Lower Mississippi River WMO

Watershed Restoration and Protection Strategy (WRAPS)

and Total Maximum Daily Load (TMDL) Report

September 2014

Rogers Lake fishing pier

LOWER MISSISSIPPI
INVER GROVE HEIGHTS
LILYDALE
MENDOTA HEIGHTS
ST. PAUL
SOUTH ST. PAUL
SUNFISH LAKE
WEST ST. PAUL

Minnesota Pollution Control Agency

CLEAN WATER LAND & LEGACY

wq-iw8-43e

Note Regarding Legislative Charge

The science, analysis and strategy development described in this report began before accountability provisions were added to the Clean Water Legacy Act in 2013 (MS114D); thus, this report does not address all of those provisions. When this watershed is revisited (according to the 10-year cycle), the information will be updated according to the statutorily required elements of a Watershed Restoration and Protection Strategy Report.

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Key Terms

Assessment Unit Identifier (AUID): The unique water body identifier for each river reach comprised of the United State Geologic Survey (USGS) eight-digit HUC plus a three-character code unique within each HUC.

Aquatic recreation impairment: Lakes are considered impaired for impacts to aquatic recreation if total phosphorus and chlorophyll-a or Secchi disc depth standards are not met.

Hydrologic Unit Code (HUC): A Hydrologic Unit Code (HUC) is assigned by the USGS for each watershed. HUCs are organized in a nested hierarchy by size.

Impairment: Water bodies are listed as impaired if water quality standards are not met for designated uses including: aquatic life, aquatic recreation, and aquatic consumption.

Protection: This term is used to characterize actions taken in watersheds of waters not known to be impaired to maintain conditions and beneficial uses of the waterbodies.

Restoration: This term is used to characterize actions taken in watersheds of impaired waters to improve conditions, eventually to meet water quality standards and achieve beneficial uses of the waterbodies.

Source (or Pollutant Source): This term is distinguished from 'stressor' to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

Stressor (or Biological Stressor): This is a broad term that includes both pollutant sources and non-pollutant sources or factors (e.g., altered hydrology, dams preventing fish passage) that adversely impact aquatic life.

Total Maximum Daily Load (TMDL): A calculation of the maximum amount of a pollutant that may be introduced into a surface water and still ensure that applicable water quality standards for that water are met. A TMDL is the sum of the wasteload allocation for point sources, a load allocation for nonpoint sources and natural background, an allocation for future growth (i.e., reserve capacity), and a margin of safety as defined in the Code of Federal Regulations.

Acronyms

BMP: Best Management Practice

BWSR: Board of Water and Soil Resources

CAMP: Citizen Assisted Monitoring Program

CLP: Curlyleaf Pondweed

CWLA: Clean Water Legacy Act

DO: Dissolved Oxygen

EWM: Eurasian Watermilfoil

HUC: Hydrologic Unit Code

LiDAR: Light Detection And Ranging

MDNR: Minnesota Department of Natural Resources

MINLEAP: Minnesota Load Evaluation Assessment Program

Mn/DOT: Minnesota Department of Transportation

MPCA: Minnesota Pollution Control Agency

MS4: Municipal Separate Storm Sewer System

NCHF: North Central Hardwood Forest

NPDES: National Pollutant Discharge Elimination System

P8: Program for Predicting Polluting Particle Passage thru Pits, Puddles, and Ponds

TMDL: Total Maximum Daily Load

TP: Total Phosphorus

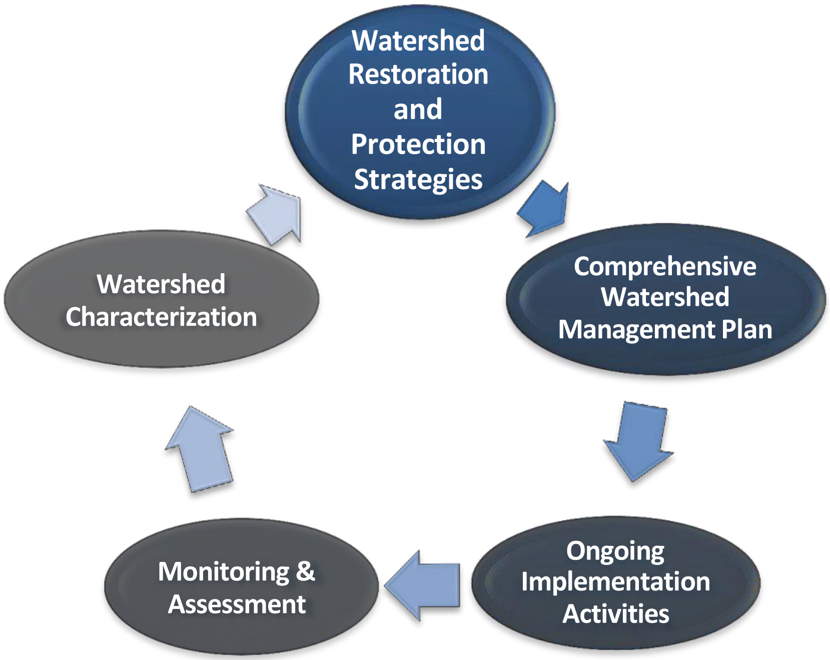
TSG: Technical Stakeholder Group

TSS: Total Suspended Solids

USGS: United States Geological Survey

WRAPS: Watershed Restoration and Protection Strategy

What is the WRAPS Report?



The State of Minnesota has adopted a "watershed approach" to address the state's 81 "major" watersheds (denoted by an 8-digit hydrologic unit code or HUC). This watershed approach incorporates **water quality assessment, watershed analysis, civic engagement, planning**, **implementation**, and **measurement of results** into a 10-year cycle that addresses both restoration and protection. In the Twin Cities Metropolitan Area, watershed approach activities may be focused at the scale of the 33 Metro Watershed Management Organizations and Districts. This report focuses on the Lower Mississippi River Watershed Management Organization (WMO).

As part of the watershed approach, waters not meeting state standards are still listed as impaired and Total Maximum Daily Load (TMDL) studies are performed, as they have been in the past, but in addition the watershed approach process facilitates a more cost-effective and comprehensive characterization of multiple water bodies and overall watershed health. A key aspect of this effort is to develop and utilize watershed-scale models and other tools to help state agencies, local governments and other watershed stakeholders determine how to best proceed with restoring and protecting lakes and streams. This report summarizes past assessment and diagnostic work and outlines ways to prioritize actions and strategies for continued implementation.

Purpose	• Support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning
	• Summarize Watershed Approach work done to date including the following reports:
	  • 2011 Adopted Lower Mississippi River Watershed Management Organization Watershed Management Plan
	  • Ivy Falls Creek, Interstate Valley Creek and Highway 13 Watersheds: Water Quality modeling Study (Barr, 2003)
	  • 2007 Gun Club Lake Watershed Management Plan

Scope	• Impacts to aquatic recreation in lakes
Audience	• Local governments (Cities of St. Paul, West St. Paul, Mendota Heights, Lilydale, Sunfish Lake, and Mendota, Dakota County and Dakota County Soil and Water Conservation District, Lower Mississippi River WMO, Metropolitan Council) • State agencies (MN Pollution Control Agency, MN Department of Natural Resources, Board of Water and Soil Resources, MN Department of Transportation) • Citizens and lake associations

1. Watershed Background & Description

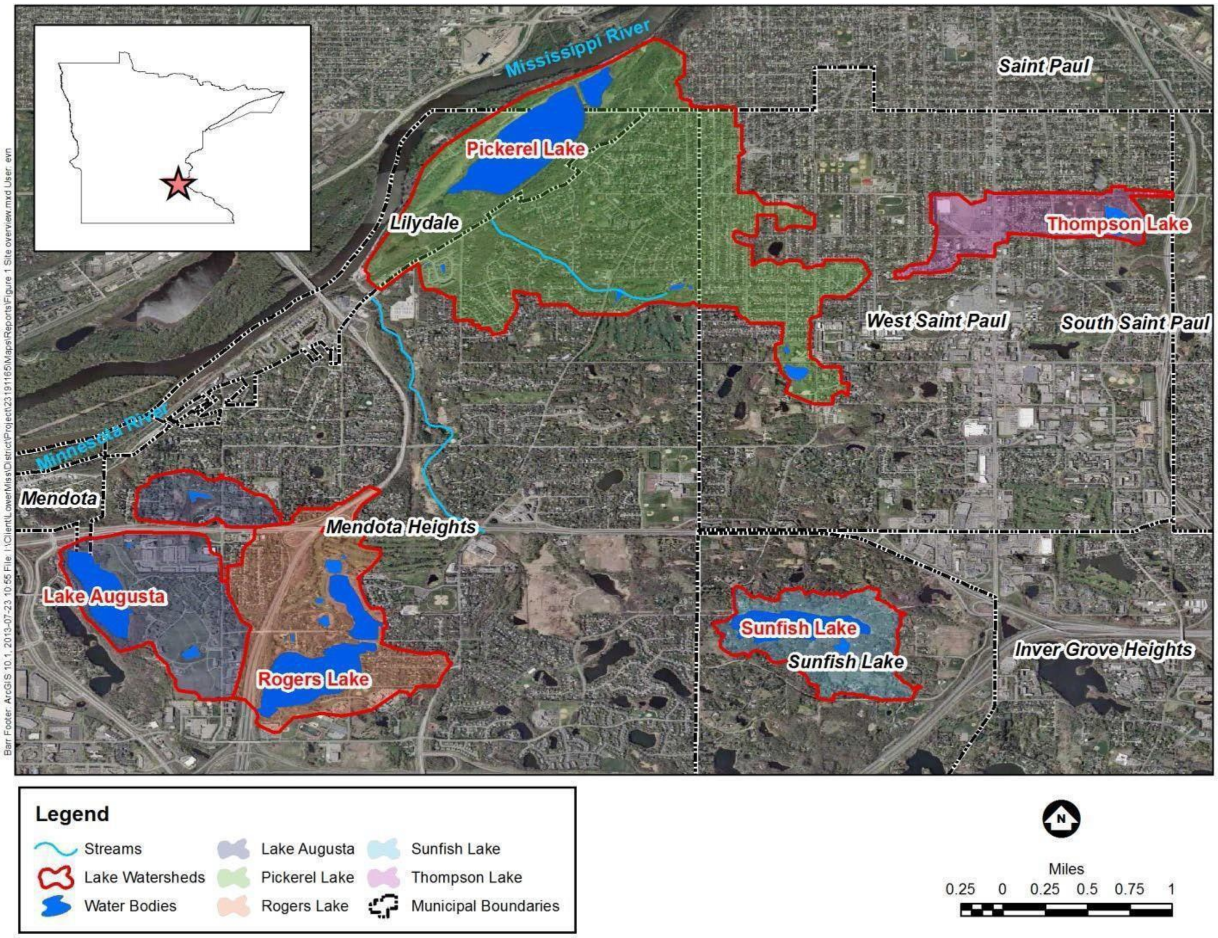


Figure 1.1 Site Overview

The Lower Mississippi River WMO watershed in northern Dakota and southern Ramsey Counties comprises 35,493 acres and includes all or part of Inver Grove Heights, Lilydale, Mendota Heights, St. Paul, South St. Paul, Sunfish Lake, and West St. Paul. The Lower Mississippi River Watershed Management Organization (LMRWMO) was established by a Joint Powers Agreement on October 25, 1985 to meet the requirements of the Metropolitan Surface Water Management Act of 1982. The LMRWMO was established to address intercommunity storm water issues within the watershed, ensure that any intercommunity storm water projects and studies follow accepted engineering standards, and that the costs incurred be allocated proportionately to member cities through a mutually agreed upon cost share formula. Guiding principles also apply to the monitoring, evaluation, and protection of the quality of storm water runoff, surface waters, groundwater, fish and wildlife habitat, as well as serving as an educational resource to the general public. The Lower Mississippi River WMO is part of the larger

Mississippi River – Twin Cities Watershed (HUC# 07010206).

The purpose of this Watershed Restoration and Protection Strategy (WRAPS) report is to gain a better understanding of the water quality and pollution sources of five lakes and to engage the residents that live around or near the lakes. The five lakes included in this study are Thompson Lake in West St. Paul, Pickerel Lake in Lilydale and St. Paul, Rogers Lake and Lake Augusta in Mendota Heights, and Sunfish Lake in the City of Sunfish Lake (see Figure 1.1). In 2010, Sunfish Lake and Augusta Lake in Dakota County were placed on Minnesota's 303(d) List of Impaired Waters for aquatic recreation due to excess nutrients (Minnesota Rules 7050.0150 and 7050.0222). Thompson, Pickerel and Rogers Lakes were also selected for inclusion in a WRAPS report by the Lower Mississippi River Watershed Management Organization (LMRWMO) and its member cities. Thompson Lake was added to the 2014 Proposed 303(d) Impaired Waters List due to excess nutrients in 2013. Pickerel Lake was added to the 2014 Proposed 303(d) Impaired Waters List in 2013 due to excess nutrients, but was removed in early 2014. Rogers Lake was included in the study to evaluate methods for protecting its high water quality. The scheduled TMDL start and end dates for the three impaired lakes are 2012 and 2014. The five lakes and their watersheds are briefly described below.

Sunfish Lake (Lake ID: 19-0050)

Sunfish Lake is a 47-acre lake located in the City of Sunfish Lake, with a maximum depth of 32 feet. The Sunfish Lake watershed is approximately 235 acres. Land use within the watershed is primarily low density residential or undeveloped and the properties surrounding the lake are serviced by Subsurface Sewage Treatment Systems (SSTS). The lake was previously monitored through the Metropolitan Council's Citizen Assisted Monitoring Program (CAMP) for years 2006 – 2011 and as part of this study for year 2012.

Sunfish Lake has a high overflow outlet, constructed in the late 1990s, that conveys water to Friendly Marsh (Mendota Heights) and Interstate Valley Creek. The outlet is located above the Ordinary High Water elevation (OHW), so discharge from the lake is typically limited to seepage.

Lake Augusta (Lake ID: 19-0081)

Lake Augusta is a 44-acre lake located in the City of Mendota Heights, with a median depth of 18 feet and maximum depth of 33 feet. The Augusta Lake watershed is approximately 420 acres. Land use within the watershed is primarily institutional (cemetery), commercial, and residential (low and high density). The lake was previously monitored through the Gun Club Watershed Management Organization for years 2007-2009. Secchi depth has a longer period of record, years 1998 – 2009. The lake is currently land locked.

Rogers Lake (Lake ID: 19-0080)

Rogers Lake is a shallow 97-acre lake located in Mendota Heights, with a maximum depth of 8 feet. The Rogers Lake watershed is approximately 470 acres, with land use comprised of highway, low-density residential, institutional, and park land. Although there is no public boat landing on this lake, there is a city park on the lake with picnic grounds, trails, and play areas. The park also provides opportunities for non-motorized boating. Outflows from the lake reach Friendly Marsh (Mendota Heights) and Interstate Valley Creek. The lake was previously monitored through Metropolitan Council's CAMP in years 2007 – 2011 and as part of this study in year 2012.

Pickerel Lake (Lake ID: 19-0079)

Pickerel Lake is a shallow, 115-acre lake located in Lilydale and St. Paul, with a maximum depth of 11 feet. The lake, located in the Lilydale-Harriet Island Regional Park complex, receives drainage from Ivy Falls Creek and the wetland southwest of the lake. The 1,320-acre watershed to Pickerel Lake includes portions of the municipalities of St. Paul, Lilydale, Mendota Heights, and West St. Paul. In addition to the park, land use in the watershed is mostly low density residential, with some high density residential and institutional land use as well as park and recreational space surrounding the lake. Prior to becoming parkland, the land adjacent to Pickerel Lake was historically used for a variety of purposes (starting in the early 1800s) including a brick manufacturing plant, brick demolition landfill, and other demolition and general landfills and unpermitted dumping of items ranging from household trash to appliances, scrap metal, cars, concrete, furniture, etc. Although no conclusive tests have been performed, it's possible some of these activities impacted the water quality of Pickerel Lake (Bonestroo, 2009).

Pickerel Lake normally discharges to the Mississippi River, but is located in the river floodplain. When river levels are high enough, the Mississippi River completely inundates or backs up into Pickerel Lake, which can greatly affect the water quality of the lake. The MN Pollution Control Agency (MPCA) previously monitored the water quality of Pickerel Lake in 2010 and 2011. Pickerel Lake was also monitored as part of this study in year 2012.

Thompson Lake (Lake ID: 19-0048)

Thompson Lake is a 7-acre lake located in the City of West St. Paul and is bordered by Thompson County Park. The Thompson Lake watershed is approximately 180 acres, comprised of commercial, institutional, low density residential and park land use. The extent of County ownership is limited to the approximate eastern side of the lake and a northern section of the inlet to the lake, adjacent to the Butler Avenue right-of-way. Most of the land along the primary inlet to the lake is owned by the St. Croix Lutheran High School as well as the western shoreline of the lake. Thompson Lake was previously monitored by Dakota County in 2011 and as part of this study in 2012.

1.1 Lake Water Quality Primer and Implications for Management

The physical, chemical, and biological characteristics of lakes are extremely variable, but highly structured. Lakes vary physically in terms of light levels, temperature, and water currents. Lakes vary chemically in terms of nutrients, major ions, and contaminants and vary biologically in terms of biomass structure and function. For the majority of Minnesota lakes, phosphorus is the limiting nutrient for algae growth, and an increase in phosphorus results in an increase in chlorophyll *a* concentrations and a decrease in water clarity. Eutrophic (or nutrient-rich) lakes can be restored by reducing phosphorus concentrations. This section is intended to provide a general background to the dynamics of nutrient availability and assimilation by introducing the basic concepts necessary to understand how lake systems function.

Density Stratification

In lakes of the upper Midwest, the water near a lake's bottom will usually be at 39°F just before the lake's ice cover melts in the spring (Water on the Web, 2004). As the weather warms, the ice melts. As the surface water heats the density of the water increases causing the surface water to sink and mix with the waters below. Spring turnover occurs when the temperature (and density) of the surface water equals that of the bottom water and continues until the water temperature of the entire lake reaches approximately 39°F. The surface waters continue to absorb heat, causing the water temperatures to rise above 39°F, resulting in the density of the water to decrease and become lighter than the cooler water below. For a while, winds may still mix shallower lakes from bottom to top, but eventually the upper water of deeper lakes become too warm and too buoyant to completely mix with the denser deeper water. The relatively large differences in density at higher temperatures are very effective at preventing mixing.

As summer progresses, the temperature (and density) differences between upper and lower water layers become more distinct (Water on the Web, 2004). Deep lakes generally become physically stratified by temperature into three identifiable layers, known as the epilimnion, metalimnion, and hypolimnion. The epilimnion is the upper, warm layer, and is typically well mixed. Below the epilimnion is the metalimnion or thermocline region, a layer of water in which the temperature declines rapidly with depth. The hypolimnion is the bottom layer of colder water, isolated from the epilimnion by the metalimnion. The density change at the metalimnion acts as a physical barrier that prevents mixing of the upper and lower layers for several months during the summer. The depth of mixing depends in part on the exposure of the lake to wind (its fetch), but is most closely related to the lake's size. Smaller to moderately-sized lakes (50 to 1000 acres) reasonably may be expected to stratify and be well mixed to a depth of 10–23 feet in north temperate climates.

As the weather cools during autumn, the epilimnion cools too, reducing the density difference between it and the hypolimnion (Water on the Web, 2004). As time passes, winds mix the lake to greater depths, and the thermocline gradually deepens. When surface and bottom waters approach the same temperature and density, autumn winds can mix the entire lake; the lake is said to turn over again in fall. As the atmosphere cools, the surface water continues to cool until it freezes. A less distinct density stratification than that seen in summer develops under the ice during winter. This pattern (spring turnover — summer stratification — fall turnover — winter stratification) is typical for temperate lakes. Deeper lakes with this pattern of two mixing periods are referred to as dimictic, while shallower lakes with several mixing periods are referred to as polymictic. Dimictic lakes, like Sunfish Lake and Lake Augusta, as well as polymictic lakes, like Thompson, Rogers and Pickerel Lakes, are common in Minnesota.

Dissolved Oxygen

Biological activity peaks during the spring and summer when photosynthetic activity is driven by high solar radiation (Water on the Web, 2004). Furthermore, during the summer most lakes in temperate climates are stratified. The combination of thermal stratification and biological activity causes characteristic patterns in water chemistry. During summer stratification, the conditions in each layer diverge. The dissolved oxygen (DO) concentration in the epilimnion remains high throughout the summer because of photosynthesis and diffusion from the atmosphere. However, oxygen conditions in the hypolimnion vary with trophic status. In eutrophic (more productive) lakes, hypolimnetic DO declines during the summer because it is cut-off from all sources of oxygen, while organisms continue to respire and consume oxygen. The bottom layer of the lake and even the entire hypolimnion may eventually become anoxic, or totally devoid of oxygen.

As microorganisms continue to decompose material in the lower water column and in the sediments, they consume oxygen, and DO is depleted (Water on the Web, 2004). No oxygen input from the air occurs with ice cover, and, if snow covers the ice, it becomes too dark for photosynthesis. This condition can cause high fish mortality during the winter, known as "winter kill." Low DO in the water overlying the sediments can exacerbate water quality deterioration; because when the DO level drops below 1 mg O_2/L chemical processes at the sediment-water interface frequently cause release of phosphorus from the sediments into the water. When a lake mixes in the spring, this new phosphorus and ammonium that has built up in the bottom water fuels increased algal growth.

Nutrients

Aquatic organisms influence (and are influenced by) the chemistry of the surrounding environment. For example, phytoplankton extract nutrients from the water and zooplankton feed on phytoplankton. Nutrients are redistributed from the upper waters to the lake bottom as the dead plankton gradually settles to lower depths and decompose (Water on the Web, 2004).

Essential nutrients such as the bioavailable forms of phosphorus and nitrogen typically increase in the spring from snowmelt runoff and from the mixing of accumulated nutrients from the bottom during spring turnover and decrease during summer stratification as nutrients are taken up by algae and eventually transported to the bottom water when algae die and settle out (Water on the Web, 2004). Any "new" input of nutrients into the surface water may trigger a "bloom" of algae. Such inputs may be from upstream tributaries after rainstorms, from die-offs of aquatic plants, or from pulses of urban stormwater. In the absence of rain or snowmelt, an injection of nutrients may occur simply from high winds that mix a portion of the nutrient-enriched upper waters of the hypolimnion into the epilimnion.

A typical lake has distinct zones of biological communities linked to the physical structure of the lake. The littoral zone is the near shore area where sunlight penetrates all the way to the sediment and allows aquatic plants (macrophytes) to grow. Plants in the littoral zone also provide habitat for fish and other organisms.

An in-depth microscopic enumeration of the dozens of species of algae present in a water column is preferred, but measuring the concentration of chlorophyll-a is easier and provides an estimate of algal biomass that is used by MPCA in evaluating the trophic state of all lakes. Chlorophyll-a is the green pigment that is responsible for a plant's ability to use sunlight energy to fix carbon dioxide into carbohydrates. Both chlorophyll-a and Secchi depth (water transparency) are long-accepted methods for estimating the amount of algae in lakes and the associated effect on water transparency.

Like all other plants, algae require phosphorus to grow and reproduce. Phosphorus enters the water in two ways:

- **Externally—**from surface runoff entering the water or from groundwater. Humans can have profound influences on lake chemistry. Excessive landscape disturbance causes higher rates of leaching and erosion by removing vegetative cover, exposing soil, and increasing water runoff velocity, which in turn, may exacerbate downstream erosion from ravine and bluff sources. Lawn fertilizers, pet waste, leaf litter, grass clippings, wastewater and urban stormwater inputs all add micronutrients such as nitrogen and phosphorus to watershed runoff. Dry deposition (typically associated with wind erosion), and atmospheric deposition from direct precipitation on the lake surface both contribute additional nutrients.
- **Internally—**from the sediments on the bottom of the lake. Phosphorus already in the lake naturally settles to the bottom and is periodically re-released from the sediments back into the water under certain conditions.

Even when external sources of phosphorus have been reduced or eliminated through best management practices, the internal recycling of phosphorus can still support explosive algal growth. Internal phosphorus loading is a large problem in Twin Cities Metropolitan Area lakes because of historic inputs of phosphorus from urban storm water runoff. Phosphorus in runoff has concentrated in the sediments of urban lakes as successive years of algal blooms have died and settled to the lake bottoms. This phosphorus is recycled from the lake sediments into the overlying waters, primarily during summer periods, when it contributes to the growth of nuisance algal blooms. This study is intended to identify nutrient sources, magnitudes, and resulting in-lake water quality in relation to previously established standards, goals or reference conditions and target water-quality-improvement management actions that will protect and improve water quality conditions in each lake.

Trophic Status

Since the early part of the 20th century, lakes have been classified according to their trophic state. "Trophic" means nutrition or growth. A eutrophic ("well-nourished") lake has high nutrients and high plant growth. An oligotrophic lake has low nutrient concentrations and low plant growth. A mesotrophic lake falls somewhere between eutrophic and oligotrophic lakes. While lakes may be lumped into a few trophic classes, each lake has a unique constellation of attributes that contribute to its trophic status. The three main factors that regulate the trophic state of a lake include the rate of nutrient supply, climate, and the morphometry (or shape) of the lake basin.

2. Watershed Conditions

2.1 Condition Status

Table 2.1 shows the five study lakes and the assessment status of each. Lake impairments are based on an aquatic recreation-based standard centered on protecting the ability to recreate in and support ecological habitat in Minnesota waters. This is considered as a Class 2 standard (MPCA, 2012). All three impaired lakes in this study are listed due to nutrient eutrophication biological indicators. The eutrophication standards applied are based on the ecoregion and lake depth. All five study lakes are located in the North Central Hardwood Forest Ecoregion (MPCA, 2012). Three of the lakes are considered shallow lakes (Thompson, Rogers and Pickerel) and are therefore subject to the shallow lake eutrophication standards (see Table 2.1). The shallow lake eutrophication standards require total phosphorus (TP) concentrations less than 60 µg/l, chlorophyll-a concentrations be less than 20 µg/l, and Secchi depth greater than 1 meter (3.3 feet). The other two lakes (Augusta and Sunfish) are subject to the deep lake eutrophication standards, which require TP concentrations less than 40 µg/l, chlorophyll-a concentrations less than 14 µg/l, and Secchi depth greater than 1.4 meters (4.6 feet).

In addition to meeting phosphorus limits, chlorophyll-a and Secchi transparency standards must also be met. 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 (MPCA, 2005). Clear relationships were established between the causal factor total phosphorus and the response variables chlorophyll-a and Secchi transparency. Based on these relationships it is expected that by meeting the phosphorus target in each lake, the chlorophyll-a and Secchi standards will likewise be met**.** Lakes where annual average TP and at least one of the response variables (chlorophyll-a or Secchi depth) do not meet the standard are considered impaired (MPCA, 2012).

Table 2.1 Assessment status of study lakes in the Lower Mississippi River WMO WRAPS study area

HUC-10 Subwatershed	Lake ID	Lake	Applicable Lake Depth Standard	Aquatic Recreation
Minnesota River	19-0081	Augusta	Deep	Impaired
City of St. Paul – Mississippi River	19-0050	Sunfish	Deep	Impaired
	19-0080	Rogers	Shallow	Supporting
	19-0048	Thompson	Shallow	Impaired
	19-0079	Pickerel	Shallow	Not Assessed

Impaired = impaired for impacts to aquatic recreation, Supporting = fully supporting aquatic recreation

Pickerel Lake was not assessed against the shallow lake standard due to the confounding effect from Mississippi River flooding

Lake Augusta and Sunfish Lake were added to the Impaired Waters List in 2010 for impairment to aquatic recreation with a pollutant or stressor classification of Nutrient/Eutrophication Biological Indicators. Thompson Lake was added to the list in 2014. Pickerel Lake was added to the list in 2013 due to excess nutrients, but was removed in early 2014. Rogers Lake has not exceeded the eutrophication standards and is considered as fully supporting aquatic life.

The Lower Mississippi River WMO includes approximately 88 lakes and wetlands, 4 streams, and the Mississippi River, but as mentioned above this report only addresses five lakes.

2.2 Water Quality Data

Water quality data including TP, chlorophyll-a, and Secchi depth for all five lakes were analyzed. Table 2.2 shows the average summer (June-September) water quality conditions for each lake, based on the results for TP, chlorophyll-a and Secchi depths analyzed between 2003 and 2012. While water quality in Rogers Lake meets all three of the shallow lake criteria, Table 2.2 shows that Sunfish and Thompson Lakes fall short of the respective deep and shallow lake criteria for TP and chlorophyll-a, while Augusta is not meeting any of the deep lake water quality criteria.

Table 2.2 Ten-year (2003-2012) average summer (June-September) water quality/ applicable standards for lakes in the Lower Mississippi River WMO WRAPS study area

Lake	TP (µg/L)	Chlorophyll-a (µg/L)	Secchi depth (meters)	Years Monitored
Deep Lake Standards	< 40	< 14	> 1.4	
Augusta	175	59	0.27	2007-2009
Sunfish	45	30	1.83	2006-2012
Shallow Lake Standards	< 60	< 20	> 1.0	
Rogers	39	6	1.38	2007-2012
Thompson	78	25	1.45	2011-2012
Pickerel	77	36	0.91	2010-2012

Shading indicates where applicable water quality standard is not being met

Growing season average concentrations (June-September) were calculated for individual years and are presented in Figures 2.1 - 2.5. The eutrophication standards applied to each lake are also displayed for comparison. The remainder of this section provides a discussion of how well each lake is meeting its representative eutrophication standards.

Lake Augusta

Lake Augusta's quality data is shown in Figure 2.1. Secchi depths for Lake Augusta were measured between 1998 and 2009. Secchi depths throughout the entire period stood well below the 1.4 meter eutrophication standard. TP and chlorophyll-a were measured between 2007 and 2009. TP and chlorophyll-a exceeded the eutrophication standards of 40 and 14 µg/l respectively during all three years. Peak summer average values were recorded in 2007 with growing season averages for TP, chlorophyll-a, and Secchi depth of 227 µg/l, 54 µg/l, and 0.25 meters respectively. Summer average concentrations during the most recent monitored year (2009) were 145 µg/l for TP, 65 µg/l for chlorophyll-a, and 0.3 meters for Secchi depth.

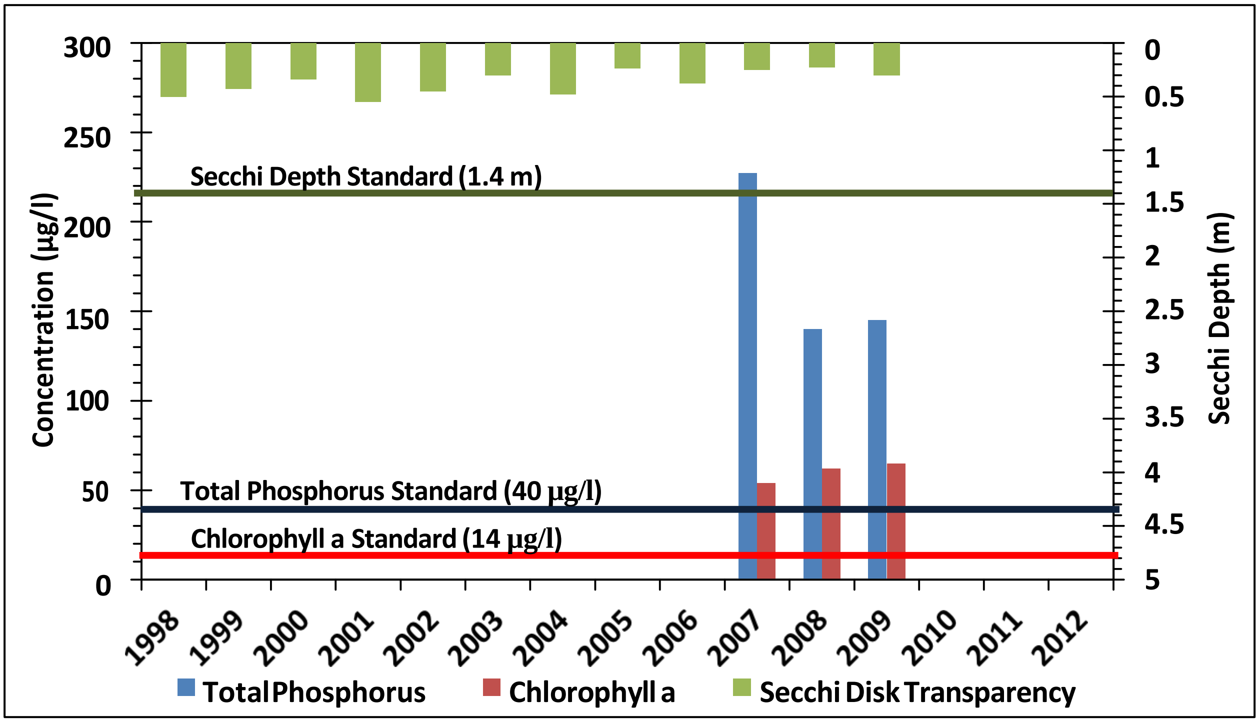


Figure 2.1 Lake Augusta Summer Average (June –September) Water Quality Data

Sunfish Lake

Sunfish Lake was monitored between 2006 and 2012 (see Figure 2.2). All three water quality standards were not met during 2006 and 2008. Both TP and chlorophyll-a standards were not met during 2012 and 2010, while all standards were met during years 2009 and 2011. Peak summer average values were observed during 2006 where growing season average values for TP, chlorophyll-a, and Secchi depth were recorded at 63 µg/l, 35 µg/l, and 1.1 meters, respectively. Average values for TP, chlorophyll-a, and Secchi depth during the most recently monitored year (2012) were measured at 56 µg/, 41 µg/l, and 1.6 meters, respectively.

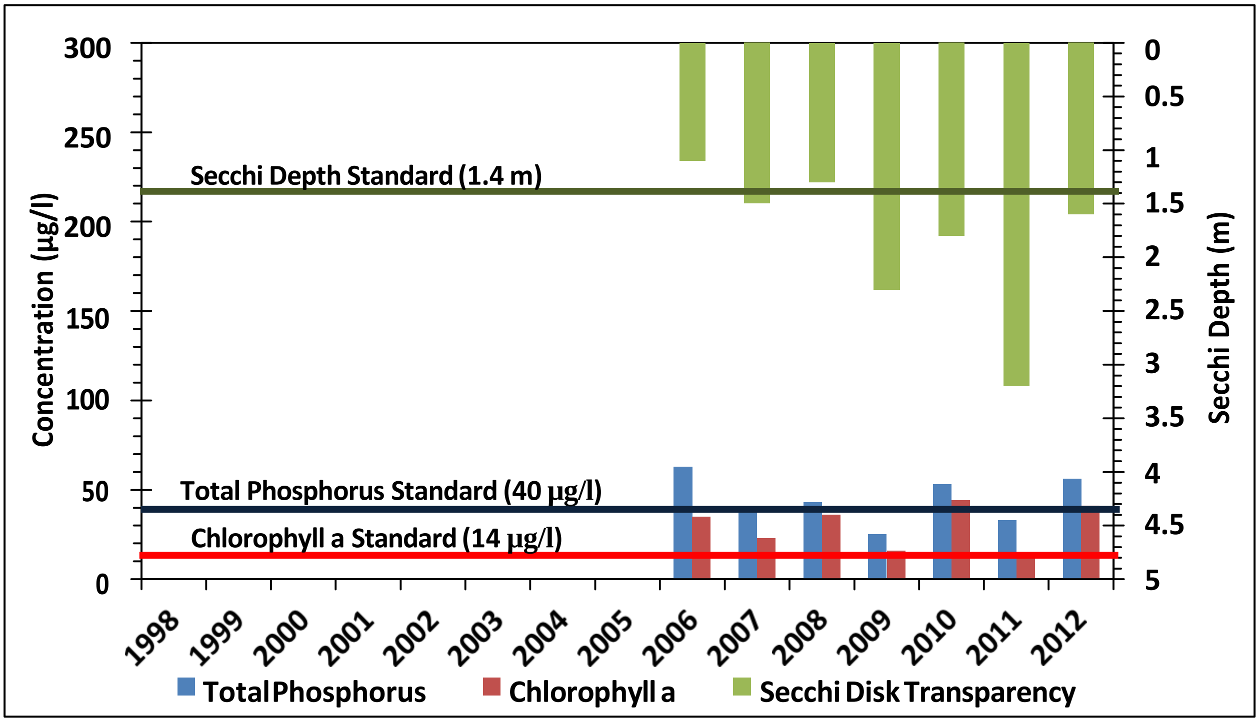


Figure 2.2 Sunfish Lake Summer Average (June –September) Water Quality Data

Rogers Lake

Rogers Lake was monitored from 2007 to 2012 (see Figure 2.3). During all six years analyzed all three parameters met the eutrophication standards for shallow lakes. Peak summer average TP, chlorophyll-a, and Secchi depth values of 51 µg/l, 8.6 µg/l and 1.0 meters, respectively, all occurred in 2007. During the most recent year growing season average values for TP, chlorophyll-a, and Secchi depth were recorded at 28 µg/l, 6 µg/l and 1.7 meters, respectively.

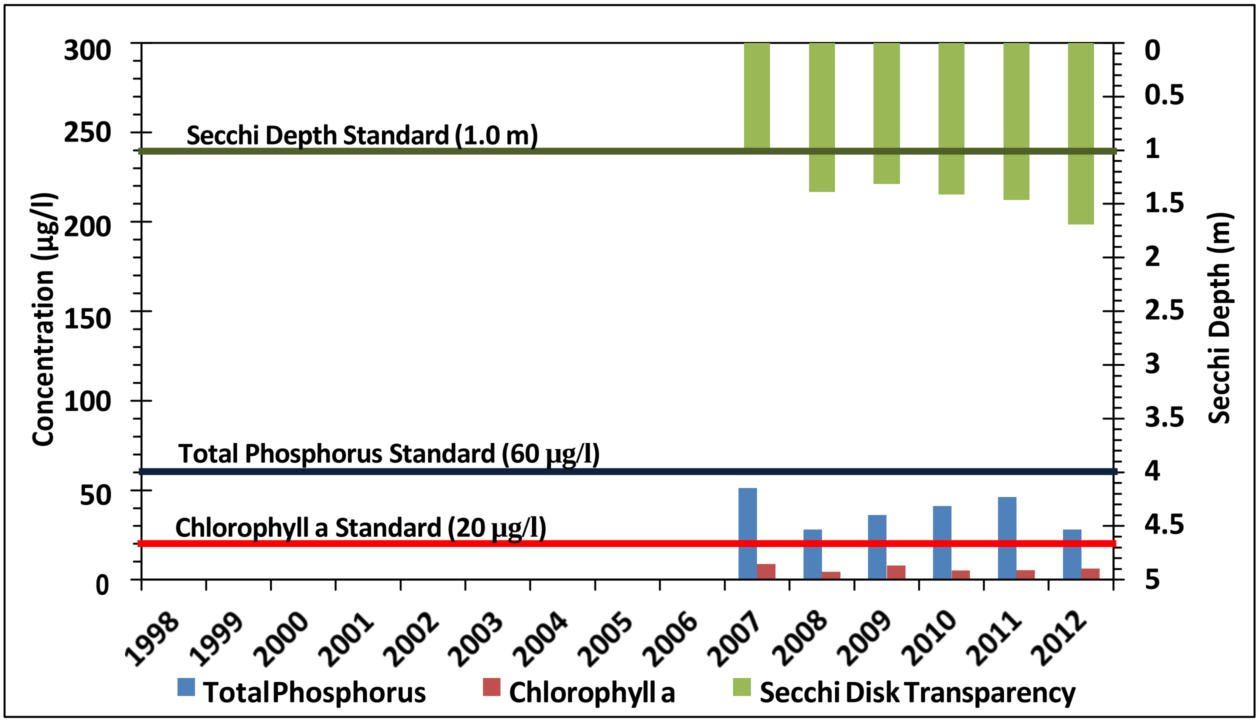


Figure 2.3 Rogers Lake Summer Average (June –September) Water Quality Data

Thompson Lake

Thompson Lake was monitored during 2011 and 2012 (see Figure 2.4). During 2011 both TP and chlorophyll-a average concentrations were 85 µg/l and 39 µg/l, respectively. Recorded Secchi depth was 1.1 meters. During 2012 average TP concentration was 75 µg/l, while the average Secchi depth and chlorophyll-a concentration was 1.5 meters and 19.5 µg/l, respectively.

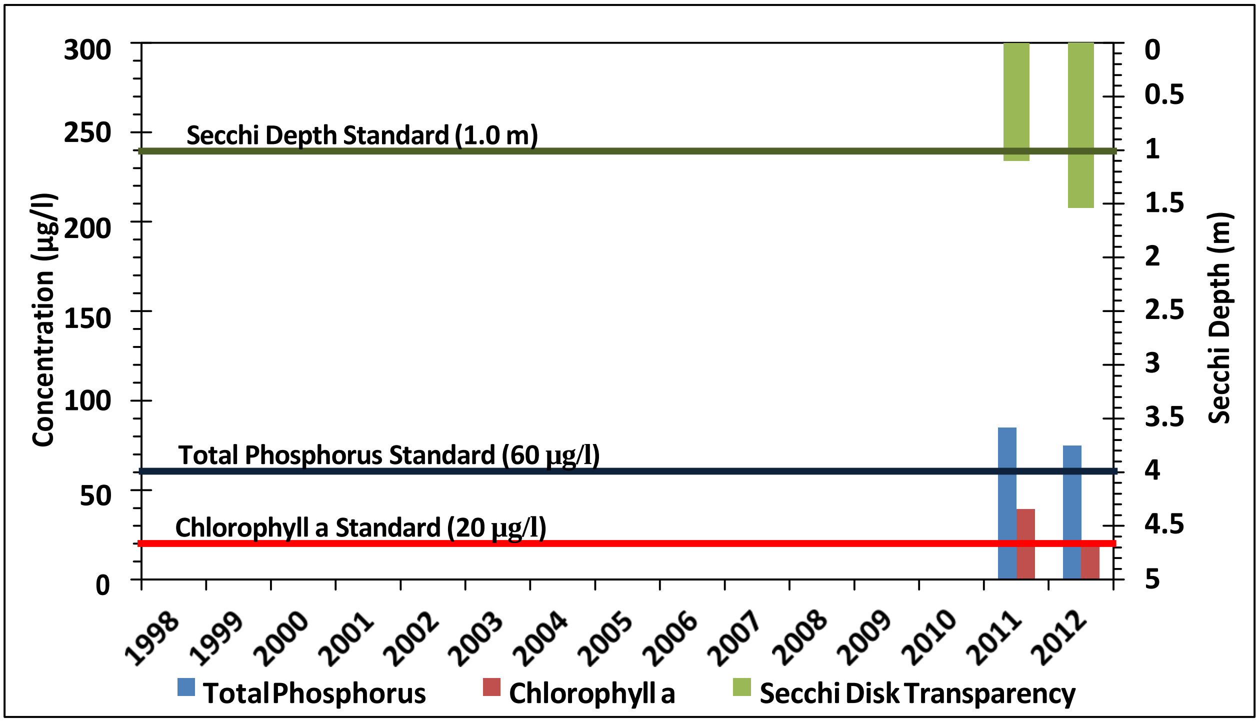


Figure 2.4 Thompson Lake Summer Average (June –September) Water Quality Data

Pickerel Lake

Pickerel Lake was monitored between 2010 and 2012 (see Figure 2.5). Average monitored TP, chlorophyll-a and Secchi depth for the most recent monitoring year (2012) were recorded at 45 µg/l, 13 µg/l, and 0.94 meters, respectively. Peak values of TP, chlorophyll-a, and Secchi depth recorded in 2011 were 123 µg/l, 69 µg/l, and 0.6 meters, respectively. See Section A.11 for a detailed discussion of the circumstances that led to poor water quality during the monitored period.

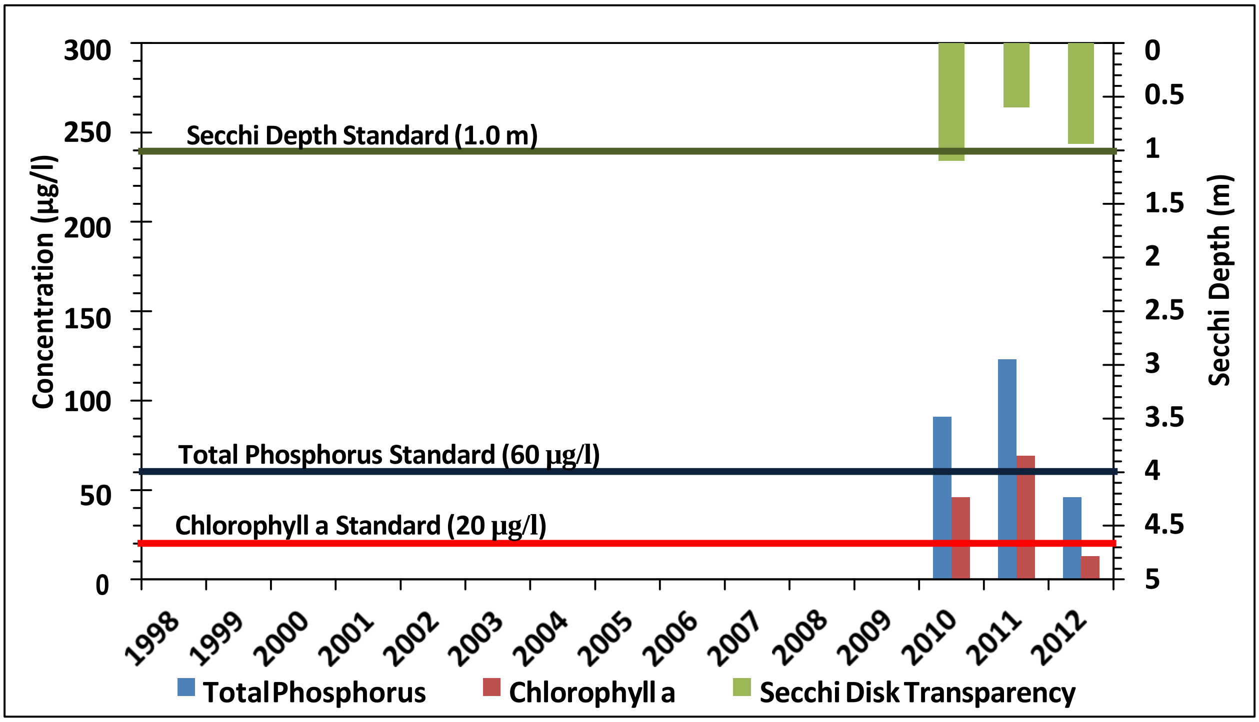


Figure 2.5 Pickerel Lake Summer Average (June –September) Water Quality Data

2.3 Stressors and Sources

Pollutant sources

In order to develop appropriate strategies for restoring or protecting waterbodies, the stressors and/or pollutant sources impacting or threatening them must be identified and evaluated. The pollutant source assessments discussed in this report were completed for the nutrient impairment listings and were not intended to address biological stressors in each watershed. Identification of the potential pollutant sources, magnitudes, and resulting in-lake water quality in relation to the state water quality standards is one of the primary objectives of this study. Further problem identification and targeting of water-quality-improvement efforts includes an evaluation of watershed loadings under various observed flow and seasonal conditions and the resulting changes to in-lake water quality. Water and lake phosphorus budgets have been determined and calibrated for the critical time period when water quality standards were exceeded to evaluate the relative contributions from the direct subwatersheds, atmospheric deposition, and other internal sources of phosphorus. The calibrated watershed modeling has been used to identify and evaluate the effectiveness of potential Best Management Practice (BMP) practices and the amount of potential load reduction that could be expected from various implementation options. The lakes' responses to the expected load reductions determined in the watershed analysis have been evaluated with the calibrated in-lake modeling. Potential in-lake improvement options have also been evaluated with the calibrated in-lake modeling.

Figure 2.6 shows the current land uses within the watershed study area. Table 2.3 and Table 2.4 provide further detail on point and nonpoint sources, respectively, of nutrients in the watersheds for each of the study lakes.

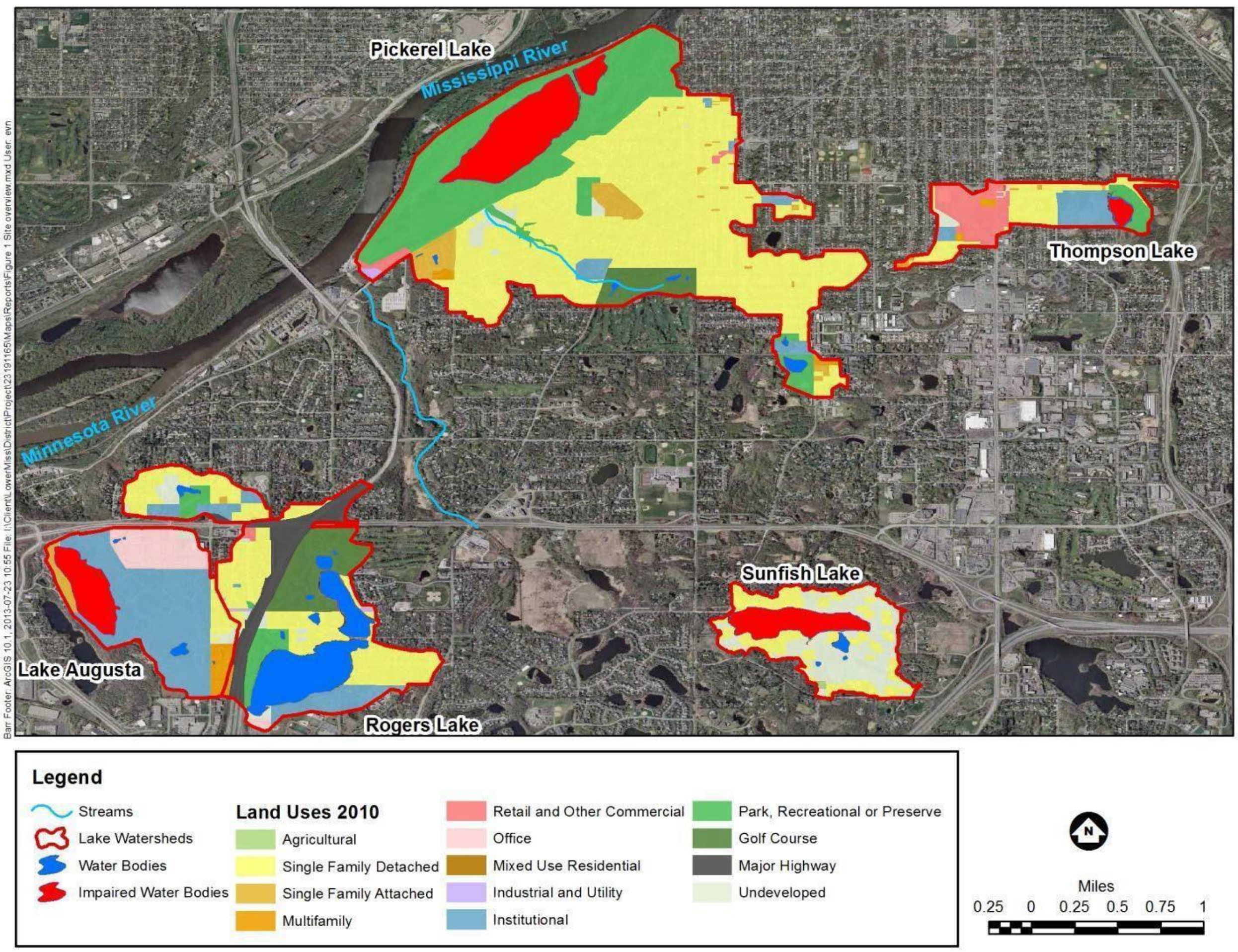


Figure 2.6 Watershed Land Uses

The CenterPoint Energy Distribution System permit (MN0063649) SD032 station shown in Table 2.3 is currently associated with construction activity and its wasteload allocation is therefore assigned as part of the categorical construction stormwater WLA. For long term (i.e. post construction) operations the surface discharge stations associated with all three pipeline permits do not represent actual discharge locations in the watershed. These permits contain language to ensure that any discharges associated with eventual hydrostatic testing of the pipelines will occur in accordance with permit conditions that are designed to be protective of surface waters. Since no regularly scheduled discharges are expected from these pipelines, no wastewater wasteload allocations are assigned to them.

Table 2.3 Point Sources in the Lower Mississippi River WMO WRAPS Report Area.

