Lower Prior Lake Diagnostic Study and Implementation Plan

Project Sponsor:

Prior Lake-Spring Lake Watershed District

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Abbreviations

Chl-*a*	chlorophyll-*a*
DNR	Minnesota Department of Natural Resources
EOR	Emmons and Olivier Resources, Inc
EPA	US Environmental Protection Agency
MCES	Metropolitan Council Environmental Services
MPCA	Minnesota Pollution Control Agency
MS4	municipal separate storm sewer systems
MUSA	municipal urban service area
NPDES	National Pollutant Discharge Elimination System
PLSLWD	Prior Lake-Spring Lake Watershed District
Scott SWCD	Scott Soil and Water Conservation District
TMDL	total maximum daily load
TP	total phosphorus

EXECUTIVE SUMMARY

The purpose of this study is to identify target water quality parameters and implementation items in Lower Prior Lake that will prevent future water quality degradation and ensure that the lake will remain a recreational lake suitable for fishing and swimming. The following water goals and objectives were identified for this study:

Lake-Wide Goals

- Quantitative water quality goals are to *maintain* existing conditions or *slightly improve* the water quality, equating to a 0-10% improvement from existing conditions (at Site 101), within 10 years of initiation of implementation activities.

Lower Prior Lake (Site 101)

Parameter	Goal Condition (10% Improvement)	Present Condition	State Eutrophication Standards
TP (µg/L)	23	26	40
Chlor-*a* (µg/L)	12	13	14
Secchi transparency (m)	3.1	2.8	1.4

- Instill an understanding of the direct connection between watershed, shoreline, and in-lake practices and the observed water quality in Lower Prior Lake in local stakeholders.
- Instill realistic expectations of water quality improvements to citizens in the project area.

Upper Bay (Site 203) Goals

- Improve water quality of Upper Prior Lake.
- Reduce internal phosphorus loading from sediments.

Remaining Bays Goals

- Reduce phosphorus loading from the watershed by improving existing BMPs, constructing new BMPs in the direct drainage area, and improving shoreline buffers around the lake.
- Reduce internal phosphorus loading from sediments.

Diagnostic Study Summary

The objective of the diagnostic study was to:

- Evaluate the spatial and temporal variability of water quality in Lower Prior Lake to determine if there are certain subwatersheds that led to spatial variability of water quality within the lake.
- Compare water quality in Lower Prior Lake to water quality in Upper Prior Lake to determine if the cause of poorer water quality during the later summer months is due to internal loading and/or ecological interactions within Lower Prior Lake or due to poor water quality from Upper Prior Lake.
- Identify areas of highest phosphorus loading to Lower Prior Lake.

Key findings of the diagnostic study were:

1. The water quality at Site 203 is influenced strongly by the water quality of Upper Prior Lake.

    Chl-*a* and Secchi transparency indicators of water quality were the worst at Site 203 and improved with increasing distance from Upper Prior Lake. Lower water quality at Site 203 was attributed to physical transport of algae and some phosphorus from Upper Prior Lake. Site 203 is located in the bay that directly receives water from Upper Prior Lake and discharges to the outlet channel of Lower Prior Lake. Upper Prior Lake has the greatest influence on water quality at Site 203 in Lower Prior Lake during spring and the beginning of summer when water levels are high and flow between Upper and Lower Prior lakes is greatest.

    Internal phosphorus loading from the sediment may also contribute to lower water quality at Site 203 due to strong summer stratification, phosphorus accumulation in the bottom waters, and strong correlation between TP and Chl-*a*.

2. The influence of Upper Prior Lake water quality on Lower Prior Lake decreases with increasing distance from Upper Prior Lake.

    Improved water quality in Upper Prior Lake will not necessarily impact water quality in most of Lower Prior Lake. While Site 203 is significantly influenced by the water quality in Upper Prior Lake, sites that are located further north and west than Site 203 from the Wagon Bridge are more greatly influenced by phosphorus loading from the watershed and internal loading from the sediments. The total drainage area of subwatersheds with high phosphorus loading rates (> 0.24 lb/ac) was 1934 acres, or 58%, of the project area. These areas should be the target of improvements to existing BMPs or construction of new BMPs to reduce the total phosphorus load from the watershed. Finally, while most of Lower Prior Lake stratified during the growing season and the bottom waters became devoid of oxygen, phosphorus accumulation in the bottom waters only occurred at Sites 101 and 206 in 2011. Internal phosphorus loading from the sediments is expected to have an influence on water quality in Lower Prior Lake in the Site 101 and Site 206 bays.

Implementation Plan Summary

The objective of the implementation plan was to identify specific load reduction activities needed to achieve the in-lake water quality, and information and education goals developed for Lower Prior Lake listed above. A balanced mix of public regional BMPs (pond expansions and large infiltration areas) and watershed-wide private projects (buffers and rain gardens) with a strong emphasis on education programs was chosen as primary components of a preliminary implementation plan to maintain water quality in Lower Prior Lake. Specifically, these include the following:

- Regional public projects
    - Infiltration areas and pond expansion in SW-N1/N2/N3/N4
    - Infiltration area and parking lot storm drain rain gardens in SW-N5/N6
    - Infiltration area and pond expansion in SW-S9/S11
    - Hwy 13 ditch checks in SW-10
- Watershed-wide private projects
    - Shoreline buffers

  - Rain garden implementation in SW-14 and SW-25
- Education programs
  - "Habitat for Watershed" neighborhood volunteer rain garden program
  - K-12 outreach programs

If all these projects were implemented, they would be expected to reduce 52 lb/year from the Lower Prior Lake watershed phosphorus load at a projected annual cost (2013-2015) of approximately $38,000 (Table 21).

These load reduction activities were chosen from a complete list of potential load reduction activities identified in the Lower Prior Lake watershed based on the following criteria:

- Phosphorus reduction cost-benefit ranking
- Other benefits such as wildlife benefits, aesthetic benefits, volume reduction
- Stakeholder interest
- Involvement of an education component, leading to long-term improvement in management practices by stakeholders.

1 INTRODUCTION AND PROJECT BACKGROUND

1.1 Description of the Lake and Project Area

Lower Prior Lake (70-0026) is located in the Prior Lake-Spring Lake Watershed District (PLSLWD) in Scott County, in the Minnesota River Basin. The lake's surface area is approximately 960 acres, with a maximum depth of 60 feet. The lake consists of a linear body of water with many interconnected bays of varying water quality. Lower Prior Lake is the third in a chain of three lakes; Spring Lake flows into Upper Prior Lake, which flows into Lower Prior Lake (Figure 1). Upper and Lower Prior Lakes were originally one body of water. The construction of a railroad causeway across a narrow portion of the lake separated the lake by 1930. The two lakes are now connected by a narrow channel of water.

The entire Lower Prior Lake watershed is approximately 30 square miles, which includes the majority of the 42 square mile Watershed District. Both Spring Lake and Upper Prior Lake are on the EPA's list of impaired water bodies, due to high nutrients that impair aquatic recreation. A total maximum daily load (TMDL) study and implementation plan have been completed for these lakes. Since the portion of Lower Prior Lake's watershed that flows through Spring and Upper Prior Lakes has been recently addressed through the TMDL implementation plan, this Lower Prior Lake Diagnostic Study and Implementation Plan focuses on only the direct drainage area of Lower Prior Lake (Figure 2 – areas outlined in yellow).

Lower Prior Lake is a resource heavily used by the public. Lake Front Park, on the southwest portion of Lower Prior Lake within the City of Prior Lake, is the second largest park facility in the Watershed District. Sand Point is a swimming beach on the north shore of the lake; annual visitors to Sand Point range from 30,000 to 48,000 (figures from Water Resources Management Plan for the PLSLWD 2010-2019, citing the City of Prior Lake). A public boat landing on the north-central / northeast shore of the lake is maintained by the DNR, and there is also a winter access point on the lake. Lower Prior Lake receives intense recreational pressure year-round. Open water activities include fishing, boating, water skiing, jet skiing, sailing, wake boarding, and swimming. During the winter when the lake is ice covered, recreational activities include snowmobiling, ice fishing, skating, and cross country skiing.

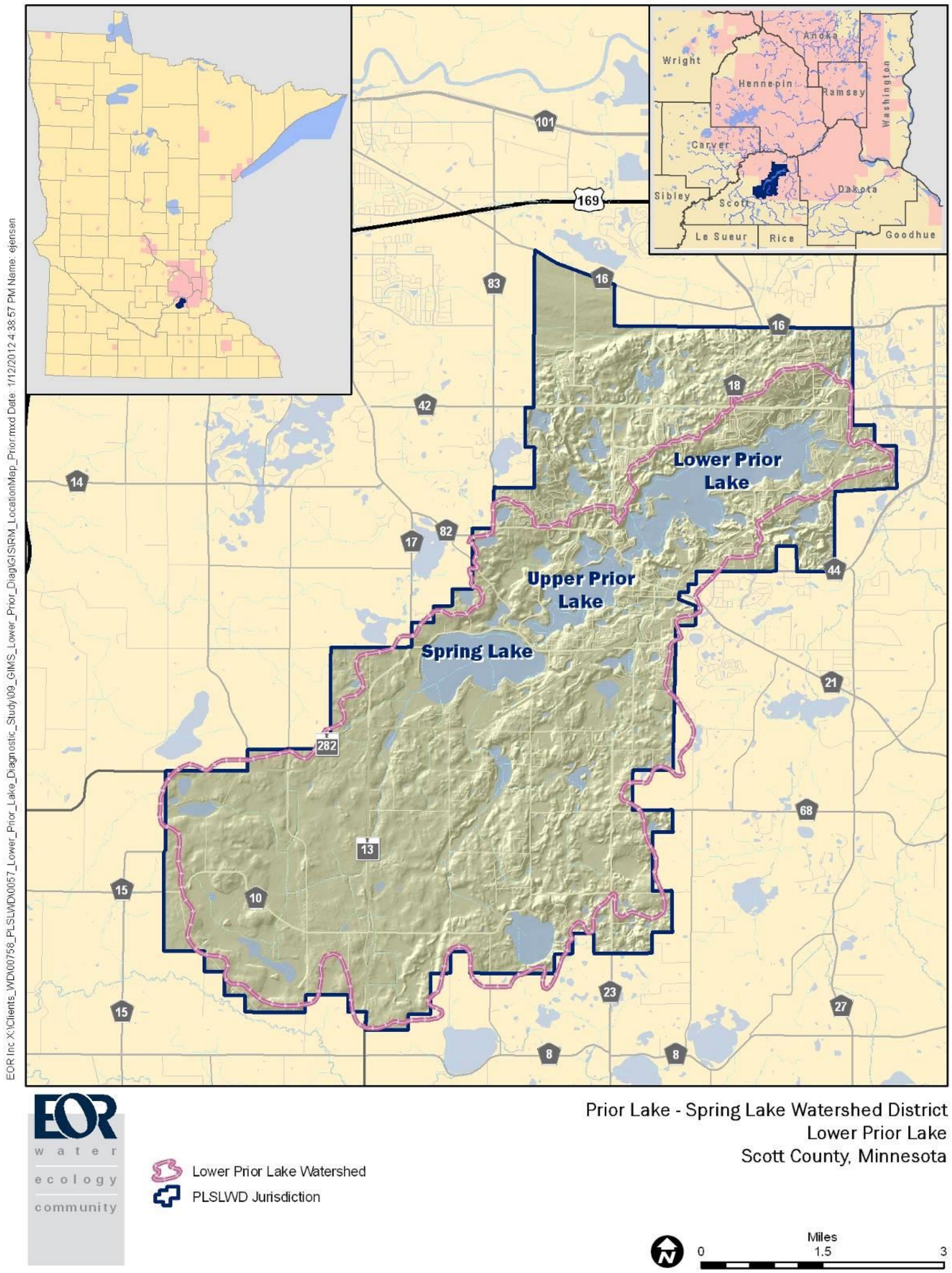

Figure 1. Lower Prior Lake location map

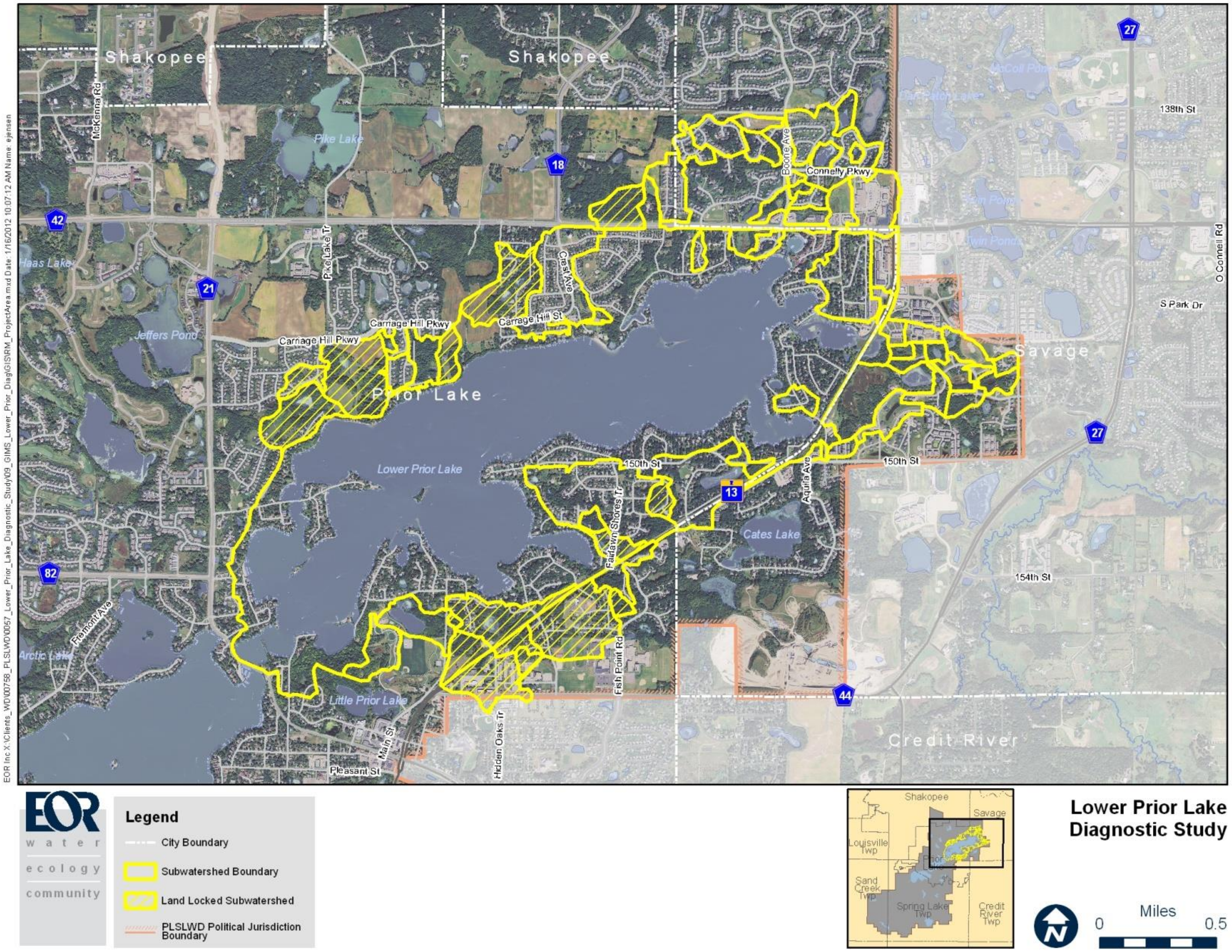

Figure 2. Project focus area - Subwatersheds delineated as part of this project

1.1.1 Known and potential water quality problems

Lower Prior Lake meets the state eutrophication standards (Table 1). The 10-year mean phosphorus concentration and Secchi transparency comfortably meet the standards, but the chlorophyll-*a* concentration is just meeting the standard of 14 µg/L (data from MPCA's Environmental Data Access system). Observational data indicate that, during August and September, there is a definite presence of algae, although it does not reach nuisance levels.

Table 1. Water quality summary, surface water growing season means

Parameter	Lower Prior Lake (Site 101)	State eutrophication standards
TP (µg/L)	26	40
Chlor-*a* (µg/L)	13	14
Secchi transparency (m)	2.8	1.4

The lake is influenced by the water quality of Spring Lake and Upper Prior Lake, which are directly upstream of Lower Prior Lake. Degradation in the water quality of the upstream lakes also degrades the quality of Lower Prior Lake.

1.1.2 Lake management efforts

Outlet channel

Lower Prior Lake has historically been landlocked. Rising water levels led to the construction in 1983 of a lake outlet by the Watershed District. The outlet is located on the northern portion of the southwest end of Lower Prior Lake, and the channel travels seven miles to the Minnesota River.

Walleye stocking

The DNR stocks Lower Prior Lake with walleye fingerlings every other year. See "*Lake Management Plan, Department of Natural Resources*" under Section 1.1.3: *Related plans and studies* for more information.

Watercraft speed limitations

The following are watercraft speed limitations on Lower and Upper Prior Lakes (City of Prior Lake City Code 703.400):

- Watercraft towing a person cannot be operated within 150 feet of the shoreline. Watercraft launching or landing a person are exempt if using the most direct and safe route to open water or the shore.
- Watercraft may not be operated at greater than a slow no-wake speed within 150 feet from shore.
- The daytime (from sunrise to one hour after sunset) speed limit is 40 miles per hour on weekends and holidays from Memorial Day weekend through Labor Day weekend.
- The nighttime speed limit (from one hour after sunset to sunrise) is twenty miles per hour.

- When the water level reaches 904 feet, watercraft may not be operated at greater than a slow no-wake speed on the entire lake.
- Watercraft may not be operated at greater than a slow no-wake speed in any no-wake channels or zones marked by the City of Prior Lake.

