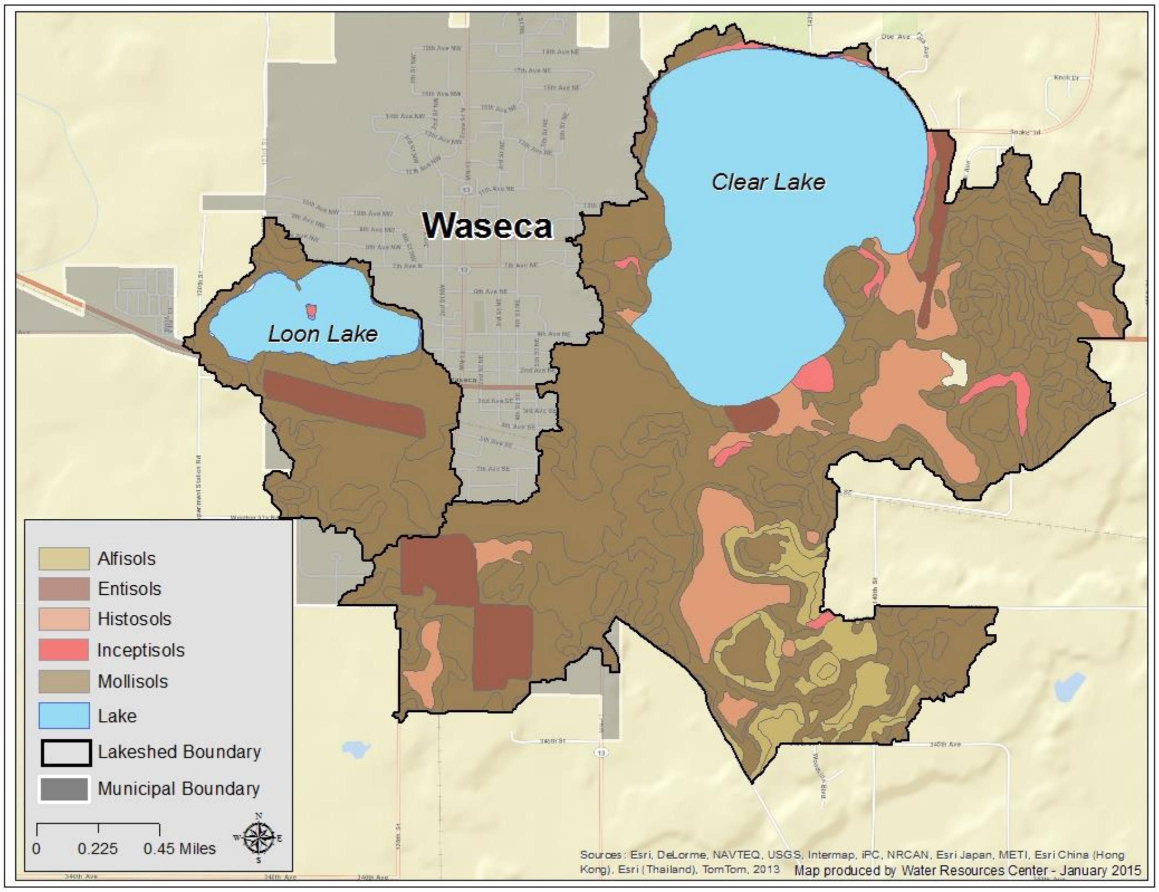



***Figure 10. Soil orders located in the watersheds for Loon Lake and Clear Lake in Waseca County, Minnesota. Lakeshed boundaries are outlined with a solid black line. Soils data were secured from Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey.*** http://websoilsurvey.nrcs.usda.gov/

## Watershed Drainage

Surface water drainage through open ditches is relatively minimal in the Waseca Lakes watersheds. Two primary ditch systems are present in the Clear Lake watershed, and no substantial open ditches are located in the Loon Lake watershed (Figure 11). Figure 11 represents our current knowledge of tile drainage within the watershed; however, subsurface tile networks are very difficult to delineate.

Tile drainage from agricultural production areas appears to be limited to a small portion of land within the northeastern portion of the Clear Lake watershed (Figure 11). These tile systems drain relatively small depressions in the landscape; however, all potential contributors of nutrient inputs to Clear Lake were considered. In addition, there is substantial stormwater drainage from the developed curb-and-gutter areas, much of which diverts to Gaiter Lake from the City of Waseca.

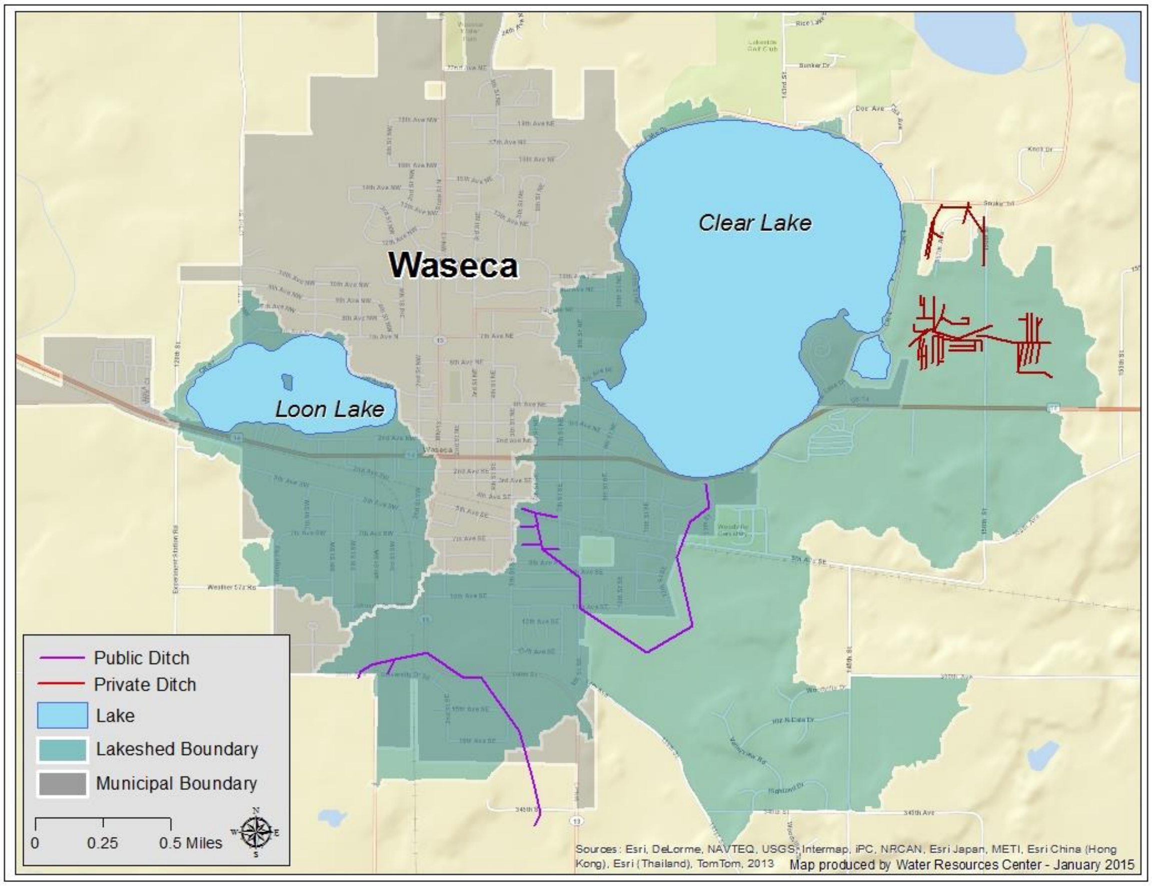



***Figure 11. Tile and open ditch drainages within the Clear Lake and Loon Lake watersheds in Waseca County, Minnesota. Lakeshed boundaries are outlined with a solid black line. Ditch systems were identified using USGS maps and the tile lines were derived from unpublished data from Waseca County and NRCS.***

## Terrain Analyses

A 1-m Digital Elevation Model (DEM) was used to calculate flow direction, flow accumulation, stream power index, and the Compound Topographic Index (CTI) within the watersheds of Clear and Loon Lakes. A CTI is a measurement of the potential wetness of a given portion of a landscape. The areas with CTI values >11.5 are often evaluated as options for green infrastructure and/or best management practice approaches to improve water storage and quality management.

The areas with CTI values greater than 11.5 were mapped using a point for the central location of each (Figure 12). Each point, therefore, represents a given portion of the landscape that may be worthy of evaluation for water quality improvement projects. We overlaid these points on the areas of poorly drained soils (*i.e.*, natural soil and surface water storage areas; Figure 12). We also attempted to overlay the CTI points on areas of well-drained soils to potentially identify areas where infiltration rates would be higher; however, all of the CTI scores of interest were in the poorly drained soil areas.

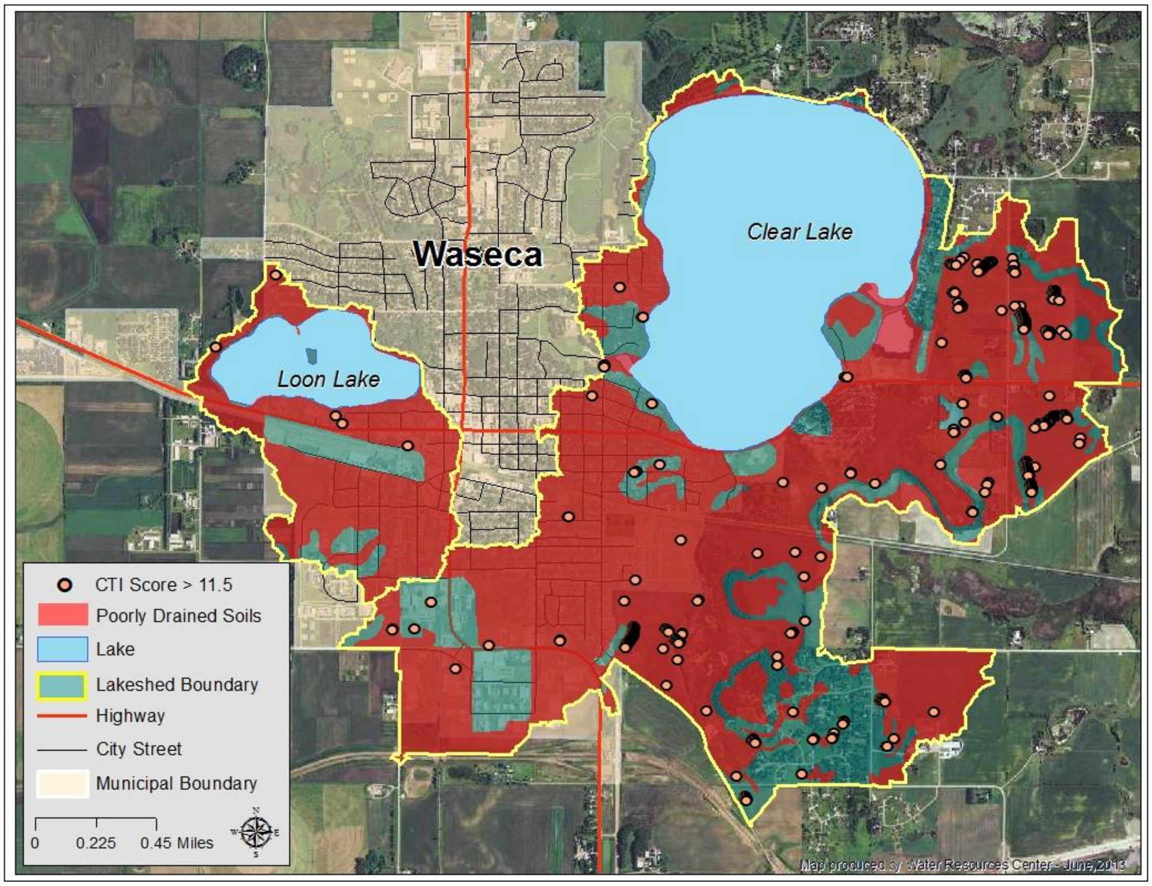



***Figure 12. Central locations of landscape areas with Compound Topographic Index (CTI) scores >11.5. In addition, the areas classified as "poorly drained soils" are also identified in the Loon Lake and Clear Lake watersheds in Waseca County, Minnesota. Lakeshed boundaries are outlined with a solid yellow line. Soils data were secured from Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [09/18/2014].***

## Climactic Factors

Climatological data needed for the models were obtained from the University of Minnesota Southern Research and Outreach Center (UMSROC 2011). Over the period of 1971 to 2000 (a period of interest due to lake eutrophication occurring), the average daily maximum and minimum ambient temperatures were 53.9°F (12.2°C) and 33.8°F (1.0°C). On average, January was the coldest month and July the warmest (Table 5).

Over the past 30 years, Waseca County has received an average of 34.7 fluid inches of precipitation per year with the majority falling between May and August (Table 5; UMSROC 2011). The precipitation includes an average of 55 inches of snow, with at least 1 inch of snow falling 19 days out of the year (UMSROC 2011). Surprisingly, August has historically been the wettest month for Waseca County (in terms of the average fluid precipitation), with February historically having the lowest levels of precipitation.

In 2011, there was a total of 29.9 inches of precipitation; 4.8 inches less than the historic mean precipitation for the area. The total amount of precipitation during the first half of 2011 exceeded historic mean precipitation levels; however, precipitation for the second half of 2011 was well below the historic means (Table 5). The precipitation patterns during the intensive monitoring associated with this study (July 2011 through June 2012) were not typical of the area, and must be taken into consideration. Discharge into and out of Clear Lake was moderately high during the first half of 2011, and exhibited little to no flow during the second half of the year.

Table 5. Average daily maximum/minimum temperatures (°F) and average precipitation (Precip.; inches) by month for Waseca County, Minnesota 1971-2000 (UMSROC 2011). Table also includes precipitation data for 2011 and 2012 and the departures from normal. Data in bold represent the time period in which intensive surface water sampling was conducted.

| Month | Avg. Max Temp | Avg. Min. Temp | Avg. Precip. | 2011 Precip. | 2011-Avg. Comparison | 2012 Precip. | 2012-Avg. Comparison |
|---|---|---|---|---|---|---|---|
| **January** | 20.5 | 1.4 | 1.38 | 1.06 | -0.32 | **0.79** | **-0.59** |
| **February** | 26.9 | 8.9 | 0.95 | 1.36 | 0.41 | **2.29** | **1.34** |
| **March** | 38.8 | 21.8 | 2.49 | 2.16 | -0.33 | **1.93** | **-0.56** |
| **April** | 55.1 | 34.6 | 3.23 | 4.46 | 1.23 | **3.08** | **-0.15** |
| **May** | 69.5 | 47.3 | 3.96 | 4.67 | 0.71 | **5.74** | **1.78** |
| **June** | 78.7 | 56.8 | 4.19 | 5.19 | 1.00 | **4.25** | **0.06** |
| **July** | 81.9 | 60.6 | 4.47 | **7.21** | **2.74** | **2.1** | **-2.37** |
| **August** | 79.5 | 58.3 | 4.64 | **0.92** | **-3.72** | 1.45 | -3.19 |
| **September** | 71.9 | 48.5 | 3.19 | **0.81** | **-2.38** | 0.27 | -2.92 |
| **October** | 59.0 | 36.4 | 2.50 | **0.44** | **-2.06** | 1.38 | -1.12 |
| **November** | 39.8 | 23.0 | 2.32 | **0.30** | **-2.02** | 0.64 | -1.68 |
| **December** | 25.3 | 8.2 | 1.40 | **1.34** | **-0.06** | 1.76 | 0.36 |
| **Totals** | | | 34.72 | 29.92 | -4.80 | 25.68 | -9.04 |

### *3.2 Subshed Identification*

#### Clear Lake

The Clear Lake watershed was divided into subwatersheds (hereafter referred to as subsheds) based on hydrogeology of the landscape (Figure 13). Hydrogeologic division of the watershed provides a basis on which to evaluate subshed contributions to Clear Lakes. Therefore, we can identify areas of the watershed that may be disproportionately contributing nutrient, sediment, and other potential pollutants to Clear Lake. As a result of subshed identification, three areas (2, 3, and 4) have relatively defined drainage networks with single primary pour-points that could be monitored. A review of previous Clear Lake research indicates that these three areas have historically contributed the greatest amount of flow and nutrients to Clear Lake.

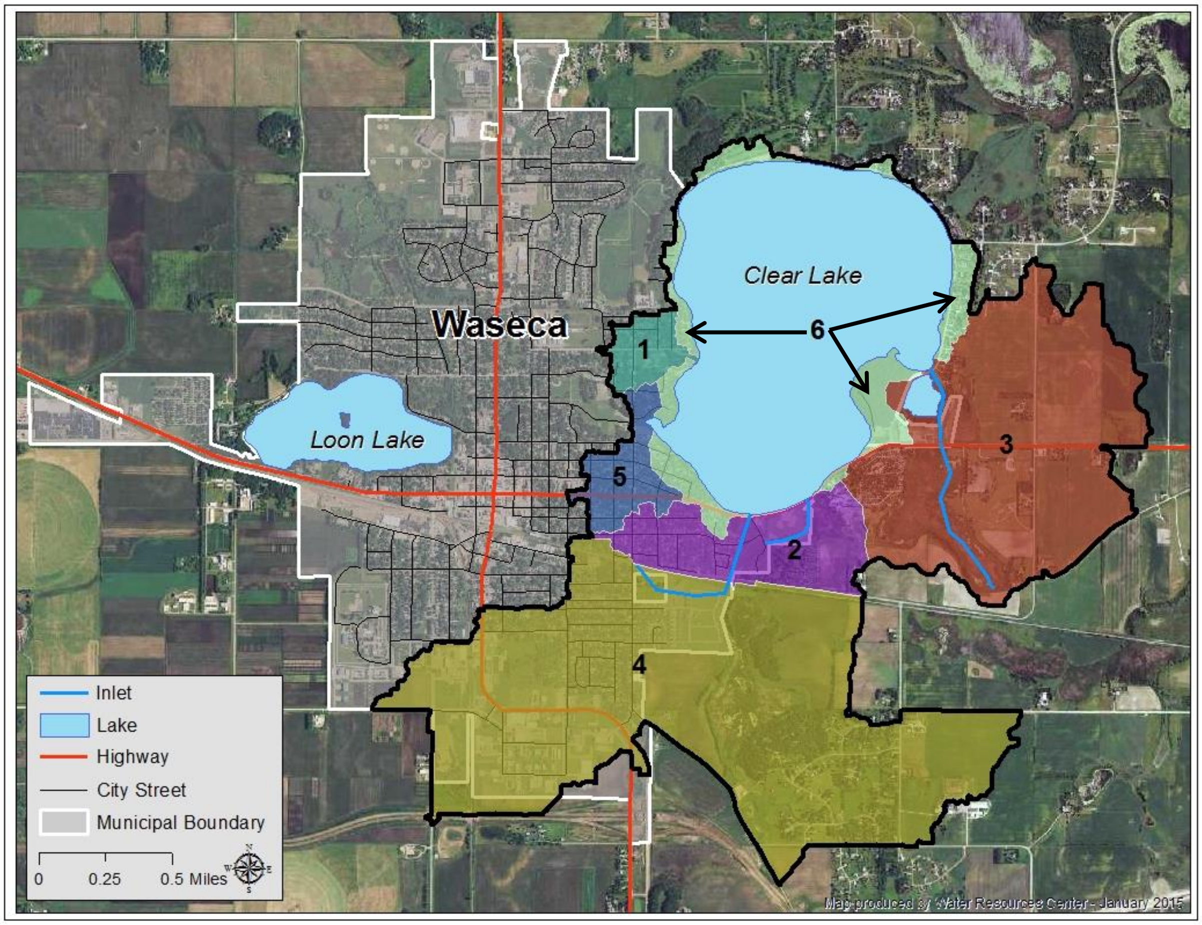



***Figure 13. Subsheds of Clear Lake in Waseca County, Minnesota. The lakeshed boundary is outlined with a solid black line and each color represents a hydrogeologic subshed unit (also numbered 1-6). Data used to identify subsheds included USGS maps and unpublished data from the City of Waseca regarding the existing stormwater system (changes the historical boundaries).***

Three additional subsheds were identified (1, 5, and 6) that have poorly-defined drainage concentrations and/or are highly ephemeral could not be monitored directly (Figure 13). Subshed 6 includes all of the overland flow areas adjacent to the lake that do not drain elsewhere. Nutrient loading from these non-monitored subsheds was estimated using a water quality modeling program referred to as BATHTUB. BATHTUB assigns runoff coefficients to the various land uses within the non-monitored subsheds. The coefficients are then used to estimate loading and can be considered in conjunction with the monitored subsheds to complete the overall Clear Lake evaluation.

Although our nutrient and sediment analyses are for the entire Clear Lake watershed, breaking down the various watershed components, such as land use, by subshed is critical. For example, 18.2% of subshed 3 is classified as developed compared to subsheds 1 and 5 that are more than 90% developed (Table 6). A comparison of nutrient loading data among the subsheds can provide significant insight into pollutant sources and facilitate the targeting and prioritization of watershed improvement options.

Table 6. Land use summary for the subsheds (1-6) for Clear Lake in Waseca County, Minnesota based on data from Fry et al. (2011). The table includes the total acres in each subshed, land uses (sorted by category), and the proportion of the land use for each category (%).

| *Clear Lake Subsheds→ | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Subshed Acres→ | 42.4 | 160.4 | 568.8 | 981.3 | 65.5 | 137.6 |
| Land Use Category | *Proportions of Subshed in each Land Use Category (%)* | | | | | |
| Open Water | 0.3 | 0.1 | 1.0 | 0.2 | 0.0 | 4.7 |
| Developed/Low Intensity | 95.2 | 71.4 | 17.5 | 52.8 | 92.6 | 71.9 |
| Developed/Med Intensity | 2.4 | 1.4 | 0.7 | 5.3 | 5.1 | 3.6 |
| Developed/High Intensity | 0.1 | 0.0 | 0.0 | 2.3 | 0.0 | 0.0 |
| Barren/Rock | 0.0 | 0.7 | 0.1 | 0.3 | 0.0 | 0.0 |
| Forest | 2.0 | 0.7 | 6.4 | 3.1 | 2.2 | 14.5 |
| Shrubland/Grassland | 0.0 | 8.6 | 12.5 | 6.3 | 0.1 | 1.1 |
| Hay/Pasture | 0.0 | 0.5 | 1.7 | 1.3 | 0.0 | 0.0 |
| Cultivated Crops | 0.0 | 11.9 | 46.0 | 21.7 | 0.0 | 0.0 |
| Wetlands | 0.0 | 4.7 | 14.1 | 6.7 | 0.0 | 4.2 |

*See Figure 13 for subshed boundaries.

## Loon Lake

The Loon Lake watershed was also divided into subsheds using the same approach as for Clear Lake (Figure 14). Unlike the Clear Lake assessment, no direct monitoring could be completed at any specific pour-points. Therefore, all 6 subsheds were assessed using the BATHTUB model as indicated above. Subshed land use varied, but less starkly than Clear Lake (Table 7).

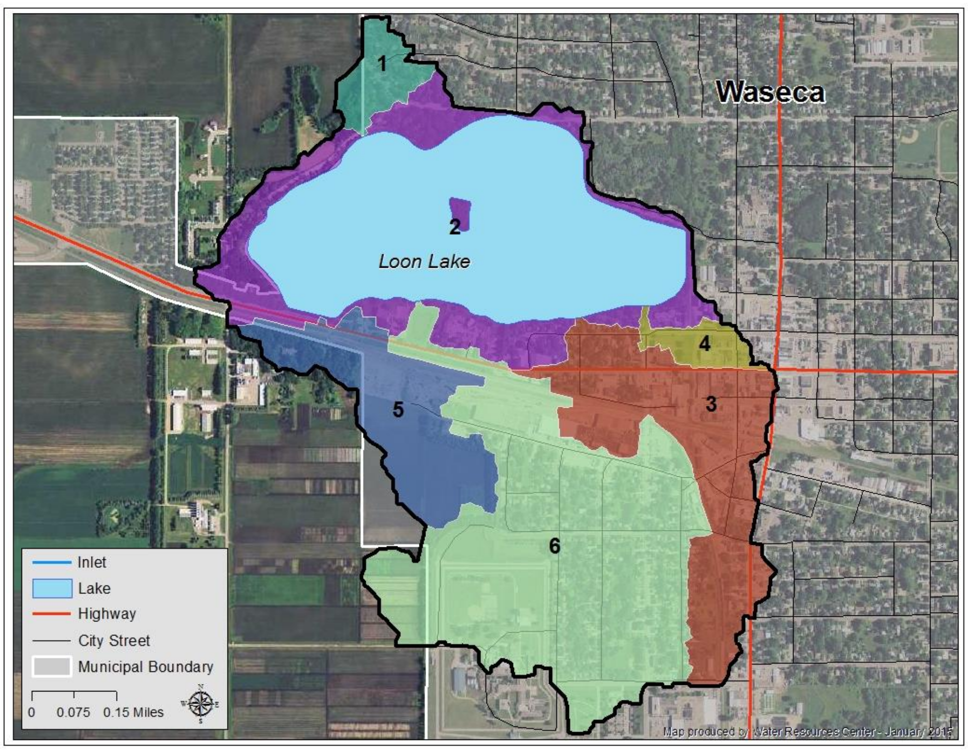



*Figure 14. Loon Lake subsheds in Waseca County, Minnesota. The lakeshed boundary is outlined (solid black line) and each color represents a hydrogeologic subshed unit (numbered 1-6). Data used to identify subsheds included USGS maps and unpublished data from the City of Waseca regarding the stormwater system (changes the historical boundaries).*

Table 7. Land use summary for the subsheds (1-6) for Loon Lake in Waseca County, Minnesota based on data from Fry et al. (2011). The table includes the total acres in each subshed, land uses (sorted by category), and the proportion of the land use for each category (%).

| *Loon Lake Subsheds→ | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Subshed Acres→ | 12.1 | 52.4 | 69.6 | 8.2 | 44.7 | 146.1 |
| <u>Land Use Category</u> | *Proportions of Subshed in each Land Use Category (%)* | | | | | |
| Open Water | 0.0 | 4.1 | 0.0 | 0.0 | 0.2 | 0.1 |
| Developed/Low Intensity | 84.7 | 68.1 | 37.5 | 24.4 | 33.2 | 76.3 |
| Developed/Med Intensity | 0.1 | 13.8 | 26.0 | 33.8 | 14.6 | 10.9 |
| Developed/High Intensity | 0.0 | 2.6 | 36.4 | 40.6 | 6.5 | 7.8 |
| Barren/Rock | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Forest | 5.5 | 7.7 | 0.0 | 1.2 | 14.3 | 0.3 |
| Shrubland/Grassland | 0.2 | 0.0 | 0.0 | 0.0 | 2.3 | 0.0 |
| Hay/Pasture | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Cultivated Crops | 9.5 | 0.0 | 0.0 | 0.0 | 28.8 | 4.5 |
| Wetlands | 0.8 | 3.7 | 0.1 | 0.0 | 0.1 | 0.1 |

*See Figure 14 for subshed boundaries.

### *3.3 Lake Bathymetry*

Clear Lake has a maximum depth of 34 ft, making it moderately deep relative to other regional lakes (Figure 15). Lake volume does play a role in nutrient cycles and assessment models. The northern half of Clear Lake remains considerably deeper than the southern half. The littoral area of Clear Lake (area of lake less than 15 ft deep) is approximately 448 acres (70% of the lake by area). Lakes that have a large littoral zone are more likely to experience mixing of sediments via wind and wave action in comparison to lakes with a small littoral zone (Sondergaard et al. 2003).

Loon Lake is a classic "shallow lake" with a maximum depth of less than 15 ft (Figure 16). The state of Minnesota has a separate set of water quality standards for shallow lakes. Shallow water bodies are naturally more eutrophic than deep lakes. The shallow morphometry of the Loon Lake basin makes it prone to re-suspension of sediments via wind and wave action. Because of a limited depth profile and wind-based mixing of the water profile, stratification in shallow lakes is rare; however, Loon Lake was occasionally stratified during sampling events in 2011 and 2012. Stratification was limited to deeper locations and limited in duration.

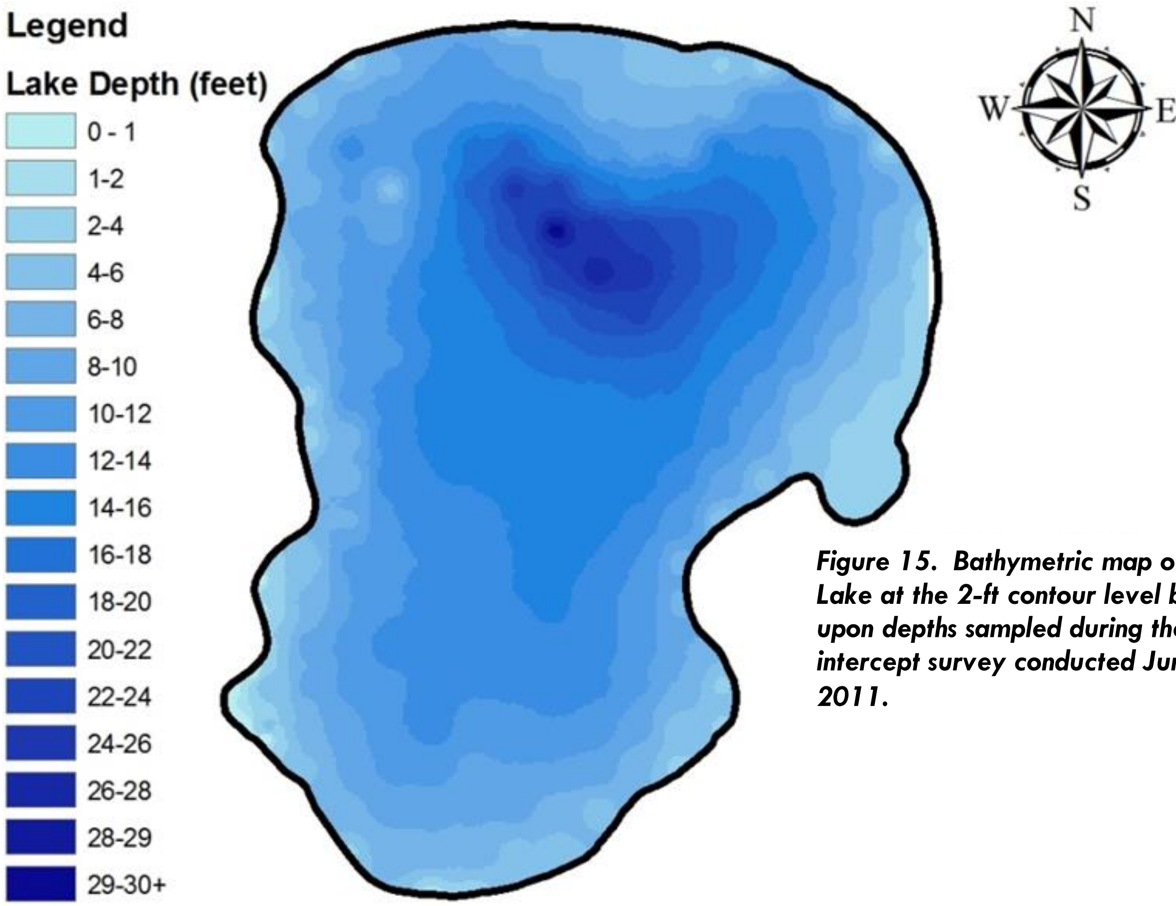



*Figure 15. Bathymetric map of Clear Lake at the 2-ft contour level based upon depths sampled during the point-intercept survey conducted June 1-2, 2011.*

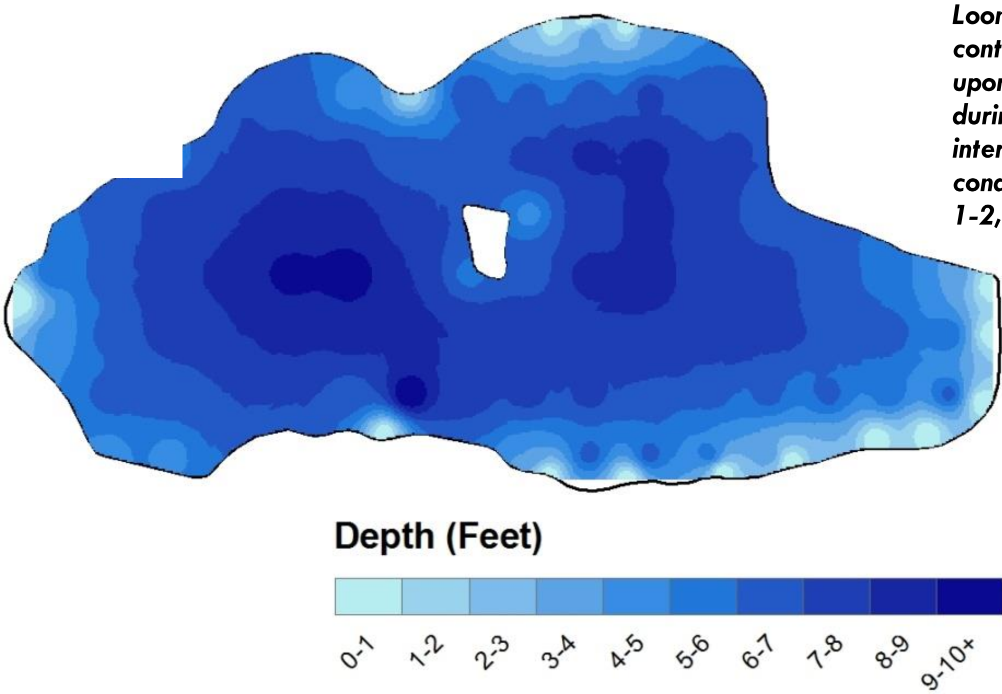



*Figure 16. Bathymetric map of Loon Lake at the 1-ft contour level based upon depth sampled during the point-intercept study conducted on June 1-2, 2011.*

### *3.4 Fisheries Community Review*

#### Clear Lake

A 2010 fish survey completed by the MDNR indicated high catch rates of black crappie (*Pomoxis nigromaculatus*) and bluegill (*Lepomis macrochirus*) that exceeded the normal range for lakes with similar physical and chemical characteristics (*i.e.*, lake class). As is common for high density panfish, particularly in lakes with heavy vegetation, the size structure for these species was poor. Small abundant bluegill have been common (Figure 17). Northern pike (*Esox lucius*) have been stocked over the past decade and were found to be moderately abundant, with some individuals exceeding 30 in.

Twenty-three walleyes were captured during the 2010 survey, with several of these fish exceeding 20 in. Largemouth bass (*Micropterus salmoides*) are generally not sampled effectively with the MDNR fish survey nets; however, twenty-three largemouth bass were still sampled with several approaching 20 in. The largemouth bass population has been protected by a catch-and-release-only regulation and there is an ample supply of prey. As noted above, Clear Lake has consistently supported an overabundance of panfish that exhibit "stunted" or slow-growing characteristics. High density panfish impact zooplankton communities and inhibit algae consumptions by *Daphnia* spp.

Common carp (*Cyprinus carpio*) and black bullhead (*Ameiurus melas*) represent the dominant "rough" species in the lake and large common carp are caught by anglers. Carp and bullheads are often central to management efforts of eutrophic lakes, as the two species are notorious culprits in sediment disturbance and nutrient re-suspension. Following massive increases in carp and bullhead populations, fisheries reclamation projects were completed in Clear Lake in 1963 and 1987. The 1963 reclamation was very short-lived; however, the 1987 attempt appears to be persisting. A generalized look, however, would suggest that carp and bullheads are not a significant component of the fish community; however, sampling gears may bias results due to species-specific behaviors and the effectiveness of each gear type (Figure 17).

#### Loon Lake

In 2009, northern pike were sampled in moderate abundance with an average length of 25 inches. Black crappies and bluegills were in high abundance in 2009; however, the size structure was extremely poor. Three walleyes were captured during the 2009 survey despite no record of walleyes ever being stocked. These walleyes were likely introduced by private citizens.

A survey was completed in April, 2010 by the MDNR following a winterkill event. According to the MDNR, the aeration equipment in place prior to 2010 was not sufficient to prevent anoxic conditions from forming, and as a result, the fishery was dominated by black bullheads (Figure 18). The 2010 survey resulted in the capture of more than 400 black bullhead, and only 3 yellow perch and 2 bluegill – no other species were sampled.