Subwatershed	Point Source			Pollutant reduction needed beyond current permit conditions/ limits?	Notes
	Name	Preferred ID #	Type		
Sunfish Lake	Sunfish Lake City MS4	MS400055	Municipal stormwater	No	
Thompson Lake	West St. Paul City MS4	MS400059	Municipal stormwater	Yes	
	Mn/DOT Metro District MS4	MS400170	Municipal stormwater	Yes	
	Dakota County MS4	MS400132	Municipal stormwater	Yes	
Pickerel Lake	Mendota Heights City MS4	MS400034	Municipal stormwater	To Be Determined	Deferred to 2020
	Lilydale City MS4	MS400028	Municipal stormwater	To Be Determined	Deferred to 2020
	West St. Paul City MS4	MS400059	Municipal stormwater	To Be Determined	Deferred to 2020
	Mn/DOT Metro District MS4	MS400170	Municipal stormwater	To Be Determined	Deferred to 2020
	Dakota County MS4	MS400132	Municipal stormwater	To Be Determined	Deferred to 2020
	CenterPoint Energy Distribution System	MN0063649	Pipeline	No	Deferred to 2020; See text above
	Flint Hills RPB Airport & Wisconsin Pipelines	MN0064696	Pipeline	No	Deferred to 2020; See text above
	Koch – Wood River Pipeline	MN0064700	Pipeline	No	Deferred to 2020; See text above
	St. Paul Municipal Stormwater	MN0061263	Municipal stormwater	To Be Determined	Deferred to 2020
Rogers Lake	Mendota Heights City MS4	MS400034	Municipal stormwater	No	
	Mn/DOT Metro District MS4	MS400170	Municipal stormwater	No	
Lake Augusta	Mendota Heights City MS4	MS400034	Municipal stormwater	No	
	Mendota City MS4	MS400033	Municipal stormwater	No	

Table 2.4 Nonpoint Sources in the Lower Mississippi River WMO WRAPS Report Area. Relative magnitudes of contributing sources are indicated.

HUC-10 Subwatershed	Lake (ID)	Pollutant	Pollutant Sources					
			Internal Loading	Atmospheric Deposition	Failing septic systems	Bluff and ravine erosion	Wildlife	Mississippi River backflow
City of St. Paul – Mississippi River	Sunfish Lake (19-0050)	TP	˜	™	™		™	
	Thompson Lake (19-0048)	TP	™	™			™	
	Pickerel Lake (19-0079)	TP	›	™		›	™	˜
	Rogers Lake (19-0080)	TP	›	™			™	
Minnesota River	Lake Augusta (19-0081)	TP	˜	™			™	

Key: ˜ = High › = Moderate ™ = Low

Water quality modeling of the five lake watersheds (Pickerel Lake, Sunfish Lake, Rogers Lake, Lake Augusta, and Thompson Lake) was conducted using the P8 Urban Catchment Model (Program for Predicting Polluting Particle Passage thru Pits, Puddles, and Ponds). P8 is a model used for predicting the generation and transport of stormwater runoff and pollutants in urban watersheds. The model tracks the movement of particulate matter (fine sand, dust, soil particles, etc.) as it is carried by stormwater runoff traveling over land and impervious surfaces. Particle deposition in ponds is tracked in order to estimate the amount of pollutants, carried by the particles that eventually reach a water body. Previous models from a 2003 study (Barr, 2003) were updated for Pickerel Lake, Rogers Lake, and Sunfish Lake. New models were created for Lake Augusta and Thompson Lake. The models were calibrated using data collected at Ivy Falls Creek during the summer of 2012. All calibrated lake models were run for the critical conditions. A full discussion on model methods and calibration is included in Appendix A.

In several of the lake watersheds, existing BMPs and natural waterbodies provide phosphorus removal prior to runoff reaching the lake. To estimate the removal achieved, annual phosphorus inflow loads to each of the five lakes were determined from the P8 model and compared to the total phosphorus load generated from each watershed. Ravine erosion sources in the Pickerel Lake watershed were excluded from this determination because the P8 model does not explicitly simulate phosphorus contributions from erosion. From these two values a percent reduction achieved throughout the entire lake watershed through existing BMPs and water bodies was calculated (Table 2.4). Table 2.4 shows the TP loads from the direct watershed. Lake Augusta and Rogers Lake are achieving over 40% reduction of TP in the watershed, Pickerel Lake has a 33% reduction, Sunfish has 21% and Thompson Lake did not have quantifiable TP reduction associated with BMP implementation in the watershed. It should be noted that Dakota County installed a rainwater garden to treat most of the runoff from a parking lot in Thompson County Park, directly east of the lake, but pertinent information about the BMP size and outlet characteristics was not available for the P8 modeling. In addition, Dakota County restored the shoreline of Thompson Lake with native plants. A further breakdown of TP removal efficiencies by individual BMPs implemented by 2012 can be found in Appendix A.

Another source of TP load in the Pickerel Lake watershed is ravine and bluff erosion along Ivy Falls Creek and other bluff areas within the watershed, as well as Mississippi River backflow under flood conditions. A discussion of how these sources were estimated is included in Appendix A, Section A.10.

The model results were used to determine TP loads to the lakes for each MS4 for the TMDL time periods discussed in Section 2.4. There are eight MS4s that contribute to the five lakes. These include the cities of West St. Paul, St. Paul, Lilydale, Mendota Heights, Mendota and Sunfish Lake, Dakota County, and Mn/DOT. The P8 results were used to calculate the total annual average watershed TP loads from each subwatershed within each MS4. Next the watershed load to reach the lake was calculated. This was accomplished by applying the annual average removal efficiencies from each BMP in succession along the watershed flow path until the cumulative flow reaches the lake. This calculation resulted in the amount of TP load from each subwatershed that reached the lake without being removed by an existing BMP. Finally an additional 38% TP loading was added to outfalls IF-28, MB-2, and MB-1 to account for erosional sources. The final loads from each MS4 were totaled as shown in Table 2.6.

Table 2.5 Watershed TP reductions from existing BMPs

Lakes	Annual Average TP Load Generated from Watershed (lbs/year)	Annual Average TP Load to Lake after BMPs (lbs/year)	Percent TP reduction from existing BMPs in Watershed (%)
Lake Augusta	121.0	68.3	44%
Pickerel Lake	326.7	218.1	33%
Rogers Lake	137.1	79.4	42%
Sunfish Lake	20.1	14.0	21%
Thompson Lake	122.4	122.4[a]	0%[a]

Notes:
[a] *Does not account for load reductions associated with practices implemented by Dakota County*

Table 2.6 TP inflow load for TMDL analysis period to each of the four lakes separated by MS4.

MS4	TP Load to Lake from each MS4 (lbs)				
	Pickerel (10/1/2009 - 9/20/2010)	Augusta (10/1/2007 - 9/30/2008)	Sunfish (10/1/2011 - 9/30/2012)	Thompson (3/1/2011 - 9/30/2011)	Thompson (3/1/2012 - 9/30/2012)
Dakota County	2.81			3.26[b]	3.58[b]
Mendota Heights City	129.88 (47.21)[a]	41.13			
West St. Paul City	65.91 (5.86)[a]			83.90	91.95
Mn/DOT	9.72 (0.59)[a]			4.58	4.98
Lilydale City	8.78				
Saint Paul City	12.84 (0.73)[a]				
Mendota City		0.12			
Sunfish Lake City			10.00		
Load Allocations				0.79	0.94
Total	229.93 (54.42)[a]	41.25	10.00	92.53	101.45

Notes:

[a] *Loads associated with ravine erosion*

[b] *Does not account for load reductions associated with practices implemented by Dakota County*

An in-lake mass balance model for phosphorus was developed for each lake to quantify phosphorus loads to the lakes. A daily time-step mass balance model that tracked the flow of water and phosphorus through the lake over the critical period was selected for modeling. Generally, the critical period corresponded to the season with the highest mean total phosphorus concentration. Other factors were considered in determining the critical period, including quality of data and number of data points. Total phosphorus budgets for each lake are summarized in the following discussion.

Sunfish Lake

The period of 10/1/2011-9/30/2012 was determined to be the critical period for Sunfish Lake. Internal loading of phosphorus accounted for 90% of the phosphorus budget to Sunfish Lake during this period, with watershed runoff (6%) and direct deposition from the atmosphere (4%) accounting for the remainder of phosphorus inputs to the lake (see Figure 2.7).

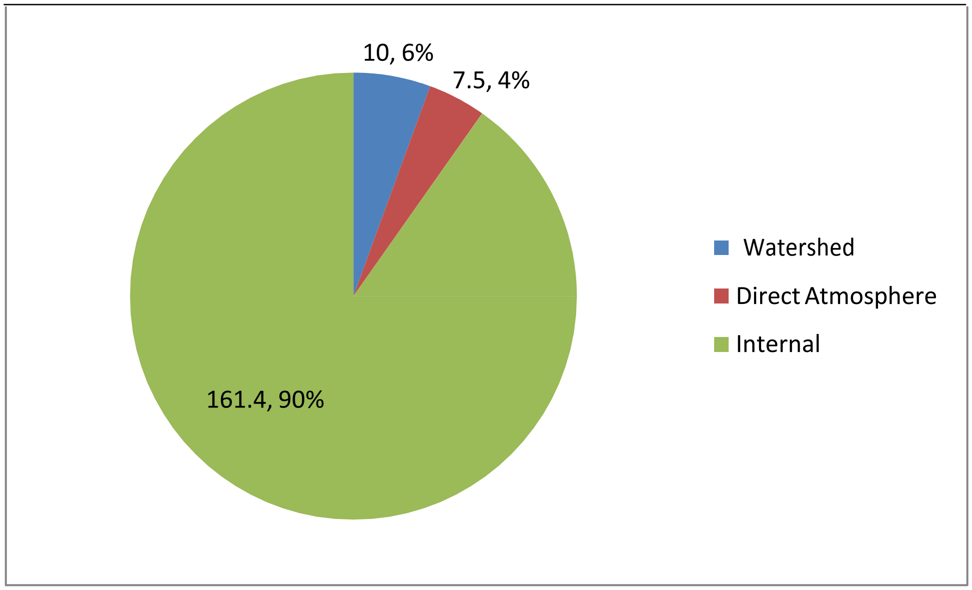


Figure 2.7 Sunfish Lake Total Phosphorus (lbs) Contributions 10/1/2011-9/30/2012

Lake Augusta

The period of 10/1/2007-9/30/2008 was determined to be the critical period for Lake Augusta. Internal loading of phosphorus accounted for 87% of the phosphorus budget to Lake Augusta during this period, with watershed runoff (11%) and direct deposition from the atmosphere (2%) accounting for the remainder of phosphorus inputs to the lake (see Figure 2.8).

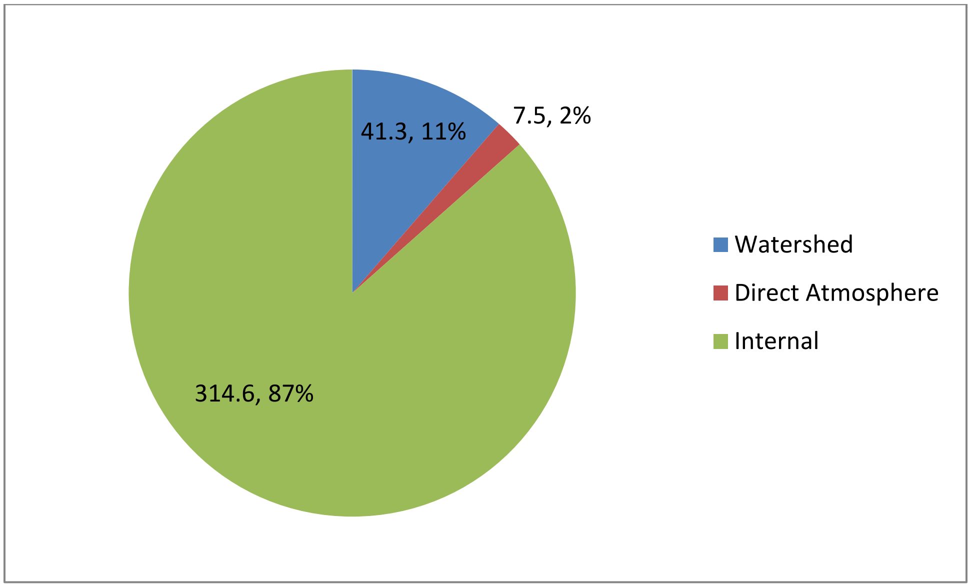


Figure 2.8 Lake Augusta Total Phosphorus (lbs) Contributions 10/1/2007-9/30/2008

Rogers Lake

The period of 10/1/2011-9/30/2012 was determined to be the critical period for Rogers Lake. Watershed runoff of phosphorus accounted for 59% of the phosphorus budget to Rogers Lake during this period, with internal loading (26%) and direct deposition from the atmosphere (15%) accounting for the remainder of phosphorus inputs to the lake (see Figure 2.9).

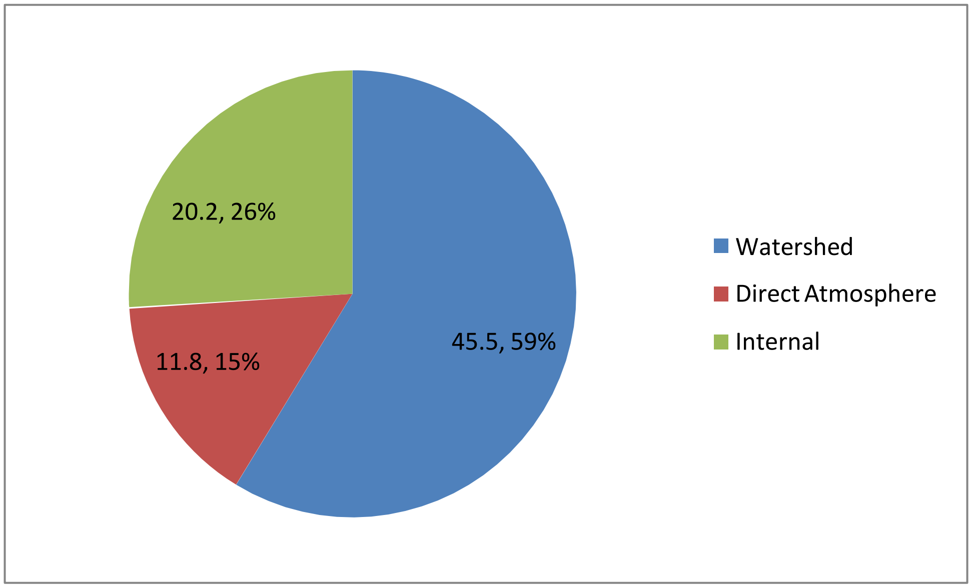


Figure 2.9 Rogers Lake Total Phosphorus (lbs) Contributions 10/1/11-9/30/12

Pickerel Lake

The period of 10/1/2009-9/30/2010 was determined to be the critical period for Pickerel Lake. In the spring of 2010, the Mississippi River flooded Pickerel Lake. The estimated phosphorus contributions associated with Mississippi River flood waters accounted for 56% of the phosphorus budget to Pickerel Lake (see Figure 2.10). The remainder of the phosphorus load to Pickerel Lake during this period included watershed runoff (31%), direct atmospheric deposition (2%), and internal loading/southwest wetland contributions (11%).

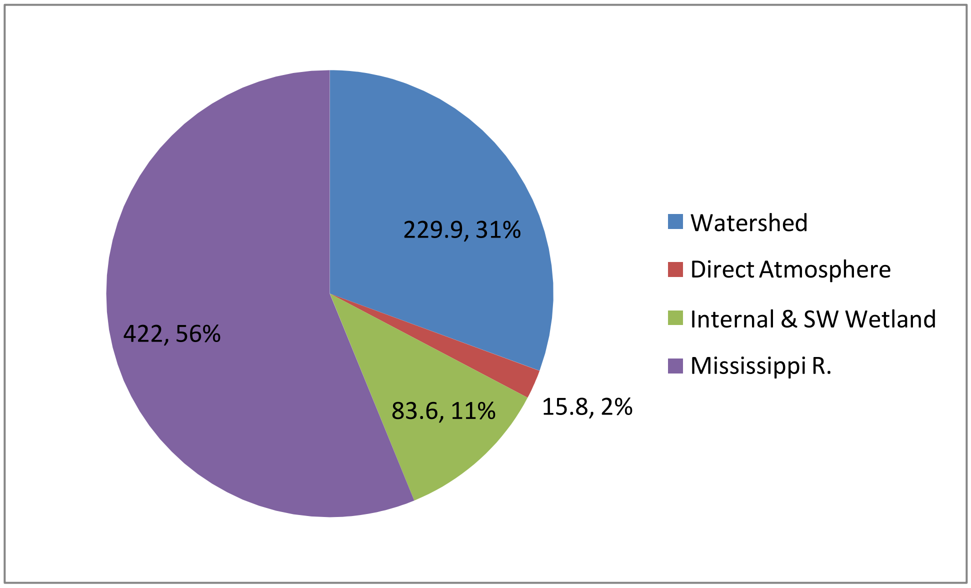


Figure 2.10 Pickerel Lake Total Phosphorus (lbs) Contributions 10/1/2009-9/30/2010

Thompson Lake

The period of 3/1/2012-9/30/2012 was determined to be the critical period for Thompson Lake. Watershed runoff of phosphorus accounted for 99% of the phosphorus budget to Thompson Lake during this period, with direct deposition from the atmosphere (1%) accounting for the remainder of phosphorus inputs to the lake (see Figure 2.11). The lake water quality mass-balance modeling did not indicate any contributions from internal loading as the modeled water quality based on the watershed contributions, alone, adequately accounted for the lake water quality observations during the modeled time period.

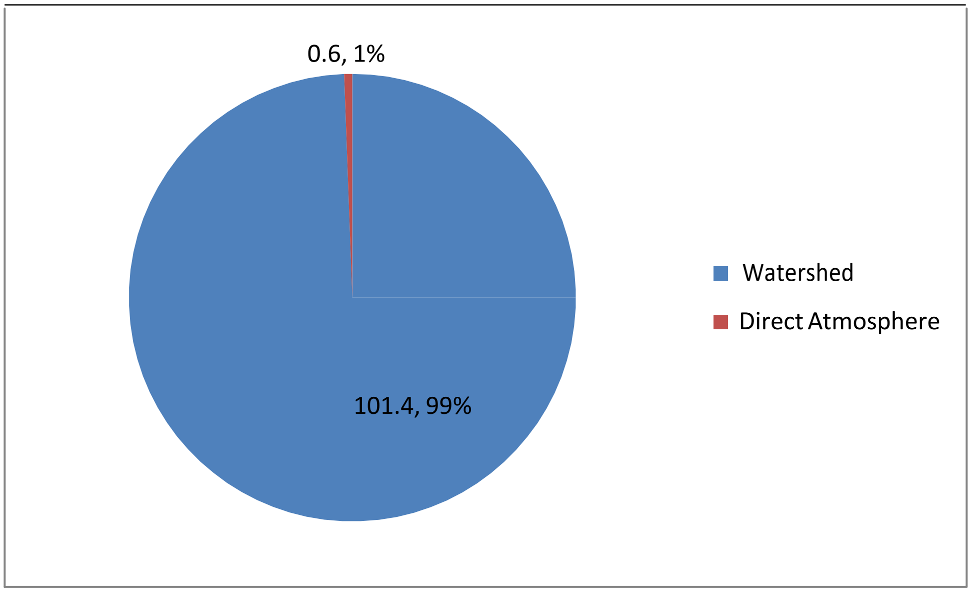


Figure 2.11 Thompson Lake Total Phosphorus (lbs) Contributions 3/1/2012-9/30/2012

2.4 TMDL Summary

Sunfish Lake, Lake Augusta, and Thompson Lake exceed their respective standards for total phosphorus concentrations, and therefore require a reduction in phosphorus loads. Water quality models were developed for these three lakes for representative years, and reductions in phosphorus loads were simulated in the models such that the lakes achieved their respective water quality goals. Details of water quality modeling are discussed in Appendix A. The phosphorus loading capacity to achieve water quality goals for these lakes are summarized in the following tables. The wasteload allocation for these include an allocation for construction and industrial stormwater that is equal to 1% of the total wasteload allocation. An explicit margin of safety of 10% of the total load allocation was included for these lakes as discussed in Section A.6.2.

Lake Augusta

The existing phosphorus contributions, along with the wasteload and load allocations to meet the phosphorus standard for Lake Augusta, are summarized in Table 2.7. In order to achieve the MPCA eutrophication standard for the critical period of 10/1/2007-9/30/2008, a 78% reduction in internal loading of phosphorus is required.

Table 2.7 Lake Augusta Total Phosphorus Allocations to Meet MPCA Eutrophication Standard

Total Phosphorus (TP) Wasteload Allocations, Load Allocations, and Existing Conditions for Lake Augusta.[a]				
Watershed TP Sources	**Existing TP Wasteload (lb/yr)**	**TMDL Wasteload Allocation (WLA)**		**Percent Reduction of TP Wasteload**
		(WLA) (lb/yr)	**(WLA) (lb/day)**	
Mendota Heights City MS4	40.72	40.72	0.1116	0%
Mendota City MS4	0.12	0.12	0.0003	0%
Construction and Industrial Stormwater	0.41	0.41	0.0011	--
Total Wasteload Sources	**41.25**	**41.25**	**0.1130**	**0%**
Internal and Nonpoint Sources	**Existing TP Load (lb/yr)**	**TMDL Load Allocation (LA)**		**Percent Reduction of TP Load**
		(LA) (lb/yr)	**(LA) (lb/day)**	
Internal Sources	314.60	68.33	0.1872	78%
Atmospheric Sources	7.49	7.49	0.0205	0%
Total Load Sources	**322.09**	**75.82**	**0.2077**	**76%**
10% Margin of Safety (MOS)	--	**13.01**	**0.0356**	--
Overall Source Total	**363.34**	**130.08**	**0.3564**	**64%**

[a] Section A.7 describes how existing TP load was calculated for the critical period of 10/1/2007-9/30/2008.

Sunfish Lake

The existing phosphorus contributions, along with the wasteload and load allocations to meet the phosphorus standard for Sunfish Lake, are summarized in Table 2.8. In order to achieve the MPCA eutrophication standard for the critical period of 10/1/2011-9/30/2012, a 44% reduction in internal loading of phosphorus is required.

Table 2.8 Sunfish Lake Total Phosphorus Allocations to Meet MPCA Eutrophication Standard

Total Phosphorus (TP) Wasteload Allocations, Load Allocations, and Existing Conditions for Sunfish Lake.[a]				
Watershed TP Sources	**Existing TP Wasteload (lb/yr)**	**TMDL Wasteload Allocation (WLA)**		**Percent Reduction of TP Wasteload**
		(WLA) (lb/yr)	**(WLA) (lb/day)**	
Sunfish Lake City MS4	9.90	9.90	0.0271	0%
Construction and Industrial Stormwater	0.10	0.10	0.0003	0%
Total Wasteload Sources	**10.00**	**10.00**	**0.0274**	**0%**
Internal and Nonpoint Sources	**Existing TP Load (lb/yr)**	**TMDL Load Allocation (LA)**		**Percent Reduction of TP Load**
		(LA) (lb/yr)	**(LA) (lb/day)**	
Internal Sources	161.39	89.75	0.2456	44%
Atmospheric Sources	7.52	7.52	0.0206	0%
Total Load Sources	**168.91**	**97.27**	**0.2662**	**42%**
10% Margin of Safety (MOS)	--	**11.92**	**0.0327**	--
Overall Source Total	**178.91**	**119.19**	**0.3263**	**33%**

[a] Section A.10 describes how existing TP load was calculated for the critical period of 10/1/2011-9/30/2012.

Thompson Lake

The existing phosphorus contributions, along with the wasteload and load allocations to meet the phosphorus standard for Thompson Lake, are summarized in Table 2.9. In order to achieve the MPCA eutrophication standard for the critical period of 3/1/2012-9/30/2012, reductions in phosphorus wasteloads from the watershed are required. Wasteload allocations for the MS4s were developed such that the flow-weighted mean total phosphorus concentration for watershed runoff contributions from each MS4 would be the same. It is noted that the lake water quality mass-balance modeling did not indicate any contributions from internal loading as the modeled water quality based on the watershed contributions, alone, adequately accounted for the lake water quality observations during the modeled time period.

Table 2.9 Thompson Lake Total Phosphorus Allocations to Meet MPCA Eutrophication Standard

Total Phosphorus (TP) Wasteload Allocations, Load Allocations, and Existing Conditions for Thompson Lake.[a]				
Watershed TP Sources	**Existing TP Wasteload (lb/season)**	**TMDL Wasteload Allocation (WLA)**		**Percent Reduction of TP Wasteload**
		(WLA) (lb/season)	**(WLA) (lb/day)**	
Mn/DOT Metro MS4	4.98	3.35	0.016	33%
Dakota County MS4	3.58	2.50	0.010	30%[b]
West St. Paul City MS4	91.95	63.60	0.298	31%
Construction and Industrial Stormwater	--	0.79	0.004	--
Total Wasteload Sources	**100.51**	**70.24**	**0.328**	**30%**
Internal and Nonpoint Sources	**Existing TP Load (lb/season)**	**TMDL Load Allocation (LA)**		**Percent Reduction of TP Load**
		(LA) (lb/season)	**(LA) (lb/day)**	
Internal Sources	0.00	0.00	0.000	0%
Atmospheric Sources	0.62	0.62	0.003	0%
Load Allocation	0.94	0.94	0.004	0%
Total Load Sources	**1.56**	**1.56**	**0.007**	**0%**
10% Margin of Safety (MOS)	--	**7.97**	**0.037**	--
Overall Source Total	**102.07**	**79.77**	**0.372**	**22%**

[a] *Section A.9 describes how existing TP load was calculated for critical period of 3/1/2012-9/30/2012.*

[b] *Does not account for load reductions associated with existing practices implemented by Dakota County, as described in Section 2.3.*

[c] *The existing TP load for Thompson Lake for Mn/DOT Metro MS4 was revised to 4.98 lb/season from 5.07 lbs/yr (December, 2017). Table 2.6 and Appendix A.10 indicate the correct existing load for Mn/DOT Metro MS4 of 4.98.*

2.5 Protection Considerations

As discussed in Section 2.4, Rogers Lake is the only lake in this study that is currently meeting MPCA's water quality standards. A primary goal of the LMRWMO is to improve water quality within the watershed. As a result, member cities will require a 50% total phosphorus removal from runoff leaving new development and redevelopment projects that exceed one acre of land disturbance. It is expected that this policy will continue to protect the high water quality of Rogers Lake.

Reference or background water quality conditions have been estimated from the MINLEAP model (Heiskary and Wilson, 1990), and a water quality relationship (based on conductivity in Rogers Lake) developed by Vighi and Chiaudani (1985) that, in turn, can be compared to the current water quality of the south basin. The MINLEAP model estimate for the average phosphorus concentration in Rogers Lake was 41 µg/l, which compares well with the observed long-term summer average phosphorus concentration of 38 µg/l. The Vighi and Chiaudani relationship estimates an average phosphorus concentration of 22 µg/l, which might be expected in an unaltered watershed condition for the south basin of Rogers Lake.

The watershed and lake modeling discussed in this report have been used to evaluate the phosphorus load contributions from watershed and internal sources to maintain and possibly improve the high water quality of Rogers Lake.

3. Prioritizing and Implementing Restoration and Protection

The Clean Water Legacy Act (CWLA) requires that WRAPS reports summarize priority areas for targeting actions to improve water quality, identify point and nonpoint sources of pollution with sufficient specificity to prioritize and geographically locate watershed restoration and protection actions. In addition, the CWLA requires including an implementation table of strategies and actions that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources.

This section of the report provides the results of such prioritization and strategy development. Because much of the nonpoint source strategies outlined in this section rely on voluntary implementation by landowners, land users and residents of the watershed it is imperative to create social capital (trust, networks and positive relationships) with those who will be needed to voluntarily implement best management practices. Thus, effective ongoing civic engagement is fully a part of the overall plan for moving forward.

3.1 Targeting of Geographic Areas

This section involves development and targeting of management actions that will protect and improve water quality conditions in each lake. The calibrated watershed modeling has been used to identify and evaluate the effectiveness of potential BMPs and the amount of potential load reduction that could be expected from various BMP types and locations within the direct watershed. The lakes' response to the expected load reductions determined in the watershed analyses have been evaluated with the calibrated in-lake modeling. Potential in-lake improvement options have also been evaluated with the calibrated in-lake modeling. This process allows for the evaluation of the direct effect of a specific BMP or in-lake improvement option on lake water quality, which can then be used to evaluate the expected cost and benefits, as well as implementation strategies for the phosphorus load reduction required to meet the water quality goals. Sections 2.4 and 3.3, as well as Appendix A, show the expected results and recommendations for implementing feasible in-lake and watershed treatment options intended to meet the water quality goals for each lake. Table A.2 shows that the Thompson Lake watershed has a relatively high percentage of imperviousness, while the Sunfish and Lake Augusta watersheds have lower imperviousness, and thus, lower watershed contributions to the annual phosphorus loadings.

The results of the above analysis were used to calculate TP loads per unit area to reach the lake for each subwatershed in the P8 model. These results are used to identify "hot spots" for TP watershed sources to each of the individual lakes. Figures 3.1 – 3.3 show the annual average TP loads per unit area for the various subwatersheds. The TP loads displayed are the loads that reach the lake after removals from BMPs are taken into account. The figures also show the total annual TP loads to the lake from the major outfalls for Pickerel Lake, Lake Augusta, and Rogers Lake. In Pickerel Lake additional loads were added to three outfalls (IF-28, MB-2, and MB-1) associated with erosional TP contributions (discussed in Appendix A, Section A.10).

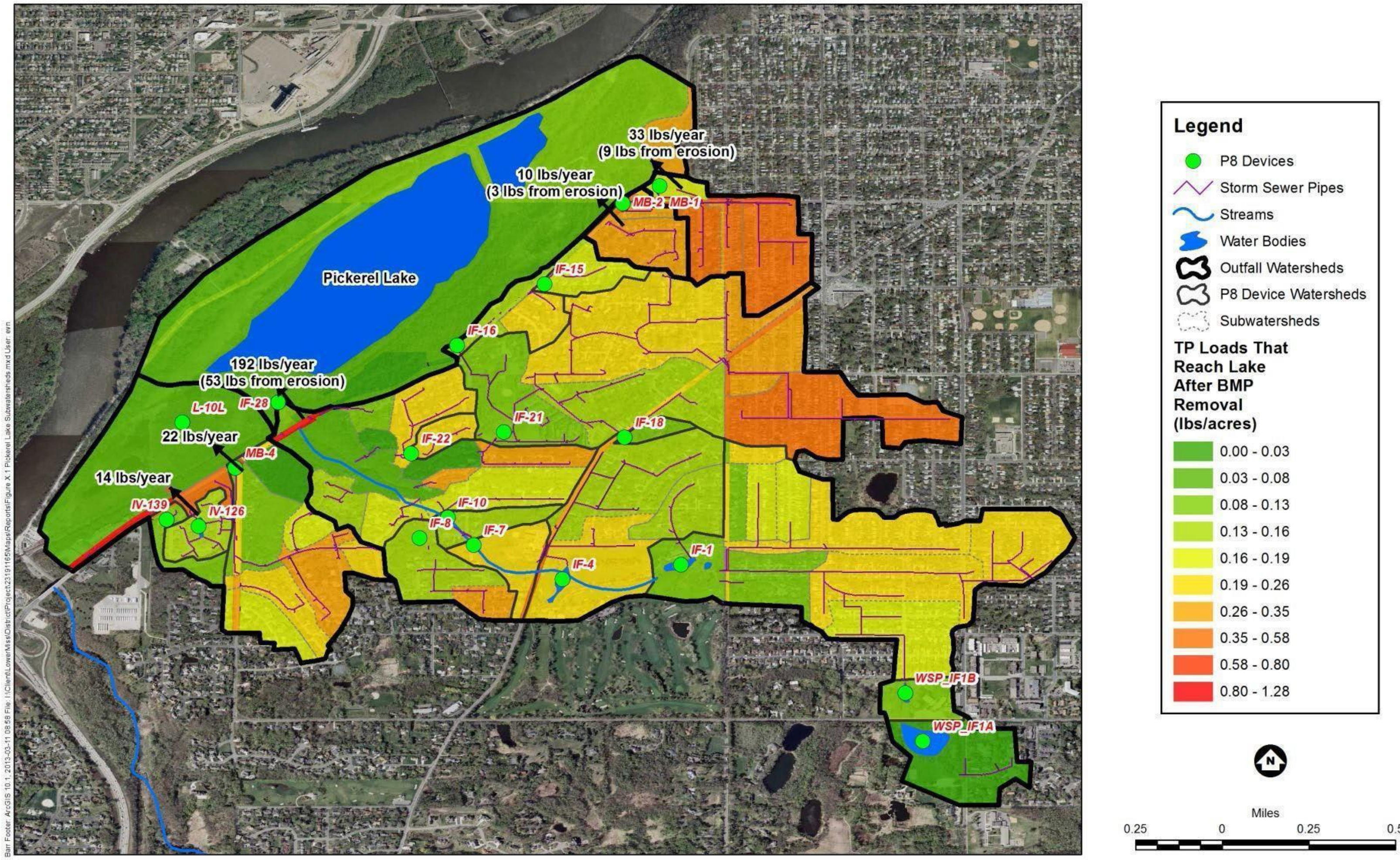


Figure 3.1 Annual Average Pickerel Lake Direct Watershed Loads to the Lake After Load Removal From Existing BMPs

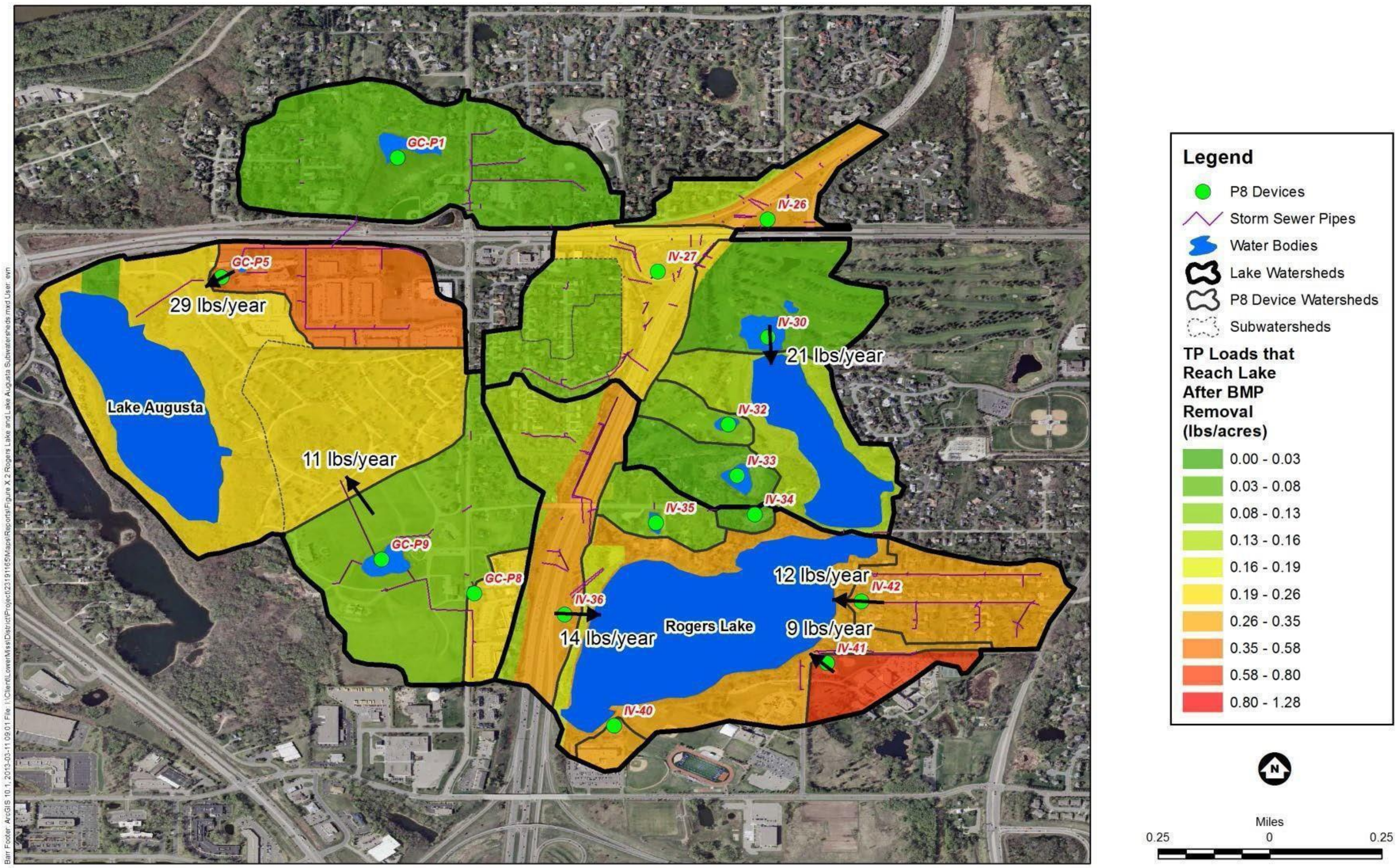


Figure 3.2 Annual Average Lake Augusta and Rogers Lake Direct Watershed Loads to the Lake After Load Removal From Existing BMPs

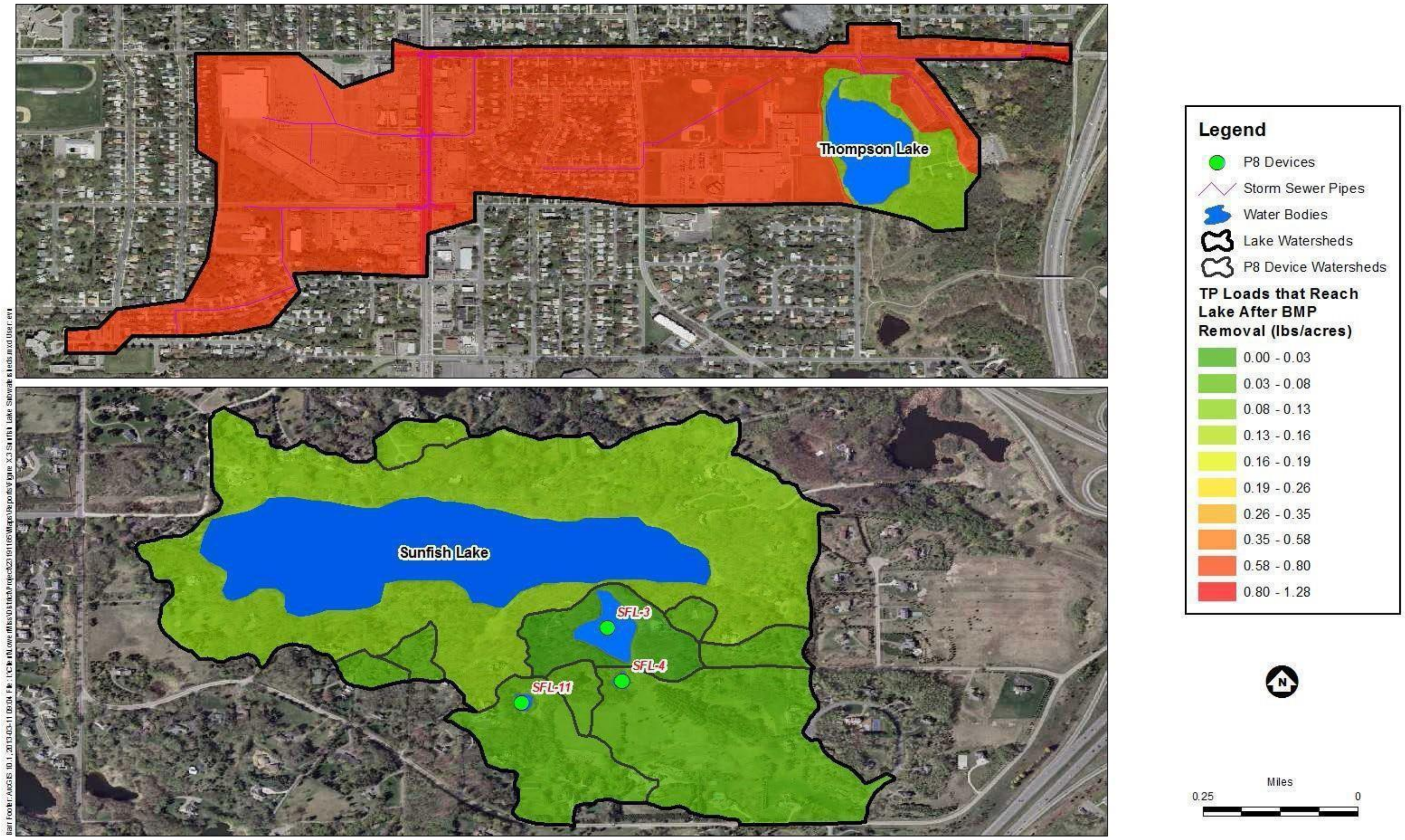
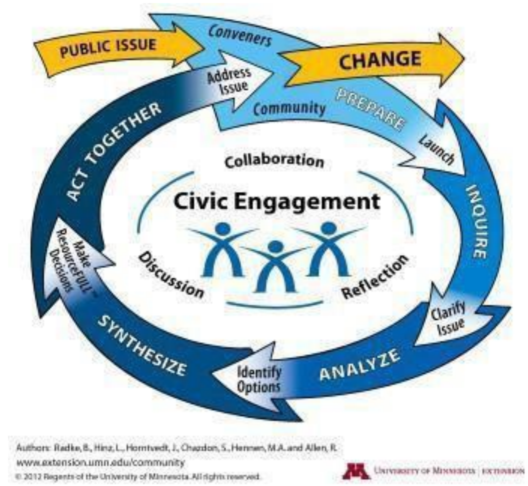


Figure 3.3 Annual Average Thompson Lake and Sunfish Lake Direct Watershed Loads to the Lake After Load Removal From Existing BMPs

3.2 Civic Engagement



A key prerequisite for successful strategy development and on-the-ground implementation is meaningful civic engagement. This is distinguished from the broader term 'public participation' in that civic engagement encompasses a higher, more interactive level of involvement. Specifically, the University of Minnesota Extension's definition of civic engagement is "Making 'resourceFULL' decisions and taking collective action on public issues through processes that involve public discussion, reflection, and collaboration." A resourceFULL decision is one based on diverse sources of information and supported with buy-in, resources (including human), and competence. Further information on civic engagement is available at: http://www1.extension.umn.edu/community/civic-engagement/.

A specific goal of the civic engagement process for the LMRWMO WRAPS was to work closely with the residents, cities, counties, businesses and other stakeholders to ensure that their ideas, concerns and visions for future conditions were understood and utilized throughout the WRAPS study process. The WRAPS process is most likely to be successful when average citizens play a greater role in helping to frame the water quality issues in their own community as well as in the creation of the solutions to those problems. Given this, the civic engagement process included two primary components: technical stakeholder engagement and citizen engagement.

A Technical Stakeholder Group (TSG) was developed to share local knowledge about problems and to guide the development of potential implementation strategies based on technical data. The WRAPS TSG included representatives from the LMRWMO, member cities and other regulated MS4s, Dakota County SWCD, St. Paul Parks and Recreation Department (Pickerel Lake), Dakota County Parks Department (Thompson Lake), National Park Service (Pickerel Lake), MDNR, BWSR (Board of Water and Soil Resources), Met Council, and MPCA.

Two of the primary strategies employed throughout the LMRWMO WRAPS study to engage citizens included 1) sharing information about water quality problems and general lake ecology with interested residents and stakeholders, and 2) listening to residents and stakeholders that care about the future of these lakes. The objective of the LMRWMO, through engagement and dialogue with citizens during this process, was to better understand the emotional, physical and financial barriers that may be keeping people from taking actions that could improve water quality. Engaged and supportive citizens can also help the LMRWMO secure the commitment of other citizens in achieving a vision for water quality.

In addition to engaging residents and the TSG throughout the project, official public notices and comments were also part of the process (see Section 3.2.4).

3.2.1 Technical Stakeholder Engagement

A project kickoff meeting was held September 6, 2012 to introduce the project to the WRAPS TSG, including presentation of the monitoring plan, the proposed modeling approach and relevant input data, and discussion of the potential implications of TMDL wasteload allocations (WLAs) for the MS4s.

Project status meetings were held with stakeholders from each individual lake watershed on May 2, 2013 to describe the known impairments and to discuss preliminary modeling results and potential implementation alternatives.

A TSG meeting was held on December 5, 2013 to review the draft WRAPS report, including allocations and implementation strategies.

An Implementation workshop was held on June 24, 2014 with citizen participants and technical stakeholders (section 3.2.3).

3.2.2 Citizen Engagement

Citizen-Input Survey

A survey was developed and mailed to residents of the Pickerel Lake, Rogers Lake, Thompson Lake and Sunfish Lake watersheds. The three primary objectives of the survey were:

1. Knowledge: To understand how residents use the lake and their knowledge of water quality, stormwater runoff, and lake stewardship best practices.
2. Attitudes: To learn more about residents' feelings and attitudes regarding their lake's water quality and its protection and their willingness to get more involved.
3. Practices: To learn what residents are currently doing to protect their lake's water quality and whether residents are willing to change their behaviors to protect or improve their lake's water quality.

The survey was mailed to 2,400 residential properties within the four watersheds, along with an educational flyer specific to each lake on water quality issues and an invitation to attend the Community Conversations. 247 survey responses were received, both through the mail and via the online Survey Monkey option. A copy of the surveys and lake flyers along with a summary of responses are included in Appendix B. An email distribution list of interested residents was generated as an additional outcome of the survey, which was used for communicating project progress and can be used to promote participation in future civic engagement opportunities within the LMRWMO.

Community Conversations

Three "Community Conversations" were held to provide opportunities for citizens to learn about and discuss water quality problems in their lakes and watersheds, and discuss their ideas on addressing water quality problems and communication strategies. The first in a series of "Community Conversations" was held on November 15, 2012. Twenty-five residents and other stakeholders attended including representation from Pickerel, Rogers, Sunfish, and Thompson Lakes. A brief presentation was given, including an overview of the LMRWMO WRAPS project and results of the citizen-input survey. Participants discussed a series of questions, sharing their knowledge and concerns about the water quality of the lakes in their communities.

The second in a series of "Community Conversations" was held on April 16, 2013. Thirty-one people attended and participated in the presentation and discussion, including representation from Pickerel, Rogers, Sunfish, and Thompson Lakes. A presentation was given, including an overview of lake ecology and information on pollution sources and preliminary "diagnoses" for all four lakes. The presentation included quiz questions about various lake ecology-related facts. Audience members participated by answering questions with electronic polling devices. Graphics with responses were shown throughout the presentation. Following the presentation, participants discussed a series of questions regarding how the information presented affected them, whether the information will change their practices, and methods to communicate similar information to community members.

The third in a series of "Community Conversations" was held on September 5, 2013. Twenty-one people attended and participated in the presentation and discussion, including representation from Pickerel, Rogers, and Sunfish Lakes. A presentation was given with a guest speaker from the Como Lakes Neighbor Network, including information about a local citizen-led organization that is making strides in engaging citizens and collaboratively improving the conditions in their lake and additional information on the citizen-input survey results. Participants then discussed and prioritized strategies for involving community members in water resources protection and improvement.

Email and Website Updates

Email updates were sent out to all residents on the LMRWMO's email list to inform them about highlights from the community conversations and WRAPS progress. The project website was maintained and updated with timely and appropriate information including progress on the overall project, details about upcoming events, all meeting materials as well as presentations from the TSG meetings and Community Conversations.

Communications Plan

A communications plan was developed to guide ongoing and future communications to support successful implementation of best management practices and public involvement and public education programs. Insight gained from the three community conversations was incorporated to guide the development of key messages. A copy of the communications plan is included in Appendix C.

3.2.3 Implementation Workshop

On June 24, 2014, eighteen residents and technical stakeholders gathered for the Implementation Workshop hosted by the LMRWMO. The workshop brought together members of the technical stakeholder group, residents who participated in the community conversations and other interested residents. At the workshop the proposed draft implementation strategies for each watershed/lake were presented. The workshop engaged technical stakeholders and citizens in a dialogue about priorities and selecting among alternative Best Management Practices (BMPs) and program strategies. Strategy priorities were discussed at the 3rd community conversations, but clarification of these discussions and decisions on mutually exclusive strategies were provided at this meeting to finalize the implementation strategies. The focus of the workshop included plan elements that have the greatest impact on citizens. The meeting included two parts. The first part discussed priorities and strategies common to all watersheds while the second part included small breakout sessions by each watershed/lake to discuss priorities and strategies specific to each watershed/lake. The results of the workshop will help those entities charged with implementing protection and restoration strategies to better prioritize and understand what practices or programs might work for a given area.

3.2.4 Public Notices and Comments

An official public comment period for the Total Maximum Daily Load (TMDL) began on June 16, 2014 and ended on July 16, 2014. Three comment letters were received during the public comment period.

3.3 Restoration & Protection Strategies

As discussed in Section 2.4, implementation of stormwater treatment measures will be required to meet the wasteload allocations for Thompson Lake, internal load reductions will be required to meet the load allocations in Sunfish Lake and Lake Augusta, and a series of implementation actions will be required to improve water quality for Pickerel Lake and ensure that the standards are in attainment on a consistent basis. Additional stormwater treatment measures, likely in conjunction with reconstruction or redevelopment, would also improve and protect the water quality of Rogers Lake. Tables 3.1 and 3.2 present the strategies and proposed actions intended to restore and protect lake water quality in the Lower Mississippi River WMO WRAPS study area.

Watershed modeling of Thompson Lake was conducted to evaluate whether a stormwater treatment pond designed to capture and treat the inflow to the north end of the lake could be accommodated in the available space while meeting the 31% point source reduction requirement shown in Table 2.8. It was determined that there could potentially be space for a BMP that would treat the inflow to Thompson Lake from the stormsewer system that would be capable of meeting the phosphorus load reduction goal, but a feasibility study will be required, as there are contaminated soils in the area and it is unlikely that a detention pond will be permitted for construction within the jurisdictional boundary of a public water body. If it is determined that an appropriately-sized pond is infeasible, an equivalent level of stormwater treatment or further source control BMPs could be installed and/or retrofitted throughout the Thompson Lake watershed to reduce impervious surface areas, increase infiltration and/or reduce runoff rates to remove the phosphorus load to the lake to meet the water quality standard.

In-lake alum treatments were chosen as the restoration strategy intended to meet the phosphorus load reduction targets from the TMDL computations in Sunfish Lake and Lake Augusta, as internal loading was identified as the primary source of phosphorus contributions to each lake during the growing season. In addition, both lakes have long residence times and external loads (e.g., phosphorus fertilizer and historic agricultural inputs) have been substantially reduced or eliminated.

At a minimum, water quality restoration of Pickerel Lake will be dependent on regional/state efforts to address the nutrient inputs and impact of Mississippi River inundation. It is also expected that stabilization measures for ravine and bluff erosion will significantly improve water quality in the Pickerel Lake watershed. Five priority sites have been identified in Figure 3.4.

Tables 3.1 and 3.2 provide more implementation details that are applicable to each lake.

Table 3.1: Strategies and proposed actions for the Lower Mississippi River WMO WRAPS study area.

Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Estimated Scale of Adoption Needed	Governmental Units with Primary Responsibility								Timeline to Achieve Water Quality Targets	Interim 10-yr Milestones
Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions	Goals / Targets			LMRWMO	Upstream Entities	Sunfish Lake	West St. Paul	Mendota Heights	Mn/DOT	St. Paul	Dakota County		
Pickerel Lake (19-0079)	Dakota, Ramsey	TP	Not Assessed	TP = 60 µg/l Chl a = 20 µg/l Secchi depth = 1.0 m	Ravine/Bluff stabilization in Ivy Creek and Lilydale Park or other upstream BMPs to reduce flow volume and/or pollutants	Local efforts to address most erosive ravines and bluffs	√			√	√	√	√	√	30 years (dependent on the Mississippi River meeting water quality targets for nutrients)	Most ravine/bluff stabilization projects will be completed in the first five years (dependent on funding)
					Increased monitoring of phosphorus sources to Pickerel Lake	Not Applicable (NA) - local efforts to monitor the lake	√									At least two years of additional monitoring will be undertaken in the first five years (dependent on funding)
					Improve Mississippi River water quality throughout the Mississippi River watershed	This is difficult to determine until large river TMDLs are completed		√								Completion of large river TMDLs, monitoring, and assessment; numerous implementation projects undertaken in the Mississippi River watershed
Sunfish Lake (19-0050)	Dakota	TP	Impaired	TP = 40 µg/l Chl a = 14µg/l Secchi depth = 1.4 m	In-lake alum treatment	Local lake effort – one time addition of alum will likely address legacy contaminants			√						5 years	Alum treatment project may be completed in the first five years (dependent on funding)
					Herbicide treatment to target Curlyleaf pondweed	Local lake effort – treatment every 5-10 years but only if needed			√							If needed, Curlyleaf pondweed treatment project may be completed (dependent on funding)
Thompson Lake (19-0048)	Dakota	TP	Impaired	TP = 60 µg/l Chl a = 20 µg/l Secchi depth = 1.0 m	Construct pond or other BMPs for treatment of stormwater entering north end of lake	Local municipal effort – either one pond or multiple BMPs implemented in watershed				√		√		√	5 years	Construction of pond or other BMPs (dependent on funding)
					Evaluation of internal load	NA - local efforts to evaluate internal loads if watershed BMPs aren't sufficient	√									If needed, project to evaluate additional internal load reductions may be completed (dependent on funding)
Rogers Lake (19-0080)	Dakota	TP	Protected	TP = 60 µg/l Chl a = 20 µg/l Secchi depth = 1.0 m	Stormwater BMPs for compliance with NPDES and WMO requirements	As opportunities arise with development/redevelopment					√				10 years, however lake already meets water quality targets	As development and redevelopment occurs, multiple BMPs are put into place
					Herbicide treatment to target Curlyleaf pondweed	Local lake effort – treatment every 5-10 years but only if needed					√					If needed, Curlyleaf pondweed treatment project may be completed (dependent on funding)
Lake Augusta (19-0081)	Dakota	TP	Impaired	TP = 40 µg/l Chl a = 14µg/l Secchi depth = 1.4 m	In-lake alum Treatment	Local lake effort – one time addition of alum will likely address legacy contaminants					√				5 years	Alum treatment project may be completed in the first five years (dependent on funding)

Table 3.2: Key for Strategies Column

Strategy	Description
	Nonpoint Source
In-lake alum Treatment	Results of sediment monitoring have been used to develop preliminary alum dose and estimated treatment cost ranges of $60,000-$100,000 for Lake Augusta and $70,000-$110,000 for Sunfish Lake. Additional watershed actions will be required if alum treatment doesn't result in water quality standards being met.
Ravine and bluff stabilization	Feasibility study should be completed to further identify and prioritize individual sources of erosion and estimate implementation costs. Estimated cost of feasibility study is $30,000-$50,000. Estimated project implementation costs of $100,000-$1,000,000.
Improve quality of flow from Southwest Wetland	Monitoring should be completed to further identify source of phosphorus release and implementation options/costs. Estimated cost of monitoring is $15,000-$30,000.
Improve Mississippi River water quality	Anticipated that this strategy will need to be developed as part of overall implementation actions for the Lake Pepin watershed to meet the 125 µg/L TP standard for Pool 2.
Herbicide treatment to target invasive aquatic plants	An aquatic vegetation management plan should be developed to evaluate the cost/benefit associated with all available options for plant management.
	Point Source
NPDES point source compliance	All NPDES-permitted sources shall comply with conditions of their permits, which are written to be consistent with any assigned wasteload allocations within next ten years.
Compliance with Lower Mississippi River WMO goals and policies	Member cities will require a 50% total phosphorus removal from runoff leaving new or redevelopment projects that exceed 1 or more acres of disturbance.
Construct pond for treatment of stormwater entering north end of Thompson Lake	Feasibility study and monitoring should be completed to further identify areas of sediment contamination to avoid for BMP implementation. Estimated cost of feasibility study is $15,000-$30,000. Estimated project implementation costs of $50,000-$200,000. Other watershed BMPs providing an equivalent level of treatment can also be considered in lieu of the proposed pond.

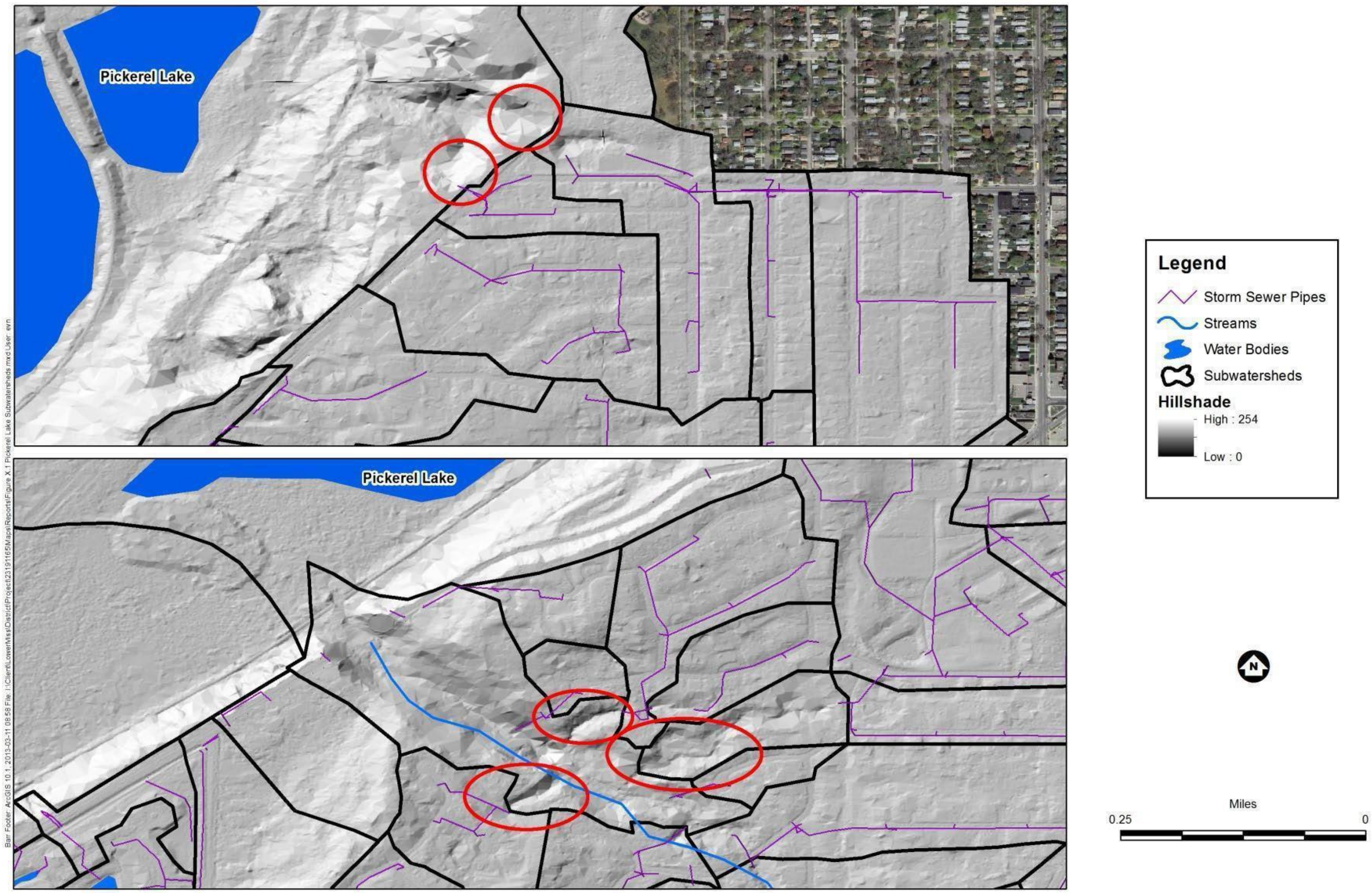


Figure 3.4 Possible Erosion Locations in Pickerel Lake Watershed

4. Monitoring Plan

The Lower Mississippi River WMO has identified evaluating and tracking water quality trends as a goal in their Watershed Management Plan and has conducted or financially supported monitoring of numerous lakes within the watershed during recent years, often through the Citizen Assisted Monitoring Program (CAMP) coordinated by the Metropolitan Council. The WMO will continue to support monitoring of the lakes addressed in this study, as well as other lakes, with prioritization of lake monitoring being determined annually based on funding availability, public interest, and partnering opportunities.

Monitoring will follow the CAMP program protocols, with typical lake sampling occurring eight to ten times between April and September. In conformance with the protocol, the annual sampling data will be submitted to the MPCA (Environmental Quality Information System (EQUIS)). In-lake water quality monitoring will be collected and analyzed for eutrophication parameters (total phosphorus (TP), ortho-phosphorus (OP), Secchi depth and chlorophyll-a) and surface water field measurements (dissolved oxygen, temperature, specific conductivity, pH, turbidity).

It will also be important to monitor the long-term effectiveness of any water quality improvement projects being implemented in each lake watershed. Documentation of installed BMPs and testing of removal effectiveness of representative phosphorus reduction BMPs should also be conducted, where possible.

5. References and Further Information

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Appendices

Appendix A: TMDL Supporting Document

<table>
<tr><th colspan="5">EPA TMDL Summary Table</th><th></th></tr>
<tr><td>EPA/MPCA Required Elements</td><td colspan="4">Summary</td><td>Page #</td></tr>
<tr><td>Location</td><td colspan="4">Lower Mississippi River WMO Watershed in northern Dakota and southern Ramsey Counties</td><td>8-9</td></tr>
<tr><td>303 (d) Listing Information</td><td colspan="4">Total of three listings for excess nutrients; See Section 2.1</td><td>9-15</td></tr>
<tr><td>Applicable Water Quality Standards/ Numeric Targets</td><td colspan="4">See Section 2.1</td><td>14</td></tr>
<tr><td rowspan="3">Loading Capacity (expressed as daily load)</td><td colspan="4">Critical condition summary: MPCA eutrophication standard for total phosphorus is compared to the growing season (June through September) average.</td><td rowspan="3">20-33</td></tr>
<tr><td>Thompson Lake (lbs/day)</td><td colspan="2">Sunfish Lake (lbs/day)</td><td>Lake Augusta (lbs/day)</td></tr>
<tr><td>0.372</td><td colspan="2">0.326</td><td>0.356</td></tr>
<tr><td>Margin of Safety</td><td>0.037 (10%)</td><td colspan="2">0.033 (10%)</td><td>0.036 (10%)</td><td>30-33, 79</td></tr>
<tr><td rowspan="10">Wasteload Allocation (WLA)</td><td>Source</td><td>Thompson (lbs/day)</td><td>Sunfish (lbs/day)</td><td>Augusta (lbs/day)</td><td rowspan="10">24-33, 75-77</td></tr>
<tr><td colspan="4">Permittees Subject to MS4 NPDES Requirements</td></tr>
<tr><td>Mn/DOT Metro MS4</td><td>0.016</td><td>NA</td><td>NA</td></tr>
<tr><td>Dakota County MS4</td><td>0.010</td><td>NA</td><td>NA</td></tr>
<tr><td>Saint Paul City MS4</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>West St. Paul City MS4</td><td>0.298</td><td>NA</td><td>NA</td></tr>
<tr><td>Sunfish Lake City MS4</td><td>NA</td><td>0.027</td><td>NA</td></tr>
<tr><td>Mendota City MS4</td><td>NA</td><td>NA</td><td>0.0003</td></tr>
<tr><td>Mendota Heights City MS4</td><td>NA</td><td>NA</td><td>0.112</td></tr>
<tr><td>Construction and Industrial Stormwater</td><td>0.004</td><td>0.0003</td><td>0.001</td></tr>
</table>

EPA TMDL Summary Table				
EPA/MPCA Required Elements	**Summary**			**Page #**
Load Allocation (LA)	Thompson Lake (lbs/day) 0.007	Sunfish Lake (lbs/day) 0.266	Lake Augusta (lbs/day) 0.208	24-33
Seasonal Variation	Lake water quality modeling methodology accounts for seasonal variation; *See Sections 2.3 and 2.4*			24-33
Reasonable Assurance	NPDES permits provide assurance for permitted sources to comply with WLAs. *See Section A.5.4*			76
Monitoring	A general overview of follow-up monitoring is included; *See Section 2.4*			47
Implement-ation	*See Sections 3.1 and 3.3*			34-35, 42-46
Public Participation	Public Comment period: June 16, 2014 to July 16, 2014 Various public participation and citizen engagement efforts were conducted; *See Section 3.2*			39-42

A.1 Watershed Modeling

Water quality modeling for the five lake watersheds studied (Pickerel Lake, Sunfish Lake, Rogers Lake, Lake Augusta, and Thompson Lake) was conducted using the P8 Urban Catchment Model (Program for Predicting Polluting Particle Passage thru Pits, Puddles, and Ponds). P8 is a model used for predicting the generation and transport of stormwater runoff and pollutants in urban watersheds. The model tracks the movement of particulate matter (fine sand, dust, soil particles, etc.) as it is carried along by stormwater runoff traveling over land and pavement. Particle deposition in ponds is tracked in order to estimate the amount of pollutants, carried by the particles that eventually reach a water body. Previous models from a 2003 study (Barr, 2003) were updated for Pickerel Lake, Rogers Lake, and Sunfish Lake. New models were created for Lake Augusta and Thompson Lake. All lake models were run for years 2000-2012.

A.1.1 Watershed and MS4 boundaries

Watershed delineations for each of the lakes were obtained from the cities of Mendota Heights and West St. Paul. These delineations were adjusted using 1m resolution LIDAR obtained in 2007. Subwatershed boundaries for Pickerel Lake, Sunfish Lake, Rogers Lake and Thompson Lake were also obtained from the LMRWMO based on previous P8 models. These subwatershed boundaries were checked and adjusted based on LIDAR data as well as stormsewer information gathered from the cities of Mendota Heights, West St. Paul and St. Paul. A previous model did not exist for Lake Augusta, therefore, new subwatersheds were created for that lake. Subwatershed boundaries and stormsewer locations are displayed in Figure A.1 to A.3 for each of the five lakes. The subwatershed naming convention used was consistent with previous modeling efforts.

MS4 boundaries were created for each of the five lakes. A total of eight MS4s are located in the five lake watersheds (Mn/DOT, Dakota County, Mendota, West St. Paul, Mendota Heights, Sunfish Lake, Lilydale, and St. Paul). MS4 boundaries were assigned to the Mn/DOT rights-of-way first. This data was obtained from Mn/DOT directly. Dakota county MS4 boundaries were assigned next using road classifications of county state-aid street and county roads from the Mn/DOT street data (received October 2010). Once roadways were identified as being operated by the county, boundaries were determined using county parcel data from 2008. Any area in the watersheds not associated with either Mn/DOT or either county was assigned to the corresponding municipality (Mendota, West St. Paul, Mendota Heights, Sunfish Lake, Lilydale, and St. Paul). MS4 boundaries for each lake are displayed in Figures A.4 to A.6. Areas associated with each MS4 are displayed in Table A.1, by lake.

Table A.1 MS4 area for each lake watershed

Lake	MS4 Areas (acres)							
	Mn/DOT	Dakota County	Mendota	West St. Paul	Mendota Heights	Sunfish Lake	Lilydale	St. Paul
Lake Augusta	--	--	2.9	--	368.4	--	--	--
Pickerel Lake	34.3	11.5	--	296.7	563.7	--	191.6	100.0
Rogers Lake	86.0	--	--	--	283.6	--	--	--
Sunfish Lake	--	--	--	--	--	184.6	--	--
Thompson Lake	4.8	5.4	--	160.7	--	--	--	--
Totals	**125.1**	**16.9**	**2.9**	**457.4**	**1215.7**	**184.6**	**191.6**	**100.0**

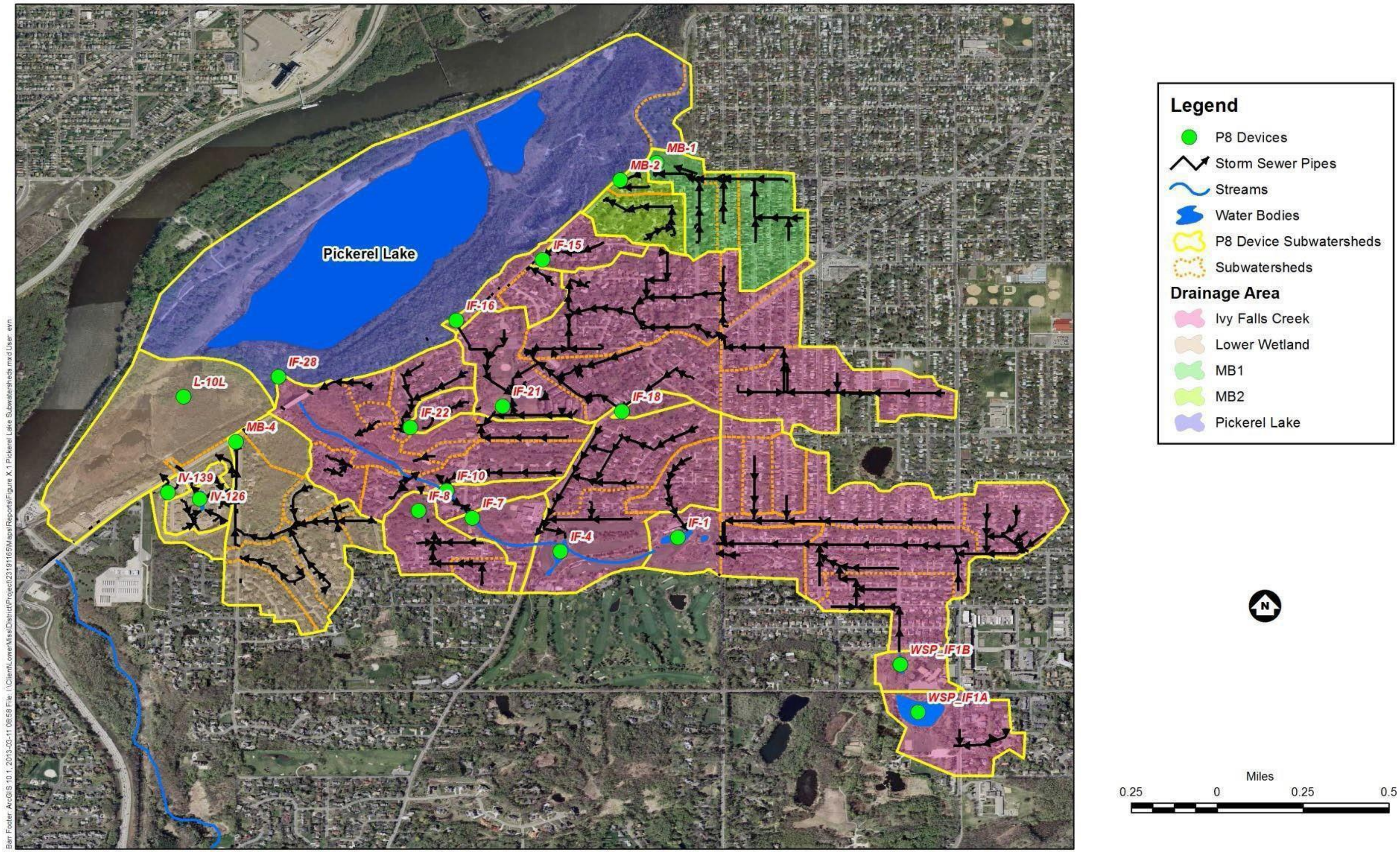

Figure A.1 Pickerel Lake Watershed

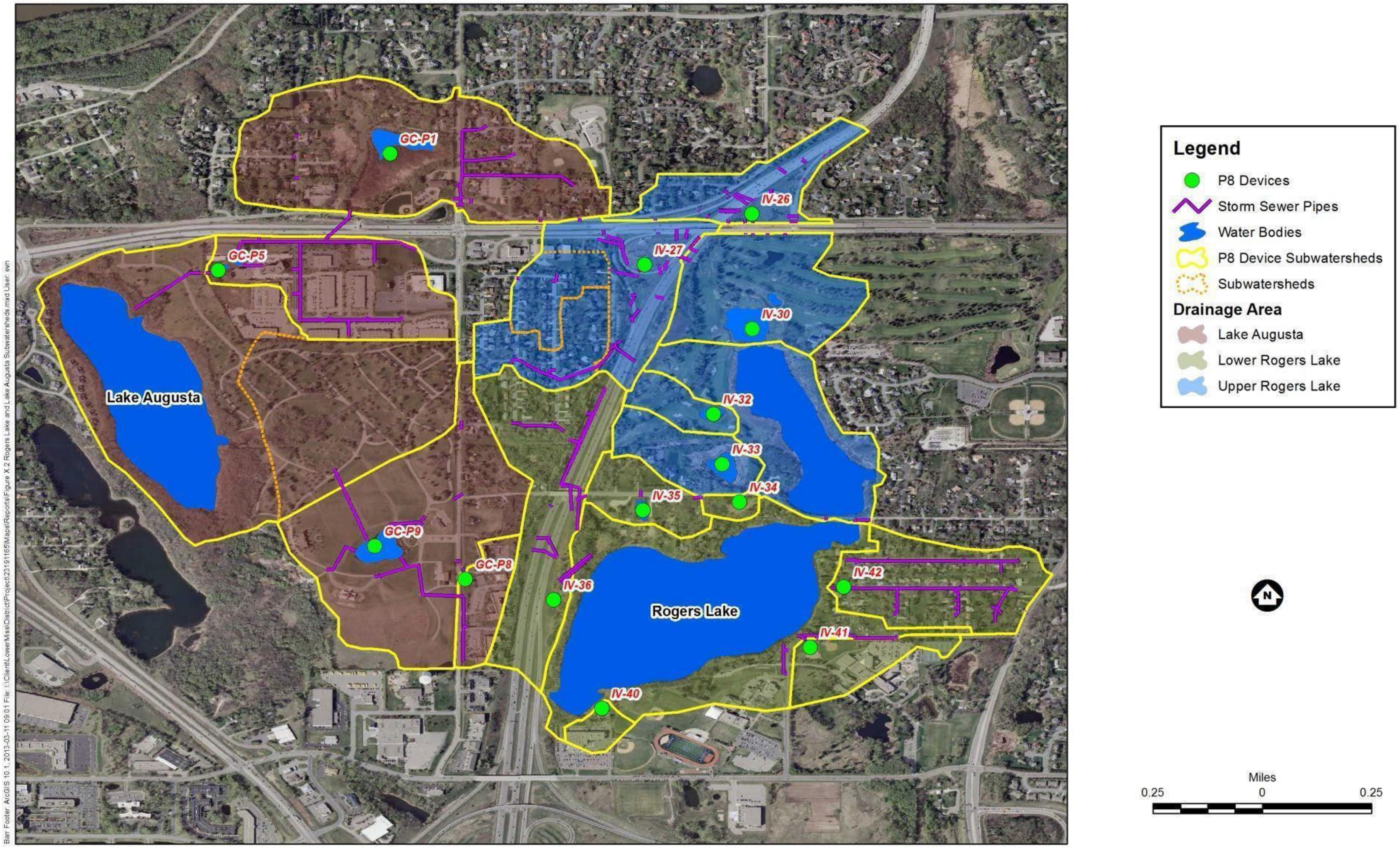

Figure A.2 Rogers Lake and Lake Augusta Watersheds

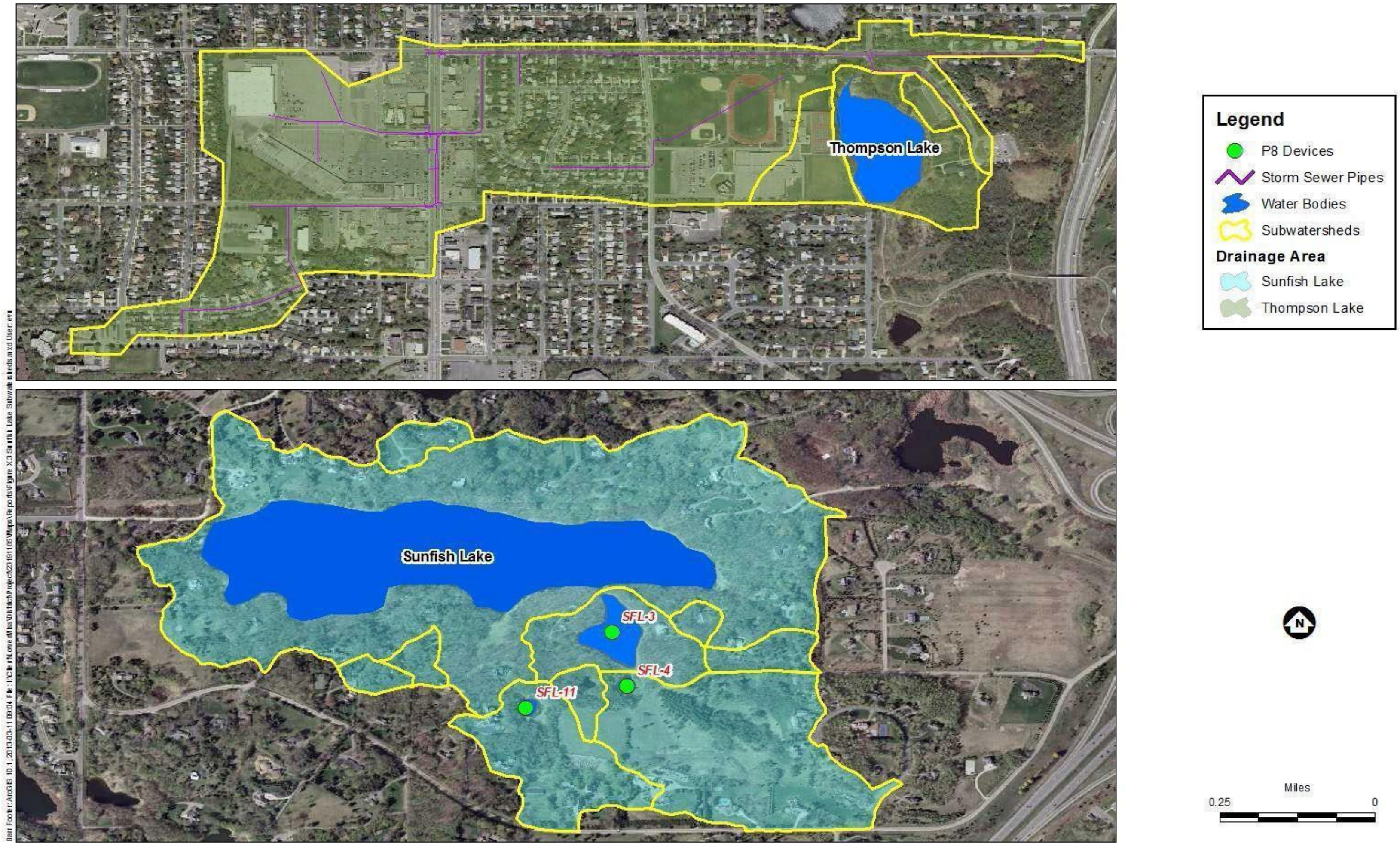

Figure A.3 Thompson Lake and Sunfish Lake Watersheds

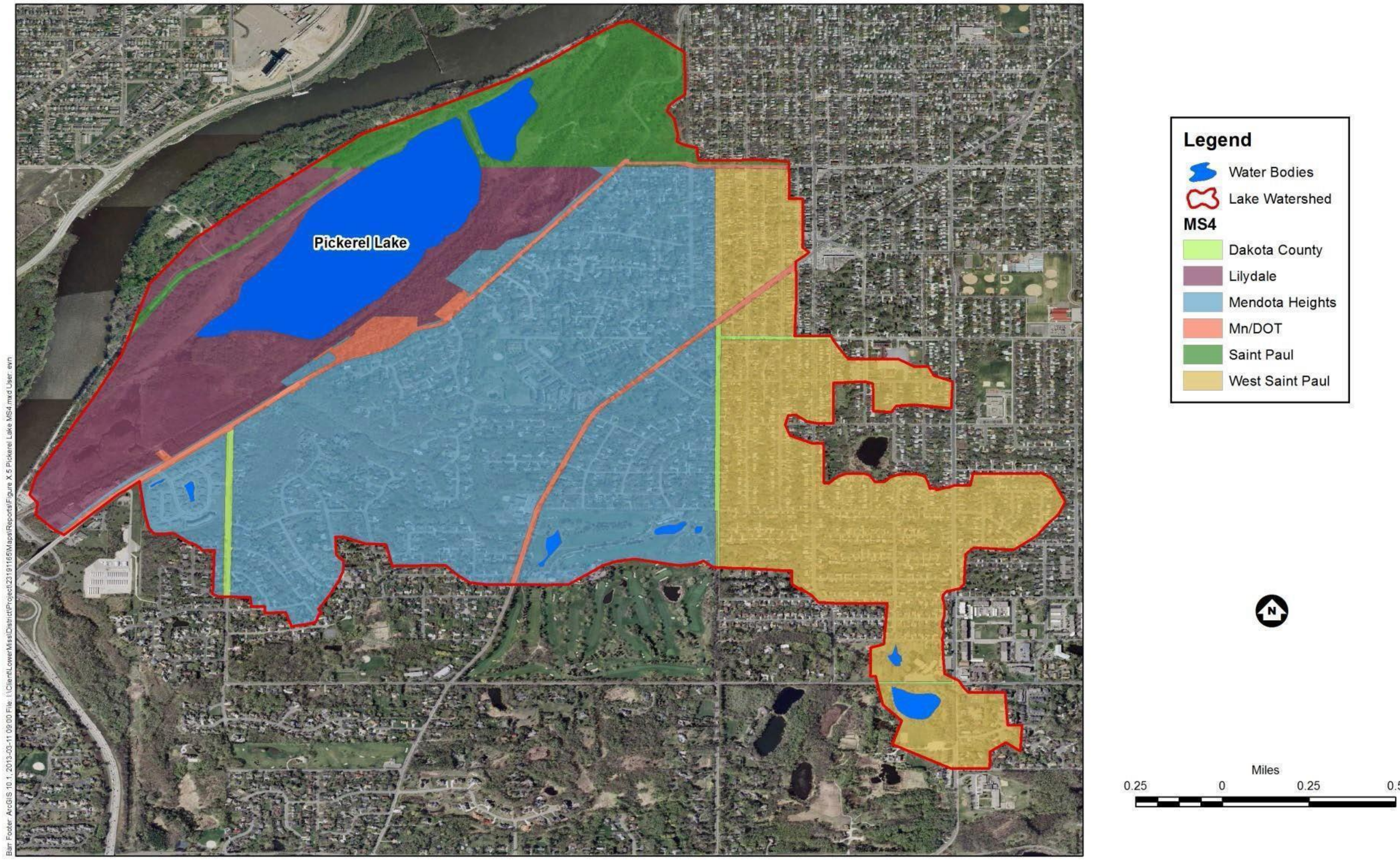

Figure A.4 Pickerel Lake MS4 Boundaries

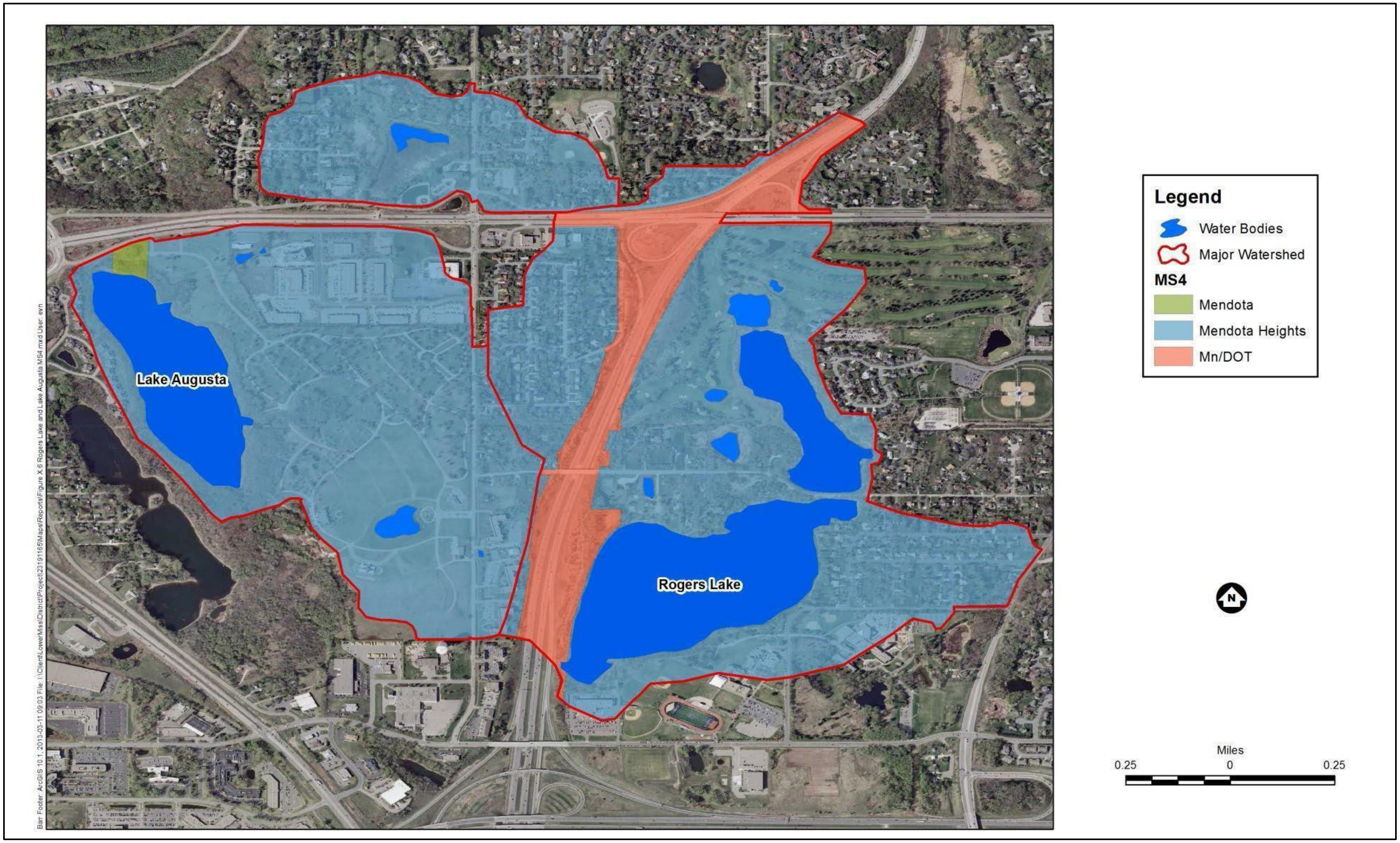

Figure A.5 Lake Augusta and Rogers Lake MS4 Boundaries

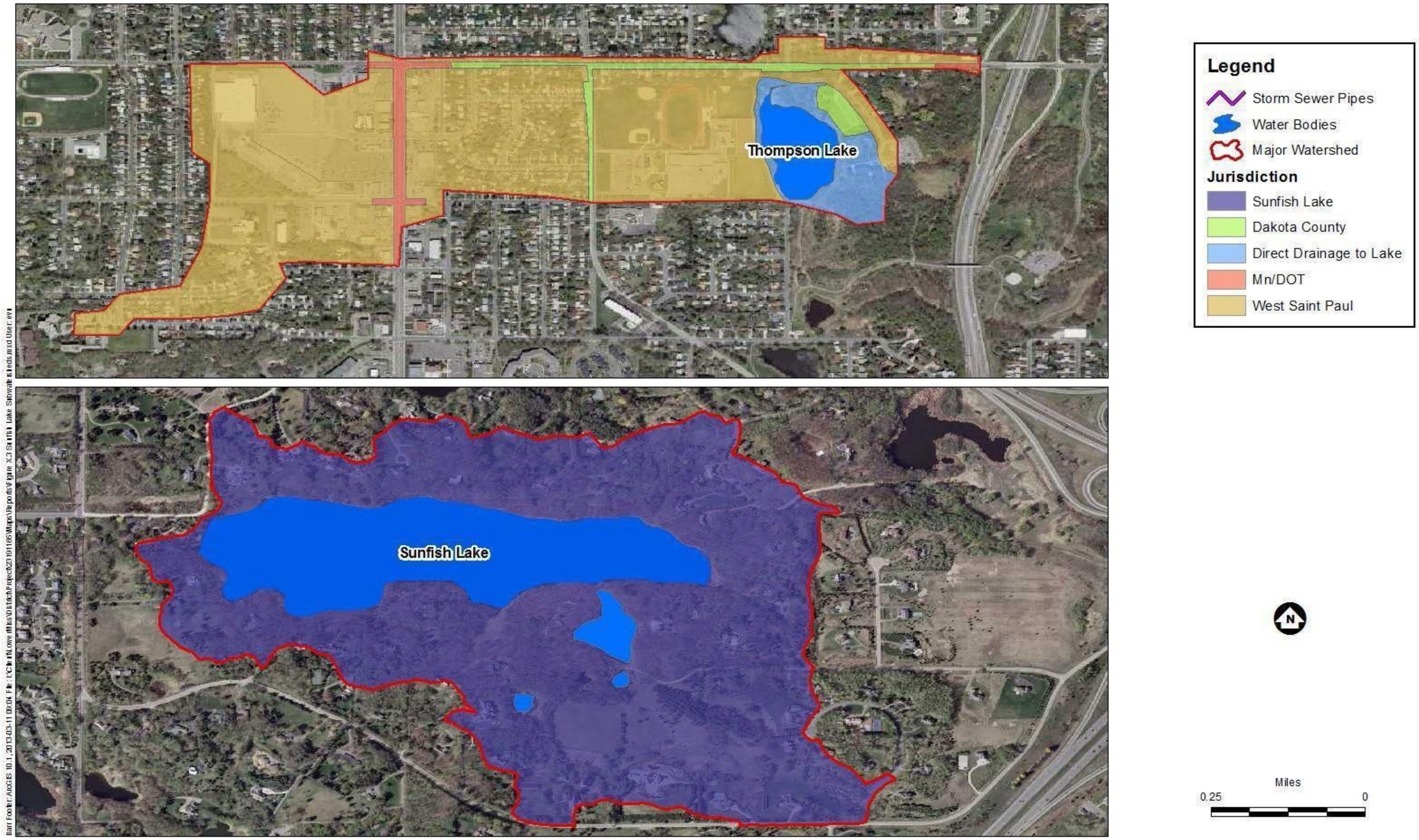

Figure A.6 Thompson Lake and Sunfish Lake MS4 Boundaries

A.1.2 Land Use

Land use data was obtained to estimate both the percentage of directly and indirectly connected imperviousness within each watershed. The directly-connected impervious fraction consists of the impervious surfaces that are "connected" directly to stormwater conveyance systems, meaning that flows do not cross over pervious areas. The indirectly connected impervious fraction represents impervious areas that flow over pervious areas before reaching the stormwater conveyance system. These fractions were calculated by first estimating the total impervious areas for each subwatershed using the National Land Cover Dataset (NLCD) 2006 impervious layer (Fry et al, 2011). Indirectly connected impervious areas were calculated using roof delineations obtained from the City of Minneapolis and land use designations from the Metropolitan Council 2010 land use study area dataset. Total roof coverage located in regions with a landuse classification consistent with having indirectly connected impervious surfaces (i.e. Park/Recreational/preserve, single family attached, single family detached, and undeveloped) were calculated for each watershed. Other impervious area types (roads, sidewalks, driveways and parking lots) were assumed to be directly connected to the storm sewer system. Directly connected impervious areas were calculated by subtracting the indirectly connected impervious areas from the total impervious area for each watershed. The impervious factions were determined by dividing each impervious value by the total watershed area. Values for impervious and directly connected impervious areas separated by watershed are displayed in Table A.2.

Table A.2 Impervious areas for each lake watershed

Lakes	Total Watershed Area (acres)	Total Impervious Area (acres)	Directly Connected Impervious Area (acres)	Total Impervious Fraction (%)	Directly Connected Impervious Fraction (%)
Lake Augusta	371	86	80	23%	22%
Pickerel Lake	1198	276	197	23%	16%
Rogers Lake	370	102	92	28%	25%
Sunfish Lake	185	13	9	7%	5%
Thompson Lake	171	93	87	55%	51%

A.1.3 Curve Numbers

The pervious curve number (a measure of how easily water can percolate into the soil) was determined for each P8 drainage basin. Data from the Dakota and Ramsey County Soils Survey (SSURGO, 2010) were used to determine the hydrologic soil group (HSG), which serves as an indicator of a soil's infiltration capacity. Hydrologic soils groups range from type A soils that are well drained with high infiltration capacities to HSG type D soils that are poorly drained with the lowest infiltration capacities. Some areas in the county soil surveys are not defined. For these areas a HSG of type B was assumed. GIS data for each HSG classification used in the P8 models are shown in Figures A.7 to A.9 for each of the modeled lakes. A pervious area curve number was assigned to each HSG (as shown in Table A.3).

Table A.3 Curve Number classifications by HSG

HSG	Curve Number
A	39
B	61
D	80

Using the curve number classifications, a composite pervious area curve number was calculated for each of the subwatersheds by using a curve number of 98 for the indirectly connected impervious areas.

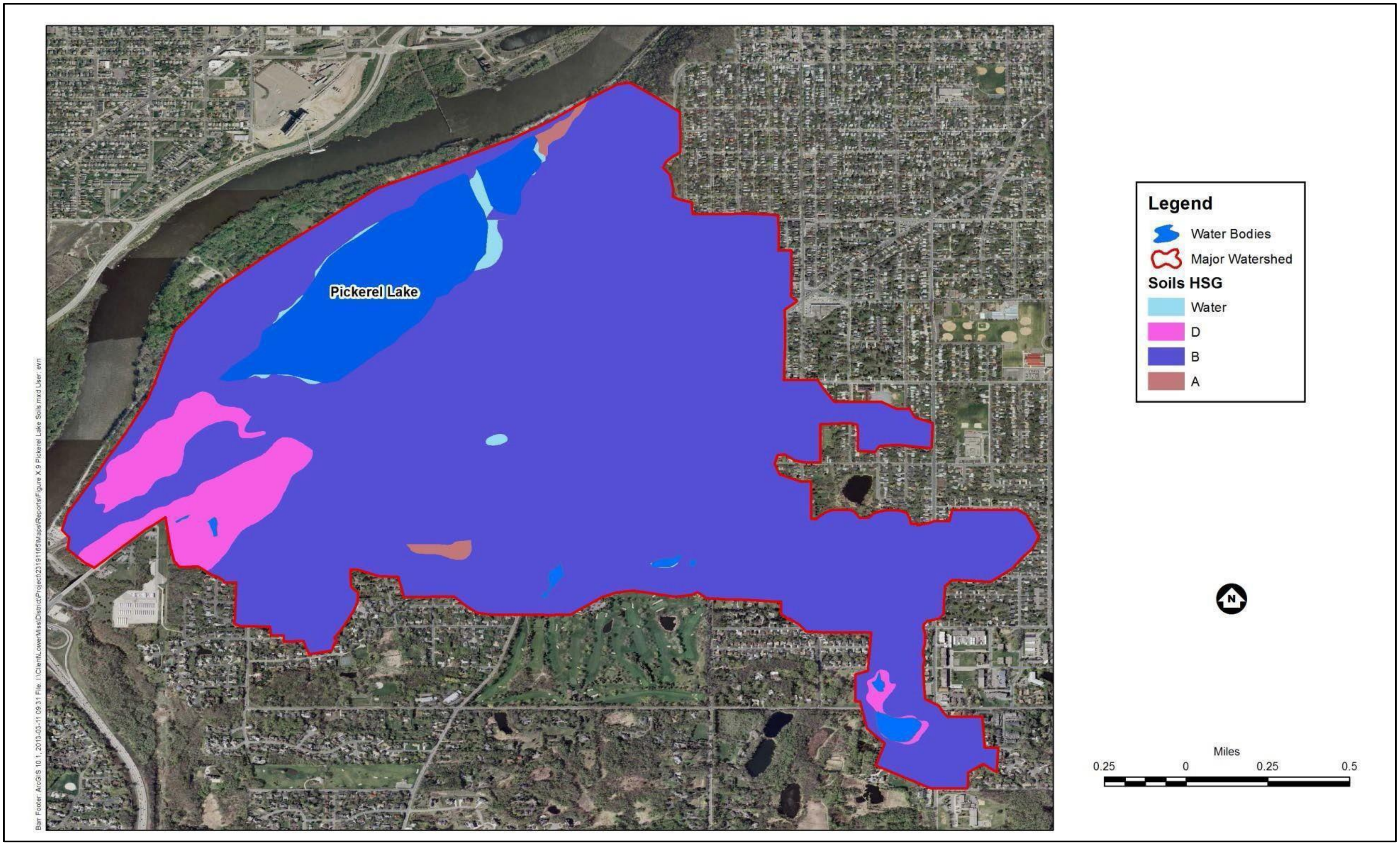

Figure A.7 Pickerel Lake Soils Data

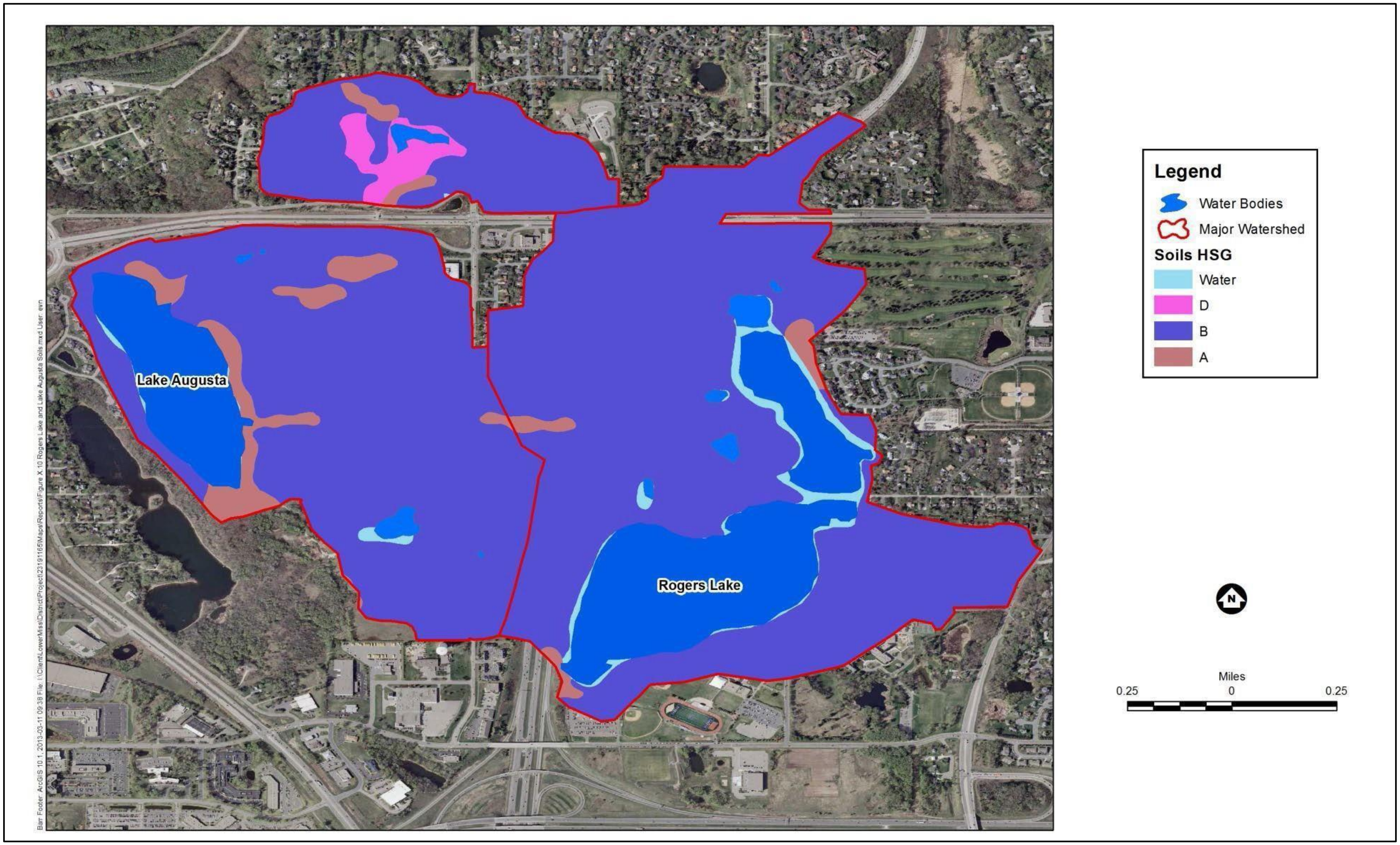

Figure A.8 Lake Augusta And Rogers Lake Soils Data

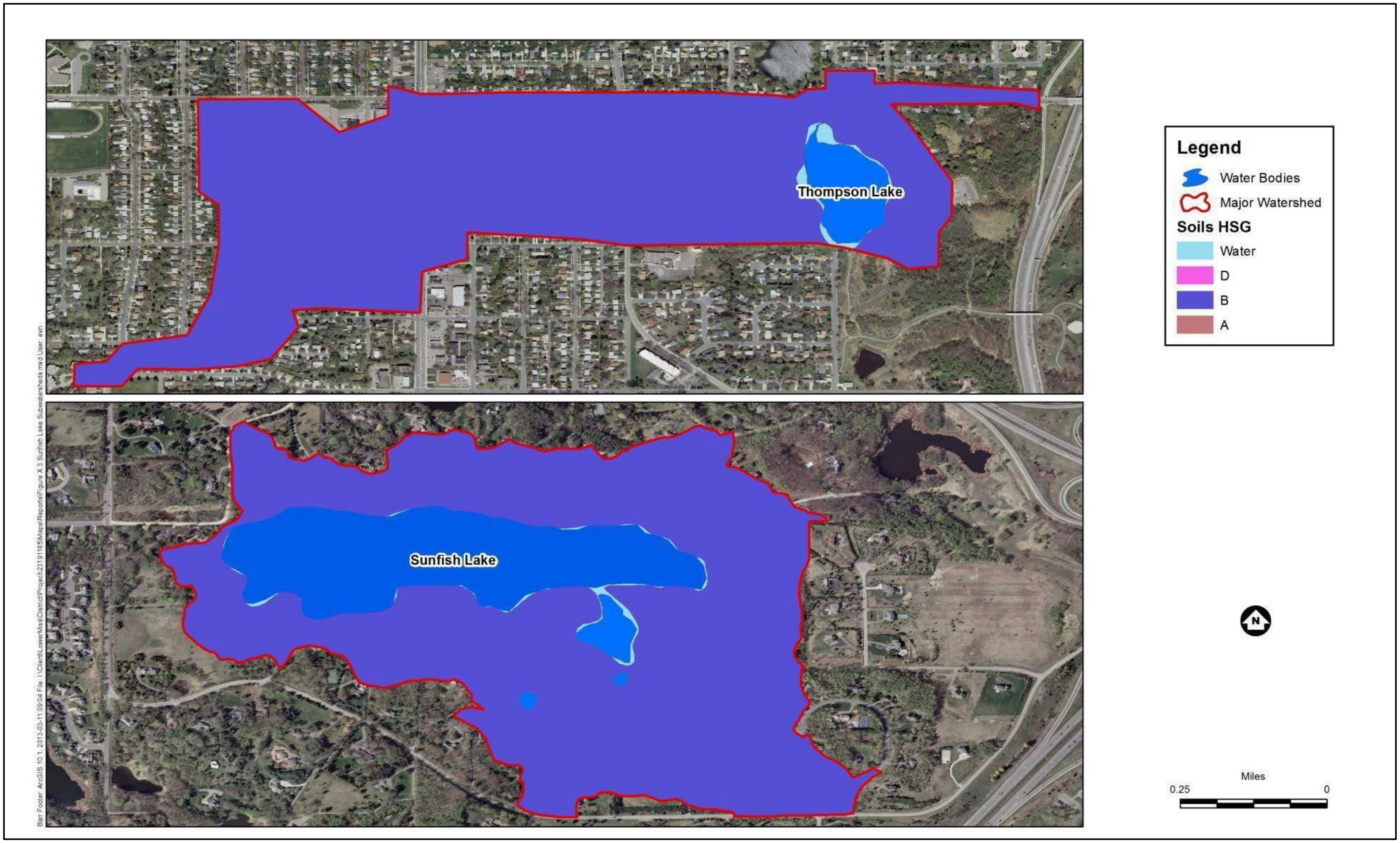

Figure A.9 Thompson Lake and Sunfish Lake Soils Data

A.1.4 Depression Storage and Runoff Coefficient

For directly connected impervious areas a depression storage value and runoff coefficient can be defined. Both of these parameters were used as calibration parameters to match the measured hydrology.