1.1.3 Related plans and studies

Diagnostic/feasibility study for Spring and Prior Lakes, 1993

A diagnostic and feasibility study was conducted for Spring Lake, Upper Prior Lake, and Lower Prior Lake in 1993. The diagnostic portion of the study included water quality and quantity monitoring for a 12-month period (October 1988 - September 1989). There were two lake monitoring sites in Lower Prior Lake, one stormsewer site in the watershed of Lower Prior Lake, and a site at Lower Prior Lake's outlet. The remainder of the monitoring sites were in Spring Lake and Upper Prior Lake and their watersheds. In-lake data collection consisted of dissolved oxygen, water temperature, transparency, pH, phosphorus, nitrogen, chlorophyll-*a*, phytoplankton, zooplankton, and submerged aquatic macrophtyes. Hydrologic budgets, nutrient budgets, and in-lake models were developed for the lakes. Relevant results from the diagnostic study are included throughout this updated 2011 diagnostic study, where appropriate.

The feasibility study proposed the following as approaches for improving the water quality in Lower Prior Lake:

- Strengthen PLSLWD's water quality ponding standards
- Reduce the use of high phosphorus fertilizers
- Improve yard waste management
- Improve maintenance of stormwater facilities
- Establish shoreline buffers around lakeshore.
- Convert the wet/dry basins at the end of Beach Steet (north side of Lower Prior Lake) and at Sand Pointe Park to wet ponds to improve their phosphorus removal capacity.

Lake Management Plan, Department of Natural Resources

This lake management plan focuses on fisheries management for Lower Prior Lake, Upper Prior Lake, and Spring Lake. The three lakes are managed as one system due to their direct connections; fish move easily between the lakes. The lakes are managed for a sport fishery, with walleye and largemouth bass being the primary species managed, and northern pike and bluegill being the secondary species managed.

Water Resources Management Plan for the Prior Lake-Spring Lake Watershed District 2010-2019

The PLSLWD's 2011 Water Resources Management Plan describes the physical, biological, and hydrological setting, and current and proposed land use and development within the District. It establishes goals, policies, and objectives for protecting water resources, and includes an implementation plan of specific activities that will be undertaken between 2010 and 2019 to achieve the plan's goals. The plan includes "Lower Prior Lake Retrofit BMP Feasibility Study and Projects," to address untreated and/or under-treated subwatersheds within the Lower Prior Lake drainage area.

1.2 Project Purpose

A diagnostic and feasibility study for Spring Lake and Prior Lake was developed in the early 1990s. Although the study addressed all three lakes in the chain (Spring, Upper Prior, and Lower Prior Lakes), it focused on Spring Lake and Upper Prior Lake, due to water quality issues apparent in those lakes at the time. The study concluded that Lower Prior Lake would reach its water quality goal through improvements in the two upstream lakes. The purpose of the proposed project is to provide information to protect the water quality of Lower Prior Lake and to propose projects that will help the lake remain a recreational lake suitable for fishing and swimming. It differs from the previous study in the focus on evaluating the variability in water quality in Lower Prior Lake and identifying BMPs for the direct drainage area. This overall purpose can be broken into a number of individual goals, grouped by the following categories:

Overall resource goals

- Protect the water quality of Lower Prior Lake to prevent water quality degradation, and to ensure that the lake will remain a recreational lake suitable for fishing and swimming.

Water quality characterization goals

- Evaluate the spatial and temporal variability of water quality in Lower Prior Lake.
- Compare water quality in Lower Prior Lake to water quality in Upper Prior Lake to determine if the cause of poorer water quality during the later summer months is due to internal loading and/or ecological interactions within Lower Prior Lake or due to poor water quality from Upper Prior Lake.
- Identify in-lake factors that might influence water quality within Lower Prior Lake
- Identify areas of highest phosphorus loading to Lower Prior Lake in the direct drainage area.

Water quality quantitative goals

- The water quality in Lower Prior should be *maintained* at existing conditions or *slightly improved*. The numeric goals are a 0-10% improvement from existing conditions (at Site 101). A 0% improvement indicates that the lake has maintained its current water quality and has not degraded. A 10% improvement equates to the following: 26 µg/l total phosphorus, 13 µg/l chlorophyll-a, and 2.8 meters Secchi transparency.
- Maintain existing conditions or improve water quality within 10 years of implementation activities.

Information and education goals for citizens in the project area

- Ensure that stakeholders understand the direct connection between watershed, shoreline, and in-lake practices and the observed water quality in Lower Prior Lake.
- Instill realistic expectations of water quality improvements to citizens in the project area.

1.3 Project Partners

As the project sponsor, the PLSLWD used their staff and consultants [Emmons & Olivier Resources, Inc. (EOR), MN Waters, and Scott County Water Resource Education Coordinator] for data collection and analysis, coordination of public input and goal setting, diagnostic study and implementation plan development, and project administration. Objectives are described in Table 4, and the responsibility for each was divided as follow: District Staff administered the project (Objective 8), assisted with monitoring (Objective 2), and provided input and review on all components of the project (Objectives 3 through 7); EOR conducted monitoring (Objective 2), data analysis (Objective 3), presentation of technical information at stakeholder meetings (Objective 4), and diagnostic study and implementation plan development (Objectives 5 through 7); MN Waters facilitated the stakeholder involvement process (Objective 4); and Scott County's Water Resource Education Coordinator, housed at the Scott SWCD, completed the outreach components (Objective 4).

Technical input from the City of Prior Lake, the MN Department of Natural Resources, the MN Pollution Control Agency, and other applicable agencies or groups was solicited on an as-needed basis throughout the course of the project. Stakeholders, including local residents and lake users, were involved in the two stakeholder meetings held for the project.

An organization chart is provided in Table 2. The staff and governing board directory is in Table 3.

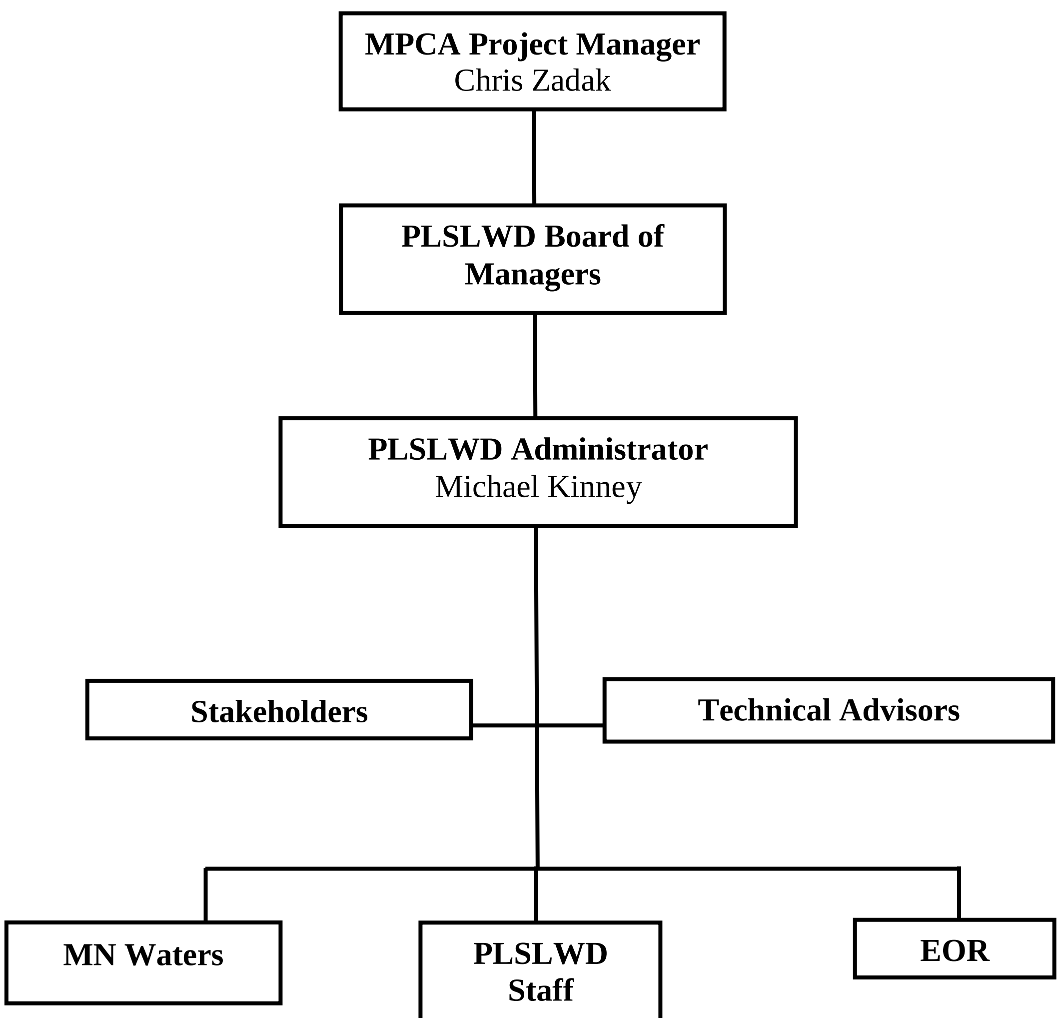

Table 2. Organizational chart

Table 3. Staff and governing board directory

Name	Organization	Phone	Email
Michael Kinney	PLSLWD	952-447-4166	mkinney@plslwd.org
Nat Kale	PLSLWD	952-378-2167	nkale@plslwd.org
Chris Zadak	MPCA	651-757-2837	Chris.Zadak@state.mn.us
Meghan Jacobson	EOR	651-203-6049	mjacobson@eorinc.com
Peter Young	City of Prior Lake	952-447-9831	pyoung@cityofpriorlake.com
Alex Gehrig	MN Waters	218-251-1462	alexg@minnesotawaters.com

1.4 Public Participation

1.4.1 Stakeholder involvement

MN Waters facilitated the stakeholder involvement process, which included two stakeholder meetings:

1. April 26, 2011 – First stakeholder meeting on Diagnostic Study results and Implementation Plan proposed process
2. October 25, 2012 – Second stakeholder meeting on Implementation Plan preliminary results and proposed prioritization of identified stormwater retrofit BMP opportunities

At these meetings, a summary of the project findings to date was presented and time was provided for participants to ask questions and provide feedback on the project goals and direction.

1.5 Project Costs

Table 4 presents the final project costs, by objective.

Table 4. Project costs, by objective

Objective		Cost
1	Develop work plan	$3,911.37
2	Data collection	$20,977.38
3	Data assessment and modeling	$21,651.05
4	Stakeholder involvement	$6,680.76
5	Diagnostic study - report	$7,405.50
6	Implementation plan	$24,515.64
7	Final report prep	$3,107.75
8	Project administration	$5,141.40
Total		**$93,390.85**

1.6 Project Milestones

Table 5. Milestone schedule

Objective	2011											2012											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1 - Develop work plan	■	■																					
2 - Data collection																							
In-lake monitoring			■	■	■	■	■	■	■														
Shoreline erosion survey and field reconn						■	■																
3 - Data assessment and modeling																							
In-lake assessment											■	■	■										
Watershed assessment				■	■	■	■	■	■														
4 - Stakeholder involvement																							
Stakeholder meetings (2)															■						■		
On-going education and information																							
5 - Diagnostic study report					■	■	■	■	■	■	■	■	■	■	■								
6 - Implementation plan																							
Implementation alternatives																■	■	■	■	■	■		
Implementation program development																		■	■	■	■		
Final Report - implementation plan																			■	■	■	■	
7 - Final report																							
One round of comments and edits														■	■							■	
Final submittal																							■
8 - Project administration	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

2 DIAGNOSTIC STUDY

2.1 Methods

2.1.1 Watershed characterization

Data from public sources were collected to characterize the direct drainage area of Lower Prior Lake, including land use, soil type, geologic characteristics, imperviousness, hydraulic and hydrologic structures, subwatershed boundaries, and flow direction.

2.1.2 Water sampling

Four sites (Sites 203, 101, 205, and 104, Figure 3) were monitored twice monthly in 2011 from April through October (7 months, for a total of 14 sampling events). Additionally, two sites in bays (Sites 206 and 207) were monitored monthly. The following data were collected at each site:

- Surface water total phosphorus (TP), total Kjeldahl nitrogen (TKN), and chlorophyll-*a* concentration
- Surface water chloride (monthly) from April through July. In August, both surface and hypolimnetic chloride were collected at five sites.
- Secchi transparency
- Depth profiles, at one-meter intervals, of temperature, dissolved oxygen, pH, and conductivity
- Hypolimnetic TP, one meter above the lake bottom

Monitoring days were coordinated to the extent possible with monitoring on Upper Prior Lake, so that water quality comparisons between the two lakes are as comparable as possible.

Pace Analytical Services and Braun Intertec performed the analytical services. Data were submitted to EQuIS following appropriate quality control procedures.

Of the six sites sampled in 2011, consistent long-term water quality records are available for Sites 203 and 101 only. TP, TKN, and Secchi data are available for Site 101 from 1980-2010, but only Secchi transparency is presented in this report because it is a robust indicator of overall long-term water quality and long-term nutrient data is not available for Site 203 (except for a few measurements between 1968 and 1981).

To compare water quality trends in Upper and Lower Prior lakes, 2011 monitoring data collected for this project were combined with historic lake water quality data (1980-2010) from the MPCA's Environmental Data Access for Upper Prior Lake (site #70-0072-00-202) and Lower Prior Lake (site #70-0026-00-101; 70-0026-00-203). Upper Prior Lake Site 202 corresponds with the bay that discharges directly into Lower Prior Lake. Lower Prior Lake Sites 101 and 203 were the only sites with long-term water quality data that were also monitored in 2011 for this project. Long-term water quality in Upper and Lower Prior lakes were compared with respect to Secchi transparency because this was the only water quality parameter with long-term (>10 years) records in the Lower Prior bay directly receiving Upper Prior Lake discharge (Site 203).

Site descriptions

The water quality sampling sites (Figure 3) covered six different bays with varying depths (Table 6, Figure 4). The majority of the bays have maximum depths of 30 to 40 feet. The shallowest bay sampled in this study was at Site 207, which has a maximum depth of ten feet.

Site 203 is located in the bay that receives water from Upper Prior Lake and also discharges to the outlet channel of Lower Prior Lake. Sites 101 and Sites 205 are located in the main western and eastern bays of the lake, respectively, northeast of Site 203. Site 104 is located in a bay south of the bay with Site 101. Site 206 is located in a small, deep bay (referred to locally as Candy Cove) that is connected to the bay with Site 104 by a narrow channel. Site 207 is located in a small, shallow bay that is connected to the bay with Site 205 by a wide channel. Hereafter, the sites are listed in the following order: 203, 104, 101, 205, 206, and 207. The outlet of Lower Prior Lake is located close to the inlet from Upper Prior Lake (Figure 3). Water flows from Upper Prior Lake towards the Lower Prior Lake outlet, and also flows from the northeastern portions of Lower Prior Lake towards the outlet, in an overall southwesterly direction. The rate of flow from Upper Prior Lake to the outlet is likely higher than the rate of flow from the northeastern portions of Lower Prior Lake, due to the large watershed size of Upper Prior Lake and the close proximity of the inlet from Upper Prior Lake to the Lower Prior Lake outlet.