Fish community imbalance inhibits management efforts. Therefore, the MDNR decided to reclaim the lake – an effort that was completed during the same time period as this evaluation. A natural compound that kills fish (rotenone) was used in an attempt to remove the fish community. The lake was then stocked with largemouth bass and bluegill. The MDNR continues to monitor the success of this most recent rehabilitation effort; however, early test netting indicates that the bullhead population was not effectively removed and is proliferating rapidly in the lake.

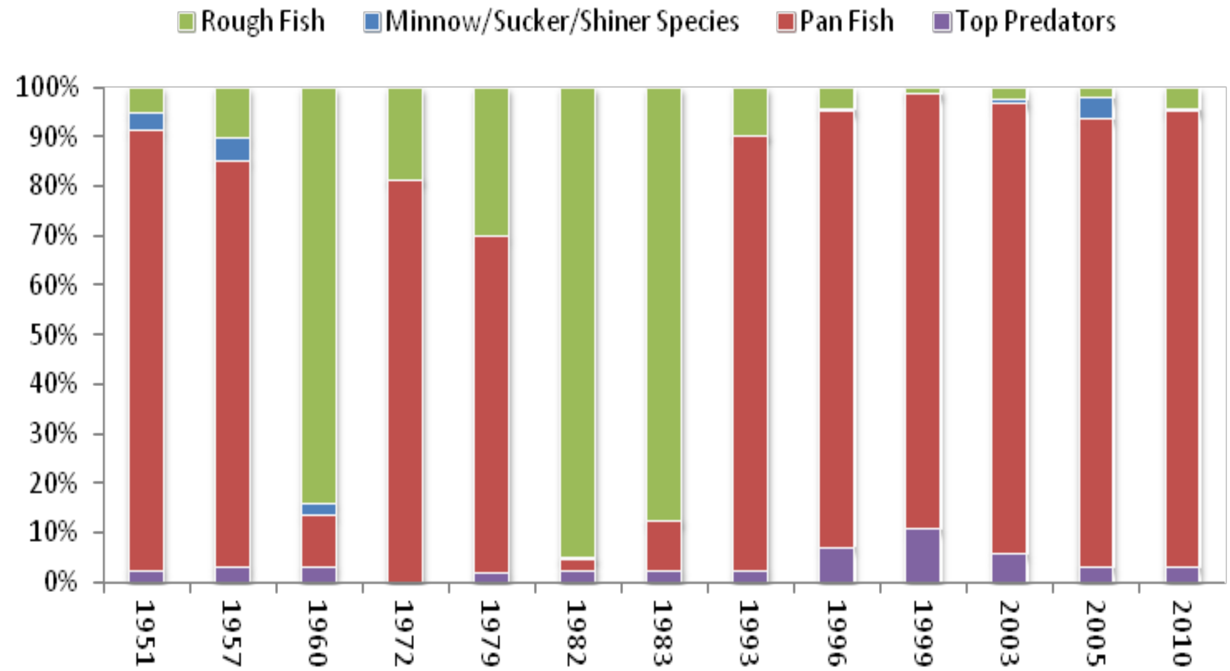



***Figure 17. The approximate proportions of several fish categories in Clear Lake, Waseca County from 1951 to 2010. Fisheries data collected by the MDNR during various years as part of their lake/fish survey program. Data were summarized into generalized categories of rough fish (carp and bullheads), minnow/sucker/shiner species, panfish (bluegills, crappies, and perch), and top predators (walleye, northern pike, largemouth bass).***

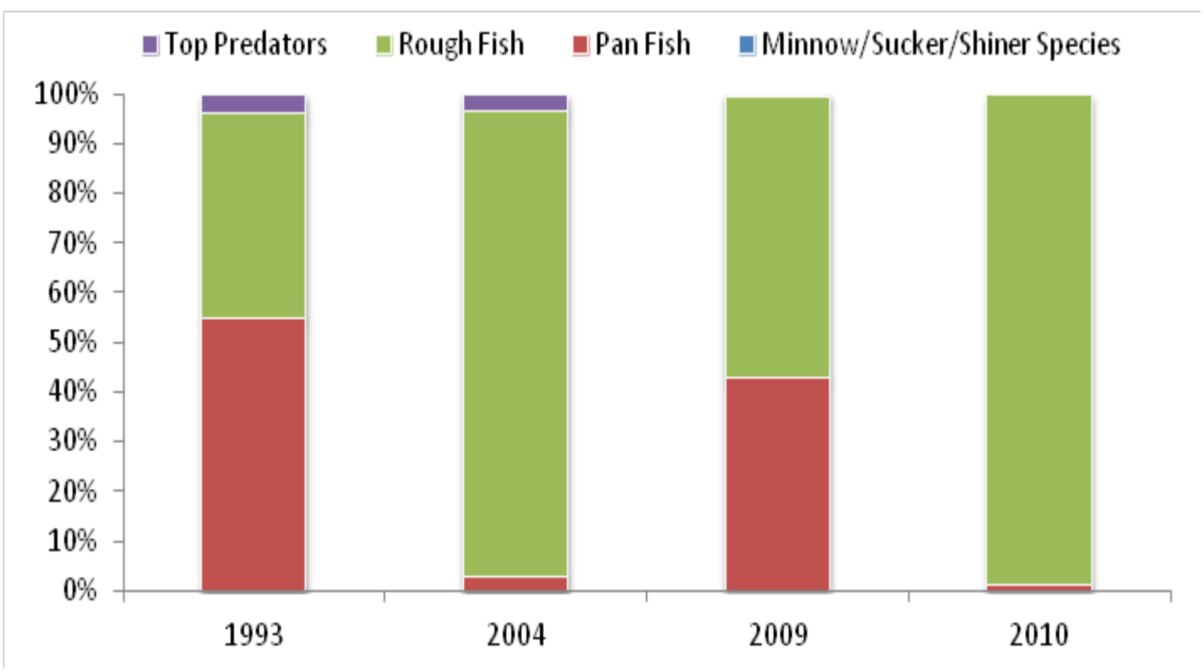



***Figure 18. The approximate proportions of several fish categories in Loon Lake, Waseca County from 1993 to 2010. Fisheries data collected by the MDNR during various years as part of their lake/fish survey program. Data were summarized into generalized categories of rough fish (carp and bullheads), minnow/sucker/shiner species, panfish (bluegills, crappies, and perch), and top predators (walleye, northern pike, largemouth bass).***

### 3.5 Vegetation Surveys

Because vegetation is a major component of the nutrient cycle in lakes, we needed to gain an understanding of the aquatic macrophyte community present in both Clear and Loon Lakes. We used the point-intercept survey method (Madsen 1999). The point-intercept technique uses GIS software to generate a series of random, equally spaced points from 75 to 100 m apart, depending on lake size. Macrophytes were sampled using the "rake method" detailed by UWSP Protocol (Appendix E). Two aquatic plant identification keys were primarily used to increase the accuracy of species identification (Borman et al. 1997, Eggers and Reed 1997).

Vegetation data were summarized as frequency of occurrence (FO; percent of sites sampled that contained each species) and by mean rake rank (where possible) as a relative indicator of density. A mean rake rank of 4 would indicate extremely dense vegetation, whereas, a rake rank of 1 indicates presence, but in sparse quantities. Data were also used to calculate a floristic quality index (FQI) for each lake. The FQI is a measure of the diversity and quality of plants within a defined area and is used as an index to assess the extent of disturbance from a natural condition, and/or the extent of remaining natural value within a water body (Rocchio 2007). The FQI can also be used as a measure of progress as management tactics are implemented – such as assessing the success of a restoration effort or setting goals based on reference lake scores. The FQI has also been utilized as a criterion on aquatic plant management permits (Swink and Wilhem 1994).

#### Floristic Quality Index (FQI)

The FQI calculations are based on a coefficient of conservatism value (C-value) that has been assigned to each aquatic plant species and ranges in value from 0 to 10. The C-value of all macrophytes sampled from a lake is used to determine the FQI for a given lake. Species with a C-value of 0 include invasives, exotics, and those tolerant of highly disturbed environments, such as CLP and EWM. In contrast, a native, but uncommon species such as Oakes pondweed (*Potamogeton oakesainus*) has a C-value of 10. Therefore, it is important that all species present be identified and included in the assessment. The basic calculation for FQI is

$$FQI = (\text{mean C-value})(\sqrt{N_s}),$$

where C-value = coefficient of conservatism and $N_s$ = number of species found.

An FQI score of <20 is indicative of a disturbed environment with limited natural plant community presence (Taft et al. 1997). Nichols (1999) noted that scores of 1-19 reflect aquatic plant communities of low quality. Taft et al. (1997) found that low quality communities are impacted by one or more factors, including invasive species, nutrient enrichment, and other forms of disturbance. Nichols (1999) suggested that FQI scores of 20-35 represent communities considered to be of good to high ecological quality, and that systems with scores >35 are in a largely historical undisturbed state. The scores can serve as status measures and restoration target goals.

## Clear Lake

Clear Lake vegetation surveys were conducted at 260 point-intercept locations before and after Curly-leaf Pondweed (CLP) senescence in 2011 and 2012. The FO and relative density (based on rake ranks) are summarized in Table 8.

**June 1, 2011 --** For all vegetation combined, the FO was 63.8%. Curly-leaf Pondweed was found at 149 of 260 (57.3%) point-intercept locations and a 2.3 mean rake rank (Table 8). Therefore, CLP was absent at only 6.5% of all sites with vegetation. Within the littoral zone (<15 ft in total depth), CLP was present at 73% of all sites. The densest CLP stands were found along the southern portion of the lake (Figure 19), where the invasive readily grew to the surface and made navigation of our outboard nearly impossible. Eurasian Watermilfoil (EWM) was found at 18 of 260 (6.9%) point-intercept sampling locations and at a 1.3 mean rake rank. The EWM stands were most dense in the bay located on the eastern shoreline just to the north of Maplewood Park. The EWM was also occasionally interspersed with CLP along the southern shoreline. Several native aquatic macrophytes were also present; however, FO and density were only a fraction of that documented for CLP (Table 8).

Given the dominance of CLP, it was not surprising to find an FQI value of 9.33 - a value reflective of a disturbed environment with invasive species and a struggling native macrophyte community (Table 8). The native submergent plant community consisted primarily of coontail, muskgrass, sago pondweed, and clasping-leaf pondweed, with a few isolated specimens of slender naiad identified. The native submergents were collectively found at 34 of 260 (13.1%) point-intercept sites (Figure 20). Although we classify muskgrass (*Chara* sp.) here as a macrophyte, or plant, it is actually a multi-cellular macro-algae. Muskgrass is typically included in assessments of lake vegetation, as it tends to be relatively intolerant of degraded conditions, and there serves as a reliable water quality indicator species.

An example of senesced (dead) Curly-leaf Pondweed accumulated on shorelines of Clear Lake in Waseca County. This photograph is from the northern shoreline in late June 2012.

Table 8. Point-intercept aquatic vegetation survey results for Clear Lake in Waseca County for four dates in 2011 and 2012. The common and scientific names for each plant species sampled are denoted. In addition, the C-value* assigned to each species used in Floristic Quality Index (FQI) evaluations is included here as a point of reference. The frequency of occurrence** and rake rank *** are also reported for each species and sample date. When the frequency of occurrence for a species was 0, the rake rank was not available (NA), as it could not be calculated.

| | | | 6/1/2011 | | 8/3/2011 | | 4/25/2012 | | 8/13/2012 | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Common Name** | *Genus species* | C-value | FO (%) | Rake Rank | FO (%) | Rake Rank | FO (%) | Rake Rank | FO (%) | Rake Rank |
| **Claspingleaf Pondweed** | *Potamogeton richardsonii* | 5 | 0.8 | 1.0 | 1.5 | 1.3 | 0.0 | NA | 0.8 | 1.2 |
| **Coontail** | *Ceratophyllum demersum* | 3 | 2.3 | 1.2 | 3.8 | 1.6 | 0.4 | 1.0 | 2.7 | 1.3 |
| **Curly-leaf Pondweed** | *Potamogeton crispus* | 0 | 57.3 | 2.3 | 1.5 | 1.0 | 58.8 | 2.1 | 0.8 | 1.0 |
| **Eurasian Watermilfoil** | *Myriophyllum spicatum* | 0 | 6.9 | 1.3 | 11.9 | 1.7 | 5.8 | 1.7 | 9.6 | 1.3 |
| **Greater Duckweed** | *Spirodela polyrrhiza* | 5 | 0.0 | NA | 1.2 | 1.0 | 0.0 | NA | 0.0 | NA |
| **Muskgrass** | *Chara spp.* | 7 | 8.1 | 1.0 | 5.8 | 1.0 | 5.0 | 1.0 | 3.8 | 1.0 |
| **Narrowleaf Cattail** | *Typha angustifolia* | 0 | 0.8 | 1.0 | 2.3 | 1.0 | 1.2 | 1.0 | 1.2 | 1.0 |
| **Northern Watermilfoil** | *Myriophyllum exalbescens* | 7 | 0.0 | NA | 0.0 | NA | 0.0 | NA | 0.4 | 1.0 |
| **Sago Pondweed** | *Potamogeton pectinatus* | 3 | 1.9 | 1.2 | 5.0 | 1.1 | 0.0 | NA | 3.5 | 1.0 |
| **Slender Naiad** | *Najas flexilis* | 6 | 0.1 | 1.0 | 0.1 | 1.0 | 0.0 | NA | 0.0 | NA |
| **Softstem Bulrush** | *Scirpus validus* | 4 | 0.4 | 1.0 | 0.4 | 1.0 | 0.8 | 1.0 | 0.4 | 1.0 |
| **Water Celery** | *Valisneria americana* | 6 | 0.0 | NA | 1.2 | 1.0 | 0.0 | NA | 1.2 | 1.3 |
| **All Vegetation (combined)** | | | 63.8 | 2.2 | 18.5 | 1.6 | 63.5 | 2.1 | 18.1 | 1.4 |
| **Species Richness ($N_s$)** | | | 9 | | 11 | | 6 | | 10 | |
| **Mean C-value** | | | 3.11 | | 3.55 | | 2.33 | | 3.50 | |
| FQI (mean C-value)($\sqrt{N_s}$) | | | **9.33** | | **11.77** | | **5.71** | | **11.07** | |

*C-values obtained from Beck et al. (2010), Perleberg et al. (2015), and Milburn et al. (2007).
**Frequency of Occurrence (FO), representing the proportion of total sites where each species was present.
***Rake rank is the mean density ranking for sites where the species was present based on the rake method sampling. A rank of 0 indicates absence, whereas a rank of 4 indicates extremely dense vegetation.

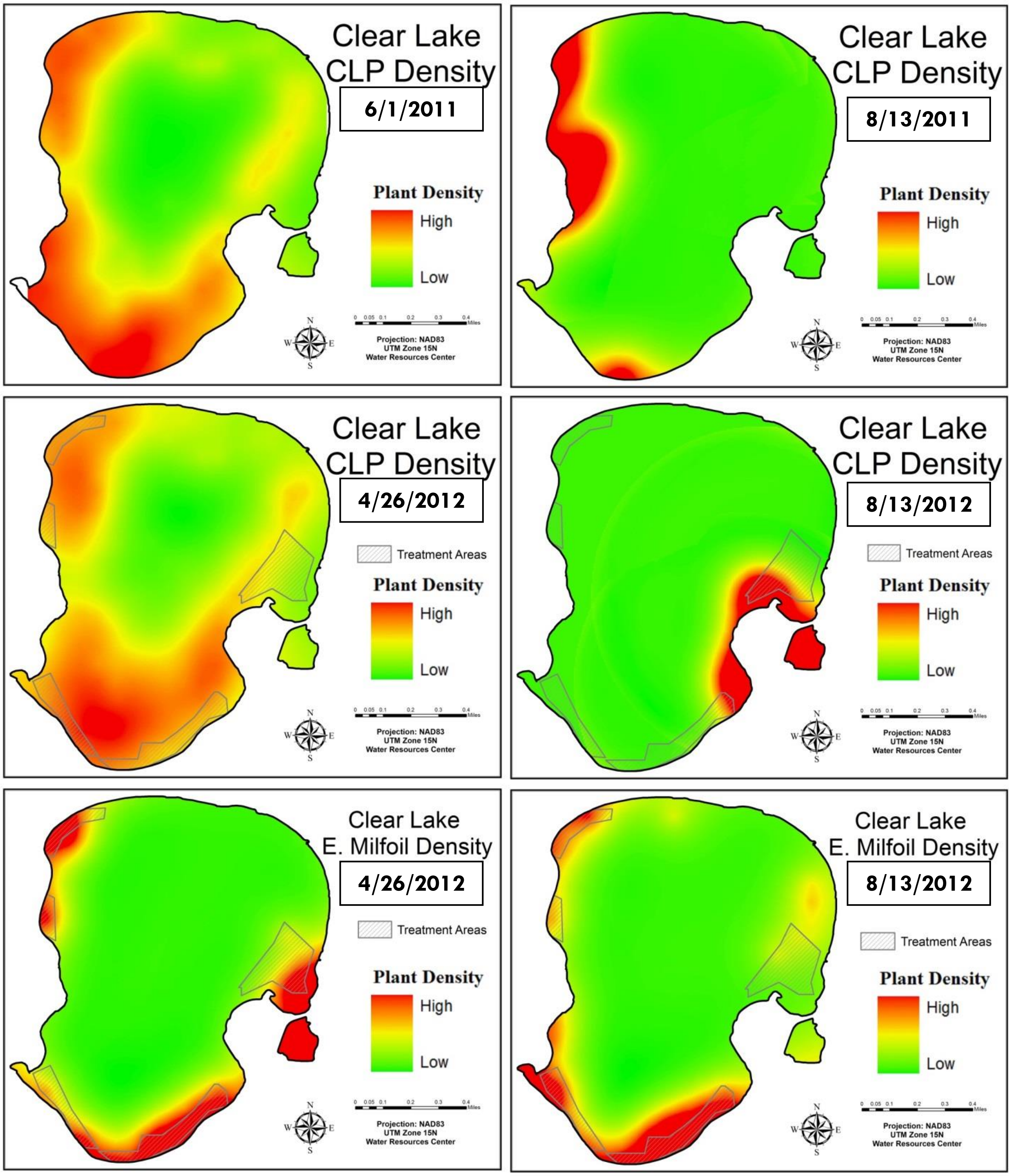



*Figure 19. Composite results for the distribution and relative density of Curly-leaf Pondweed (CLP) in 2011 and 2012 and Eurasian Watermilfoil (E. milfoil) in 2012 from Clear Lake. Maps are derived from a sampling grid that averages the presence-absence and relative density of macrophytes to show broad regions, rather than individual points, where invasive species are present. For each map, the area in green indicates the species is absent and areas in red are where the species is most dense. The areas treated in the spring of 2012 to reduce CLP are denoted.*

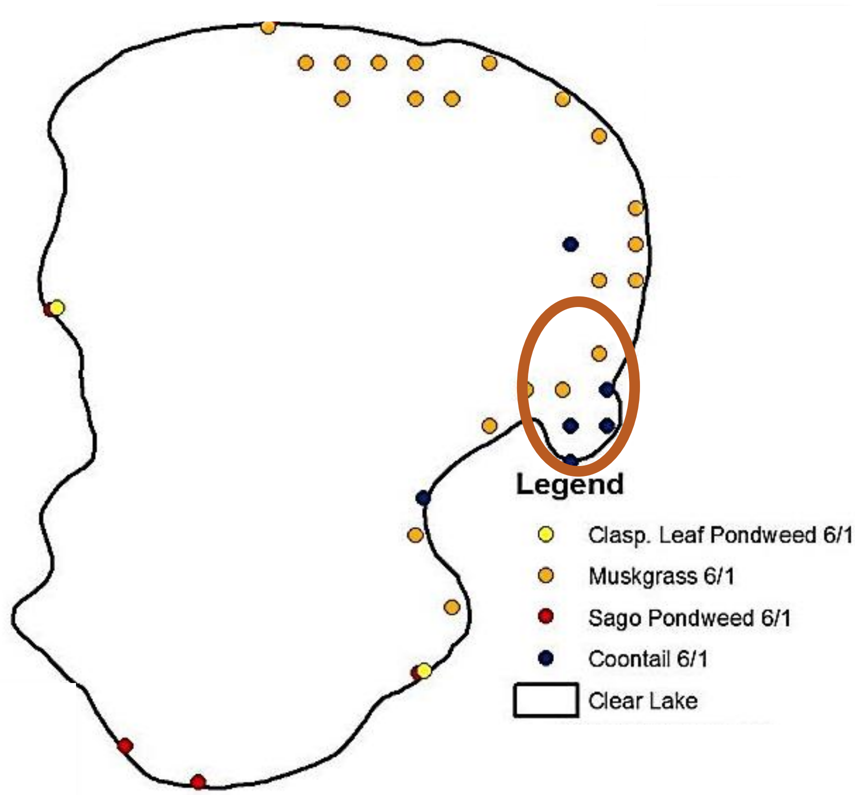



***Figure 20. Native macrophyte presence from point-intercept sampling locations for Clear Lake based on a June 2011 survey using a 100*100 m grid. The bay circled in brown is the location of the remaining emergent macrophyte stands present in June 2011.***

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A majority of the native macrophytes were found along the northern and eastern shoreline, where relatively sandy substrates are present. The northern and eastern sections of Clear Lake, in part due to native macrophyte presence, are also valuable habitat for fish and other wildlife. Furthermore, native macrophytes persist all season and compete with algae for available nutrients in these areas.

The emergent plant community on Clear Lake was limited to two species in June 2011. A softstem bulrush stand was present on the eastern shoreline near Maplewood Park, representing one of the few areas of relatively intact shoreline vegetation. The lack of native emergent stands is in direct contrast with historical representations that suggest bulrushes once lined at least 1/3 of the Clear Lake shoreline. Bulrush stands are important, particularly during high water periods, as the plants absorb nutrients, slow wave action, and reduce shoreline erosion and sediment re-suspension. The other emergent species was narrowleaf cattail – an invasive species that has an affinity for nutrient-rich water and is therefore an additional indication of eutrophication. Overall, the emergent plant community on Clear Lake is scarce; likely a result of a long history of shoreline modifications, elevated water levels, and loss of water level variability.

**August 3, 2011 –** Following typical life history patterns, the CLP population strongly died back (senesced) by mid-summer and CLP was only found in low density at 4 of 260 (1.5%) of the point-intercept sampling locations (Table 8). Turions, a form of CLP propagule (reproductive structure), however, were abundant and sampled at >90% of all sites up to 15 ft. At the time of the survey, turions had not started to germinate and CLP coverage was <10 acres - a sharp contrast to the approximately 340 acres of CLP found in June 2011. The EWM coverage, however, increased from approximately 43 acres in June to 78 acres by August, with the densest stands along the southern shore of Clear Lake (Figure 21).

The native submergent plant community primarily consisted of six species in August 2011, including coontail, muskgrass, sago pondweed, clasping-leaf pondweed, water celery, and slender naiad. Native species were more likely to be sampled in the northern half of Clear Lake, especially in the northeastern quarter of the lake – similar to the June survey. In total, native submergent macrophytes were found at 33 of 260 (12.7%) point-intercept sampling locations (Figure 21). Occasionally, multiple species of native macrophytes were found at one location, it is important to protect and enhance these areas of the lake and establish other similar locations within Clear Lake. Softstem bulrush and narrow-leaf cattail were the only emergent species documented during the August 2011 survey, with the same stands persisting near Maplewood Park and a few sporadic plants attempting to colonize along the northeastern shoreline.

The FQI score for the August 2011 plant survey improved slightly in comparison to the June score (Table 8). However, a FQI score of 11.77 is still strongly indicative of a distressed plant community. The overall vegetative community had a FO of 18.5% and a mean rake-rank density estimate of 1.6 (Table 8) – meaning that 81.5% of the point-intercept sampling locations within Clear Lake were not supporting any type of aquatic plant growth during the August 2011 survey. Even with the EWM included, a total of 88 individual plants were recorded among the 11 different species sampled (emergent and submergents combined).

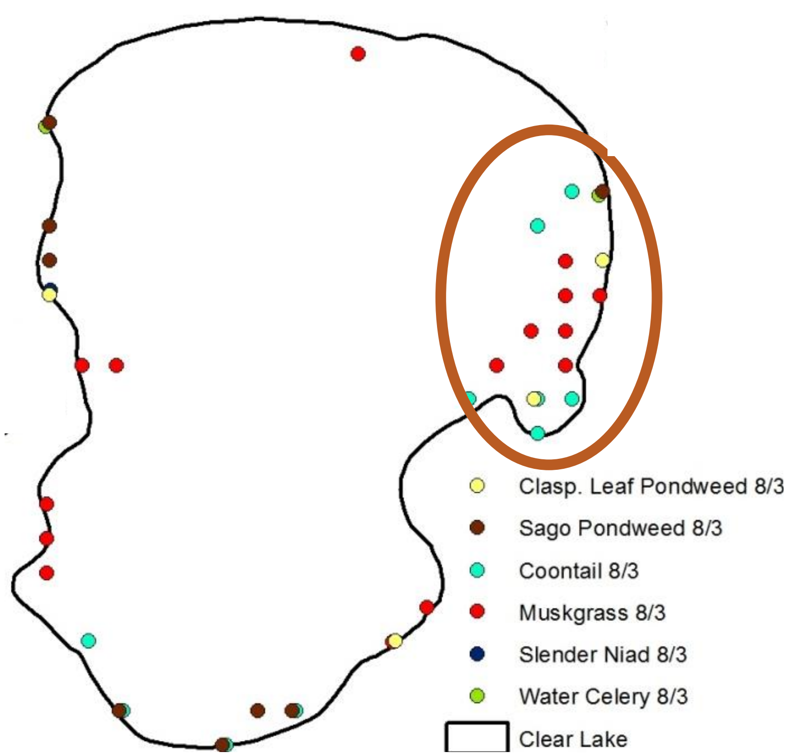



***Figure 21. Native macrophyte presence from point-intercept sampling locations for Clear Lake based on an August 2011 survey using a 100*100 m grid. The area within the brown circle is the shoreline section where emergent macrophytes were persisting.***

**April 25, 2012 –** The April 2012 vegetation survey results were very comparable to data collected in June 2011. For all vegetation combined, the FO was 63.5%. Curly-leaf Pondweed was found at 153 of 260 (58.8%) point-intercept sampling locations and had a 2.1 mean rake rank (Table 8). Therefore, CLP was absent at only 4.7% of all sites with vegetation. Within the littoral zone (<15 ft in total depth), CLP was present at 79% of all sites sampled. The densest CLP stands continued to persist along the southern portion of the lake. Eurasian Watermilfoil (EWM) was found at 15 of 260 (5.8%) point-intercept sampling locations and was slightly denser than in 2011, with a mean rake rank of 1.7. The EWM stands were again most dense in the bay located on the eastern shoreline just to the north of Maplewood Park. There was less notable interspersion of EWM among the CLP and fewer and more sparse native macrophytes found in 2012 compared with 2011 (Table 8).

With the continued presence of dense and widespread invasive species, combined with three fewer native species (no documentation of claspingleaf pondweed, slender naiad, or sago pondweed) in April 2012, as compared with June 2011, the FQI score was only 5.71 (Table 8). The only submergent native documented in April 2012 was muskgrass, found at 13 of 260 (5.0%) point-intercept sites (Figure 20).

*April 2012 Endothall Treatment*

The WRC, WLA, and the City of Waseca collaborated to secure a grant from the MDNR Aquatic Invasive Species Control Program to chemically treat some of the densest and problematic CLP stands mapped during the June 2011 survey. According to MDNR records, there had been no prior chemical treatments for CLP in Clear Lake, and therefore, an experimental treatment was completed.

Using an industry recommended 1-ppm Aquathol-K (Endothall) concentration, 30 acres were treated in April 2012. The CLP had grown rapidly in the early spring of 2012 due to excellent growing conditions. The winter of 2011-2012 was mild minimal snow cover allowed excellent light penetration through the ice to facilitate CLP growth. In addition, record-breaking warm temperatures in February and March of 2012 further enabled rapid CLP growth. The cost of the endothall treatment was $235/acre, of which the MDNR grant reimbursed $150/acre. The WLA, Kiesler's Campground, and the Boathouse Restaurant contributed cash match to cover the additional $85/acre. The direct cost to treat 30 acres of CLP in 2012 was $7,534.

**August 13, 2012 –** The CLP again senesced as anticipated, and was only found in low density at 2 of 260 (0.8 %) point-intercept sampling locations (Table 8). Turions were again located and nearly all sites in 15 feet of water or less and a few had already started to germinate. The EWM coverage, had increased since the April 2012 survey, however, was approximately 1/3 less frequent and had a mean rake rank of 0.4 less than the August 2011 survey. The CLP treatment areas had backfilled with EWM; however, those same areas backfilled with EWM after natural senescence of CLP in 2011 as well (Figure 19).

The native submergent plant community in August 2012 was similar to the August 2011 observations. The native submerged macrophytes included coontail, muskgrass, sago pondweed, clasping-leaf pondweed, water celery, and northern watermilfoil; however, the overall frequency and rake-rank density was lower than observed in 2011. In total, native submergent macrophytes were only found at 20 of 260 (7.7%) point-intercept sampling locations and the average rake-rank density values dipped by 0.2. Softstem bulrush and narrow-leaf cattail were again documented in similar locations as 2011; however, only half the number of narrowleaf cattail plants were present in 2012 compared with 2011.

The FQI score for August 2012 improved from the April score to 11.07, but was lower than the score from August 2011 (Table 8) and continued to indicate the persistence of a distressed plant community. Overall FO was similar to 2011, with 18.1% of the sites supporting some type of vegetation. Overall density of all vegetation was lower in August 2012 than it was in August 2011, with an average rake-rank of 1.4.

### Loon Lake

Using the same methodology as described above, vegetation surveys were completed at 87 point-intercept locations on Loon Lake in June and August of 2011 and May of 2012. A survey was attempted in August 2012, however, due to extremely low water levels, the survey could not be completed. The FO and relative density (based on rake ranks) are summarized in Table 9.

**June and August 2011 --** Remarkably, CLP was not documented in either of the 2011 surveys – even though CLP presence had been previously verified by the DNR. Loon Lake continues to be free from EWM, possibly due to the non-motorized boat restriction in place and a shallow environment that may be inhospitable to the species. In the absence of CLP, sago pondweed and coontail were the most common macrophytes in Loon Lake during both surveys. Low-density sago pondweed was found at 42 of 87 (48.3%) point-intercept sites in June 2011, dropping to 19 of 87 (21.8%) sites by August 2011. Sago pondweed was sampled at all depths of Loon Lake in June 2011, but in water no deeper than 4 ft deep in August 2012. Coontail was found at 26.7% and 18.6% of the points in June and August of 2011, respectively. Coontail was found at higher densities and in shallower water than sago pondweed.

By late summer, Loon Lake exhibited reduced water clarity from biological turbidity (*i.e.,* algae). As a result, late summer macrophytes were found primarily in water less than 3 ft deep (Figure 22). Emergent macrophytes, although typically common along portions of Loon Lake were nearly absent in 2011, with only a few scattered bulrush and narrowleaf cattail along a small area of the north shore. During the June 2011 survey, muskgrass was found at 3 of 87 (3.4%) points (Table 9). The presence of muskgrass is noteworthy because it has a coefficient of conservatism ranking of 7 and is typically found in lakes with good water quality and coarse substrate. Coarse substrate in Loon Lake is rare and limited to one small area in the southeastern corner of Loon Lake. Not surprisingly, it was in the coarse substrate areas where the muskgrass was located.

Although muskgrass was present, the FQI scores for June and August 2011 were 6.50 and 5.00, respectively. FQI scores this low are indicative of a seriously distressed plant community in a significantly disturbed environment. Summerkill is a symptom of distressed systems, and during the August 2011 vegetation survey on Loon Lake, approximately 100 dead bullheads were observed. The dissolved oxygen (DO) throughout that lake on August 2, 2011 was <2 mg/L and near the heavy organic sediments, decomposition was generating anoxic conditions.

**May 2012 –** The May 2012 survey revealed CLP at 10 of 87 (11.5%) point-intercept locations. Sago pondweed was widely dispersed, being found at 57 of 87 (65.5%) survey sites (Table 9). In addition, coontail, muskgrass, narrowleaf cattail, and softstem bulrush were again present. Also of interest were a few plants of narrowleaf pondweed, a species with a c-value of 8, found in Loon Lake in May 2012. A c-value of 8 indicates a species that is intolerant of poor water quality. The May 2012 FQI score was 9.45, indicating a substantially impaired system.

The late summer survey could not be completed due to extremely dry conditions and an on-going lake down in preparation for reclamation. A qualitative assessment of the shoreline, however, indicated that emergent plants were present and abundant along about 50% of the Loon Lake shoreline. Drawdowns are an extremely effective management tool, and the emergents responded to shoreline stabilization when exposed sediments compact. Scheffer (2004) and Moss et al. (1996) both noted that although drawdowns and water level manipulations are important, internal loading must still be addressed.

Table 9. Point-intercept aquatic vegetation survey results for Clear Lake in Waseca County for four dates in 2011 and 2012. The common and scientific names for each plant species sampled are denoted. In addition, the C-value* assigned to each species used in Floristic Quality Index (FQI) evaluations is included here as a point of reference. The frequency of occurrence** and rake rank *** are also reported for each species and sample date. When the frequency of occurrence for a species was 0, the rake rank was not available (NA), as it could not be calculated.

| Common Name | Genus species | C-value | 6/1/2011 FO (%) | 6/1/2011 Rake Rank | 8/2/2011 FO (%) | 8/2/2011 Rake Rank | 5/21/2012 FO (%) | 5/21/2012 Rake Rank |
|---|---|---|---|---|---|---|---|---|
| **Coontail** | *Ceratophyllum demersum* | 3 | 26.4 | 2.1 | 18.4 | 2.1 | 11.5 | 1.2 |
| **Curly-leaf Pondweed** | *Potamogeton crispus* | 0 | 0.0 | NA | 0.0 | NA | 11.5 | 1.3 |
| **Muskgrass** | *Chara spp.* | 7 | 3.4 | 2.0 | 0.0 | NA | 3.4 | 2.0 |
| **Narrowleaf Cattail** | *Typha angustifolia* | 0 | 1.1 | 1.0 | 3.4 | 1.0 | 1.1 | 1.0 |
| **Narrowleaf Pondweed** | *Potamogeton strictifolius* | 8 | 0.0 | NA | 0.0 | NA | 3.4 | 1.0 |
| **Sago Pondweed** | *Potamogeton pectinatus* | 3 | 48.3 | 1.0 | 21.8 | 1.1 | 65.5 | 1.3 |
| **Softstem Bulrush** | *Scirpus validus* | 4 | 0.0 | NA | 1.1 | 1.0 | 4.6 | 1.0 |
| **All Vegetation (combined)** | | | 60.9 | 1.6 | 25.3 | 1.9 | 65.5 | 1.4 |
| **Species Richness (N)** | | | 4 | | 4 | | 7 | |
| **Mean C-value** | | | 3.25 | | 2.50 | | 3.57 | |
| FQI (mean C-value)(√N) | | | **6.50** | | **5.00** | | **9.45** | |

*C-values obtained from Beck et al. (2010), Perleberg at al. (2012), and Milburn et al. (2007).

**Frequency of Occurrence (FO), representing the proportion of total sites where each species was present.
***Rake rank is the mean density ranking for sites where the species was present based on the rake method sampling. A rank of 0 indicates absence, whereas a rake rank of 4 indicates extremely dense vegetation.