A.2 Pollutant Removal Device Information

The P8 water quality model can predict pollutant removal efficiency for a variety of treatment practices such as detention ponds and infiltration basins. The model can also be used to simulate pollutant removal from alternative BMPs such as underground treatment devices. The modeled treatment practices are referred to in the P8 model as pollutant removal 'devices'.

A.2.1 Ponds

Water quality ponds (also called detention ponds or stormwater ponds) are the most common BMP within the study area. The "dead" storage volume (storage below the normal water level) is an important factor in the pollutant removal efficiency. Pond information was obtained from the 2003 models (Barr, 2003) for Pickerel Lake, Rogers Lake and Sunfish Lake. No ponds exist in the Thompson Lake watershed. Information from the ponds in the Lake Augusta watershed and new ponds created since 2003 in the Pickerel Lake watershed (IV-126, IV139) were found in the City of Mendota Heights Local Surface Water Management Plan (Bonestroo, 2006). The particle removal scale factor, which allows for adjustment of the particle removal rates, was set to the default value of 1 for all ponds with an average depth greater than 2 feet. All other ponds including dry ponds were set to a value of 0.02 feet. Pond device data are shown in Table A.4.

Table A.4 Pond device information

Device Name[a]	Lake	Permanent pool area (acres)	Perm Pool Volume (Ac-Ft)	Flood Pool Area (Acres)	Flood Pool Volume (Ac-Ft)	Orifice Diameter (inches)	Weir Length (ft)	Particle Removal Scale Factor
WSP_IF1A	Pickerel	3.81	11.43	4.70	5.40	24		1
WSP-IF1B	Pickerel	0.32	0.32	0.82	2.10	18		1
IF-1	Pickerel	2.00	4.00	2.80	17.40	42		1
IF-4	Pickerel	1.15	2.30	1.97	8.10	48		1
IF-10	Pickerel	0.00	0.00	0.21	0.30	72		0.02
IF-18	Pickerel	0.06	0.01	1.50	2.50	18		0.02
IF-21	Pickerel	0.30	0.60	2.46	9.40	48		1
IF-15	Pickerel	0.00	0.00	0.31	1.16	12		0.02
IF-16	Pickerel	0.42	0.21	0.67	2.26	12		0.02
IF-22	Pickerel	0.00	0.00	0.07	0.20	27		0.02
IF-8	Pickerel	0.10	0.01	4.83	3.70	15		0.02
IV-126	Pickerel	0.85	3.38	1.04	2.80	15		1
IV-139	Pickerel	0.25	0.46	0.37	0.60	12		1
MB-1	Pickerel	0.00	0.00	0.31	1.81	18		0.02
L-10L	Pickerel	5.64	4.16	42.45	67.60		20	0.02
GC-P1	Augusta	3.60	6.10	13.70	15.40	18		1
GC-P5	Augusta	0.70	1.40	1.60	4.60	48		1
GC-P8	Augusta	0.20	0.30	2.00	2.80	18		0.02
GC-P9	Augusta	1.80	4.50	2.90	8.20	12		1
IV-30	Rogers	3.20	9.60	4.92	13.00	18		1
IV-34	Rogers	0.60	0.60	2.07	0.40	15		1
IV-36	Rogers	0.50	1.00	2.38	4.90	24		1
IV-26	Rogers	0.00	0.00	1.25	1.69	48		0.02
SFL-4	Sunfish	0.51	0.26	0.84	1.71	12		1
SFL-3	Sunfish	3.51	10.53	4.38	13.10	12		1
SFL-11	Sunfish	0.64	0.48	1.16	1.44		3.3	1

[a] – Acronyms are consistent with subwatershed naming convention used in previous modeling efforts.

A.3 P8 Model General Parameters

The P8 model requires a variety of inputs beyond the watershed characteristics and pollutant removal device (ponds, etc.) characteristics. P8 also requires hourly precipitation and temperature data for either a single storm event or for a long-term climatic period. Additionally, pollutant characteristic information is required. The default pollutant and particle information has typically been used in this study, based on national average information. The parameters selected for the P8 model are discussed in the following paragraphs. P8 parameters not discussed in the following paragraphs were left at the default setting. Version 3.4 of the P8 Model was used for the updated modeling.

A.3.1 Precipitation

P8 reads hourly precipitation from a data file for a continuous simulation of watershed hydrology and the buildup/washoff of water quality constituents. The precipitation file is comprised of hourly precipitation measured at the Minneapolis–St. Paul (MSP) International Airport (Station ID – GHCND:USW00014922) weather station obtained from the National Climatic Data Center (NCDC).

A.3.2 Temperature

P8 reads daily average temperature data. The temperature file used in each model run was comprised of daily average temperature data from the Minneapolis–St. Paul International Airport during the period from 1949 through 2012.

A.3.3 Time Step, Rainfall Breakpoint and Water Quality Components

Time Steps Per Hour (Integer)

A time steps per hour value of 20 was used in the model. The selection was based upon the number of time steps required to eliminate continuity errors greater than two percent.

Rainfall Breakpoint

The rainfall breakpoint parameter tells the program when to apply the impervious area runoff coefficients specified for each subwatershed. When a storms cumulative rainfall + snowmelt depth is less than or equal to the rainfall breakpoint the impervious area runoff coefficient is applied. If the precipitation depth is greater than the rainfall breakpoint a runoff coefficient of 1 is applied to all subwatersheds. The default runoff breakpoint value of 0.8 inches was used in the model.

Water Quality Components

The NURP50 particle file was used as a starting point for the water quality components of the stormwater runoff. The NURP50 particle file was developed as part of the Nationwide Urban Runoff Program (NURP), a research program conducted by the U.S. Environmental Protection Agency, and provides default parameters for several water quality components, based upon calibration to median, event-mean concentrations reported by NURP (Athayede et al., 1983).

A.4 P8 Model Calibration

Modeled parameters were calibrated using data collected at the outflow of Ivy Falls Creek into Pickerel Lake (IF-28 in Figure A.1) during the summer of 2012. Continuous water level data was recorded as well as grab samples collected and analyzed for water quality constituents during storm events and baseflow. Grab sample data collected at Ivy Falls Creek are show in Table A.5. Flow data for Ivy Falls Creek, along with the flow rates when grab samples were taken, and daily precipitation rates are show in Figure A.10.

Table A.5 Ivy Fall Creek outfall grab sample data

Monitored Grab Sample Data				
Sample Date	Flow Rate at Sample date (cfs)	Dissolved Phosphorus Concentration (mg/l)	Total Phosphorus Concentration (mg/l)	Total Suspended Solids Concentration (mg/l)
06/18/2012 15:00		0.087	0.11	5
06/20/2012 09:30		0.085	0.093	5
06/25/2012 11:15		0.1	0.099	5
07/03/2012 09:30	0.31	0.099	0.19	5
07/07/2012 00:10	19.92	0.11	0.74	320
07/13/2012 18:40	32.69	0.08	0.44	180
07/18/2012 11:35	19.28	0.079	0.25	74
07/24/2012 07:45	23.97	0.093	0.18	47
07/29/2012 11:30	2.02	0.086	0.1	5
08/04/2012 00:50	11.37	0.2	0.43	88
08/15/2012 09:20	15.21	0.082	0.46	150
08/22/2012 16:30	0.17	0.08	0.096	5
09/10/2012 10:15	0.15	0.085	0.16	5
09/12/2012 13:50	0.23	0.083	0.093	5
09/17/2012 06:59	1.21	0.14	0.22	11
09/24/2012 11:00	0.17	0.063	0.061	5
	Average	**0.10**	**0.23**	**57.19**

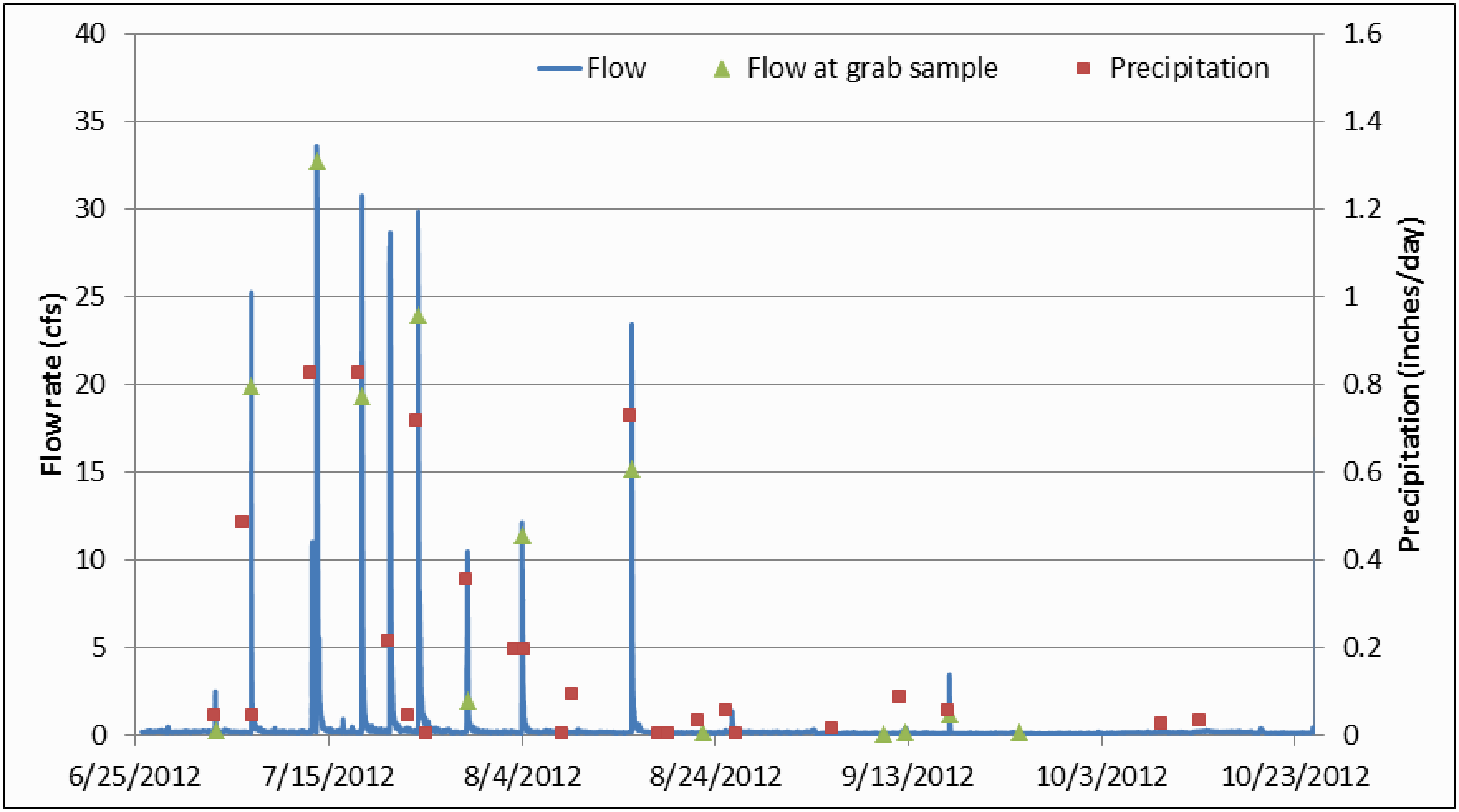

Figure A.10 Ivy Fall creek outfall flow data, precipitation, and grab sample data

A.4.1 Hydrologic Calibration

Calibration of the hydrologic parameters were conducted by adjusting the directly connected impervious area depression storage and the impervious runoff coefficient until the modeled total event flow matched the total flow monitored for that same event. The Nash Sutcliffe (1970) model efficiency equation was used to calibrate the modeled total and peak flow rates based on the following equation:

$$E = 1 - \frac{\sum_{t=1}^{T}(Q_o^t - Q_m^t)^2}{\sum_{t=1}^{T}(Q_o^t - \overline{Q_o})^2}$$

where E is the Nash Sutcliffe model efficiency, Q_o is observed discharge, Q_m is modeled discharge. Table A.6 shows the events used to calibrate the model including modeled and monitored peak and total flow rates. Figures A.11 and A.12 show the relationships between modeled and monitored results for total flow and peak flow rates, respectively. The Nash Sutcliffe model efficiency between the modeled and monitored values of total flow was calculated to be 0.82. The Nash Sutcliffe model efficiency between the modeled and monitored values of peak flow was calculated to be 0.93. The depression storage was calibrated to a value of 0.04 inches while the impervious runoff coefficient was calibrated to a value of 0.65. The calibrated parameters for depression storage and impervious runoff coefficient were transferred to all watersheds in the other four lake models.

Table A.6 Modeled and monitored peak and total flow rates

Event Start Date	Precipitation (in.)	Monitored Peak Flow (cfs)	Modeled Peak Flow Rate (cfs)	Monitored Total Flow (acre-ft)	Modeled Total Flow (acre-ft)
7/3/12 4:00	0.05	2.51	0.50	0.23	0.08
7/6/12 20:00	0.54	25.19	17.24	2.92	3.87
7/13/12 18:00	0.83	33.39	33.47	8.13	6.23
7/18/12 11:00	0.83	30.68	32.96	4.99	6.22
7/24/12 0:00	0.77	27.46	24.83	6.83	5.67
7/29/12 5:00	0.36	10.49	8.01	2.36	2.49
8/4/12 0:00	0.40	12.10	10.50	2.26	2.78
8/15/12 8:00	0.72	23.35	26.68	2.77	5.24
8/15/12 23:00	0.01	0.58	0.09	0.00	0.04
8/25/12 13:00	0.07	0.52	0.52	0.00	0.23
9/17/12 4:00	0.06	3.47	0.67	0.33	0.15

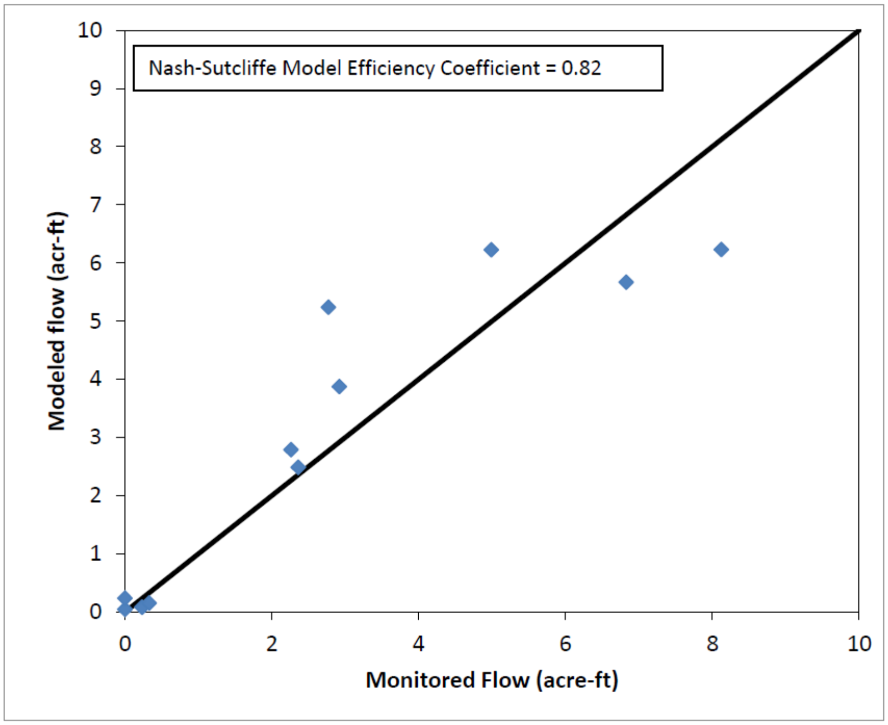

Figure A.11 Relationship between modeled and monitored total flow

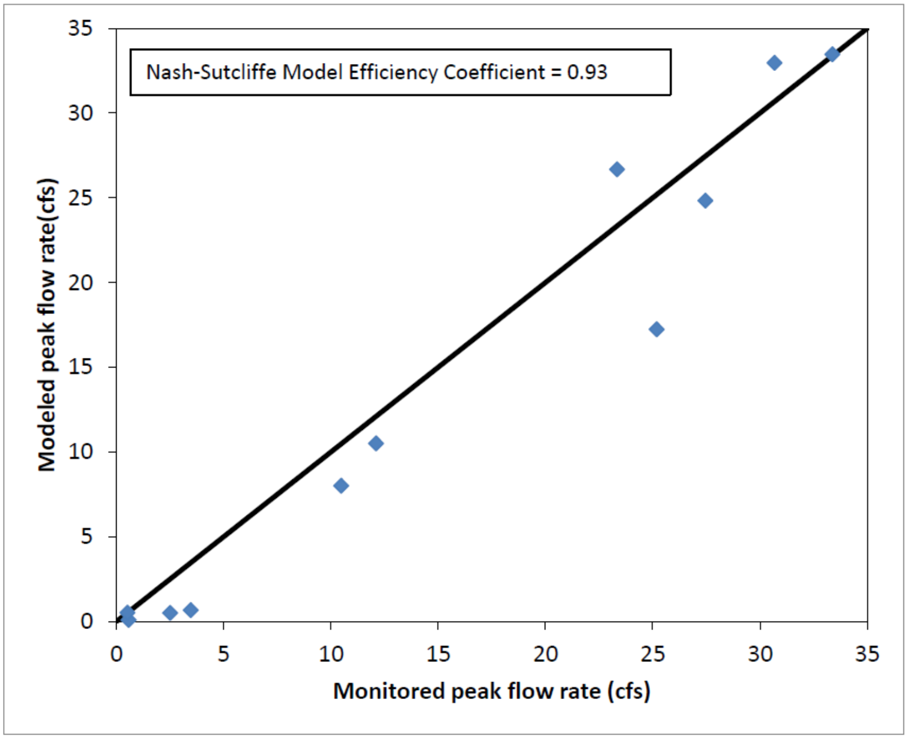

Figure A.12 Relationship between modeled and monitored peak flow rates

A.4.2 Pollutant Calibration

Modeled average pollutant loads for each event were compared with the grab sample data for 7 events. Grab sample data is shown in Table A.7 and modeled results are show in Table A.8. While results are comparable for dissolved phosphorus concentrations; total phosphorus and TSS concentration were higher in the grab sample data compared to the modeled results. It was expected that these higher concentrations were associated with ravine erosion contributions to Ivy Falls Creek. As a result, the default P8 water quality parameters were maintained in the model without further adjustment.

Table A.7 Monitored grab sample data for calibration events

Sample Date	Flow Rate at Sample date (cfs)	Dissolved Phosphorus Concentration (mg/l)	Total Phosphorus Concentration (mg/l)	Total Suspended Solids Concentration (mg/l)
07/07/2012 00:10	19.92	0.11	0.74	320
07/13/2012 18:40	32.69	0.08	0.44	180
07/18/2012 11:35	19.28	0.08	0.25	74
07/24/2012 07:45	23.97	0.09	0.18	47
08/04/2012 00:50	11.37	0.08	0.43	88
08/15/2012 09:20	15.21	0.08	0.46	150
09/17/2012 06:59	1.21	0.14	0.22	11
	Average	**0.10**	**0.39**	**124.29**

Table A.8 Modeled event average values for calibration events

Event Start Date	Peak Flow Rate (cfs)	Event Dissolved Phosphorus Concentration (mg/l)	Event Total Phosphorus Concentration (mg/l)	Event Total Suspended Solids Concentration (mg/l)
7/6/12 20:00	17.24	0.10	0.35	80
7/13/12 18:00	33.47	0.10	0.27	53
7/18/12 11:00	32.96	0.10	0.24	45
7/24/12 0:00	24.83	0.10	0.24	44
8/4/12 0:00	10.50	0.10	0.29	62
8/15/12 8:00	26.68	0.10	0.31	66
9/17/12 4:00	0.67	0.10	0.11	5
	Average	**0.10**	**0.28**	**58.42**

A.4.3 Results

The calibrated models were run for years 2000 to 2012. The P8 results were used to calculate the total annual average watershed TP loads for each subwatershed device. Next, the watershed load discharging to each lake was calculated. This was accomplished by applying the annual average removal efficiencies from each BMP in succession along the watershed flow path until the final lake destination was reached. This calculation resulted in the amount of TP load from each subwatershed device that reached the lake without being removed by an existing BMP. The final results including device removal efficiencies are displayed in Table A.9.

Table A.9 Device Watershed Loads and Removal Efficiencies

P8 Devices	Device TP Reduction (%)	Direct Watershed TP Load (lbs/year)	Watershed TP Load Contributing to Lake (lbs/year)
Pickerel Lake	0%	20.1	20.1
IF-1	47%	79.7	32.7
IF-4	23%	20.7	16.0
IF-7	0%	3.9	3.9
IF-8	12%	5.9	5.2
IF-10	0%	1.7	1.7
IF-15	0%	4.1	2.4
IF-16	23%	5.9	3.4
IF-18	22%	0.7	0.4
IF-21	26%	72.1	53.6
IF-22	0%	1.4	1.4
IF-28	0%	16.5	16.5
IV-126	65%	7.4	1.7
IV-139	35%	2.2	0.9
L-10L	35%	17.2	11.1
MB-1	0%	23.5	23.5
MB-2	0%	7.0	7.0
MB-4	0%	22.0	14.2
WFP-IF1A	68%	9.4	0.8
WFP-IF1B	32%	5.0	1.4

P8 Devices	Device TP Reduction (%)	Direct Watershed TP Load (lbs/year)	Watershed TP Load Contributing to Lake (lbs/year)
Rogers Lake Upper	0%	3.8	3.8
Rogers Lake Lower	0%	14.2	14.2
IV-26	0%	15.2	6.2
IV-27	17%	32.4	11.0
IV-30	59%	8.2	3.4
IV-32	61%	2.1	0.8
IV-33	63%	3.2	1.2
IV-34	67%	0.6	0.2
IV-35	62%	4.4	1.7
IV-36	50%	27.4	13.8
IV-40	65%	3.9	1.4
IV-41	0%	9.3	9.3
IV-42	0%	12.4	12.4
Lake Augusta	0%	28.0	28.0
GC-P1	65%	28.5	6.4
GC-P5	35%	35.0	22.6
GC-P8	23%	8.7	2.7
GC-P9	59%	20.8	8.5
Sunfish Lake	0%	9.7	9.7
SFL-2	0%	0.1	0.1
SFL-3	39%	0.5	0.3
SFL-4	53%	5.9	1.7
SFL-5	0%	0.2	0.1
SFL-8	0%	0.1	0.1
SFL-10	0%	0.1	0.1
SFL-11	58%	2.6	1.1
SFL-12	0%	0.4	0.3
SFL-13	0%	0.4	0.4
Thompson Lake	0%	122.4	122.4

A.5 MS4 Contributions

The model results were used to determine TP loads to the lakes separated by MS4 for the critical time periods discussed in Section 2.4. There are eight MS4's that contribute to the five study lakes. These include the cities of West St. Paul, St. Paul, Lilydale, Mendota Heights, Mendota and Sunfish Lake, Dakota County, and Mn/DOT. The P8 results were used to calculate the total annual average watershed TP loads from each subwatershed within each MS4. Next the watershed load discharged to the lake was calculated. This was accomplished by applying the annual average removal efficiencies from each BMP in succession along the watershed flow path until the cumulative flow reaches the lake. This calculation resulted in the amount of TP load from each subwatershed that reached the lake without being removed by an existing BMP. Finally an additional 38% TP loading was added to outfalls IF-28, MB-2, and MB-1 to account for erosional sources. The final loads from each MS4 were totaled as shown in Table A.10.

Table A.10 TP inflow load for critical period to each of the four study lakes separated by MS4.

MS4	TP Load to Lake from each MS4 (lbs)				
	Pickerel (10/1/2009 - 9/20/2010)	Augusta (10/1/2007 - 9/30/2008)	Sunfish (10/1/2011 - 9/30/2012)	Thompson (3/1/2011 - 9/30/2011)	Thompson (3/1/2012 - 9/30/2012)
Dakota County	2.81			3.26	3.58
Mendota Heights City	129.88 (47.21)[a]	41.13			
West St. Paul City	65.91 (5.86)[a]			83.90	91.95
Mn/DOT	9.72 (0.59)[a]			4.58	4.98
Lilydale City	8.78				
Saint Paul City	12.84 (0.73)[a]				
Mendota City		0.12			
Sunfish Lake City			10.00		
Load Allocations				0.79	0.94
Total	229.93 (54.42)[a]	41.25	10.00	92.53	101.45

Notes:

[a] *Loads associated with ravine erosion*

A.5.1 Transfer and Future Growth Language for MS4s

Future transfer of loads in this TMDL may be necessary if any of the following scenarios occur within the impaired reaches watershed boundaries:

1. New development occurs within a regulated MS4. Newly developed areas that are not already included in the WLA must be given additional WLA to accommodate the growth.
2. One regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more non-regulated MS4s become regulated. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of an urban area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an Urban Area at the time the TMDL was completed, but are now inside a newly expanded urban area. This will require either a WLA to WLA transfer or a LA to WLA transfer.
5. A new MS4 or other storm water-related point source is identified and is covered under a NPDES permit. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting the allocations in other TMDLs. WLAs for new MS4s will be transferred from the LA and calculated by multiplying the municipalities' percent watershed area by the total watershed loading capacity after the MOS has been subtracted (MPCA, 2006). In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer. Ultimately, increases in urban storm water also increase the loading capacity of the receiving water thereby supplying their own increases in receiving water assimilative capacity.

A.5.2 Regulated Construction Stormwater

The wasteload allocation for stormwater discharges from sites where there is construction activities reflects the number of construction sites > 1 acre expected to be active in the watershed at any one time, and the Best Management Practices (BMPs) and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in the State's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local construction stormwater requirements must also be met.

A.5.3 Regulated Industrial Stormwater

The wasteload allocation for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES industrial stormwater permit coverage is required, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at the industrial sites are defined in the State's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying and Hot Mix Asphalt Production facilities (MNG490000). If a facility owner/operator obtains coverage under the appropriate NPDES/SDS General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local stormwater management requirements must also be met.

A.5.4 Reasonable Assurance

The following should be considered as reasonable assurance that implementation will occur and result in sediment, nutrient load, and pH reductions in the listed waters toward meeting their designated uses.

- The BMPs and other actions outlined in Sections 3.1 and 3.3 have all been demonstrated to be effective in reducing the source amounts and/or transport of pollutants to surface water. Also, many of these actions are currently being promoted by local resource managers with some local efforts showing significant levels of adoption of these BMPs and actions by landowners.

- The technical advisory committee formed to provide feedback and input into the project had broad representation from government, citizens, and municipal experts.

- Monitoring will be conducted to track progress and suggest adjustment in the implementation approach.

- This TMDL will be approved after the effective date of the current MS4 general permit, which was August 1, 2013. Therefore, MS4 permittees assigned a Waste Load Allocation (WLA) in this TMDL will not be subject to NPDES regulation under the MS4 general permit until the subsequent permit term. At that time, they will be required to comply with parameters similar to those described in the current MS4 permit (Note: current permit requirements are subject to change, as necessary, prior to reissuance of the subsequent MS4 permit). The current MS4 general permit requires permittees to address all applicable WLAs in TMDLs approved prior to the effective date of the permit (August 1, 2013). For each applicable WLA approved prior to the effective date of this permit, the applicant shall submit the following information as part of the SWPPP document: TMDL project name, numeric WLA(s), including units, type of WLA (i.e., categorical or individual), pollutant(s) of concern, applicable flow data specific to each applicable WLA. They must also determine if they are currently meeting their WLA(s). If the WLA is being achieved at the time of application, the permittee will need to provide documentation on BMPs implemented to meet each WLA along with a narrative describing the permittee's strategy for long-term continuation of meeting each applicable WLA. If the WLA is not being achieved at the time of application, a compliance schedule is required that includes interim milestones, expressed as best management practices, that will be implemented over the current five-year permit term to reduce loading of the pollutant of concern in the TMDL. Additionally, a long-term implementation strategy and target date for fully meeting the WLA must be included. Some of the lake TMDLs in this report require reductions in internal load (i.e., control of sediment phosphorus release). Internal lake load reductions are outside of any regulatory control. However, watershed management organizations such as the Lower Mississippi River WMO have the scope and capability to undertake internal load reductions under capital improvement plans. It is a possibility that the LMRWMO will take on these necessary projects over time.

A.6 In-Lake Water Quality Modeling

For the majority of Minnesota lakes, phosphorus is the limiting nutrient for algae, and an increase in phosphorus results in an increase in chlorophyll *a* concentrations and a decrease in water clarity. Eutrophic lakes can be restored by reducing phosphorus concentrations. An in-lake mass balance model for phosphorus was developed for each lake in order to quantify phosphorus source loads to the lake. In-lake modeling for each lake was accomplished through the creation of a daily time-step mass balance model that tracked the flow of water and phosphorus through the lake over the range of observed climatic conditions. The following sections detail the in-lake modeling that was conducted for the study lakes.

A.6.1 General Approach to In-Lake Water Quality Modeling

In-lake modeling for each lake was accomplished through the creation of a daily time-step mass balance model. The first use of the model is development of a water balance for the lake, where

Δ Lake Volume = Watershed Inflow + Direct Precipitation to Lake Surface - Net Groundwater Outflow – Evaporation From Lake Surface

Watershed inflow was estimated using the P8 modeling (described above). Direct precipitation to the lake surface was calculated by using daily precipitation records from Minneapolis-St. Paul International Airport multiplied by the lake surface area. Evaporation from the lake surface was calculated using the Meyer evaporation model (Meyer, 1944) and climate data (wind speed, air temperature, and relative humidity) from the Minneapolis-St. Paul International Airport. Water temperature measurements of the study lakes were also utilized in determining evaporation.

When available, lake surface elevation measurements were used to track the change in lake volume. Groundwater inflows and outflows to a lake are very difficult to measure, and measurements of groundwater flows were not available for the study lakes. Net groundwater flows were estimated for the study lakes such that model predicted changes in lake volume agreed with observed changes in lake volume. Water balances for several of the study lakes indicated that net groundwater outflow is a significant component to the water balance for the lake.

The in-lake phosphorus mass balance model assumed a fully mixed lake volume, i.e. the phosphorus concentration is uniform throughout the lake volume. The change in the total phosphorus mass within the lake was calculated with the following mass balance equation:

Δ Phosphorus Mass = Watershed Inputs + Direct Deposition to Lake Surface + Internal Loading – Surface Outflow – Groundwater Outflow – Settling of In-Lake Phosphorus

The change in the phosphorus mass in the lake was calculated on a daily time step. Computations were completed with Microsoft Excel spreadsheet software.

The watershed phosphorus inputs were estimated with the P8 model (Appendix A). For daily inputs of phosphorus due to direct atmospheric deposition to the lake surface, the daily atmospheric deposition rate was multiplied by the lake surface area. For an average climatic year, the atmospheric deposition of phosphorus in the Mississippi River watershed is approximately 0.17 kg/hectare/year (Barr, 2004), or expressed as a daily rate, 292 mg/hectare/day. The losses of phosphorus due to surface outflow and groundwater outflow were determined by multiplying the model estimated in-lake concentration of phosphorus by the water volume losses determined from the water balance modeling. The loss of phosphorus due to settling was determined with a first order loss function, where the rate of phosphorus loss due to settling is equal to the settling rate parameter (σ) multiplied by the mass of phosphorus in the lake:

Rate of Settling of In-Lake Phosphorus = (σ) (Mass of In-lake Phosphorus)

The parameter σ will vary from lake to lake, and was therefore calibrated separately for each lake. To the extent possible, the settling rate was calibrated when phosphorus loading to the lake was at a minimum for the season (i.e. extended periods without rainfall or internal loading). The calibrated settling rate was applied as a constant throughout the period that was being modeled for each lake.

The mass balance model described above is consistent with the mass balance equation developed by Vollenweider (1969). The following modified version of Vollenweider's (1969) mass balance equation was used to differentiate internal and external sources of phosphorus:

$$TP = (L + L_{int}) / (\bar{z} * (\rho + \sigma))$$

Where:

$\bar{z}$ = average lake depth in meters

ρ = flushing rate in yr^{-1}

σ = sedimentation rate in yr^{-1}

L = areal loading rate in $mg/(m^2*yr)$

$Lint$ = internal loading rate in $mg/(m^2*yr)$

A difference between Vollenweider's equation and the model used for this study is that the parameters in the above equation were used on a daily timestep as opposed to an annual basis. Also, the magnitude of the net internal phosphorus load to the lake surface was determined by comparing the observed water quality in the lake to the water quality predicted by the in-lake model under existing conditions.

A.6.2 Margin of Safety

Margin of Safety (MOS) is the component of the TMDL allocation that accounts for uncertainty within the calculation methods, sample data, or the allocations which will result in attainment of water quality standards. For the purposes of developing the TMDLs for each lake, an explicit 10 percent MOS was selected due to the potential variability of the monitored parameters from spatial, temporal and seasonal changes seen within each lake. The explicit MOS also allows for some uncertainty in the modeling process relating to several variables including: atmospheric loading, evaporation, surface runoff, and internal loading. After using the calibrated lake modeling to determine the phosphorus budget necessary to meet the respective lake standards, 10 percent of the loading capacity was used for the MOS for each lake.

A.7 Lake Augusta Water Quality Modeling

Lake Augusta is a 46 acre lake located in Mendota Heights, Dakota County, Minnesota. The lake has a maximum depth of 33 feet. Approximately 63%, or 29 acres, of the lake has a water depth greater than 15 feet. The average residence time of Lake Augusta is 3 years.

Available phosphorus and chlorophyll-a data used for Lake Augusta is limited to three years (2007-2009) of data since only one summer sample was collected in 2013 (see Table A.11). Limited measurements were collected in 2009, with a total of three water samples collected in May and June. Total phosphorus concentrations of samples collected at the lake surface were consistently higher than the MPCA's deep lake standard of 0.040 mg/L total phosphorus. Concentrations were consistently observed in the range of 0.100-0.210 mg/L. The two highest observed concentrations of total phosphorus at the lake surface were 0.260 and 0.510 mg/L, collected on 7/19/07 and 9/22/07, respectively. The value of 0.510 mg/L is inconsistent with other total phosphorus samples collected in August and early-October of 2007, and is therefore suspect as a possible error, or outlier that is not representative of the Lake Augusta water quality.

With the exception of extremely high total phosphorus measurements on 7/19/07 and 9/22/07, total phosphorus concentrations in 2007 and 2008 were similar: total phosphorus concentrations were generally highest in the month of May (0.190-0.210 mg/L), declined in June (0.170-0.180 mg/L), and continued to decline in August (0.110-0.130 mg/L) and September (0.100 mg/L). Limited measurements were collected in 2009, with no water samples collected after 6/23/09, but available data indicates total phosphorus concentrations started out lower that year (0.140 mg/L on 5/18/09).

As would be expected for high concentrations of phosphorus, chlorophyll-*a* and Secchi disk transparency measurements indicate high concentrations of phytoplankton and corresponding low water clarity. During the months of June-September, Secchi disk transparency ranged from 0.10 to 0.38 meters (0.33-1.25 feet), consistently worse than the MPCA Secchi disk transparency standard of 1.4 meters for deep lakes in the NCHF ecoregion.

Table A.11 Lake Augusta Summer Averages of Water Quality Parameters

Year	**Total Phosphorus**		**Chlorophyll-*a***		**Secchi Disk Transparency**	
	June-Sept. Average (mg/L)	Number of Samples	June-Sept. Average (µg/L)	Number of Samples	June-Sept. Average (m)	Number of Samples
1998	--	--	--	--	0.50	5
1999	--	--	--	--	0.43	2
2000	--	--	--	--	0.34	3
2001	--	--	--	--	0.55	2
2002	--	--	--	--	0.45	3
2003	--	--	--	--	0.30	2
2004	--	--	--	--	0.48	1
2005	--	--	--	--	0.24	1
2006	--	--	--	--	0.38	1
2007	0.227	6	54	6	0.25	7
2008	0.140	7	62	7	0.23	7
2009	0.145	2	65	2	0.30	3
2013	0.183	1	--	--	0.40	1
MPCA Criteria	≤0.040	--	≤14	--	≥1.4	--

The observed concentrations of phosphorus in Lake Augusta are much higher than can be explained by external phosphorus loading given the size of the Lake Augusta watershed. In order to reach these high concentrations of phosphorus in the lake, significant internal loading of phosphorus within Lake Augusta must be occurring. Typically, phosphorus is lost from the water column of a lake by two main mechanisms: surface or subsurface outflow, and settling of particulate phosphorus (e.g. settling plankton) to the lake bottom. The phosphorus that settles to the bottom of the lake and accumulates in lake sediments can be recycled back into the water column. When dissolved oxygen is present, oxidized iron in the upper layers of sediment will bind with phosphorus, preventing the release of soluble phosphorus back into the water column. When dissolved oxygen becomes depleted, a condition referred to as anoxia, iron in the lake sediment is reduced, and phosphorus that was previously bound to the iron becomes resoluble, and can be released back into the water column. This is often observed in Minnesota lakes that are deep enough to thermally stratify during the summer months. Following the depletion of oxygen in the deeper waters of the lake, concentrations of phosphorus near the lake bottom will increase over the course of the summer as phosphorus is released from the sediment.

Depending on the lake's morphology, a portion of the phosphorus that is released from lake sediments may be transported to the lake surface during the summer months, where it can be utilized by phytoplankton. For deeper lakes, phosphorus from internal loading may build up in the hypolimnion throughout the summer until the lake turns over in the fall and spring. Both Sunfish Lake and Lake Augusta experience significant internal loading of phosphorus, but the manner in which the phosphorus from internal loading contributes to poor water quality differs between the two lakes. For Sunfish Lake (discussed in detail in Section A.9), phosphorus concentrations at the lake surface start out low in early summer. As the summer progresses, a substantial portion of phosphorus from internal loading diffuses to the lake surface, triggering algal blooms in August and September. By contrast, Lake Augusta experiences high concentrations immediately following ice out and concentrations tend to decline during the course of the summer months (Figure A.13). The available water column profile monitoring from the spring indicates that Lake Augusta is highly anoxic and internal phosphorus loading is likely more significant during the winter. Other sources of internal load, such as waterfowl, would not be expected to contribute nutrients during the open water season following the same pattern observed in Figure A.13.

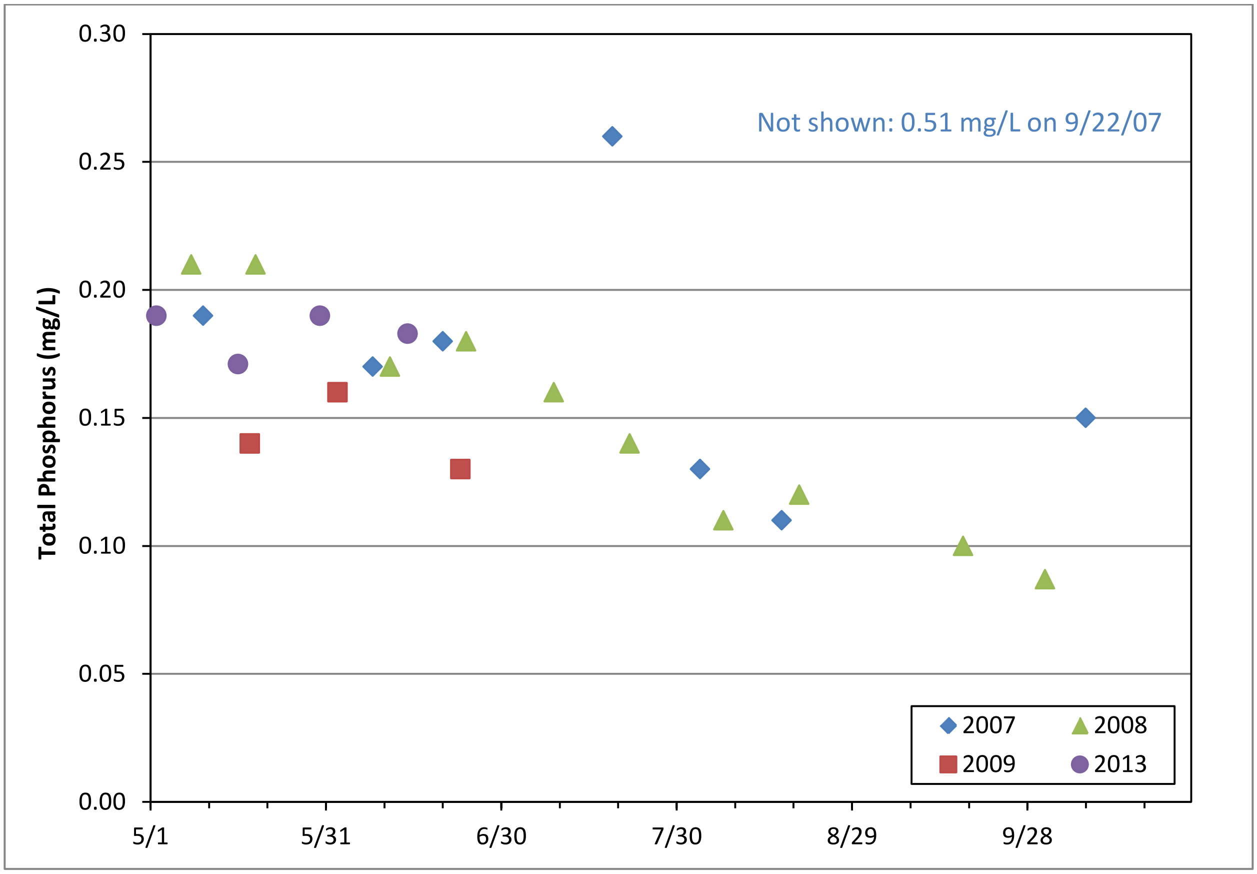

Figure A.13 Lake Augusta Total Phosphorus Concentrations at Lake Surface

Year 2008 was selected as the year to model water quality for Lake Augusta. As shown on Figure A.13, limited water quality data was collected in 2009. Total phosphorus data collected in 2007 included two outliers or potentially erroneous data points (7/19/07 and 9/22/07). With the exception of these two data points in 2007, the total phosphorus concentrations observed over the 2007 monitoring season were similar to those observed in 2008.

A.7.1 Lake Augusta Water Balance Calibration

Water inflows to Lake Augusta included direct precipitation to the lake surface and watershed runoff. There is no surface outflow from Lake Augusta, and water outflow consists of evaporation from the lake surface and net groundwater outflow. Insufficient water level data exists for Lake Augusta to calculate seasonal changes in lake volume. Therefore, it was assumed the lake volume at the end of the modeling period was equal to the volume at the beginning of the modeling period.

A.7.2 Lake Augusta Phosphorus Model Calibration

Phosphorus inputs to Lake Augusta included direct deposition to the lake surface, watershed runoff, and internal loading. Phosphorus losses in the model included net groundwater outflow and settling (i.e.

deposition to lake sediments). Model predicted phosphorus was compared to observed total phosphorus concentrations for the period of May 2008 through September 2008, and model parameters were adjusted until model predicted phosphorus concentrations provided the best agreement with observed concentrations over the modeling period (Figure A.14). The phosphorus settling rate for the 2008 modeling period was calibrated to 12.0 meters/year. The first water quality sample of 2008 was collected on May 8, when total phosphorus concentrations were 0.210 mg/L. It was estimated that total phosphorus concentrations may have been as high as 0.25 mg/L following spring turnover. Ice out occurred the third week of April 2008 in the Twin Cities.

Lake Augusta remains strongly stratified during the summer monitoring period. Due to the morphometry of Lake Augusta, phosphorus that is released from lake sediments builds up in the hypolimnion (i.e. the deeper water of the lake) to high concentrations during summer months when the lake is stratified. When Lake Augusta mixes during spring and fall turnover, the phosphorus enriched hypolimnion water is brought to the surface. The amount of phosphorus that is present in the water after spring turnover is high enough that it affects water quality throughout the following summer season.

In order to estimate the amount of internal loading of phosphorus in Lake Augusta, total phosphorus concentrations measured near the lake surface and in the deeper waters of the hypolimnion were compared to estimate the increase in phosphorus mass in the lake in 2008. The total in-lake phosphorus mass was estimated to be 203 kg (448 lbs) on 5/8/08 (0.21 mg/L total phosphorus at lake surface, 0.25 mg/L at 11 meters [36 feet]), and increased to 272 kg (600 lbs) by 7/9/08 (0.16 mg/L at lake surface, 0.62 mg/L at 7 meters [23 feet]). This was a 69 kg (152 lbs) estimated increase in in-lake phosphorus mass over the period of 5/8/08-7/9/08. Over this same time period, there was an external phosphorus load to the lake of 3.1 kg (6.8 lbs), and a loss of phosphorus due to settling of 77 kg (170 lbs). In order to balance the phosphorus mass balance equation for Lake Augusta (*Δ Phosphorus Mass = Watershed Inputs + Direct Deposition to Lake Surface + Internal Loading – Settling of In-Lake Phosphorus*), an internal load of phosphorus of 143 kg (315 lbs) was estimated. Put another way it is estimated that the overall phosphorus loading to the lake is 146 kg (143 kg from internal loading combined with 3.1 kg of external load estimated to be entering the lake based on the P8 watershed modeling), of which 77 kg settles to the bottom of the lake during the course of the summer.

A sediment core was collected from Lake Augusta in November 2012, and analyzed for phosphorus fractions (i.e. mobile phosphorus and organic phosphorus). Using the relationship of Pilgrim et al. (2007), a maximum internal loading rate of phosphorus from Lake Augusta sediment was determined and compared to the estimated 2008 internal loading mass of 143 kg (315 lbs) determined by mass balance, as described above. The maximum potential internal loading rate of phosphorus was determined to be greater than that observed 2008 internal loading rate, confirming that the internal loading rate of phosphorus estimated from the 2008 phosphorus mass balance lake model is reasonable.

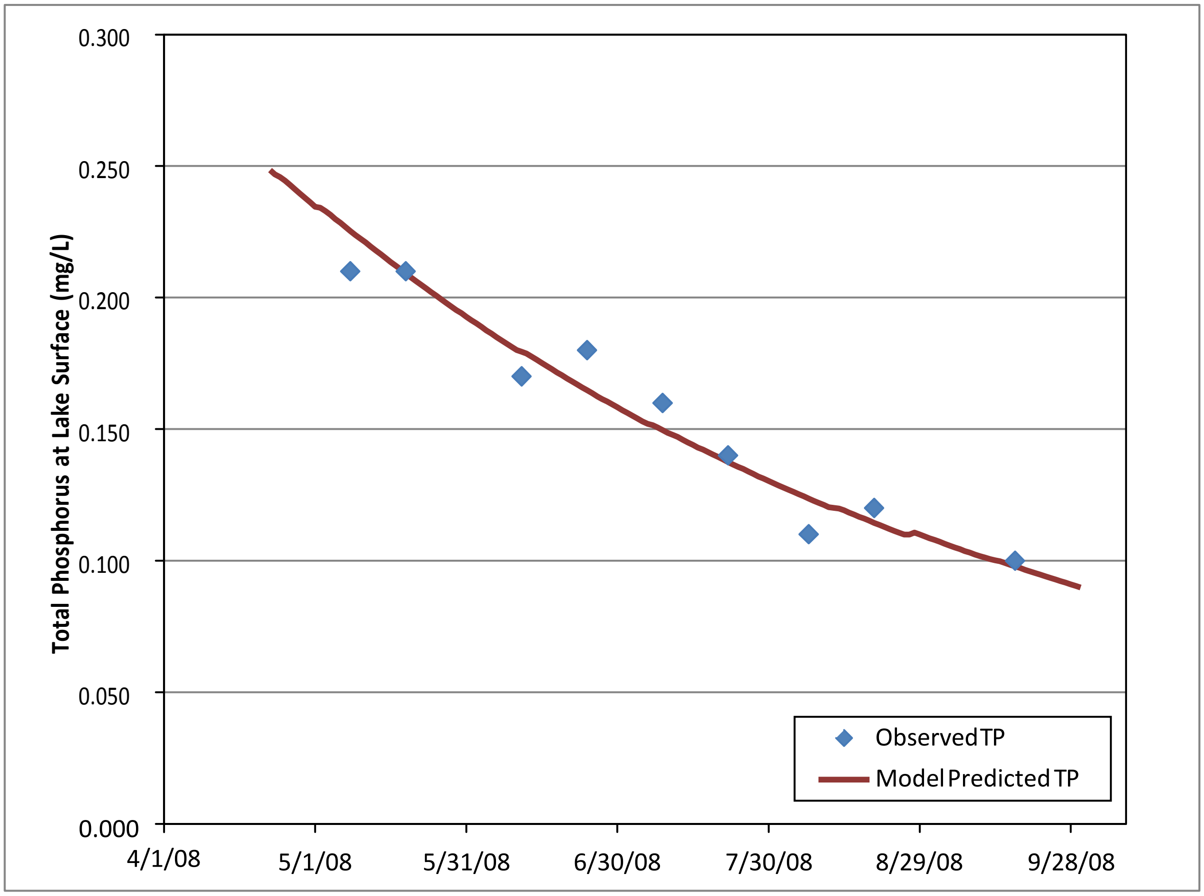

Figure A.14 Lake Augusta 2008 In-Lake Phosphorus Model Calibration

A.8 Rogers Lake Water Quality Modeling

Rogers Lake is a shallow 107 acre lake located in Mendota Heights. Land use in the 414 acres watershed consists of low density residential, park, a golf course, and highway. The lake has a maximum depth of 8 feet, and has two basins that are connected by culverts beneath a roadway. Water quality measurements are collected in the larger, southern basin. The average residence time of Rogers Lake is 0.6 years. Water quality in Rogers Lake is good, with total phosphorus concentrations meeting MPCA shallow lake criteria for the period of 2007-2012. As would be expected for a shallow lake with good water clarity, the lake has dense aquatic vegetation throughout. In addition to an assortment of native vegetation, a June 6, 2012 aquatic vegetation survey found curlyleaf pondweed (*Potamogeton crispus*), a non-native species. Curlyleaf pondweed can have a negative effect on water quality due to its growth cycle – it grows earlier in the year than native aquatic vegetation, and will die off earlier, releasing phosphorus into the water column in the first half of summer.

Summer averages of water quality measurements for the period of 2007-2012 were compared (Table

A.12). The summer averages of 2007 exhibited the poorest water quality for all three parameters (total phosphorus, chlorophyll-*a*, and secchi disk transparency). As a result, 2007 was selected as one of the years to model, since it exhibited the poorest water quality. Year 2012 exhibited one of the best years of water quality for the period of 2007-2012, and was also modeled (see Figure A.15).

Table A.12 Rogers Lake Summer Averages of Water Quality Parameters

Year	Total Phosphorus		Chlorophyll-*a*		Secchi Disk Transparency	
	June-Sept. Average (mg/L)	Number of Samples	June-Sept. Average (µg/L)	Number of Samples	June-Sept. Average (m)	Number of Samples
2007	0.051	8	8.6	8	1.01	8
2008	0.028	7	4.4	7	1.39	7
2009	0.036	8	8.0	8	1.31	8
2010	0.041	8	5.1	8	1.41	8
2011	0.046	8	5.2	8	1.46	8
2012	0.028	8	6.2	8	1.69	8
MPCA Criteria	≤0.060	--	≤20	--	≥1.0	--

Water quality measurements are collected from the south basin of Rogers Lake, which is the larger of the two basins. Water quality modeling focused on the south basin, but water quality of the north basin was considered during modeling efforts, as the north basin flows into the south basin. The outlet of Rogers Lake is a culvert structure located on the northeast corner of the south basin, a short distance east of the culverts connecting the two basins.