Table 6. Lower Prior Lake 2011 monitoring sites and maximum depths

Site	Maximum Depth of Bay (ft)
203	40
104	42
101	36
205	40
206	34
207	10

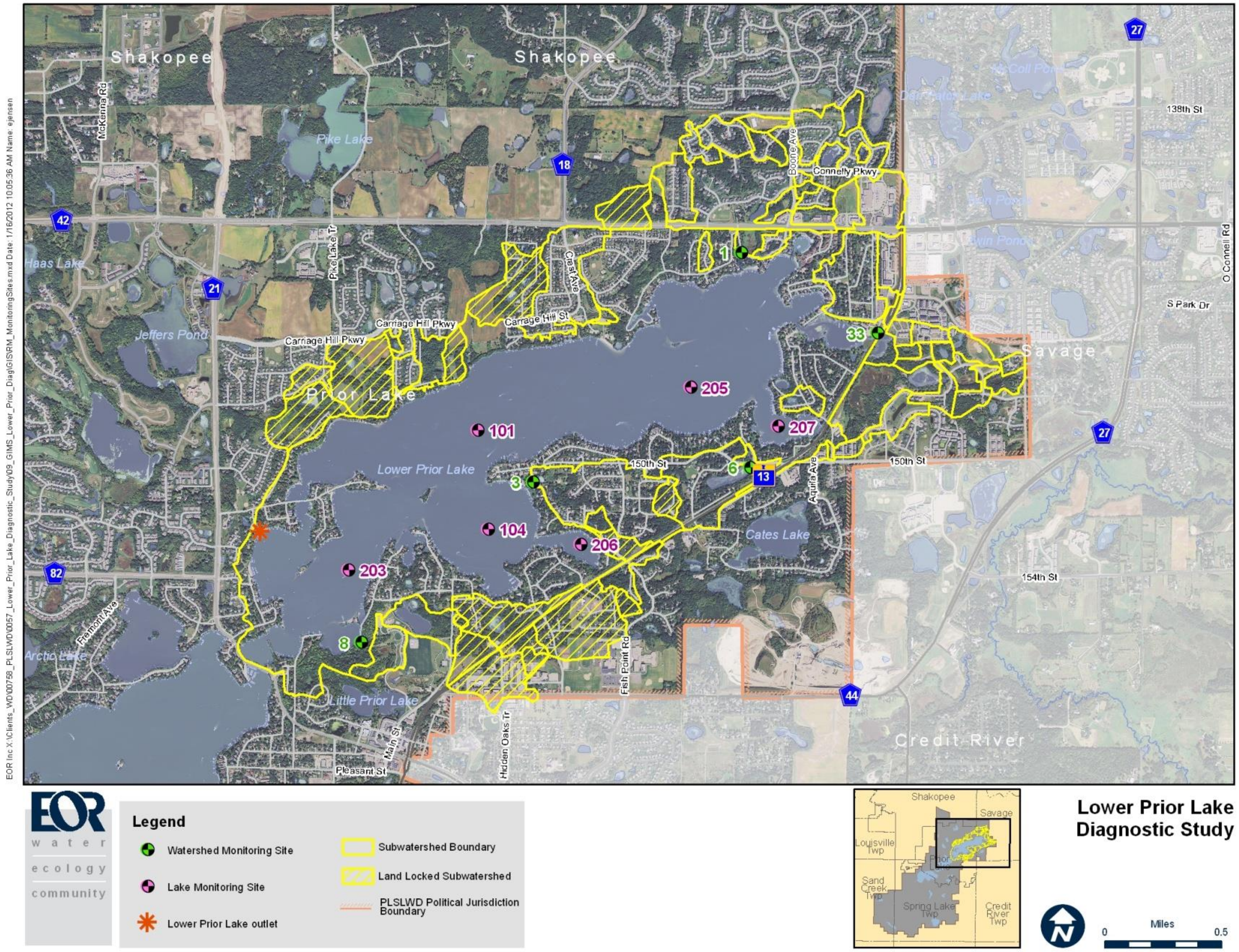

Figure 3. Monitoring site locations

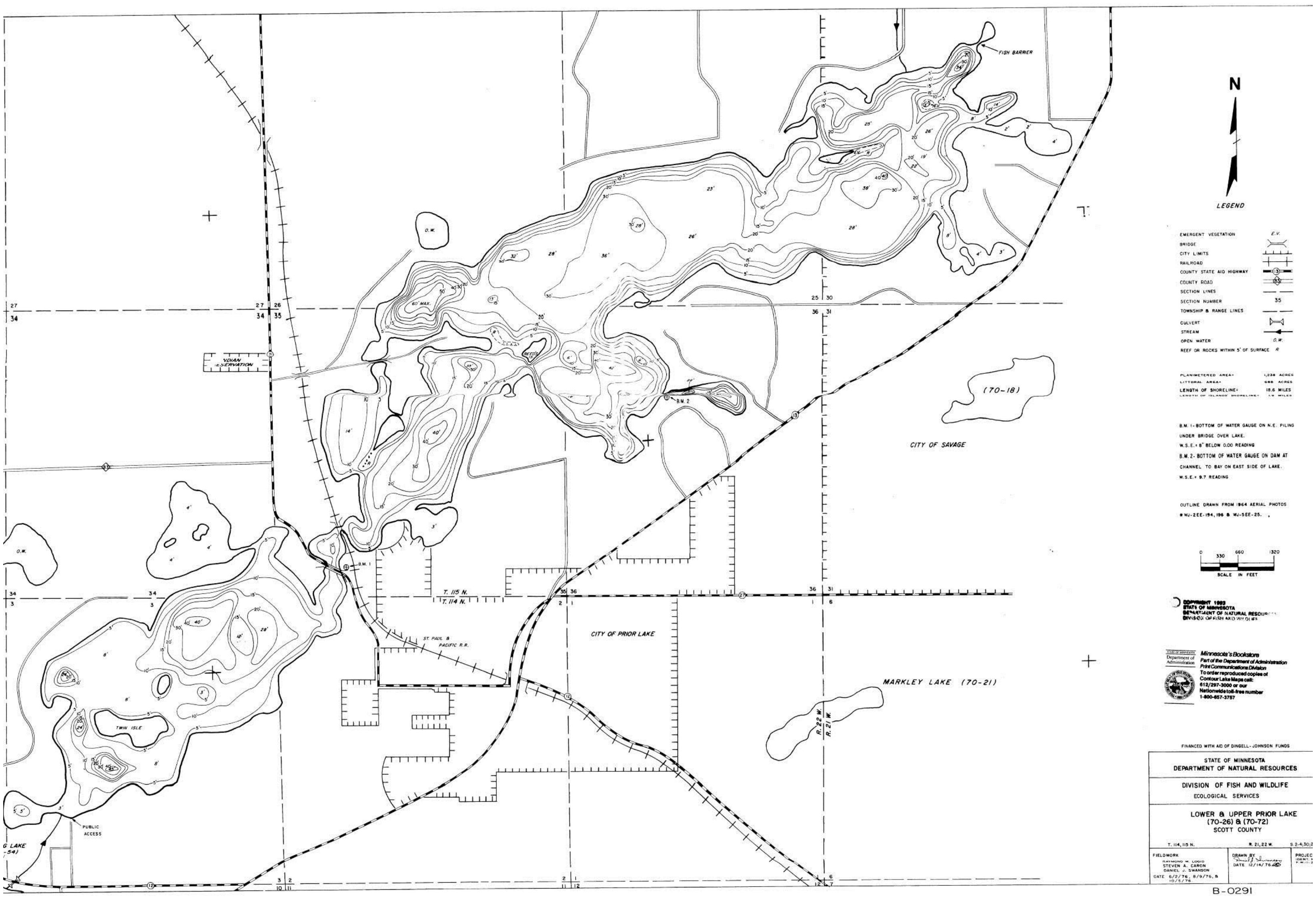

Figure 4. Lower Prior Lake bathymetry (source: DNR)

2.1.3 Sediment sampling

Sediment samples were collected at sites 203, 101, and 205 (Figure 3). Samples were taken from the top 5 to 10 cm of the lake sediments, and the following soil parameters were tested:

- Organic matter
- Total phosphorus
- Iron-adsorbed phosphorus (BD-P, or bicarbonate dithionite extractable phosphorus)

Braun Intertec performed the analytical services.

Results were used to model the potential phosphorus release rates in the lake. Concentrations of phosphorus within the sediment were used to evaluate differences in internal loading potential from the different monitoring locations. Phosphorus release rates were calculated using two different equations relating the sediment concentrations to release rate. Given the potential error and uncertainty in the estimates, multiple equations were used in order to increase confidence and arrive at a reasonable range of release rates.

Both equations are statistical regression equations, developed using measured release rate and sediment concentration data from different sets of lakes[1,2]. The approach assumes that if a regression equation adequately characterizes the relationship between release rate and sediment phosphorus concentration in the study set of lakes, then it is reasonable to apply the same equation to other lakes for which the sediment phosphorus concentration is known.

2.1.4 In-lake biology

In-lake biology was investigated to the extent possible with data from the following sources:

- DNR fisheries surveys
- Diagnostic/Feasibility Study for Spring and Prior Lakes, Scott County, Minnesota (1993)
- Watershed District aquatic macrophyte surveys conducted by Blue Water Science in the spring and late summer of 2002, 2005 and 2008, and in the spring of 2009 and 2010.

2.1.5 Shoreline survey

The shoreline was evaluated to identify erosion and sedimentation issues and any activities that may be contributing to pollutant loadings to the lake or decreased clarity.

A qualitative shoreline survey was conducted using two steps. The first step was a remote analysis of shoreline buffer vegetation. Data were viewed and analyzed using spatial tools in ArcGIS. Recent aerial photography was viewed to determine the width and delineation of shoreline vegetation or lack thereof. Using ArcGIS, a boundary around the entire shoreline was then created. Within this shoreline buffer, vegetation was delineated according to type and width. These spatial data were then used in the field to further verify vegetation type and width.

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[1] Nürnberg, G. K. 1988. The prediction of phosphorus release rates from total and reductant-soluble phosphorus in anoxic lake sediments. Can. J. Fish. Aquat. Sci. 45: 453-462.

[2] Nürnberg, G.K. 1996. Trophic state of clear and colored, soft- and hard-water lakes with special consideration of nutrients, anoxia, phytoplankton and fish. Lake Reserv. Manage. 12: 432-447.

The entire shoreline was surveyed from the water using a boat and a GeoXT handheld GPS. The buffer shapefile was loaded into the GPS and was used to locate buffer boundaries along the shoreline. Any discrepancies between the actual buffer and the buffer shapefile were marked on an aerial photo that contained the original buffer boundaries. Any erosion locations were surveyed with the handheld GPS and were photographed.

2.1.6 Watershed loading

The direct drainage area to Lower Prior Lake was modeled in the P8 (Program Predicting Polluting Particle Passage thru Pits, Puddles and Ponds) Water Quality Model developed by William Walker, Jr. P8 is a model for predicting the generation and transport of stormwater runoff pollutants in urban watersheds. Continuous water-balance and mass-balance calculations are performed on a user-defined system consisting of watersheds, stormwater BMPs, particle classes and water quality components. P8 was chosen for its ability to simulate flow conditions and pollutant transport in an urban environment, along with its ability to discretely model BMPs such as stormwater ponds, infiltration basins, and wetlands. The following data are needed for input to the P8 model: precipitation files, subwatershed boundaries, hydrologic characteristics of each individual subwatershed, configuration of stormwater treatment facilities (e.g. ponds, infiltration basins).

The P8 model has implicit limitations both in general and when applied specifically to Lower Prior Lake.

- P8 is most accurate for relative predictions (removal efficiencies from a BMP, and relative loading rates among subwatersheds) than absolute values (concentrations and loads).
- The model was designed to simulate pollutant removal from NURP ponds and may be less accurate when modeling wetlands and other types of BMPs (as was done for the Lower Prior Lake model) than when modeling only NURP ponds.

The main parts of the model are broken down into watershed and device components. The following is a summary of the routines used in the model to simulate pollutant loading.

- Device
  - Ponds use settling equations to remove pollutants.
  - Filters remove a specified amount of pollutants.
  - Pipes are used to extend the time of concentration and combine flows.
- Watershed
  - Produces runoff based on curve numbers and impervious areas.
  - Impervious area pollutants are generated based on a buildup/washoff routine.
  - Pervious area pollutants are generated based on a fixed concentration that occurs at runoff rates of 1 inch/hour and adjusted based on increased or decreased runoff intensity.

The default pollutant file (Nurp50.p8p) and Minneapolis precipitation file (msp4989.pcp) were used for the general case input files in the model, and the average water year of 1959 was used for analysis.

While P8 can be calibrated using long-term flow and phosphorus loading data, it can also be used without an in-depth calibration to predict relative loads throughout a watershed. Available water quality and quantity data from the lake's direct drainage area were used for a cursory model calibration.

Geographic extent of model

The P8 model was developed for the Lower Prior Lake watershed downstream of the outlet from Upper Prior Lake. The model focuses on the direct drainage area of Lower Prior Lake and does not include Little Prior Lake or Cates Lake and their watersheds (see Figure 2). Landlocked areas were not modeled. Landlocked areas were determined using two-foot contour data and City of Prior Lake and Savage stormsewer data.

Devices

All ponds that were included in GIS shapefiles obtained from the City of Prior Lake and the City of Savage were modeled. Additional ponds and wetlands that provide stormwater treatment were identified and modeled for a total of 56 devices.

Stormwater treatment facilities were defined using as-builts obtained from the cities to calculate dimensions. When as-builts were not available for stormwater BMPs, the BMPs were included in the model by making assumptions about the geometry below the normal water level. These assumptions provide a reasonable view of the treatment that occurs within the BMPs, and, by including the BMPs in the model, the geometry of the BMPs can be updated in the future with more information as it becomes available. Outlet configuration and normal water level area were available for all modeled ponds, and the remaining pond geometry inputs were defined based on whether the practice was a pond or wetland (Table 7).

Table 7. BMP dimension assumptions

Type	Pond	Wetland
Maximum depth (ft)	5	3
Side slope below NWL	4:1	10:1
Side slope above NWL	4:1	4:1
Stormwater bounce	1' greater than outlet diameter	1' greater than outlet diameter

Watersheds

The drainage area to each of the BMPs was delineated from 2-foot contours, aerial photography, and stormsewer data.

Impervious surface estimates made as part of this project were based on satellite imagery and were used to calculate the areas of roads, rooftops, and open water within the modeled area. This technique has been shown to be the most accurate method of automatic impervious cover generation. In water quality models it is particularly important to distinguish between manmade impervious surfaces and open water, because open water contributes to pollutant inputs in a much different way than roads and rooftops. P8 allows for impervious surface areas to be divided into manmade impervious surfaces and naturally occurring impervious surfaces by allowing two different types of impervious surfaces to be entered into each watershed. For this model, the *Swept Impervious* parameter represents the water surface and the *Unswept Impervious* parameter represents the manmade impervious surfaces. (The "swept" and "unswept" designation is used in this case only to indicate water surface vs. manmade impervious surfaces; it is not related to actual swept and unswept watershed areas. When the model is used in this way, street sweeping cannot be explicitly modeled. However, the benefits gained from differentiating between types of impervious surfaces outweigh the drawbacks.)

2.1.7 Data management and statistics

Water quality monitoring data (chemistry and biological) were managed according to Section B10 of the *Lower Prior Lake Diagnostic Study CWP Project Quality Assurance Project Plan* (QAPP) prepared by MPCA.

2.1.8 Quality assurance

The main work environments encountered by the project team are the field, the laboratory, and the office. The Quality Assurance Project Plan (QAPP) addresses both monitoring and office activities and was prepared as part of the work plan for this project In brief, the following description is provided.

Laboratory and field activities

Pace Analytical Services, Inc. and Braun Intertec completed the laboratory analyses. Table 8 identifies the methods that were used.

Table 8. Laboratory methods

Chemical Parameter	Method	Laboratory
Water - chlorophyll-*a*	SM 10200 H	Pace Analytical Services, Inc. / Braun Intertec
Water - phosphorus, total	EPA 365.4 / 365.1	Pace Analytical Services, Inc. / Braun Intertec
Water - nitrogen, total Kjeldahl	EPA 351.2	Pace Analytical Services, Inc. / Braun Intertec
Water - chloride	EPA 300.0 / SM4500 CL-E	Pace Analytical Services, Inc. / Braun Intertec
Sediment - phosphorus, total	EPA 365.4	Braun Intertec
Sediment - phosphorus, iron–adsorbed	USGS–NWQL I–5381	Braun Intertec
Sediment - organic matter	NIR Spectroscopy	Braun Intertec

Office activities

Data received from lab analyses were delivered in spreadsheet format and as pdf files. Originals remained unchanged and on record. Data analysis was conducted with the supervision of project managers. In addition, the organizational chart in *Section 3 Project Organization and Responsibility* of the work plan created a framework for checks and balances throughout the data analysis, interpretation, and report development process.

2.2 Results and Discussion

2.2.1 Watershed characterization

The City of Prior Lake and the City of Savage are both within the project area. Both of these cities have municipal separate storm sewer systems (MS4s) that are regulated through a National Pollutant Discharge Elimination System (NPDES) permit, administered by the MPCA. There are no point sources in the project area. The majority of the project area is within the municipal urban service area (MUSA); the Metropolitan Council Environmental Services (MCES) operates regional wastewater treatment facilities for areas within the MUSA boundary.

Land use within the direct drainage area of the Lower Prior Lake watershed is dominated by single family residential (58%), undeveloped land (22%), and parkland (9%). A large portion of the parkland in the watershed is LakeFront Park; multiple smaller parks are scattered throughout the watershed. Other land uses in the watershed include small areas of commercial, institutional, and agricultural.

Annual precipitation reported in the MN Hydrology Guide (1961-1990) is 29.5 inches; this is consistent with the precipitation (1996-2007) data presented in the PLSLWD 2010 Water Resources Management Plan.

The surficial geology of the District is mostly composed of glacial till deposits with a few small regions of peat deposits. The project area consists of till forming irregular hills and ice-contact stratified drift. The majority of the soils in the project area are B type soils with pockets of D soils occurring in wetland areas (Figure 5)[3]. Some A type soils can be found surrounding the lake and, although these would be ideal locations for infiltration based on soil texture, are likely very close to the water table making infiltration difficult. Portions of the project area have a relatively high susceptibility of the bedrock aquifers to contamination (Figure 6).

[3] Soils are classified A through D, with A soils signifying coarse soils that water can easily pass through and D soils signifying fine-grained soils that stop water (like clay). Combination soils (A/D and B/D) can act like either type and typically occur in wetlands, particularly those that are partially drained. For example, if it has been dry out, a wetland area containing A/D soils will act as an A soil and water will easily pass through; if conditions have been wet, an A/D soil will act more like a D soil and water will not penetrate as easily.