*Chara spp., commonly known as muskgrass, sampled on the rake from Loon Lake in 2011.*

*Muskgrass is used as a vegetative indicator, but is really a type of algae. The photo also shows heavy algae and vegetation beds in the background (circled area).*

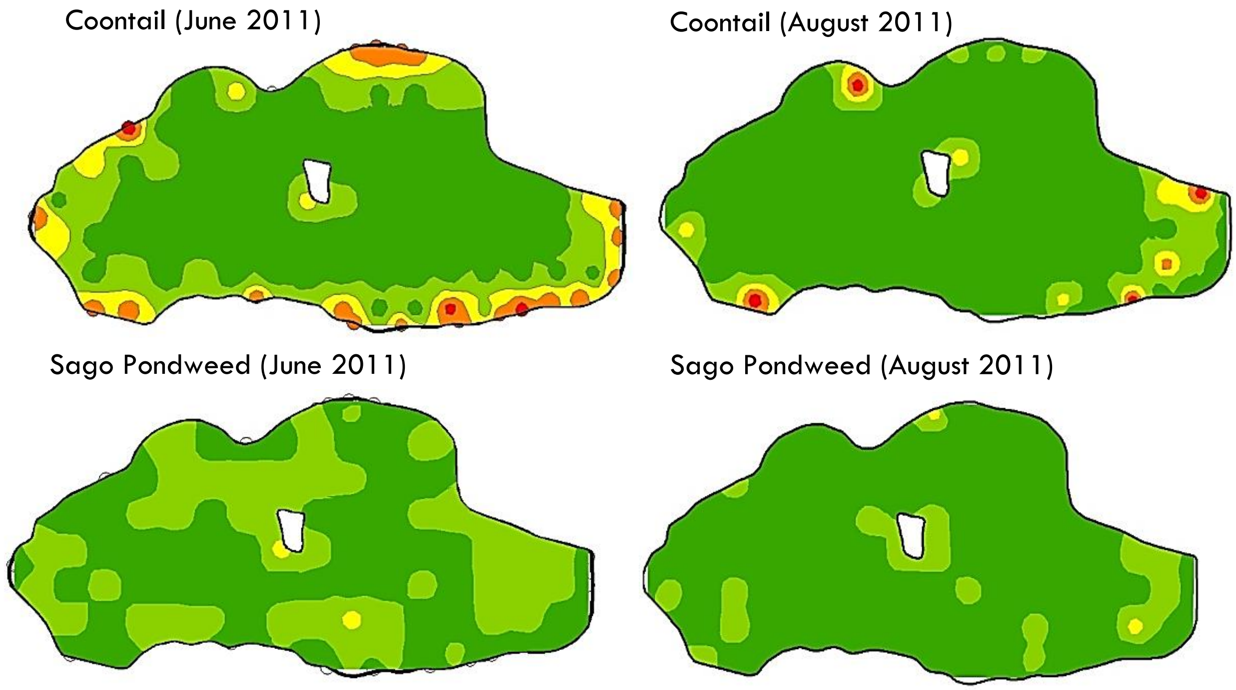



***Figure 22. Composite results for the distribution and relative density of coontail (top maps) and sago pondweed (bottom maps) from June 2011 (left maps) and August 2011 (right maps) from Loon Lake. The maps above are derived from a sampling grid that averages out the presence-absence and relative density of macrophytes to show broad regions, rather than individual points where each species is present. For each map, the area in dark green indicates the species is absent (rake ranking = 0) and areas in red are where the species is most dense (rake ranking = 4).***

# 4.0 WATER QUALITY EVALUATION

Previous studies of the Waseca Lakes have included various degrees of water quality evaluations. The data provide a documented history of prior water quality and can often be used as a reference point; however, methodology has changed over time, and therefore must be considered when attempting to compare data from different eras. In addition to evolving assessment approaches, the Waseca Lakes have not remained static. Watershed land use, status of exotic vegetation, fish community dynamics, and weather patterns have all evolved in Clear Lake have prompted the need for updated water quality conditions. All samples were evaluated at Minnesota Valley Testing Laboratories (MVTL) in New Ulm, Minnesota. The Minnesota Department of Health has certified MVTL as a state-approved water quality testing facility.

## *4.1 Clear Lake Assessment*

Water quality data were collected via grab samples at four monitored inflow/outflow sites (Figure 23). At each of the four inlet/outlet locations, velocity, stage, and cross-sectional area of flow were assessed. Grab sample data were extrapolated based on velocity and stage measurements to calculate daily flows and nutrient loads passing through each site. Although other drainage areas were identified, defined inlets were not present or sufficient to facilitate sampling.

Concurrent with our study, the MPCA collected in-lake water quality data. The in-lake data were used to calibrate the BATHTUB and Minnesota Lake Eutrophication Analysis Procedure (MINLEAP) models. In-lake samples were taken two m below the water surface at the deepest location on the lake using a 2-m integrated sampler (Figure 23). During periods of thermal stratification, additional samples were taken below the thermocline using a Kemmerer sampler at a depth of 0.5 to 1 m off the lake bottom (Anderson and Lindon 2013).

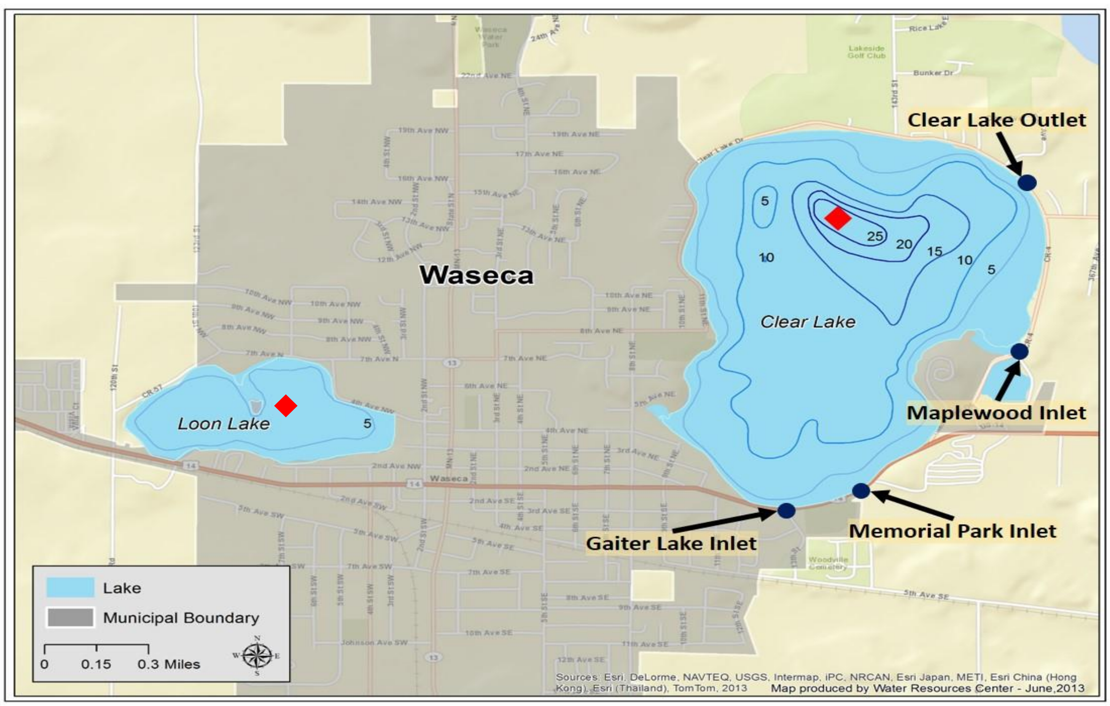



***Figure 23. Locations of three inlets and one outlet (dark blue circles) to Clear Lake, Waseca County that were monitored in 2011-2012. The in-lake data collection point is also denoted (red diamonds) for both Clear and Loon Lakes. Referring back to Figure 13, the Maplewood Inlet is the drainage point for Area 3, the Memorial Park Inlet receives the water from Area 2, and the Gaiter Lake Inlet receives the water from Area 4.***

Water quality parameters were monitored in an attempt to secure sufficient data to complete various pollutant/nutrient enrichment models, including development of draft allocations and an overall nutrient budget. Table 10 summarizes the water quality parameters tested during the study. All inlet/outlet water quality samples at Clear Lake were taken from the portion of the channel that was deepest. Each monitoring location contained a reference point that was used to determine the measured stage. The measured stage was used to ensure that the stage read by the monitoring equipment (gauge height) was accurate. A difference of 0.03 between the two devices was maintained. Flow data and water quality samples were used to calculate mean flow weighted concentrations for nutrients moving through each inlet/outlet area.

The second half of July, as well as August through November of 2011, was extremely dry. The Memorial Park and Maplewood Inlets (Areas 2 and 3) became stagnant (i.e., lacked flow and/or became dry) on August 10, 2011. The Memorial Park Inlet regained some flow in early October despite the lack of precipitation; however, the Maplewood Inlet remained stagnant until the equipment was removed November 7, 2011. Clear Lake Inlet 1 had continuous flow throughout the 2011 monitoring season despite the extremely low rainfalls. The outlet also had limited flow during most of 2011. During the 2012 sampling season, similar trends were observed.

Table 10. Water quality parameters assessed from July 2011 through the early fall of 2012 from the Waseca Lakes (Clear and Loon Lakes) in Waseca County, Minnesota. For each parameter, or analyte, the collection method specifications [including sample quantity, container type, preservative, and holding time (hours = hr or days = d)], analytical method, and sample locations (acronyms limited to this table include C=Clear Lake, L=Loon Lake, I=in-lake sample, and O=outlet/inlet samples) are denoted.

| Analyte | Sample Quantity | Sample Container | Preservative | Holding Time | Analytical Method | Sample Locations |
|---|---|---|---|---|---|---|
| Chlorophyll-a | 1 L | Amber Glass | Cool* | 4 hr | 5M 10,200 H | C-I L-I |
| Nitrate-Nitrite | 250 mL | Plastic | $H_2SO_4$ to pH<2/Cool* | 28 d | EPA 353.2 Rev. 2.0 | C-O L-I |
| Orthophosphorus | 500 mL | Plastic | Cool* | 2 d | EPA 365.1 Rev. 2.0 | C-I-O L-I |
| pH | NA | NA | NA | NA | Hach Hydrolab | C-I-O L-I |
| Specific Conductance | NA | NA | NA | NA | Hach Hydrolab | C-I-O L-I |
| Total Phosphorous | 500 mL | Plastic | $H_2SO_4$ to pH<2/Cool* | 28 d | EPA 365.1 Rev. 2.0 | C-I-O L-I |
| Total Suspended Solids | 500 mL | Plastic | Cool* | 7 d | USGS I-3765-85 | C-I-O L-I |
| Transparency | NA | NA | NA | NA | Secchi Disk | C-I L-I |

*Preservative methods denoted as "Cool" are all reductions in temperature to $4^{o}$C.

## Inlet Monitoring

Monitoring equipment was installed in early July 2011 at the Gaiter Lake, Memorial Park, and Maplewood Inlets. Each inlet was equipped with an ISCO 2150 area velocity flow module/sensor that uses continuous wave Doppler technology to measure mean velocity. Level or stage measurements are achieved by a differential pressure transducer. The equipment takes a stage and velocity reading every 3 minutes, averages the data, and compiles the stage and velocity data into 15 minute intervals. Data were processed with Flowlink® software.

The 2011 sampling season began on 7/22 with the first grab sample collection and flow measurements and ended on 11/7 with the final grab sample collection and removal of equipment. The 2012 sampling season began on 2/29 with the re-installation of monitoring equipment and the collection of water quality grab samples. The 2012 season ended on 7/24 with the final grab sample collection and removal of equipment. At all three inlet sites, emphasis was placed on collecting water quality data for one calendar year during different stages of the hydrograph including rising and falling limbs, as well as base flow conditions.

***Memorial Park Inlet (Area 2)*** -- The Memorial Park Inlet serves as the pour point for Area 2 (Figure 13), flowing under old TH 14 and entering Clear Lake along the southwestern shoreline (Figure 23). Water quality samples were taken 5 times in 2011 and 14 times in 2012 (Table 11). Water clarity was checked 13 and 14 times in 2011 and 2012.

***Maplewood Inlet (Area 3)*** -- The Maplewood Inlet drains Area 3 (Figure 13) and flows underneath Clear Lake Drive prior to entering Clear Lake along the eastern shoreline (Figure 23). Water quality samples were taken 4 times in 2011 and 15 times in 2012 (Table 11). Water clarity was checked 13 and 18 times in 2011 and 2012.

***Gaiter Lake Inlet (Area 4)*** -- The Gaitor Lake Inlet flows from Area 4 (Figure 13) underneath old TH 14 prior to entering Clear Lake on the southern shoreline (Figure 23). Outflow from Gaiter Lake and County Ditch 15-1 (CD-15) have historically represented a large proportion of the water entering Clear Lake. In addition, CD-15 was identified as a major phosphorus source during a 2003 study (Bolton and Menk 2003). According to the former City of Waseca engineer, a portion of CD-15 tile was found to be completely blocked in 2005. As a result, it was assumed that the total phosphorous loading into Gaitor Lake and ultimately into Clear Lake from Area 4 had been reduced; however, this assumption had not been adequately substantiated. Water quality samples were taken 11 times in 2011 and 27 times in 2012 (Table 11); however, OP evaluations could only be completed on 6 of the 11 water samples in 2011. Water clarity was checked 15 and 19 times in 2011 and 2012.

## Outlet Monitoring

Clear Lake has a single defined outlet located on the northeastern shoreline (Figure 23). This site was equipped with a stilling well, a Solinist Levelogger Gold, and a Solinist Barologger. The stilling well was used to minimize error associated with changes in lake level resulting from wave action. The Levelogger and Barologger were both suspended on wires within the stilling well. The Levelogger and Barologger are equipped with pressure transducers and temperature sensors. Both devices can be used to determine the lake level, water temperature, atmospheric pressure, and air temperature. For the Clear Lake Outlet site, the Levelogger was used to measure the lake level and water temperature while the Barologger was used to measure atmospheric pressure and air temperature. To achieve an accurate lake level reading, the lake level information collected by the Levelogger was corrected for daily changes in atmospheric pressure that were recorded by the Barologger.

Table 11. Water quality data collection summary for the Memorial Park (Area 2), Maplewood (Area 3), and Gaitor Lake Inlets (Area 4) from July-November 2011 and February-July 2012. The data include Nitrate-Nitrite ($NO_3$–$NO_2$; ppm), total suspended solids (TSS; ppm), total phosphorus (TP; ppb), orthophosphorus (OP; ppb), percent (%) of TP that is OP, and water clarity (cm). The flow-weighted mean concentrations (FWMC) are reported for $NO_3$–$NO_2$, TSS, TP, and OP, along with the average (Avg) %OP of TP and clarity. The maximum/minimum individual observations, along with sample size are noted. Data are parts per million (ppm), parts per billion (ppb), and centimeters (cm), or represented as a percentage (%).

| Inlet/Year | $NO_3$–$NO_2$ (ppm) | TSS (ppm) | TP (ppb) | OP (ppb) | % OP of TP | Clarity (cm) |
|---|---|---|---|---|---|---|
| **Memorial Park Inlet 2011** | | | | | | |
| **FWMC** | 0.1 | 19 | 290 | 64 | 33.5 | 49 |
| **Maximum** | 0.1 | 46 | 400 | 190 | | 60* |
| **Minimum** | 0.1 | 3 | 150 | 10 | | 5 |
| **Sample Size** | 5 | 5 | 5 | 5 | 5 | 13 |
| **Maplewood Inlet 2011** | | | | | | |
| **FWMC** | 0.7 | 6.1 | 250 | 217 | 29.4 | 34 |
| **Maximum** | 1.2 | 18.0 | 570 | 430 | | 60* |
| **Minimum** | 0.1 | 4.0 | 130 | 30 | | 6.5 |
| **Sample Size** | 4 | 4 | 4 | 4 | 4 | 13 |
| **Gaitor Lake Inlet 2011** | | | | | | |
| **FWMC** | 0.12 | 17.2 | 510 | 190 | 37.3 | 54 |
| **Maximum** | 0.22 | 57.3 | 1,140 | 410 | | 60* |
| **Minimum** | 0.10 | 2.8 | 190 | 50 | | 20 |
| **Sample Size** | 11 | 11 | 11 | 6 | 6 | 15 |
| **Memorial Park Inlet 2012** | | | | | | |
| **FWMC** | 1.0 | 285 | 780 | 99 | 34.7 | 69 |
| **Maximum** | 1.6 | 548 | 5,720 | 361 | | 100* |
| **Minimum** | 0.1 | 13 | 50 | 10 | | 10 |
| **Sample Size** | 14 | 14 | 14 | 14 | 14 | 14 |
| **Maplewood Inlet 2012** | | | | | | |
| **FWMC** | 2.8 | 10.3 | 350 | 377 | 36.5 | 88 |
| **Maximum** | 6.8 | 56.0 | 1,290 | 780 | | 100* |
| **Minimum** | 0.1 | 2.0 | 70 | 20 | | 25 |
| **Sample Size** | 15 | 15 | 15 | 15 | 15 | 18 |
| **Gaiter Lake Inlet 2012** | | | | | | |
| **FWMC** | 0.37 | 10.1 | 340 | 142 | 41.9 | 91 |
| **Maximum** | 1.83 | 59.5 | 640 | 320 | | 100* |
| **Minimum** | 0.10 | 1.1 | 160 | 10 | | 33 |
| **Sample Size** | 27 | 27 | 27 | 27 | 27 | 19 |

*Maximum water clarity could not be recorded, as the 2011 T-tube, the device used to measure clarity, could not be used when water clarity exceeded 60 cm. In 2012, the T-tube could not read clarity greater than 100 cm.

The 2011 sampling season commenced on 6/22. Initially, the stilling well was placed downstream of the dam; however, the equipment was re-installed above the dam in early August 2011 as per recommendation of hydrologists from the MDNR. An appropriate shift in the data was made using surveying equipment to account for the difference in water level above and below the dam. The 2011 monitoring season ended on 11/7 when both the Barologger and Levelogger were removed from the stilling well. The 2012 sampling season began on 3/17 with the installation of monitoring equipment and the collection of water quality grab samples. The outlet monitoring season was offset from the inlet monitoring because the inlets started flowing earlier, and because of dry conditions going into the previous winter, the lake did not start outflowing until several weeks later. The 2012 season ended on 7/24 with the final grab sample collection and removal of equipment. The Outlet monitoring data are summarized in Table 12.

Table 12. Water quality data collection summary for the Clear Lake Outlet July-November 2011 and March-July 2012. The data include Nitrate-Nitrite ($NO_3–N0_2$; ppm), total suspended solids (TSS; ppm), total phosphorus (TP; ppb), orthophosphorus (OP; ppb), percent (%) of TP that is OP, and water clarity (cm). The flow-weighted mean concentrations (FWMC) are reported for $NO_3–N0_2$, TSS, TP, and OP, along with the average (Avg) %OP of TP and clarity. The maximum/minimum individual observations, along with sample size are noted for all parameters. Data are parts per million (ppm), parts per billion (ppb), and centimeters (cm), or represented as a percentage (%).

| Inlet/Year | $NO_3–N0_2$ (ppm) | TSS (ppm) | TP (ppb) | OP (ppb) | % OP of TP | Clarity (cm) |
|---|---|---|---|---|---|---|
| **Clear Lake Outlet 2011** | | | | | | |
| **FWMC** | 0.10 | 30.6 | 190 | 16 | 8.4 | 32 |
| **Maximum** | 0.10 | 50.0 | 400 | 84 | | 60* |
| **Minimum** | 0.10 | 22.0 | 100 | 2 | | 7 |
| **Sample Size** | 5 | 5 | 5 | 5 | 5 | 12 |
| **Clear Lake Outlet 2012** | | | | | | |
| **FWMC** | 0.10 | 42.8 | 410 | 27 | 6.7 | 84 |
| **Maximum** | 0.10 | 268.0 | 3,250 | 120 | | 100* |
| **Minimum** | 0.10 | 6.0 | 50 | 2 | | 46 |
| **Sample Size** | 12 | 12 | 12 | 12 | 12 | 9 |

*Maximum water clarity could not be recorded, as the 2011 T-tube, the device used to measure clarity, could not be used when water clarity exceeded 60 cm. In 2012, the T-tube could not read clarity greater than 100 cm.

## In-lake Sampling Summary

The 2011 and 2012 in-lake monitoring ran from May through September of each year (Table 13). Rather than duplicate in-lake sampling that was already going to be done by the MPCA, we opted to acquire their data via the Environmental Database Access. The in-lake samples were processed at the Minnesota Department of Health Laboratory. The following methods are summarized from the MPCA protocol.

In-lake samples were taken at the deepest point found within Clear Lake (Figure 23). Vertical profiles at 1-m intervals were recorded for temperature, pH, conductivity, and DO using a multi-parameter probe in 2011; however, detailed profiles were not recorded in 2012. Other data collected included Secchi disk clarity, Chl-a, and pheophytin, TP, OP, TSS, total Kjeldahl nitrogen (TKN), and total nitrites-nitrate-nitrogen. Given the maximum depth of Clear Lake is greater than 2

m, surface samples were taken using a 2-m integrated sampler that collected a sample from the 0 – 2 m depth. The integrated sample was then transferred to a 2-L plastic bottle.
Because Clear Lake stratifies during portions of the year, samples were also collected from the hypolimnion to assess nutrient concentrations below the thermocline. Assessing water samples from below the thermocline is typically done to determine if nutrient release from the sediment has occurred due to anaerobic conditions in the hypolimnion. To determine if stratification was present, the DO and temperature profiles were reviewed to identify any sharp contrasts that may exist (Figure 25). If a thermocline was present, DO readings from the hypolimnion were collected and anaerobic conditions were recorded as "present" when DO concentrations fell below 0.8 ppm. If anaerobic conditions were present, a water sample was collected within 1 m of the bottom, making certain that the bottom sediments were not disturbed. If the sediments were disturbed with the sampler (Kemmerer) the boat was moved and a sample was taken from a nearby undisturbed site.

Table 13. In-lake water quality data for Clear Lake, Waseca County, Minnesota for various dates in 2011 and 2012. Data secured from sampling conducted by the Water Resources Center in 2011 and from the Minnesota Pollution Control Agency in 2012. Parameters measured in ug/L (ppb) included chlorophyll-a (Chl-a), pheophytin (Pheo), and total phosphorous (TP). Parameters measured in mg/L (ppm) included dissolved oxygen (DO), total Kjeldahl nitrogen (TKN), Nitrate-Nitrite-Nitrogen ($NO_2$-$NO_3$), and total suspended solids (TSS). Secchi disk water clarity measurements (m) were also completed

| Date | Chl-a (ppb) | DO (ppm) | TKN (ppm) | $NO_2$-$NO_3$ (ppm) | Pheo (ppb) | TP (ppb) | TSS (ppm) | Secchi (m) |
|---|---|---|---|---|---|---|---|---|
| 5/16/2011 | 16.3 | 9.9 | 0.99 | < 0.05 | 4.89 | 44 | 9 | 0.9 |
| 6/22/2011 | 15.0 | 8.4 | 0.84 | < 0.05 | 1.98 | 67 | 10 | 1.1 |
| 7/26/2011 | 113.0 | 12.6 | 2.41 | < 0.05 | 9.73 | 131 | 23 | 0.4 |
| 8/17/2011 | 96.1 | NA | 2.31 | < 0.05 | 7.51 | 188 | 28 | 0.3 |
| 9/22/2011 | 69.2 | 9.3 | 1.87 | < 0.05 | 7.05 | 175 | 28 | 0.4 |
| 5/2/2012 | 11.8 | 9.8 | 1.11 | < 0.05 | 2.40 | 32 | 11 | 1.0 |
| 6/5/2012 | 21.3 | 13.5 | 1.09 | < 0.05 | 1.03 | 25 | 9 | 1.2 |
| 7/9/2012 | 45.2 | 8.8 | 1.59 | < 0.05 | 2.51 | 18 | 15 | 0.4 |
| 8/15/2012 | 84.4 | 8.8 | 1.90 | < 0.05 | 6.13 | 72 | 26 | 0.5 |
| 9/18/2012 | 108.0 | 9.0 | 1.67 | < 0.05 | 9.58 | 48 | 27 | 0.4 |

### Seasonality
Nutrient loading can vary due to seasonal influences. Based on data collected in 2011, in-lake nutrient concentrations and secchi disk readings exceeded the minimum Western Cornbelt (WCB) ecoregion standards in the spring and early summer. It should be noted that CLP are also most abundant in the sprint and early summer and absorb a substantial proportion of the incoming nutrient load (Table 13, Figure 24). In 2011, WCB standards were not being met in Clear by late June, coinciding with the CLP senescence in mid-June. As the CLP died back, in-lake nutrient concentrations increased and secchi disk readings decreased (Figure 24). Through the remainder of the 2011 sampling season, Clear Lake continued to fail to meet eco-region standards.

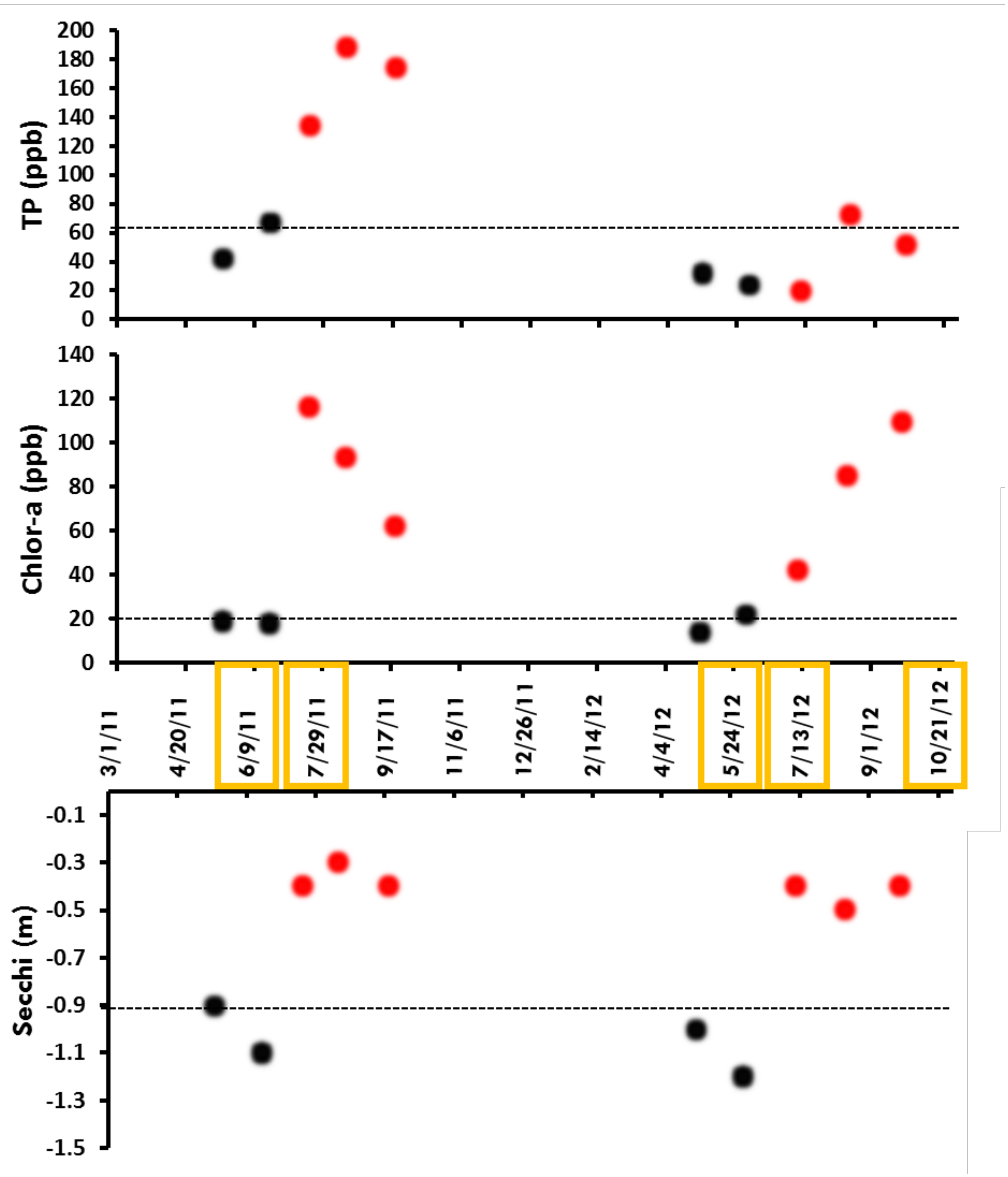



*Figure 24. The total phosphorus (TP) concentrations in parts per billion (ppb), chlorophyll-a (Chl-a) concentration (ppb), and Secchi disk water clarity readings meters (m) below the surface for Clear Lake on various dates in 2011 and 2012. The Western Cornbelt (WCB) eco-region standards of 65 ppb TP, 22 ppm Chl-a, and 0.9 m Secchi disk are denoted by the horizontal dashed lines. Data points in black indicate sample dates when Curly-leaf Pondweed stands were alive and in place. The red data points indicate sample dates when Curly-leaf Pondweed was senescing or absent (post-senescence). The samples collected on the dates in the yellow boxes were collected during periods of lake stratification. Data from other dates were collected during periods of full water column mixing.*

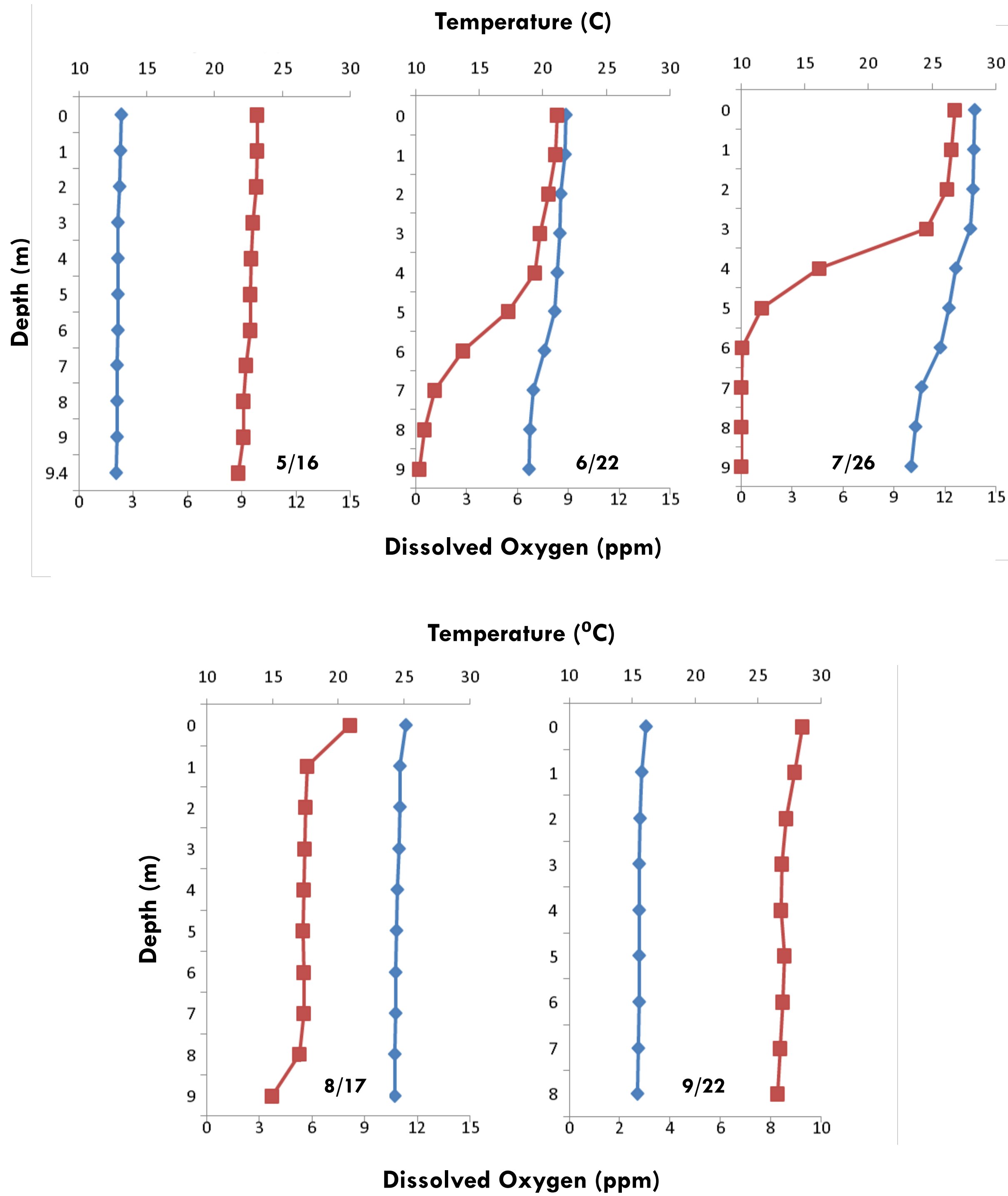



*Figure 25. Temperature in degrees Celsius ($^oC$) and dissolved oxygen in parts per million (ppm) profiles for Clear Lake from five dates in 2011. The dates are indicated on each profile. Profiles were conducted at 1-m intervals at the same location as the in-lake water quality samples (deepest known point of the lake). Red box data points represent dissolved oxygen observations (bottom axis on each graph) and temperature is represented by the blue diamonds (top axis on each graph). Profiles to this level of detail were not collected in 2012.*

These data provide additional evidence that there is a strong correlation between the CLP life cycle and in-lake water quality on Clear Lake. Furthermore, Chl-a concentrations increased in July to 113 ppb, exceeding the WCB eco-region standard. Chl-a decreased to 69 ppb by September, but still remained considerably higher than the WCB minimum standard. The Chl-a increase coincided with increased TP, suggesting that increased nutrients stimulated phytoplankton growth.

In 2011, Clear Lake irregularly switched between periods of thermal stratification and mixing (Figure 24 and 25). There did not appear to be a significant difference in mean TP concentration observed during either period. However, there may have been an internal release of nutrients from the lake sediment during periods of thermal stratification that were re-introduced to the epilimnion during periodic turnover. Heiskary and Wilson (2005) noted that lakes with persistent stratification during the summer months (dimictic) in the WCB had a $50^{th}$ percentile TP concentration of 69 ppb; whereas, lakes that stratify and de-stratify, or turn over more frequently (polymictic) had a $50^{th}$ percentile TP of 141 ppb. Clear Lake, at least in 2011, was polymictic.

During 2012, TP was generally below the eco-region standard of 65 ppm, although it was slightly higher than the standard by August. Secchi disk readings were generally lower in 2012 than they were in 2011, meaning the water was less clear in 2012 than 2011. In 2012, all of the Secchi clarity readings failed to meet the WCB eco-region standard of 0.9 m. TP was highest near the end of the 2012 summer, which may have catalyzed a simultaneous spike in Chl-a to occur. A gradual increase in Chl-a concentration in April and May coincided with a slight decrease in TP, indicating that Chl-a and TP are not always directly correlated – or that in some circumstances, TP is used in the production of phytoplankton faster than it is replenished. We secured stratification status data for our water quality sample dates, but did not complete profiles as was done in 2011.

### *4.2 Loon Lake Assessment*

Water quality data from the Loon Lake watershed could not be collected due to poorly defined inlet/outlet areas and absent flow during nearly all of the study. As a result, some available historical data were used as reference points for the watershed models. Given the availability of MPCA data for Clear Lake in 2012 and the lack of inlet-outlet monitoring for Loon Lake, we were able to intensify the in-lake sampling for Loon Lake. Loon Lake maintained abnormally low water levels in 2011 and 2012, likely due to a combination of drawdown for a lake rehabilitation project and limited precipitation. In-lake water quality samples were collected during 2011 and 2012 using the same 2011 Clear Lake methods described above.

In-lake monitoring at Loon Lake was completed from 7/19/11 to 10/25/11, and then again from 3/28/12 through 5/22/12 (Table 14). In-lake samples were taken at the deepest point found within Loon Lake (Figure 23). Vertical profiles for temperature and DO were checked on each sample collection date using a multi-parameter probe. Parameters tested in the field included Secchi disk depth (m) and laboratory samples for water quality included TP, OP, $NO_2$-$NO_3$, TSS, and Chl-a. Given that the maximum depth of Loon Lake is >2 m, the methods to collect and assess these parameters are the same as described above for Clear Lake.

#### **Seasonality**

As discussed above, nutrient loading can vary substantially across seasons and/or environmental conditions. Based on the limited data from the second half of the 2011 and first portions of the 2012 growing seasons, TP concentrations in Loon Lake decline throughout the summer and fall of 2011, and Chl-a and water clarity responded as one would expect – less chlorophyll and increased water clarity (Table 14, Figure 26). The late summer concentrations of TP in 2011are not uncommon in Minnesota's shallow lakes. Although we did not locate CLP in 2011 in Loon Lake, the TP and other parameters behaved as would be expected from a mid-summer curly-leaf die off.