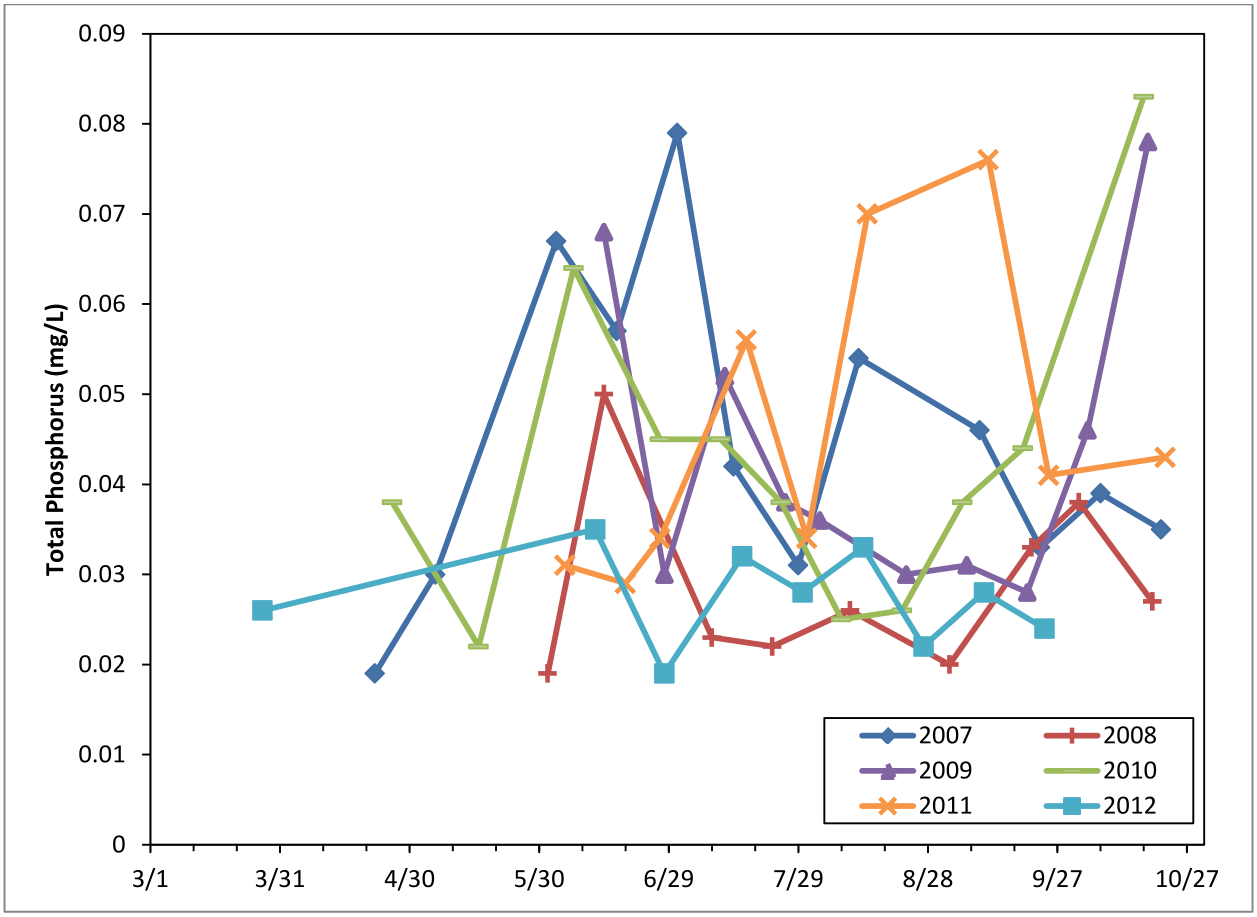

Figure A.15 Rogers Lake Total Phosphorus Concentrations at Lake Surface

A.8.1 Rogers Lake Water Balance Calibration

For the purposes of modeling water quality in Rogers Lake, a water balance was conducted for the period of March 15 through September 30 for the modeled years 2007 and 2012. Inflow to Rogers Lake includes watershed runoff and direct precipitation to the lake surface. Outflows include surface outflow through the south basin outlet structure, evaporation, and net groundwater outflow. The average residence of Rogers Lake is 0.6 years. The water balance was calibrated by comparing modeled water surface elevations to observed water surface elevations. Net groundwater outflow, which was not directly measured, was adjusted in the model so that the modeled water levels matched observed levels. The net groundwater outflow was determined to be 1.0 acre-feet/day – the net groundwater outflow rate necessary for the model to accurately simulate the continuous drop in water levels in the lake during periods when the water level was below the lake's outlet structure. Water levels were below the outlet structure for most of the period from 3/15/07-8/19-07, and the entire period of 3/15/12-9/30/12. The net groundwater outflow was estimated to be 1.0 acre-feet/day in both years modeled, and was applied consistently throughout the modeling period of March 15 – September 30.

A.8.2 Rogers Lake Phosphorus Model Calibration

For the purposes of water quality modeling, phosphorus inputs to Rogers Lake included watershed runoff, direct atmospheric deposition to the lake surface, and internal loading of phosphorus. Due to the shallow morphometry of the lake, internal loading of phosphorus may include physical disturbance and resuspension of sediment, in addition to the release of soluble phosphorus due to reduction of iron-phosphorus complex under anoxic conditions (i.e. low oxygen). Internal loading may also include the release of phosphorus from dying and senescing aquatic vegetation, in particular the non-native curlyleaf pondweed that dies off earlier than native aquatic vegetation. Distinguishing and directly measuring internal loading from any of the above mentioned mechanisms is difficult; therefore, for the purposes of water quality modeling, the phosphorus contributions from various in-lake sources are combined as “internal loading”. Phosphorus losses from Rogers Lake included surface outflow, net groundwater outflow, and in-lake settling. For much of the periods that were modeled, Rogers Lake did not have any surface outflow from the south basin. When there was no surface outflow from the south basin, phosphorus loads in the flow from the north basin to the south basin were included as contributions to the south basin. However, due to the close proximity of the culverts connecting the north and south basin and the outlet culvert of the south basin, it is assumed that inflow from the north basin short circuits and immediately flows out of the lake, and therefore does not affect phosphorus concentrations in the center of the south basin of Rogers Lake when there is outflow from the south basin.

The estimates of phosphorus loads from P8 were input into the Rogers Lake phosphorus model, along with estimates of direct atmospheric deposition to the lake surface. The phosphorus settling rate was adjusted until modeling results matched observed phosphorus concentrations during periods when phosphorus inputs to the lake were minimal (e.g. July 2007, July-August 2012). The phosphorus settling rate was determined to be 5.0 meters/year for Rogers Lake. After the phosphorus settling rate was calibrated, internal loading rates of phosphorus were calibrated such that modeled phosphorus concentrations matched observed phosphorus concentrations.

In 2007, Rogers Lake phosphorus concentrations increased from a concentration of 0.019 mg/L on 4/22/07 to 0.067 mg/L on 6/3/07. This increase is substantially more that could be explained by external phosphorus loading, and therefore indicates internal loading of phosphorus is occurring during this period. To match the observed increase in phosphorus concentrations in Rogers Lake during the period of April-June 2007, 50 kg of phosphorus due to internal loading was included in the model inputs (see Figure A.16 for comparison of model results versus observed phosphorus concentrations). In August 2007, heavy rainfall events resulted in substantial runoff to Rogers Lake, and the in-lake phosphorus concentration increased. Observed in-lake phosphorus concentrations increased from 0.031 mg/L on 7/29/07 to 0.054 mg/L on 8/12/07.

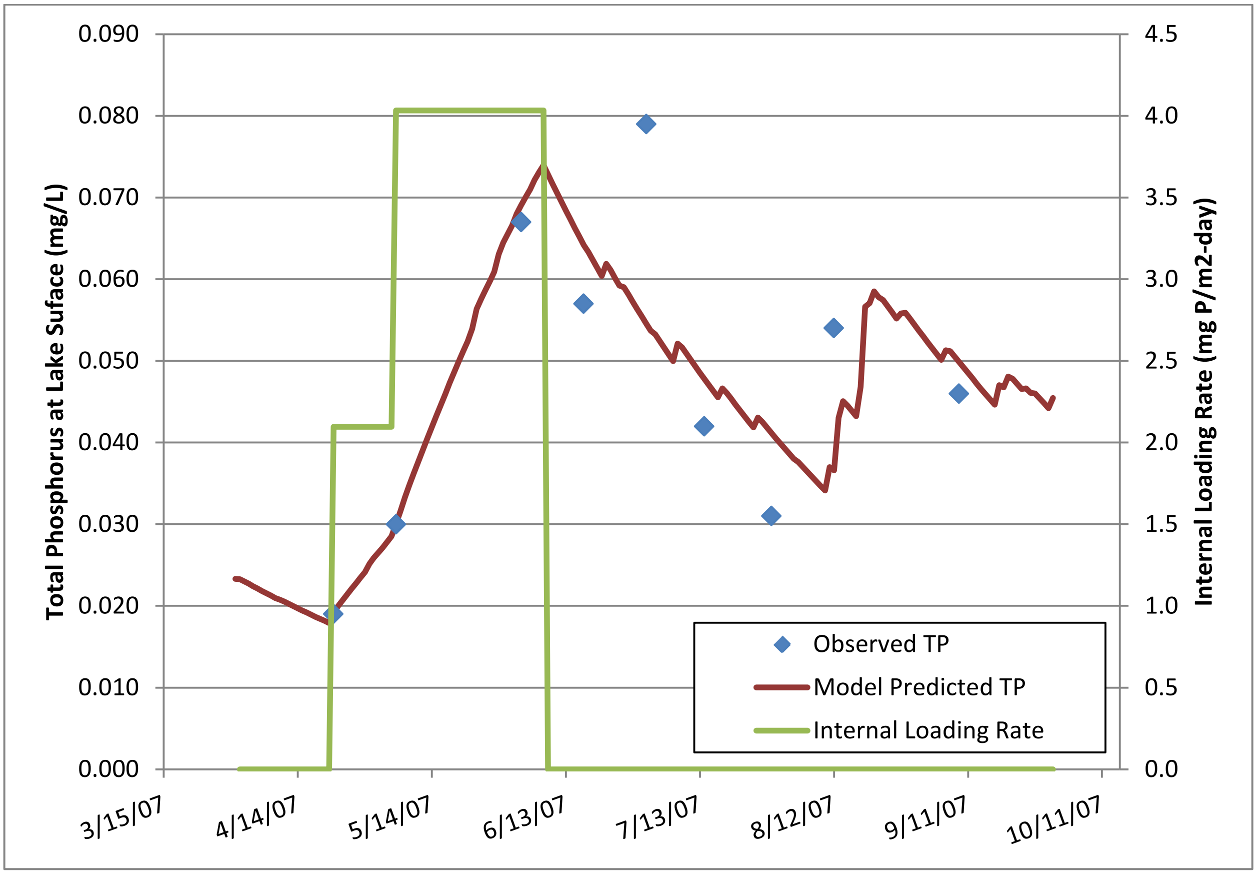

Figure A.16 Rogers Lake In-Lake Phosphorus Model Calibration for 2007

In 2012, Rogers Lake phosphorus concentrations increased from a concentration of 0.026 mg/L on 3/27/12 to 0.035 mg/L on 6/12/12. Similar to modeling results of 2007, this early summer increase in total phosphorus concentrations is greater than can be explained by external phosphorus loads, and internal loading was added to the model for the period of April 1 through June 12. A total of 9.2 kg internal loading of phosphorus was estimated from the modeling (see Figure A.17 for comparison of model results versus observed phosphorus concentrations). With the addition of early summer internal loading of phosphorus, the 2012 in-lake model prediction of phosphorus concentrations matched observed phosphorus concentrations reasonably well. It should be noted that the observed total phosphorus concentration of 0.019 mg/L on 6/28/12 is a suspected outlier, as total phosphorus concentrations on 6/12/12 and 7/16/12 were 0.035 mg/L and 0.032 mg/L, respectively.

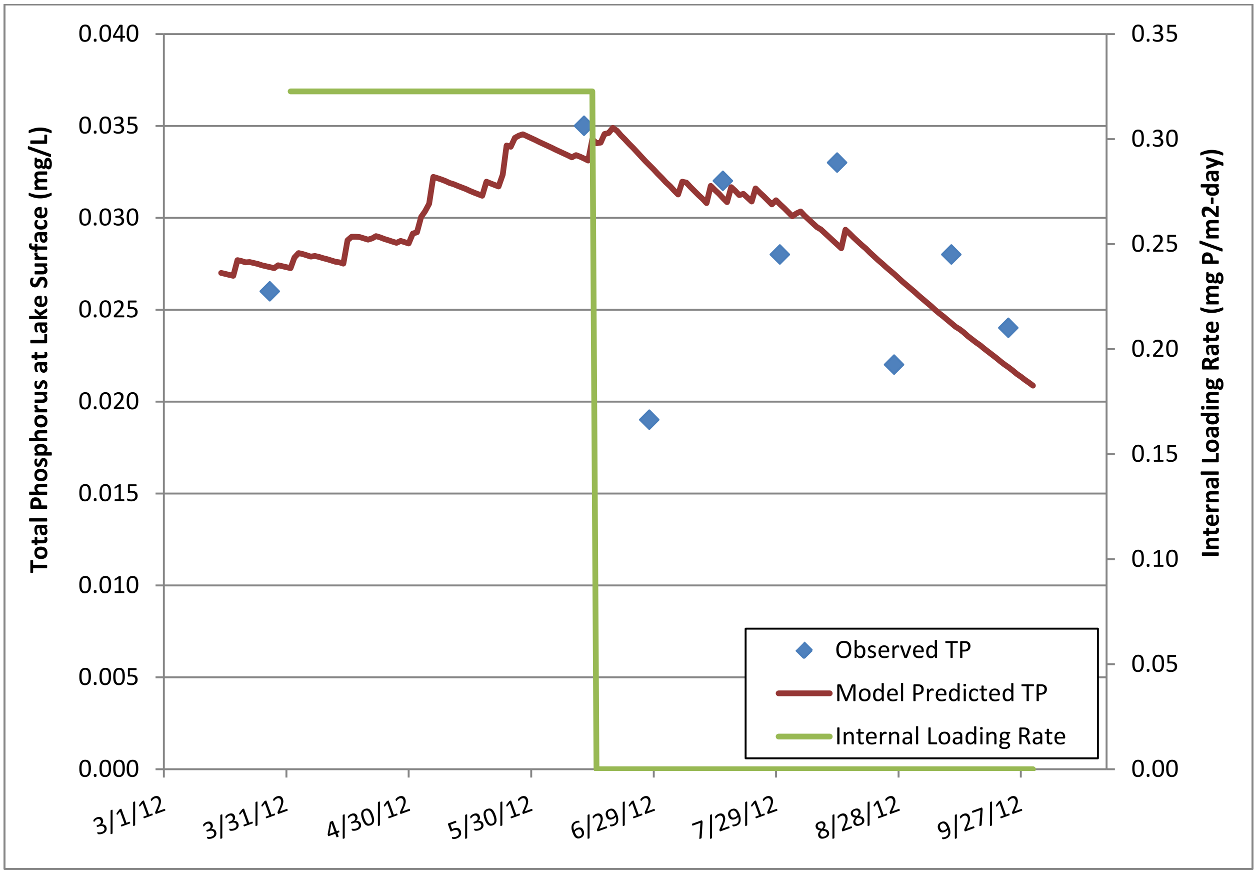

Figure A.17 Rogers Lake In-Lake Phosphorus Model Calibration for 2012

A.9 Thompson Lake Water Quality Modeling

Thompson Lake is a 7 acre lake located in West St. Paul. The lake has an average depth of 5-6 feet. With a watershed area of 182 acres, Thompson has the largest ratio of watershed area to lake surface area of the five lakes in this study. Correspondingly, it has the highest flushing rate and shortest residence time of the five lakes in this study, with an average residence time of 0.3 years. A June 2012 aquatic vegetation survey found the lake was vegetated throughout. However, the deeper areas in the center of the lake were primarily vegetated with coontail. Several species of aquatic vegetation were found in the shallower depths, including moderate densities of the non-native curlyleaf pondweed. Curlyleaf pondweed grows and dies back earlier in the season than native aquatic plants. Senescence of curlyleaf pondweed can release phosphorus into the lake in the early part of summer, and have a negative impact on water quality of a lake. Given the large ratio of watershed to lake surface area for Thompson Lake, watershed contributions of phosphorus are expected to be the most important factor affecting water quality of Thompson Lake (see Table A.13 and Figure A.18).

Table A.13 Thompson Lake Summer Averages of Water Quality Parameters

Year	Total Phosphorus		Chlorophyll-*a*		Secchi Disk Transparency	
	June-Sept. Average (mg/L)	Number of Samples	June-Sept. Average (µg/L)	Number of Samples	June-Sept. Average (m)	Number of Samples
2011	0.085	4	39.3	4	1.10	3
2012	0.075	12	19.5	11	1.54	12
MPCA Criteria	≤0.060	--	≤20	--	≥1.0	--

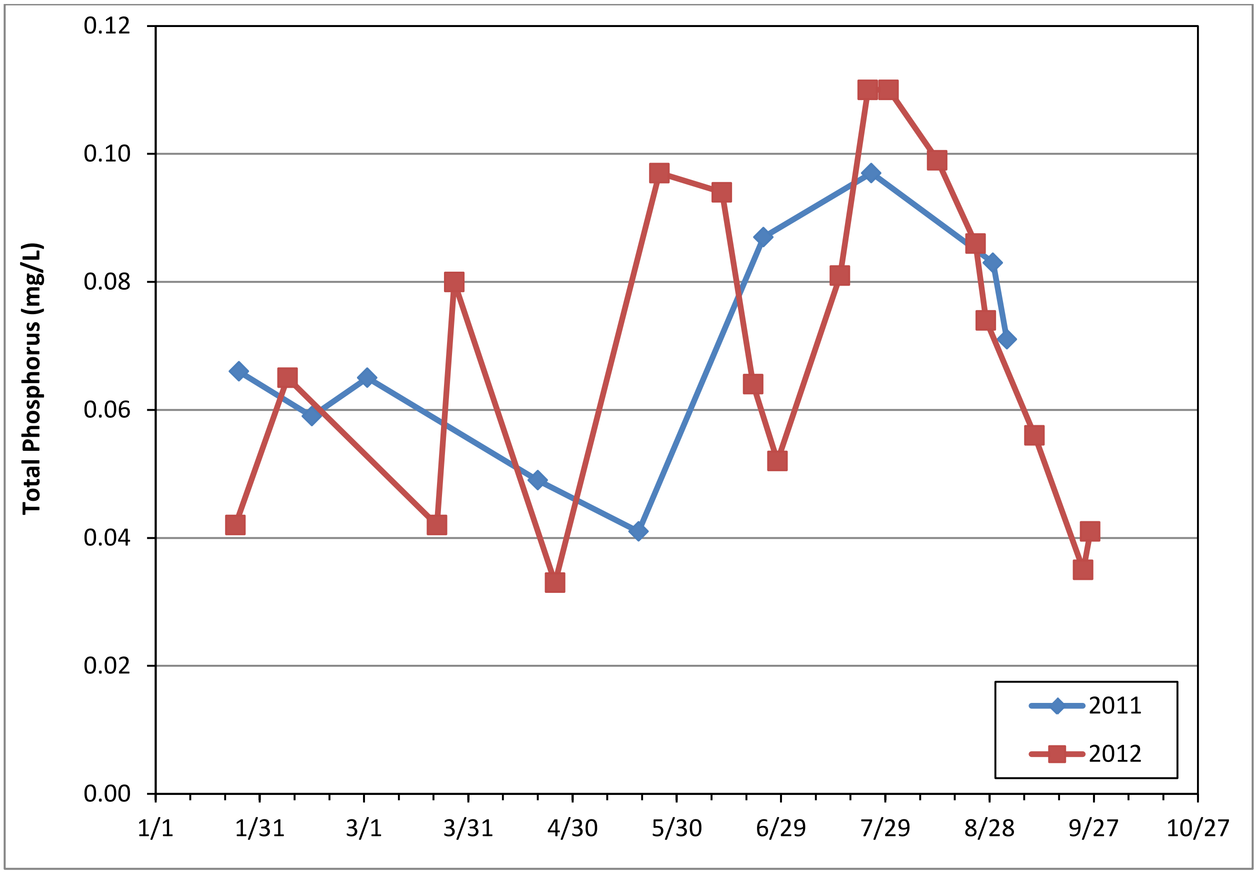

Figure A.18 Thompson Lake Total Phosphorus Concentrations at Lake Surface

A.9.1 Thompson Lake Water Balance Calibration

Thompson Lake water quality was modeled for the period of 3/1/12 through 9/30/12. First, a water balance was conducted for the lake. Inflow included watershed runoff (estimated from the P8 model) and direct precipitation to the lake surface. Outflows included surface outflow and evaporation. The outlet structure of Thompson Lake, located on the south end of the lake, is an engineered concrete structure. When the lake surface elevation is above 944.6 feet above MSL, water flows through a 0.65 foot wide opening in the concrete outlet structure. If the water level of Thompson Lake rises to 947.2 feet, water can flow over a 12 feet long weir-like structure, increasing the outflow rate. The daily outflow rate of Thompson Lake was estimated with consideration of the outlet structure and the lake's water surface elevation. Daily outflow rates were adjusted so that model predictions of water levels were comparable to observed water surface elevations.

A.9.2 Thompson Lake Phosphorus Model Calibration

Phosphorus inputs to the Thompson Lake model include watershed runoff (estimated from the P8 modeling) and direct atmospheric deposition to the lake surface. Phosphorus losses include settling of phosphorus and surface outflow. The phosphorus settling rate was calibrated by comparing model predicted phosphorus to observed phosphorus concentrations for the relatively dry months of August-September, when phosphorus inputs from stormwater were low. The settling rate of phosphorus was calibrated to 25 meters/year for both years 2011 and 2012. Results of the model prediction of phosphorus concentrations for Thompson Lake in 2011 are shown on Figure A.19. Results of the model prediction of phosphorus concentrations for Thompson Lake in 2012 are shown in Figure A.20. Model results and observed concentrations of phosphorus agreed reasonably well both years. Both figures show that significant variations in the phosphorus concentrations would be expected in Thompson Lake, as phosphorus concentrations would decrease at a substantial rate during dry periods due to the high settling rate (25 meters/year), and then increase rapidly following significant rainfall events due to the short residence time of the lake (as discussed in Section A.9). No internal loading of phosphorus was included in the Thompson Lake model for either 2011 or 2012. Curlyleaf pondweed, which is known to contribute to internal loading of phosphorus when it dies off in early summer, could contribute to internal loading, but the impact would be minimal on Thompson Lake when compared to the external phosphorus load from stormwater due to the large watershed to lake surface area ratio.

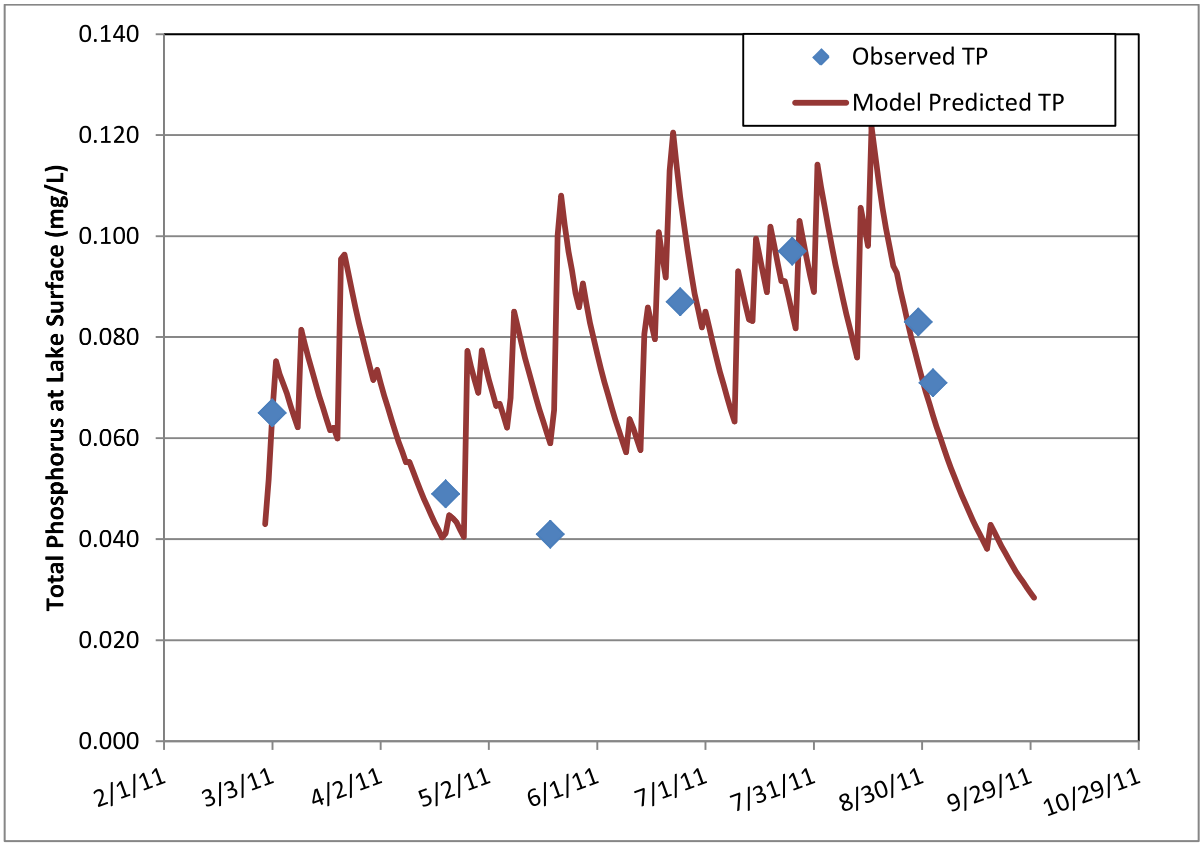

Figure A.19 Thompson Lake In-Lake Phosphorus Model Calibration for 2011.

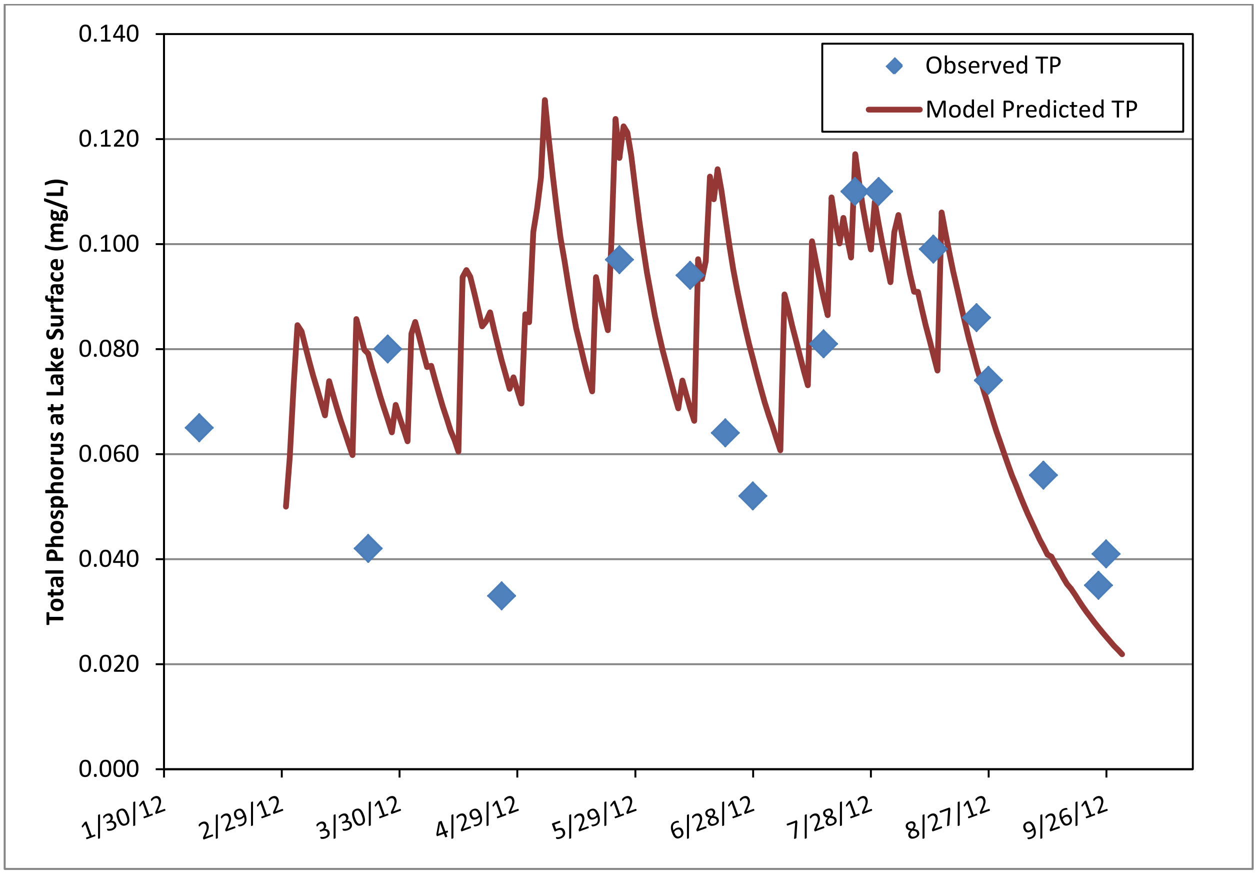

Figure A.20 Thompson Lake In-Lake Phosphorus Model Calibration for 2012

A.10 Sunfish Lake Water Quality Modeling

Sunfish Lake is a 51 acre lake located in the City of Sunfish Lake. The lake has a watershed area of 235 acres. The lake has a maximum depth of 32 feet, and an average residence time of 3.2 years. Although the lake has a high water overflow outlet, the lake does not experience surface outflow under normal conditions.

Several years (2006-2012) of water quality data were examined for Sunfish Lake. Although water quality is variable from year to year, a clear trend was apparent for total phosphorus concentrations within each season. Sunfish Lake total phosphorus concentrations in spring and early summer are typically in the range of 0.015-0.035 mg/L. In mid-July and early-August, total phosphorus concentrations begin to increase, and continue to increase into September. In 2009, one of the better years for water quality in Sunfish Lake, phosphorus concentrations remained below 0.04 mg/L throughout the summer season (June-September). One year later in 2010, and again in 2012, total phosphorus concentrations were greater than 0.08 mg/L by the end of August, well above the MPCA total phosphorus criterion of 0.04 mg/L. The repeated, continual increase of total phosphorus in late summer is a signature of internal loading of phosphorus from lake sediments. The morphometry of Sunfish Lake, with a maximum depth of 32 feet, is conducive to internal loading – the lake becomes thermally stratified in summer, and the deeper waters of the lake become oxygen depleted. When oxygen is absent, ferric iron can be reduced to ferrous iron, and iron-bound phosphorus becomes soluble again. Soluble phosphorus will build up in the deeper waters of the lake, and eventually a portion will be transported to the lake surface. The Sunfish Lake water quality data indicates a substantial amount of internal loading of phosphorus is reaching the lake surface by late summer in most years because the highest amount of phosphorus buildup corresponds with the beginning of lake destratification. Water quality modeling of phosphorus in Sunfish Lake was used to estimate the rate of internal loading of phosphorus. Two years were modeled for water quality: 2009, which was one of the best years for water quality in Sunfish Lake, and 2012, which was one of the worst years for water quality (see Table A.14 and Figure A.21).

Table A.14 Sunfish Lake Summer Averages of Water Quality Parameters

Year	**Total Phosphorus**		**Chlorophyll-*a***		**Secchi Disk Transparency**	
	June-Sept. Average (mg/L)	Number of Samples	June-Sept. Average (µg/L)	Number of Samples	June-Sept. Average (m)	Number of Samples
2006	0.063	9	35	9	1.1	9
2007	0.039	8	23	8	1.5	8
2008	0.043	9	36	9	1.3	9
2009	0.025	8	16	8	2.3	8
2010	0.053	9	44	9	1.8	9
2011	0.033	9	12	9	3.2	9
2012	0.056	16	41	16	1.6	8
MPCA Criteria	≤0.040	--	≤14	--	≥1.4	--

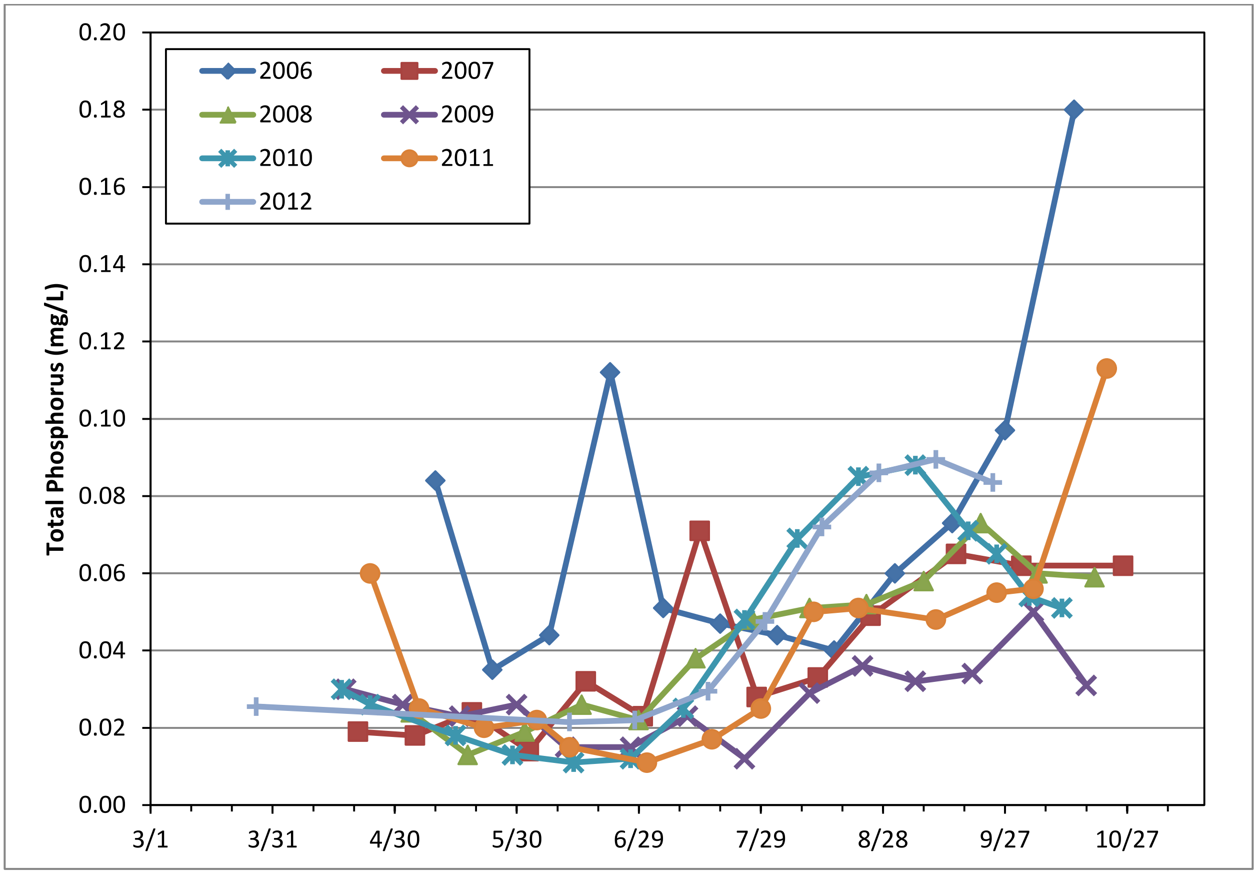

Figure A.21 Sunfish Lake Total Phosphorus Concentrations at Lake Surface

A.10.1 Sunfish Lake Water Balance Calibration

A water balance was calibrated for Sunfish Lake. Inflows included runoff from the watershed and direct precipitation to the lake surface. Outflows included evaporation and net groundwater outflow. The net groundwater outflow was adjusted until the lake surface elevation in the model was comparable to observed lake surface elevations. Net groundwater outflow ranged from 0 to 0.55 acre-feet/day.

A.10.2 Sunfish Lake Phosphorus Model Calibration

Phosphorus inputs in the model include watershed runoff, direct atmospheric deposition to the lake surface, and internal loading. Internal loading may include physical disturbance and resuspension of sediment or release of iron-bound phosphorus from lake sediment. In Sunfish Lake, water quality and sediment data indicate that the release of iron-bound phosphorus is the primary mechanism for internal loading of phosphorus in Sunfish Lake. For the water quality model, the settling rate for phosphorus in Sunfish Lake was calibrated by comparing predicted phosphorus levels from the modeling with observed phosphorus concentrations prior to the onset of internal loading in late-July. A settling rate of 8.0

meters/year was selected as the optimized settling rate for both 2009 and 2012. Once the settling rate was calibrated, internal loading of phosphorus was added to the model. Internal loading rates were adjusted until model predicted phosphorus concentrations agreed with observed total phosphorus concentrations.

In 2009, total phosphorus concentration at the lake surface were at a season low of 0.012 mg/L on 7/11/09 before rapidly increasing to 0.029 mg/L on 8/10/09, and further increasing to 0.036 mg/L on 8/23/09. An internal loading rate of phosphorus equivalent to 2.5 mg/m^2-day was added to the model over this time period to achieve this increase in phosphorus (Figure A.22).The total mass of phosphorus that was added to the 2009 Sunfish Lake water quality modeling was 17.9 kg during the months of July-September. By comparison, external phosphorus sources (watershed runoff and direct atmospheric deposition) from March-September totaled 3.4 kg.

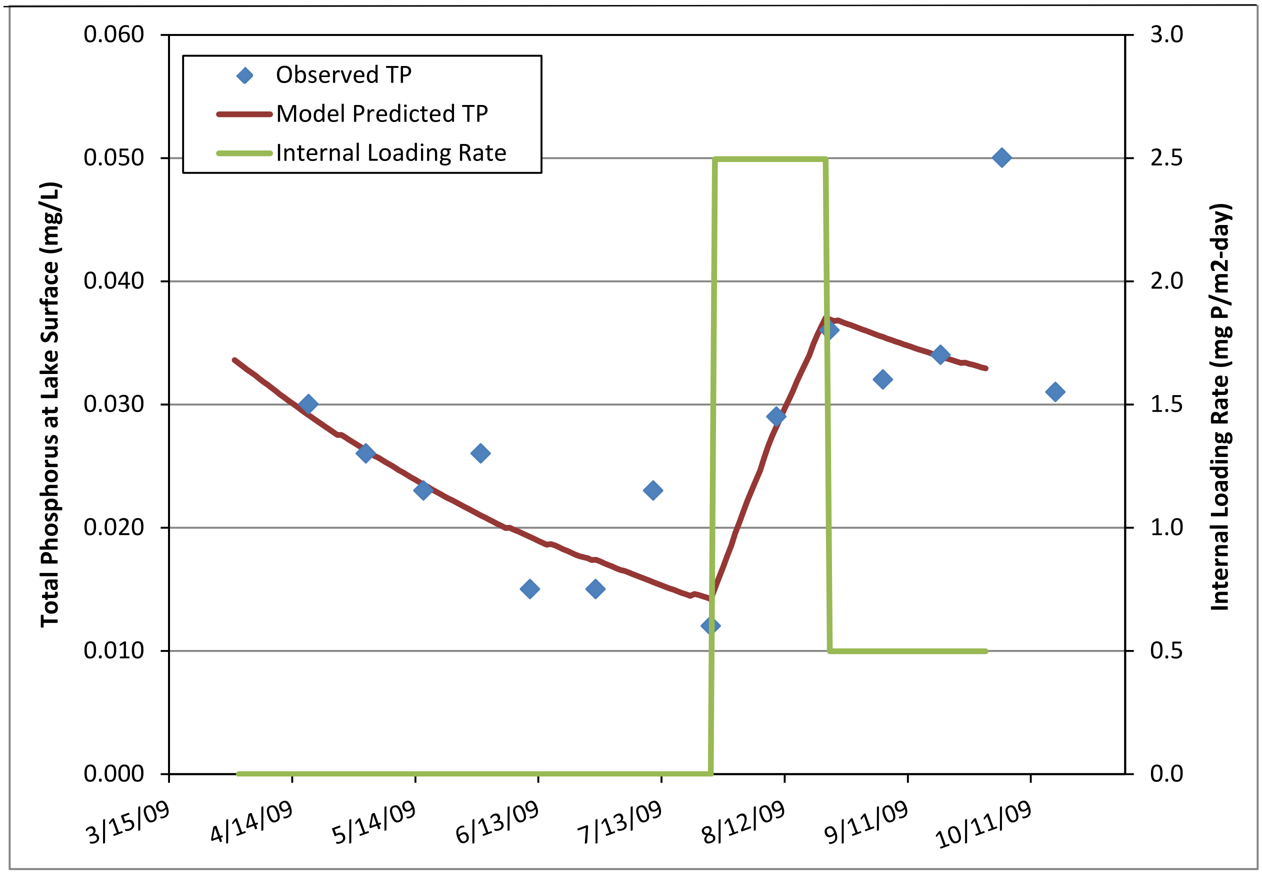

Figure A.22 Sunfish Lake In-Lake Phosphorus Model Calibration for 2009

In 2012, the internal loading rate of phosphorus was significantly greater than in 2009, as demonstrated by late summer total phosphorus concentrations that reached 0.091 mg/L. It also appeared that internal loading was occurring much earlier in the season (Figure A.23), which may be a result of an early ice-out and unusually warm spring that occurred in 2012. For 2012, the estimated internal loading of phosphorus in Sunfish Lake was 73 kg. By comparison, the estimated external phosphorus load during the period of March-September 2012 was just 4.7 kg.

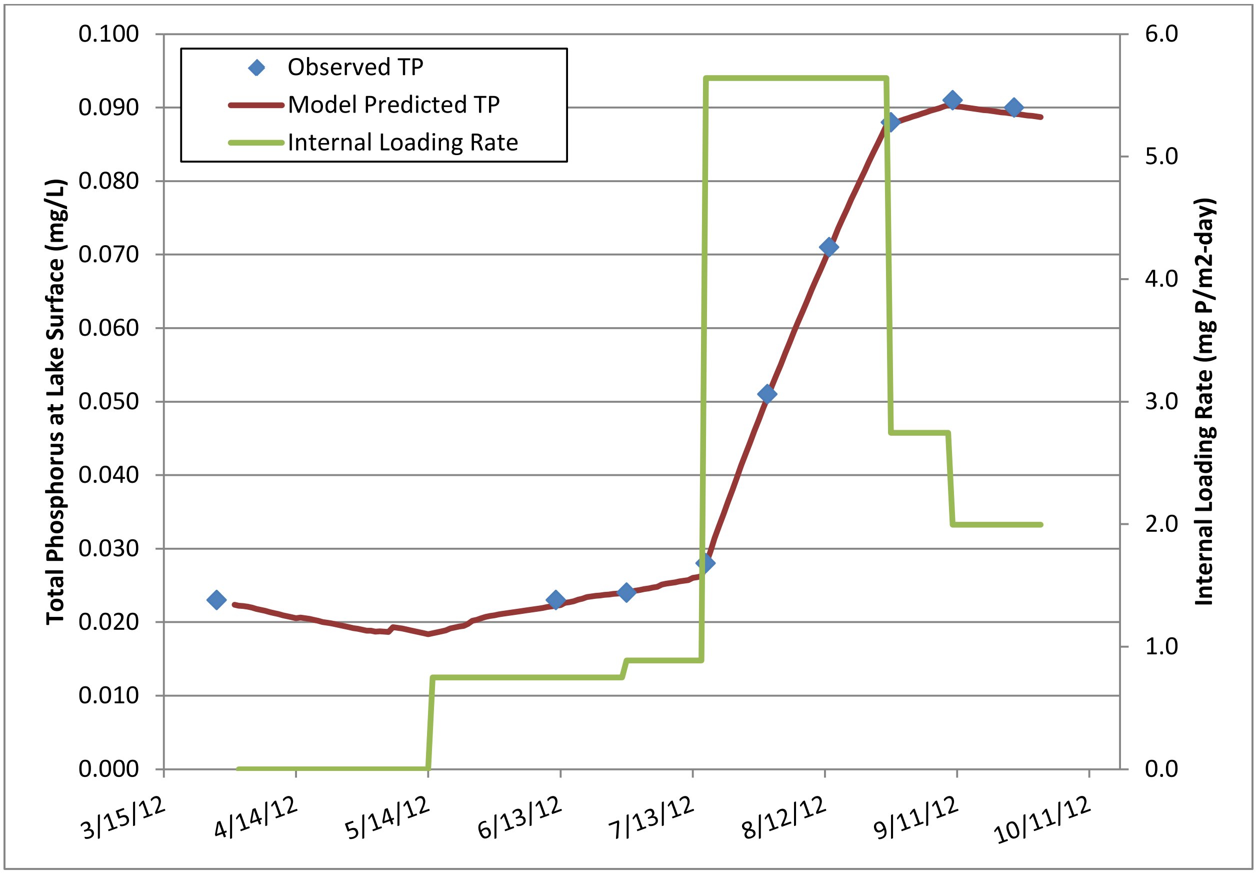

Figure A.23 Sunfish Lake In-Lake Phosphorus Model Calibration for 2012

A.11 Pickerel Lake Water Quality Modeling

Pickerel Lake is a 90 acre lake located in the floodplain of the Mississippi River along the boundary of Lilydale and St. Paul. The lake is shallow, with a maximum depth of 11 feet. The total watershed area of Pickerel Lake is 1,500 acres, with the majority of the watershed flowing in from Ivy Falls Creek. The level of the Mississippi River can get high enough to flood the low lying area between the lake and the river, allowing the Mississippi River to flow into and through the lake. The frequency of this level of flooding is approximately once every 10 years (see Figure A.24); however, the Mississippi River flooded Pickerel Lake on three separate occasions in 2010 and 2011 (see Figure A.25). The lake surface elevation is ordinarily about 10-12 feet above the normal elevation of the Mississippi River (see Figure A.26).

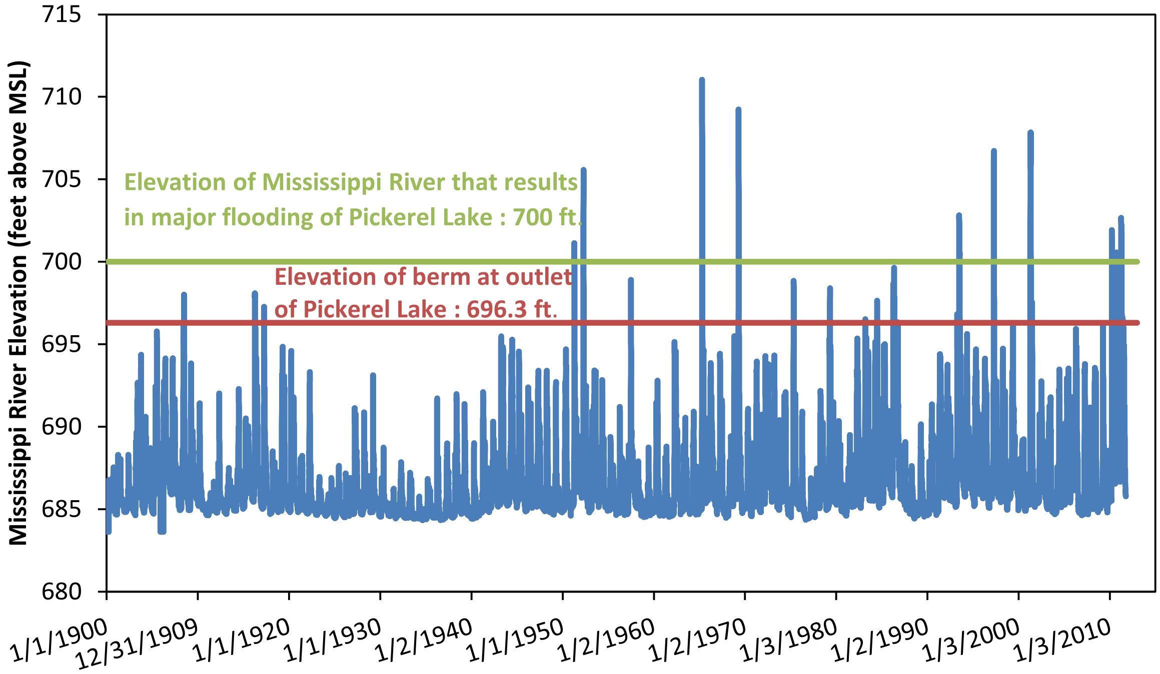

Figure A.24 Mississippi River Elevation at St. Paul, 1900-2012

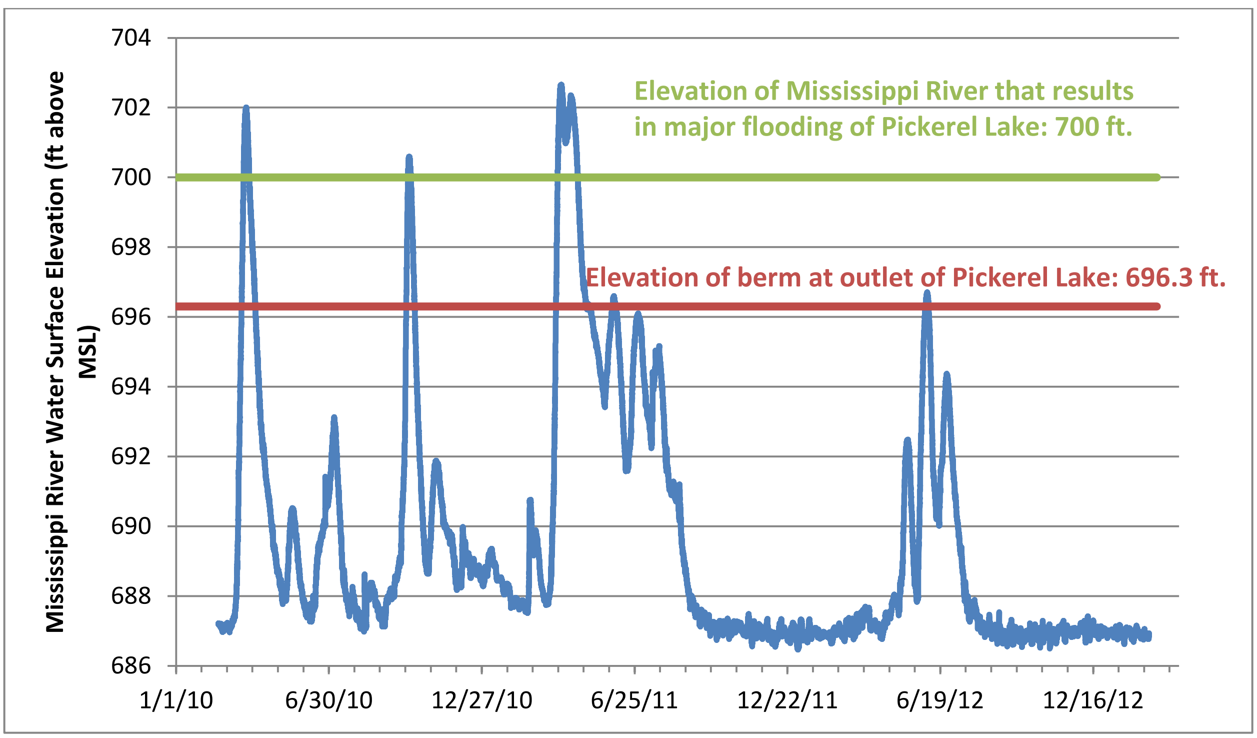

Figure A.25 Mississippi River Elevation at St. Paul, 2010-2012

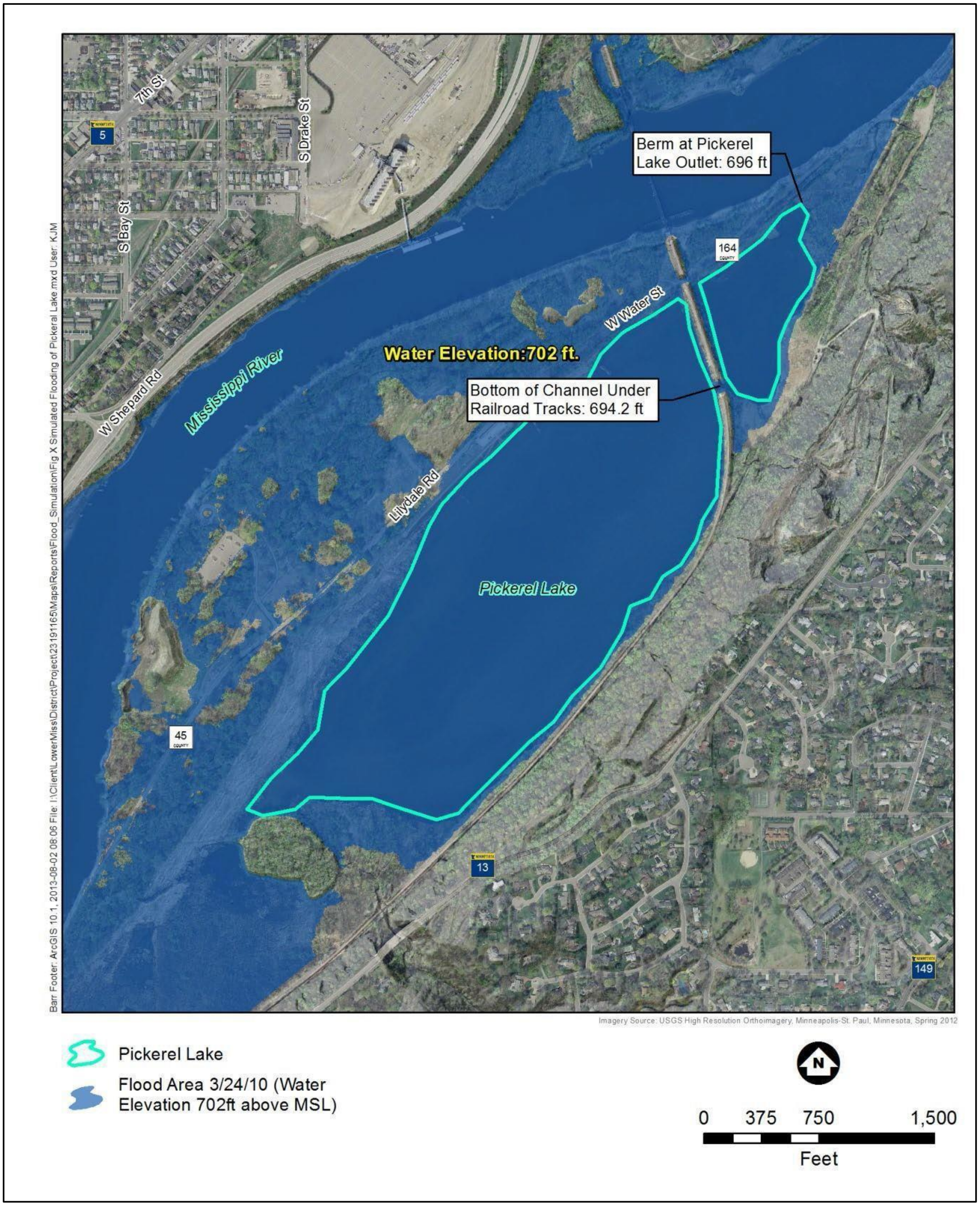

Figure A.26 Pickerel Lake Simulated Flooding

Water quality data has been collected on Pickerel Lake during the growing seasons between 2010 and 2012. Water quality data was also collected in Ivy Falls Creek and at the southwest wetland in 2012. Of the three years monitored, 2012 exhibited the best water quality (see Table A.15 and Figure A.27). Two years were selected for water quality modeling of Pickerel Lake: 2010 and 2012. Year 2010 represents a year in which the Mississippi River flooded Pickerel Lake. Year 2011 also experienced flooding, but there was a data gap from 5/24/11 to 7/27/12, and duplicate samples collected on 7/27/12 varied by a factor of two; therefore, year 2010 was selected over 2011 for modeling the critical conditions that combined poor water quality with Mississippi River flooding.