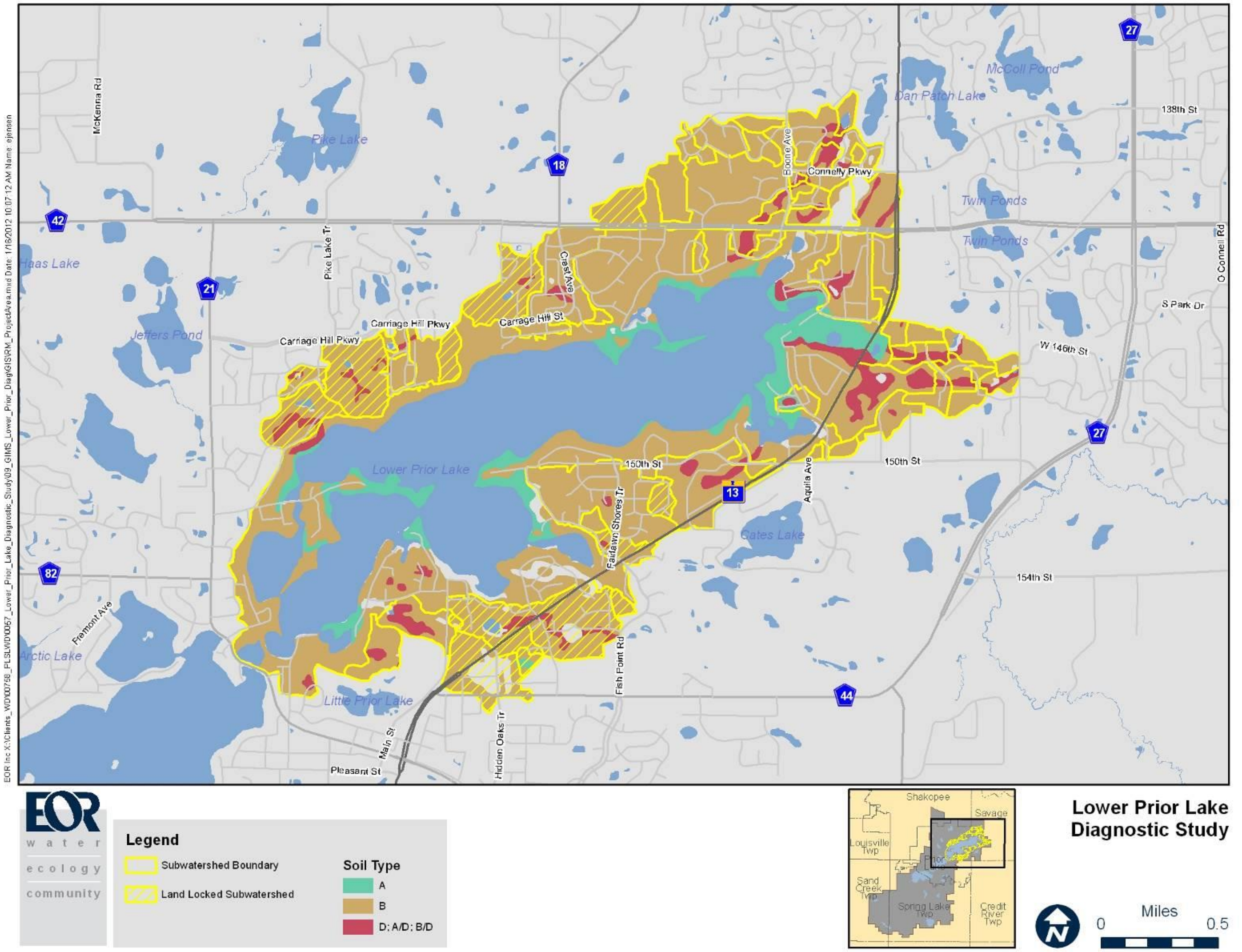


Figure 5. Soil types

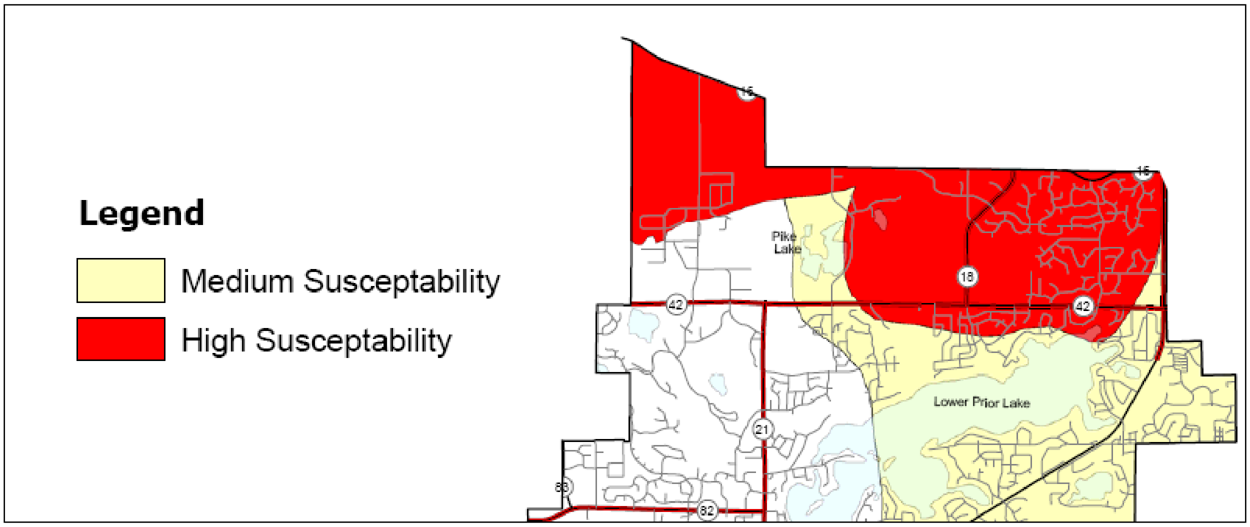


Figure 6. Bedrock susceptibility

Excerpt from figure in Appendix B of PLSLWD 2010 Water Resources Management Plan

2.2.2 Water sampling

Spatial and temporal variability of water quality in Lower Prior Lake

Growing season mean TP and TKN were low and variable across all six sites (Figure 7 and Figure 8), while Chl-*a* and Secchi transparency were the worst in Site 203 and improved with increasing distance from Upper Prior Lake (Figure 9 and Figure 10). These data suggest that Site 203 was most influenced by the poor water quality of Upper Prior Lake. In addition, because Chl-*a* was highest at Site 203 but not TP or TKN, Upper Prior Lake appears to have influenced water quality in Site 203 via physical transfer of algae, not by increased nutrient loading.

Seasonal variability in TP, TKN, and Secchi transparency were similar across all six sites monitored in 2011 (Figure 11, Figure 12, and Figure 14). The maximum concentration of TP and maximum Secchi transparency occurred on May 23, and the maximum concentration of TKN occurred on July 18. Peak transparency (called the clear-water phase) typically occurs during the spring when zooplankton biomass is at a seasonal maximum and therefore zooplankton consume algae at very high rates. The peak transparency in Lower Prior also corresponded to the peak TP, and, while there is not a well-known ecological reason to explain this trend, it could have resulted from the release of TP during zooplankton grazing of algae or a large pulse of TP during a large storm event that was not quickly incorporated into algal biomass. Seasonal variability in Chl-*a* was also similar across all sites monitored in 2011, except for two large peaks in algal abundance occurring on May 10 and July 18 at Site 203 (Figure 13).

Correlations between water quality parameters indicated that algal abundance (Chl-*a*) was not strongly limited by TP nor TKN in Lower Prior Lake, except by TP at Site 203 (r^2 = 0.54, P-value < 0.05; Table 9). And, while the correlation between TKN and Chl-*a* at Site 101 is strong and significant (r^2 = 0.60, P-value < 0.05), this relationship is negative and does not support the hypothesis that increasing nitrogen levels increases algal abundance (a positive relationship). However, Secchi transparency was strongly and significantly correlated to Chl-*a* at Sites 203 and 104 (r^2 = 0.61 and 0.52, respectively, P-value < 0.05). Across all samples sites, the strength and significance of this correlation increases (r^2 = 0.58, P value < 0.001). Similarly, algal abundance

(Chl-*a*) has been found to be the dominant contributor to low water clarity in most lakes. Weak correlations between water quality parameters at Sites 101 and 205 may have been a result of low seasonal variability at these sites. In addition, the strength and significance of correlations tend to increase with sample size. While there was a wide spatial range of data collected for this study (6 sample sites), data were collected on an ecologically narrow temporal scale (one season).

Lower Prior Lake stratified from mid-June until mid-September in 2011, with several meters of bottom water devoid of dissolved oxygen at Sites 203, 104, 101, and 206 during the stratified period (Figure 15, Figure 16, Figure 17 and Figure 19). Stratification at Site 205 was weaker than the other stratified sites, with only one meter of bottom water devoid of oxygen for several weeks. Site 207 was located in the shallowest bay (maximum depth = 10 ft) and did not stratify in 2011. Site 206 was located in a small, deep bay (maximum depth = 34 ft.), and the dissolved oxygen profiles in this bay suggested that stratification was maintained throughout the year and the bottom and surface waters do not mix. In addition, the peak DO concentration was located in the thermocline (the border between the stratified upper and bottom waters). This trend is typical in deep or permanently stratified basins where the dominant source of nutrients is from diffusion of nutrient-rich bottom waters or sediments. Therefore, peak algal growth occurs deeper in the water to take advantage of nutrients diffusing up from the bottom waters.

Bottom water TP concentrations increased during the stratified period at Sites 203, 101, and 206 and decreased during lake mixing in October at Sites 203 and 101 (Figure 21). Internal loading of phosphorus from the sediments at Sites 203 and 101 was likely because the bottom waters became devoid of oxygen during the growing season and accumulated TP. While Site 104 also stratified, the length of time the bottom waters were anoxic was much shorter than at Sites 203 and 101; this may be why hypolimnetic phosphorus concentrations did not increase throughout the growing season at Site 104. At Site 206, the bottom water TP concentration was relatively high throughout the season. Since the bottom and surface waters did not mix before the end of the monitoring period at Site 206, high TP concentrations were maintained in the bottom waters.

At Site 203, long-term growing season mean Secchi transparencies have fluctuated between 1 and 2 m since 1985 (Figure 22). Long-term growing season mean Secchi transparencies at Site 101 were better than at Site 203 and have steadily improved since 1999, reaching over 3.5 m in 2011 (Figure 23). The lack of water quality improvement at Site 203 may be influenced by poor water quality from Upper Prior Lake.

Comparison of water quality in Lower and Upper Prior Lakes

Long-term growing season mean Secchi transparencies in Upper Prior Lake were poorer than in Lower Prior Lake and have fluctuated between 0.8 and 1.7 m since 1981 (Figure 24). Long-term water quality in Upper and Lower Prior lakes were compared with respect to Secchi transparency because this was the only water quality parameter with long-term (>10 years) records in the Lower Prior bay directly receiving Upper Prior Lake discharge (Site 203). Comparing seasonal water quality in Upper Prior Lake to Site 203 in Lower Prior Lake in 2011, TP and Chl-*a* increased while Secchi transparency decreased in both lakes from the end of May until July 18 (Figure 25, Figure 26, and Figure 27). This corresponded to the period of high water levels in Lower Prior Lake and therefore the greatest flow between Upper and Lower Prior Lakes (Figure 28).

Before July 18, most of the variability in water quality parameters in Site 203 could be explained by the water quality of Upper Prior Lake, with chlorophyll-*a* and Secchi transparency strongly and significantly correlated (r^2 = 0.95 and 0.78, respectively, and P-value < 0.01 and 0.05, respectively; Table 10), and TP was correlated (r^2 = 0.56) but not statistically. In addition, this correlation tended to decrease with increasing distance from Upper Prior Lake. After July 18, the water level of Lower Prior Lake declined, resulting in reduced flow from Upper Prior Lake into Lower Prior Lake. This corresponded to improved water quality in Lower Prior Lake at Site 203 and maintained poor water quality in Upper Prior Lake (Figure 28, Figure 22, and Figure 24).

This comparison supports the hypothesis made from observations of the spatial variability of water quality in Lower Prior Lake that poor water quality in Upper Prior Lake influenced water quality in Lower Prior Lake most strongly at Site 203, and decreased with increasing distance from Upper Prior Lake. In addition, poor water quality in Upper Prior Lake most influenced the water quality at Site 203 by physical transfer of algae (r^2 = 0.95, P-value < 0.01) with less influence from increased phosphorus loading (r^2 = 0.56, P-value = 0.09). Finally, Upper Prior Lake had the greatest influence on water quality at Site 203 in Lower Prior Lake early in the summer when water levels were high and flow between Upper and Lower Prior lakes was greatest.

Table 9. Correlation coefficients between water quality parameters by Site in Lower Prior, 2011.

Site	TP vs. Chl-*a*	TKN vs. Chl-*a*	Chl-*a* vs. Secchi
203	0.54*	0.19	0.61*
104	0.05	0.19	0.52*
101	0.05	0.60*	0.04
205	0.08	0.01	0.16
All	0.15*	0.07	0.58***

Note: P-values denoted by * < 0.05, ** < 0.01, *** < 0.001

Table 10. Correlation coefficients between Upper Prior Lake and individual Lower Prior Lake sites through July 18, 2011.

Lower Prior Site	TP	TKN	Chl-*a*	Secchi
203	0.56	0.15	0.95**	0.78*
104	0.32	0.03	0.42	0.41
101	0.08	0.39	0.38	0.33
205	0.16	0.28	0.15	0.38

Note: P-values denoted by * < 0.05, ** < 0.01, *** < 0.001

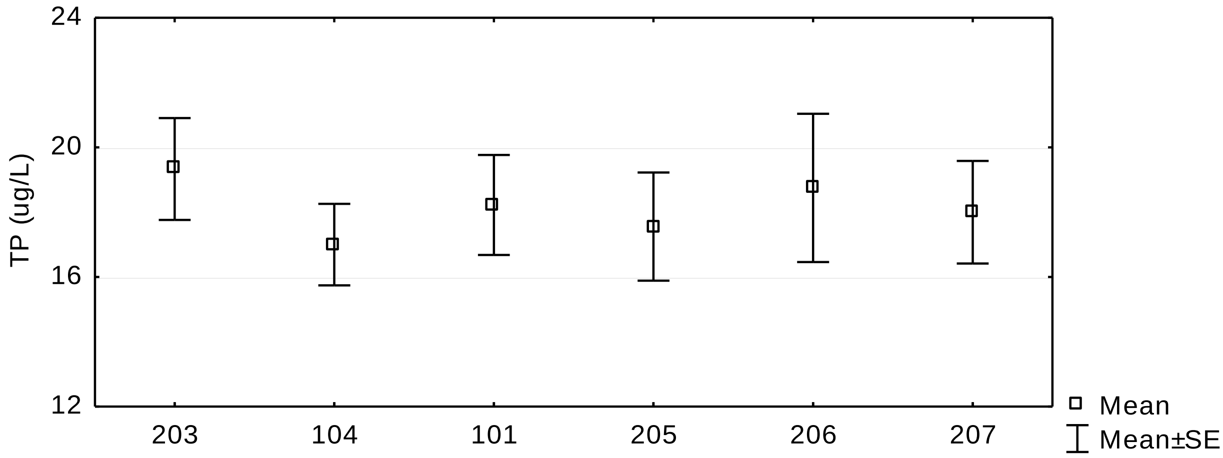


Figure 7. Growing season mean TP (±SE) by site in Lower Prior Lake, 2011

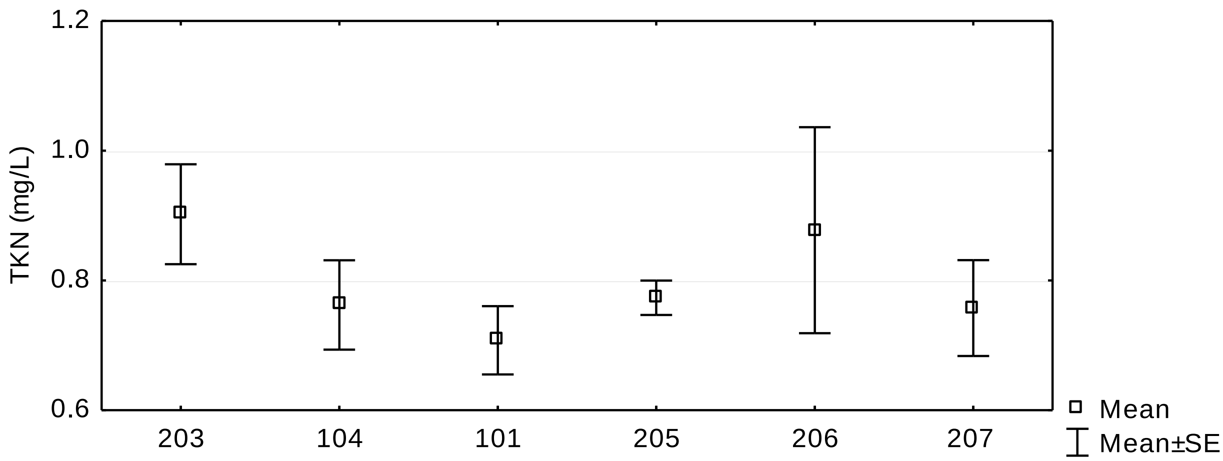


Figure 8. Growing season mean TKN (±SE) by site in Lower Prior Lake, 2011

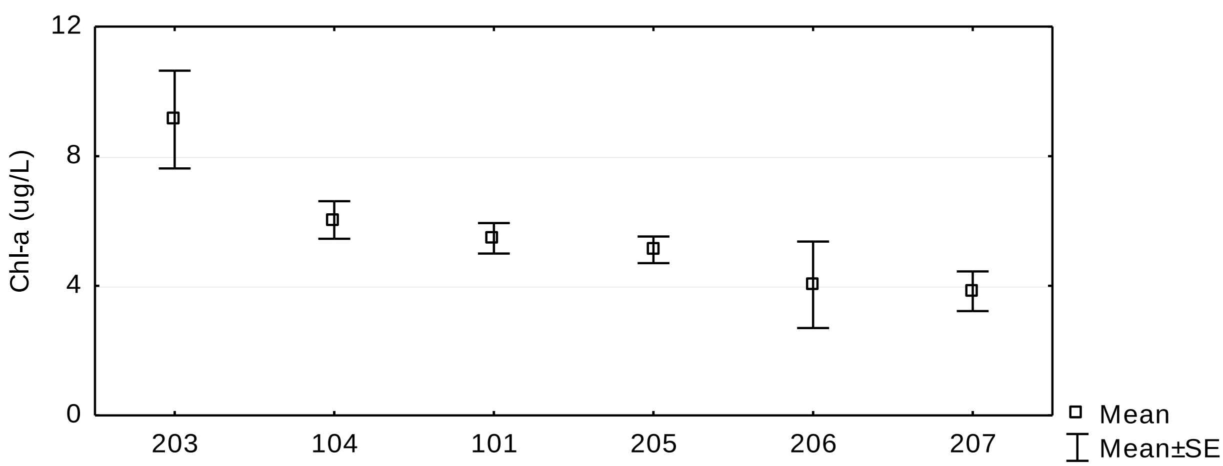


Figure 9. Growing season mean Chl-*a* (±SE) by site in Lower Prior Lake, 2011

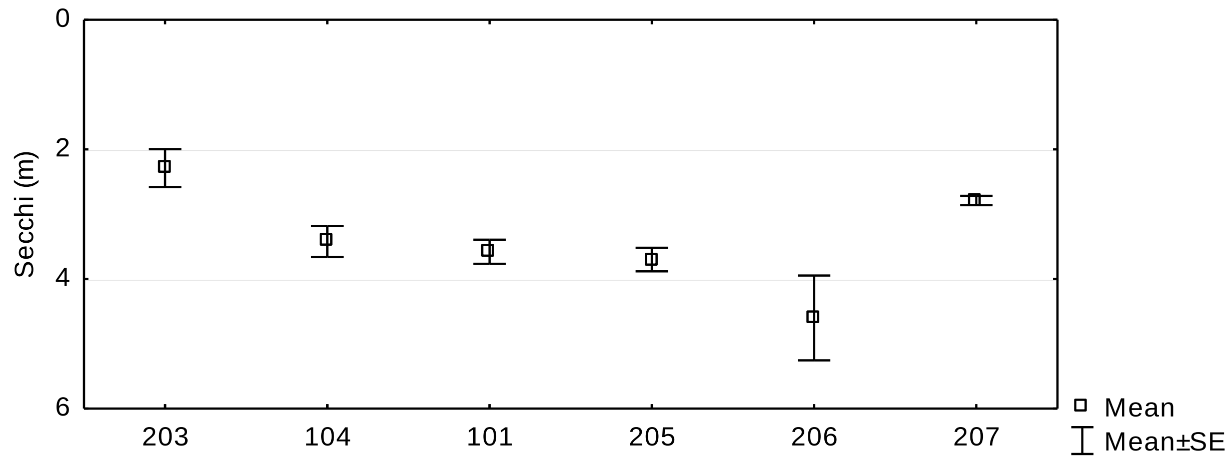


Figure 10. Growing season mean Secchi transparency (±SE) by site in Lower Prior Lake, 2011