Lake profiles for DO and temperature revealed limited stratification in Loon Lake (Table 15). Short periods of stratification did occur; however, profiles were checked 11 times and stratification was absent during 9 of the 11 checks. Stratification, when it did occur, followed periods of limited wind and/or precipitations events; however, the stratification was weak and the lake mixed regularly. Low DO levels were periodically present in Loon Lake and could be very problematic (Table 15). The challenge in Loon Lake is periodic anoxia that likely occurs year-round. Given the small size and shallow depths of Loon Lake, anoxia can set up and dissipate rapidly, making it very difficult to predict and manage.

Table 14. In-lake water quality data for Loon Lake, Waseca County, Minnesota for various dates in 2011 and 2012. Data secured from sampling conducted by the Water Resources Center. Parameters measured in ug/L (ppb) included chlorophyll-a (Chl-a) and total phosphorous (TP). Parameters measured in mg/L (ppm) included dissolved oxygen (DO), total Kjeldahl nitrogen (TKN), Nitrate-Nitrite-Nitrogen ($NO_2$-$NO_3$), and total suspended solids (TSS). Secchi disk water clarity measurements (m) were also completed

| Date | Chl-a (ppb) | DO (ppm) | $NO_2$-$NO_3$ (ppm) | TP (ppb) | OP (ppb) | TSS (ppm) | Secchi (m) |
|---|---|---|---|---|---|---|---|
| 7/19/2011 | 29.7 | *15.5 | < 0.2 | 324 | 68 | 20 | 0.2 |
| 8/2/2011 | 67.3 | 3.5 | <0.2 | 282 | 24 | 14 | 0.2 |
| 8/16/2011 | 168.0 | *12.7 | <0.2 | 264 | 8 | 25 | 0.2 |
| 9/13/2011 | 84.1 | 7.9 | <0.2 | 251 | 10 | 24 | 0.3 |
| 9/27/2011 | 54.0 | 7.5 | <0.2 | 222 | NA | 10 | 0.5 |
| 10/10/2011 | 2.3 | 1.9 | <0.2 | 312 | 224 | 17 | 0.6 |
| 10/25/2011 | 1.5 | 6.1 | <0.2 | 233 | 106 | 9 | 1.8 |
| 3/28/2012 | 6.2 | 9.2 | <0.2 | 81 | <5 | 7 | 0.9 |
| 4/11/2012 | 3.7 | 11.9 | <0.2 | 96 | 12 | 27 | 0.9 |
| 4/26/2012 | 9.0 | 11.6 | <0.2 | 102 | NA | 17 | 0.8 |
| 5/22/2012 | 18.0 | 4.0 | <0.2 | 140 | NA | 18 | 0.5 |

*DO concentrations were >12 ppm in the top 0.3 m of the water column and <4 ppm in the remainder of the water column on these dates.

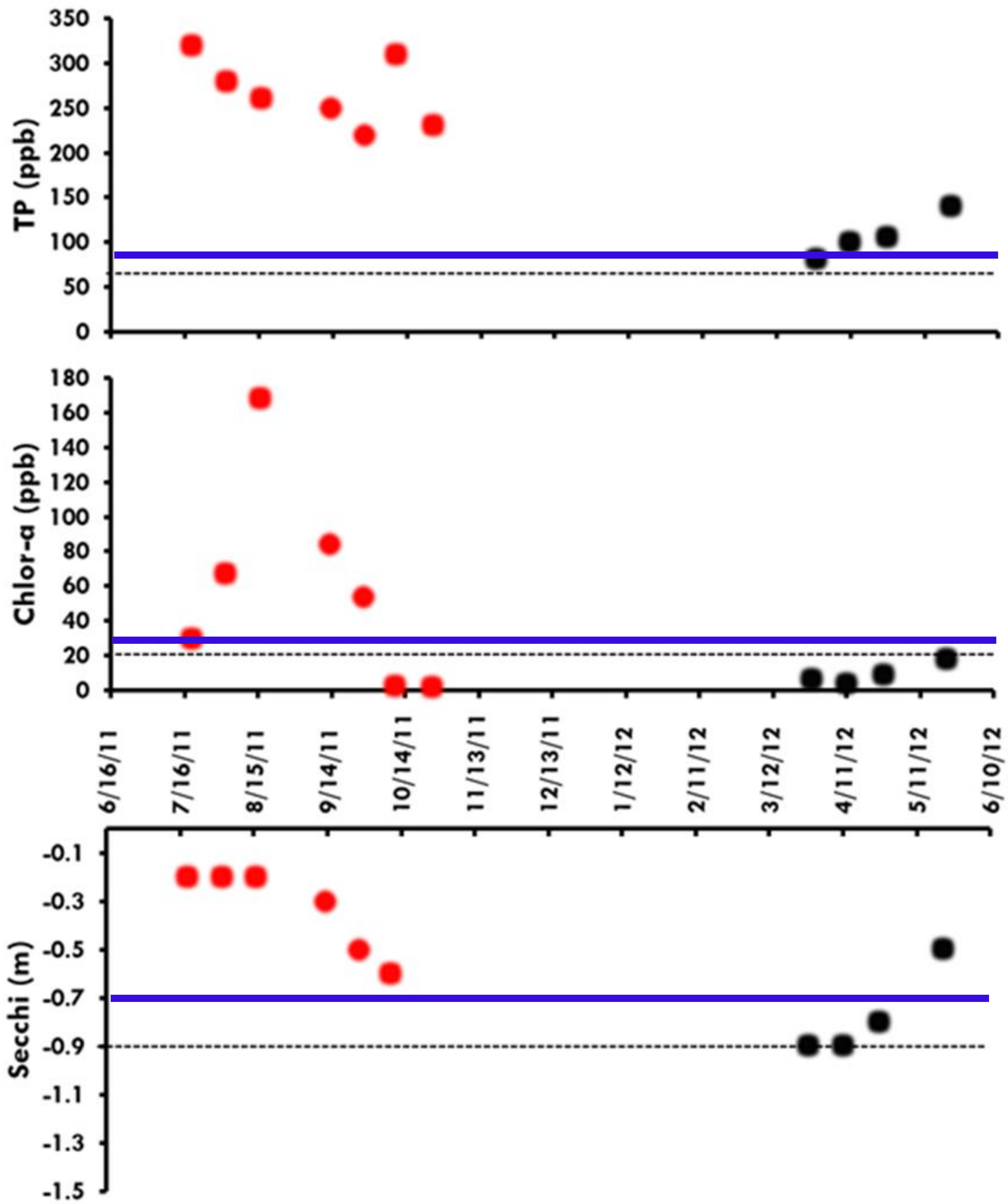



*Figure 26. The total phosphorus (TP) concentrations in parts per billion (ppb), chlorophyll-a (Chl-a) concentration (ppb), and Secchi disk water clarity readings meters (m) below the surface for Loon Lake on various dates in 2011 and 2012. The Western Cornbelt (WCB) eco-region standards of 65 ppb TP, 20 ppm Chl-a, and 0.9 m Secchi disk are denoted by the horizontal dashed lines. The WCB shallow lake standards of 90 ppb TP, 30 ppm Chl-a, and 0.7 m Secchi depth are denoted by the solid blue line. Data points in black indicate sample dates when Curly-leaf Pondweed stands were alive and in place. The red data points indicate sample dates when Curly-leaf Pondweed was senescing or absent.*

Table 15. Dissolved oxygen (DO) profiles in mg/L (ppm) for Loon Lake, Waseca County, Minnesota for various dates in 2011 and 2012. Readings <2 ppm are highlighted to depict time periods where anoxic sediment conditions could be present and catalyze the release of phosphorus.

| Dates→ | 2011 DO Profiles (ppm) | | | | | 2012 DO Profiles (ppm) | | | |
|---|---|---|---|---|---|---|---|---|---|
| Depth (m) | 7/19 | 8/2 | 8/16 | 9/27 | 10/10 | 4/11 | 4/26 | 5/10 | 5/22 |
| 0.3 | 13.2 | 3.4 | 12.7 | 7.5 | 1.9 | 11.9 | 11.6 | 7.5 | 4.0 |
| 0.6 | 3.9 | 3.2 | 11.8 | 7.3 | 1.9 | 11.6 | 12.4 | 7.6 | 4.4 |
| 0.9 | 2.5 | 2.8 | 9.5 | 7.6 | 1.9 | 11.5 | 12.4 | 6.4 | 4.4 |
| 1.2 | 2.5 | 2.5 | 7.4 | 7.6 | 1.9 | 11.7 | 12.2 | 6.2 | 4.6 |
| 1.5 | 2.4 | 2.5 | 6.4 | 7.4 | 1.9 | 11.4 | 12.3 | 6.2 | 4.9 |
| 1.8 | 2.4 | 1.6 | 3.7 | 7.1 | 1.9 | 11.4 | 12.4 | 7.2 | 4.4 |
| 2.1 | 2.2 | 1.5 | 3.2 | 7.0 | 1.9 | 11.6 | 12.3 | 6.7 | 3.3 |
| 2.4 | 2.2 | 1.6 | 2.2 | 7.0 | 1.9 | 11.4 | 12.3 | 6.4 | 2.7 |
| 2.7 | 2.1 | 1.6 | 2.3 | 6.9 | 1.8 | 11.5 | 9.2 | 0.4 | 0.5 |

The TP concentrations observed from Loon Lake in July-October 2011 were nearly 300% higher (270 ppb average) than the WCB shallow lake standard (90 ppm; Figure 26). The TP concentrations observed in the spring of 2012 were lower, but only 1 observation was below the shallow lake standard. During periods of high algae abundance, Chl-a concentrations increased and OP levels decreased. The inverse relationship between Chl-a and OP may indicate that although TP is extremely high, OP availability could actually be limiting, at least to some extent, algal production.

Secchi disk readings were generally less than (*i.e.*, poorer water quality) than the shallow lake WCB eco-region standard of 0.7 m in 2011. Water transparency improved slightly in the spring of 2012; however, by May, water clarity was trending towards values <0.7 m. Lower secchi readings were directly associated with algal blooms, and were further exasperated after wind events that stirred sediments and increased TSS.

Native emergent vegetation (above) was once abundant in the Waseca Lakes, but is now significant reduced. Emergent vegetation is critically important for processing nutrients and stabilizing shorelines.

### *4.3 Nutrient Analyses*

## Nutrient Loading and Allocation Models

**MINLEAP**

The MINLEAP model, developed by Bruce Wilson and Dr. William Walker Jr., uses the Canfield Bachmann equation (Canfield and Bachmann 1981) to predict hydrologic and eutrophication indicators (TP, Chl-a, and transparency) based on watershed, lake morphometry and ecoregion. MINLEAP requires minimal inputs and relies on ecoregion values for stream phosphorus concentration, precipitation, evaporation and runoff developed from reference lakes within each ecoregion. Because of its simplicity, MINLEAP is best thought of as a screening tool to identify lakes that have significantly different water quality than a hypothetical lake with the same characteristics (ecoregion, depth, volume). The model tests for significant differences between the observed and predicted eutrophication indicators using a t-test. This section includes several small tables that facilitate the reader to visualize the steps in the process.

**FLUX**

The FLUX Model is a program designed by hydrologists with the U.S. Army Corps of Engineer Waterways Experimental Station to estimate the load of nutrients or other water quality constituents passing a location over a given period of time (Walker 1999). The model requires grab sample concentration data and continuous (*e.g.*, daily) flow records. The FLUX Model produces graphic and tabular displays that allow users to evaluate input data and calculation results. Mass loads, and associated error statistics, from FLUX are input to BATHTUB.

**BATHTUB**

The BATHTUB model (version 6.14) was also developed by the U.S. Army Corp of Engineers and has been widely used to model nutrient balance calculations and nutrient sedimentation dynamics within lake and reservoir systems (Walker 1999). It is designed to handle simultaneous modeling and analysis of the basin to help ensure accurate representation of processes occurring within the system. The model is primarily used to perform diagnostic analysis of the current conditions of the basin and/or to predict impact of potential changes within the system.

BATHTUB generates outputs and calculates confidence levels by performing error analysis using water quality inputs. The model predicts eutrophication status based on water quality parameters including TP, total nitrogen, Chl-a, transparency, organic nitrogen, non OP, and hypolimnetic oxygen depletion rate. Outputs are predicted using empirical relationships developed and tested for in-reservoir (and in our case, in-lake) applications (Walker 1985).

The BATHTUB model allows continuous calibration by comparing predicted nutrient loading with observed data collected through the grab samples. The model can be calibrated to individual data points or all data points in a global calibration by changing model inputs such as levels of internal loading or nutrient residence time.

The model requires that all areas contributing to the lake be designated as segments or tributaries. Segments are useful when the lake has connected areas that cannot be spatially separated due to the nature of flows within the system. Tributaries allow the model to use runoff coefficients and runoff data to model nonpoint and point source data.

### Clear Lake - MINLEAP

The mean observed TP concentration for Clear Lake was not statistically significantly higher than the predicted TP concentration for lakes with similar morphometry in the WCB eco-region (Table 16). The mean observed Chl-a concentration was higher than the predicted Chl-a concentration; however, this difference was not significant. The mean secchi disk reading was lower (worse) than predicted values, but the difference was not significant. A t-test value of 2 or greater (95% confidence interval) was used to detect a significant difference.

Based solely on watershed size, lake morphology, and eco-region location, MINLEAP predicted that the average TP load to Clear Lake should be 666 kg/yr (Table 16). This is a cursory estimate that will be compared with estimates from the BATHTUB model. The MINLEAP model can then be calibrated to make predicted and observed TP match. This calibration provides a useful estimate of the nutrient load that is currently coming into Clear Lake. Based on this calibration, MINLEAP estimates that the current nutrient load to Clear Lake is 1,187 kg/year (Table 17). This initial estimate will be compared with estimates of nutrient loading from the BATHTUB model.

Table 16. Clear Lake MINLEAP predictions based on watershed size, lake morphology, and eco-region location.

| Average TP Inflow (µg/L) | TP Load (kg/yr) | Phosphorus Retention Coefficient | Lake Outflow ($hm^3$/yr) | Residence Time (years) | Areal Water Load (m/yr) |
|---|---|---|---|---|---|
| 561 | 666 | 0.90 | 1.19 | 7.7 | 0.45 |
| **Variable** | **Observed** | **Predicted** | **Std Err** | **Residual** | **T-test** |
| **TP (µg/L)** | 80 | 57 | 24 | 0.15 | 0.76 |
| **Chl-a (µg/L)** | 58.0 | 24.1 | 17.1 | 0.80 | 1.16 |
| **Secchi (m)** | 0.7 | 1.2 | 0.6 | -0.26 | -1.22 |

Table 17. Clear Lake MINLEAP predictions calibrated to the observed value.

| Average TP Inflow (µg/L) | TP Load (kg/yr) | Phosphorus Retention Coefficient | Lake Outflow ($hm^3$/yr) | Residence Time (years) | Areal Water Load (m/yr) |
|---|---|---|---|---|---|
| 999 | 1,187 | 0.92 | 1.19 | 7.7 | 0.45 |
| **Variable** | **Observed** | **Predicted** | **Std Err** | **Residual** | **T-test** |
| **TP (µg/L)** | 80 | 80 | 34 | 0.00 | 0.01 |
| **Chl-a (µg/L)** | 58.0 | 39.3 | 28.4 | 0.17 | 0.50 |
| **Secchi (m)** | 0.7 | 0.9 | 0.4 | -0.13 | -0.61 |

While MINLEAP has been demonstrated to perform well in the Northern Lake/Forest and Northern/Central Hardwood forest areas, it does not perform as well in the WCB eco-region. Lakes in the WCB exhibit high levels of internal loading/nutrient cycling and/or macrophyte (aquatic vegetation) production and require additional modeling to better understand nutrient loading of the system. The difference between the observed and predicted eutrophication indicators suggest the MINLEAP model does not account for all of Clear Lake's phosphorus dynamics. Therefore, we must employ an additional model to further address internal nutrient loading.

### Clear Lake - FLUX

Table 18 provides a summary of the flow rate, estimated nutrient, and flow-weighted mean concentrations (FWMC) from each monitored inflow site during the study. The FWMCs are calculated by dividing the total constituent load by the total flow volume. By doing so, we obtain an overall average concentration for each constituent during the monitoring period. The data in Table 18 are useful in understanding the total amount and concentrations of nutrients from various watershed areas. The FWMC data are also utilized in subsequent models.

Table 18. Flow-weighted mean concentrations for total phosphorus (TP), orthophosphorus (OP) and Nitrate-nitrite ($NO_2$-$NO_3$) in ppm (mg/L) for the three measured inlets and the one outlet at Clear Lake. Flow is represented in cubic feet per second (cfs).

| | | |
|---|---|---|
| **Area 2 (Memorial Park)** | *Average daily flow:* | *0.115 cfs* |
| | **Mass (kg)** | **FWMC (mg/L)** |
| TP | 57.4 | 0.762 |
| OP | 9.9 | 0.131 |
| $NO_2NO_3$ | 23.2 | 0.225 |
| **Area 3 (Maplewood)** | *Average daily flow:* | *0.072 cfs* |
| | **Mass (kg)** | **FWMC (mg/L)** |
| TP | 103.3 | 0.232 |
| OP | 24.2 | 0.054 |
| $NO_2NO_3$ | 955.5 | 2.14 |
| **Area 4 (Gaiter Lake)** | *Average daily flow:* | *0.68 cfs* |
| | **Mass (kg)** | **FWMC (mg/L)** |
| TP | 195.8 | 0.428 |
| OP | 84.7 | 0.185 |
| $NO_2NO_3$ | 212.3 | 0.464 |
| **Clear Lake Outlet** | *Average daily flow:* | *1.020 cfs* |
| | **Mass (kg)** | **FWMC (mg/L)** |
| TP | 114.5 | 0.178 |
| OP | 4.6 | 0.007 |
| $NO_2NO_3$ | 64.4* | 0.1* |

*$NO_2NO_3$ value were all below the <0.2 detection limit. All data points were set to 0.1 to allow FLUX to run; however, values could have been lower.

## Clear Lake - BATHTUB

Seven “tributary” areas, or subsheds, were identified in the Clear Lake model (Figure 13). The tributaries are as follows:

Area 1: West Inflow,
Area 2: Memorial Park Inlet,
Area 3: Maplewood Inlet,
Area 4: Gaiter Lake Inlet,
Area 5: Andy’s Stink,
Area 6: Clear Lake Overland Flow, and
Area 7: Septic Systems (not specifically shown on Figure 13).

The inflows from Areas 2-4 were the monitored inlet sites. These tributaries are entered in the model as “monitored inflow” and the actual data collected for these inlets were used for the model. All three inlets also have a stormwater and septic component within them based on the land use within the tributary, and that value is included in the total load coming from each inflow.

The subsheds identified as Andy's Stink, Clear Lake Overland Flow, and West Inflow are entered into the model as nonpoint sources, given that site-specific data were not collected at these locations. The load coming from each of these areas is calculated using the land use data, precipitation data, and established runoff coefficients for each land use. Phosphorus loading from the watershed was estimated from land cover and phosphorus export coefficients specific to the land covers. Land cover was divided into the categories of forest, cultivated, urban, wetland/open water and pasture/open. The medium land cover P export coefficients from the Reckhow-Simpson model were converted from kg/ha to ppb and applied to the BATHTUB model.

On-site septic systems as a point source were considered the final tributary. Phosphorus loading from septics was estimated based on the number of homes within the lake watershed that were not included in any of the monitored inflows, census data of average number of people per household, and finally using the Reckhow-Simpson model to estimate a load (Reckhow and Simpson 1980). A moderate sediment retention coefficient of 0.7 was assumed. Sediment retention coefficients generally range from 0.5 to 0.9, with well drained soils having lower coefficients (Reckhow and Simpson 1980, Robertson et al. 2003). The areas assumed to be septic were mostly on the north-eastern and northern edges of Clear Lake, where the soils are largely a mix of entisols (well-drained, Figure 10) and alfisols (more poorly drained). The soil drainage map also supported a mixture of well-drained and poorly drained soils (Figure 12).

Although multiple Reckhow analyses using "low," "most likely," and "high" estimates of the sediment retention coefficient may be used, the septic P flux was less than 25% of the total P load, so therefore only the "most likely" sediment retention coefficient value of 0.7 was used (Reckhow and Simpson 1980). A flow rate of 0.01 $hm^3/yr$ and a phosphorus concentration of 2,200 ppb were applied. While these values likely do not reflect actual conditions, applying the data forces the BATHTUB model to deliver the 22 kg P/yr that was estimated in the Reckhow-Simpson model.

The BATHTUB program uses multiple models allowing for different methods of calculating loading using the watershed and observed water quality data. The Canfield and Bachmann Lakes option yielded the best agreement with the observed in-lake phosphorus concentration. Using these model options, BATHTUB predicted TP concentrations and annual loads from external sources (Table 19).

Table 19. BATHTUB Model output compared with observed data for Clear Lake in Waseca County based on data collected from 2011 and 2012.

| Observed Mean P (µg/L) | Predicted Mean P (µg/L) | Predicted Annual P (kg) |
|---|---|---|
| 80 | 56.1 | 522 |

To model internal processes in BATHTUB, the phosphorus sedimentation coefficient can be reduced. The default BATHTUB phosphorus sedimentation coefficient of 1.0 can be adjusted to reduce sedimentation and increase in-lake phosphorus concentration. The Canfield-Bachmann Lakes model requires reducing the P sedimentation coefficient to 0.688 in order to approximate the observed conditions. The Canfield-Bachmann lakes model underestimates the observed phosphorus concentration. The discrepancy between predicted and observed is likely the result of in-lake processes. The internal load can also be modified in the model to approximate the in-lake phosphorus concentration. An internal load of 0.517 $mg/m^2$ per day within the Canfield-Bachmann lakes model results in an estimated lake phosphorus concentration matching the observed lake condition of 80 µg/L (Table 20).

Table 20. Predicted annual phosphorus loading with additional internal phosphorus loading included for Clear Lake in Waseca, Minnesota.

| Observed Mean P (µg/L) | Predicted Mean P (µg/L) (with additional internal load) | Predicted Annual P (kg) (with additional internal load) |
|---|---|---|
| 80 | 80 | 998 |

The internal load values used to calibrate the models are similar to values computed in several Wisconsin lake studies where the estimated senescence of CLP contributed 0.87 mg P/m$^2$–day and bottom sediments released 1.38 mg P/m$^2$ –day in Wisconsin's Big Chetek Lake. James and Owens (2006) observed anoxic sediment P release rates within a range of 0.1 to 2.9 mg P/m$^2$–day in Shawano Lake.

The Clear Lake nutrient budget does not have independent measurements of internal phosphorus loading. Therefore, it is not possible to fully quantify the internal phosphorus dynamics within Clear Lake. Rather this modeling exercise illustrates the relative importance of internal processes in Clear Lake with respect to the observed water quality overall. The internal component can be placed into perspective with the watershed tributary areas.

Based on the modelling results, the Gaiter Lake Inlet (Area 4) remains a large contributor (19.3%) of the annual Clear Lake TP load (Table 21), followed by Area 3, the Maplewood Inlet, contributing an estimated 10% of the annual TP load. The remaining areas ranged from 1.6 to 5.6%.

Overall, an estimated 37.0% of the annual phosphorus load could be attributed to tributary in-flow, with 8.4% associated with non-point sources, and 7.5% coming in with precipitation. The internal load estimate was significant at approximately 47.1% of the annual TP load (Table 21). The high loading rates, including internal cycling of P, continues to present a very difficult management challenge for Clear Lake – as there remains significant loading coming into the lake, with only a very small percentage leaving from the outlet (3.1%). Therefore, 96.9% of the annual load remains in the Lake each year. It should be noted, however, that a substantial portion of this load is being taken up from the lake itself, utilized in the nutrient cycles, and then returned to the annual load.

A moderate to large amount of internal load would be required to produce the observed current lake conditions. It appears to be a reasonable assumption given the large internal phosphorus concentration variability associated with annual CLP and the on-going decay of rich organic sediments fed by dead invasive plant materials. Therefore, the Canfield-Bachmann Lakes model with 0.517 mg P/m$^2$–day additional internal load was used to model observed conditions in Clear Lake. As internal load appears to be a significant contributor of phosphorus to the lake (nearly 50% annually), in-lake strategies must be a major component of any plans to meet improved water quality goals. However, for the long term health of Clear Lake, all potential sources of phosphorus should be addressed. External inputs must be curbed before significant expenditures are implemented to manage internals loads.

To estimate the phosphorus loading capacity of Clear Lake, loads were reduced until the estimated in-lake phosphorus concentration matched the standard concentration (Table 22). To accomplish the load reduction, internal load was reduced from 0.517 mg P/m$^2$–day to 0.175 mg P/m$^2$–day.

Table 21. Total phosphorus annual load allocations for Areas identified around Clear Lake. Values were derived from a BATHTUB model with 2011 and 2012 data. Additional loading from internal sources, precipitation, and other non-point origins are also noted.

| ***Tributary Area*** | **Loading kg/yr** | **Percentage %** |
|---|---|---|
| Area 1: West Inflow | 16.8 | 1.6 |
| Area 2: Memorial Park Inlet | 57.4 | 5.6 |
| Area 3: Maplewood Inlet | 103.3 | 10.0 |
| Area 4: Gaiter Lake Inlet | 198.6 | 19.3 |
| Area 5: Andy's Stink | 26.0 | 2.5 |
| Area 6: Clear Lake Overland Flow | 43.3 | 4.2 |
| Area 7: Septic Systems | 22.0 | 2.1 |
| ***Additional loading*** | | |
| PRECIPITATION | 77.1 | 7.5 |
| INTERNAL LOAD | 485.1 | 47.2 |
| TRIBUTARY INFLOW | 381.3 | 37.0 |
| NONPOINT INFLOW | 86.1 | 8.4 |
| ***Total Loading*** | | |
| ***TOTAL INFLOW | 1029.6 | 100.0 |
| ADVECTIVE OUTFLOW | 32.1 | 3.1 |
| ***TOTAL OUTFLOW | 32.1 | 3.1 |
| *****RETENTION** | **997.5** | **96.9** |

A moderate to large amount of internal load would be required to produce the observed current lake conditions. It appears to be a reasonable assumption given the large internal phosphorus concentration variability associated with annual CLP and the on-going decay of rich organic sediments fed by dead invasive plant materials. Therefore, the Canfield-Bachmann Lakes model with 0.517 mg P/m$^2$–day additional internal load was used to model observed conditions in Clear Lake. As internal load appears to be a significant contributor of phosphorus to the lake (nearly 50% annually), in-lake strategies must be a major component of any plans to meet improved water quality goals. However, for the long term health of Clear Lake, all potential sources of phosphorus should be addressed. External inputs must be curbed before significant expenditures are implemented to manage internals loads.

To estimate the phosphorus loading capacity of Clear Lake, loads were reduced until the estimated in-lake phosphorus concentration matched the standard concentration (Table 22). To accomplish the load reduction, internal load was reduced from 0.517 mg P/m$^2$–day to 0.175 mg P/m$^2$–day.

Table 22. Estimated Clear Lake phosphorous loading capacity to achieve the Western Cornbelt Ecoregion standard

| Observed Mean TP (µg/L) | TP Standard (µg/L) | Annual Load Capacity to Meet Standard (kg) (Canfield Bachmann Lakes Model) |
|---|---|---|
| 80 | 65 | 683 |

If we apply the current state of Minnesota Total Maximum Daily Load standards to our model, we would also provide for a 10% margin of safety (MOS). Therefore, the total maximum annual phosphorus load was reduced by 10%, yielding an annual maximum load of 614.37kg P/yr. Annual and daily load capacities are shown in Table 23. Based on the model, the total annual phosphorus load that would allow Clear Lake to meet standards is 1,354.454 lbs/year, or approximately 3.71 lbs/day.

Table 23. Annual and daily phosphorus loading capacity estimates to achieve the Western Cornbelt Ecoregion standard for Clear Lake.

| Annual P Load Capacity | | Daily P Load Capacity | |
|---|---|---|---|
| (kg/yr) | (lbs/yr) | kg/day | lbs/day |
| 614 | 1,354 | 1.68 | 3.71 |

In developing the lake nutrient standards for Minnesota lakes (Minn. Rule 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (Heiskary and Wilson 2008). Clear relationships were established between the causal factor total phosphorus and the response variables Chl-a and Secchi disk. Based on these relationships it is expected that by meeting the phosphorus target of 65 µg/L for Clear Lake the Chl-a and Secchi standards (22 µg/L and 0.9 m, respectively) would also likely be achieved.

### Loon Lake - MINLEAP

The mean observed TP concentration for Loon Lake was higher than predicted TP concentration for lakes with a similar morphometry to Loon Lake in the WCB eco-region; this difference was statistically significant (Table 24). The mean observed Chl-a concentration was also higher than the predicted Chl-a concentration; however, this difference was not statistically significant. The mean secchi disk reading was also lower (worse) than predicted values; the difference was not statistically significant. A t-test value of 2 or greater (95% confidence interval) was used to detect a significant difference.

Based solely on watershed size, lake morphology, and eco-region location, MINLEAP predicted that the average TP load to Loon Lake would be 115 kg/yr. This number is a cursory estimate; however it can be used to compare and contrast with estimates from the BATHTUB model.

The MINLEAP model can also be calibrated such that predicted TP concentrations match observed TP concentrations. This calibration provides a useful estimate of the nutrient load that is currently coming into Loon Lake. Based on this calibration, MINLEAP estimates that the current nutrient load to Loon Lake is 598 kg/year. This initial estimate will be compared with estimates of nutrient loading from the BATHTUB model.

Table 24. Loon Lake MINLEAP predictions based on watershed size, lake morphology, and eco-region location.

| Average TP Inflow (µg/L) | TP Load (kg/yr) | Phosphorus Retention Coefficient | Lake Outflow ($hm^3$/yr) | Residence Time (years) | Areal Water Load (m/yr) |
|---|---|---|---|---|---|
| 560 | 115 | 0.86 | 0.21 | 3.8 | 0.40 |
| **Variable** | **Observed** | **Predicted** | **Std Err** | **Residual** | **T-test** |
| **TP (µg/L)** | 210 | 80 | 32 | 0.42 | 2.21 |
| **Chl-a (µg/L)** | 40.3 | 39.4 | 27.2 | 0.01 | 0.03 |
| **Secchi (m)** | 0.6 | 0.9 | 0.4 | -0.15 | -0.74 |

Table 25. Loon Lake MINLEAP predictions calibrated to the observed value.

| Average TP Inflow (µg/L) | TP Load (kg/yr) | Phosphorus Retention Coefficient | Lake Outflow ($hm^3$/yr) | Residence Time (years) | Areal Water Load (m/yr) |
|---|---|---|---|---|---|
| 2,906 | 598 | 0.93 | 0.21 | 3.8 | 0.40 |
| **Variable** | **Observed** | **Predicted** | **Std Err** | **Residual** | **T-test** |
| **TP (µg/L)** | 210 | 210 | 91 | -0.00 | -0.01 |
| **Chl-a (µg/L)** | 40.3 | 162.8 | 118.3 | -0.61 | -1.80 |
| **Secchi (m)** | 0.6 | 0.4 | 0.2 | 0.21 | 0.99 |

## Loon Lake - BATHTUB

Six subsheds were identified in the Loon Lake model (Figure 13) and were identified as follows:

Area 1: Hwy 14,
Area 2: East Inflow,
Area 3: North Inflow,
Area 4: Overland Flow,
Area 5: Ag-Train Area, and
Area 6: Alum Treatment.

Similarly to Clear Lake, the observed mean P was higher than the mean P predicted by the Canfield Bachman model (Table 24). The Canfield Bachmann Lakes model required reducing the P sedimentation coefficient to 0.447 in order to approximate the observed conditions. Alternatively, an additional internal load of 1.45 mg/$m^2$/day (Table 25). After calibrating the model with the additional internal load, the predicted annual load was 364.1 kg P/year (Table 25). The BATHTUB model determined that most of the phosphorus load in Look Lake was due to internal loading, and found that the Alum Treatment Subshed (overland flow) contributed 14.2% of the load, the highest of the nonpoint sources (Table 26).

The annual loading capacity required to meet the TP standard of 90 µg/L was calculated to be 121.9 kg P/year (Table 21). To achieve the TP standard, the additional internal phosphorus load to Loon Lake was reduced from 1.45 mg P/$m^2$–day to 0 mg P/$m^2$–day, and the phosphorus sedimentation coefficient was increased to 1.274.

To provide for a 10% MOS, the total maximum annual phosphorus load was reduced by 10% yielding an annual maximum load of 109.7 kg P/yr (241.8 lbs/year). Annual and daily load capacities are shown in Table 22. Based on the model, the total daily phosphorus load that would allow Loon Lake to meet the TP standard is 0.300 lbs/day (0.662 lbs/day).

Table 26. BATHTUB Model output compared with observed data for Loon Lake in Waseca County based on data collected from 2011 and 2012.

| Observed Mean P (µg/L) | Predicted Mean P (µg/L) | Predicted Annual P (kg) |
|---|---|---|
| 210 | 111 | 118 |

Table 27. Predicted annual phosphorus loading with additional internal phosphorus loading included for Loon Lake in Waseca, Minnesota.

| Observed Mean P (µg/L) | Predicted Mean P (µg/L) (with additional internal load) | Predicted Annual P (kg) (with additional internal load) |
|---|---|---|
| 210 | 210 | 364 |

Table 28. Total phosphorus annual load allocations for Areas identified around Loon Lake. Values were derived from a BATHTUB model with 2011 and 2012 data. Additional loading from internal sources, precipitation, and other non-point origins are also noted.

| ***Tributaries*** | **Loading kg/yr** | **Percentage %** |
|---|---|---|
| Hwy 14 Subshed | 28.1 | 7.0 |
| East Inflow Subshed | 3.3 | 0.8 |
| North Inflow Subshed | 4.4 | 1.1 |
| Overland Flow | 18.2 | 4.5 |
| Ag Train Subshed | 12.2 | 3.0 |
| Alum Treatment Subshed | 57.2 | 14.2 |
| ***Additional loading*** | | |
| PRECIPITATION | 15.0 | 3.7 |
| INTERNAL LOAD | 264.3 | 65.6 |
| NONPOINT INFLOW | 123.4 | 30.7 |
| ***Total Loading*** | | |
| ***TOTAL INFLOW | 402.7 | 100.0 |
| ADVECTIVE OUTFLOW | 38.6 | 9.6 |
| ***TOTAL OUTFLOW | 38.6 | 9.6 |
| ***RETENTION** | **364.1** | **90.4** |

Table 29. Estimated Loon Lake phosphorous loading capacity to achieve the Western Cornbelt Ecoregion standard.

| Observed Mean TP (µg/L) | TP Standard (µg/L) | Annual Load Capacity to Meet Standard (kg) (Canfield Bachmann Lakes Model) |
|---|---|---|
| 210 | 90 | 122 |

Table 30. Annual and daily phosphorus loading capacity estimates to achieve the Western Cornbelt Ecoregion standard for Loon Lake.

| Annual P Load Capacity | | Daily P Load Capacity | |
|---|---|---|---|
| (kg/yr) | (lbs/yr) | kg/day | lbs/day |
| 110 | 242 | 0.30 | 0.66 |

Lake nutrient standards for Minnesota lakes (Minn. Rule 7050) are based on a cross-section of lakes within each ecoregion (Heiskary and Wilson 2008). Relationships were established between the causal factor TP and the response variables Chl-a and secchi disk that suggested by meeting the 90 µg/L TP target, Chl-a and Secchi standards (30 µg/L and 0.7 m) will also be achieved.

### *4.4 Additional Factors to Consider for Loon Lake*

There are two variables that have not yet been accounted for in the Loon Lake calculations, and have the potential to influence the TP goals established: 1) use of the alum treatment facility and 2) TP inputs from waterfowl. Waterfowl fecal matter and regular alum treatments are not considerations at this time for Clear Lake, but are worthy of additional contemplation for Loon Lake.