Table A.15 Pickerel Lake Summer Averages of Water Quality Parameters

Year	**Total Phosphorus**		**Chlorophyll-*a***		**Secchi Disk Transparency**	
	June-Sept. Average (mg/L)	Number of Samples	June-Sept. Average (µg/L)	Number of Samples	June-Sept. Average (m)	Number of Samples
2010	0.091	5	46	5	1.10	4
2011	0.123	4	69	4	0.60	3
2012	0.046	8	13	8	0.94	8
MPCA Criteria	<u><</u>0.060	--	<u><</u>20	--	<u>></u>1.0	--

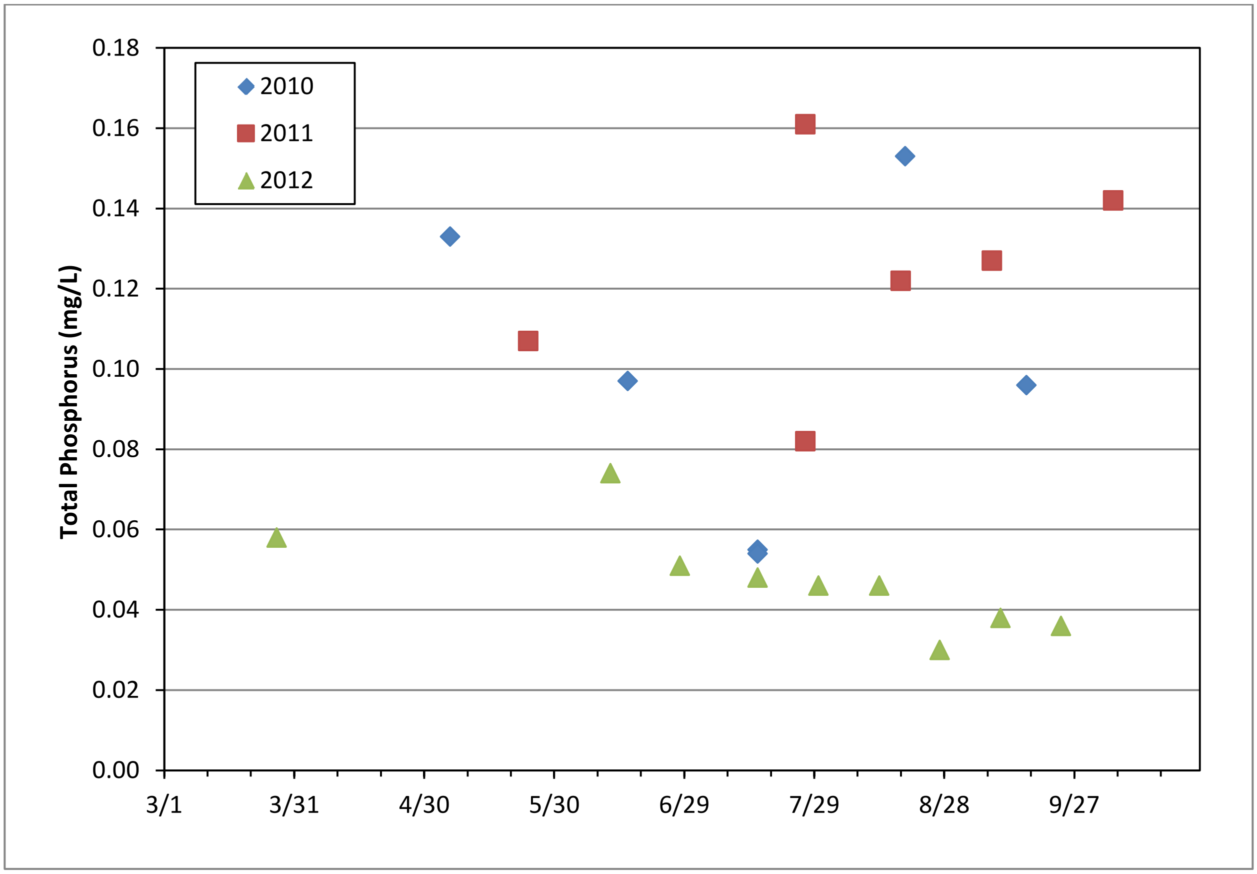

Figure A.27 Pickerel Lake Total Phosphorus Concentrations at Lake Surface

A.11.1 Pickerel Lake Water Balance Calibration

A water balance was completed for the lake for 2010 and 2012. The watershed inflows were split into three separate portions: Ivy Falls Creek, the direct watershed, and the southwest wetland watershed (see Figure A.1). Direct precipitation to the lake surface was also included. Outflows include evaporation, surface outflow, and net groundwater outflow. Water surface elevations were recorded for Pickerel Lake for the period of 6/25/12-11/26/12. For 2012, the water surface elevations were compared to the elevation of outlet control features. Water level elevation data was not available for the lake for 2010. However, in 2010 the Mississippi River was high enough to flood Pickerel Lake. Mississippi River elevation data was obtained from the St. Paul USGS gaging station, and was used as a proxy for lake surface elevation data for the period when the river was flooding Pickerel Lake. For much of the 2012 monitoring period, the lake level was below the elevation of the outlet control features. Even when the lake elevation was below the outlet control feature elevation, the water level of Pickerel Lake continued to drop, indicating net groundwater outflow from the lake under normal conditions.

A.11.2 Pickerel Lake Phosphorus Model Calibration

Phosphorus inputs for the Pickerel Lake modeling included watershed inputs (Ivy Falls Creek, the direct watershed, and the southwest wetland watershed), direct atmospheric deposition to the lake surface and internal loading. Additionally, the Mississippi River floodwaters were considered in 2010 when the river was flooding Pickerel Lake. Water quality data for the Mississippi River was obtained from the Metropolitan Council's online environmental database. On 3/31/10, total phosphorus in the Mississippi River in St. Paul was measured at 0.273 mg/L, which was the only sample result during this period. The Mississippi River crested in St. Paul on 3/23/10, and the river level dropped below the elevation that would cause major flooding of Pickerel Lake on 3/28/10. The flooding of Pickerel Lake and the surrounding watershed with water from the Mississippi River would have a negative impact on water quality of Pickerel Lake. During flooding events like those that occurred in March 2010, the lake would be completely flushed and replaced with river water high in phosphorus. Mississippi River flooding occurred again in October 2010 and March-April 2011, impacting water quality during the 2011 summer season. The Mississippi River did not flood Pickerel Lake in 2012. Although water quality data for Pickerel Lake is limited to three years (2010-2012), it appears that flooding from the Mississippi River that occurred in 2010 and 2011 had a significant negative impact on water quality of Pickerel Lake. In 2012, when the river did not flood Pickerel Lake in the spring, the water quality of Pickerel Lake was much improved.

The Pickerel Lake phosphorus model for 2010 was calibrated for the period of 4/6/10-9/30/10 (see Figure A.28). It was assumed that Pickerel Lake's phosphorus concentration on 4/6/10 was 0.273 mg/L, equal to the Mississippi River concentration observed on 3/31/10. No additional Mississippi River phosphorus inputs were included in the model, as the river had receded below the elevation where it would flood Pickerel Lake by the start of the model timeframe. Phosphorus inputs to the model included watershed runoff (Ivy Falls Creek, direct watershed, and southwest wetland) estimated from the P8 modeling, direct atmospheric deposition to the lake surface, and internal loading. The phosphorus settling rate was calibrated for periods of low rainfall and runoff. For 2010, the settling rate was determined to be 5.0 meters/year. The first phosphorus observation in 2010 was 0.133 mg/L on 5/6/10, and phosphorus concentrations dropped to a season low of 0.055 mg/L on 7/16/10. On 8/19/10, phosphorus concentrations had increased to 0.153 mg/L, nearly triple the concentration observed one month earlier. Heavy rainfall had produced significant runoff from the watershed during the period of 8/8/10-8/14/10, increasing phosphorus loading to Pickerel Lake. However, the P8 estimates of phosphorus loading could not account for such a large increase in in-lake phosphorus concentrations in August. Therefore, the addition of internal loading was required to calibrate the phosphorus model to simulate observed phosphorus concentrations. A total of 38 kg of phosphorus internal loading was included in the 2010 Pickerel Lake model. Given Pickerel Lake's shallow morphometry, this is a relatively high rate of internal loading. It is possible the spring flooding of the Mississippi River created conditions in Pickerel Lake that allowed for abnormally high internal loading in the same year, such as sediment that was easily resuspended from storm driven turbulence. It is also possible the southwest wetland was affected by the floodwaters, and the wetland may have become a source of phosphorus that was flushed into the lake during heavier rainfall events that occurred in August.

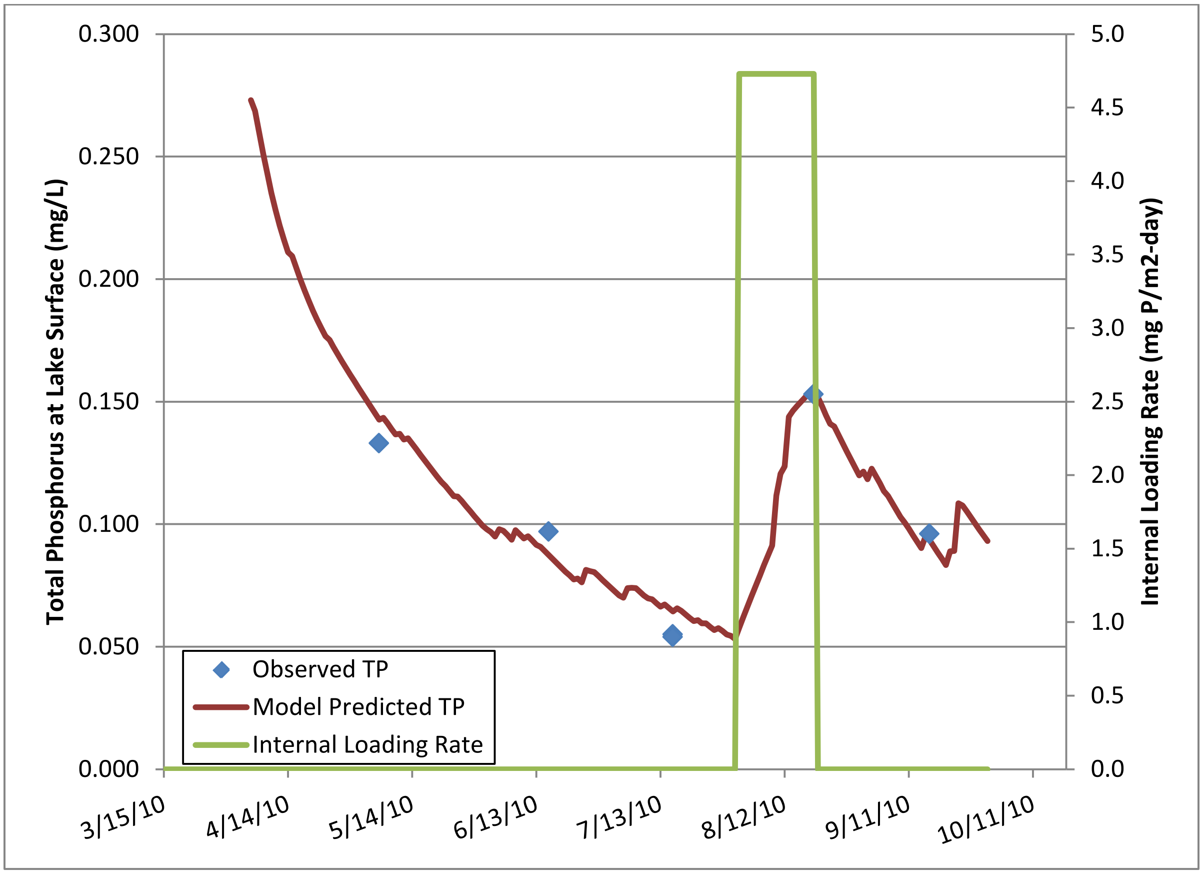

Figure A.28 Pickerel Lake In-Lake Phosphorus Model Calibration for 2010

The 2012 phosphorus modeling was calibrated for the period of 3/15/12-9/30/12 (see Figure A.29). The Mississippi River did not flood Pickerel Lake in Spring 2012, and the phosphorus concentration in Pickerel Lake on 3/27/12 was 0.058 mg/L, significantly lower than spring concentrations observed in 2010 or 2011 following Mississippi River flooding events that occurred in both of those years. The only high total phosphorus observation during 2012 was 0.074 mg/L on 6/12/12. Phosphorus concentrations generally decreased from the high observed on 6/12/12, and concentrations were less than 0.040 mg/L during the period of 8/27/10-9/24/10. The phosphorus settling rate for 2012 was calibrated to 7.2 meters/year, which is 44% higher than the 5.0 meters/year calibrated for 2010. Zero internal loading was added to the 2012 model calibration, as phosphorus concentrations generally decreased during the course of the summer.

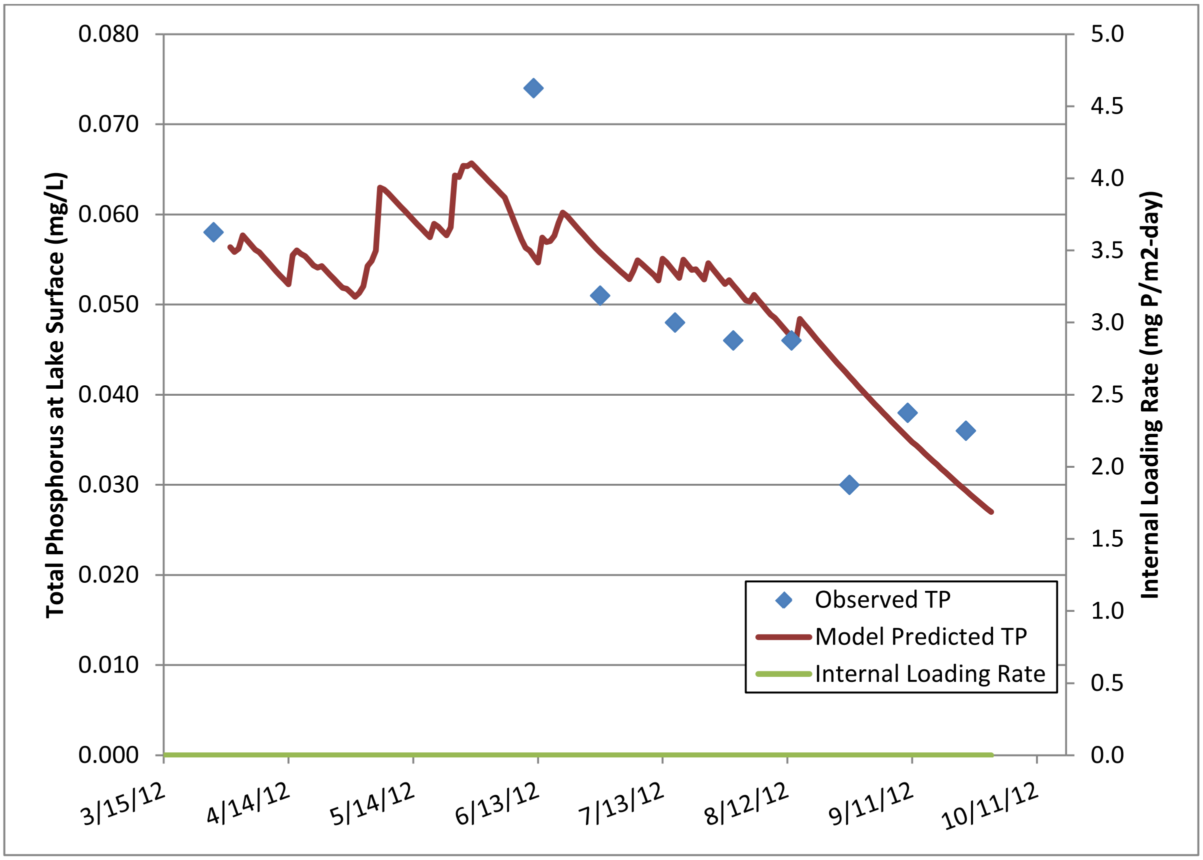

Figure A.29 Pickerel Lake In-Lake Phosphorus Model Calibration for 2012

Pickerel Lake water quality observations and phosphorus model calibration for years 2010 and 2012 were significantly different, primarily as a result of the Mississippi River inundating the lake in the spring of 2010.

In Pickerel Lake another source of TP loads in the watershed is from ravine and bluff erosions along Ivy Falls Creek and other bluff areas within the watershed, as well as Mississippi River backflow under flood conditions. Erosional sources of TP were estimated using the monitored and modeled data from 2012. A total of 7 events were both monitored and modeled during this time. Phosphorus concentrations and total flow rates were used to calculate total TP loads for both the monitored and modeled datasets (Table A.16). The monitored data indicate a TP load of 25.2 lbs for the 7 events. The modeled data using the P8 default pollutant load parameters estimated resulted in a TP load of 18.3 lbs for the 7 events at the Ivy Falls Creek outfall. This comparison indicated a 38% increase between to the modeled results and monitored results, which was applied to subwatersheds MB-1, MB-2 in the northern part of the lake watershed as well as the load at the Ivy Creek Watershed outfall to reflect ravine and bluff erosion sources.

Table A.16 Ivy Falls Creek monitored and modeled data comparison for year 2012.

Event Start Date	Monitored Grab Sample Data			Modeled Event Data		
	Total Phosphorus Concentration (mg/l)	Total Flow (acre-ft)	Load (lbs)	Total Phosphorus Concentration (mg/l)	Total Flow (acre-ft)	Load (lbs)
7/6/12 20:00	0.74	2.92	5.88	0.35	3.87	3.67
7/13/12 18:00	0.44	8.13	9.72	0.27	6.23	4.53
7/18/12 11:00	0.25	4.99	3.39	0.24	6.22	4.11
7/24/12 0:00	0.18	6.83	3.34	0.24	5.67	3.69
8/4/12 0:00	0.43	2.26	2.65	0.29	2.78	2.19
8/15/12 8:00	0.46	0.00	0.00	0.31	0.04	0.04
9/17/12 4:00	0.22	0.33	0.20	0.11	0.15	0.05
Totals	**0.39**	**25.47**	**25.19**	**0.26**	**24.97**	**18.28**

A.12 Macrophyte (Aquatic Plant) Surveys

Macrophytes are aquatic plants that are large enough to be visible to the naked eye. Macrophytes grow in the littoral zone of lakes which is the shallow area of the lake. Depending on the water transparency, the littoral zone is the area of the lake up to approximately 15 feet deep. Dominance by Eurasian watermilfoil (EWM) and Curlyleaf pondweed (CLP) is unfavorable for the study lakes because they are non-native invasive species that alter aquatic habitat and may contribute nutrients to the water column during the growing season. To understand the macrophyte communities within the study lakes, macrophyte surveys were completed on Pickerel, Rogers, Sunfish and Thompson Lakes (see Figures A.30 through A.33, respectively). A macrophyte survey was not completed for Lake Augusta as it is a deep lake with a small littoral zone and has very few plants along the lake shoreline.

Curlyleaf pondweed is a nuisance invasive plant introduced to Minnesota in 1910. In spring, CLP can outcompete native plants because it starts to grow under the ice. It forms dense mats that may interfere with boating and other recreation on lakes. CLP can also cause ecological problems because it can displace native aquatic plants. In midsummer, CLP plants usually die back, which results in rafts of dying plants piling up on shorelines, and often is followed by an increase in phosphorus release to the water column. CLP is present in moderate to heavy densities in Pickerel, Rogers, Sunfish and Thompson Lakes.

The presence of Eurasian watermilfoil was documented by Barr in Sunfish Lake. Once established in an aquatic community, EWM reproduces from fragments and stolons (runners that creep along the lake bed). Stolons, lower stems, and roots persist over winter and store the carbohydrates that help EWM claim the water column early in spring, photosynthesize, divide, and form a dense leaf canopy that shades out native aquatic plants. EWM's fast growth rate, up to two inches per day in spring and summer, its ability to spread rapidly by fragmentation, and its ability to effectively block out sunlight needed for native plant growth often result in monotypic stands. Monotypic stands of EWM threaten the integrity of aquatic communities by disrupting predator-prey relationships and reducing the number of nutrient-rich native plants available for waterfowl. EWM spreads rapidly and can grow to dominance in as little as two years (WDNR, 2012a and 2012b). Dense stands of EWM also inhibit recreational uses like swimming, boating, and fishing. Cycling of nutrients from sediments to the water column by EWM may lead to deteriorating water quality and algae blooms of infested lakes (WDNR, 2012a).

Native aquatic plants are important to the health of lakes. Overly aggressive control of aquatic plants can damage habitat needed by fish and other animals. Harvesting does provide for important recreational access, but it does not lessen the degree of invasive plant infestation. Aquatic plant control is regulated by Minnesota Department of Natural Resources (MDNR) who issues a permit for this work. State law allows aquatic plant control "*to provide riparian access, enhance recreational use, control invasive aquatic plants, manage water levels, and protect or improve habitat.*" Aquatic plant control may not be performed for aesthetic reasons alone and no more than 50% of the littoral area (the zone less than 15 feet deep) may be harvested.

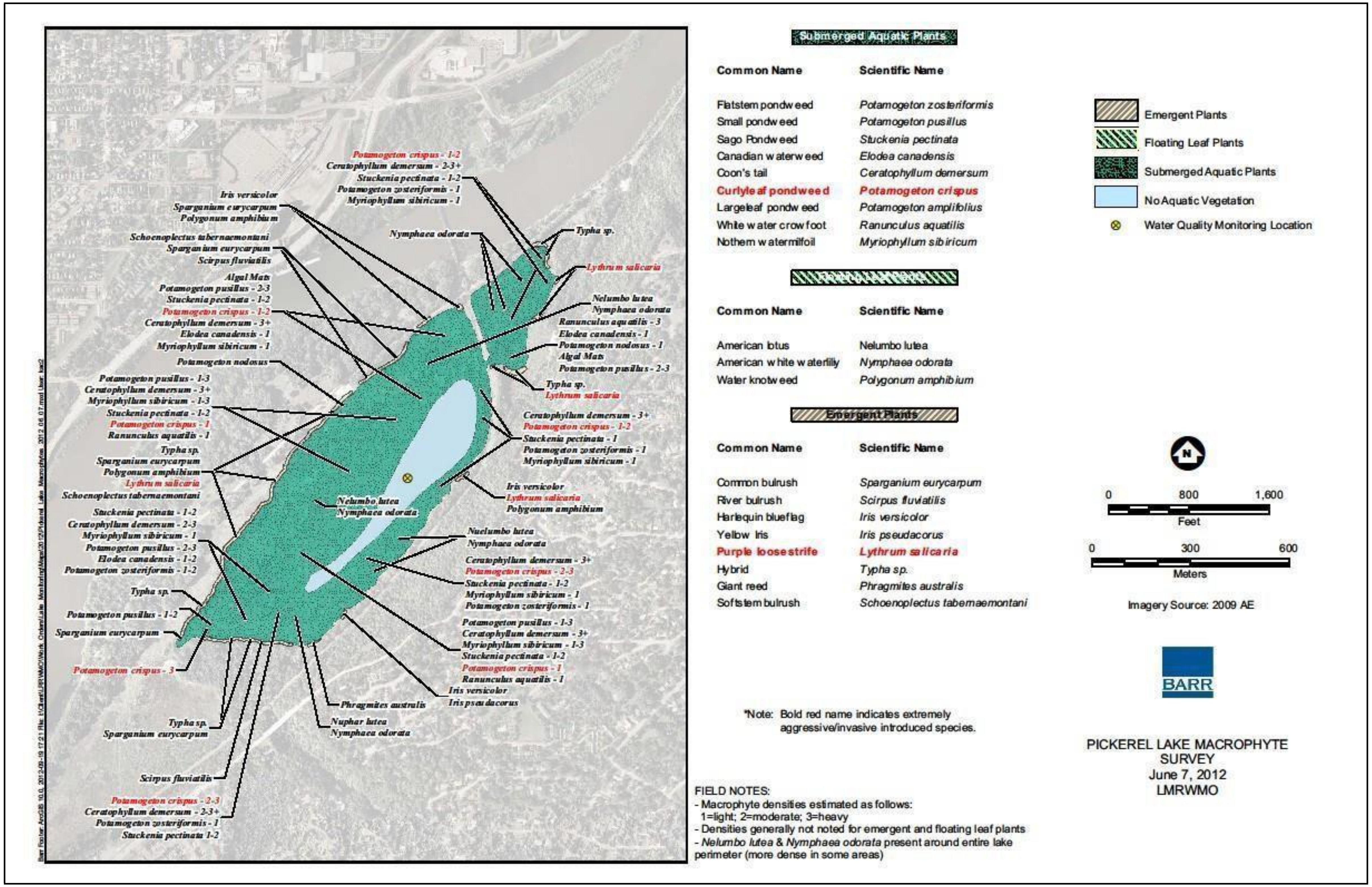

Figure A.30 Pickerel Lake Macrophyte Survey June 7, 2012

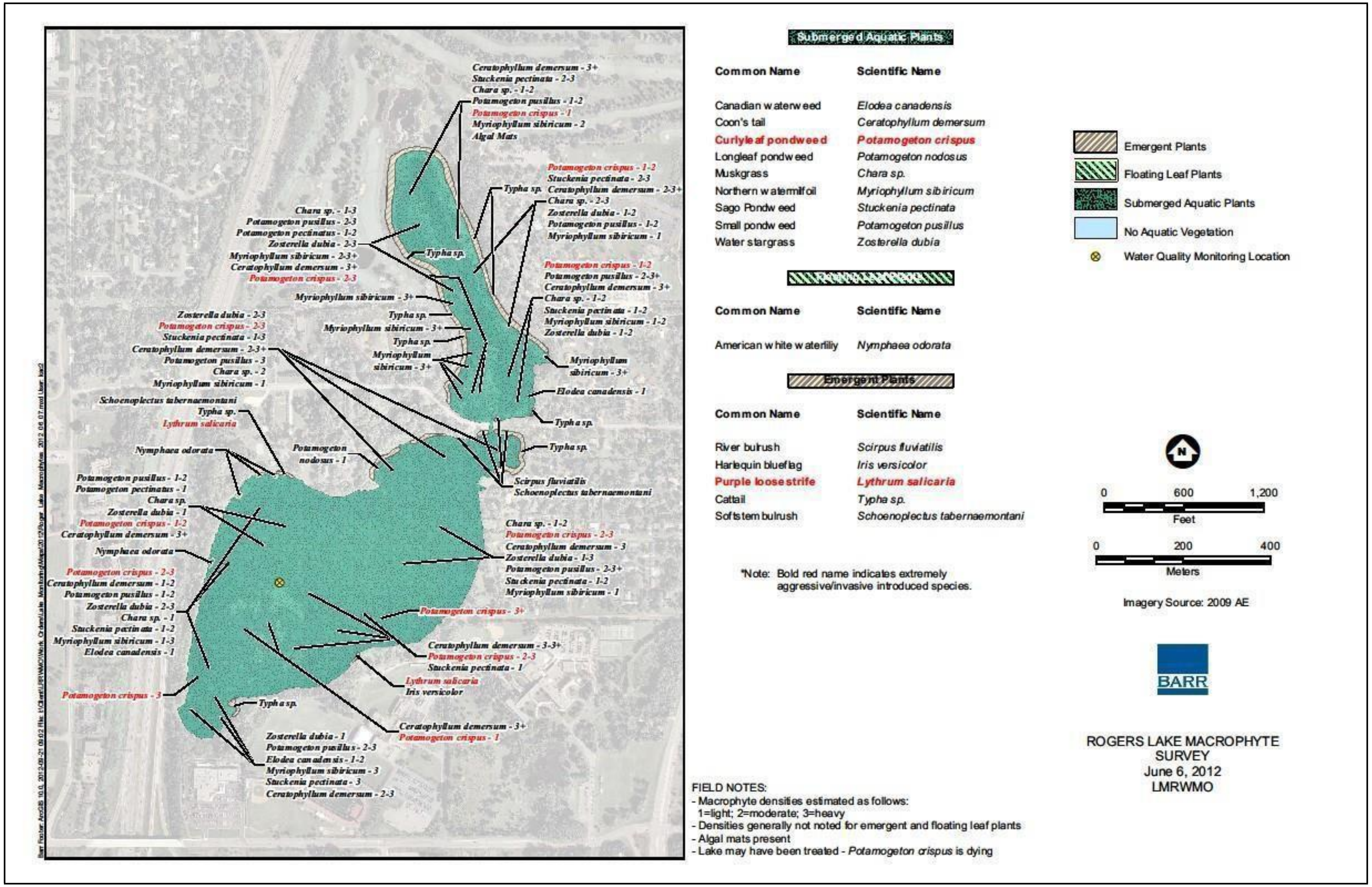

Figure A.31 Rogers Lake Macrophyte Survey June 6, 2012

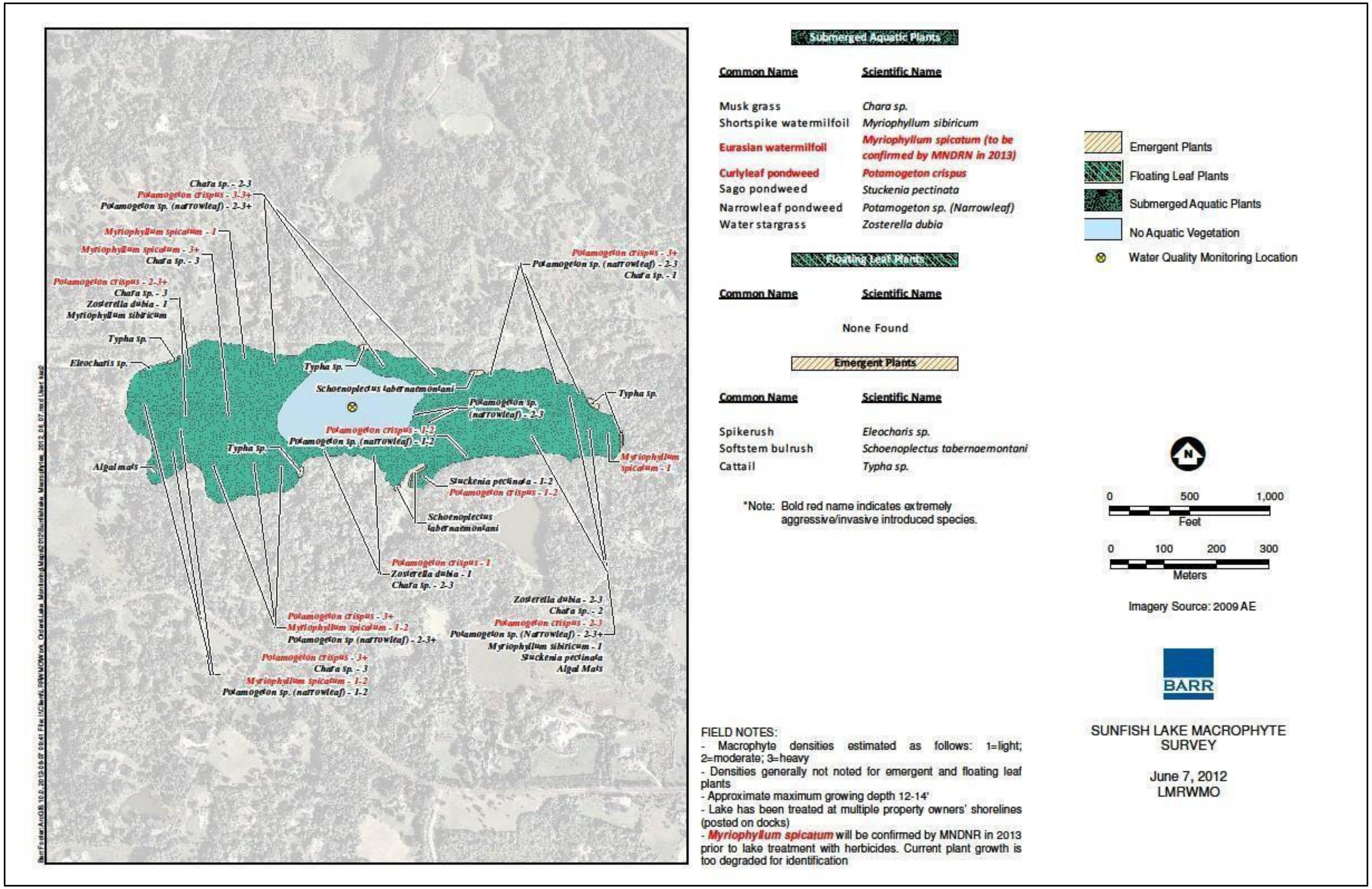

Figure A.32 Sunfish Lake Macrophyte Survey June 7, 2012

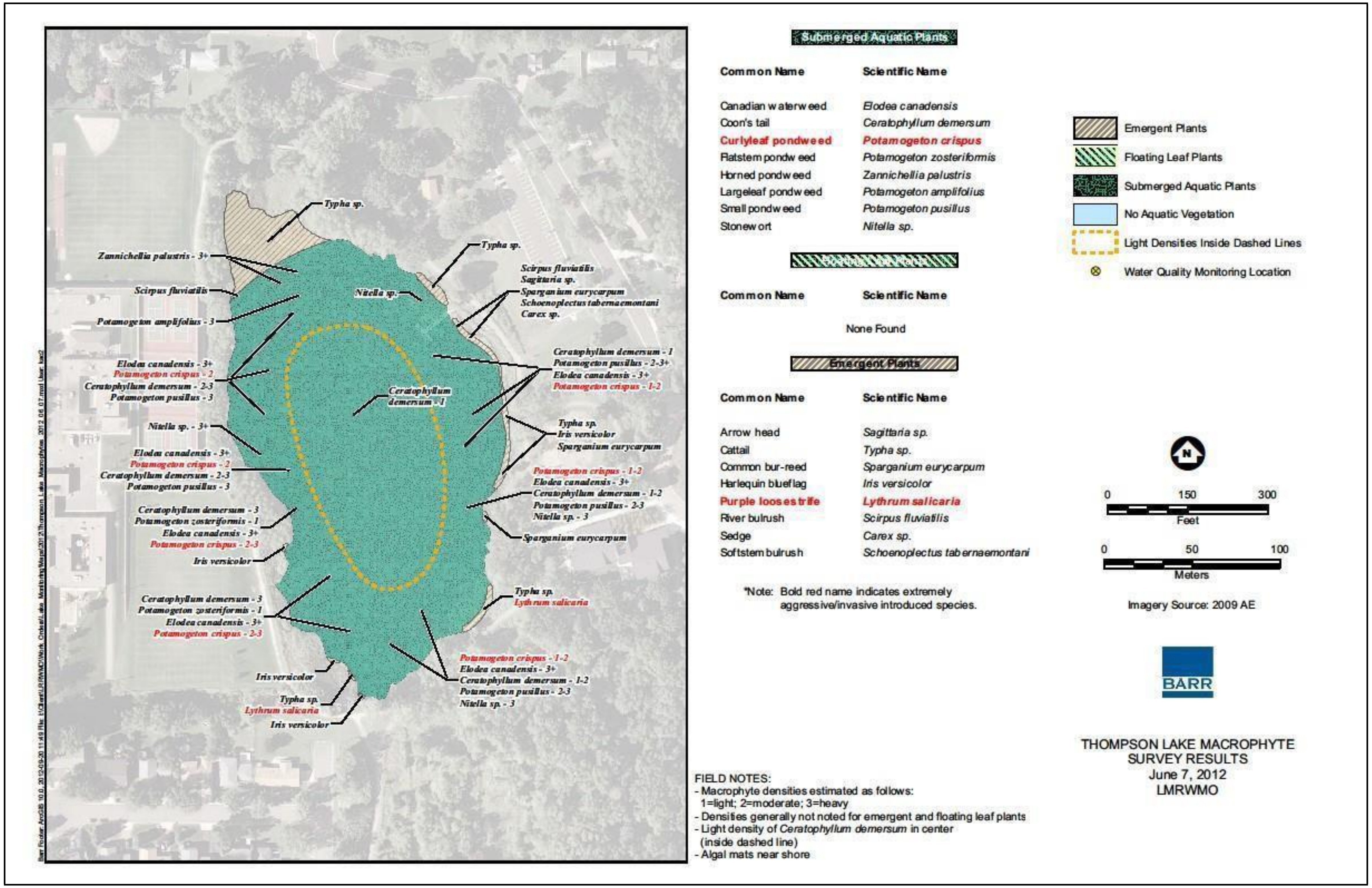

Figure A.33 Thompson Lake Macrophyte Survey June 7, 2012

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Appendix B: Informational Flyers and Results of Citizens Input Survey by Lake

Your Connection to Rogers Lake

Water Quality Study on Rogers Lake

PURPOSE: *To understand the quality and conditions of Rogers Lake and three other lakes in the area. And, to hear from residents in the watershed to understand their thoughts about Rogers Lake and their willingness to contribute to improved or protected water*

This year, the Lower Mississippi River Watershed Management Organization (LMRWMO) is embarking on a project to gain a better understanding of four lakes and to engage the residents that live around or near these lakes. The Minnesota Pollution Control Agency is funding the project through the Clean Water Land and Legacy Act to study the water quality and pollution sources of Thompson Lake in West St. Paul, Pickerel Lake in Lilydale, Rogers Lake in Mendota Heights, and Sunfish Lake in the City of Sunfish Lake. The project, called a "Watershed Restoration and Protection (WRAP) Study," will result in restoration plans for lakes with poor water quality, and protection plans for lakes with good water quality.

Your property lies within the watershed of Rogers Lake. That means that even if you live several blocks or even miles away, the rainwater and snowmelt that leave your property and neighborhood ultimately end up in the lake. Therefore, you and your neighbors may play an important role in improving and protecting Rogers Lake into the future.

In addition to understanding the conditions of Rogers Lake, possible threats to its water quality, and key protection measures, the WRAP Study will involve residents of the watershed, like you. We hope to learn your thoughts about the lake, your vision for its future condition, and your willingness to be part of its improvement and protection. Right now, you can help by completing and returning the enclosed survey, and participating in the community conversations about Rogers Lake.

CLEAN WATER LAND & LEGACY AMENDMENT

WE WANT YOUR FEEDBACK!

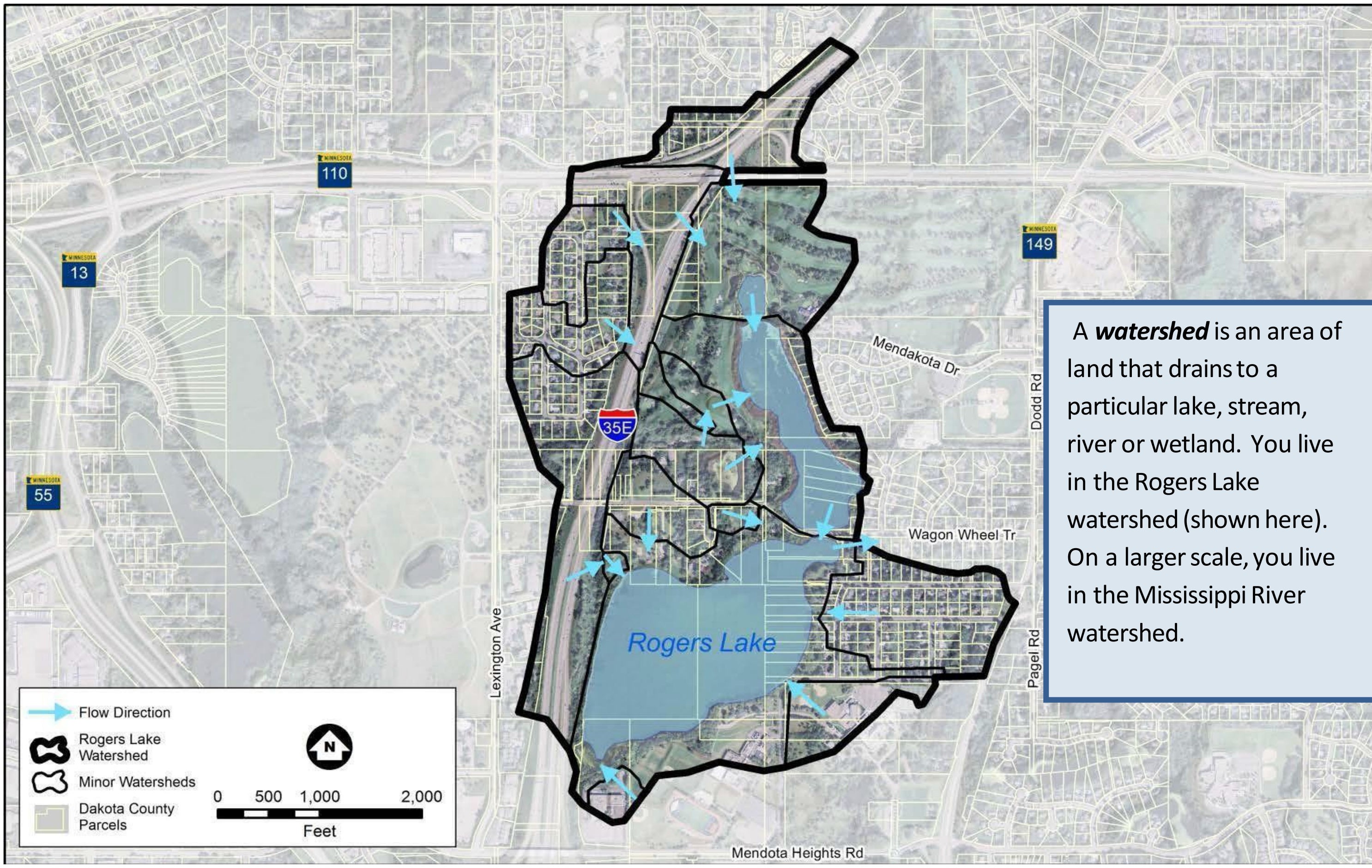
We want your thoughts, ideas and knowledge about Rogers Lake! Complete and return the enclosed survey. Also, plan to participate in a community conversation about Rogers Lake.

Community Conversation
November 15, 2012
Dakota Lodge
Thompson Lake Park
1200 Stassen Lane
West St. Paul
6:30 p.m.

What is the Lower Mississippi River Watershed Management Organization?

VISION: *Water resources and related ecosystems are managed to sustain their long-term health and integrity through member city collaboration and partnerships with other water management organizations with member city citizen support and participation.*

The Lower Mississippi River Watershed Management Organization (LMRWMO) is a local unit of government in northern Dakota County and southern Ramsey County that works to manage storm water and protect the lakes, streams and wetlands in all or part of Inver Grove Heights, Lilydale, Mendota Heights, St. Paul, South St. Paul, Sunfish Lake, and West St. Paul. Ultimately, these areas drain to the Mississippi River. Because rainfall and storm water runoff extends beyond municipal boundaries, the LMRWMO was established through an agreement among these cities in 1985. Its purpose is to address intercommunity storm water issues, ensure that storm water projects and studies follow accepted engineering standards, meet regulatory requirements, and ensure that the costs incurred are fairly divided among member cities. The LMRWMO also monitors water quality, provides water resource education to residents, elected officials, and city staff, provides grants to landowners installing practices that improve water quality, and performs studies such as the Watershed Restoration and Protection Study. (See article above.) Further information about the LMRWMO is available on their website: www.dakotaswcd.org/watersheds/lowermisswmo/index.html.



A ***watershed*** is an area of land that drains to a particular lake, stream, river or wetland. You live in the Rogers Lake watershed (shown here). On a larger scale, you live in the Mississippi River watershed.

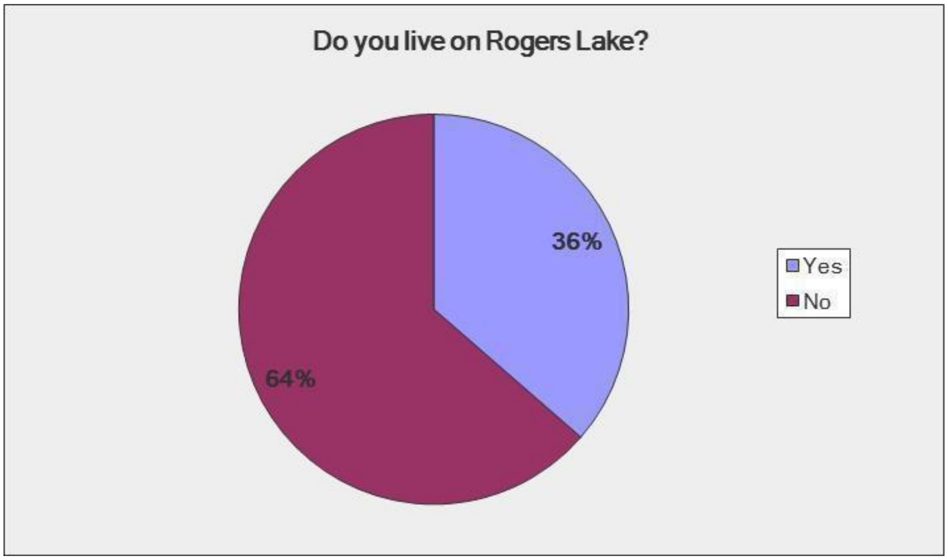
Treat Your Curb Like a Shoreline

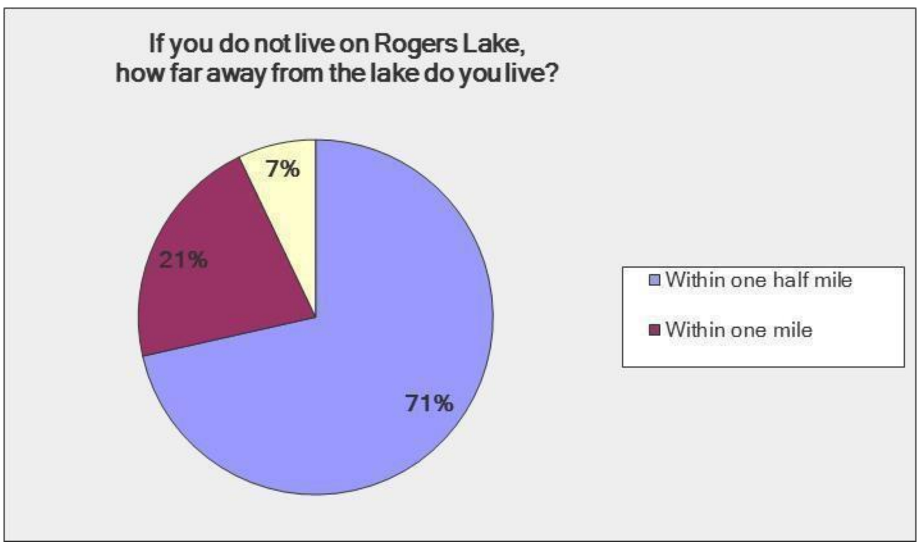
If you live along the shore of Rogers Lake, it's probably obvious that water running off your property ends up in the lake. However, even if you live several blocks or miles off the lake, runoff from your property drains to the lake through stormsewer pipes under your street – essentially turning every curb into a shoreline. Stormsewer systems are different from the sanitary sewer systems in which water used *inside* your home is treated at a wastewater treatment plant before being discharged to a waterbody. *Outside* your home, stormsewers collect rainwater and snowmelt leaving your property and convey them to Thompson Lake without treatment.

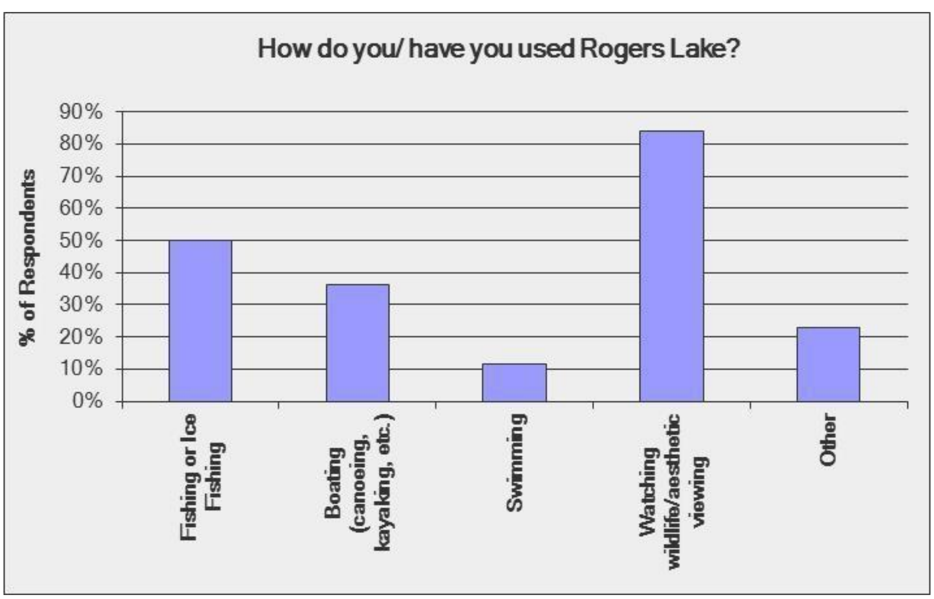
Pollutants carried in that runoff include lawn fertilizers, nutrients from decaying grass clippings and leaves, pesticides, toxins from coal-tar driveway sealants, oil and gas from leaking cars, pet waste, and salt, sand and other deicers. In the lake, these pollutants result in poor water quality – effecting aesthetics and recreational enjoyment of the lake as well as fish, bugs, birds, and their habitats.

As you might guess, once a waterbody is degraded, it can be costly to clean up. You can be part of the solution by using some easy practices at home: 1) sweep up grass clippings, fertilizer, leaves, and extra sand and salt before they get into the storm drain; 2) clean up after your pet; 3) install a rain barrel to collect rainwater for use in gardens; 4) keep your car in good repair; 5) use asphalt-based driveway sealants; 6) wash your car on the lawn. To learn more visit www.cleanwatermn.org or www.bluethumb.org.

Summary of results from Resident Input Survey sent to residents of the Rogers Lake Watershed. 45 responses out of 213 surveys mailed September 2012.