Note: the Secchi transparency depth equals the maximum depth in Site 207

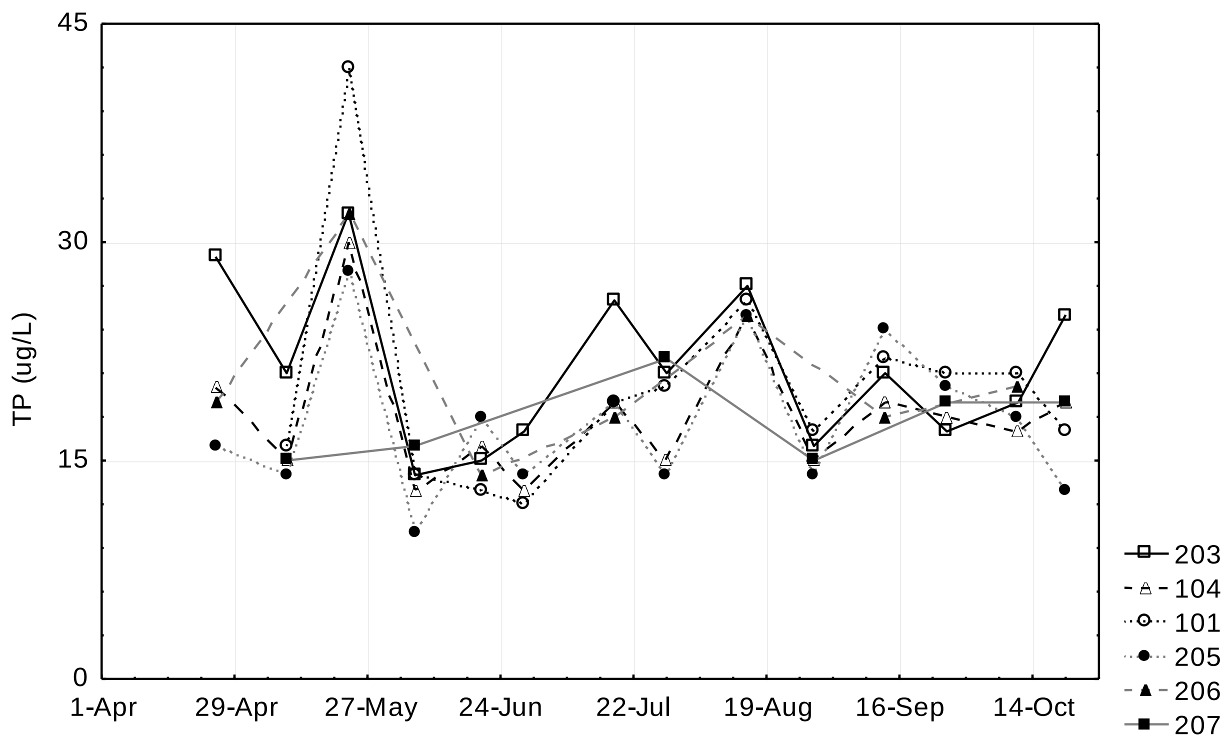


Figure 11. Seasonal TP trends for 6 sites in Lower Prior during 2011.

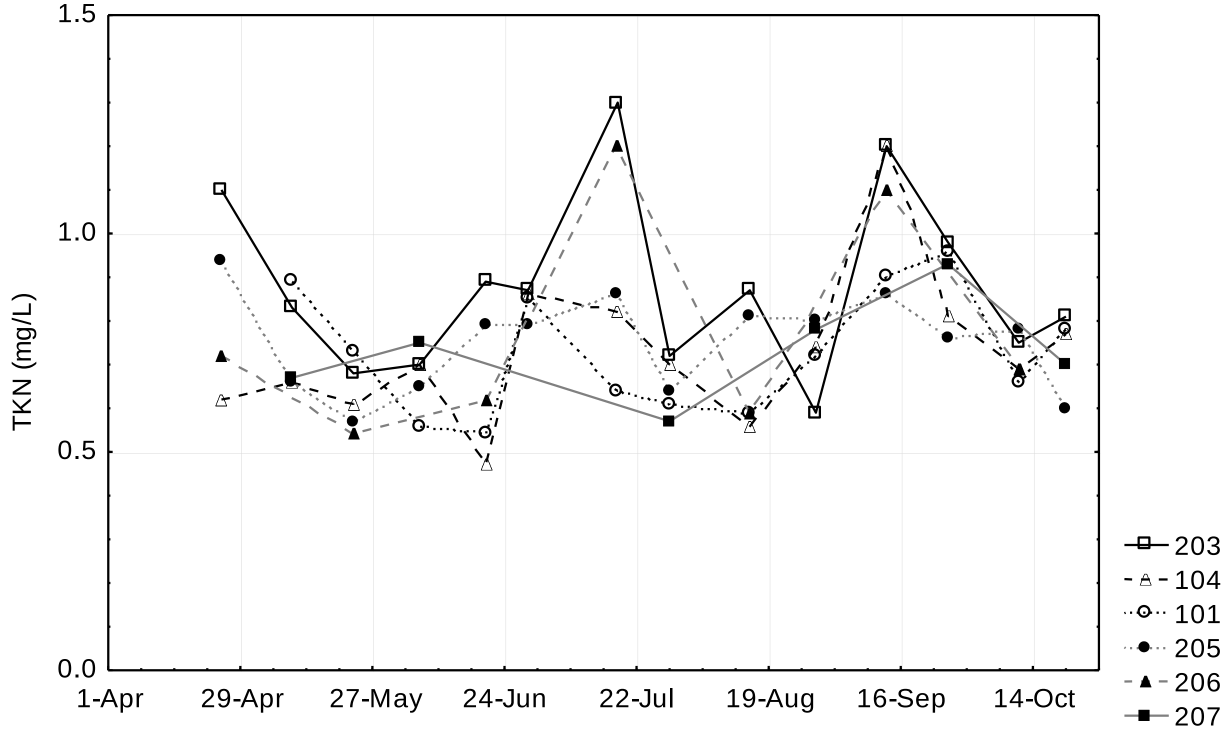


Figure 12. Seasonal TKN trends for 6 sites in Lower Prior during 2011.

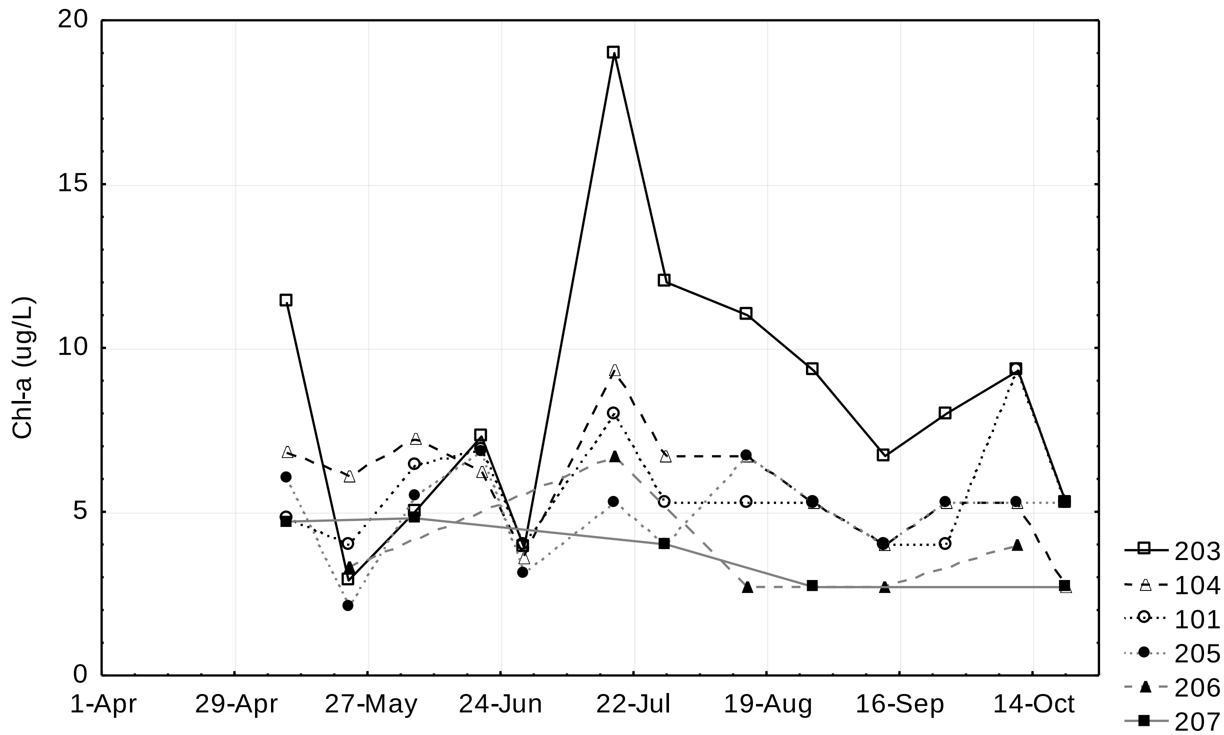


Figure 13. Seasonal Chl-*a* trends for 6 sites in Lower Prior during 2011.

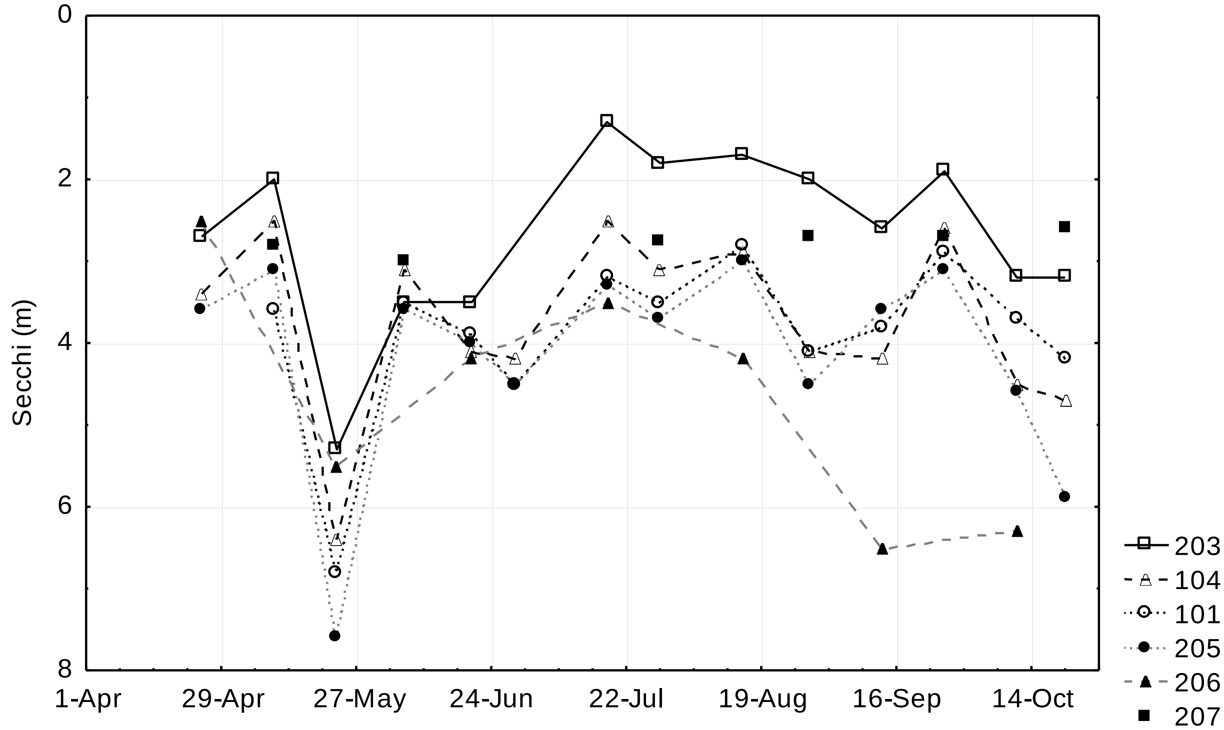


Figure 14. Seasonal Secchi transparency trends for 6 sites in Lower Prior during 2011.

Note: Secchi transparencies at Site 207 were approximately equal to the maximum depth.

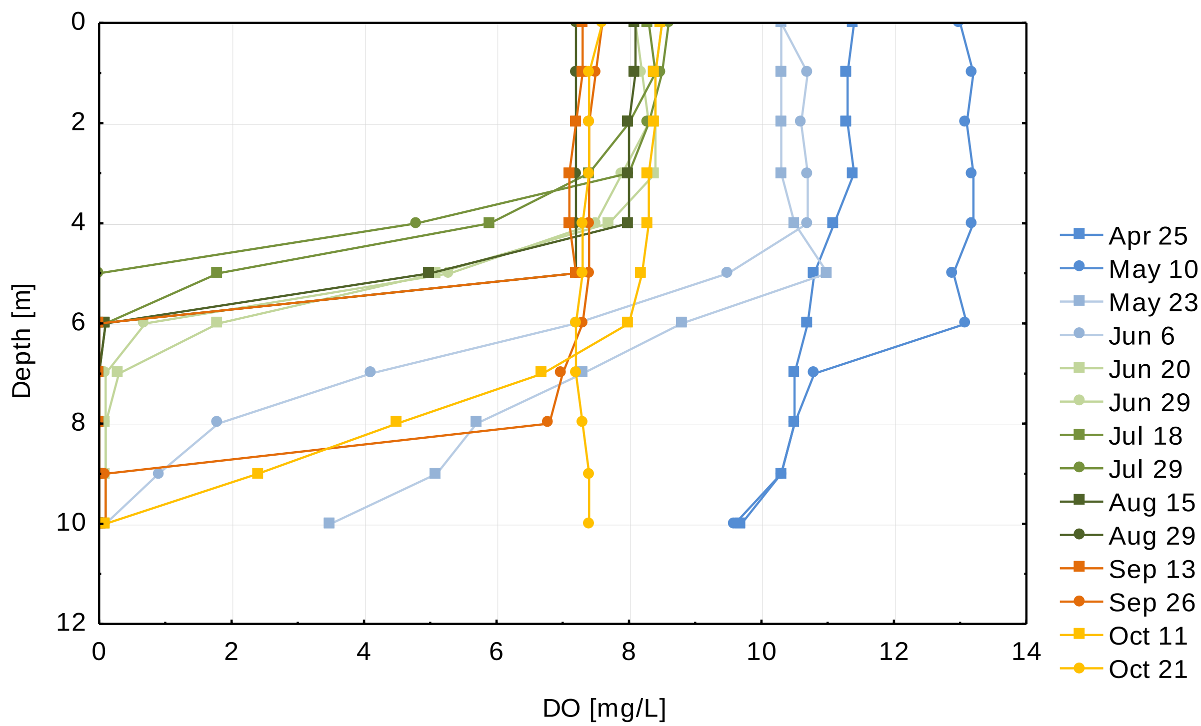


Figure 15. Dissolved oxygen profiles at Site 203, 2011.