#### Alum Treatment

With a goal of reducing external inputs of TP to Loon Lake by 66%, the alum treatment facility began full operation in 1992. Alum dosing of stormwater inflows to Loon Lake occurred from 1992-2000, 2002-2004, and again in 2014 (data from City of Waseca). Although alum was used in 2001 and 2005-2008, the records are incomplete and the actual amount of alum administered cannot be verified. From 2007-2012, the treatment facility was used for sanitary sewer treatment (no alum) and malfunctions shut the system down in 2013. McComas and Stuckert (1998) evaluated the alum treatment performance, but noted that design limitations and computational errors reduced alum delivery by 53%. The average TP removed was <5%, with the amount dependent on the nature of the stormwater events. More information is available in McComas and Stuckert (1998).

No alum treatments occurred in 2011 and 2012, the data collection years within this evaluation. Therefore, it stands to reason that the external TP loading could be adjusted to deduct for the reductions in TP from the alum treatment. Given that the alum treatment, however, is a remediation tool that must be applied annually, and its benefits cease when not in operation, TP reductions from alum treatments should also be attributed to load reduction efforts each year. McComas and Stuckert (1998) indicated that for every 100 gallons of alum, approximately 1 kg of phosphorous could theoretically be inactivated. From 1992-1997, an average of 897 gallons of alum were dosed annually, and an estimated 9 kg/yr TP were inactivated. The use of alum treatments to reduce Loon Lake TP loading is further discussed in the “Reduction Strategies” section below.

#### Phosphorous Loading from Waterfowl

Loon Lake is heavily utilized by waterfowl, particularly Canada Geese, in the winter months while open water is being maintained by the aeration system. Research has suggested that geese can produce 0.45-0.50 g of phosphorous per bird per day (*e.g.*, Don and Donavan 2002, Gaddis and Voinov 2010, and Chaichana et al. 2010). Nutrient loading from avian fecal materials, however, is highly debated (*e.g.*, Unckless and Makarewicz 2007) and is believed to vary substantially from lake to lake. Hahn et al. (2008) suggested that lake morphology, the existence of other external TP sources, and the concentration and duration of geese are important factors affecting the relative importance of the TP loading from geese (Moore et al. 2009).

Canada geese readily become year-round residents, such as shown here, when lake aerators maintain open water conditions.

The production of fecal matter by geese is not arguable, but the assignment of the phosphorous associated with bird droppings to either internal or external loading has been a point of disagreement. Scherer et al. (1995) made the assumption that phosphorous from geese feces was part of the internal cycling, as there was a paucity of food in the vicinity of the lake because of its urban setting. However, most other studies did not make this assumption, and instead viewed waterfowl feces as an external source due to feeding that occurred on surrounding lands, with feces deposited in the lake (e.g., Manny et al. 1994 and Pettigrew et al. 1998). As it was outside of the original scope of this study, we do not have sufficient information to determine if phosphorous from waterfowl in Loon Lake should be classified as autochthonous (coming from within) or allochthonous (coming from outside).

Unckless and Makarewicz (2007) suggested that the actual loading of TP from geese may not be critical as it typically sinks to the bottom in a relatively solid form. Therefore, as fecal matter becomes part of the sediment, decomposition associated with low oxygen levels becomes the catalyst for TP release and dictates the degree to which the droppings may be a problem. If TP from waterfowl fecal materials is classified as internal loading, the model output remains valid, as the internal loading estimate would be inclusive of all TP sources cycling in the lake. If classified as external loading, model parameters and output would need further consideration. In this case, if/when geese leave the lake to feed, they are not likely ingesting items from within the Loon Lake watershed, as it is mostly urban. The geese have ready access to thousands of acres of agricultural fields in close proximity because of the small size of the Loon Lake watershed. Therefore, some TP external loading could be sourced from a broader region, but not necessarily included in the precipitation allocation that represents inputs from broader atmospheric releases.

If TP from sources outside of the lakeshed are contributing factors, adjustments may be needed to the allocations. If we want to know the true nature of TP from fecal matter of waterfowl, documentation of flock feeding behaviors, movement, densities, and time spent on the lake would be needed and could be an entire study in itself. Unofficial counts of geese around the perimeter of and in the lake aeration hole of Loon Lake were conducted in January and February of 2013. The rather conservative estimated number of geese ranged from approximately 2,100 to 4,900 individuals per day, with an average of 3,200. Although it remains undetermined how, or if, TP from goose fecal matter should be applied to the Loon Lake TP budget, the question of their potential impact is valid. Therefore, it is possible to estimate the potential TP cycling through and/or being contributed by resident Canada geese on Loon Lake using the following data:

- 0.45 to 0.50 g TP/goose/day (will use 0.475 mid-point),
- 32-day span from first to last goose number estimation period, and
- Average of 3,200 geese estimated per day.

The calculation is as follows:

**(0.475 g TP/goose/day) * (3,200 geese) = 1,520 g TP/day,**

**(1,520 g TP/day) * (32-day observation period) = 48,640 g TP in observation period, and**

**48,640 g TP converts to 48.64 kg TP.**

The calculation above is an academic exercise for the sake of discussion, and should not be cited or used in regulatory decisions. The estimate, however, is worthy of future consideration, as it potentially represents conservative estimates of more than 18% of the annual internal loading and 35% of the combined nonpoint flow and precipitation external loading.

### 4.5 Nutrient Reduction Summaries and Goals

#### Clear Lake

Based on available data, the models anticipated the background TP loading for Clear Lake to be between 522 and 666 kg/yr. The MINLEAP and BATHTUB Models also estimated an actual TP load of 998 and 1,187 kg/yr (78 to 91% higher than anticipated). The BATHTUB model predicted that 52.8% of the annual TP load was from external sources and 47.2% came from internal loading. Internal loading was the single most significant TP source. The subsheds estimated to contribute the greatest TP to the annual load were Gaiter Lake (19.3%) and Maplewood (10.0%).

The loading capacity of Clear Lake has been greatly exceeded for decades, resulting in substantial sediment TP accumulations. Internal TP loading has been further exacerbated by both floral and faunal invasive species. To meet the 65 µg/L TP water quality standard, comply with state rules, and include a 10% MOS, **the Clear Lake TP goal is 614 kg/yr (31.6 to 42.5% reduction).** The 65 µg/L TP water quality standard equates to a $TSI_{TP}$ of 64. Since 1979, data suggest that several growing seasons have had $TSI_{TP}$ values $\leq$64, including 1996, 1997, and 2012 (Table 31). Seasonality of TP infusions is evident, and therefore reduction strategies can be targeted.

Table 31. Trophic-state indices (TSI; Carlson 1977) based on chlorophyll-a (Chl-a) concentrations (µg/L), total phosphorous (TP) concentrations (µg/L), and secchi depth readings (m) for historical data and dates sampled in 2011-2012 for Clear Lake, Waseca County. The composite (comp) averaged TSI for Chl-a, TP, and secchi combined is also included. Target TSI values for lakes in the Western Cornbelt Ecoregion, are also denoted. Values in **bold** print exceed the target values.

| May-September Average TSI Values | | | | | Daily TSI Values During Study | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Year(s)** | **$TSI_{Chl-a}$** | **$TSI_{TP}$** | **$TSI_{Secchi}$** | **$TSI_{comp}$** | **Date** | **$TSI_{Chl-a}$** | **$TSI_{TP}$** | **$TSI_{Secchi}$** | **$TSI_{comp}$** |
| 1979-1982 | **68** | **71** | 61 | **67** | 5/16/11 | 58 | 59 | 62 | 59 |
| 1990 | 56 | 63 | 52 | 57 | 6/22/11 | 57 | **65** | 59 | 60 |
| 1996 | **65** | 64 | **65** | **65** | 7/26/11 | **77** | **74** | **73** | **75** |
| 1997 | 59 | 57 | 36 | 51 | 8/17/11 | **75** | **80** | **77** | **77** |
| 2011* | **68** | **71** | **69** | **69** | 9/22/11 | **72** | **79** | **73** | **75** |
| 2012* | **67** | 55 | **67** | 63 | 5/2/12 | 55 | 54 | 60 | 56 |
| | | | | | 6/5/12 | 61 | 51 | 57 | 56 |
| **TSI values based on 2011-2012 data from Table 13.* | | | | | 7/9/12 | **68** | 46 | **73** | 62 |
| *Target Values* | | | | | 8/15/12 | **74** | **66** | **70** | **70** |
| *for Clear Lake* | *61* | *64* | *62* | *62* | 9/18/12 | **77** | 60 | **73** | **70** |

#### Loon Lake

The Loon Lake models anticipated background TP loading levels of 115 to 118 kg/yr. The MINLEAP and BATHTUB models, however, estimated the actual Loon Lake TP load at 598 and 364 kg/yr (308 to 520% higher than anticipated). The BATHTUB model predicted that 34.4% of the annual TP load was from external sources, whereas 65.6% came from internal loading. Therefore, internal loading is the most significant TP source for Loon Lake at 264.3 kg/yr. Estimated external loading from the Alum Treatment Subshed and Hwy 14 Subsheds were still substantial at 57.2 and 28.1 kg/yr (21.2% of the annual TP load combined).

The loading capacity of Loon Lake has been substantially inundated and thus the high internal loading rates. To meet the 90 µg/L TP shallow lake water quality standard, comply with state rules, and have a MOS, **the Loon Lake TP goal is 110 kg/year (69.8 to 81.6% reduction).** The 90 µg/L

TP water quality standard for shallow lakes (as compared to the 65 µg/L TP standard for deeper lakes) equates to a $TSI_{TP}$ of 69. Since 1981, $TSI_{TP}$ values have exceeded the target value. The $TSI_{TP}$ values >80 indicate strong eutrophication moving into a hypereutrophic state (e.g., $TSI_{TP}$ values >84 for nearly all of 2011 (Table 32). Unlike the seasonality documented for Clear Lake, Loon Lake maintained TP levels above the standard throughout the year (Table 32), suggesting that TP cycling is problematic in the winter too.

Table 32. Trophic-state indices (TSI; Carlson 1977) based on chlorophyll-a (Chl-a) concentrations (µg/L), total phosphorous (TP) concentrations (µg/L), and secchi depth readings (m) for historical data and dates sampled in 2011-2012 for Loon Lake, Waseca County. The composite (comp) averaged TSI for Chl-a, TP, and secchi combined is also included. Target TSI values for shallow lakes in the Western Cornbelt Ecoregion, are also denoted. Values in **bold** exceed target values.

| May-September Average TSI Values | | | | | Daily TSI Values During Study | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Year(s)** | **$TSI_{Chl-a}$** | **$TSI_{TP}$** | **$TSI_{Secchi}$** | **$TSI_{comp}$** | **Date** | **$TSI_{Chl-a}$** | **$TSI_{TP}$** | **$TSI_{Secchi}$** | **$TSI_{comp}$** |
| 1981-1982 | **65** | **82** | 52 | 66 | 7/19/11 | 64 | **88** | **83** | **78** |
| 1990 | **65** | **83** | **77** | **75** | 8/2/11 | **72** | **86** | **83** | **80** |
| 1992-1995 | 62 | **74** | 52 | 63 | 8/16/11 | **81** | **85** | **83** | **83** |
| 1996-1997 | **67** | **76** | 55 | 66 | 9/13/11 | **74** | **84** | **77** | **78** |
| 2011-2012* | **67** | **81** | **67** | **72** | 9/27/11 | **70** | **82** | **70** | **74** |
| 2011-2012** | **70** | **83** | **78** | **77** | 10/10/11 | 39 | **87** | **67** | 64 |
| | | | | | 10/25/11 | 35 | **83** | 52 | 56 |
| **TSI values based on 2011-2012 data from Table 14.* | | | | | 3/28/12 | 48 | 68 | 62 | 59 |
| ***Based on May-September 2011-2012 data from Table 14.* | | | | | 4/11/12 | 43 | **70** | 62 | 58 |
| *Target Values* | | | | | 4/26/12 | 52 | **71** | 63 | 62 |
| *for Loon Lake* | 64 | 69 | 65 | 66 | 5/22/12 | 59 | **75** | **70** | **68** |

## The primary objective to improve the Waseca Lakes continues to be <u>phosphorous reduction</u>!

## The challenge is to identify and achieve <u>meaningful</u> phosphorous abatement strategies!

# 5.0 CATALYZING IMPROVED CONDITIONS IN THE WASECA LAKES

Nutrient reduction initiatives, with wide-ranging results, have been attempted in numerous lake environments across North America and Europe. Unfortunately, there are many nuances associated with each individual lake system, and strategies proven to be effective in one lake system, may fail miserably in others. In addition, approaches to manage excess nutrients in surface waters inevitably vary based on community priorities, available funding, scientific feasibility, and regulatory limitations. Therefore, it is always best to at least consider a broad and inclusive set of potential options to address lake needs.

Efforts to address excess phosphorous that leads to increased levels of Chl-a and decreased water clarity are diverse; however, most are variants of several foundational management approaches. Phosphorous reduction strategies can largely be grouped into three categories for the purpose of this report:

1) Civic Engagement and Local Government Unit (LGU) Leadership,
2) Watershed Approaches, and
3) In-Lake Strategies.

In the sections below, brief descriptions of phosphorous reduction tools, strategies, and practices are provided. Please note that this section includes options that have potential applications to the Waseca Lakes, however, the feasibility of each option has not been fully addressed.

## *5.1 Civic Engagement and LGU Leadership*

Successful management of environmental features hinges on public support, citizen participation, and visionary LGU leadership. Given that human activity is a significant driver of current and future lake conditions, actions taken by citizens can be a powerful component in achieving goals. Shandas and Messer (2008) noted that successful community-based environmental stewardship programs have several common characteristics, including

- flexibility that allows for innovation and accommodation in the planning process,
- completion of projects initiated by the public,
- includes projects that are physically close and visible, and
- developing partnerships with local educational institutions.

In the case of Waseca, there are many fully engaged citizens already, however, success requires that a majority of community members are not only aware of, but are engaged in the solutions. Shandas and Messer (2008) also identified three key questions that should be included in the evaluation of civic engagement options.

1) Within each practice, are there feasible and identifiable pathways to allow citizens to become more involved in the stewardship of their local watershed?

2) Can an optimal mix of local technical expertise, voluntary community involvement, and regulatory enforcement be achieved?

3) What changes to and allowances from local governing units and public agencies would be needed to improve community involvement in environmental stewardship?

Engaging the public in lake management requires strong LGU leadership, because hard decisions often need to be made. However, when done transparently and inclusively, leaders can build rapport among residents, government officials, and interest groups. The development of trust among the interested parties if foundational for real improvements to be achieved. Urban watershed management is often rooted in "perception" management to balance citizen desires, ecological potential, and financial constraints to restore and protect important local resources. Baumann et al. (2013) suggested that strong local support for strict enforcement of state rules and local ordinances must be in place.

We have categorized Citizen Engagement and LGU Actions that have successfully contributed to lake management into three areas:

1) Public Relations and Outreach Initiatives,
2) Incentive Programs, and
3) LGU Actions.

Various potential options that fall under each of these broad approaches are included in the following discussion.

### Public Relations and Outreach Initiatives

<u>Interpretive Signage</u>

Investment in public information signage serves a number of purposes, and if done correctly, can be an important component of an encompassing lake restoration and protection program. Based on recommendations from several naturalist organizations, tourism bureaus, and environmental education specialists, interpretive signs could benefit the Waseca Lakes Area in several ways.

1) Interpretive signs highlight community priorities and demonstrate the level of significance placed on certain resources, activities, and/or goals.
2) Interpretive panels are more than just facts, but can also inspire individuals to improve stewardship, increase awareness, and generate community pride.
3) Interpretive signage is passive, always available, and works for the betterment of the lakes without regular involvement of staff or need for facilities.
4) Signage, when properly planned, delivers a consistent message to visitors, and serves as a regular reminder about community priorities to locals.
5) High quality interpretive panels help create the desired environment, perception, and attitudes around lake management needs and civic responsibilities.
6) By drawing attention to the value of the Waseca Lakes, and the challenges these water bodies face, readers appreciate these resources more.

The development of signage should be guided by a public relations professional with experience in natural resources. There are many available resources that overview guidelines for development of interpretive signs, including the examples listed below.

http://www.nrsrcaa.org/interp/manual/finalpdfs/Section4revised.PDF
http://history.sd.gov/preservation/OtherServices/CHTInterpretiveSignRecommendations.pdf
http://www.americantrails.org/resources/wildlife/Interpretive-trail-signs-exhibits.html

<u>Adopt-a-Lake Program</u>

The MDNR has managed an Adopt-a-River program for more than 20 years (http://www.dnr.state.mn.us/adoptriver/details.html). An adopt-a-lake program would directly provide an opportunity for the community to get involved with lake and watershed clean-up efforts, and by engaging various community groups, will help connect people to the lakes.

Adopt-a-lake programs have been successfully implemented in many areas. Examples of such programs that particularly focus on urban lakes can be reviewed at the links below:

http://www.lakelandgov.net/publicworks/lakes-stormwater/participate/volunteer-lake-programs
http://lakemorton.org/adopt-a-lake/
http://science.kennesaw.edu/~jdirnber/aal/

Youth Programs

The young people of Waseca have substantial potential to serve as valuable partners in lake restoration programs. Youth can be very persuasive, and regularly make a difference in nearly all programs in they engage. Young people, however, need encouragement and support of trusted enthusiastic leaders. The University of Wisconsin Extension Service lays out a solid approach to get youth involved in environmental stewardship (http://www.uwex.edu/erc/cesyes/engagingfactsheet.pdf). Not only can young people impact lake improvement success immediately, the investment in future leaders and environmental stewards cannot be understated.

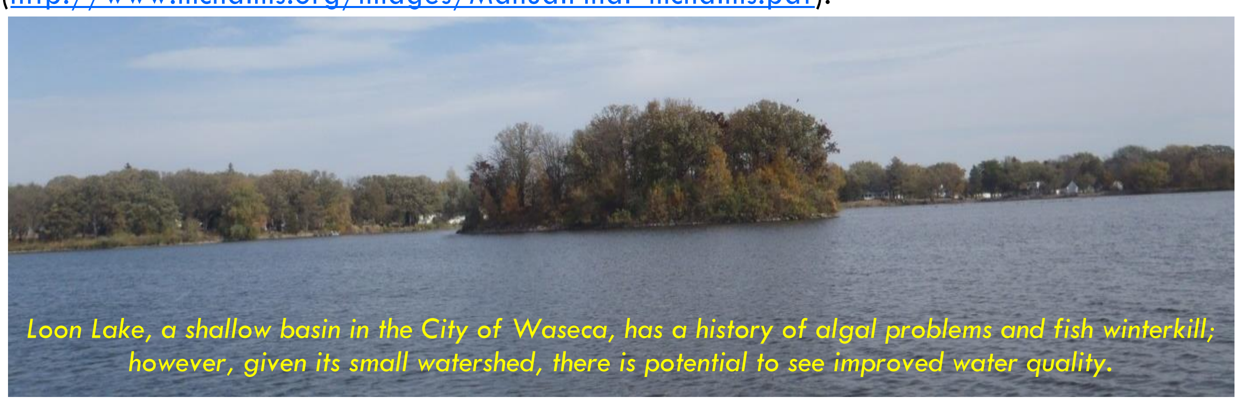
Youth programs come in a wide range of approaches and many entities (e.g., LWSB 2006) views awareness-building in future generations critical to progress. The following resource links introduce several existing programs.

http://www.miwaterstewardship.org/youthstewards
http://ruralaction.org/programs/environmentaled/youth-environmental-stewardship-program/
http://edis.ifas.ufl.edu/fr120

Implement and Grant Authority to a Lakes Management Commission

Advisory groups have been part of the lake management efforts in the City of Waseca for more than 30 years. The WLA has informally filled a citizen advisory role for many years; however, the success of a Lake Management Board, Council, or Commission depends not only on the group's composition, but also on the level of LGU support and the degree to which it has authority to make decisions.

There are numerous potential structures that could be utilized for a lake management entity associated with local government. The Michigan Chapter of the North American Lake Management Society developed a comprehensive overview of these structures and the value of lake management commissions in 2012 (http://www.mcnalms.org/images/ManualFinal_mcnalms.pdf).



*Loon Lake, a shallow basin in the City of Waseca, has a history of algal problems and fish winterkill; however, given its small watershed, there is potential to see improved water quality.*

According to Stengel Solutions (2003), advisory boards typically have no authority over funding decisions and recommendations are non-binding. Experience has demonstrated that advisory boards often do not feel valued, and their recommendations are often routinely ignored. Successful environmental commissions, on the other hand, have granted authority and tend to have several common traits, including

- a clear directive with well-defined authorities and scope,
- representation by those that are problem solvers,
- meeting frequently enough to demonstrate issue importance and maintain momentum,
- fair compensation of members for their time,
- a professional support person within the LGU to serve as coordinator,
- an environment conducive to honest discussions and non-attacking debates,
- respect of the commission's decisions that are within their granted authority, and
- defined terms and duties for board members with criteria for dismissal.

### Incentive Programs

Incentive programs are diverse and can be crafted to meet very specific community needs. The use of incentives promotes innovative approaches and facilitates flexibility in BMP implementation. Incentive programs are not use independently, but rather become part of a broader LGU approach that includes engineered solutions, reward programs, and regulatory actions (WERF 2009).

<u>Rewarding Lake Stewardship</u>
The beauty of incentive programs is that the approach does not punish anyone, but rather rewards those that have completed certain improvements and/or met other criteria. Examples of incentive programs from are listed below.

1) Landowners that reduce impervious surface and/or manage substantial amounts of stormwater on site would qualify to receive a <u>fee discount</u> on their utility bills.

2) Municipals can offer <u>development incentives</u>, such as planning and zoning exemptions, fee waivers, etc... when development projects include significant measures to protect water quality.

3) Infrastructure improvements with long-term benefits to the lakes could be supported by various types of <u>rebates, low/no-interest loans, and discounted permit fees</u>.

4) Development of <u>grant award programs</u> that recognize innovative efforts to improve watershed conditions and/or lake water quality.

5) Implementation of <u>planning and zoning options</u> that allow for greater flexibility in water quality improvement and protection practices and reward those projects with incentives that meet certain thresholds.

<u>Ecosystem Services Approach</u>
Another incentive option is the development of economic opportunities that can also advance conservation efforts. This approach may have merit when NPDES permit requirements, impairment implementation plans, and/or industrial green programming facilitates the need and/or opportunity to fund conservation practices to meet conservation foals. For example, if a local company had an NPDES permit with phosphorous limits that the entity was failing to meet, the company could pay local citizens to implement practices that reduce phosphorous and thereby help them meet their effluent limits.

For more information on how ecosystem services could be used to enhance BMP installations, please refer to Conservation Marketplace Midwest (http://conservationmarketplace.org/).

### LGU Actions

Regular Monitoring

An on-going water quality and watershed monitoring program is a necessity to track changing conditions in the watershed and provide a mechanism to measure progress as corrective actions are implemented. Monitoring is also important because natural systems are highly variable and often unpredictable. Regular data collections facilitate adaptive management approaches, where, it is embraced that plans are not and should not be rigid when attempting to manage dynamic systems. Walters and Holling (1990) noted that in natural resource management, learning by doing and then adapting based on what has been learned is foundational to success.

Williams and Brown (2012) found that the heart of adaptive decision making is the recognition of resource dynamics and that only through ongoing assessment (i.e., monitoring), can we even begin to consider new, previously dismissed, or otherwise emerging management options. Regardless of the lake improvement strategies selected, monitoring should be completed, as the need for measureable outcomes justifies investments and helps direct future implementation direction. Monitoring efforts should target the data needed to measure progress towards goals. A monitoring plan should be developed (e.g., parameters to be measured, frequency, and applicability to progress measures).

Enforcement of Existing Water Quality Protections

In 1994, the Minnesota River Citizen's Advisory Committee identified "enforce existing laws" as one of the ten recommendations with the greatest potential to improve surface water quality in the Basin. The participants noted that there are many laws designed to protect water quality, however, many existing protections are not enforced. In rural counties with tight-knit communities, enforcement actions can have far-reaching repercussions. Therefore, water quality protection rules are often not reviewed, simply overlooked, and/or dealt with after-the-fact. Although too numerous to mention here, a good example of a state-required water protection rules is manure management. Manure applications in areas adjacent to open tile intakes and waterways are regulated and must be done properly to reduce the transport of phosphorous from fields into surface waters.

Jarcho (2014) found that subsurface tile water from fields with open tile intakes contained significantly greater concentrations of TP, TSS, and bacteria – particularly in fields where manure had been applied. State rules require a 300' setback from open tile intakes unless soil P levels are <75 ppm. Although formal review of manure application rules enforcement has been limited, state agency staff routinely receive calls about manure application violations. In 2013, the Star Tribune published an article entitled "Manure runoff threatens southern Minnesota streams, fish," largely due to manure that had been spread on snow pack with >6% slope – a clear violation of state rules, but yet very limited efforts to enforce those rules were completed. More information about the story above and applying manure in sensitive areas can be located at the following links:
http://www.twincities.com/ci_22966358/manure-runoff-threatens-southern-minnesota-streams-fish
http://www.pca.state.mn.us/index.php/view-document.html?gid=3530.

Enhancing Surface Water Protections

Local government units with jurisdiction over permitting, planning, and zoning can catalyze surface water protections. Federal and state rules provide guidance on permits and zoning restrictions intended to protect water quality; however, LGUs have the option to be more restrictive. For example, Odefey (2013) stated that new trends in stormwater permitting represents a substantial shift in regulatory approaches and suggests improving attitudes by engineers and elected officials about environmental protections.

As with any initiative, it is recommended that LGUs lead by example and elevate lake protection expectations. Griffith (2003) noted that "municipal governments play a significant role in developing, refining, and enforcing environmental standards for the protection of their communities' waters." But what can be done? There are numerous available resources that can be utilized to identify, develop, promote, and implement "green" infrastructure options. The list below is from Odefey (2013):

- The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental, and Social Benefits, Available online at www.cnt.org/repository/gi-values-guide.pdf
- Green Values National Stormwater Management Calculator, Available online at http://greenvalues.cnt.org/national/calculator.php
- EPA's Municipal Handbook: Incentive Options, Available online at http://water.epa.gov/infrastructure/greeninfrastructure/upload/gi_munichandbook_incentives.pdf
- Green Streets, EPA's Municipal Handbook: Managing Wet Weather with Green Infrastructure, Available online at http://water.epa.gov/infrastructure/greeninfrastructure/upload/gi_munichandbook_green_streets.pdf
- Water Quality Scorecard: Incorporating Green Infrastructure Practices at the Municipal, Neighborhood, and Site Scales, Available online at www.epa.gov/smartgrowth/pdf/2009_1208_wq_scorecard.pdf
- EPA's Stormwater Management Model (SWMM) with LID Controls, Available online at www.epa.gov/nrmrl/wswrd/wq/models/swmm
- National Low Impact (LID) Atlas, Available online at http://lidmap.uconn.edu/
- EPA Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure, Available online at www.epa.gov/owow/NPS/lid/gi_case_studies_2010.pdf

The Vermont Department of Environmental Conservation (Winsten 2004) evaluated 136 towns in the Lake Champlain Basin and determined that most did not have adequate protective water quality standards in their zoning ordinances and other permit-based regulations (http://www.watershedmanagement.vt.gov/erp/htm/mun.htm).

The Vermont study also determined that strong municipal plans, programs, and regulations are an essential tool for reducing phosphorus runoff. By establishing city plans with strong water quality protection goals, decision makers have legal support for zoning regulations and establish a high priority status for resource protections. Examples of LGU-influenced practices that provide beneficial phosphorous management include, but are certainly not limited to, development of improved setback and shoreline vegetation requirements, establishment of grassed waterways, impervious surface reductions, adoption of stronger construction erosion control standards, requiring new site plans to minimize disturbance and hold stormwater, and conservation easements (Winsten 2004). Baumann et al. (2013) noted that the complete elimination of fertilizers on and adjacent to impervious surfaces was important to reduce external loading.

Cappiella and Schueler (2001) noted that lake protection ordinances are an essential tool for protecting water quality in urban lakes. In many cases, ordinances are designed to protect and maintain, but in the case of Clear Lake, ordinances may play a critical role in lake improvements. A well-developed lake protection ordinance includes measures that address the shoreline, a buffer area extending away from the water, a lake protection zone that goes well beyond the buffer, and watershed nutrient loading clauses (Cappiella and Schueler 2001).

If the City of Waseca and Waseca County desire to further explore ordinance modifications, I urge those involved to review the Cappiella and Schueler (2001) document. The report provides an excellent summary of key factors to consider, developing lake protections that focus on P reduction, ecological benefits of shoreline improvements, roles that citizens can play, and the importance of individualized language for your local lakes.

Boat Wake Limitations

The National Marine Manufacturers Association reported that in 2010, Minnesota had the second highest number of registered boats in the country at 813,976 (http://www.nmma.org/news.aspx?id=18028). Loon Lake's motorized boats ordinance takes that lake out of this discussion. Clear Lake, however, receives moderate boat traffic. Boat characteristics and intended use can make substantial differences in the impacts to shoreline areas. The Lake Harmony Association in Pennsylvania has become particularly concerned with "wake" boats that are designed to create large wakes for recreational activities (http://www.lakeharmonyassociation.com/).

Boats and oversized outboards that produce wakes with deep valleys and high crests re-suspend substantial amounts of sediment and have more erosive energy when hitting shoreline – both of which contribute to increased nutrients and algal problems. Boats that have been modified to create large wake typically have a large fillable bladder that allows water to be taken on – a practice that can also lead to increased transport of aquatic invasive species. Many lake associations have worked with their local communities to pass ordinances that prohibit boats with modifications to produce large wakes.

The Oregon State Marine Board (2003) noted that hydrologists estimated that a single wake of 5 inches does little to no damage to the shoreline, however, a wake of 10 inches is 5-times more destructive and a 25-in wake is 30 times more destructive. Most boats currently being utilized on Clear Lake do not have displacement hulls that push water away, and therefore, wakes great than 10 inches would be unlikely, however, high frequencies of small wakes can slowly destabilize shoreline. Wake is also additive to each other, so as the number of boats in use at one time increases, so does wake size. Many lakes establish a no-wake zone 200-300 ft from the shore to minimize this damage; however, unless the restrictions are enforced consistently, the tool is rather ineffective.

### *5.2 Watershed Approaches*

As was suggested by the Clear and Loon lake assessments, non-point source nutrient loading is a substantial contributor to the overall water quality challenges. More than 3 decades ago, Novotny and Chesters (1981) found that more than half of the phosphorous transported off the landscape into surface waters originated from agricultural lands. Numerous federal and state agencies have indicated that non-point sources continue to have a major impact on surface water quality.

Reducing the transfer of nutrients from the watershed into surface waters is critical, and for lakes that have overwhelming internal TP cycling already in place, it is an imperative component of the restoration plan. To reduce non-point source loads, many different Best Management Practices (BMPs) have been attempted. The success of BMPs has, however, been inconsistent due to numerous localized conditions (e.g., soil type and slope interactions) that make broad BMP application difficult.

Selected BMPs need to have the potential to address water quality goals, but must do so within the context of local environmental constraints, community expectations, and the magnitude of the required reductions. The nutrient reduction BMP approaches are often categorized based on the pollutant source it is being employed to address. Therefore, we can summarize potential watershed nutrient reduction practices as

1) Urban BMPs,
2) Rural BMPs, and
3) Dual-purpose BMPs.

## Urban BMPs

Nutrient reduction strategies in urbanized areas typically follow two basic strategies – reduce runoff that subsequently results in pollutant loading and treating runoff water before it enters other water bodies (Kennedy 2002). The BMPs used for runoff reduction and treatment strategies are widely variable, but often attempt to slow and retain stormwater to facilitate infiltration and suspended solids removal. All of the BMPs listed here are used in "Urban Stormwater Management" programs.

### Reduction and Restriction of Impervious Surfaces

Imperviousness has often been identified as one of the most significant factors in non-point source loading from urbanized habitats (Kennedy 2002). The establishment of roads, structures, and parking lots increases imperviousness in a watershed and the deleterious impacts have been well documented. Schuler and Holland (2000) found that runoff from a 1-ha paved parking lot was typically 16 times greater than that of a 1-ha field with natural vegetation. Impervious surfaces also catalyze the accumulation of pollutants, such as petroleum waste, nutrients, and sediment. Of particular interest for the Waseca Lakes, is that Schuler and Holland (2000) also found that parking lots export phosphorus at 4 times the concentration of undeveloped areas.

For many developments, the availability of space can limit the ability to implement stormwater BMPs. Permeable parking is an excellent way to utilize limited space and store, treat and cool stormwater runoff onsite while also promoting infiltration. Parking areas can be created using permeable pavers, permeable concrete and asphalt. The Vermont Department of Environmental Conservation summarized design principles and BMPs that reduce the impacts of impervious surface (see link below). The following mechanisms have potential applicability to the Waseca Lakes scenario and should be reviewed:

- Adopt ordinances and policies that reduce impervious surface allowances,
- Preserve publicly-accessible green space and keep the areas vegetated,
- Incorporate curvilinear designs into road/trail projects to promote sheet flow of runoff,
- Reduce standard roadway widths whenever possible,
- Incorporate vegetated swales in place of concrete curbs and gutters,
- Use permeable materials when possible on parking lots and trails,
- Add permeable material strips to parking lots and other paved areas,
- Be watchful for opportunities to incorporate green roofs, and
- Route stormwater through vegetated areas and bioretention areas.

(http://www.watershedmanagement.vt.gov/stormwater/docs/sw_gi_1.7_reduce_impervious_surfaces.pdf)

### Water Quality Manholes and Baffle Boxes

Because sediment often carries nutrients, the removal of sediment and organic debris from urban stormwater flows reduces the amount of phosphorous transported into surface waters. Two structures designed to capture sediment from stormwater are baffle boxes and water quality manholes.

**Baffle box** structures contain a series of sediment settling chambers separated by baffles to facilitate the capture of sediment and organic debris, both of which can contribute substantial amounts of nutrients to lake systems. Baffle boxes can also be designed to capture trash and can be configured in-line or terminally within the stormwater system. Baffle boxes have been shown to be an effective BMP for sediment removal from stormwater, however, the key to successful performance is regular inspection and cleaning (USEPA 2001). The cost to install a baffle box varies based on the level of difficulty, as most are retrofits.

Like a baffle box, **water quality manholes** trap sediment, oil, and debris in a chamber before stormwater is discharged back into the environment. Water quality manholes require annual inspections and periodic cleaning that is dependent on the volume of materials filtered. The State of Oregon has been implementing water quality manholes, but have not released much information about the BMPs performance. More information can be located at the link below: http://www.oregon.gov/ODOT/HWY/GEOENVIRONMENTAL/docs/Hydraulics/Hydraulics%20Manual/Chapter_4_Appendix_D/D00032_Report_Water%20Quality%20Manhole.pdf.

Street Cleaning

The accumulation of sediment, organic debris, trash, and other materials can contribute to stormwater quality degradation, but all of these potential pollutants can be reduced by street sweeping. Bannerman (1999) found that street debris loads can be as high as 8,000 pounds per curb mile in the spring through a residential area and sustain at 400 pounds per curb mile in the summer months. Removal of street debris has water quality benefits, but also improve community aesthetics, can help control dust, and reduces maintenance costs of wastewater infrastructure (Selbig and Bannerman 2007).

Schilling (2005) reported that street sweeping was cost-effective when compared to structural BMPs (e.g., detention ponds and filtering devices), prolongs the life of structural BMPs, and reduces the amount of required maintenance. Street sweeping is often integrated with other BMPs to deliver a multi-faceted approach to water quality protections. Venner (2004) noted that studies are indicating that street sweeping contributes to water quality improvements, but that in most cases, the frequency of sweeping is insufficient. Implementing and/or increasing a street-sweeping program is an option to be considered.

Snow Storage

Snow removed from city streets can contain an array of pollutants, including sediments and organic debris rich in nutrients. Novotny and Chesters (1981) found that contaminant loads generated from melting snow on urban roadways was polluted at the same magnitude as that of raw sewage. Unfortunately, municipals are often faced with snow disposal challenges, and as a result, do not give sufficient consideration to snow storage locations and the subsequent impacts that occur when the snow melts.

It has historically been a common practice for communities near lakes to dump snow removed from streets onto the lake ice. The contaminant loads associated with snow disposal requires careful consideration. The State of South Dakota issued guidance that calls for setbacks from surface waters, meltwater filtration through sand or gravel berms, disposal on sites with low erosion potential, and verified avoidance of wetland habitats (http://denr.sd.gov/dfta/wp/snow.aspx).