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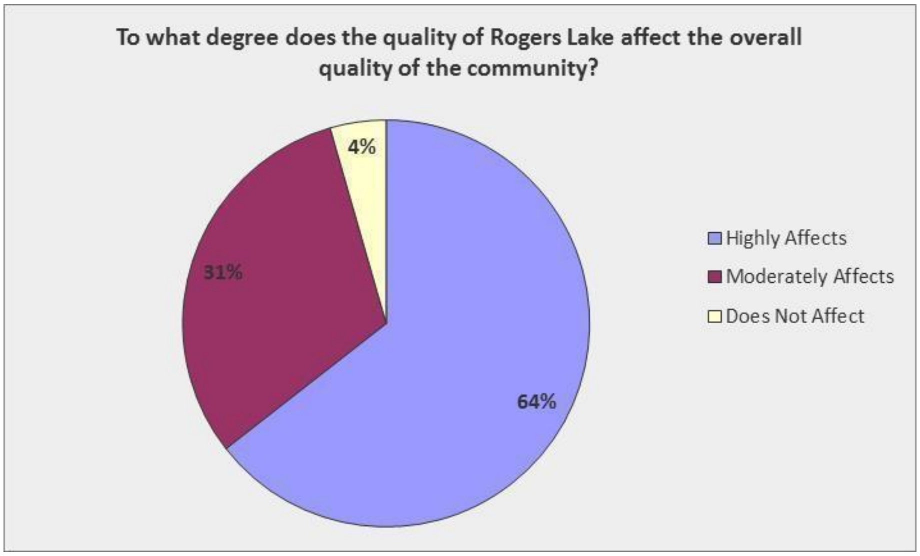

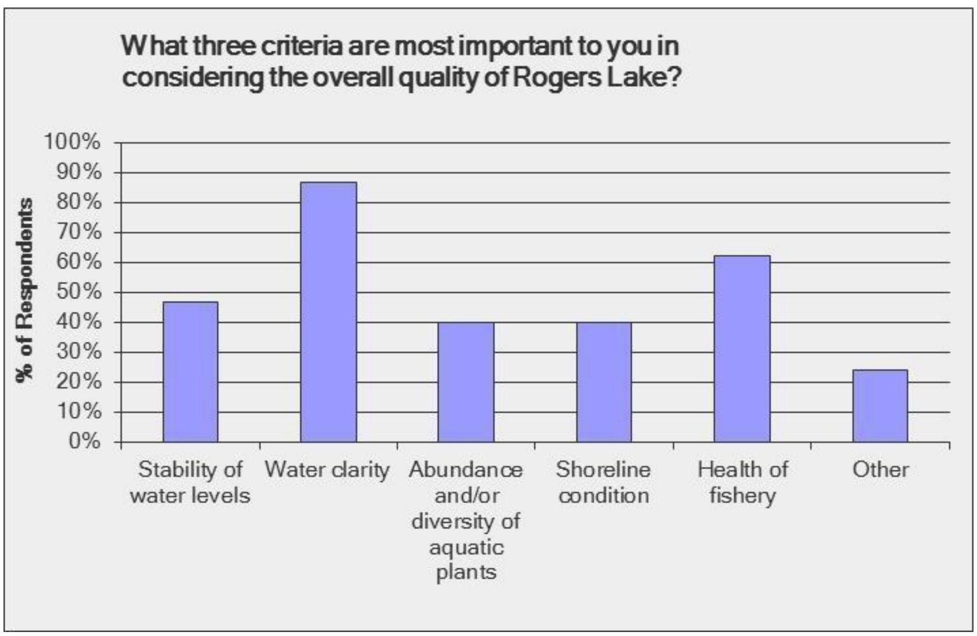

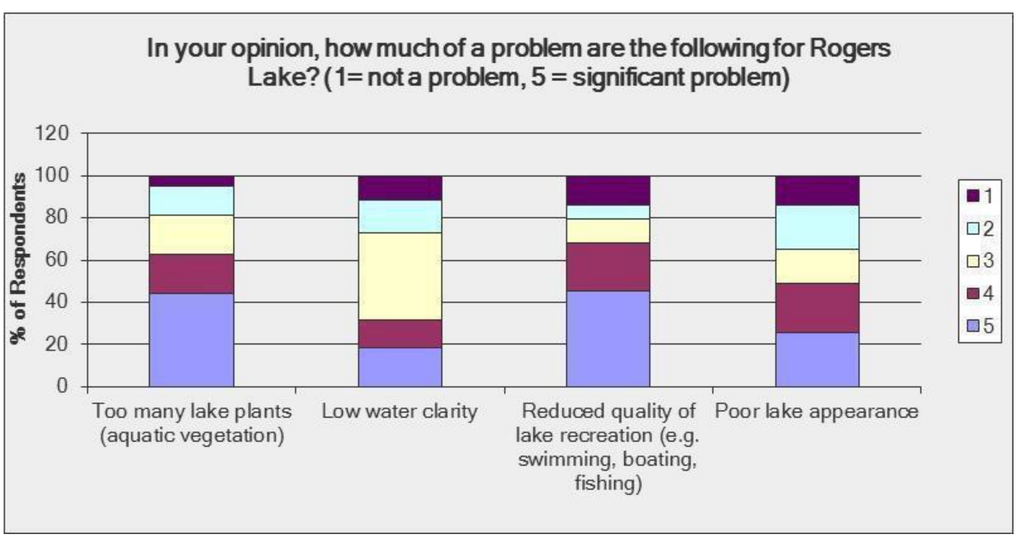

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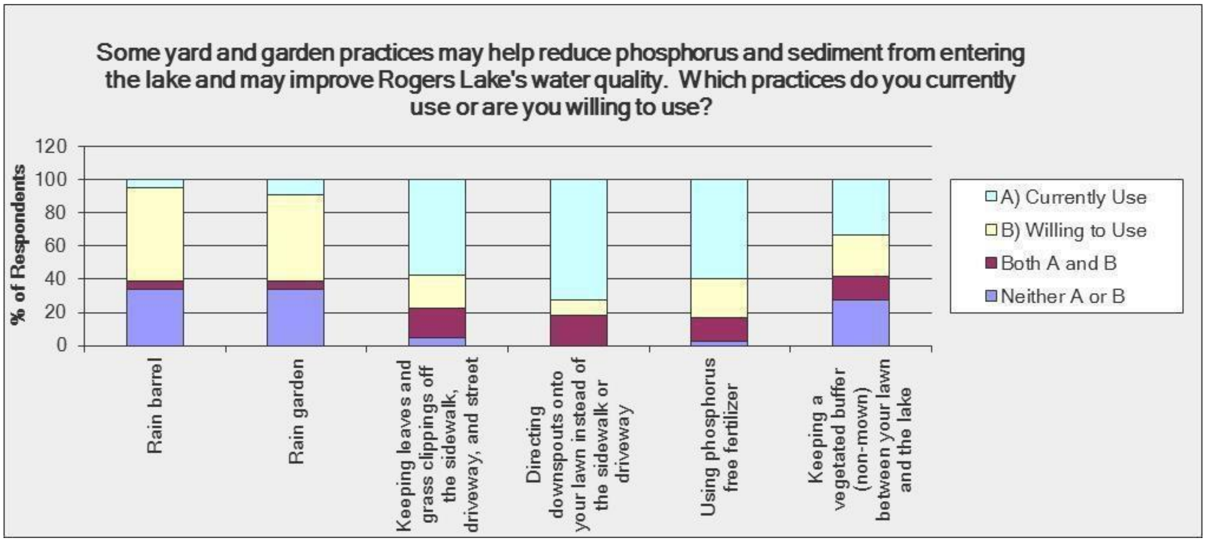

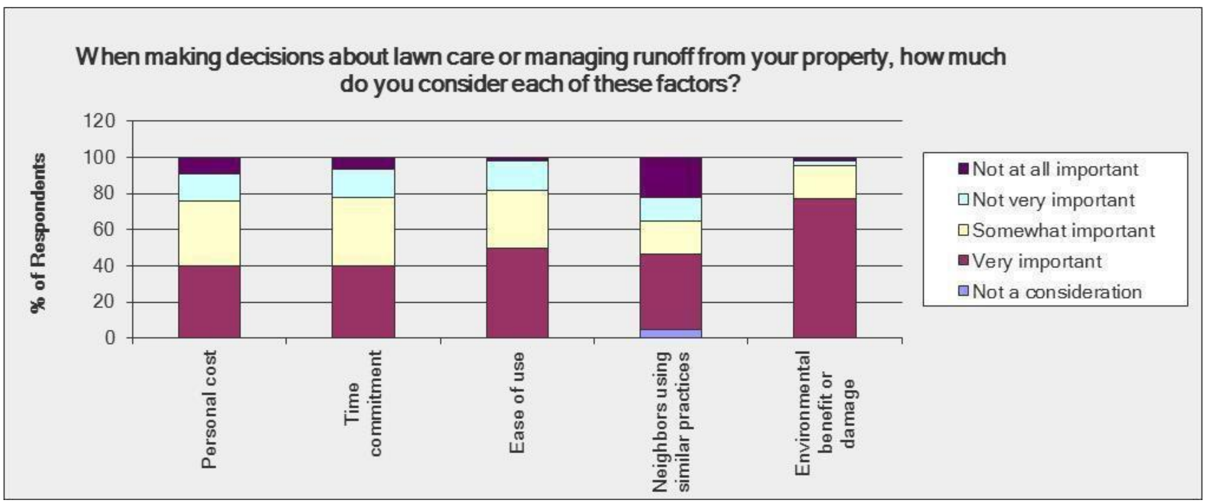

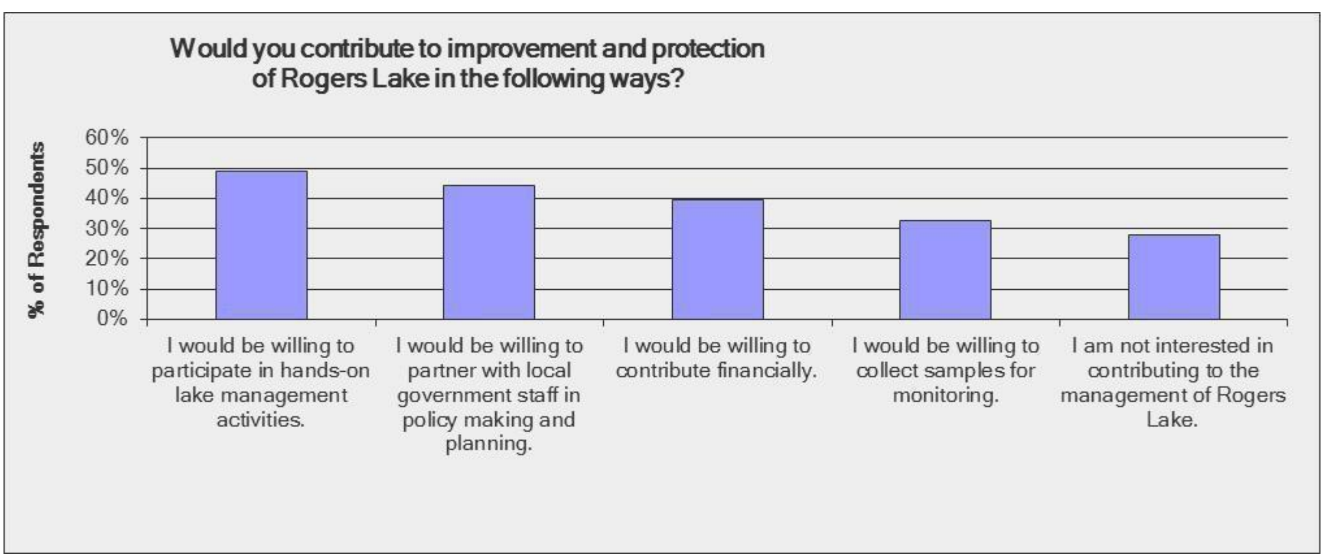

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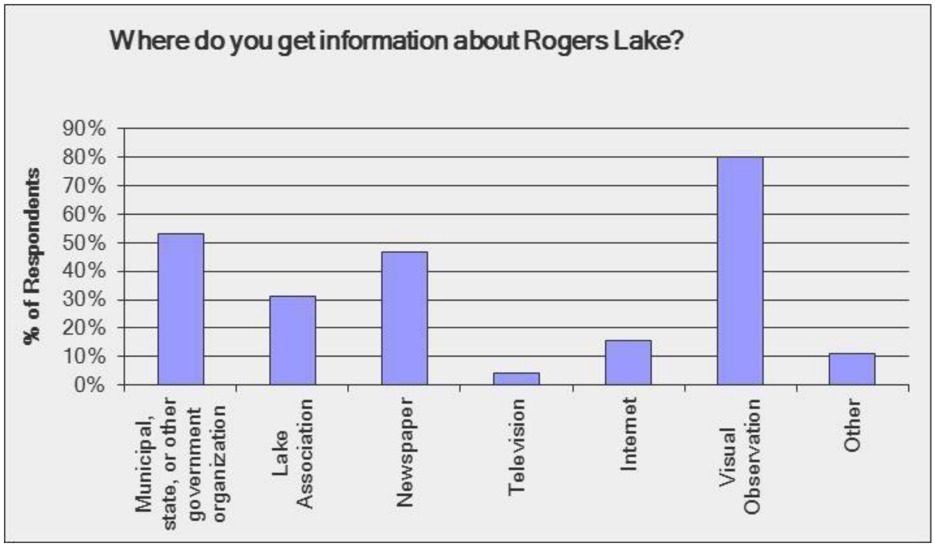

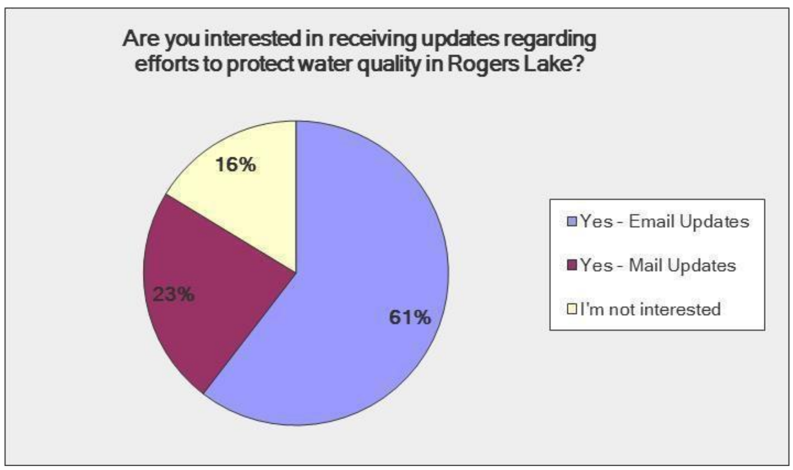

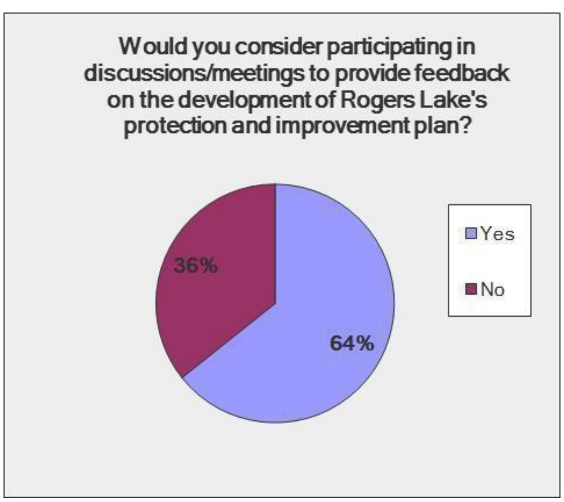

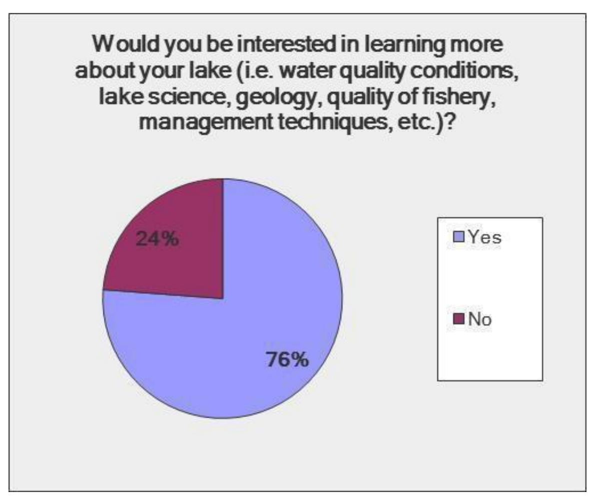

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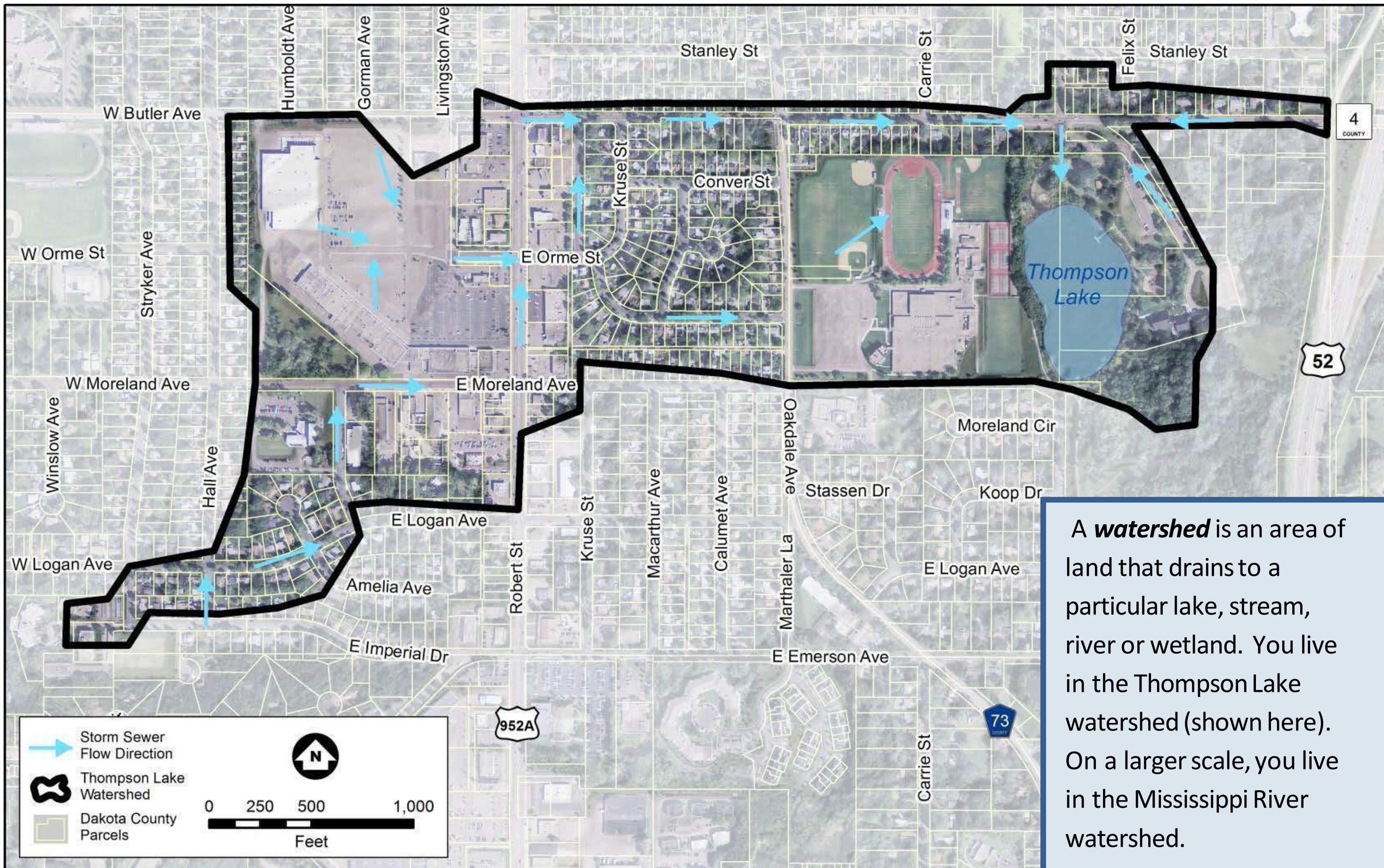


A ***watershed*** is an area of land that drains to a particular lake, stream, river or wetland. You live in the Thompson Lake watershed (shown here). On a larger scale, you live in the Mississippi River watershed.

Treat Your Curb Like a Shoreline

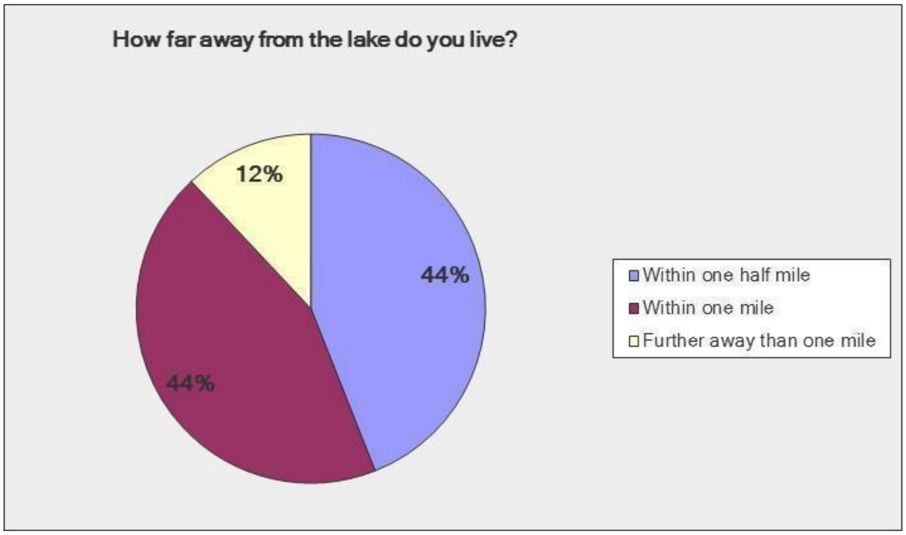
If you live along the shore of Thompson Lake, it's probably obvious that water running off your property ends up in the lake. However, even if you live several blocks or miles off the lake, runoff from your property drains to the lake through stormsewer pipes under your street – essentially turning every curb into a shoreline. Stormsewer systems are different from the sanitary sewer systems in which water used *inside* your home is treated at a wastewater treatment plant before being discharged to a waterbody. *Outside* your home, stormsewers collect rainwater and snowmelt leaving your property and convey them to Thompson Lake without treatment.

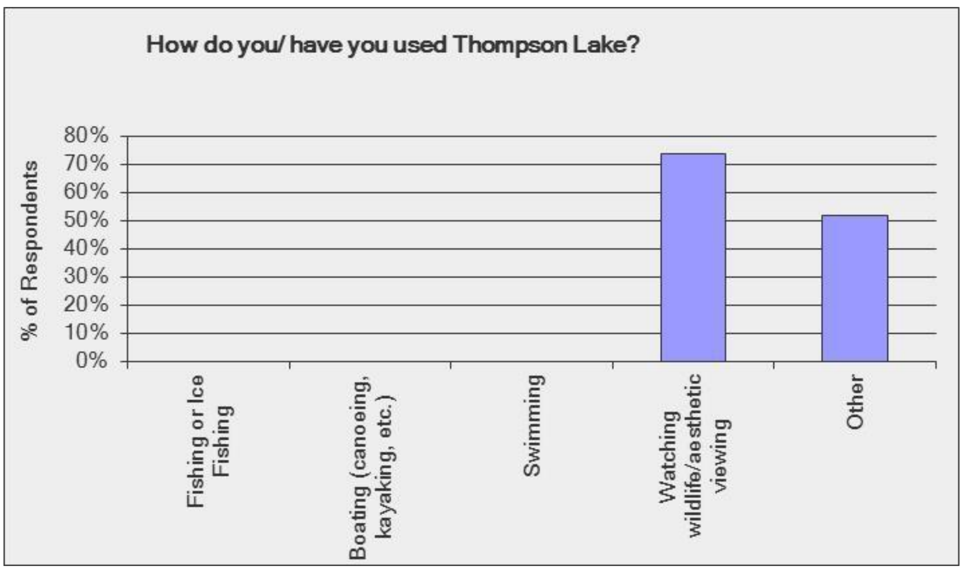
Pollutants carried in that runoff include lawn fertilizers, nutrients from decaying grass clippings and leaves, pesticides, toxins from coal-tar driveway sealants, oil and gas from leaking cars, pet waste, and salt, sand and other deicers. In the lake, these pollutants result in poor water quality – effecting aesthetics and recreational enjoyment of the lake as well as fish, bugs, birds, and their habitats.

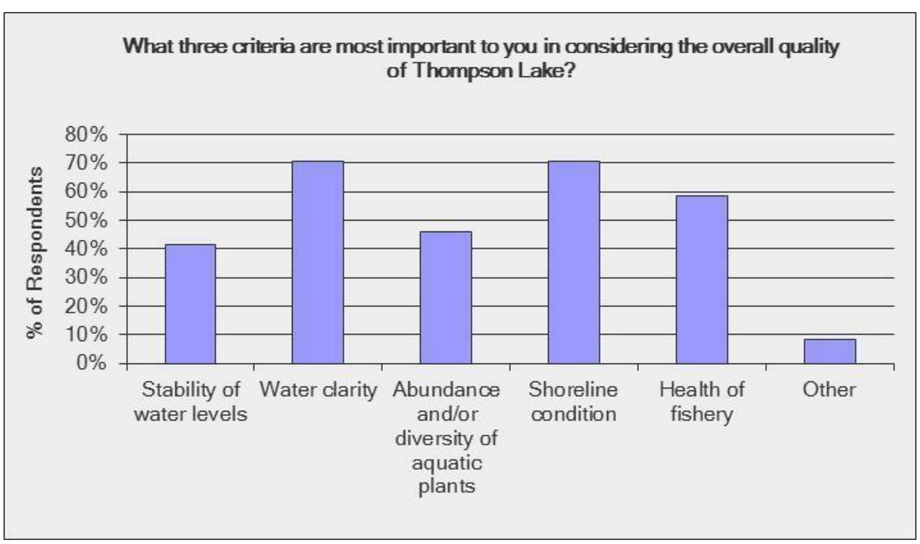
As you might guess, once a waterbody is degraded, it can be costly to clean up. You can be part of the solution by using some easy practices at home: 1) sweep up grass clippings, fertilizer, leaves, and extra sand and salt before they get into the storm drain; 2) clean up after your pet; 3) install a rain barrel to collect rainwater for use in gardens; 4) keep your car in good repair; 5) use asphalt-based driveway sealants; 6) wash your car on the lawn.

To learn more visit www.cleanwatermn.org or www.bluethumb.org.

Summary of results from Resident Input Survey sent to residents of the Thompson Lake Watershed. 25 responses out of 309 surveys mailed September 2012.







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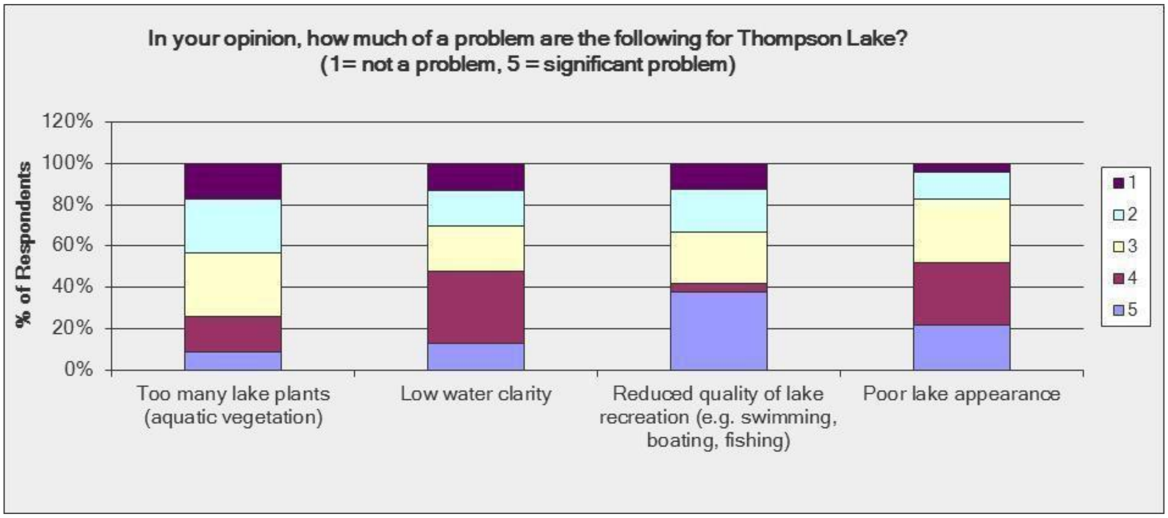

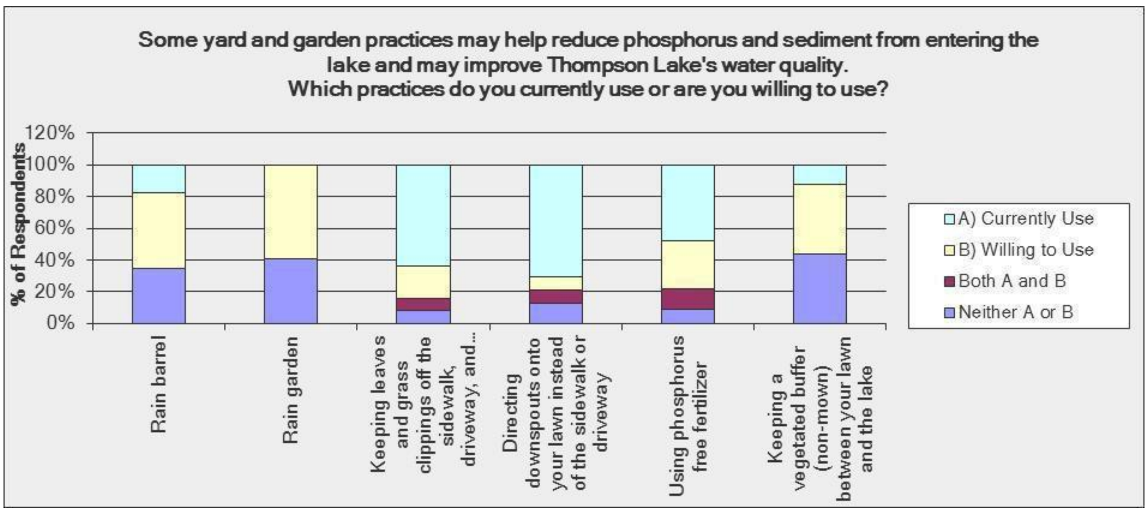

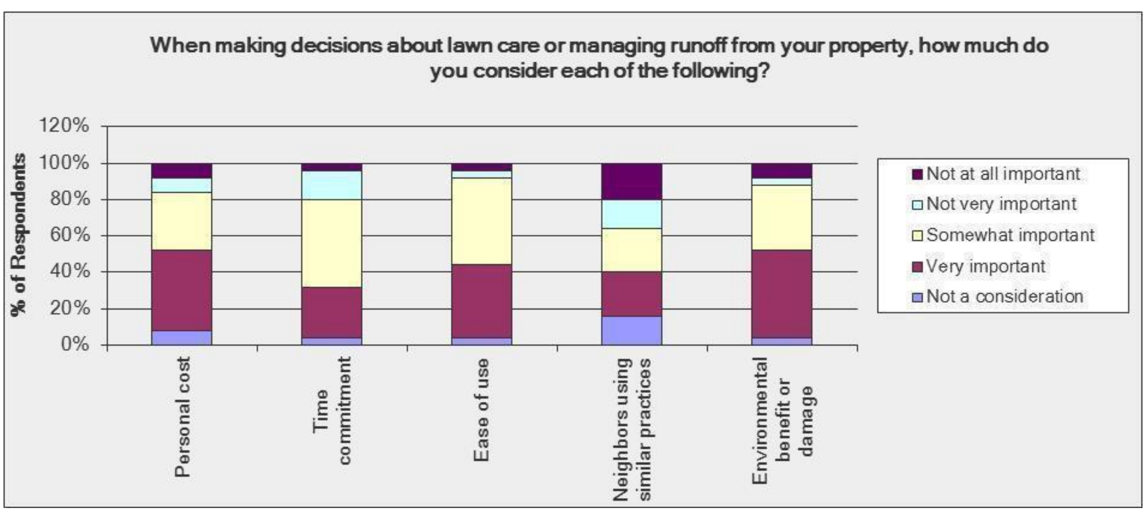

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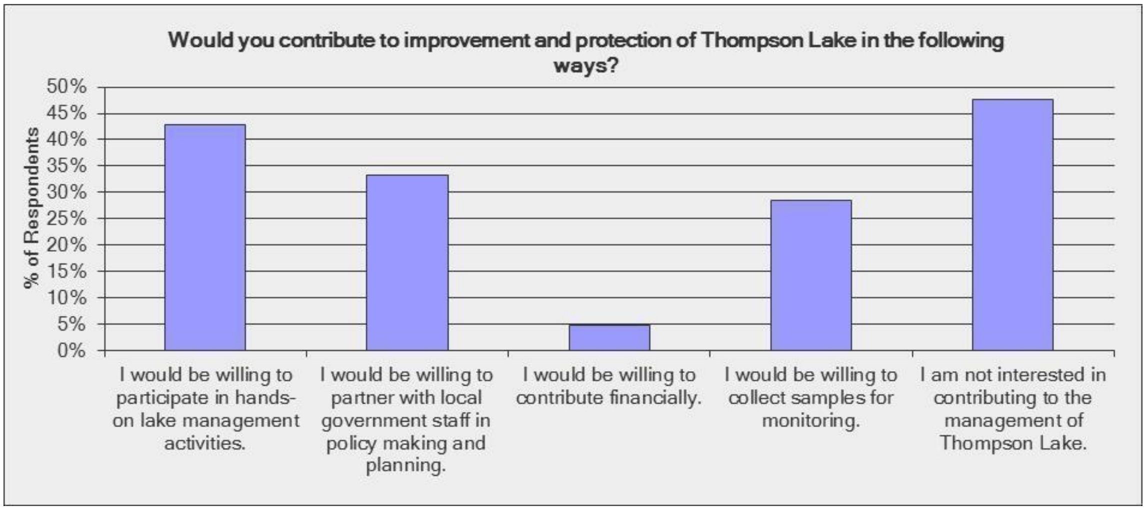

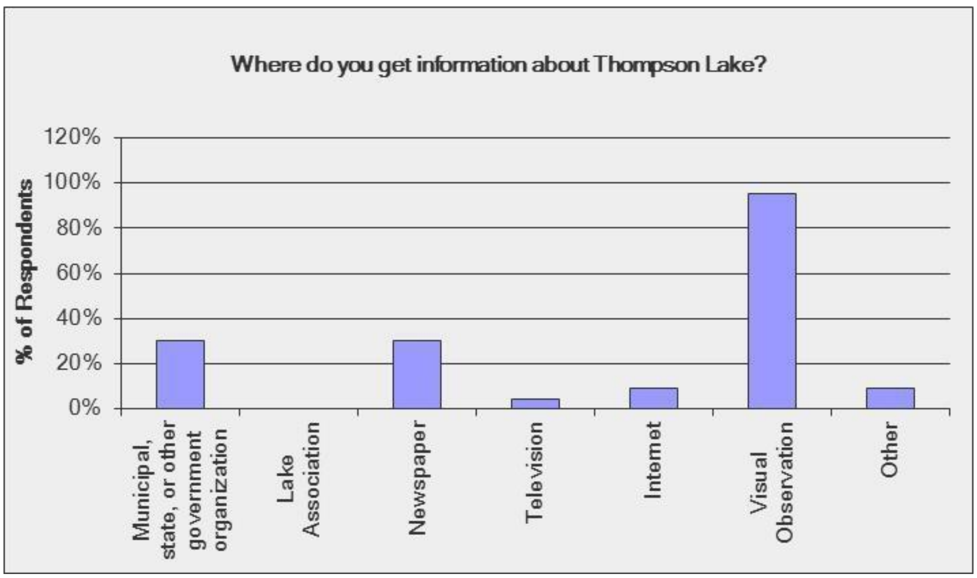

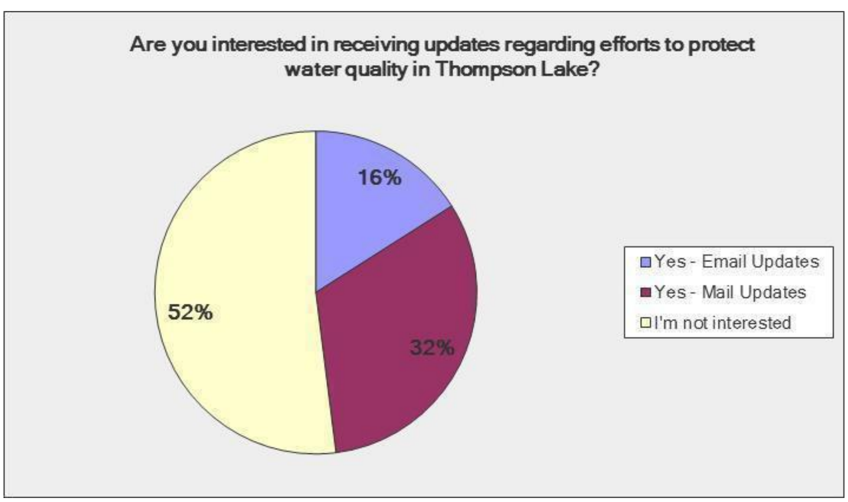

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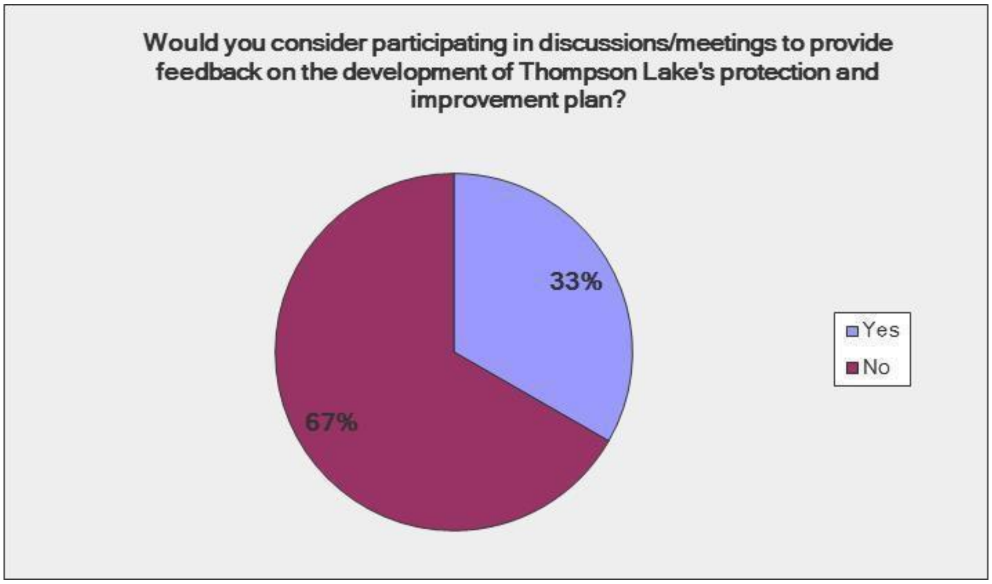

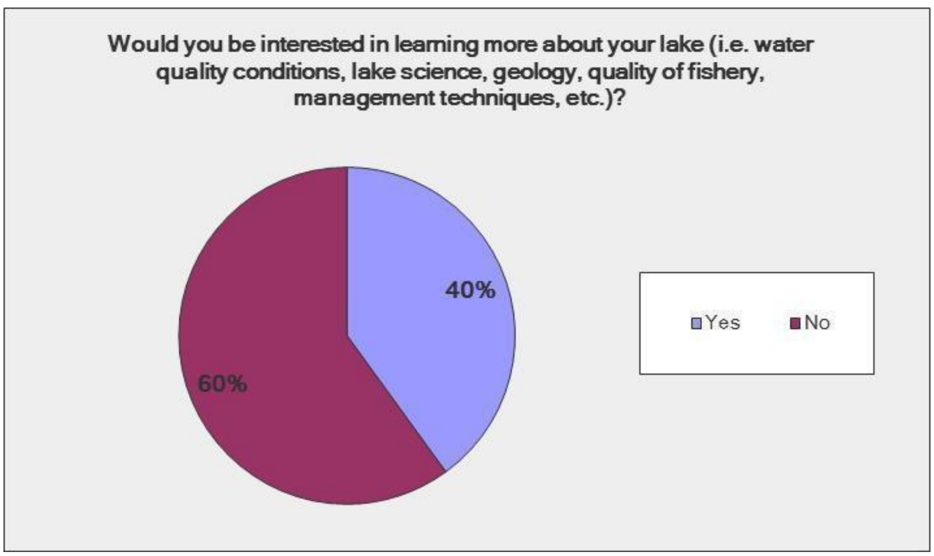

Your Connection to Sunfish Lake

Water Quality Study on Sunfish Lake

PURPOSE: *To understand the quality and conditions of Sunfish Lake and three other lakes in the area. And, to hear from residents in the watershed to understand their thoughts about Sunfish Lake and their willingness to contribute to improved wate r quality.*

This year, the Lower Mississippi River Watershed Management Organization (LMRWMO) is embarking on a project to gain a better understanding of four lakes and to engage the residents that live around or near these lakes. The Minnesota Pollution Control Agency is funding the project through the Clean Water Land and Legacy Act to study the water quality and pollution sources of Thompson Lake in West St. Paul, Pickerel Lake in Lilydale, Rogers Lake in Mendota Heights, and Sunfish Lake in the City of Sunfish Lake. The project, called a "Watershed Restoration and Protection (WRAP) Study," will result in restoration plans for lakes with poor water quality, and protection plans for lakes with good water quality.

Your property lies within the watershed of Sunfish Lake. That means that even if you live several blocks or even miles away, the rainwater and snowmelt that leave your property and neighborhood ultimately end up in the lake. Therefore, you and your neighbors may play an important role in improving and protecting Sunfish Lake into the future.

In addition to understanding the conditions of Sunfish Lake and the possible sources of degradation, the WRAP Study will involve residents of the watershed, like you. We hope to learn your thoughts about the lake, your vision for its future condition, and your willingness to be part of the solution. Right now, you can help by completing and returning the enclosed survey, and participating in the community conversations about Sunfish Lake.

WE WANT YOUR FEEDBACK!

We want your thoughts, ideas and knowledge about Sunfish Lake! Completeand returnthe enclosed survey. Also, plan to participate in a community conversation about Sunfish Lake.

Community Conversation
November 15,2012
Dakota Lodge
Thompson Lake Park
1200 Stassen Lane
West St. Paul
6:30p.m.

What is the Lower Mississippi River Watershed Management Organization?

VISION: *Water resources and related ecosystems are managed to sustain their long-term health and integrity through membercity collaboration and partnerships with other water management organizations with member city citizen support and participation.*

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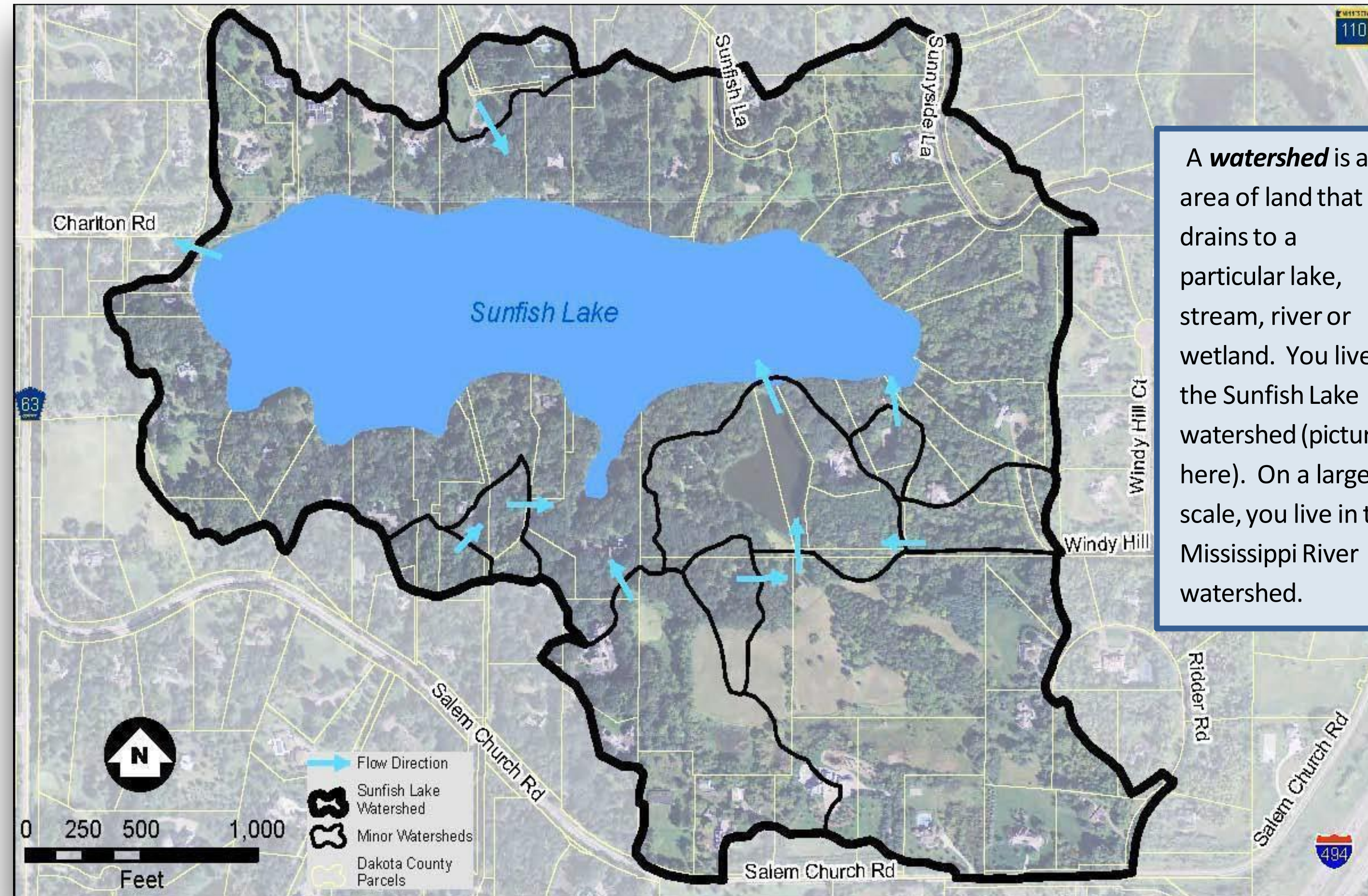


A ***watershed*** is an area of land that drains to a particular lake, stream, river or wetland. You live in the Sunfish Lake watershed (pictured here). On a larger scale, you live in the Mississippi River watershed.

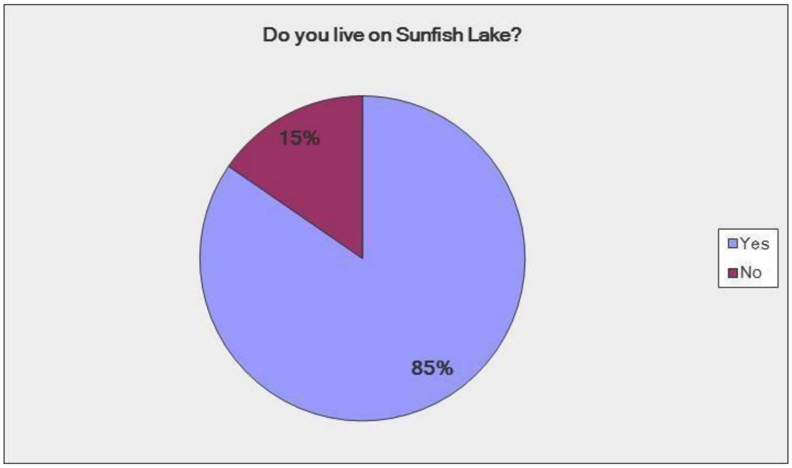
Every Property is Like a Shoreline

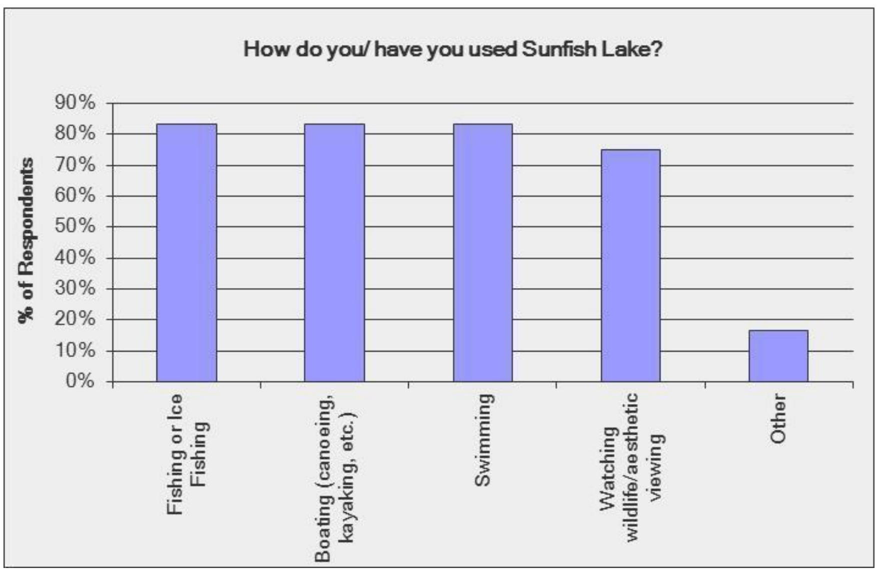
If you live along the shore of Sunfish Lake, it's probably obvious that water running off your property ends up in the lake. However, even if you live several blocks off the lake, runoff from your property likely gets to the lake through drainage swales on your land. These pathways to the lake essentially turn every property into a shoreline. These swales collect rainwater and snowmelt leaving your property and convey them to Sunfish Lake without treatment.

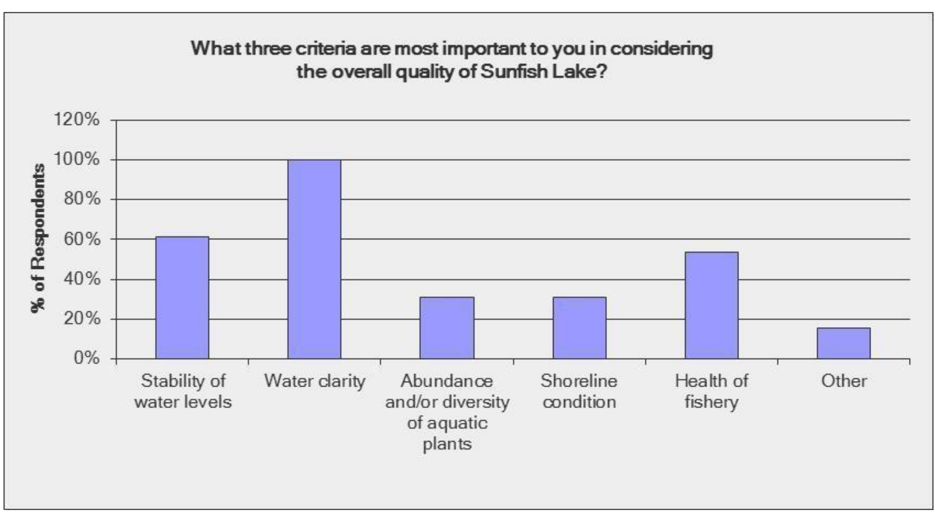
Pollutants carried in that runoff include lawn fertilizers, nutrients from decaying grass clippings and leaves, pesticides, toxins from coal-tar driveway sealants, oil and gas from leaking cars, pet waste, and salt, sand and other deicers. In the lake, these pollutants result in poor water quality – affecting aesthetics and recreational enjoyment of the lake, as well as fish, bugs, birds, and their habitats. Other sources of pollution in Sunfish Lake may include leaking or non-compliant septic systems, re-suspension of nutrients that entered the lake long ago, and the die-off of aquatic plants through natural processes or herbicide treatments.

As you might guess, once a waterbody is degraded, it can be costly and time consuming to clean up. You can be part of the solution by using some easy practices at home: 1) plant a native garden along your shoreline to provide a buffer from the lawn; 2) stabilize any eroding areas along the lake with vegetation; 3) sweep or rake excess grass clippings, fertilizer, leaves, and deicers before they get into the drainage swale; 4) clean up after your pet; 5) install a rain barrel to collect rainwater for use in gardens; 6) keep your car in good repair; 7) use asphalt-based driveway sealants; 8) wash your car on the lawn. To learn more visit www.cleanwatermn.org or www.bluethumb.org.