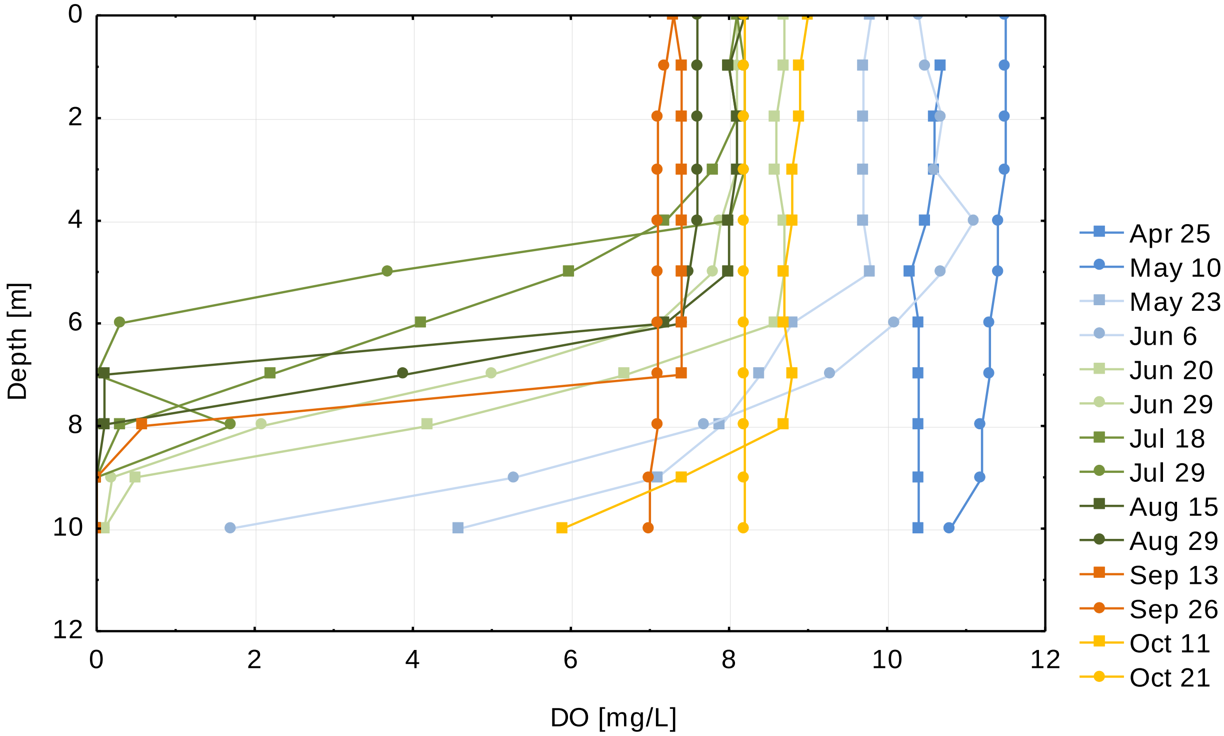


Figure 16. Dissolved oxygen profiles at Site 104, 2011.

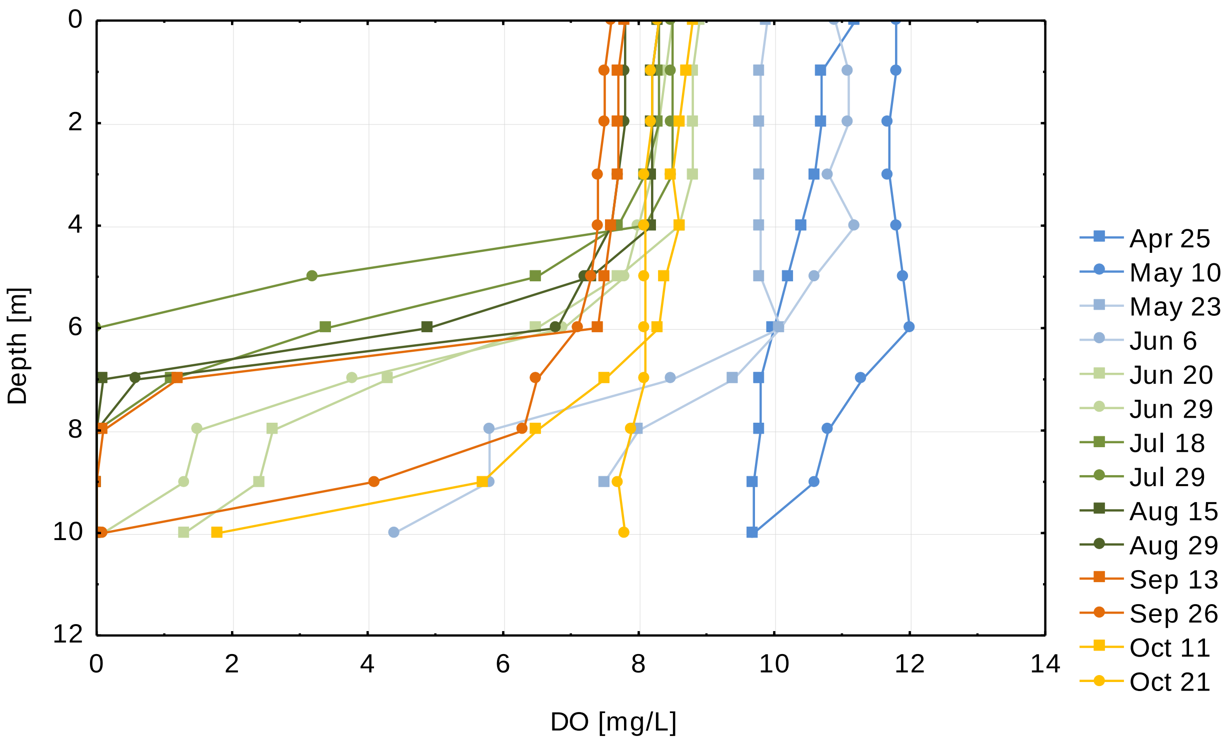


Figure 17. Dissolved oxygen profiles at Site 101, 2011.

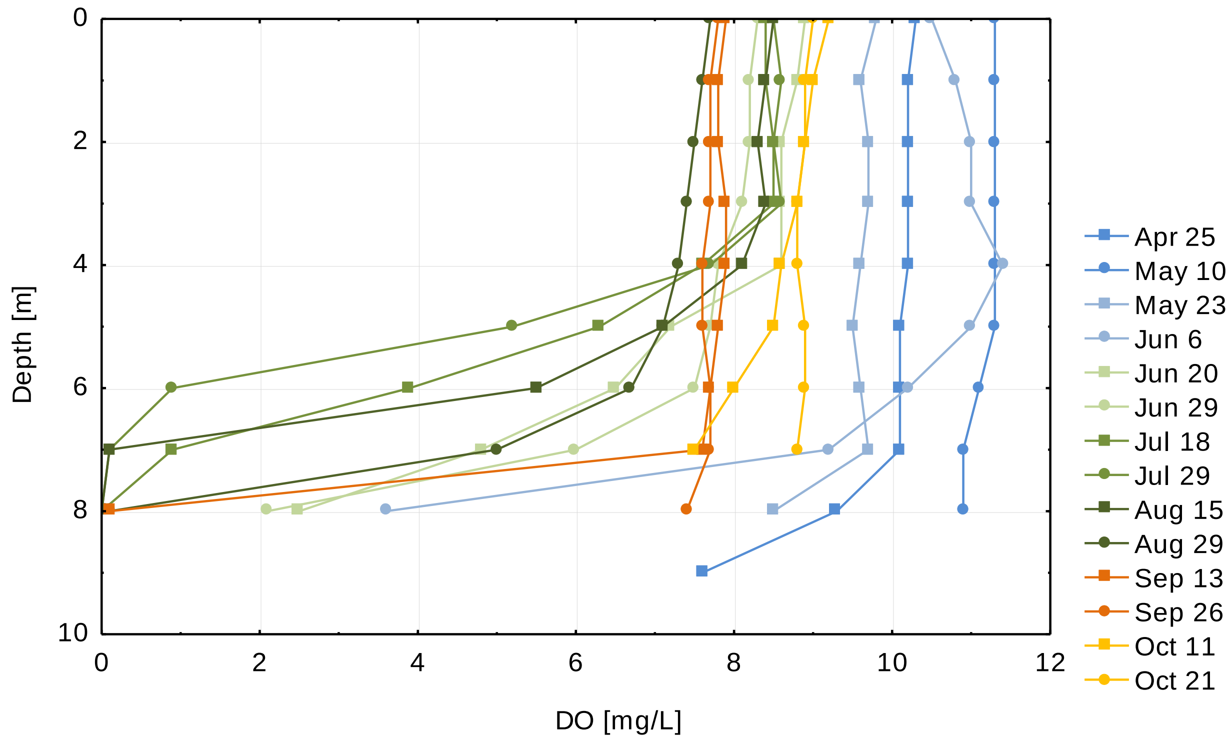


Figure 18. Dissolved oxygen profiles at Site 205, 2011.

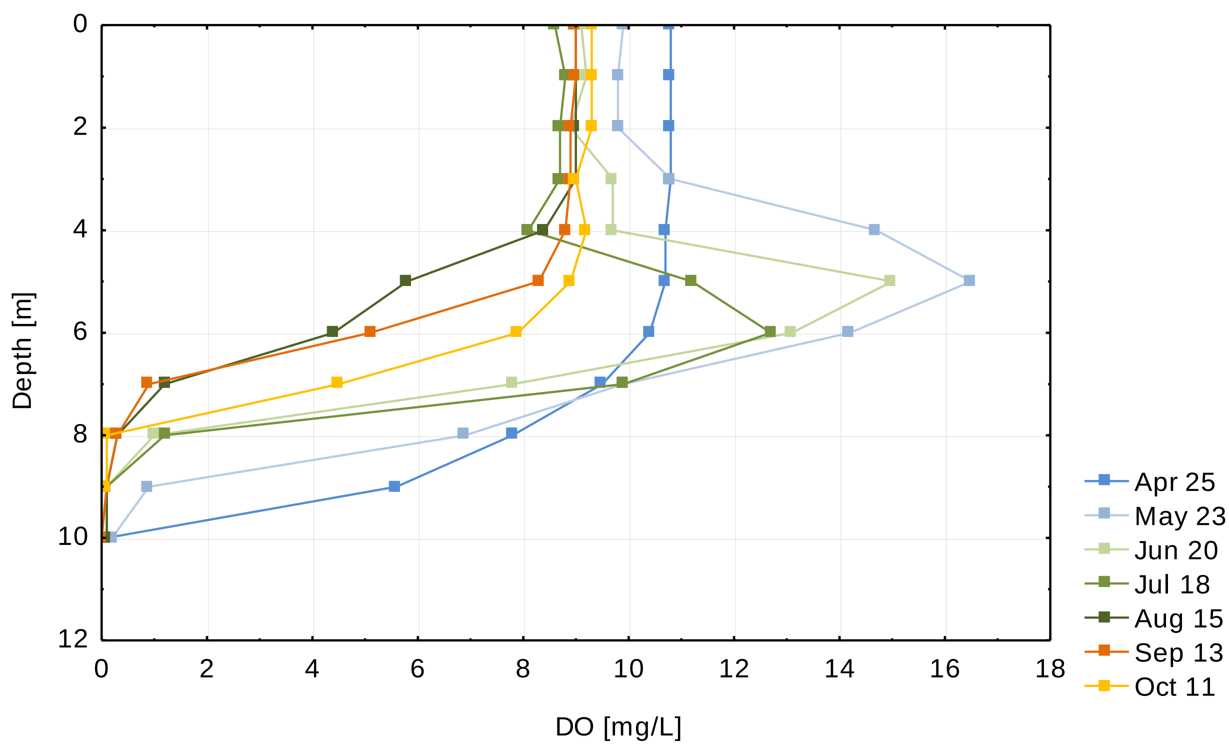


Figure 19. Dissolved oxygen profiles at Site 206, 2011.

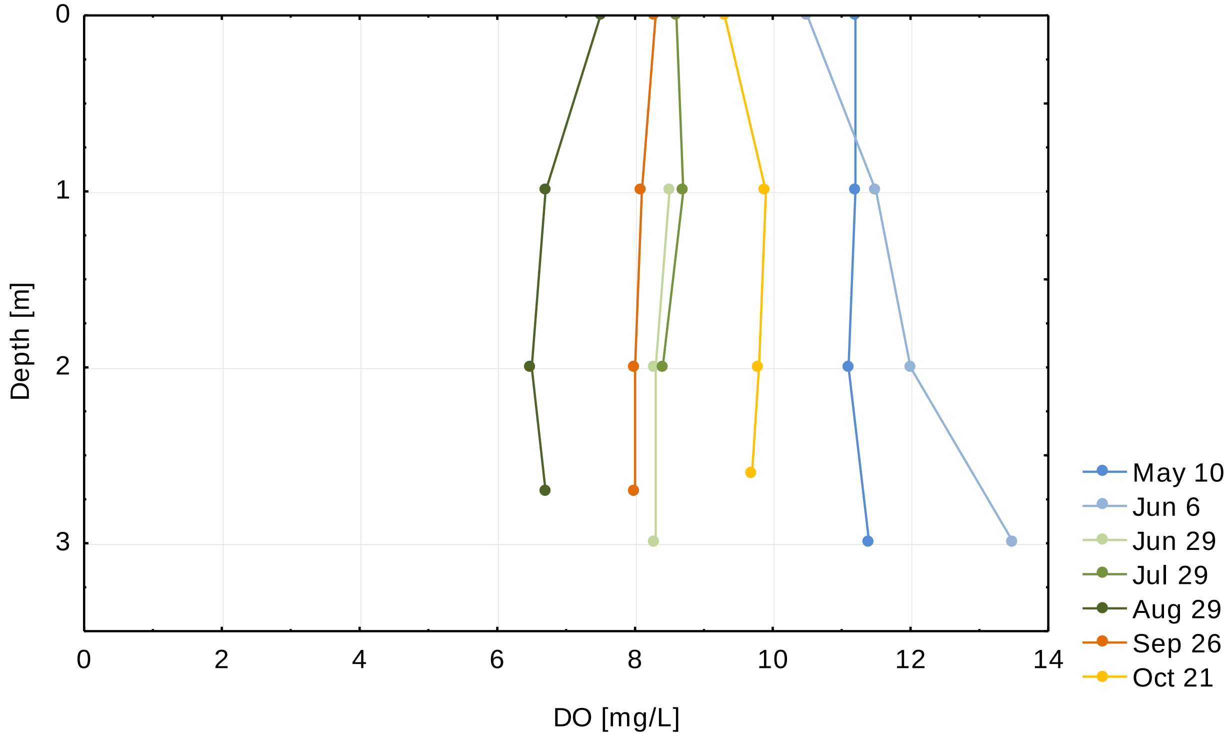


Figure 20. Dissolved oxygen profiles at Site 207, 2011.

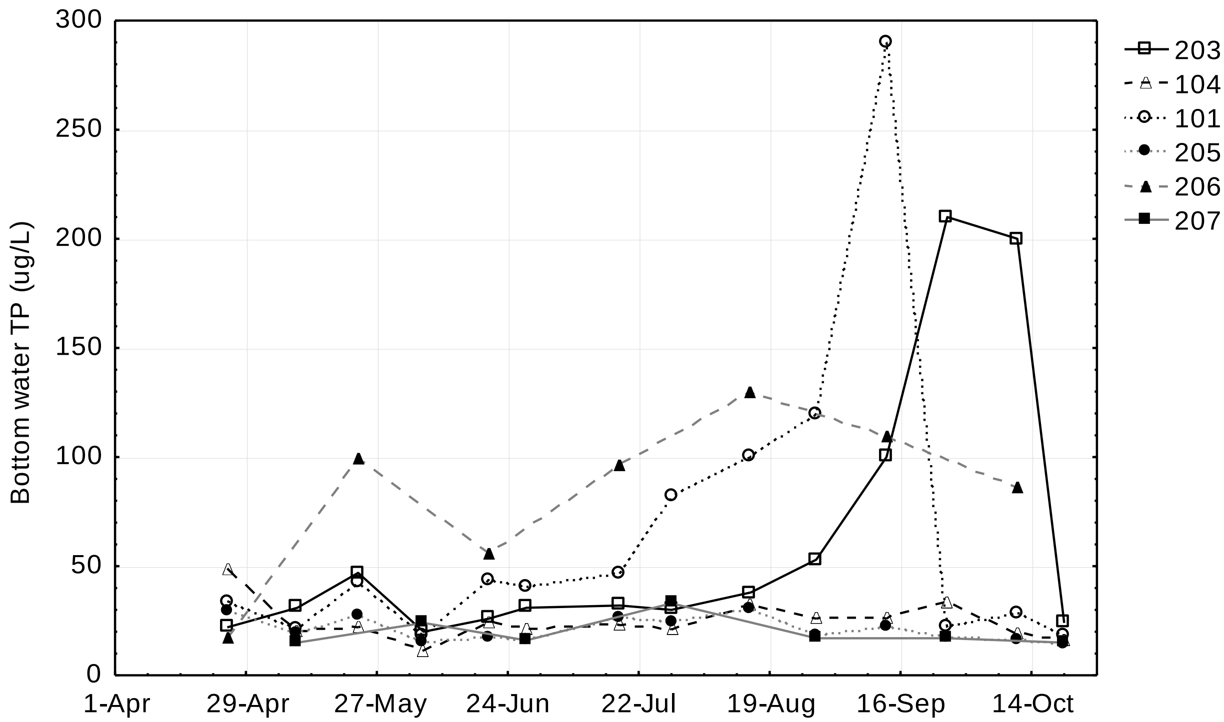


Figure 21. Seasonal bottom water TP trends for 6 sites in Lower Prior Lake, 2011.