Lawn Management

In some lakeside communities, poor lawn management practices can be a substantial factor in water quality degradation. The Minnesota Department of Agriculture has reiterated that phosphorus is a problematic stormwater pollutant, and that the nutrient is present in leaves, lawn clippings, animal wastes, and most fertilizers – all of which can be transported from yards into surface waters and trigger algal blooms (http://www.mda.state.mn.us/protecting/waterprotection/lawnsheds.aspx). The LWSB (2006) stated the collective perception of green space needed to be modified so that lakeshed-wide elimination of phosphorous for "cosmetic" purposes could be achieved.

Landowners can help reduce the amount of phosphorus entering the Waseca Lakes by embracing and adhering to a few basic lawn BMPs:

- Keep leaves and lawn clippings out of the streets and gutters,
- Test lawn soils and apply only the amount of fertilizer your lawn needs,
- Make a strong effort to avoid dispensing fertilizer onto impervious surfaces,
- Adhere to the state's phosphorus-free fertilizer requirements (fertilizers containing phosphorus cannot be used on lawns in Minnesota),
- Avoid leaving bare soils exposed,
- Encourage lawn aeration, because large-scale aeration increases the soil's water holding capacity and infiltration,
- Let your grass grow a bit higher and leave the clippings on it as natural fertilizer.

Water Reuse Systems

The USEPA (http://www.epa.gov/region9/water/recycling/#p2) has reported that an average family uses some 400 gallons of water each day, and that approximately half of that water could be reutilized on site for toilet flushing, clothes washing, and lawn watering. There is a growing interest in water reuse systems, and HGTV (http://www.hgtv.com/remodel/mechanical-systems/reusing-household-water-with-graywater-systems) and PBS (http://www.pbs.org/newshour/bb/science-jan-june08-water_03-24/) have both given the topic some attention. There are many practical reasons to reuse household grey water, including reduced wastewater management costs for local municipals and the often nutrient-rich grey water can be recycled for agricultural and landscape irrigation. The USEPA has prepared guidelines for water reuse (http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf). Although water reuse is logical, it is included here as a long-term consideration.

### Rural BMPs

Rural-based BMPs are also quite diverse, but generally share the same objective to reduce the loss of sediment and nutrients from the watershed. Brach (1991) suggested that upwards of 70% of nutrients and sediment entering degraded lakes in Minnesota originated from rural non-point sources. Although there is much disagreement about the extent and mechanisms of nutrient transport from rural lands into surface waters, most agree that active watershed management to reduce nutrient loss from disturbed soils is important (e.g., Rehm et al. 2002).

Many non-point challenges originate from the use of fertilizers, but soil disturbance for crop production, grazing, forestry, and mineral extraction substantially change local and regional erosion rates, hydrologic conditions, and nutrient cycles. To address these challenges, rural BMPs often include modifications to farming practices, soil stabilization efforts, and strategies to retain, slow, and filter runoff. The BMPs listed here include those often promoted by state and local agencies to reduce water, sediment, and nutrient transport off agricultural fields. In consideration of the options available for rural areas, the most applicable to the Waseca Lakes included

1) Sediment Retention,
2) Drainage Modifications, and
3) Agricultural Production BMPs.

Sediment Retention

The retention of sediment, given its association with phosphorous, is often the targeted outcome of rural BMPs. There are many strategies to filter out, or otherwise retain, sediment on the landscape. A primary mechanism that catalyzes sediment migration is water velocity. Vegetated BMPs, such as buffer strips, vegetated treatment systems, and vegetated waterways (e.g., grass swales) function by creating impediments to water movement that result in slowed velocities that give suspended particles an opportunity to drop out of the water column. Additionally, vegetative production also utilizes the nutrients and reduces the total concentration available for transport off the vicinity.

**Vegetated waterways** tend to be shallow channels with dense grasses to help filter out solids and to slow water movement and facilitate additional infiltration. Site evaluations are needed on a case-by-case basis to verify that land use, soil type, slope, imperviousness of the contributing watershed, and watershed dimensions are conducive for the practice. Vegetated waterways are often constrained by drainage area size and slope. The BMP is generally applied in areas where natural drainage occurs.

**Buffers** are established to physically protect and separate surface waters from potentially negative land uses. If properly designed, a buffer can provide stormwater management and can act as a right-of-way during floods, sustaining the integrity of stream ecosystems and habitats. Similarly, **vegetated treatment systems** are engineered bands of dense vegetation strategically located to intercept runoff. To be effective, however, vegetated treatment systems must also be applied where there is gentle slope to allow plant establishment and channelized flow is not likely to form. Common uses include treating runoff from transportation corridors, buildings, stream buffer fringe and pretreatment for a structural practice.

Drainage Modifications

**Elimination of Open Tile Intakes –** Morrison (2012) reported that both a USDA drainage expert and a University of Minnesota agricultural engineer have stated that open tile intakes is a practice that should be ended. Research completed by Jarcho (2014) supports this contention, finding that subsurface tile water from fields with open tile intakes contained significantly greater concentrations of suspended solids and nutrients. The researchers cited by Morrison (2012) noted that open tile intakes allow debris, sediment, and pollutants to enter the tile system. There are various alternatives to open-tile intakes, such as inlet risers and intensive pattern tiling that have the potential to provide comparable water transport – and, would viewed favorable by most producers and would improve water quality.

**Farm Ponds/Stormwater Wetlands --** Over the past decade, drainage practices have been increasingly scrutinized, however, installation of drain tile and other soil water management actions have proliferated rapidly. Historically, nearly all farms had one or more ponds, but production pressures have forced many landowners to convert their ponds into producing acres. Also over the past decade, and in contradiction to increased drainage, conservation organizations have been calling to improve water storage in the landscape. Is there an opportunity here?

Broadly distributed agricultural runoff is typically concentrated via drain tiles and ditching to facilitate rapid transport off farm fields to surface waters – a practice that has debated impacts on water quality. There are associations between drainage and the transport of sediment and nutrients. Farm ponds, that may also be considered stormwater wetlands, could use natural processes to treat stormwater. In addition, these ponds could be planted with native vegetation and be designed to offer wildlife and fisheries values to landowners. A network of such basins across the landscape could collectively have substantial impacts on water storage and water quality improvements.

Agricultural Production BMPs

There exists a wide range of production-related tillage and nutrient/manure BMPs that can significantly impact surface waters (Devlin et al. 2003). Tillage and manure management practices interact with fertilizer regimes, to generate potential water impairment issues. The effectiveness of agricultural BMPs has been rather extensively studied.

**Residue Management/Tillage Practices --** Tillage practices that incorporate crop residue and manure with high levels of soil disturbance typically result in higher levels of soil erosion and surface runoff. Where soil types allow, conservation tillage is a farming approach where plant residue from a harvested crop is allowed to remain on the soil surface. The general guidance is that to provide these conservation benefits, at least 30% of the soil surface must be covered with residue after planting the next crop (Fisher and Moore 2008).

Conservation tillage should be considered for farmed acres in the Waseca Lakes watershed that is erosion-prone. There are several conservation tillage options, and if technical assistance is needed by landowners, there are knowledge conservation staff in the region who could assist. The benefits of conservation tillage include soil loss reductions, improving soil and water quality, need for less fuel, and provision of additional resources for wildlife (http://www.mda.state.mn.us/protecting/conservation/practices/constillage.aspx).

Applications of liquid animal wastes conflicts with conservation tillage practices to a degree, because the injection and incorporation process disturbs soil surfaces and reduces residue coverage. Therefore, manure and tillage management must be integrated to effectively retain soil and still facilitate nutrient use by plants. To strike a balance between manure management and conservation tillage, a range of options should be considered and changes to long-standing practices, as difficult as that can be for landowners, may be needed.

**Fertilizer Modification Strategies –** Nutrients, including phosphorus, are required for crop production, however, retaining nutrients where they are needed – at the site of the crop roots – should be an important aspect of farm management plans. Nutrients that are transported off the production fields are often "in excess" of what the crop needs, and instead feed the production of algae in surface waters. To address the "over-application" of fertilizers, several BMPs warrant consideration:

- Soil Testing,
- Manure Testing,
- Variable Rate Nutrient Applications, and
- Use of Low-Solubility P-Fertilizer

Nutrient inputs from the watershed are exacerbating already challenging internal nutrient cycles in Clear Lake. Eutrophication, or a rise in nutrient levels, results in increased plant and algal growth. The biomass that is produced eventually dies and decomposes, potentially causing oxygen depletions that can be detrimental to biota and create internal lake conditions that catalyze the release of phosphorous from lake sediments.

The BMPs listed above can collectively result in application rates that strive to meet, but not exceed crop nutrient demands as they vary across the production acres. In addition, the use of certain forms of fertilizer, such as P with lower solubility potential reduces its bioavailability for algal production if it does migrate from the field. There are also tools to help with phosphorous management, such as the Iowa Phosphorous Index. The Index uses soil nutrient concentrations, nutrient application factors, soil transport factors, and soil drainage factors to determine the phosphorus movement risk for site

specific management (NRCS 2003). Identifying those fields with the highest risk of phosphorus loss would facilitate BMP targeting efforts.
Colorado State University Extension summarized BMPs to address P-Fertilizers, and included the following main points (http://www.ext.colostate.edu/pubs/crops/xcm175.pdf):

- Sample the tillage layer of soil in each field on a regular basis and have soil analyzed to determine available soil P levels prior to applying P fertilizer.
- Credit all available P from manures and other organic residues to the P requirement for the crop.
- Fertilize soils with 'low' to 'medium' P soil test values using environmentally and economically sound agronomic guidelines. In general, soils testing 'high' will not respond to additional P and should not receive fertilizer unless a banded starter is needed to compensate for low soil temperatures. Phosphorus fertilizer should not be applied to soils testing 'very high' for soil P.
- Divide large, non-uniform fields into smaller fertility management units based upon yield potential or soil type and fertilize according to P levels determined through soil analysis.
- Apply P fertilizers where they can be most efficiently taken up by the crop. Band application of P in the root zone reduces surface loss potential and enhances nutrient availability, especially in cold or P deficient soils.
- Incorporate surface applied P into the soil where any potential for surface runoff or erosion exists.
- Minimize soil erosion and corresponding P losses by establishing permanent vegetative cover, conservation tillage and residue management, contour farming, strip cropping, and other management practices as feasible.
- When erosion potential is severe, install structures such as diversions, terraces, grass waterways, filter fences, and sediment basins.
- Maintain a buffer strip (where fertilizer and manure is not applied) a safe distance from surface water and drainage channels.
- Maintain grass filter strips on the downhill perimeter of erosive crop fields to catch and filter P in surface runoff.
- Evaluate fields with historical manure applications using a Phosphorus Index Risk Assessment.

Septic System Management
Surface waters typically represent low points in a watershed and groundwater interactions are common. Shallow groundwater can be contaminated by failing septic systems, and the pollutants can migrate toward and discharge into surface waters. The South Carolina Department of Health and Environmental Control has estimated that up to 30% of septic systems fail to work properly on an annual basis, primarily because home owners do not understand how their system works or what maintenance is required (http://www.scdhec.gov/HomeAndEnvironment/YourHomeEnvironmentalandSafetyConcerns/SepticTanks/). Although rural septic rules are in place, the triggers for mandatory septic inspections are few and often infrequent. Failing septic systems can contaminate wells, spread disease, release untreated sewage, pollute surface waters, and have costly repairs.

McDowell et al. (2005) noted that in lake-front settings, septic systems have been documented to discharge phosphorus to the lakes via a shallow groundwater aquifer, contributing to noxious algae blooms. McDowell et al. (2005) found that collective treatment systems may offer the best way to control wastewater nutrients in suburban and semi-rural settings, combining some advantages of both centralized sewers and individual septic systems.

## Dual-purpose BMPs

Although many BMPs are promoted as "Urban" or "Rural," there are many practices that can be dual-purposed to help achieve water quality results in a broad range of scenarios. These BMPs can typically be adapted to meet the needs on larger rural scales, or on smaller urban scales. As with other BMPs, the reduction of stormwater flows and the subsequent reduction of sediments and nutrients are a primary objective. The BMPs listed in this section have potential application to the Waseca Lakes and could be used on both urban and rural areas.

Water Infiltration

**Bioretention cells/ Rain Gardens –** The development of depressions capable of retaining water, but with a porous bed and vegetative layer, encourages both filtration and infiltration to reduce water discharge and remove sediment and nutrients. With careful planning, rain gardens can be stunningly beautiful collections of native grasses, flowers, and shrubs. To develop a properly functioning bioretention cell, construction criteria and soil conditions must be carefully considered. Although this practice has primarily been utilized in urban areas, larger versions in rural areas are also built. This BMP requires considerable labor to maintain quality for the first few years, and if not done correctly, will frustrate those responsible for the BMPs function.

For more information on rain gardens, and to consider the proper construction sequence and design requirements, there are many reference sources available, including the following:
http://www.12000raingardens.org/wp-content/uploads/2013/03/7-Final-Catching-Rain-factsheet-rain-garden-construction-sequencing-1.pdf
http://www.lowimpactdevelopment.org/raingarden_design/construction.htm
http://dnr.wi.gov/topic/shorelandzoning/documents/rgmanual.pdf
http://www.bae.ncsu.edu/stormwater/PublicationFiles/DesigningRainGardens2001.pdf.

Nutrient diversion

The diversion of nutrients away from holding basins is an approach that has been considered for decades (e.g., Lorenzen 1973). Drainage channels or pipes can be used to divert nutrient-rich waters to the downstream side of a lake, or into a different receiving water. Studies have shown that nutrient diversion can reduce P entering a lake, and result in P reductions over time; however it is not generally sufficient to reach restoration goals by itself (e.g., Romo et al. 2005). Diversion projects are often controversial, require careful permitting, and typically involve substantial engineering needs and construction. Diversion of water from Gaitor Lake, unless TP transport can be significantly reduced using other methods, needs to be a continued consideration.

### *5.3 In-lake Strategies and Practices*

The "need" for in-lake treatment

Controlling external nutrient sources is critically important, however, decades can pass before lakes can effectively manage internal nutrient loads. Therefore, in-lake interventions can accelerate recovery. The need for in-lake management is well documented in Cooke et al. (2005). Cooke et al. (2005) discusses many different techniques, and makes an emphasis that not all techniques are suitable for all lakes or conditions. Consider using these techniques only after a lake specialist has evaluated the lake and recommended one or more of these options.

Although we often strive to apply proven strategies, each water body is unique. Therefore, the approaches used to address nutrient enrichment problems are lake-specific, and should only be implemented after, or at least simultaneously with, an aggressive watershed nutrient reduction program. Too often, lake managers also focus on the solutions that give rapid results, and in reality, only address symptoms of nutrient enrichment, not the underlying causes. That is not to say that quick-fix approaches cannot be part of the overall management plan, but long-term strategies must also be in play. Long-term solutions, however, require considerable and enduring community investment.

Although there are many potential approaches to in-lake reductions of P, the strategies generally fall into one of the following categories:

1) Physical controls,
2) Geochemical controls, and
3) Biological controls.

## Physical Controls

Targeted Water Withdrawals and Circulations

**Selective withdrawal –** Lakes with sufficient depth to stratify often have layers of water with notably higher nutrient concentrations. With sufficient monitoring and equipment, these layers can be identified and siphoned from the lake. For example, after the CLP dies and reaches peak decomposition, the layer of water near the sediment often becomes anoxic and catalyzes the release of P. Siphoning water from the layer adjacent to the sediment can remove substantial amounts of P at a very reasonable cost.

Selective withdrawals can be relatively quick to set up, and therefore present themselves as an adaptable practice that could be used "as conditions warrant." The IDNR (2013) cautioned that the receiving waters of a selective withdrawal must be carefully considered. If the receiving water is also nutrient impaired, adding nutrient-rich water from a lake will only magnify the problem. The risk of adding to receiving water impairment issues is lowest during times of high flows, and thus should be set up to be turned on and off based on receiving water conditions as well.

**Circulation and destratification –** To reduce algal bloom frequency/severity, mixing water in shallow lakes can help prevent the development of anoxic conditions. In deeper lakes, mixing can destratify water layers and have the same effect. Mixing is often accomplished by using mechanically circulated water and injected air (IDNR 2013). Like all in-lake strategies, a mixing plan is going to be unique to the lake. Circulating water can also have benefits for the fishery in years when the thermocline encompasses large portions of the littoral area (Hill 1987, 1992). Mixing is not a whole-lake approach, but rather targets problem areas where thermoclines are well established. There is investment in equipment with this approach and in some cases may have an undesired impact by redistributing sediments and increasing biological oxygen demand (IDNR 2013).

**Aeration or oxygenation –** To reduce the in-lake release of phosphorus to the water column, the hypolimnion can be oxygenated (Hupfer and Lewandowski 2008). Oxygenation has also been shown to slow the buildup of minimally decomposed organic matter in the lake (IDNR 2013). Oxygenation of the hypolimnion is often implemented during the spring and summer months. Holdren et al. (2001) noted that a diagnostic study should show a significant internal nutrient cycle with hypolimnetic oxygen demand before attempting oxygenation – and this study would suggest that conditions warrant the consideration of this technique.

To accomplish sufficient oxygenation, air is typically pumped into a nutrient-enriched hypolimnion that is showing reduced oxygen levels. For this strategy to work, enough oxygen must be added to satisfy hypolimnetic oxygen demand, and ions capable of bonding with phosphorous must also be present (Holdren et al. 2001). Hypolimnetic aeration can increase fish habitat and food supply by providing more oxygenated waters. However, aerators can be costly to operate and it may be difficult to introduce enough oxygen to truly make a difference. This technique may have application in Clear Lake, but would be much more limited in Loon Lake.

Dredging

Dredging is also a practice that has been in use for many decades, with widely variable results. Zhang et al. (2010) found that suction dredging reduced internal nutrients and improved water quality in a shallow eutrophic system. The IDNR continues to utilize dredging as a common tool in shallow lakes to enhance fish habitat, reduce sediment re-suspension, and manage internal nutrient loads (Iowa Lakes RC&D 2012).

Dredging is typically accomplished by using hydraulic suction devices to remove accumulated, and typically nutrient-rich, organic sediments from the lake bottom. Dredging has been used as a tool to control rooted vegetation (e.g., Sleepy Eye Lake) and is often viewed favorably by the public because it is making the lake "deeper." The removal of nutrient-rich sediments is likely the greatest advantage of dredging, however, during the dredging process, resuspension of sediments and temporary habitat destruction also occur. Dredging projects also come with significant permitting issues, environmental assessments (e.g., contaminant loads of the sediment and evaluation of the spoil disposal site), and cost. Because dredging can be very expensive, the practice tends to be extremely targeted in scope.

Water Level Management/Drawdowns

**Lake drawdown –** lake drawdown, in the opinion of this report's author, can be one of the most effective management tools currently available. Wetzel (1990) noted that natural water level fluctuations are hard to predict, and thus make adapting natural trends to management approaches difficult. Evaluating the potential for a drawdown should include the following considerations:

1) Water level control (ability to control and extent of potential drawdown),
2) Shoreline topography (how much sediment will be exposed),
3) Substrate improvements and protection (what are the drawdown goals), and
4) Vegetation establishment (pros and cons of macrophyte stimulation).

Abrahams (2006) noted that when conditions and control structures allow for a drop in water elevation, drawdowns can deliver a number of key benefits. Drawing down lake water levels can have several benefits, including shoreline stabilization, nuisance plant controls, and reconsolidation of sediments – all of which help address lake nutrient challenges. The MDNR noted that many shallow lakes benefit from drawdowns that are intended to help reverse the impacts of lakes that fall into the turbid-water state (Hutchins and Hansel-Welch 2014).

Organic sediments that remain continuously inundated tend to be flocculent. Exposing these loose sediments to ambient conditions catalyzes consolidation and oxidation that reduces sediment resuspension, reduces the potential for the release of P, and stimulates plant growth along shorelines that is critical for both stabilization and nutrient uptake. To accomplish these improvements, drawdowns of as little as a foot can be very helpful, but more is better. Full drawdowns are often difficult to achieve, but can have dramatic results.

Southern Minnesota lakes historically demonstrated dynamic water levels. In our interest to increase water level stability, fixed-crest elevation control structures have often been installed and subsequently contribute to shoreline degradation. Coops and Hosper (2002) found that water level fixation has had severe negative impacts on aquatic systems in the Netherlands and that water-level management that includes fluctuations, had an equally strong positive impact on lake restoration efforts. Therefore, variable-crest structures are recommended, and a management approach that allows for some bounce in water levels tends to be beneficial.

Shoreline Stabilization

Shoreline erosion can impact water quality, in terms of clarity and nutrients that drive algal production. Asplund (2000) noted that two primary factors affect shoreline stability, including the intensity of the erosive factor (e.g., water movement) and the characteristics of the shoreline itself.

Although overland flow can cause some shoreline erosion, the biggest impacts are typically caused by wave action and artificially maintained high water levels. The soil characteristics of the shoreline are also factors, as well as the quantity and quality of vegetative cover, slope, and the intensity of human disturbance (Asplund 2000). Some shoreline erosion is a natural occurrence, however, when it is accelerated, it contributes to cultural eutrophication.

Breakwaters

In large lakes, breakwaters have been a tool used for decades; however, the installation of breakwaters into smaller lakes is a more recent practice. A report from Winnebago County, Wisconsin in the archives of The Wisconsin Lake and Water Conservation Association (http://wisconsinlandwater.org/) was entitled "Breakwaters installed in Winnebago County come with big benefit." The article reported that since 1998, off-shore breakwaters have been installed to protect shorelines from excessive erosion. The added benefits of breakwaters also includes the creation of calmer habitats between the breakwater and shoreline that serves as critical habitat for larval fish and invertebrate production, increases emergent vegetation growth, and aids in the retention of sediment.

Breakwaters are not only intended to protect sensitive shorelines from boat wake, but also wind-driven wave action. Breakwater installation in Minnesota would require careful planning and communications with state agencies. The materials used to create the breakwater would likely be considered "fill" and face a difficult permitting process; however, with sufficient demonstration of the potential environmental benefits, I believe that state could be a collaborative partner. Federal permits would also likely be needed, but your state hydrologist can assist with that determination.

Groins

Given the challenges that may be faced by efforts to install breakwaters, smaller structures, called groins, might be a better option. Groins have been used and evaluated in flowing water systems for decades, and are often referred to by river managers as finger weirs or modified J-hooks. Lake groins are narrow "finger-like" structures that extend into the water typically perpendicular to the shore (MDE 2008). Groins are often placed in small clusters to trap and retain sediment between each other and the shoreline.

Groins are designed to interrupt the movement of sediment along the shoreline, facilitate sedimentation, and at times can also create areas where vegetation can re-establish. The accumulation of sand and sediments between the groins acts as a wave/wake barrier that protects shoreland areas (MDE 2008). Groins are only effective in specific situations, where the movement of materials is more prominent in one direction than the other, thereby facilitating the accumulation of materials on one side of the structure. Groins could also be developed in a manner to create shore-fishing opportunities.

### Geochemical Controls

Phosphorous Precipitation/Inactivation

Mattson et al. (2004) stated that "phosphorus precipitation and inactivation are techniques used to control algal blooms by reducing the availability of phosphorus that fuels the growth of algae." Several compounds have been utilized to strip P from the water column and/or trap P in the sediments (Hickey and Gibbs 2009). Mattson et al. (2004) provided the following definitions:

*Phosphorus <u>precipitation</u> uses a relatively low dose of alum to provide temporary control of algal abundance in the water column until the phosphorus supply is replenished.*

*Phosphorus <u>inactivation</u> typically involves some amount of phosphorus precipitation, but aims to achieve long-term control of phosphorus release from lake sediments by adding as much phosphorus binder to the lake as possible within the limits dictated by environmental safety. It is essentially an application of "anti-fertilizer" to the lake.*

**Aluminum Phosphate –** The most common compound used is aluminum sulfate (*a.k.a.*, alum). When applied in lakes, alum rapidly binds with phosphorus and forms a fluffy aluminum hydroxide precipitate called a floc (Cooke et al. 2005). The floc settles out of the water column and removes phosphorus and other particulates from the water column. The floc settles on the sediment and forms a barrier layer so that when nutrients are released from the sediment, it cannot escape into the water column and fuel algal production. Alum treatments are most effective after external loading has been substantially reduced and when common carp are sparse (preferably absent).

Quaak et al. (1993) indicated that a thorough understanding of the lake's chemistry is needed before treating a lake with alum. If a whole-lake alum treatment is successful, it will typically be evident within a few days. Alum can also be used in-line as Waseca has already been doing at Loon Lake. Alum is often a popular option because it has a more immediate impact, makes the lake more aesthetically appealing, and in the right conditions, can provide relatively long-term improvements (Welch and Schrieve 1994). A successful alum treatment increases water clarity and therefore often results in rapid growth of aquatic macrophytes; however, changes in pH can cause fish kills, and recreational activity should be reduced in shallow areas to increase treatment longevity (Peterson et al. 1973).

**Ferric Chloride –** Lind (1997) noted that ferric chloride is the most widely used iron salt and is second only to alum in the amount of water it treats in North America. This compound, due to impurities in its production, can introduce heavy metal contaminants and care must be taken if treating drinking water supplies (Lind 1997). Ferric chloride can be applied similarly to alum and catalyzes similar outcomes.

**RIPLOX Method –** This method has been described as flexible, fast, and cost-effective approach to treat sediment in shallow lakes with phosphate binding chemicals. The method involves thoroughly mixing the upper 0.15 m of the sediment and infusing it with ferric chloride using water jets (Quaak et al. 1993). The intent is to expose, via disturbance, the sediment layer capable of releasing P and then directly introduce an inactivation agent.

**Phoslock –** Phoslock is a modified bentonite clay product designed to be spread on the surface of water bodies that binds with and permanently removes free reactive phosphorus (Rossa et al. 2008). Although Phoslock shows promise, lanthanum, a rare earth metal present in the product, has unknown impacts on the environment and alum, which is easily obtained and likely more cost effective, has been recommended by the Ramsey-Washington Watershed District (RWMWD 2012).

**Ferro-Gypsum –** Salonen et al. (2001) found that ferro-gypsum treatments can be a versatile method for in-lake restoration in comparison with other sediment inactivation methods. The Salonen et al. (2001) study cited unpublished data from one of the co-authors that suggests ferro-gypsum interacts to serve as a mechanical cover, a chemical offering binding sites for phosphorus, and a catalyst of favorable conditions for sulphur bacteria instead of methane bacteria. Although the Salonen et al. (2001) study showed great promise, it was difficult to find and review additional research for the same product because most publications were only available in non-English formats.

In the evidence that I could gather, ferro-gypsum treatments were shown to reduce hypolimnetic P concentration by up to 90% and 1 year after treatment, the P reduction for the entire lake was estimated at 62%. Salonen et al. (2001) reported that the gypsum treatment substantially increased the sulphate content of the water, but that much of it settled out. The study found no significant changes in iron concentrations or pH. Transparency increased from 50 to 270 cm. Although information is limited on this approach, it may be worthy of additional research.

**Modified Zeolite –** Margeta et al. (2013) noted that "natural zeolites are environmentally and economically acceptable hydrated aluminosilicate materials with exceptional ion-exchange and sorption properties." Their research team found that zeolite has three key attributes that make it a valuable component of lake restorations involving nutrient enrichment. It should be noted, that the information is provided by, and the researcher worked for, a for-profit organization. Zeolite is porous and absorbent – traits that allow it to soak up nutrient anions, and break the cycle of nutrient excess. Margeta et al. (2013) noted that the compound appeared to be particularly effective during the summer months when temperatures rise.

Phosphorous Precipitation/Inactivation Summary

Biswas and Jana (2010) completed a full review of various compounds and approaches to precipitate and/or inactivate phosphorous in lakes. In general, they noted that the approach is effective as a tool to reduce P in the water column and inactivate P in the sediment. However, not all compounds performed equally. The researchers found that a combination dosing of alum plus lime (not discussed above) was the most effective treatment among the chemical candidates tested. Biswas and Jana (2010) also found that ferric chloride treatments had very good potential in conditions where the redox insensitive but pH sensitive chemical treatment of alum and lime was not effective. The length of treatment effectiveness varied based on the amount of product applied, lake depth, and levels of sediment disturbance. Alum treatments were found to commonly persist for eight or more years in shallow lakes and even longer in deeper lakes.

## Biological Controls

Plant Management

The Aquatic Plant Management Society defines aquatic plant control as techniques used alone or in combination that result in a timely, consistent, and substantial reduction of a target plant population to levels that alleviate an existing or potential impairment to the uses or functions of the water body (http://apms.org/resources/control/). It is important to note that macrophytes are a critical component of the lake nutrient cycles. Therefore, any notions that a clear water "weedless" lake can be achieved, should be promptly dismissed. Invasive plants, however, such as CLP and EWM have significantly altered some aspects of the nutrient cycles and pose desired use challenges.

The MDNR works with the public to monitor invasive plants. Oversight also includes permitting for invasive plant management options, including removal and chemical treatment. Therefore, it is important to consult with MDNR staff before proceeding on any of the plant management options. By far, the most problematic macrophyte species in Clear Lake is CLP, however, management options are somewhat limited and have thus far demonstrated moderate to inconsistent success at best.

**Curly-leaf Pondweed Reduction –** For more information about the life history, problems caused by, and management strategies for CLP, please see the MDNR fact sheet at: http://files.dnr.state.mn.us/natural_resources/invasives/aquaticplants/curlyleafpondweed/curlyleaf_factsheet.pdf. Prevention is always the best protection against invasive plants, aquatic plant management strategies generally fall into the methodological reduction categories of chemical, physical, and biological.

Chemical Reduction: Based on the findings of Netherland et al. (2000), Poovey and Skogerboe (2002), and Johnson (2010), as well as ongoing research from the U.S. Army Engineer Research and Development Center, the MDNR continues to recommend (if chemical applications are desired) herbicide treatments of endothall-based herbicides (e.g., Aquathol) and to apply the product when water temperatures are approximately 55°F in the spring. Several other states, including Indiana, Wisconsin, and Iowa also recommend the endothall spring treatments (see the state resources links bulleted below).

http://www.in.gov/dnr/files/CURLYLEAF_PONDWEED.pdf
file:///C:/Users/jm4487ws/Downloads/BMP_Manual2.pdf
http://sewisc.org/invasives/invasive-plants/170-curly-leaf-pondweed

The state of Iowa has produced an excellent aquatic vegetation management manual (see the link at the second bullet above). Chemical controls often seem attractive, but in many cases, the treatments are not target-specific, and must be repeated almost every year.

Physical Reduction: Curly-leaf Pondweed can be physically removed by raking and cutting. This approach is labor intensive, and care must be taken to avoid fragmenting the plants more than necessary to prevent additional dispersal of the invasive plant. Plants that are removed must be disposed of carefully to avoid the transport of reproductive units into non-infested surface waters. Physical controls can be very effective on smaller-scale efforts, such as targeted problem spots and smaller water bodies. It should be noted that removal of CLP is a noteworthy option, as the removal of biomass from the lake also takes nutrients out of the internal cycle (Pallardy 2012, Ribikawskis 2010).

Another physical approach is shading. The use of dyes can reduce nuisance growth by limiting the required light from reaching the plants. This method can also be utilized for algal reduction efforts. The use of a non-toxic dye can be appropriate when managing public perception is a major component of the plan. With shading comes reduced photosynthesis, and consequently, potential for increased anoxia near the sediment water boundary increases and may further impact lake nutrient cycling (IDNR 2013). This approach cannot be utilized on lakes with high flushing rates, and may therefore be an option for Loon Lake for the reduction of algae.

Other mechanical/physical control strategies include bottom blankets that prevent plant growth and shoreline deepening via dredging (IDNR 2013). Both of these methods are applied to prevent plant growth, not specific to CLP, by preventing it from taking root and/or creating a depth at which the plants can no longer survive. Both of these options can be effective, but are also very expensive. Dredging has potential, but requires extensive permitting and the sediments to be removed are often concentrated with heavy metals and other compounds that create extreme challenges in disposal. Like plant removal, however, dredging does remove nutrient-laden sediments and may be one tool in an integrated approach to gain some control over internal nutrient cycles.

The use of aquatic vegetation harvesters has been attempted many times. The IDNR (2013) noted that mechanical equipment can cut the top 5-6 feet of vegetation and remove it from the lake. Like other physical removal cautions noted above, fragmentation of invasive plants caused by the cutters can be problematic. Acquiring a cutter is an investment and before a harvester is secured, allowances (via permits) must be in place first – just to verify that the cost-benefit scenario is desirable. Harvesters currently being used in Iowa lakes have the capacity to clear 15-23 acres per week (assumes approximately 30 hours of harvest time; IDNR 2013). As of 2012, harvest operation costs varied from $10-$25/hour, excluding payroll. Additional information about harvesters can be found in the North American Lake Management Society Bulletin (Volume 18, Number 1) from March 1998.

Pallardy (2012) noted that CLP removal would be best targeted in May of each year when the phosphorous content in the plant tissue is greatest. Although not a solution to the much bigger cultural eutrophication problem, the removal of CLP may represent one facet of an integrated management approach. Based on models from the German-Jefferson Chain of Lakes, Pallardy (2012) suggested that the CLP removal from 460 acres of the lakes, could result in 2,241 lbs of phosphorous removal. The cost of an effort at this scale was estimated to be more than $200,000 annually; however, it should also be noted that the removal of TP associated with 460 acres of CLP represented 72% of the needed internal phosphorous reduction. Ribikawskis (2010) completed similar models for Lake Crystal, but did not find that CLP removal would make much of an impact in that lake on the total P budget. The difference between the two studies was CLP density, with a much greater density present in the German-Jefferson Chain.

<u>Biological Reduction</u>: Biological control, or biomanipulation, utilizes introduced living organisms that have the capacity to suppress the undesirable species. Several aquatic plant bio-controls include grass carp (*Ctenopharyngodon idella*), the water milfoil weevil (*Euhrychiopsis lecontei*), and pathogens such as *Mycoleptodiscus terrestris* that may be used for controlling EWM and hydrilla (Getsinger et al. 2005, Cuda 2009). Grass carp can be an effective biological control for CLP (Swistock 2008), however, grass carp cannot legally be stocked into waters of Minnesota.

**Shoreline Re-Vegetation –** Vegetated buffers are important components of a healthy lake system, by stabilizing the terrestrial-aquatic interface. Johnson et al. (1997) noted that landscape characteristics, such as buffer quality, play important functions including surface runoff filtration, nutrient uptake, habitats for wildlife, food production for fishes, and reduced maintenance needs/costs for lakefront properties. Reed-Anderson et al. (2000) also noted that buffers are an important aspect of a lake protection plan, but that watershed nutrient reductions must also occur. Likewise, in-lake vegetation buffers are critically important to protect shorelines from boat wake and wind disturbances.

**Floating Wetlands --** Floating treatment wetlands are islands of emergent vegetation that are designed and placed to treat urban stormwater. Plants are grown on a floating mat and can therefore be used in a system with fluctuating water levels. Tanner and Headley (2011) found that planted floating mats reduced the transport of fine suspended particles, physical turbidity, and dissolved reactive P. Van de Moortel et al. (2010) found that engineered floating wetlands removed P, but that P removal was greatest when temperatures were between 5°C and 15°C. Tanner and Headley (2011) went on to indicate that the plants take up nutrients, and the roots also serve as substrate for the development of additional biofilm that contained a bacterial community capable of also removing nutrients. Given the scenario for Loon and Clear lakes, floating wetlands may be difficult to implement; however, as the community grapples with what to do about Gaiter Lake, the practice may have some application potential.

<u>Aquatic Animal Management</u>

**Waterfowl Staging Reduction –** When a large population of waterfowl spends considerable time on a lake, particularly a smaller body of water, the flock can be a significant contributor of phosphorus. In Green Lake, Washington, researchers noted that Canada Geese produced large amounts of excrement that were deposited directly into the lake through digestion was soluble (KCM 1995). Depending on the source of vegetation, excrement-based phosphorous could be classified as either internal or external loading, but in reality is likely a mix of the two. To address the increasing number of resident geese at Green Lake, the City has been operating a Goose Management Program since 1987 (KCM 1995).