Summary of results from Resident Input Survey sent to residents of the Sunfish Lake Watershed. 13 responses out of 45 surveys mailed September 2012.







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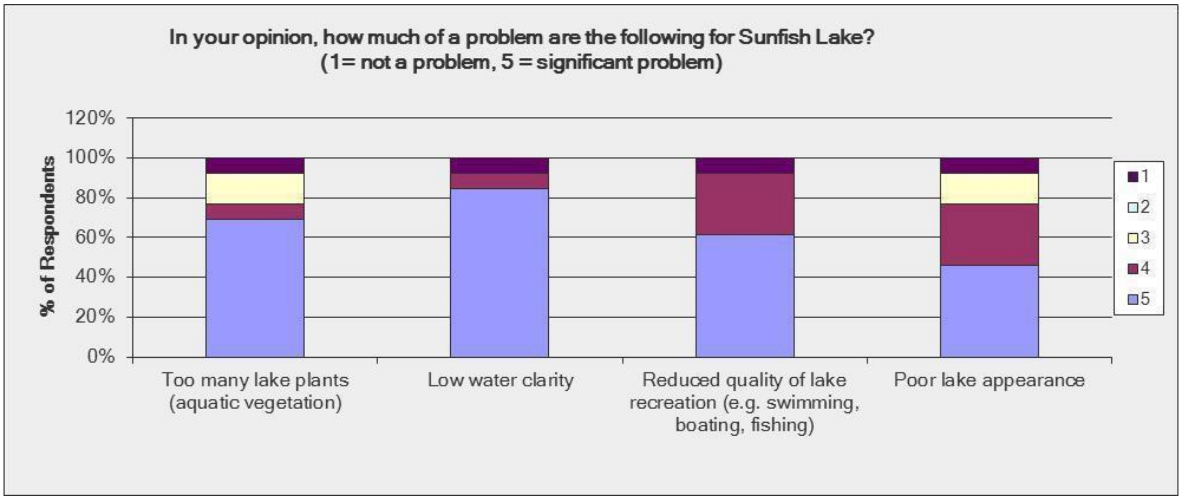

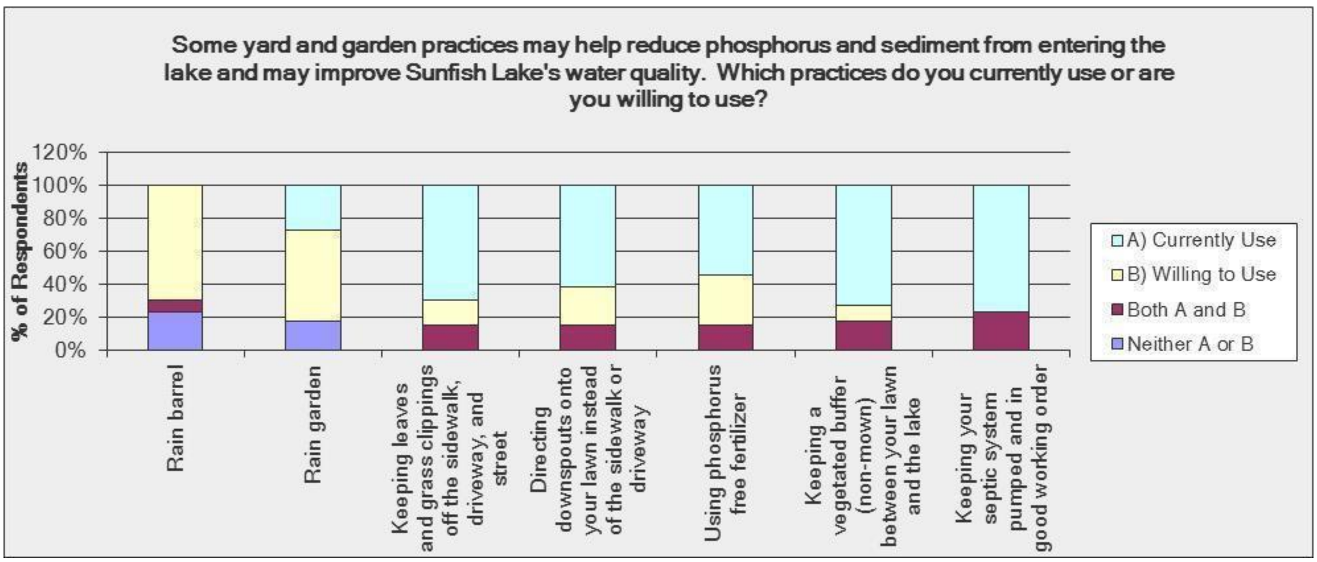

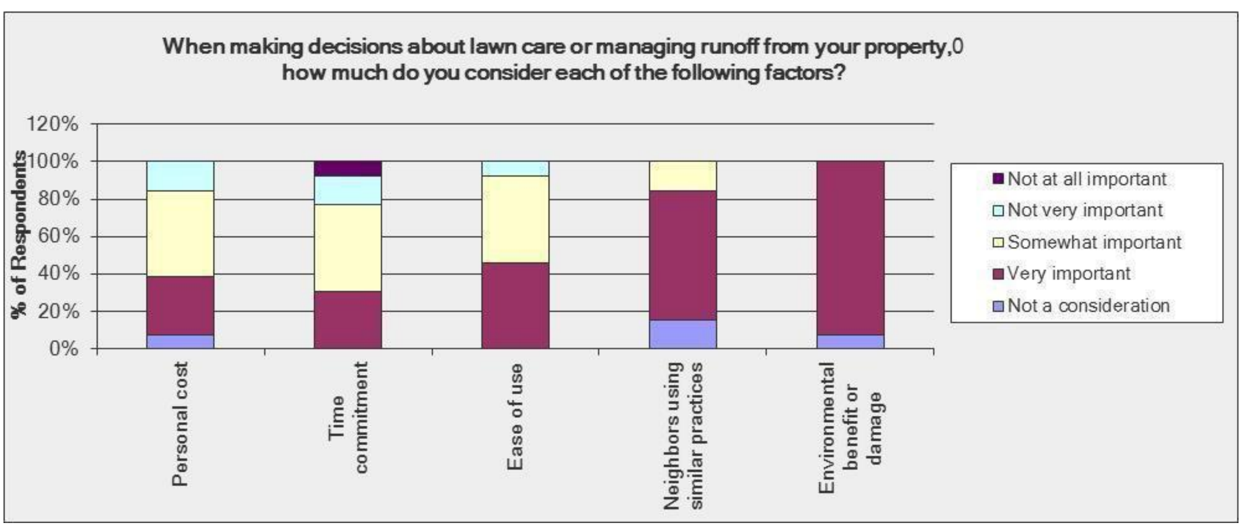

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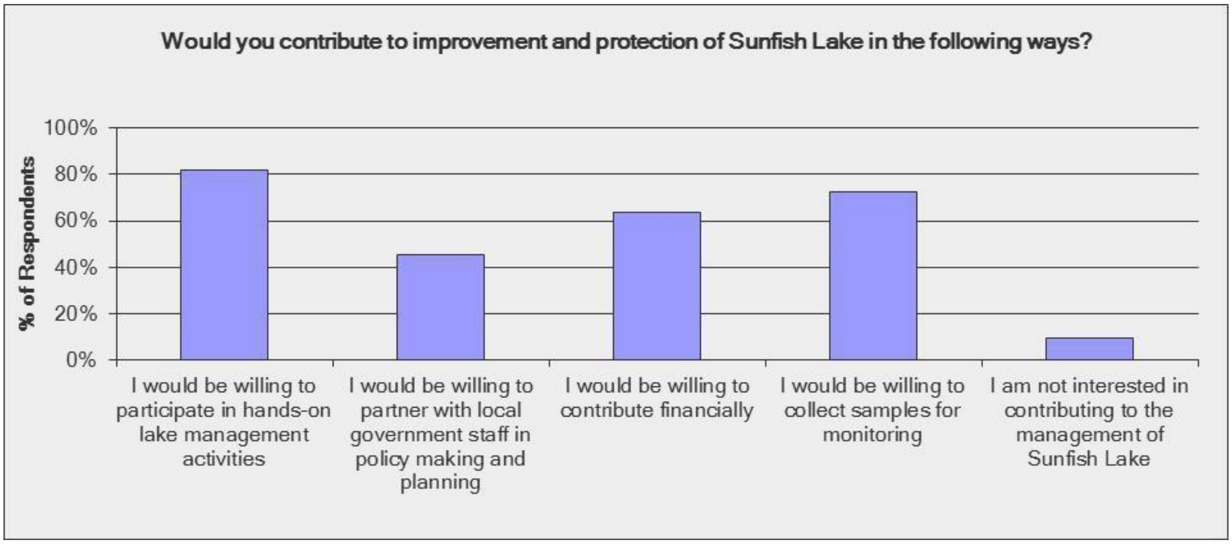

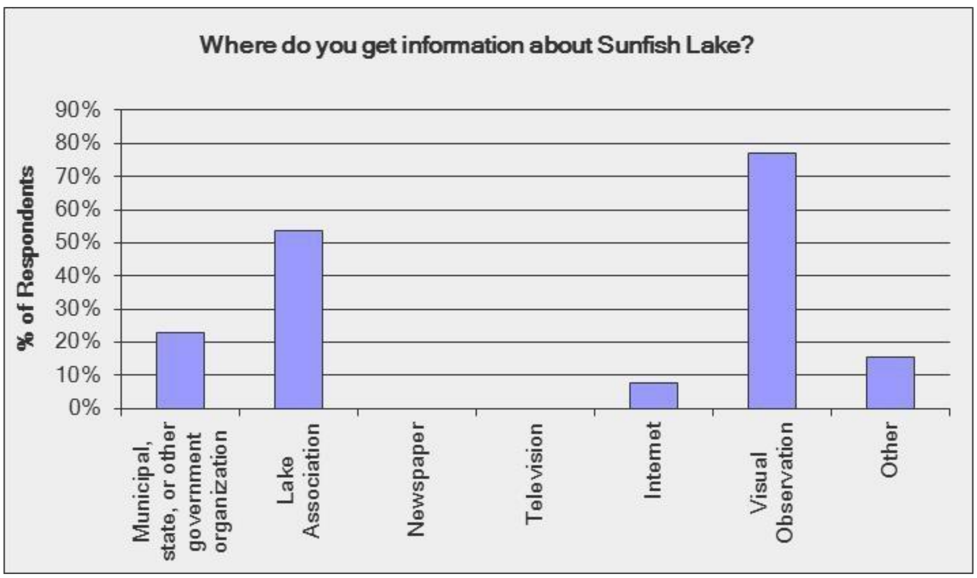

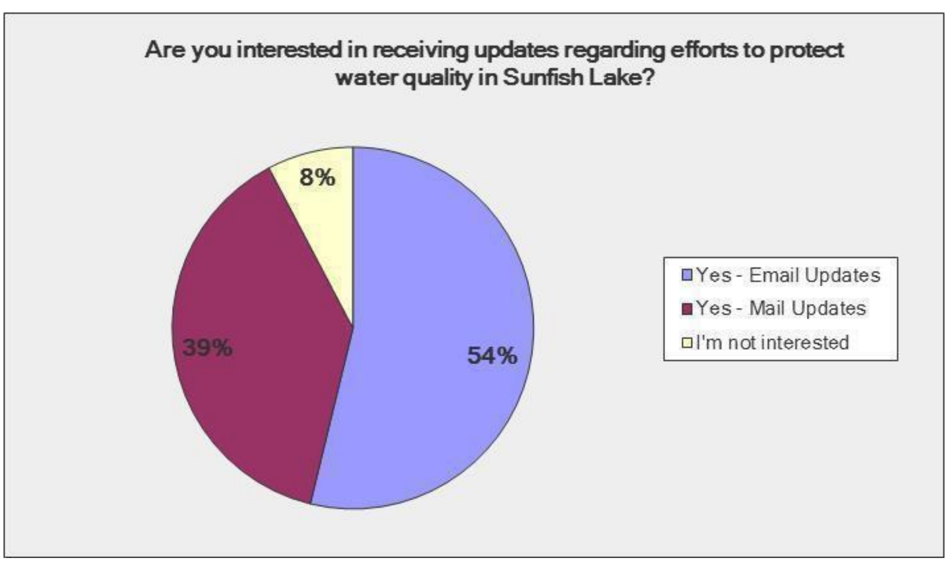

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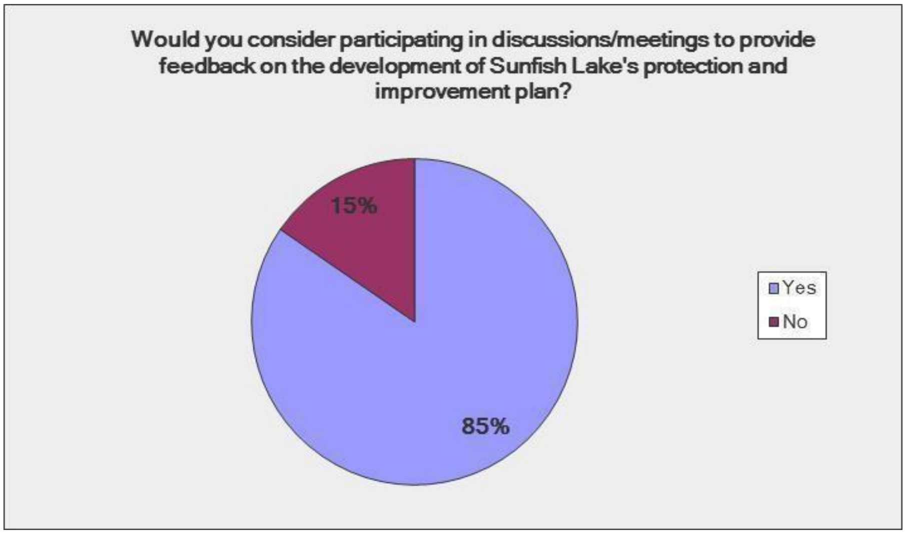

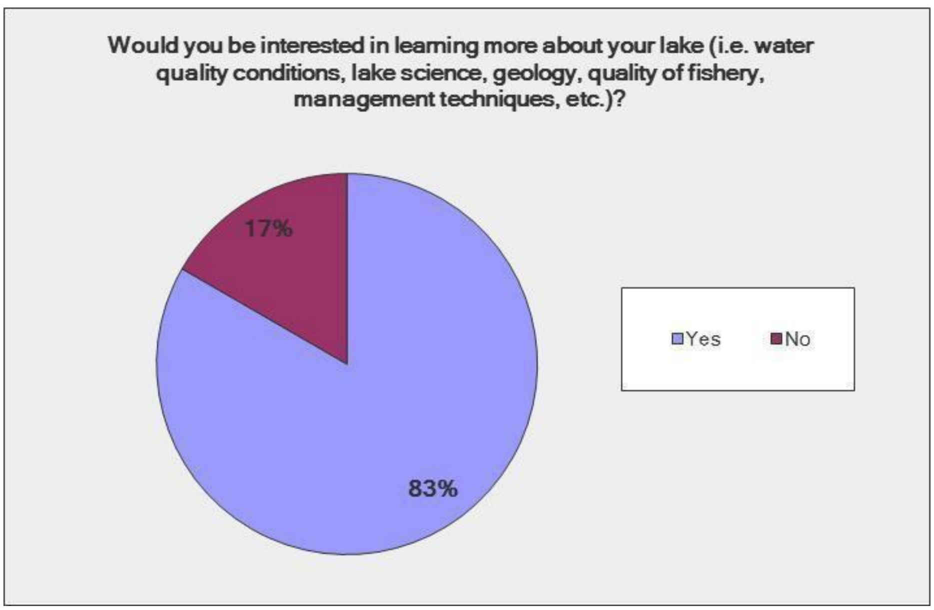

Your Connection to Pickerel Lake

Water Quality Study on Pickerel Lake

PURPOSE: *To understand the quality and conditions of Pickerel Lake and three other lakes in the area. And, to hear from residents in the watershed to understand their thoughts about Pickerel Lake and their willingness to contribute to improved water quality.*

This year, the Lower Mississippi River Watershed Management Organization (LMRWMO) is embarking on a project to gain a better understanding of four lakes and to engage the residents that live around or near these lakes. The Minnesota Pollution Control Agency is funding the project through the Clean Water Land and Legacy Act to study the water quality and pollution sources of Thompson Lake in West St. Paul, Pickerel Lake in Lilydale, Rogers Lake in Mendota Heights, and Sunfish Lake in the City of Sunfish Lake. The project, called a “Watershed Restoration and Protection (WRAP) Study,” will result in restoration plans for lakes with poor water quality, and protection plans for lakes with good water quality.

Your property lies within the watershed of Pickerel Lake. That means that even if you live several blocks or even miles away, the rainwater and snowmelt that leave your property and neighborhood ultimately end up in the lake, in most cases by traveling through Ivy Falls Creek. Therefore, you and your neighbors may play an important role in improving and protecting Pickerel Lake into the future.

In addition to understanding the conditions of Pickerel Lake and the possible sources of degradation, the WRAP Study will involve residents of the watershed, like you. We hope to learn your thoughts about the lake, your vision for its future condition, and your willingness to be part of the solution. Right now, you can help by completing and returning the enclosed survey, and participating in the community conversations about Pickerel Lake.

WE WANT YOUR FEEDBACK!

We want your thoughts, ideas and knowledge about Pickerel Lake! Complete and return the enclosed survey. Also, plan to participate in a community conversation about Pickerel Lake.

Community Conversation
November 15, 2012
Dakota Lodge
Thompson Lake Park
1200 Stassen Lane
West St. Paul
6:30 p.m.

CLEAN WATER LAND & LEGACY AMENDMENT

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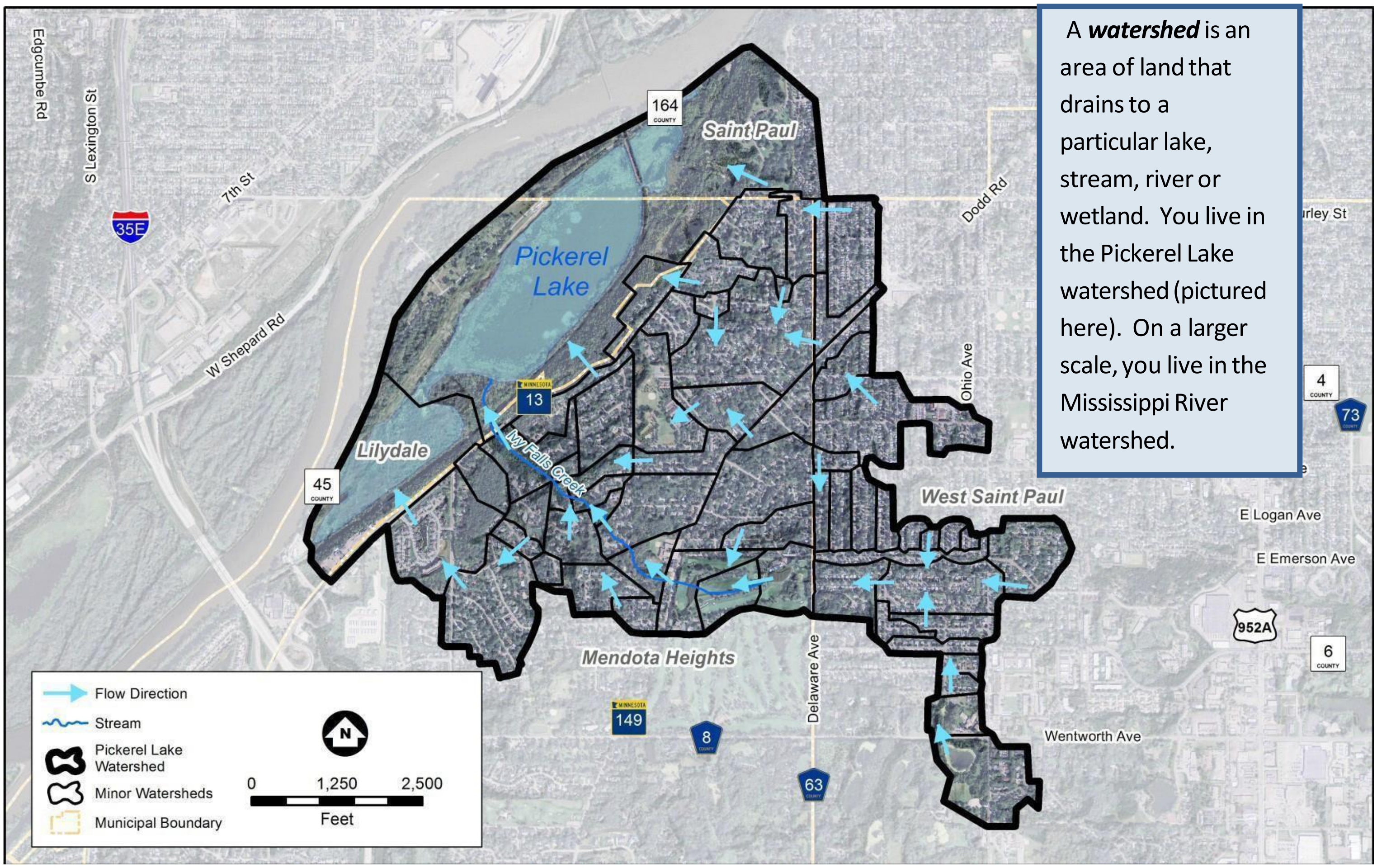

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Treat Your Curb Like a Shoreline

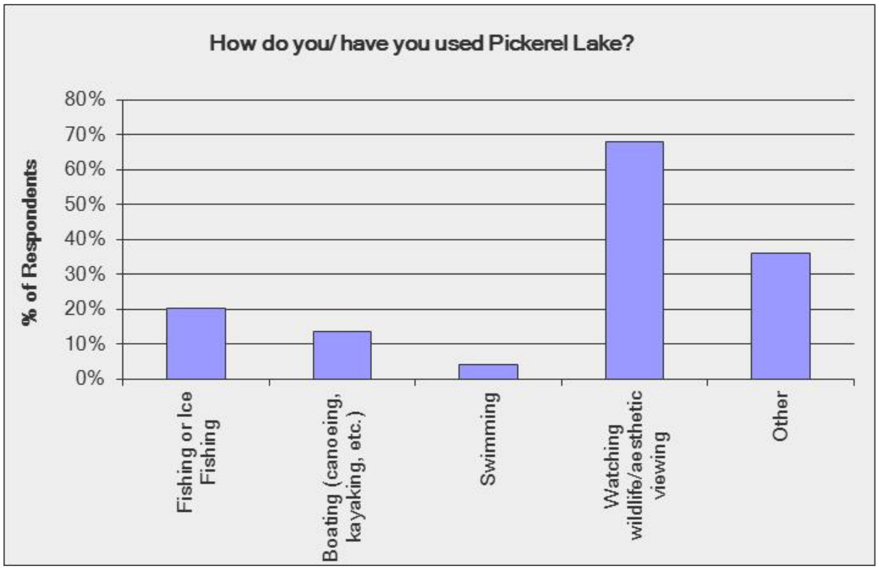
Your connection to Pickerel Lake probably isn't obvious. However, even if you live several blocks or even miles off the lake, runoff from your property drains to the lake through stormsewer pipes under your street – essentially turning every curb into a shoreline. Stormsewer systems are different from the sanitary sewer systems in which water used *inside* your home is treated at a wastewater treatment plant before being discharged to a waterbody. *Outside* your home, stormsewers collect rainwater and snowmelt leaving your property and convey them to Pickerel Lake without treatment.

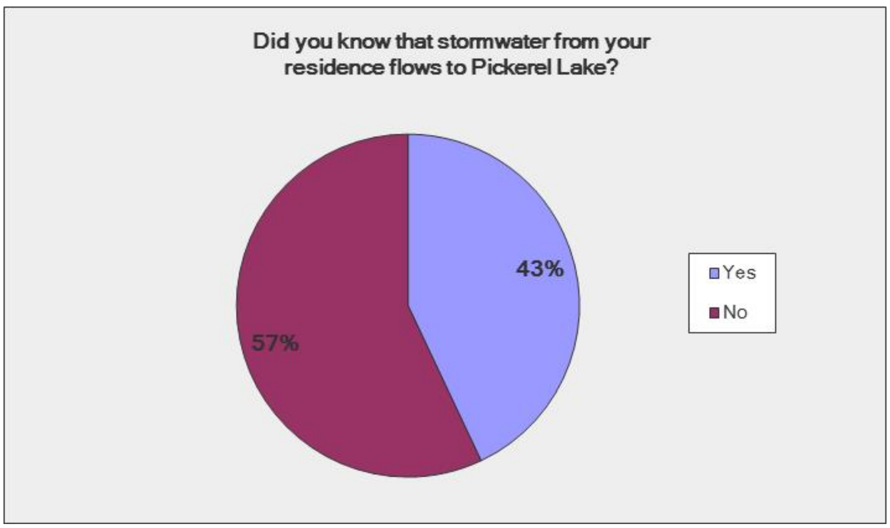
Pollutants carried in that runoff include lawn fertilizers, nutrients from decaying grass clippings and leaves, pesticides, toxins from coal-tar driveway sealants, oil and gas from leaking cars, pet waste, and salt, sand and other deicers. In the lake, these pollutants result in poor water quality – effecting aesthetics and recreational enjoyment of the lake as well as fish, bugs, birds, and their habitats.

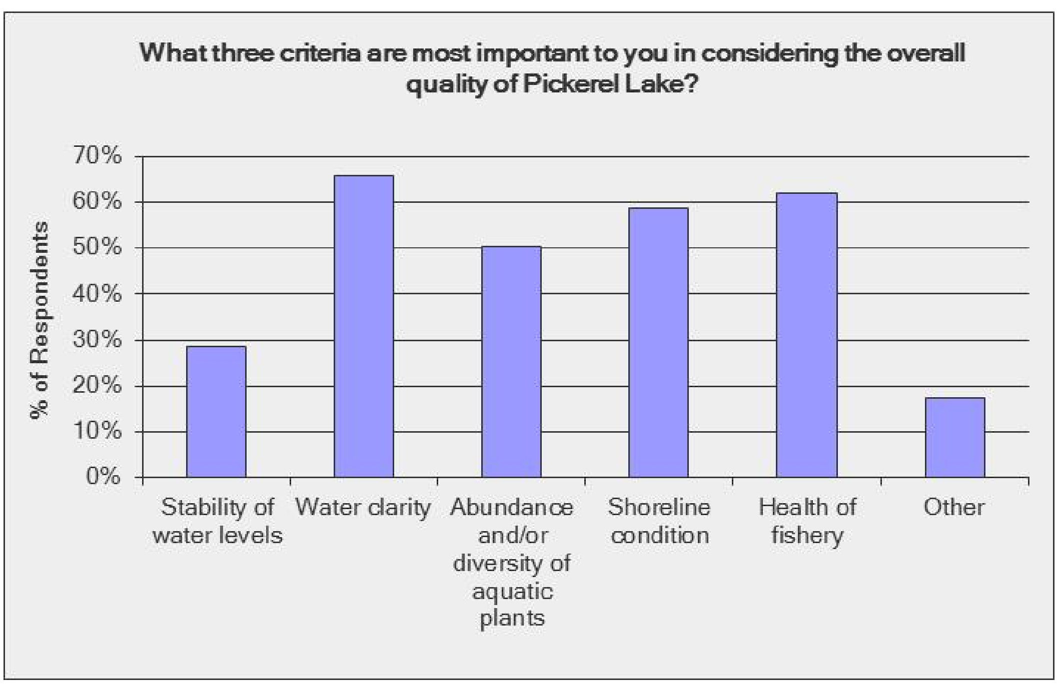
As you might guess, once a waterbody is degraded, it can be costly to clean up. You can be part of the solution by using some easy practices at home: 1) sweep up grass clippings, fertilizer, leaves, and extra sand and salt before they get into the storm drain; 2) install a raingarden to capture runoff from your roof or driveway and let it soak into the ground; 3) clean up after your pet; 4) install a rain barrel to collect rainwater for use in gardens; 5) keep your car in good repair; 6) use asphalt-based driveway sealants; 7) wash your car on the lawn.

To learn more visit www.cleanwatermn.org or www.bluethumb.org.

Summary of results from Resident Input Survey sent to residents of the Pickerel Lake Watershed. 162 responses out of 1942 surveys mailed September 2012.







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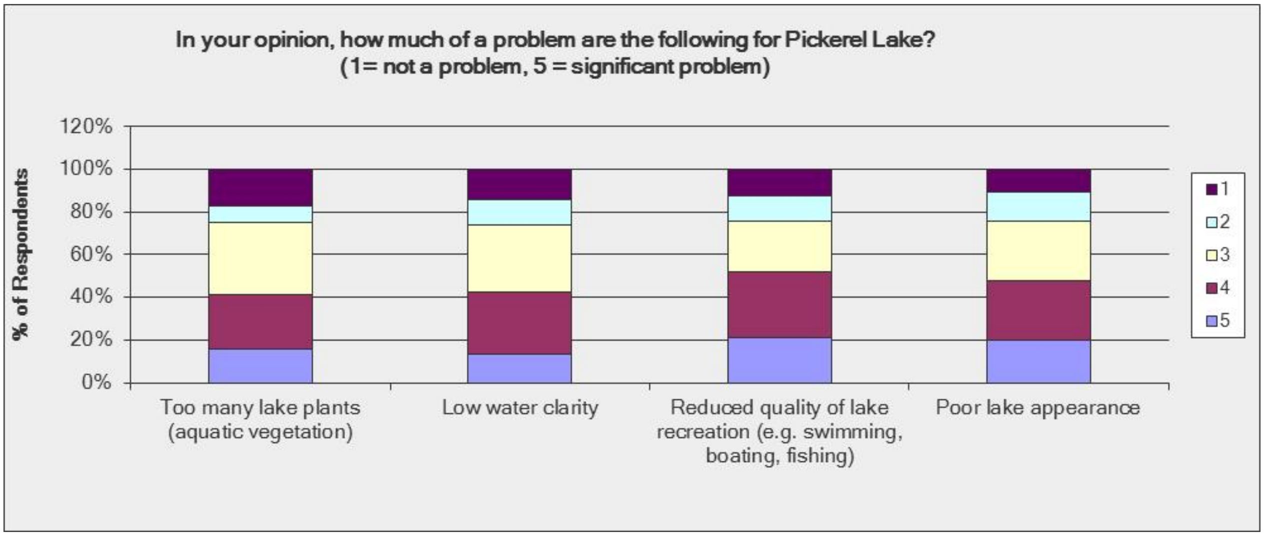

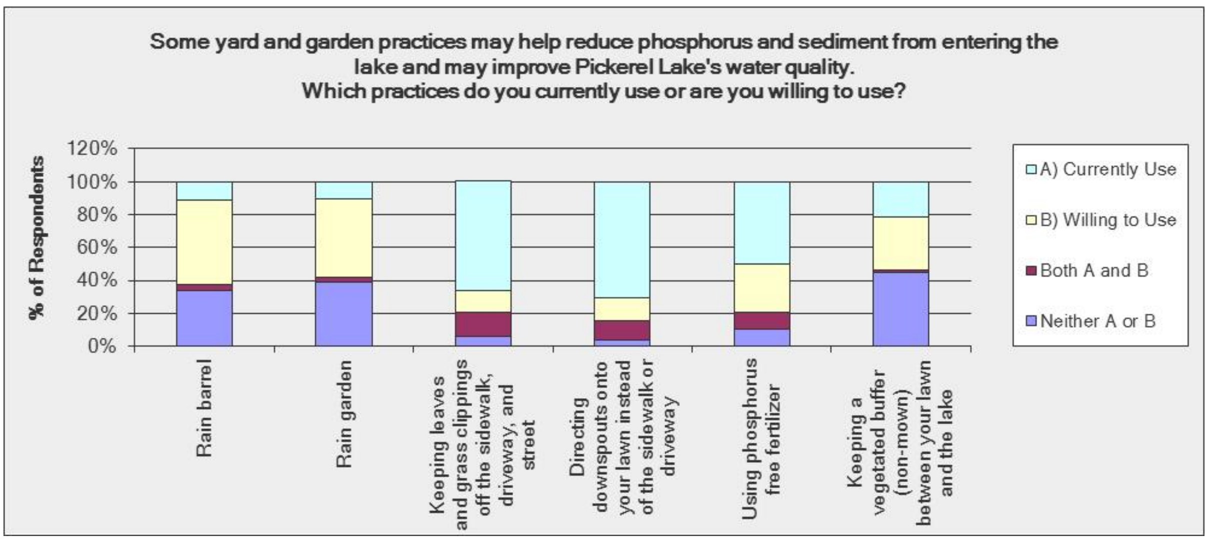

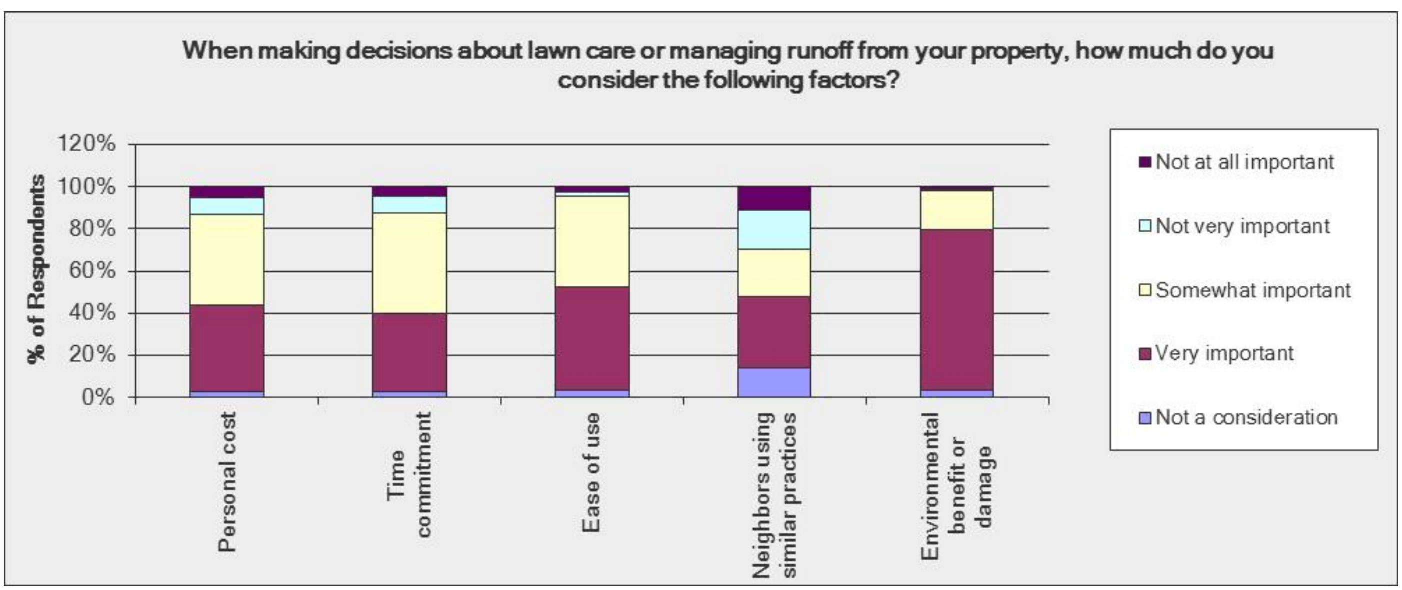

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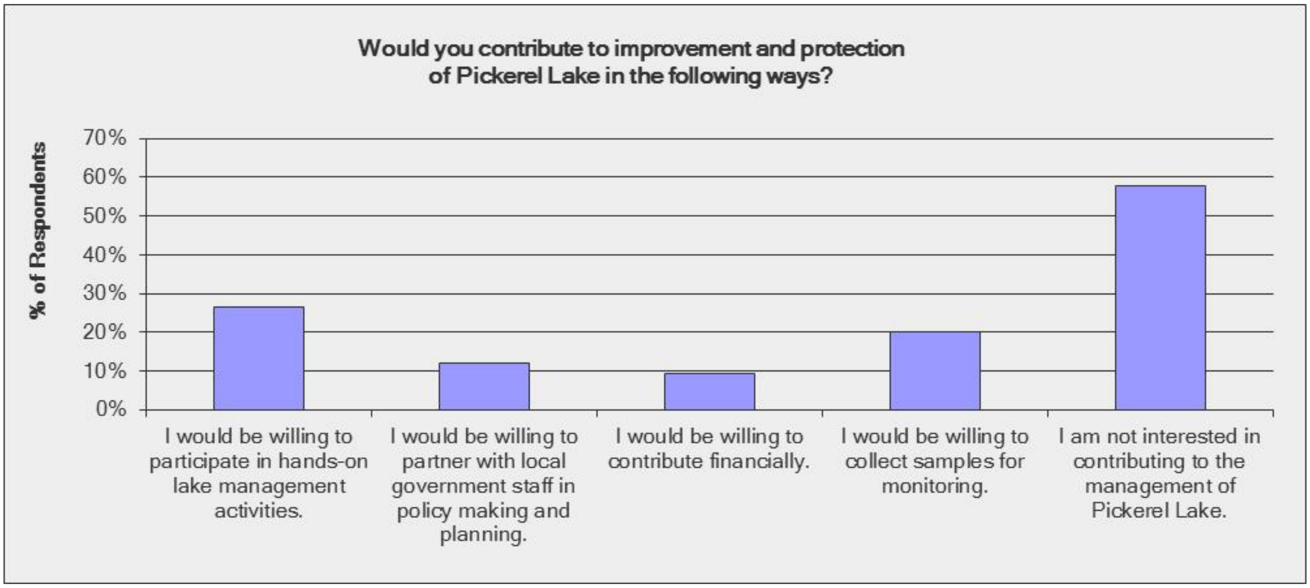

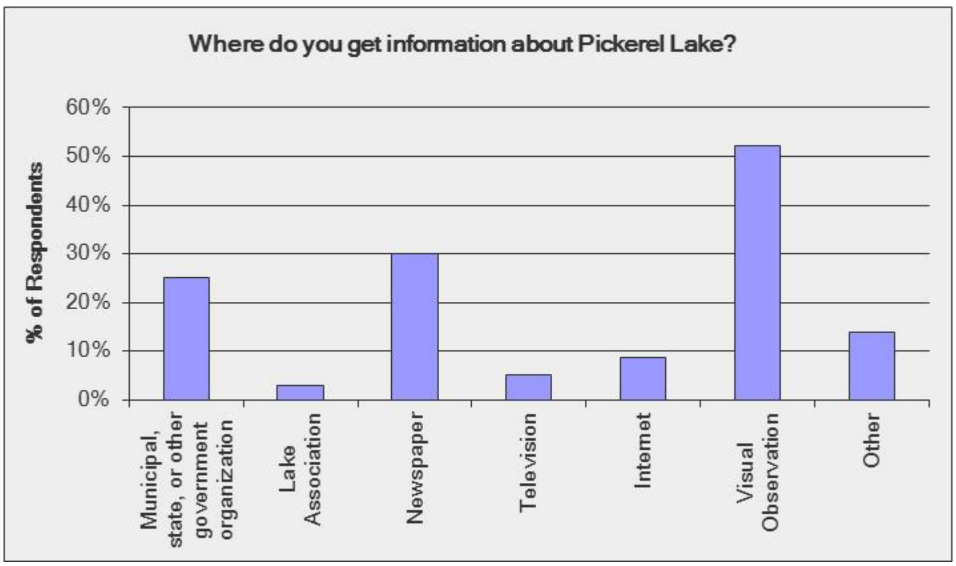

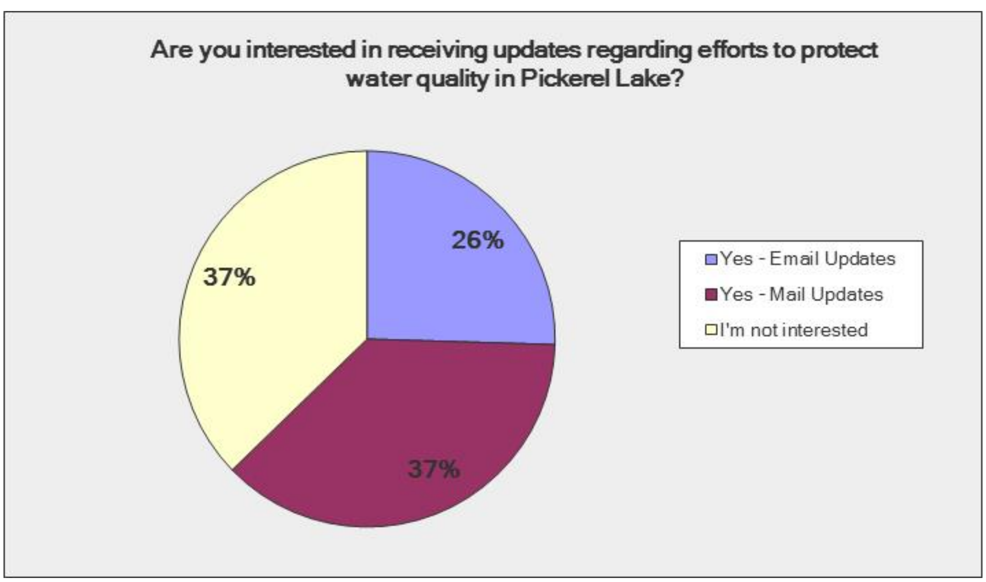

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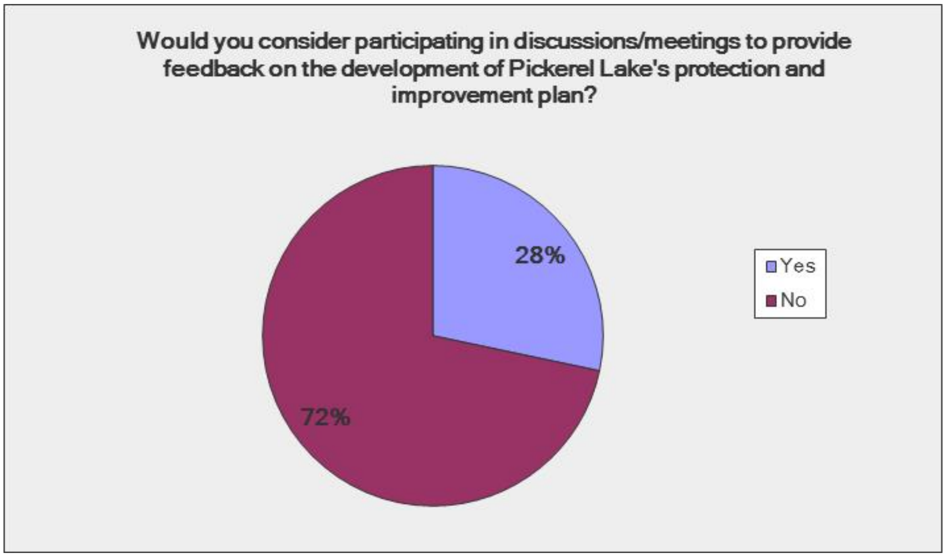

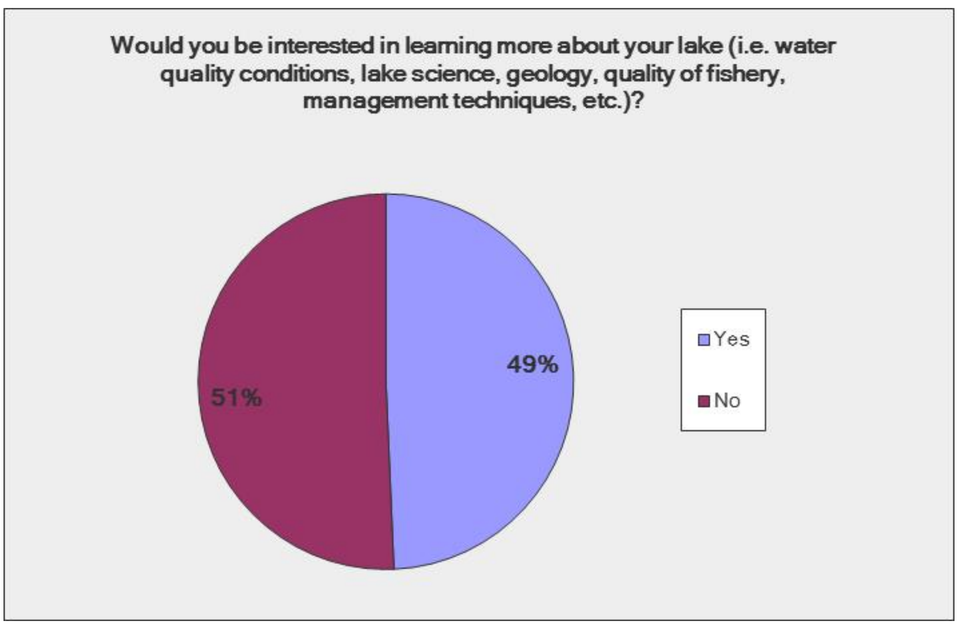

Appendix C: Communications Plan

Lower Mississippi River Watershed Management Organization
Watershed Restoration and Protection Strategy

Communications Plan

August 2014

NOTE: This communications plan is aimed at reducing pollutants from residential storm water runoff. Although it does not include suggestions for communication with businesses, industries, institutions, or cities, these entities should also be targeted with messages regarding best practices. Professional landscaping and lawn care companies, in particular, should receive regular training or materials regarding best practices, local regulations, and State Law. The following plan presents ideas about messages and communication avenues gathered from participants of the three WRAPS Community Conversation events (http://www.dakotaswcd.org/watersheds/lowermisswmo/wrapp.html) and through public input during the WRAPS public review period.

Rogers Lake

Define the Problem

Issue: Runoff from residential properties is impacting Rogers Lake
Goal: Reduce the amount of stormwater and pollutants reaching the lake
Objective to achieve goal: Educate residents about their connection to Rogers Lake (through storm sewers). Provide easy best practices or alternative practices that reduce polluted runoff.

Plan for Communication

Audience: All residents of the watershed of Rogers Lake, Mendota Heights
Message: Clean streets lead to clean water. Your yard practices affect the quality of Rogers Lake.
Channels for message dissemination (also see "all lakes" below):

1. Lake Association communications – email list, social media, mailbox flyers
2. City newsletter – regular "clean water" column where targeted, specific messages can emphasized
3. Correspondence with new residents
4. Educational signage at Mendakota Country Club and Rogers Lake Park
5. Informational displays at City Hall, city events, churches, other indoor gathering spots near the lake
6. Neighborhood events; National Night Out
7. Point of sale messages at hardware stores and garden centers

Implement Communications

Timing of different messages throughout the year is important.

Spring: fertilizer use and grass clippings sweeping; disconnect downspouts; Arbor Day/Earth Day messages

Summer: rain barrel use to save water for gardens; don't over water lawns; pick up pet waste; wash cars on lawns
Fall: keep leaves out of streets
Winter: minimize salt use; sweep up extra salt

Evaluate

Perform surveys of residents regarding practices and knowledge in conjunction with other city surveys. Inventory streets with and without leaves in gutters, use of rainbarrels, disconnected downspouts, or other practices and after a communication effort to determine its effectiveness.

Thompson Lake

Define the Problem

Issue: Runoff from residential properties is impacting Thompson Lake

Goal: Reduce the amount of stormwater and pollutants reaching the lake

Objective to achieve goal: Educate residents about their connection to Thompson Lake (through storm sewers). Provide easy best practices or alternative practices that reduce polluted runoff.

Plan for Communication

Audience: All residents of the watershed of Thompson Lake, West St. Paul

Message: Clean streets lead to clean water. Your yard practices affect the quality of Thompson Lake.

Channels for message dissemination (also see "all lakes" below):

1. City newsletter – regular "clean water" column where targeted, specific messages can emphasized
2. Correspondence with new residents
3. Educational signage at Thompson County Park
4. Informational displays at City Hall, Wentworth Library, city events
5. Neighborhood events; National Night Out
6. County-led activities and programs at Thompson County Park (e.g. Earth Day program)
7. Point of sale messages at hardware stores and garden centers

Implement Communications

Timing of different messages throughout the year is important.

Spring: fertilizer use and grass clippings sweeping; disconnect downspouts; Arbor Day/Earth Day messages

Summer: rain barrel use to save water for gardens; don't over water lawns; pick up pet waste; wash cars on lawns

Fall: keep leaves out of streets

Winter: minimize salt use; sweep up extra salt

Evaluate

Perform surveys of residents regarding practices and knowledge in conjunction with other city surveys. Inventory streets with and without leaves in gutters, use of rainbarrels, disconnected downspouts, or other practices before and after a communication effort to determine its effectiveness.

Sunfish Lake

Define the Problem

Issue: High phosphorus in the lake mainly from internal recycling; alum treatment would reduce phosphorus levels; native aquatic plants are good for habitat and water quality
Goal: Reduction of phosphorus in the water; residents knowledgeable about lake ecology
Objective to achieve goal: Educate residents on difference between treating algae with herbicide and reducing phosphorus with alum treatment. Educate residents on lake ecology.

Plan for Communication

Audience: All residents of the City of Sunfish Lake
Message: Basics of alum treatments vs. use of copper sulfates and Lake Ecology 101
Secondary Messages: Yard practices affect the habitat and water quality of Sunfish Lake
Channels for message dissemination (also see "all lakes" below):

1. City newsletter or other correspondence (mailbox flyers) , correspondence with new residents
2. Informational presentations at city meetings or other widely- attended gatherings
3. Connect information with Arbor Day activities

Implement Communications

Timing of different messages on best practices throughout the year is important.
Spring: fertilizer and pesticide use and septic system maintenance; planting or maintaining a native buffer at the lake edge; Arbor Day/Earth Day messages
Summer: rain barrel use to save water for gardens; don't over water lawns
Fall: keep leaves out of waterways that lead to the lake
Winter: minimize salt use; sweep up extra salt

Evaluate

Perform surveys of residents regarding practices and knowledge. This could be done in conjunction with other city surveys or could be done informally with neighbor to neighbor (or Council member to neighbor) conversations.

Pickerel Lake

Define the Problem
Issue: Residents in the lake's watershed do not know runoff from their properties flows into Pickerel Lake
Goal: Reduce the amount of stormwater and pollutants reaching the lake
Objective to achieve goal: Educate residents about their connection to Pickerel Lake (through storm sewers). Provide easy best practices or alternative practices that reduce polluted runoff.

Plan for Communication
Audience: All residents of the watershed of Pickerel Lake
Message: Storm sewer pipes connect you to Ivy Falls Creek and/or Pickerel Lake below the bluff. Your yard practices affect the quality of Pickerel Lake.
Channels for message dissemination (also see "all lakes" below):

1. City newsletter – regular "clean water" column where targeted, specific messages can emphasized; lake watershed maps could be included occasionally or different lakes highlighted in different issues
2. Correspondence with new residents
3. Educational signage at Pickerel Lake showing watershed to lake
4. Informational displays at City Hall, city events, churches, other indoor gathering spots in or near watershed neighborhoods
5. Neighborhood events; National Night Out
6. Point of sale messages at hardware stores and garden centers

Implement Communications
Timing of different messages throughout the year is important.

Spring: fertilizer use and grass clippings sweeping; disconnect downspouts; Arbor Day/Earth Day messages
Summer: rain barrel use to save water for gardens; don't over water lawns; pick up pet waste; wash cars on lawns
Fall: keep leaves out of streets
Winter: minimize salt use; sweep up extra salt

Evaluate
Perform surveys of residents regarding practices and knowledge in conjunction with other city surveys. Inventory streets with and without leaves in gutters, use of rainbarrels, disconnected downspouts, or other practices and after a communication effort to determine its effectiveness.

All Lakes

Avenues of communication that could reach residents of all lake watersheds:

1. Articles in local newspapers
    a. Contact specific reporters
    b. Report on successful activities or exemplary homeowners, upcoming programs, classes, community activities
    c. Use photos
2. Utility bill inserts
3. Educational talk at local clubs and regular gatherings/meetings (Rotary, Kiwanis, Scouts, Lions, Jaycees, churches)
4. Neighborhood Activity (leaf clean up, trash clean up)
5. Point of sale messages at hardware stores and garden centers
6. Continue and/or expand BlueThumb classes
7. Consider implementing a Master Water Stewards Program
8. Partnership with Dodge Nature Center
    a. Classes or programs for adults (building and using rain barrels, Blue Thumb classes, etc.)
    b. Classes or programs for youth (Project WET)

Use drawings or photos to convey best practices.