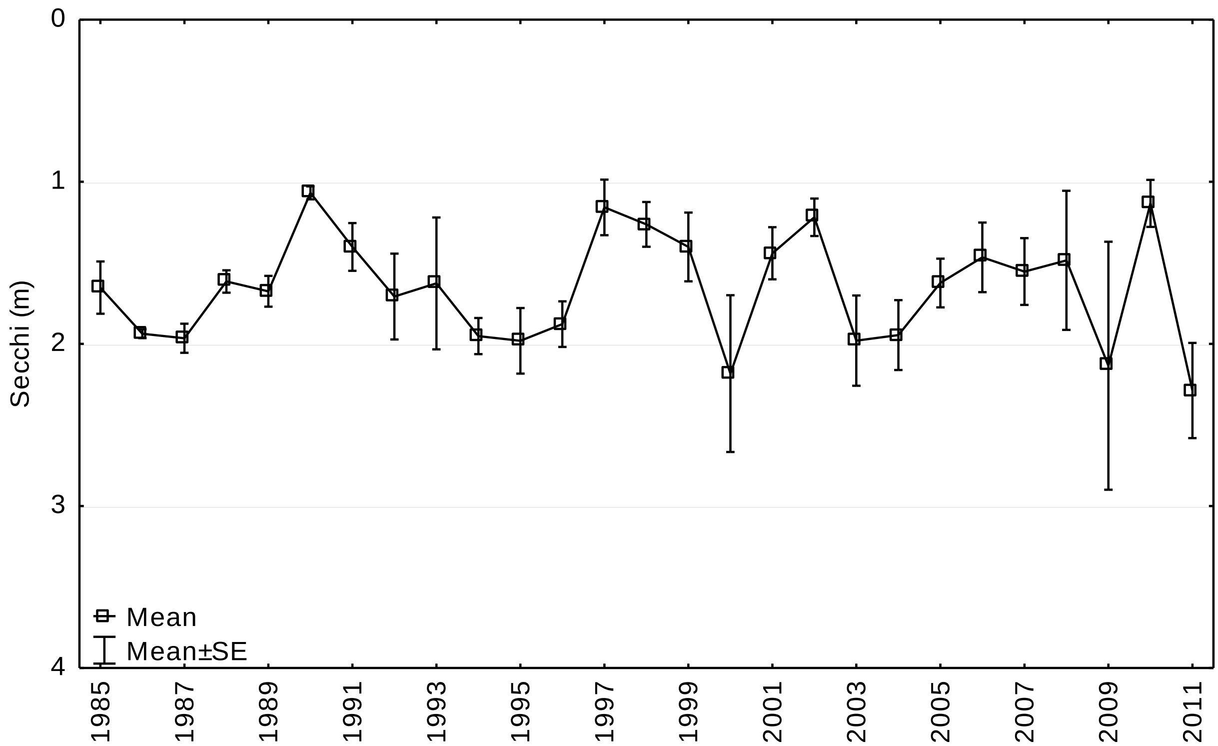


Figure 22. Growing season mean Secchi transparency in Lower Prior Lake (Site 203), 1985-2011.

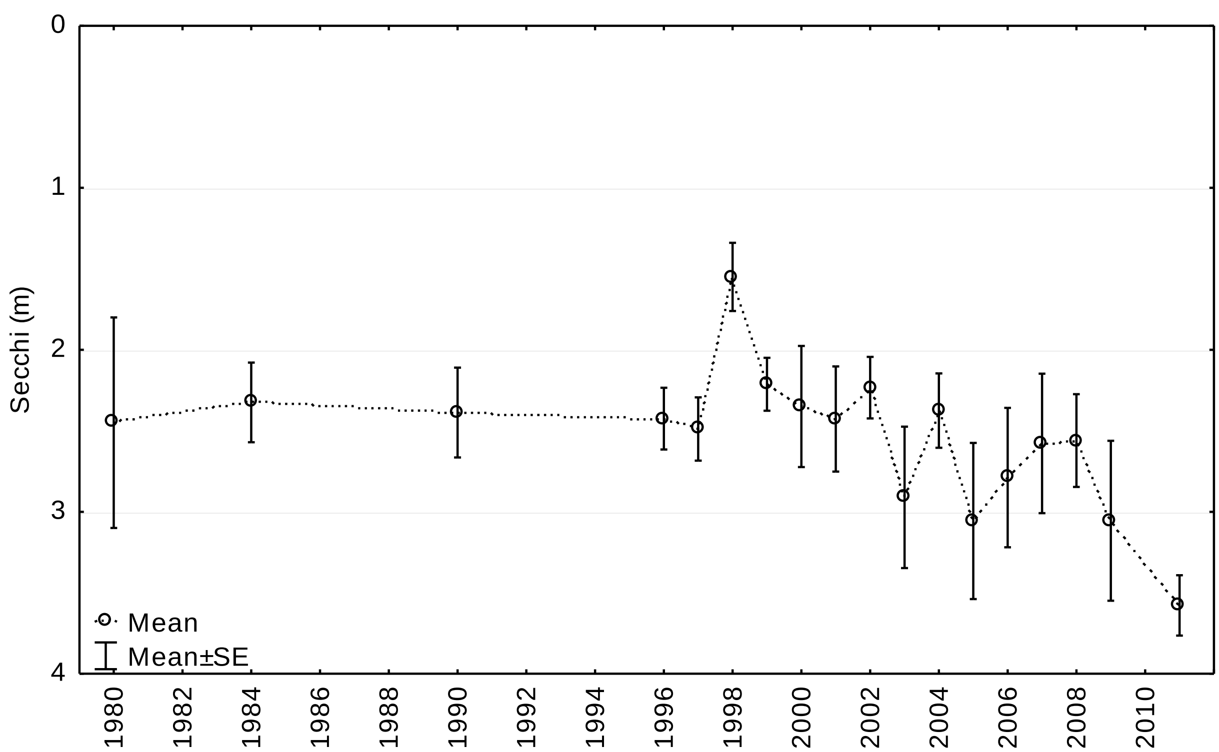


Figure 23. Growing season mean Secchi transparency in Lower Prior Lake (Site 101), 1980-2011.

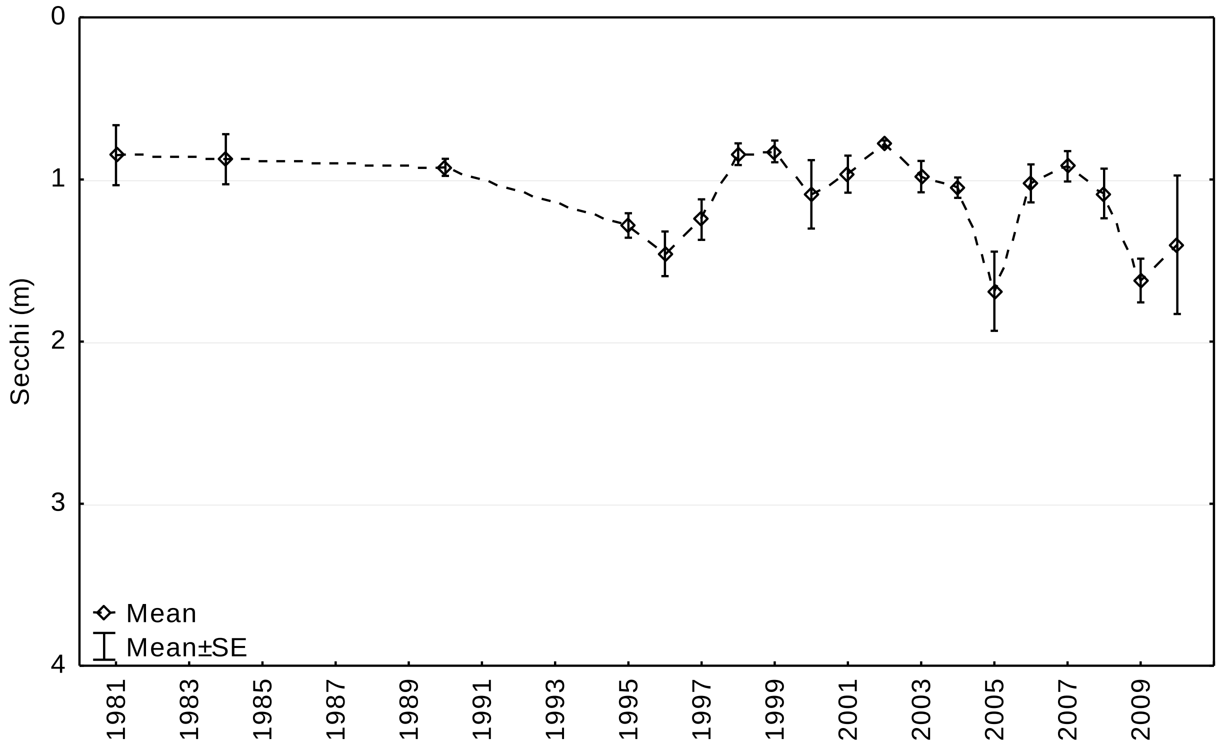


Figure 24. Growing season mean Secchi transparency in Upper Prior Lake (Site 202), 1981-2011.

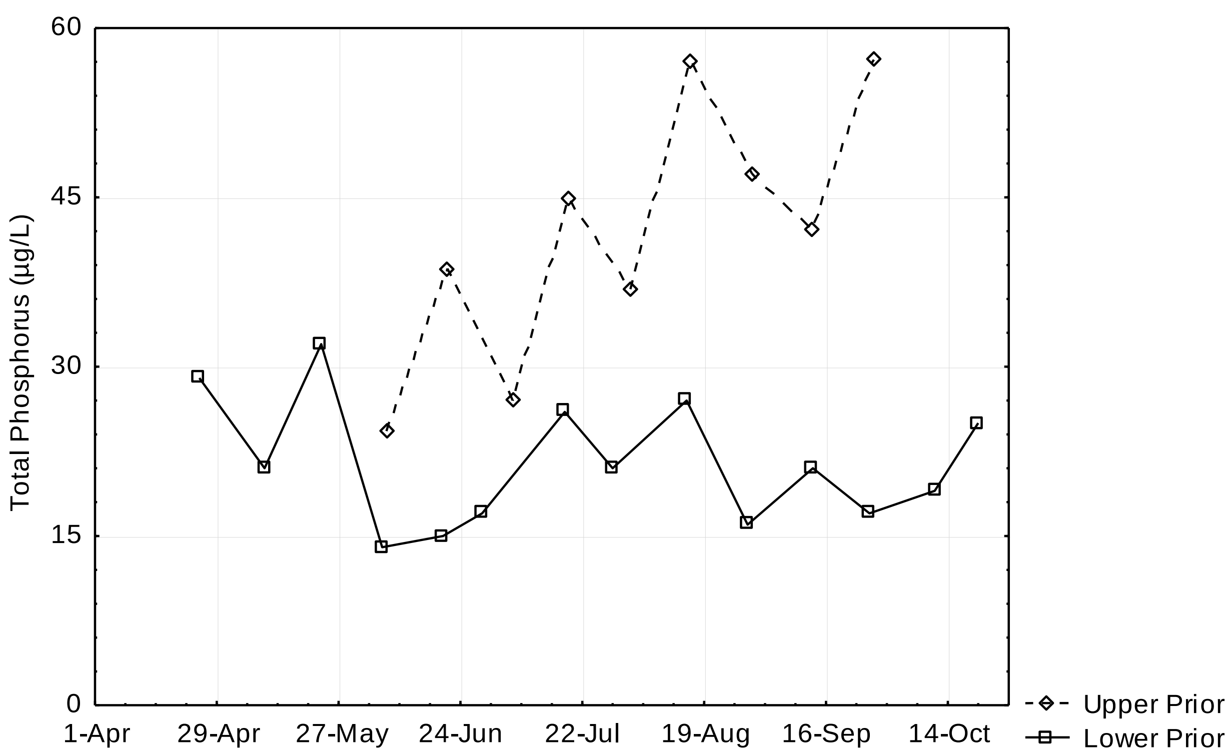


Figure 25. Seasonal TP trends in Upper (Site 202) and Lower (Site 203) Prior Lakes, 2011.

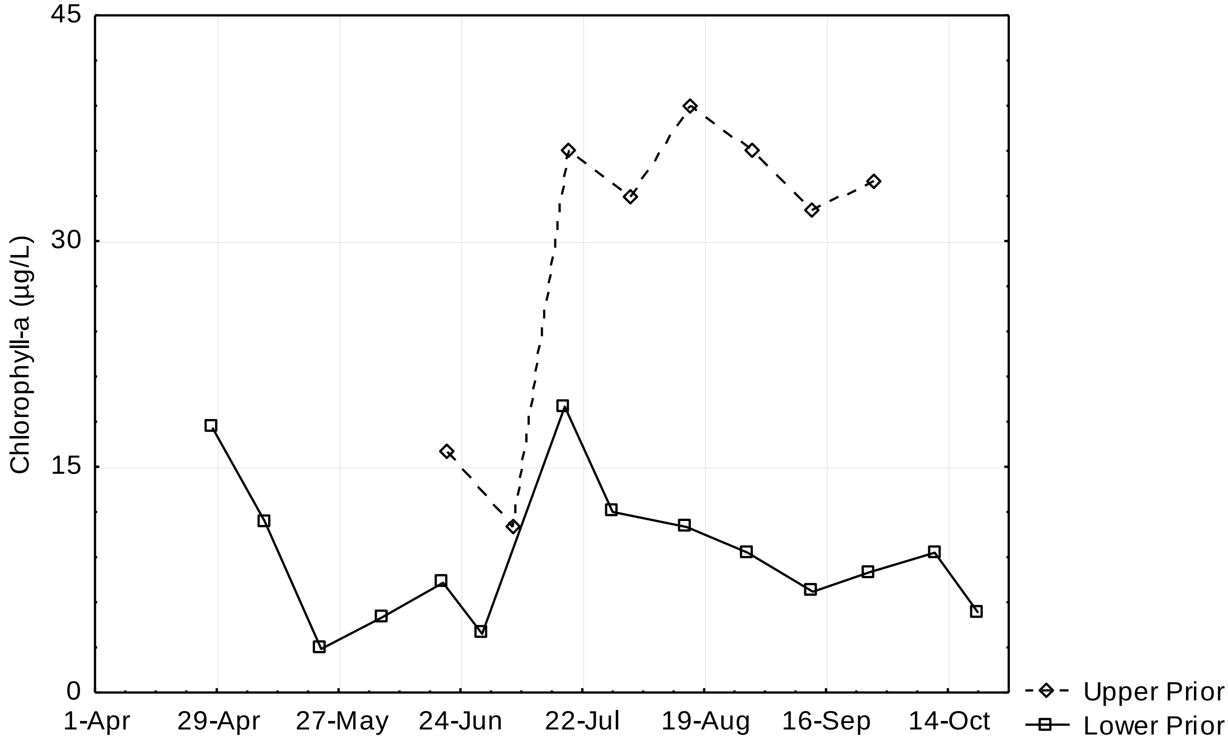


Figure 26. Seasonal Chl-*a* trends in Upper (Site 202) and Lower (Site 203) Prior Lakes, 2011.

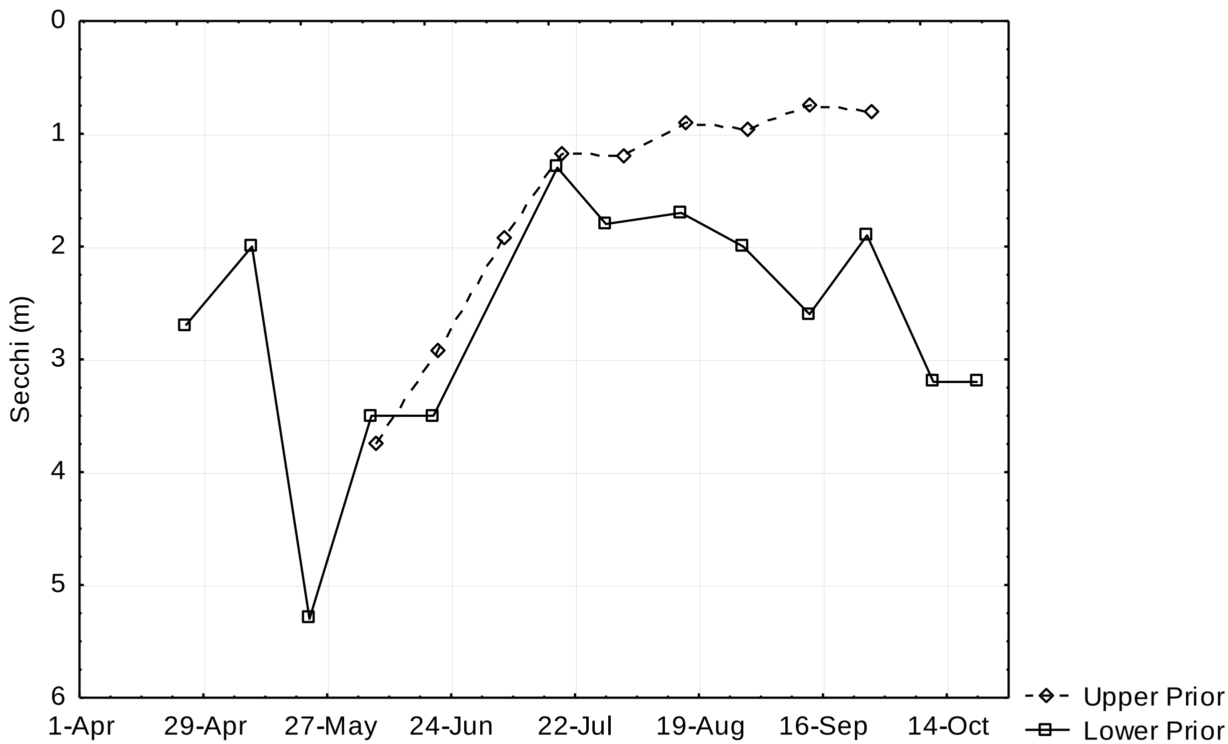


Figure 27. Seasonal Secchi trends in Upper (Site 202) and Lower (Site 203) Prior Lakes, 2011.