Management approaches for geese in urban environments range from chemical repellents to scare tactics and reproductive inhibition to euthanasia, and disturbance tactics (Smith et al. 1999). Smith et al. (1999) also found that open water in the winter is a particularly favorite habitat in northern areas, and if goose population problems are to be addressed, aerators need to be turned off to allow for full ice cover. In Loon Lake, a periodic reduction in aeration that allows the lake to freeze over for short periods of time could be useful, but would need to be assessed.

**Fish Community Biomanipulation –** The management of fish populations, where possible, can be approached with the goal of changing the aquatic ecosystem. In most cases, fisheries are managed to obtain goals related to fish size structure, density, recreational opportunity, and/or food production. Studies, however, have documented the importance of fish species, to water quality management (e.g., Jeppesen et al 2007). Herwig et al. (2004) found that biomanipulative suppression of fathead minnows using walleye may be useful to improve water quality in Minnesota wetlands. Noonan (1998) found mixed, but generally positive trends after biomanipulation in an urban Minnesota lake following a rotenone treatment. Waseca Lakes have been involved in rotenone treatments in the past, also with mixed results; however, biomanipulation should not be dismissed.

Bernes et al. (2015) critically evaluated 233 fish biomanipulations, of which 128 case studies included reduction in zooplanktivorous fishes to improve water quality. The removal of planktivores and benthivores, regardless of predator fish stocking efforts, was generally found to increase water clarity and decrease Chl-a concentrations during the reduction effort and for the following 3 years. Bernes et al. (2015) also found that among these studies where predator stocking was the only mechanism used to reduce zooplanktivore density, no significant changes in water clarity or Chl-a could be detected. Many of the studies that Bernes et al. (2015) reviewed clearly indicated that reductions in Chl-a were greatest in lakes with the most intensive biomanipulation strategies, including intense fish removal in smaller lakes with high TP concentrations.

Successful biomanipulations are intensive, require both financial and labor investment, but also have the general support of the local community (Gulati et al. 2008). Therefore, implementing a biomanipulation program requires careful consideration. Lammens (2001) prepared a report for the Food and Agricultural Organization of the United Nations that provided guidance for when a biomanipulation should be considered as a possible management approach (Appendix F).

### *5.4 Phosphorous Reduction Strategy Recommendations*

Internal loading of TP, as anticipated, is a significant portion of the annual TP cycles in both Waseca Lakes (47% for Clear Lake, and nearly 66% at Loon Lake; Tables 21 and 28). Researchers have suggested (e.g., Whitehead et al. 2011), and agencies have often adopted, the nutrient management approach that places reductions in external loading as a prerequisite to effective internal load management. Although external load reductions are critically important, simultaneous efforts to begin addressing internal load reductions are prudent.

As a result of this assessment, information to better identify and verify TP allocations contributing to the eutrophication of Waseca's lakes have been secured. The phosphorous reduction management options described above are summarized in Table 33 below. For each option, several evaluation criteria, based on published literature and state conservation agencies implementation reports, are categorically ranked.

As reported by McCormick and Campbell (2007), the evaluation of various nutrient reduction practices and strategies can be completed, but is inevitably tied to a subjective review of published literature. Overall, McCormick and Campbell (2007) found that several BMP types, including riparian buffer strips and constructed wetlands had good potential to reduce phosphorus loading in some rural areas, but that no single BMP is likely to be the most effective in all locations or situations. Disclaimer – the Table 33 rankings are subjective, but offer educated insight from the authors. The options highlighted in bold in Table 33 are recommended for implementation.

Table 33. Summary of potential options to reduce phosphorous concentrations in the lake environment. For each option, implementation timing needed [short- (<2 years), mid- (3-5 years), and long-term (>5 years)], potential effectiveness [regardless of cost, regulatory limitations, and social acceptance), 1=weak/unknown potential, 3=strong potential], relative cost ($=low cost, $$$=high cost), regulatory limitations [e.g., permitting, zoning, state and federal requirements (1=limited challenges, 3= challenges that with proper planning can be overcome, 5=significant challenges)], social acceptance (1=likely to be accepted well, 3=likely to meet resistance). Please note that within any set of conditions, all of these options have some potential to help reduce phosphorous. It is also recognized that some of these options may have been implemented during the preparation of this report. In some cases, sufficient information was not available (NA) to make a reasonable estimate for a given criteria and option.

| Phosphorous Reduction Option and/or Strategy | Timing | Potential Effectiveness | Relative Cost | Regulatory Limitations | Social Acceptance |
|---|---|---|---|---|---|
| **Interpretive Signage** | Short | 2 | $ | 1 | 1 |
| Adopt-a-Lake Program | Mid | 1 | $ | 1 | 1 |
| Youth Programs | Short | 2 | $ | 1 | 1 |
| **Implement and Grant Authority to a Lakes Management Commission** | Long | 3 | $$ | 3 | 2 |
| **Rewarding Lake Stewardship** | Mid | 3 | $$ | 3 | 2 |
| Ecosystem Services Approach | Mid/Long | 2 | $$ | 3 | 3 |
| **Regular Monitoring** | *Ongoing monitoring allows for adaptive management!!!* | | | | |
| **Enforce Existing Water Protections** | Short | 3 | $$ | 1 | 3 |
| **Enhancing Surface Water Protections** | Mid/Long | 1 | $ | 3 | 3 |
| **Boat Wake Limitations** | Short | 2 | $ | 3 | 2 |
| Reduce/Restrict Impervious Surfaces | | | | | |
| Adopt/enhance ordinances and policies | Mid | 2 | $ | 5 | 3 |
| Preserve public vegetated green space | Short | 2 | $ | 1 | 1 |
| Incorporate curvilinear surface designs | Mid | 1 | $$ | 3 | 1 |
| Reduce standard roadway widths | Long | 2 | $$$ | 5 | 2 |
| Incorporate vegetated swales | Mid | 3 | $$ | 3 | 2 |
| Use permeable materials | Long | 1 | $$$ | 3 | 3 |
| Incorporate green roof plans | Long | 1 | $$$ | 3 | 2 |
| Route stormwater through bioretention | Long | 3 | $$$ | 3 | 2 |
| Water Quality Manholes and Baffle Boxes | Mid/Long | 2 | $$$ | 3 | 1 |
| **Street Cleaning** | Short | 3 | $$ | 1 | 1 |
| **Snow Storage** | Short | 2 | $ | 1 | 1 |
| Lawn Management | Short | 2 | $ | 1 | 3 |
| Water Reuse Systems | Long | 1 | $$$ | 5 | 3 |
| **Vegetated waterways** | Short/Mid | 2 | $$ | 3 | 2 |
| **Buffers/Vegetated treatment systems** | Short | 2 | $$ | 3 | 2 |
| **Elimination of Open Tile Intakes** | Short | 2 | $$ | 3 | 3 |
| Farm Ponds/Stormwater Wetlands | Long | 2 | $$$ | 5 | 2 |
| Residue Management/Tillage Practices | Short | 2 | $ | 1 | 2 |
| Fertilizer Modification Strategies | | | | | |
| Soil Testing | Short | 3 | $ | 1 | 3 |
| Manure Testing | Short | 2 | $ | 1 | 3 |
| Variable Rate Applications | Short | 3 | $ | 1 | 3 |
| Use of Low-Solubility P-Fertilizer | NA | 1 | NA | 1 | 3 |
| **Septic System Management** | Long | 2 | $$$ | 3 | 3 |
| Bioretention cells/ Rain Gardens | Mid | 2 | $$ | 3 | 2 |
| Nutrient diversion | Long | 1 | NA | 5 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| **Table 33 Continued** | | | | | |
| Targeted Withdrawals and Circulations | | | | | |
| Selective withdrawal | Mid | 1 | $$ | 5 | 1 |
| Circulation and Destratification | Mid | 1 | $$$ | 3 | 1 |
| Aeration or oxygenation | Mid | 1 | $$ | 3 | 1 |
| Dredging | Long | 2 | $$$ | 5 | 1 |
| **Water Level Management/Drawdowns** | Long | 3 | $$ | 3 | 3 |
| Breakwaters | Long | 1 | $$$ | 5 | 2 |
| **Groins** | Short | 3 | $ | 3 | 1 |
| **Aluminum Phosphate** | Mid | 3 | $$$ | 3 | 1 |
| Ferric Chloride | Mid | 2 | $$$ | 3 | 1 |
| RIPLOX Method | NA | 1 | NA | 5 | 2 |
| Phoslock | NA | 1 | NA | 5 | 2 |
| FE-Gypsum | NA | 1 | NA | 5 | 2 |
| Modified Zeolite | NA | 1 | NA | 5 | 2 |
| Curly-leaf Pondweed Reduction | | | | | |
| Chemical | Short/Mid | 1 | $$ | 3 | 2 |
| Physical | Mid/Long | 2 | $$ | 3 | 1 |
| Biological | NA* | | | | |
| Shoreline Re-Vegetation | Mid | 1 | $$ | 1 | 3 |
| Floating Wetlands | Long | 1 | $$$ | 5 | 3 |
| **Waterfowl Staging Reduction** | Short | 2 | $ | 3 | 2 |
| **Biomanipulation of Fish Community** | Mid/Long | 3 | $$$ | 3 | 2 |

**In this case, NA is "Not Available" as an option at this time. The only feasible approach for this option is the use of grass carp, however, release of this species into Minnesota waters is strictly prohibited.*

# 6.0 SUPPORTING AND SUPPLEMENTAL RESOURCES

## *6.1 References Cited*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### 6.2 List of Abbreviations, Acronyms, and Units of Measure

The conservation community utilizes a wide range of abbreviations and acronyms. Although these acronyms improve communication among those familiar with the nomenclature, it causes confusion for others. The list below is intended to serve the reader as a quick reference guide for defining abbreviations, units of measure, and acronyms.

| | |
|---|---|
| *a.k.a.* | also known as |
| Alum | Aluminum Phosphate |
| avg | average |
| BMP | Best Management Practice |
| C-value | Conservatism Value |
| CD | County Ditch |
| Chl-a | Chlorophyll-a |
| CLP | Curly-leaf Pondweed |
| CTI | Compound Topographic Index |
| CWA | Clean Water Act |
| DEM | Digital Elevation Map |
| DO | Dissolved Oxygen |
| DOW# | Division of Waters Number |
| *e.g.* | for example |
| EWM | Eurasian Watermilfoil |
| FO | Frequency of Occurrence |
| FQI | Floristic Quality Index |
| FWMC | Flow-weighted Mean Concentration |
| GIS | Geographic Information Systems |
| HGTV | Home and Garden Television |
| IDNR | Iowa Department of Natural Resources |
| *i.e.* | that is |
| LGU | Local Government Unit |
| MDNR | Minnesota Department of Natural Resources |
| MOS | Margin of Safety |
| MPCA | Minnesota Pollution Control Agency |
| MVTL | Minnesota Valley Testing Laboratory |
| N | Nitrogen (also denotes sample size in some tables and figures) |
| $N_s$ | Number of Species (Species Richness) |
| NA | Not Available |
| $NO_2+NO_3$ | Nitrate + Nitrite Nitrogen |
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | Natural Resource Conservation Service |
| OP | Ortho-phosphorus |
| P | Phosphorous |
| PBS | Public Broadcast System |
| Pheo | Pheophytin |
| sp. | One unknown species within a genus |
| spp. | Multiple unknown species within a genus |
| ST | Secchi Transparency |
| TKN | Total Kjeldahl Nitrogen |
| TMDL | Total Maximum Daily Load |
| TN | Total Nitrogen |
| TP | Total Phosphorus |
| TSI | Trophic State Index |
| TSS | Total Suspended Solids |
| WCB | Western Corn Belt |
| WLA | Waseca Lakes Association |
| WRC | Water Resources Center (Minnesota State University, Mankato) |
| USEPA/EPA | Environmental Protection Agency |
| USDA | United States Department of Agriculture |
| USGS | United States Geological Survey |
| UWSP | University of Wisconsin – Stevens Point |

| Units of Measure | |
|---|---|
| C | Celsius |
| cfs | cubic feet/second |
| cm | centimeter |
| d | Day |
| F | Fahrenheit |
| ft | feet |
| ha | hectare |
| $hm^3$ | cubic hectometers |
| hr | hour |
| in | inches |
| kg | kilogram |
| L | liter |
| m | meters |
| mg | milligram |
| ppb | parts per billion |
| ppm | parts per million |
| µg | microgram |
| yr | year |

### 6.3 Appendices and Other Supplemental Materials

## Appendix A. Clear Lake Timeline and Historical Documentation.

Timeline of historical documentation for Clear Lake in Waseca, Minnesota. The data in the first table were compiled by the Waseca Lakes Association and Bolton and Menk (2003) and are provided here as a ready reference of influential events, important observations, and lake improvement strategies that have been attempted. The second table are fish-specific records for Clear Lake compiled from MDNR Records.

| Date | Implementation Effort | Responsible Party |
|---|---|---|
| 1873 | Legislation passes rule to prevent digging, draining, and/or manipulating Clear Lake | Minnesota State Legislature |
| 1926 | DNR begins stocking game fish | MDNR |
| 1937 | Waseca grants permission to the State to construct and maintain a dam. | DNR, Waseca County |
| 1954 | Copper sulfate is applied to kill algae. | ? |
| 1958 | Copper sulfate is applied again to kill algae | ? |
| 1957-1962 | Dam was replaced, half of the structure was poured concrete, while the other half was make up rocks and chunks of concrete | ? |
| 1963 | Lake was treated with toxaphene in an attempt to kill off all rough fish, however this treatment did not have the intended affects. Waseca Sportsmen construct a rough fish barrier at the outlet of Clear Lake. DNR initiates a fish reclamation project. DNR constructs a northern pike spawning area adjacent to Maplewood Park. | Waseca Sportsmen, MDNR |
| 1964 | DNR conducts plant survey and finds that aquatic plants responded well to fish reclamation project. | MDNR |
| 1974 | City of Waseca Contracts with National Biocentric, Inc to determine where the greatest sources of nutrients are to Clear Lake. They find that Loon Lake was contributing approximately 191 pounds of phosphorus to Clear Lake at this time. Flow passing through monitoring location #3 contributed 643 pounds of phosphorus to Clear Lake at this time. Inflow passing through monitoring location #3 represents flow through a 72 inch storm sewer pipe that discharges into Clear Lake near Andy's Stink. The city is awarded a grant by the EPA. National Biocentric, Inc. develops a plan to incorporate a treatment marsh that will treat inflow from Loon Lake and flow passing through monitoring location #3. | City of Waseca, National Biocentric, Inc |
| 1979 | Two storm sewers were diverted into Gaiter Lake Marsh to remove phosphorus | City/County of Waseca |
| 1980 | Treatment marsh is constructed in the NW corner of Clear Lake on December 23, 1980. | City of Waseca, National Biocentric Inc. |
| 1981 | Water from Loon Lake and water passing through monitoring location #3 is diverted to a low lying peatland treatment area that eventually outlets via a pumping station back to Clear Lake on June 26, 1981. Water quality on Clear Lake improves significantly, 52% reduction in TP in 1981 and 70% in 1982. | City of Waseca |
| 1986 | The southwest shoreline near US 14 is rip-rapped. | City/County of Waseca |
| 1987 | DNR conducts a second fish reclamation project. Rotenone is used to kill off all fish and the lake is restocked with game fish. | MDNR |
| 1988 | The southeast shoreline along US 14 is rip-rapped. | City/County of Waseca |

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| 1988-1990 | City of Waseca upgraded sanitary sewers to prevent overflow of raw sewage into Clear Lake during storm events | City of Waseca |
| 1988 | Clear Lake is treated with alum to reduce phosphorus and help to control algae. In-lake phosphorus concentrations are reduced in the two years following alum treatment. Two downstream lakes (Rice and Watkins) were drawn down to prevent migration of rough fish back to Clear Lake. The DNR renovates the northern pike rearing pond. A fish barrier is installed at the Clear Lake Outlet to prevent fish from falling over the dam. No fish passage from Loon Lake to Clear Lake | City of Waseca, MDNR |
| 1988-1990 | The City conducts a leaf and brush pickup from spring through fall to prevent debris from city streets from entering storm sewer systems. The City also begins an education program designed to reduce the use of fertilizers that contain phosphorus. | City of Waseca |
| 1988 | The City upgrades two sanitary sewers to prevent overflow during storm events (Park Street and 2nd Street NE). | City of Waseca |
| 1997 | An experimental regulation preventing the harvest of Largemouth Bass regardless of size was employed on Clear Lake. This regulation still persists today. | MDNR |
| 2000-2002 | Discharge from the treatment marsh is re-directed to Rice Lake via County Ditch 54. The re-direction of this water source effectively limits a large phosphorus source to Clear Lake but also reduces the amount of water entering Clear Lake; thereby reducing the flushing capacity of Clear Lake. The majority of the run-off generated by the developed lands within the municipality had now been diverted. The remaining watershed as it stands today consists of an area only a few hundred yards to the west of the Clear Lake shoreline. | City of Waseca |
| 2003 | Results from the Bolton and Menk study find that a majority of the flow from CD 15-1 bypasses Gaiter Lake. This major phosphorus source is therefore not being treated by Gaiter Lake. | Bolton and Menk, City of Waseca |
| 2005 | Construction of a city subdivision results in the complete collapse/plugging of the CD 15-1 tile. The CD 15-1 tile had previously been identified as the largest source of phosphorus to Clear Lake. | City of Waseca |
| 2008 | The Upper Cannon Lakes TMDL study is slated to begin in the spring of 2009. Staff members from the WRC and MPCA meet to discuss monitoring locations for Clear Lake. However, complications with the Gaiter Lake Diversion project prevent Clear Lake from begin included in this study. | MPCA, WRC, DNR, City of Waseca |
| 2011 | The City of Waseca and Waseca County partner with the WRC at MSU to develop a lake management plan for Clear Lake and Loon Lake. This plan will provide implementation suggestions and quantify the necessary phosphorus reduction. | City of Waseca, Waseca County, WRC |

Summary of fish survey data from various sources for Clear Lake, Waseca County, Minnesota from 1990-2010.

| Survey Date | Assessment Type | Why it was done | Yielded Results | Comments |
|---|---|---|---|---|
| **8/4/2010** | Population Assessment | | | Backpack Electrofishing |
| **11/8/2006** | Special Assessment | Evaluate status of LMB and WAE populations and determine presence of young of the year WAE | 28 LMB and 2 WAE were sampled in 1 hour of EF. "…continues to support a good production of older individuals with 83% of sampled fish being older than age-5…" | Electrofishing |
| **Early 2009** | Fish Stocking | Stock mixed age classes of fish into Clear Lake | | Fish came from Blowers Park/Watkins Lake and Goose Lake |
| **7/12/2005** | Resurvey | Monitor status of fish community | Abundant blue gills, golden shiners, and yellow perch. Pike ranged from 12-32in, walleye ranged from 5.5-7.5in. Other spp. of low abundance: black and yellow bullheads, carp, pumpkinseeds, and white suckers. | |
| **10/12/2004** | Special Assessment | LMB and WAE Survey in October 2004 | WAE catch primarily age-1 fish. WAE caught at 39 fish/hr. Only 11 LMB caught ranging from 9.3-18.4in. | Fall WAE and LMB Electrofishing |
| **6/03/2004** | Special Assessment | Day Survey of LMB | 3 20 minute stations sampled: 26 LMB caught from 8.3-18in long | LMB Electrofishing |
| **10/1/2003** | Special Assessment | Survey of LMB and WAE | LMB caught at a rate of 30 fish/hr; WAE was 6 fish/hr. | Fall WAE and LMB Electrofishing |
| **8/4/2003** | Population Assessment | Monitor status of fish community | WAE catch per GN was highest level since 1980's; Northern Pike GN catches stayed consistent | |
| **5/29/2003** | Special Assessment | Night survey of LMB | 15 LMB caught and 4 WAE caught in 3 20 minute stations | LMB Electrofishing |
| **10/24/2002** | Special Assessment | Survey LMB and WAE | H2O temp was only 43F; 1 WAE, 5 LMB, but numerous golden shiner and yellow perch were observed | LMB and WAE Electrofishing |
| **9/27/2001** | Special Assessment | Survey of LMB and WAE | 3 20 minute runs were done. Mean catch rate for the samples was 54 LMB/hour (not significantly different from 2000), 32 WAE were caught – major increase from 2000; most were age-1 WAE and probably from fingerling stock in 2000 | LMB and WAE Electrofishing |
| **9/25/2000** | Special Assessment | Survey of LMB | 101 LMB caught in 73 minutes of sampling; no WAE captured in this survey | LMB Electrofishing |
| **5/30/2000** | Lake Management Plan | Reduce urban runoff and drainage from outside lakeshed; | | Summarized in different document with more detail |

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| | | address problems associated with increased development | | |
| **10/11/1999** | Special Assessment | Night survey of LMB | 53.86 LMB/hour; 29% of total bass sampled were over 16in long. | LMB Electrofishing |
| **9/14/1999** | Population Assessment | Survey of fish community | "Bluegill and B. Crappie [dominate]…"<br>"WAE management will continue in 2000…fry stocked at 1500/littoral acre 3 out of 4 years." | |
| **6/2/1998** | Population Assessment | Survey of fish community | Lake is managed for bluegills and B. crappies with northern pike and LMB as secondary species. | |
| **6/2/1998** | Lake Information Report for Clear | | Identical "Status of Fishery" section as Population Assessment (above) | |
| **10/13/1998** | Special Sampling | Night Survey of LMB | LMB yielded an on-time catch rate of 36 fish/hour; 14% of LMB sampled were longer than 16 inches | LMB Electrofishing |
| **7/29/1996** | Population Assessment | Survey of fish community | Community is strongly influenced by dominant 1988 year class of B Crappie and, to a lesser extent, bluegill. LMB continue to be abundant. | |
| **9/25/1996** | Special Sampling | Night Survey of LMB | 45 fish/hour; Poor sampling conditions limited netting efficiency<br>*Secchi disc readings less than 1 foot. | LMB Electrofishing |
| **7/31/1995** | Population Assessment | Survey of fish community | Compared to other class 24 lakes: B Crappie catch was high, bluegill, northern, WAE, yellow perch, and bullhead catches were average.<br>"Panfish continue to grow slowly and continue to be dominated by 1988 year class." | |
| **8/15/1994** | Population Assessment | Survey of fish community | "Panfish continue to grow slowly and continue to be dominated by 1988 year class."<br>"B Crappie growth is almost stalled..."<br>"A single carp was netted, the first seen since 1987 reclamation." | |
| **8/15/1994** | Lake Information Report for Clear | | Identical "Status of Fishery" section as Population Assessment (above) | "…dominated by post reclamation game fish." |
| **7/28/1993** | Lake Information Report for Clear | | Nothing in "Status of Fishery" | |
| **8/19/1992** | Special Assessment | Panfish Assessment – "Hugh Valiant to | "Panfish continue to grow at a slow pace…attributed to elevated stocking rate, and exceeding the recommended | "…removal of 50.3lb of panfish/a. in 1990-92 has no |

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| | | assess panfish removal" | stocking rate for bluegill and b. crappie following 1987 reclamation | apparent effect on the growth rate." |
| **8/14/1991** | Special Assessment | Assess panfish removal | *"Northern pike appear to be thin – lack of submerged veg present"<br>"…removal of 13.1 lbs/acre of panfish in 1990 and 16.4 lbs/acre in 1991 – density of B Crappie increased<br>Only a single bluegill was other than age 3 (age 2) and all b. crappie were age 3 | Reason: Slow growing crappie |
| **8/27/1990** | Population Assessment | Update information for management purposes | Secchi disc reading 3.5; moderate algal bloom<br>Fish sampled are dominated by 1988 year class<br>Bluegills were abundant – fast growth not exhibited after reclamation<br>Northern pike represented with large, fast growing 2-3 year olds<br>WAE exhibited fast growing average<br>B Crappie were abundant – growth slows after age 2 and poor body condition is evident | |

## Appendix B. Loon Lake Timeline and Historical Documentation.

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| 6/4/2013-City of Waseca | The City of Waseca has agreed to purchase and donate a new aeration system for Loon Lake to protect the investment of the fish reclamation already performed in the lake. |
| 10/23 /2012-MDNR | Loon Lake Fish Reclamation tentative date using rotenone as a piscicide. |
| Spring 2012 -MDNR | Loon Lake will be stocked with Bluegills, Northern Pike and Largemouth Bass |
| 4/22/2010-MDNR | Winter Kill Assessment on Loon Lake was performed by the MDNR. The DNR set 3 Trap nets catching 319 Black bullheads, 2 Bluegill, and 3 yellow perch. Using 2 3/8-in trap nets lifted the same day 97 black bullheads were sampled. Feels that the aeration equipment is undersized. |
| 7/26/2004-MDNR | Full Lake assessment performed. Watershed Characteristics were evaluated 35 % municipal, 44% other land uses. Shoreline Characteristics were evaluated 75% municipal, with 40 homes on Loon Lake. |
| 7/28/2004-MDNR | Gill nets lifted. Assessment of fish population performed. 4 trap nets were set with 232 black bullhead, 64 northern pike, and 1 yellow perch being caught, with a total of 74.25 caught per net. Total weight of bullhead was 27.85, N. pike 69.18, y. perch 0.30 pounds.<br><br>9 Trap Nets (Standard Mesh) were lifted with 5081 black bullhead, 76 black crappie, 83 bluegill, 125 Northern Pike, 10 painted turtles, 1 snapping turtle, 1 white crappie and 1 yellow perch. Total Weights of the black bullhead 448.04, Black crappie 20.58, Bluegill 36.99, N. pike 118.78, white crappie .44 and yellow perch .02 pounds. |
| 9/7/2004-MDNR | Seine hauls were taken to determine natural reproduction on the SE shoreline. 43 YOY bluegill and 12 YOY largemouth were sampled. 103 black bullhead, 1 fathead minnow and 4 green sunfish greater than 1 year old were sampled. |
| 01/08/2008 | Stocking history and gill net, trap net, and seine net catch history can be found on Historic Catch Summary Sheets. |
| 7/15/2005-MDNR & Lakeshore Inn Nursing Home | Shoreline habitat improvement grant was awarded to the nursing home with a completion date of 6/30/2007. |
| 6/1/2005-MDNR | Standard electrofishing sampling was performed on Loon Lake, which was targeting largemouth bass. A total 16 largemouth bass were sampled with a total weight of 32.01pounds. Historic electrofishing catch and stocking reports up to 2005 can be found in separate documents. |

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| 7/5/2005 | Donation of Loon Lake Fishing pier by the MDNR and Kwik Trip |
| 05/11/2005-MDNR & The City of Waseca | The MDNR acknowledges that substantial efforts to improve aquatic vegetation and upland vegetation that is conducive to good water quality has been made by the city. |
| 3/30/2005-MDNR City of Waseca | Both parties signed a aeration agreement |
| 7/26/2004 | Aquatic vegetation sample was taken by the MDNR. They performed 10 transects in depths of water up to 6.5 ft. Found 8 species of macrophyte with rare abundance. Two other Species were found outside transects.<br><br>Physical and Chemical Water Quality sampling was performed. Dissolved oxygen showed a declining curve as depth increased. Hypolimnion Anoxic at 9 feet. Algae caused the water color to be green. P was .159 ppm, Total alk was 175 ppm, Total Dissolved Solids was 516 ppm, Chlorophyll a was 40.2 ppb, conductivity was 620 micro-mho, and pH was 9.06. |
| 8/27/2003-MDNR | Performed a natural reproduction check on Loon Lake. 1 gill net was set using standard sampling methods. 179 Black bullheads, 1 Black Crappie, 5 Bluegill, 27 Northern Pike and 1 yellow perch were sampled. 21.06 pounds of bbh, .32 pounds of blcrappie, 2.60 pounds of bluegill, 31.93 pounds of n. pike and .55 pounds of yellow perch was caught in the one gill net.<br><br>2 gillnets were set using standard sampling methods. A total of 110 (7.55 lbs) black bullheads, 1 (0.02 lbs) of black crappie, 1 (0.03 lbs) of largemouth bass and 5 (1.93 lbs) of northern pike were sampled.<br><br>Historical gill and trap net catches can be found in a separate document that can be identified by the date. |
| 4/25/2003-MDNR | Loon lake habitat project received authorization to make expenditures to begin the contract, with a landowner agreement form to continue project for 10 years. Grant money expired on the 6/30/2004 |
| 9/17/2002-MDNR | DNR Waters Field survey was conducted on the North Shore finding that it was heavily rip-rapped with no suitable habitat for tree growth. |
| 08/19/2002-MDNR | Natural reproduction check. Six trap nets were lifted on 8/21/2013 using standard sampling methods. 9 (5.41 lbs) black bullheads, 17 (6.83 lbs) black crappies, 102 (11.95 lbs) bluegill and 45 (23.83 lbs) northern pike were sampled. |
| 9/17/2001-MDNR | Natural reproduction check was conducted in response to winter kill events in 1999-2000 and 2000-2001. 4 trap nets were set using standard sampling procedures. 1 (0.34 lbs) black bullhead, 5 (1.21 lbs) black crappie, 153 (4.21 lbs) bluegill, and 5 (0.61) northern pike were sampled. |

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| March 2000 | Waseca County News reported a large fish kill of northern pike on Loon Lake March 7. Craig Berberich (Waterville Fisheries) counted 125 dead pike just along the park, and roughly 200 around the treatment plant. March 24 – DNR estimates between 1,000 and 2,000 dead fish. |
| 9/12/2000-MDNR | This survey was conducted to determine the extent of reproduction following the re-introduction of bluegill and largemouth bass. Re-introduction was following a winterkill event in 1999-2000. 3 trap nets were deployed using standard sampling methods. 18 (0.80 lbs) black crappie, 200 (2.45 lbs) bluegill, and 2 (0.041 lbs) pumpkinseed were sampled. |
| 10/1/1999-MDNR | Air line on aeration system notification for replacement. |
| 9/7/1999-MDNR | Sampling was in response to the reclamation of Loon Lake in 1996 to check reproduction rates. Notes include good water quality and plant growth. CPUE declined from 1998. 2 (0.02 lbs) bluegill, 10 (12.17 lbs) northern pike, and 1 (1.78 lbs) walleye was sampled using 3 trap nets. 2 seine hauls produced 1 bluegill and 7 largemouth bass that were greater than age one. |
| 11/2/1999-MDNR | No kill fishing regulation is put into effect. Regulations will last until February 2000. |
| 9/8/1999 | Trap net and seine data from September 8 1999 was unclear why it was sampled. 3 bluegill were sampled, 7 largemouth bass, 10 northern pike and 1 walleye. |
| 6/23/1999-MDNR | Aeration agreement |
| 9/10/1998-MDNR | Fish sampling survey after the Loon Lake Reclamation by rotenone in 1996. 5 trap nets were deployed using standard sampling procedures. 1 Black crappie, 6 bluegill, 2 largemouth bass, 30 northern pike, and 10 walleye were sampled. Weight data may be a repeat of the fish count data. In 1997, after the reclamation, northern pike, largemouth bass and bluegill were stocked. Walleye and crappie were introduced to the lake by unknown sources. |
| 11/14/1997 | Lake management plan outlines goals for future management of Loon Lake. Provide bluegill fishery with secondary northern pike and largemouth bass fishery. Outlines plans to build fishing pier. |
| 8/5/1997-MDNR | Reclamation evaluation after rotenone treatment in 1996, this survey was to determine natural reproduction of stocked bluegill, northern pike, and largemouth bass. 1 black bullhead, 2 bluegill and 1 walleye over age 1 were caught within the 4 trap nets with a ¼ in mesh. 2 black crappie, 43 bluegill, 22 largemouth bass, and 60 northern pike were sampled as Young of the year. |

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| | Aquatic vegetation healthy after rotenone treatment in 1996. Coontail was the most abundant macrophyte species.<br><br>Anoxic conditions were sampled at 7.0 feet of water. Bottom depth is 9 feet. Dissolved oxygen relatively uniform at 6.6 mg/l up to 5 feet. Secchi disk reading up to 6.8 feet with a green water color. |
| 8/1/1997 | Contract with Clean Flo Laboratories Inc. for aeration system. Clean Flo provided assistance for installation. |
| 1/13/1997-MDNR | Installation of helixor aeration system to aerate Loon Lake in the winter months. |
| 11/12/1996-MDNR | Rotenone treatment took place at 7 am and went until about 2:30. Cleanup done by 3:30. 2 foot drawdown proposed. 4092 pounds of 5% rotenone used and 55 gallons of liquid rotenone in 1 drip station in shoal area. 100% desired kill. |
| 7/15/1996-MDNR | The piscicide rotenone was approved by the DNR to target black bullhead within Loon Lake. Plan outlines that it will be in liquid form and powder form and will be sprayed from boat. It also states this procedure is to rehabilitate a good centrarchid fishery. After the rotenone treatment re-introduction of game fish will follow. |
| 6/1/1996-MDNR | Rehabilitation proposal sheet suggests that partial winterkills have caused large standing crops of black bullhead that prevent game fish from establishment. 3000 black bullheads, 1 yellow perch, 3 bluegill and 3 WTS were sampled using 4 trap nets. |
| January 1996 | Dissolved oxygen levels deemed critically low in Loon Lake. Aeration system was found to be insufficient to carry most game fish through the winter and was shut off to avoid creating a refuge area for black bullheads in hopes of a complete kill. |
| 8/3/1995-MDNR | 4 trap nets were deployed in august before a winterkill event between 1995-1996 using standard sampling procedure. 42 black bullheads, 29 black crappie, 150 bluegill, 1 channel catfish, 10 largemouth bass, 2 pumpkinseed sunfish, and 24 yellow perch were sampled. Winterkill affected game fish populations and increased black bullhead numbers. |
| 1/31/1996-MDNR | A letter sent from the DNR to the city manager, stated that they started to observe a winterkill. DNR personal listed options for management such as: turn off aeration system for complete kill so Black bullhead don't dominate the community, chemical rehabilitation if BBH survive, etc. |
| 9/30/1994 | MDNR staff noted that shoreline vegetation was dense and included considerable abundance of coontail and sago pondweed. Electrofishing sample to check for |

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| | LMB and WAE yielded 47 fish ranging from 170 to 220 mm and a catch rate of 87/hr. |
| 8/17/1994-MDNR | A special sampling event before the winterkill event in 1995. 4 trap nets were deployed using standard procedure. 125 black bullhead, 443 black crappie, 169 bluegill, 1 hybrid sunfish, 49 largemouth bass, and 9 yellow perch were sampled. The DNR found that Loon Lake is a good panfish lake with an abundance of bluegill and an overabundance of black crappie. They also believed that largemouth bass were very abundant.<br><br>When sampling trap nets, the MDNR took a dissolved oxygen profile and found that DO was uniform above ten ppm to six feet. After six feet DO dropped to 6.3 at the deepest point in the lake. Secchi disc readings were up to 8.7 feet with clear water. |
| 7/21/1993-MDNR | In 1993 the DNR resampled Loon Lake. The DNR deployed 2 gill nets and sampled 535 black bullheads, 179 black crappie, 46 bluegill, 2 channel catfish, 45 largemouth bass, 2 walleye, 1 white sucker, and 16 yellow perch. 8 trap nets were also set sampling 323 black bullhead, 344 black crappie, 570 bluegill, 34 Largemouth bass, and 1 yellow perch. The DNR also sampled using electrofishing and found 23 black crappie, 15 bluegill, and 127 largemouth bass. Black bullhead were up from 1992 and bluegill and crappie were down from 1992.<br><br>Aquatic vegetation was sampled in the 1993 resurvey of Loon Lake. Only three species were identified; coontail, curled pondweed, and sago pondweed. 20 aquatic vegetation transects were taken with a maximum sample depth of 6 ft.<br><br>In a resurvey of Loon Lake, the DNR tested multiple parameters. They found that the current water level is high at BM-2. They found 11 inlets that have a mean width was 8 ft. with a mean depth a 4.1 ft. 1 outlet was identified with carriers water to clear lake that has a mean width of 1.50 ft, a mean depth of 1.40 ft and a flow of 4.2 cubic feet per second.<br>They DNR analyzed the surrounding watershed finding that 5% was woodland, 5% agricultural crops, and 90% is municipal. They analyzed land use of the shoreline as well to determine that 10% is woodland and 90% is municipal.<br><br>DO was sampled finding that DO was relatively constant up to 4.5 feet at 11.5 ppm. After 6 ft DO drops in ppm to 4.0 ppm at 7 feet. The secchi disc reading was 6.5 feet with a water color of green. |
| 7/14/92-MDNR | A fish survey was taken for management purposes. 1 gillnet was deployed. 1 (1.94 lbs) white sucker, 35 (20 lbs) black bullhead, 67 (21 lbs) bluegill, 97 (18.00 lbs) black crappie, 3 (0.44 lbs) yellow perch, and 3 (12.38 lbs) channel catfish were sampled using the gill net. 4 trap nets were also using in this fish survey. 65 (31.50 |

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| | lbs) black bullhead, 2 (0.37 lbs) pumpkinseed sunfish, 377 (99.50 lbs) bluegill, 1 (3.13 lbs) largemouth bass, 241 (44.37 lbs) black crappie, and 1 (1.31 lbs) walleye were sampled using the trap nets as a capture method.<br><br>Sample taken to gain information for management purposes. Secchi disc reading was 2 feet. Dissolved oxygen was relatively low at the surface at 6.8 ppm decreasing to 3.6 at 2.5 meters down. |
| 6/15/1992-IRI | The lake restoration committee entrusted Instrumental Research Inc. to process water quality samples. Sample dates include 6/15/1992, 7/2/1992, 7/23/1992, and 8/8/1992. |
| 5/15/1992-MDNR | A creel survey found that from Dec 1991 to March 1992 the amount of angling hours were 12,400. 41,00 bluegill (including releases), 23,000 black crappie (including releases) were catch in that time period Bluegill caught (including releases), 23,000 black crappie caught (including releases), total harvest (crappie+bluegill) of 54,000 fish. |
| December 1991-March 1992 | Creel Survey conducted. 12,400 angler hours, 41,000 |
| 9/20/1991 City of Waseca | Loon Lake Treatment Facility dedication ceremony |
| 8/19/1991-MDNR | A fish survey was completed to determine the amount of panfish removal in Loon Lake. 1 gillnet sampled 25 (10 lbs), black bullhead, 2 (6 lbs) channel catfish, 114 (22.62 lbs), and 33 (8.19 lbs) black crappie. Also 2 trap nets were deployed sampling 45 (19.50 lbs) black bullhead, 1 (0.12 lbs) pumpkinseed sunfish, 420 (94 lbs) bluegill, and 192 (48.50 lbs) black crappie. This survey was done in response to a hundred pound removal of bluegill and crappie. They found that bluegill and crappie numbers decreased but overall size increased.<br><br>A 1.7 feet secchi disc reading and dissolved oxygen was taken as part of a fish survey. DO was over 9 ppm down to 4 feet deep after 4 feet DO decreased to 7.6 ppm at 7 feet. Low visibility was caused by and dense algal bloom. |
| Spring 1991 | 48 adult channel catfish (240 lbs) and 200 adult bluegills stocked (50 lbs). |
| 10/29/1990-MDNR | Water quality data was taken in response to a summerkill event. |
| 10/5/1990-MDNR | Letter to the City of Waseca stating that summerkills are taking place because of thermal stratification.<br><br>DNR moves 9,000 lbs of adult bluegill (51,600 fish) and 2,175 lbs of adult black crappie (13,050 fish) out of Loon Lake. |
| 8/20/1990-MDNR | Investigation of summer kill event. 7000 to 8000 bluegills, 200 black crappie and 15 largemouth bass are estimated fatalities. Low oxygen in the water |

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| | column suspected cause. Green color water noted which was caused by heavy algal bloom. Surface DO at 2.6 ppm. |
| 8/21/1990-MDNR | Fish survey was completed in response to low oxygen levels and summer kill events. Heavy algal blooms occurred in the summer. 1 gill net was deployed that sampled 26 (9.63 lbs) black bullhead, 563 (67.25 lbs) bluegill, and 160 (25.62 lbs) black crappie. 3 trap nets were also used that sampled 322 (109.50 lbs) black bullhead, 856 (124.88 lbs) bluegill, 5 (5.19 lbs) largemouth bass, 434 (78.80 lbs) black crappie, and 1 (2.63 lbs) walleye. Bluegills are dominated by year 3 individuals. Black crappie are dominated by age 3 individuals and they also found a decrease in largemouth bass per net was recorded. |
| 12/27/1989-MDNR | Proposed removal of landing in Loon Lake by the city of Waseca |
| Spring 1989 | DNR harvested 58 one-lb adult largemouth bass out of Loon Lake to be used as broodstock elsewhere. |
| 1988-1990 – MDNR | Secchi disc readings were compiled for the entire year of 1988 through 1990. Readings can be found in a separate document. The document stated that in 1990 the secchi readings were greatly reduced from 1988. |
| 7/27/1988-MDNR | A fish survey was completed after the reclamation in 1983 and 1984. 3 gillnets were deployed sampling in 44 (19.50 lbs) black bullhead, 654 (29.77 lbs) bluegill, 43 (25.93 lbs) largemouth bass, and 238 (3.90 lbs) black crappie. 3 trapnets were also deployed sampling 2 (1.12 lbs) black bullhead, 279 (26 lbs) bluegill, 24 (2.94 lbs) largemouth bass, and 110 (5.11 lbs) black crappie. Bluegill rates have increased since 1986 with the population being dominated by age 1 individuals. Largemouth bass were in good numbers as well as black crappie. |
| 12/2/1986-MDNR | Possible fish kill on November 26, found large amounts of dead fish and 2 dead ducks. Also noted a cloudy substance entering the lake by the nursing home. |
| 7/30/1986-MDNR | A fish re-survey was completed on Loon Lake after the 83 and 84 reclamations. Dense algal blooms have been reported causing dense black bullhead populations. 3 gillnets were set sampling 212 (21 lbs) black bullhead, 61 (31.50 lbs) largemouth bass, 227 (22.50 lbs) bluegill, and 39 (6.80 lbs) black crappie. 3 trap nets were also set sampling 348 (48 lbs) black bullhead, 69 (26.70 lbs) largemouth bass, 45 (5.50 lbs) bluegill, and 2 (0.19 lbs) black crappie. Largemouth bass were abundant. Black crappie growth is good. Three year classes of bullhead present. |
| | DNR harvested 60 adult largemouth bass (totaling 85 lbs) out of Loon Lake to be used as broodstock elsewhere. |

| | |
|---|---|
| 4/16/1986-MDNR | Partial fish kill was recorded on Loon Lake. Noted that fish were attracted to Bird Eye's inlet as winter severity increased. |
| 5/2/1985-MDNR | News release stating 30 broodstock and 3000 yearlings of largemouth bass will be stocked in Loon Lake. The broodstock are expected to produce 13000 eggs per pound of fish. |
| 8/1/1984-MDNR | Permit to draw water levels down on Loon Lake to improve the quality of the lake. Dredging will occur in in selected areas. A jetty will be constructed and shoreline portions will be rip-rapped. |
| 1/6/1984-MDNR | An outline of the lake rehabilitation plan. Described drawdown procedures and rotenone treatment. Dead black bullheads were observed on 10/26/1983. Draw down levels were at 5 feet when ice over started. DNR did not feel trap netting was necessary to determine kill percentage; due to the lack of oxygen will be available during the winter months. |
| 5/18/1984-MDNR | A ban on motorboats was place on Loon Lake except those being propelled by electric motors. |
| 2/28/1984-MDNR | The MDNR outline their lake management plan. Reclamation in 1983 using rotenone will follow a draw down. City will provide aeration system in 1984, and LMB will be stocked. Population assessments will be completes in following years. |
| 10/26/1983-MDNR | Rotenone was dispensed on Loon Lake using a drip station, creating a 10-ppm solution that will stand for 8 hours. Also rotenone was dispensed on to Loon Lake from a canoe using a spray method. And on 10/29/1983 a 10 gallons per acre of 4 ppm of rotenone was applied to mudflats via helicopter. |
| 10/18/1983-MDNR | Chemical reclamation on Loon Lake agreement with the sportsman club. |
| 10/5/1983-MDNR | Fisheries Lake survey prior to reclamation of Loon Lake. DO showed a steady decline with depth with 10.7 ppm at the surface to 6.8 ppm at 2.5 meters. 60.0 ppm of sulfate, 0.229 ppm of TP, 202.5 total alkalinity and 560 AHMOS were analyzed in Loon Lake. Secchi.<br><br>Reading was 1.1 feet and water color was green due to algal bloom. Bank erosion was slight to severe in various locations. Pollutants are able to enter the system in through storm water systems. Watershed use is 90% municipal and 10% agricultural. Shoreline use is 100% urban development except on the NW shore which is occupied by pasture. Shoal soils present 50% muck and 50% sand. |
| 8/5/1983-MDNR | A fish survey was completed prior to the Loon Lake Reclamation in 1983 and 1984. 6 gill nets were used to sample 862 (142.2 lbs) black bullhead, 239 (50.4 lbs) walleye, and 1 (0.1 lbs) black crappie. 4 Trap nets |

| | |
|---|---|
| | were used to sample 707 (109.8 lbs) black bullhead, 258 (57.2 lbs) walleye, and 8 (1.3 lbs) black crappie.<br><br>An aquatic vegetation survey was completed in conjunction with a fish survey. Less than one percent of the lake surface was occupied by Cattail. Two submerging macrophytes found in the survey are Curly-leaf Pondweed (which was found occasionally) and Sago Pondweed (which was Common). |
| 7/14/1983-MDNR | Document outlining drawdown activities in Loon Lake like lakebed exposure to reduce nutrient levels, bullhead elimination, regrowth of aquatic vegetation, lake aeration system, dredging small portions of the lakebed and restocking the lake with bluegills and largemouth bass. |
| 4/27/1982 | DNR natural reproduction check for walleye survival provides inconclusive data. |
| 4/29/1981 | MDNR Commissioner orders an end to minnow collections on Loon Lake so the water body can be used as a walleye rearing pond. |
| 8/12/1980 | Fish kill documented as a result of fertilizer spill from Midland Coop Inc. while unloading rail freight car. Killed a minimum of 2,500 6-inch walleye, of which Midland Coop was ordered to replace at $1.50 each. |
| 10/6/1964 | Minnesota Department of Conservation considers a request to close Loon Lake to commercial minnow harvesting and to have the designation as a “minnow lake” removed. |
| | |

## Appendix C. Public Information Meeting Information

CITY OF waseca

WRC
WATER RESOURCES CENTER
MINNESOTA STATE UNIVERSITY MANKATO

You are invited to attend a Community Meeting to discuss Waseca's Lakes
Wednesday, May 9, 2012
6—7:30 p.m.
Waseca County East Annex Building
300 N. State Street; Waseca
For More Information Contact Joe Pallardy
Water Resources Center (507) 389-2704

# WASECA'S LAKES NEED YOU!

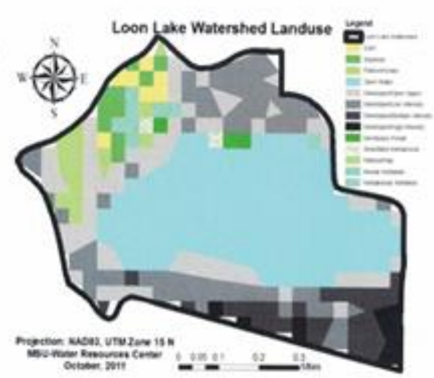
The City of Waseca and Waseca County have partnered together to contract with Minnesota State University's Water Resources Center to monitor the quality of Waseca's lakes and watershed and to draft a Lake Management Plan.

### Who should attend?

- Everyone who enjoys walking, biking, hiking, fishing, swimming, boating, canoeing, and other lake activities;
- Anyone with an interest in the management and protection of Waseca's lakes and watersheds.

### What is the purpose of this meeting?

- Garner community input to develop a sustainable Lake Management Plan;
- Provide an overview of the water quality data collected by the Water Resource Center; and
- Discuss possible funding opportunities.

**Wednesday May 9th Resident Discussion Agenda**

1) Introduction

A) City of Waseca and Waseca County have partnered together with the Water Resources Center at Minnesota State University to develop a Lake Management Plan for Clear Lake and Loon Lake

i) 18-Month Partnership

ii) Watershed Hydrology/Watershed Characteristics

iii) Nutrient Budget for Clear Lake/Loon Lake

iv) Aquatic Vegetation Management

v) Determine Priority Management Areas within the Watersheds.

B) Purpose of this meeting

2) Grant Writing

A) MN DNR Curly-Leaf Pondweed Grant

B) EPA Urban Waters Grant

C) EPA Green Infrastructure Grant

***- These first two sections will be fairly brief; I just want to provide a terse overview of the partnership between the City/County and MSU and then move on.***

3) Resident Participation Session

A) Hand out three sticky notes, each sticky note has a different color (Red, Blue, and Yellow).

B) On the Red sticky note, residents will be asked to list and rank the top 3 activities that they enjoy most on Clear/Loon Lake with the number 1 indicating the activity that they enjoy most, 2 indicating the activity they enjoy second most, and 3 indicating the activity they enjoy third most. After they are done, they will pass their sticky notes to the end of the aisle. I will collect all of the notes and tally the scores. Three points will be awarded for the top activity identified on each note, two for the second activity, and one for the third activity.

Example:

1) Fishing (3 pts)

2) Swimming (2 pts)

3) Boating (1 pt)

C) While I am tallying up the points, residents will be asked to list the top 3 problems or concerns (with Clear/Loon Lake) that prevent them from enjoying the activities that they previously listed. After they have listed the top 3 concerns, I will have the residents introduce themselves to someone or work with the person sitting next to them to identify their top 2 concerns as they relate to the activities they previously listed. I will then ask the residents to write one concern each (2 per group) on the opposite side of the Blue sticky notes. Next, I will ask the residents to write one goal on the Yellow sticky notes that they would like to see accomplished so that the residents can better enjoy the activities they listed on the Red sticky notes, this goal should address the concern/problem that they wrote down on the Blue sticky notes. If the resident does not have a goal or idea for addressing the problem, they can simply state that they are not sure how to address this concern.

Example:

1) Concern: Fishing- I cannot seem to catch any quality size bluegills/crappies on Loon Lake; the fishery appears to be stunted.
Goal: Improve the size structure of quality size bluegills/crappies on Loon Lake.

2) Concern: Swimming-We can't swim in Clear Lake in July because of algae blooms.
Goal: Reduce the frequency of algae blooms in Clear Lake during July.

3) Concern: Boating- The weeds prevent me from taking my boat into certain areas of Clear Lake because the weeds become entangled around my propeller.

Goal: Reduce the amount of lake area where excessive aquatic plant growth prevents recreation by 15% by 2015.

D) At this point, I will have tallied the scores for each activity listed on the Red sticky notes. I will then group the activities into common themes and make a list of the activities that Waseca residents enjoy most on Clear Lake and Loon Lake. Next, I will label pieces of tape with the top activities and place them at various locations within the room. The total number of tallies for each activity will also be clearly marked on the tape. I will then have the residents place their blue and yellow sticky notes underneath each of the top activities. Next, I will have a volunteer read off a concern from the Blue note and a subsequent goal on the Yellow sticky note for a given activity. A brief discussion period will follow to determine if this concern represents a major priority that many residents agree upon. I will be taking notes over the course of this discussion on my laptop. The WRC staff and the City of Waseca will review these notes at a later date and will come up with a list of activities, concerns, and goals that will be incorporated into the lake management plans. This list will then be emailed out to all residents who attended the meeting. We will listen to suggestions that are generated by residents; however, the final list will be composed based on the discretion of the City of Waseca and WRC staff.

7:30- Meeting Concludes

WRC
WATER RESOURCES CENTER
MINNESOTA STATE UNIVERSITY MANKATO
2012

# Lake Management Plan: May 9th Resident Discussion

Waseca Resident,

Thank you for attending the Waseca Resident Meeting on May 9th, your voice has been heard! The resident meeting on May 9, 2012 was a success, with twenty-eight people attending the meeting. In addition to a strong turnout from Waseca residents, several members from the MNDNR (Todd Kolander, Craig Berberich, and Joe Eisterhold) attended the meeting. The opinions of these professionals contributed to the success of this meeting.

Waseca residents value their lakes as evidenced by the large number of activities listed. We know these lakes are an important part of how Waseca residents define themselves. Make no mistake; we **are** making progress towards improving these lakes! The partnership between the City of Waseca/Waseca County and the Water Resources Center represents a foundation for an effort to improve the quality of these valued resources. Remember, it took a long time for us to get to where we are at today!

The most common concerns reported during the meeting included the green color of the lakes during the summer, water quality/clarity, weeds, water depth, and storm water management. While Mother Nature can certainly play a large role in effecting certain components (*i.e.,* water depth), there are ways that we can begin to improve these lakes that have not been attempted to date. I briefly touched on two examples of potential opportunities to address storm water runoff and internal nutrient sources during the meeting.

The Water Resources Center in coordination with City of Waseca staff submitted a grant to the Environmental Protection Agency to determine optimal locations for implementing green infrastructure (rain gardens, curb cuts, wetland restoration) within the Clear Lake watershed. If funded, this grant opportunity would help to identify optimal locations within the Clear Lake watershed for installing green infrastructure for maximum water quality benefit. A second grant opportunity submitted to the EPA involves the creation of a demonstration study area for in-lake management practices that reduce the largest internal nutrient sources to Clear Lake. Developing management practices that reduce both external and internal nutrient sources will ultimately be required to fully restore both lake systems.

While these grants represent great opportunities to begin improving Clear/Loon Lake, it is important to realize that there are funding opportunities available for installing certain practices (rain gardens, rain barrels) in your own backyard. Several attendees to the May 9th meeting mentioned that they were interested in installing these types of structures on their own property. I would encourage you to contact your local soil and water conservation office to determine if funds are available for a project in your own backyard. Together, we can make a difference!

This fall, you will be invited to participate in a discussion of the water quality results observed during this study. At this meeting, the WRC staff will outline the necessary phosphorus reductions required from external and internal sources to both lakes. The WRC staff will relate the necessary reductions to the goals you listed during the May 9th meeting. An invitation to the fall discussion will be sent to your home address.

Thank you very much for your time,

Joe Pallardy

## Appendix D. Soil Order Information

**Information Box – Soil Orders**

Information gathered via the Plant and Soil Science eLibrary, University of Nebraska-Lincoln. (Accessed 4/28/14)

**Alfisols** are found in cool to hot humid areas under former forest vegetation and grass savanna. Alfisols often contain distinct argillic (clay) accumulations in the subsoil horizons that reduces the rate of water infiltration. Generally fertile and productive, these soils typically have a high concentration of nutrient cations (Ca, Mg, K, and Na) and are therefore, naturally fertile and productive.

**Entisols** are the soils of unstable environments, such as floodplains and slopes. Entisols are typical of recently deposited materials, such as alluvium aggradation or where glacial soils resist weathering. Productivity potential of Entisols varies widely, from very productive alluvial soils found on floodplains, to low fertility/productivity soils found on steep slopes or in sandy areas. Once disturbed, Entisols are often classified as highly erodible.

**Histosols** are soils predominately composed of organic materials in various stages of decomposition and are usually saturated. The saturation often creates anaerobic conditions and causes organic matter accumulation at rates faster than that of decomposition. Histosols can form in wetland areas.

**Inceptisols** are soils that exhibit minimal horizon development. They are more developed than Entisols, but still lack the features that are characteristic of other soil orders. Inceptisols are widely distributed and occur across a wide range of ecological settings. They are often found on fairly steep slopes, young geomorphic surfaces, and on resistant parent materials.

**Mollisols** are mineral soils that developed on grasslands, a vegetation that has extensive fibrous root systems. The topsoil of Mollisols is characteristically dark and rich with organic matter, making it extremely fertile. These soils are typically well saturated with basic cations ($Ca2+$, $Mg2+$, $Na+$, and $K+$) that are essential plant nutrients and due to high organic matter holds water within the soil profile.

## Appendix E. UWSP Rake Sampling Method for Macrophytes

Methods Excerpt (pp 13-19) from the Following Publication

Recommended Baseline Monitoring of Aquatic Plants in Wisconsin: Sampling Design, Field and Laboratory Procedures, Data Entry and Analysis, and Applications

*Jennifer Hauxwell[1], Susan Knight[2], Kelly Wagner[1], Alison Mikulyuk[1], Michelle Nault[1], Meghan Porzky[1], and Shaunna Chase[1]*

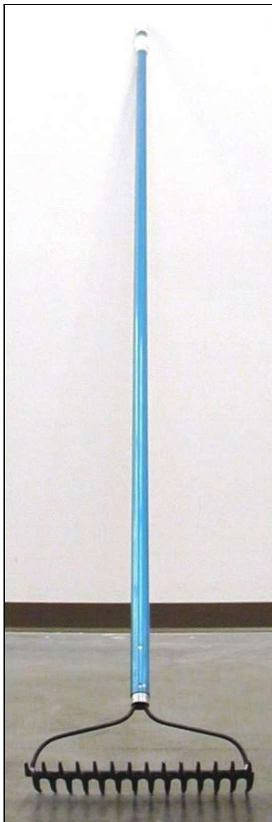
[1]Wisconsin Department of Natural Resources Bureau of Science Services
Fisheries and Aquatic Sciences Research Section 2801 Progress Road
Madison, WI 53716

[2]University of Wisconsin – Madison Trout Lake Station
10810 County Hwy N Boulder Junction, WI 54512

Last Updated: March 2010

**Constructing the Rake Samplers**

The rake samplers are each constructed of two rake heads welded together, bar-to-bar, to form a double-sided rake head. The rake head is 13.8 inches (35 centimeters) long, with approximately 14 tines on each side. For use in shallow waters, mount a double-sided rake head to a pole that has the capability to extend to 15 feet (4.6 meters). For use in deeper waters, attach a second double-sided rake head to a rope; this rake head should also be weighted (Figure 2).

| | |
|---|---|
|   | **Pole Sampler**<br><br>To make the pole samplers shown in the photographs, we removed the handles from 2 standard bow rakes (available at most hardware stores), and welded the rake heads together bar-to- bar.  We mounted the rake head to an<br>8-foot (telescoping to 15.5 feet) pool skimmer handle purchased from a supply store (left, $50). For an even sturdier sampler we purchased an aluminum Co-Handle from Duraframe Dipnet and designed a rake pole which attaches and detaches into 3 sections (right, $200). For depth recording, mark the rake handle in one-foot increments. Electrical tape marked with permanent marker, then covered with a length of clear packing tape works well and holds up over time. |
|  | **Rope Sampler**<br><br>A similar rake head should be constructed and attached to a 40-foot- long rope or anchor line. In order to ensure a quick vertical descent to the lake bottom, attach a light weight (~5 lb) to the rake head, away from the tines. The rope sampler pictured here has a short piece of steel tubing welded to the rake head to serve as a handle through which 45 feet of rope is attached. |

OLLECTING AND RECORDING FIELD DATA

Using the Rake Samplers

Collect one rake sample per sample site.

In water shallower than 15 feet deep, use the pole sampler. At each sample site, lower the rake straight through the water column to rest lightly on the bottom, twist the rake around twice, and then pull the rake straight out of the water.

In water deeper than 15 feet, drop the rope sampler straight into the water alongside the boat, drag the rake along the sediment surface for approximately one foot (0.3 m), and then pull the rake to the surface.

A large tray or bin may be used to aid in processing the entire sample.

Navigating to Sites

Accuracy

The location reported by the GPS receiver has an element of error that varies under different conditions. The total error from the GPS and your navigational error combined should not exceed half of the sampling resolution. Therefore, when sampling with a Garmin 76 receiver, navigate at no greater than an 80-foot zoom level and aim to completely cover the sampling site with the arrow. At 80-foot zoom, the locator arrow shown on the screen represents approximately 25 feet in length. In order to sample with acceptable accuracy, the arrow must completely cover the sample site on screen. At coarser zoom levels, because the size of the arrow remains constant, the boat may be more distant from the site even though the arrow completely covers the site. You can use a lower zoom level (120-feet is appropriate) in order to travel from site to site, but as you approach the target site, you must confirm your location at using at least the 80-ft zoom resolution to ensure you are sampling with acceptable accuracy.

Determining Maximum Depth of Plant Colonization

When sampling, you will have to determine the maximum depth at which the plants are rooted. The maximum depth of colonization (MDC) can vary greatly among lakes, from just a few feet to as deep as the physiological requirements of a species will allow. When sampling a line of sites heading from shore out to deep water, take samples until plants are no longer found on the
rake. Continue sampling at least two sites deeper to ensure you sampled well over the maximum depth of colonization. If no plants are found at these sites, simply record the depth, sampling tool used, and dominant sediment type. Leave the rake fullness and species information blank. Depending on the lake bathymetry, you may choose to continue down the same row to the other side of the lake. Use a depth finder and begin sampling again when the depth reaches that of the last (no plant) site sampled. Alternatively, if the rows are very long, you may choose to move over to the next row and
sample sites back into shore, working back and forth along the shoreline and around the lake. However, if the second row is shallower than the first, be sure to start sampling sufficiently far from shore so that the depth is similar to that at which you stopped sampling in the first row. By sampling in this way, over time you will begin to hone in on the maximum depth of plant colonization.

After working several rows crossing the edge of the littoral zone, estimate the maximum depth of colonization (e.g. 20 feet) and only continue to sample deeper sites within 6 feet of this estimation (all sites ≤ 26 feet). As you complete more rows and gain confidence in your estimation, you can then begin to gradually omit sampling depths that are too deep for plants to grow. Once you have sampled the deep end of your estimated maximum depth of colonization (i.e. 26 feet) at least three times and have not found any plants, then you can discontinue sampling at anything deeper, but continue to sample any sites shallower (≤ 25 feet). If you then sample a shallower depth three times (i.e. 25 feet) and find no plants at any of those sites, you may now discontinue sampling at these deeper sites and only sample sites shallower than this new sampling depth (≤ 24 feet). Continue to successively eliminate shallower depths in sequence until you establish the maximum depth of colonization. To account for patchiness and other sources of variation, never narrow the sampling window to less than 1.5 feet of the estimated maximum depth of colonization. Use your best judgment when eliminating depths, and remember that plant distribution may be uneven and that different areas of a single lake may have plants growing relatively deeper or shallower. It is good practice to err on the side of oversampling.

Recording Data

Completing the Field Sheet

General site information
Complete the top portion of the "Field Sheet" with the lake name, county, WBIC, date, names of observers, and how many hours each person worked during the survey.

Site number
Each site location is numbered sequentially. Each site number will have one row of data on the "Field Sheet."

Depth
Measure and record the depth to the nearest half-foot increment at each site sampled, regardless of whether vegetation is present. The pole mounted rake and rope sampler should be marked to measure the depth of water at a sample site. However, a variety of options exist for taking depth measurements, including sonar handheld depth finders (trigger models) and boat-mounted depth finders. If you are using a depth finder, it is useful to know that the accuracy may decrease greatly in densely vegetated areas. Depth finders sometimes report the depth to the top of the vegetation instead of to the sediment surface. In most cases, it is best to use depth markings on a pole-mounted rake for shallow sites.

Dominant sediment type
At each sample site, record the dominant sediment type based on how the rake feels when in contact with the sediment surface as: mucky (M), sandy (S), or rocky (R).

Pole vs. Rope
Record whether the pole (P) mounted rake or the rake-on-a-rope (R) was used to take the sample.

Rake fullness
At each site, after pulling the rake from the water record the overall rake fullness rating that best estimates the total coverage of plants on the rake (1 - few, 2 - moderate, 3 - abundant; see Figure 3). Also identify the different species present on the rake and record a separate rake fullness rating for each. Account for plant parts that dangle or trail from the rake tines as if they were fully wrapped around the rake head. The rake may dislodge plants that will float to the surface, especially short rosette species not easily caught in the tines. Include the rake fullness rating for plants dislodged and floating but not collected on the rake. Record rake fullness ratings for filamentous algae, aquatic moss, freshwater sponges, and liverworts, but do not include these ratings when determining the overall rake fullness rating. While at a site, perform a brief visual scan. If you observe any species within 6 feet (2m) of the sample site, but not collected with the rake, record these species as observed visually ("V") on the field sheet. These species will be included in total number of species observed.

| Fullness Rating | Coverage | Description |
|---|---|---|
| 1 |  | Only few plants. There are not enough plants to entirely cover the length of the rake head in a single layer. |
| 2 |  | There are enough plants to cover the length of the rake head in a single layer, but not enough to fully cover the tines. |

| | | |
|---|---|---|
| 3 |  | The rake is completely covered and tines are not visible. |

Species names
Note that the field datasheet does not include any species names, except for EWM (Eurasian water milfoil) and CLP (Curly-leaf Pondweed). The sampling crew must write the species name in subsequent columns the first time that species is encountered. Names must be re-written on successive field sheets as they are encountered. You may use common or Latin names, but be sure there is no ambiguity in the name that will present problems during data entry. The use of standard abbreviations can greatly shorten this process. It is generally safe to shorten the names to include the first three letters of the genus name followed by the first three letters of the species name (i.e. Ceratophyllum demersum = CerDem).

Inaccessible sites
It may be impossible or unsafe to reach some sample sites. Where the water is very shallow, rocks are present, or dense plant growth prevents navigation, field workers should attempt to access the site as long as doing so is safe and relatively practical. It is often possible to reach difficult sites by using oars or poling; however, keep safety in mind and practice good judgment. Do not get out and drag the boat through mucky sediment to reach a site. If the sampling site is shallow but the substrate is firm, you may be able to walk to the site from shore or from the boat. If you cannot access a site, leave the depth blank and record the appropriate comment on the field datasheet from the list below. Remember to also transfer these to the “Comments” column of the ENTRY sheet (see data entry section):

NONNAVIGABLE (PLANTS)
Sample site cannot be accessed due to thick plant growth.
Aquatic plants that are visible within 6 feet of a non-navigable sample site (e.g. water lilies, cattails, bulrushes, etc.) should be recorded as visuals (V) on the datasheet.

TERRESTRIAL
Sample site occurs on land (including islands).
Aquatic plants visible within 6 feet of a terrestrial sample site (e.g. water lilies, cattails, bulrushes, etc.) may be included in the general boat survey list, but should not be marked as visuals (V) on the datasheet.
Only species rooted in water should be recorded as present or as part of the boat survey.

SHALLOW
Sample site is in water that is too shallow to allow access.
Aquatic plants that are visible within 6 feet of a shallow sample site should be recorded as visuals (V) on the datasheet.

ROCKS
Sample site is inaccessible due to the presence of rocks.

DOCK
Sample site is inaccessible due to the presence of a dock or pier.

SWIM AREA
Sample site is inaccessible due to the presence of a designated swimming area.

TEMPORARY OBSTACLE
Sample site is inaccessible due to the presence of a temporary obstacle such as a boater, swimmer, raft, loon, etc. If possible, try to revisit this site later on during the survey once the temporary obstacle has moved.

NO INFORMATION

No information is available about the sample site because it was not traveled to (inaccessible channel, accidently omitted during survey, skipped due to time constraints, etc.).

OTHER
Site was not sampled for another reason; please provide a brief description.

Filling Out the Boat Survey Datasheet
Often there will be localized occurrences of certain species (e.g., floating-leaf or emergent species) that are missed by the point-intercept grid. For areas that are outside the grid or in between sampling sites, record the name of the plant and the closest site to the plant. This information will be entered into the “BOAT SURVEY” section of the data entry file. Emergent near-shore vegetation should only be recorded if it’s rooted in water.

Collecting and Identifying Voucher Samples

Voucher each plant species for verification and identification. You can often use plants collected on the rake as vouchers. However, if the sample is of poor quality or lacks reproductive structures, attempt to collect a better specimen. If a better specimen is unavailable, voucher and press what you are able to collect. Remember that the more material collected, the easier identification will be. Whenever possible, collect at least two specimens, and include reproductive material such as seeds, flowers, fruit, roots, etc. Place the voucher plant into a re- sealable plastic bag with a waterproof voucher label. The voucher label should include the species name, or in the case of unknown species, a unique identifier, the lake name, county, sample site, sediment type, collector’s name, and the date. Additional information about habitat or co-occurring species may also be included on the tag. Place all specimens in a cooler for transport to the lab. See below, “Pressing Plants” for instructions once back at the laboratory.

Plant Identification and Troublesome Taxa

Plants should be identified to species whenever possible. Certain genera, including Carex, Sparganium, and Sagittaria must be flowering and/or fruiting to confirm identification and may not be identifiable to species without these parts.

Non-angiosperms such as Chara or Nitella are identified to genus only. Often, Isoetes can be identified to species by looking at spores, if present. Filamentous algae, aquatic moss, and freshwater sponge can be referred to simply as algae, moss, and sponge.

If a plant cannot be identified in the field, place the two voucher specimens in a re-sealable bag with a separate voucher label. Take these specimens back to the lab to verify the identity. The label should include a unique identifier, lake, county, the sample site number, and sediment type. The presence and fullness of the species should be recorded on the field datasheet under the same unique identifier name listed on the voucher label.

In the lab, try to identify the plant using plant identification keys and a stereo microscope. If you are still uncertain of the identity of the plant, contact a DNR biologist in your region to help with identification. Do not send specimens to an expert until you notify them of your intended shipment and they have instructed you to do so. Once the plant is identified, record this information so that the correct identification is used during data entry.

## Appendix F. Biomanipulation Guidance

**WHEN IS BIOMANIPULATION AN OPTION?** (Lammens 2001)

In most cases reported here, the real determining factor leading to the decision to initiate biomanipulation is not quite obvious, i.e. the actual criteria on which this decision was based are usually not evident. In fact these criteria are more or less arbitrary and will depend on the knowledge of the particular lake manager. Until now, the decision of lake managers usually depends on the following questions:

1. how serious is the (eutrophication) problem?
2. what are the chances for success of fish biomanipulation?
3. how will it affect the present users of the lake?
4. is there sufficient support of the present users?

*The problem*
In general, the most important criterion is the level of eutrophication. If the lake has a high concentration of nutrients even after serious reductions in the load of nutrients, and high concentrations of algae, in particular cyanophytes, the lake is considered as a serious candidate for biomanipulation. If nutrient reduction has only little or no effect at all on the recovery of the lake, biomanipulation will speed up the process of recovery (Meijer, 2000).

*The chance for success*
The chances for success will depend on the strategy adopted, i.e. whether the removal of fish was partial or complete, or if only predatory fish were stocked. The size and depth of the lake are critical for the whole technical operation and will be decisive for success or failure. For technical reasons small lakes are usually easy and large lakes (> 1000 ha) difficult to manipulate (Meijer, 2000).

*Effect on present users*
When a water manager proposes to biomanipulate a lake or a reservoir for the sake of water quality, then there is usually a lot of resistance coming from different groups of people, all having different interests in the specific waterbody. Anglers and commercial fishermen fear for their catches, nature conservation associations expect the decrease of piscivorous birds, yachtsmen expect problems with aquatic macrophytes. In fact, most people fear changes because they know what they have and are unsure about the potential changes. In a way they are right because it is impossible to predict the changes with 100% security. What we have is empirical evidence and a theoretical framework about the mechanisms involved. This knowledge is used to advise lake managers. The decision of the lake managers could profit from a cost-benefit analysis. In some cases a cost-benefit analysis can easily be made if the main users of the lake have only economic profits, such as drinking water companies or commercial fishermen. In some cases (e.g. Finland) the improvement of the water quality led to an increase in the value of the surrounding land. Improved leisure benefits for anglers, yachtsmen and swimmers, or ecological benefits for flora and fauna, are more difficult to express in economic values. If conditions for angling, sailing or swimming are improved, an infrastructure may be developed that benefits from these conditions and then a cost-benefit analysis may be made. For nature conservation it seems more a matter of appreciation, which is difficult to be translated in economic terms. At the moment it is only possible to provide a qualitative scale for the evaluation of the noneconomic changes using the positive, neutral and negative criteria. With the knowledge we have about the various ways of biomanipulation and their effects on the fish community and the aquatic vegetation we can make a best guess what the score will be for all the users of a water body.

*The support of the users*
The support of the current users is necessary if they have (legal) rights in the specific waterbody. It implies that biomanipulation in a large lake with recreation, commercial fishing and nature conservation requires a lot of preparatory work in order to receive the support of the users involved. Using fish in biomanipulation will be more effective in small water bodies than in large ones. It should be remembered, however, that in many situations only a continual, sustained removal effort, used in tandem with other nutrient reduction and control mechanisms, will be fully effective (cf. Wetzel, 2000).