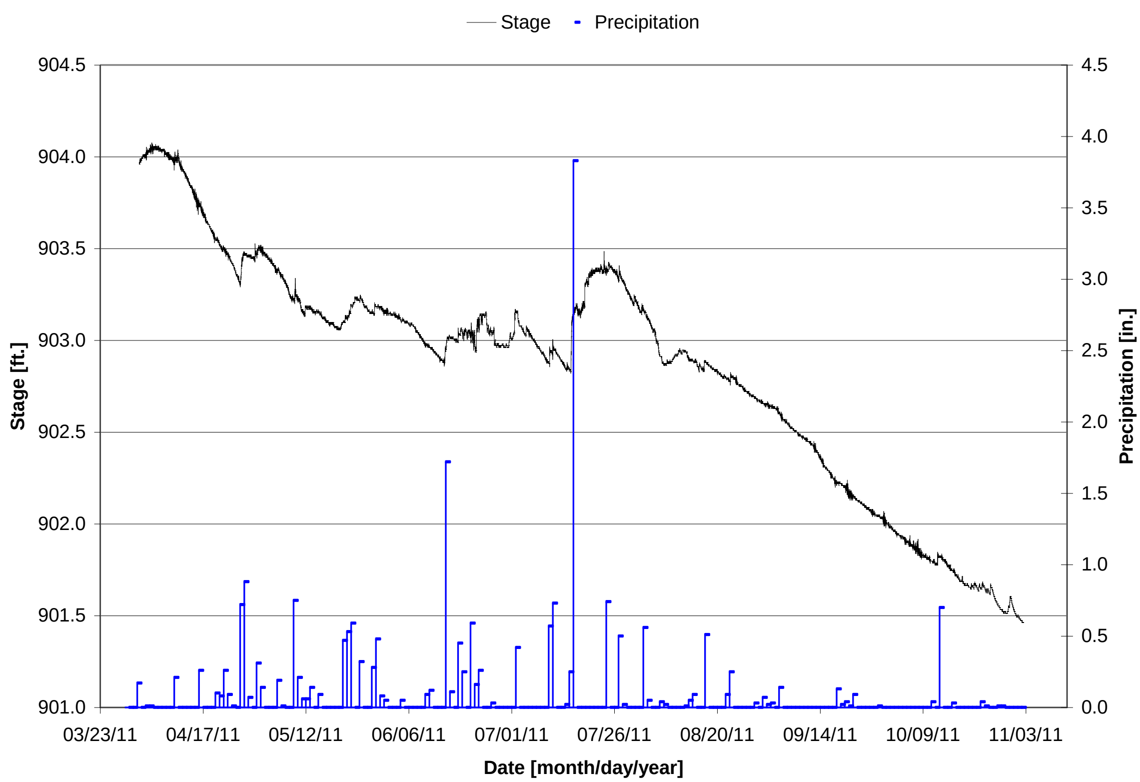


Figure 28. Lower Prior Lake outlet stage

Continuous stage data collected at the Prior Lake outlet; precipitation data from the MN Climatology Network (BYRG at 114N 22W Sec4)

2.2.3 Sediment sampling

Sediment organic matter was similar across all three sites sampled in 2011 (26-28%; Table 11). Sediment phosphorus release rates based on sediment phosphorus concentration in Lower Prior Lake varied among the three sites sampled in 2011 (Table 11). Phosphorus release rates based on iron-bound phosphorus concentration were higher at Sites 203 and 101 (1.34 and 0.93 mg/m^2/day, respectively) compared to Site 205 (0.44 mg/m^2/day). This is consistent with the hypolimnetic phosphorus concentrations measured at these sites; hypolimnetic TP increased throughout the season at sites 203 and 101, but not at site 205 (Figure 21). The phosphorus release rates based on total sediment phosphorus concentration were the same at all three sites (7.70 mg/m^2/day) due to equal sediment TP concentrations.

Table 11. Sediment properties and phosphorus release rates in Lower Prior Lake, 2011.

Site	Organic matter (%)	Iron-bound P (BDP, mg/kg dry sediment)	Total P (mg/kg dry sediment)	Release Rate NA Lakes BDP* (mg/m^2/day)	Release Rate Global Dataset TP* (mg/m^2/day)
203	26	140	1300	1.34	7.70
101	28	110	1300	0.93	7.70
205	28	74	1300	0.44	7.70

*Two release rates are based on models using two different data sets.

2.2.4 In-lake biology

Macrophytes

Two macrophyte surveys per year are typically completed: one in June to evaluate the prevalence of curly-leaf pondweed (an invasive aquatic plant that can affect the seasonal phosphorus concentration in a lake), and one in later summer to evaluate the extent of other macrophytes after the curly-leaf pondweed dies off. Additional macrophyte surveys were conducted in April and June of 2009-2010 to monitor the growth of curly-leaf pondweed in Lower Prior Lake (Figure 29 and Figure 30). Most sample sites (16 of 18) were concentrated around Martinson Island between the bays corresponding to Sites 203 and 101 from this study. One site was sampled in each of three other bays, corresponding to Sites 104, 205, and 207 from this study.

In the two most recent June surveys, curly-leaf pondweed was found in at least half of the surveyed sites and at low to medium densities (Figure 30 and Figure 32). Eurasian watermilfoil (another invasive aquatic plant, thought to have less effect on phosphorus concentrations) has been present in Lower Prior Lake since 1991. In recent macrophyte surveys (2002-2008), Eurasian watermilfoil occurrence declined throughout the lake while the density per site remained variable (Figure 29 and Figure 31).

In bays with Sites 203 and 101, moderate to heavy growth of curly-leaf pondweed was found in approximately two-thirds of the sampled sites in 2009, and in approximately one-half of the sampled sites in 2010. Curly-leaf pondweed could be contributing to internal phosphorus load in these bays during die-back and senescence in mid-summer. At Sites 104, 205, and 207, curly-leaf pondweed was present in all three years but the average density was low and not considered a problem.

The 2002-2008 survey data and the 2009-2010 survey data are not comparable representations of the macrophyte community in Lower Prior Lake because the 2002-2008 macrophyte survey data were a summation of plants found along a transect out from shore, while the 2009-2010 macrophyte survey data were plants found at a single point. The 2009-2010 macrophyte survey data seem to have been collected at the depth of maximum curly-leaf pondweed growth and thereby result in a lower abundance and density of other macrophytes than were actually present.

Plankton

A detailed summary of the phytoplankton and zooplankton community was reported in the 1993 Diagnostic and Feasibility Study. In brief, the dominant phytoplankton groups observed in Lower Prior Lake in 1993 were blue-greens, green algae, and diatoms. Green algae were most abundant in March, diatoms were most abundant in April and May, and blue-green algae were most abundant from June to September. Blue-green algae can form noxious blooms; however, algal blooms are not a concern in Lower Prior Lake. The dominant zooplankton group observed in Lower Prior Lake in 1993 was copepods, with cladocerans composing 40% of the zooplankton community in July. At that time, the zooplankton density in Lower Prior Lake was less than in Upper Prior Lake. Plankton data were not collected as part of the current diagnostic study.

Fish

The fish community in Lower Prior Lake was composed of common carp, bullheads (yellow, brown, and black), planktivores (bluegill, green sunfish, hybrid sunfish, and pumpkinseed), small piscivores (perch and black crappie), and large piscivores (largemouth bass, northern pike, and walleye; Figure 33). The abundance of bullheads has risen since 1991 but is not expected to have a strong impact on water quality. Carp were present in Lower Prior Lake from 1982 to 2000, but were not present in the four fish surveys conducted since 2000[4]. Walleye fingerlings were stocked annually from 1970 to 1992 and in alternate years since 1993. A northern pike spawning area was operated periodically from 1979 to 1998 (DNR Fisheries Management Plan).

Zebra mussels

Zebra mussels were found in Lower Prior Lake in 2009. Zebra mussels are filter-feeding organisms that can change the food web within a lake by filtering plankton and increasing water transparency. They attach to hard substrates, including structures such as pipes, boats, and docks, interfering with aquatic recreation and other lake uses.

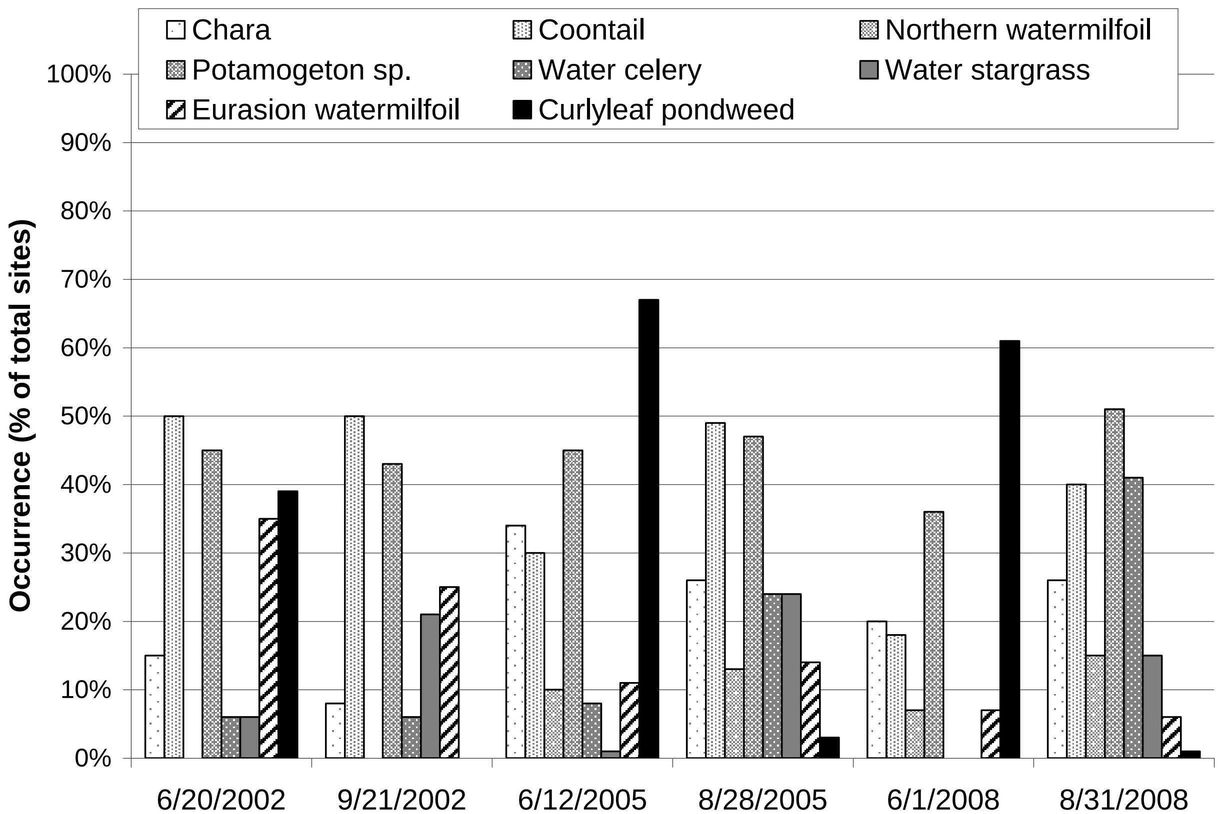


Figure 29. Macrophyte abundance as % occurrence of total sites, 2002-2008.

[4] DNR fish survey techniques, such as gill nets, are not designed to capture carp, and likely underestimate their abundance.

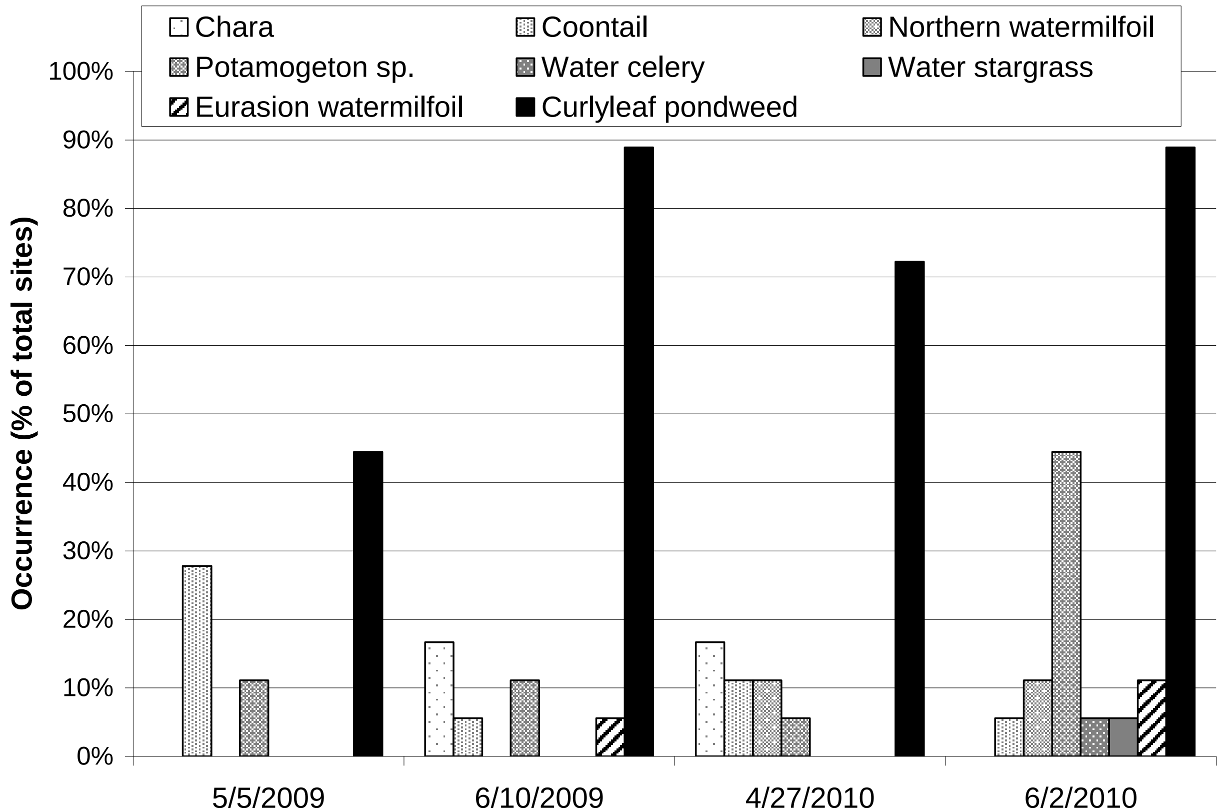


Figure 30. Macrophyte abundance as % occurrence of total sites, 2009-2010.

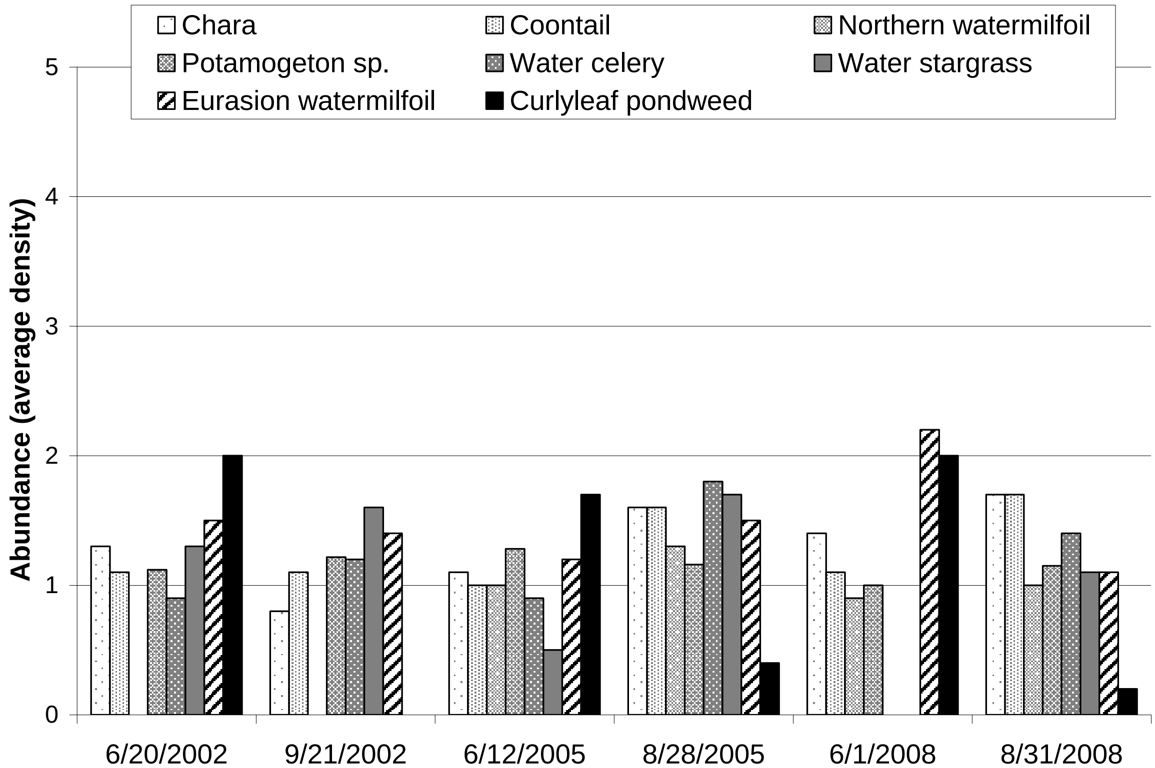


Figure 31. Macrophyte abundance as average density (low = 1 to high = 5), 2002-2008.

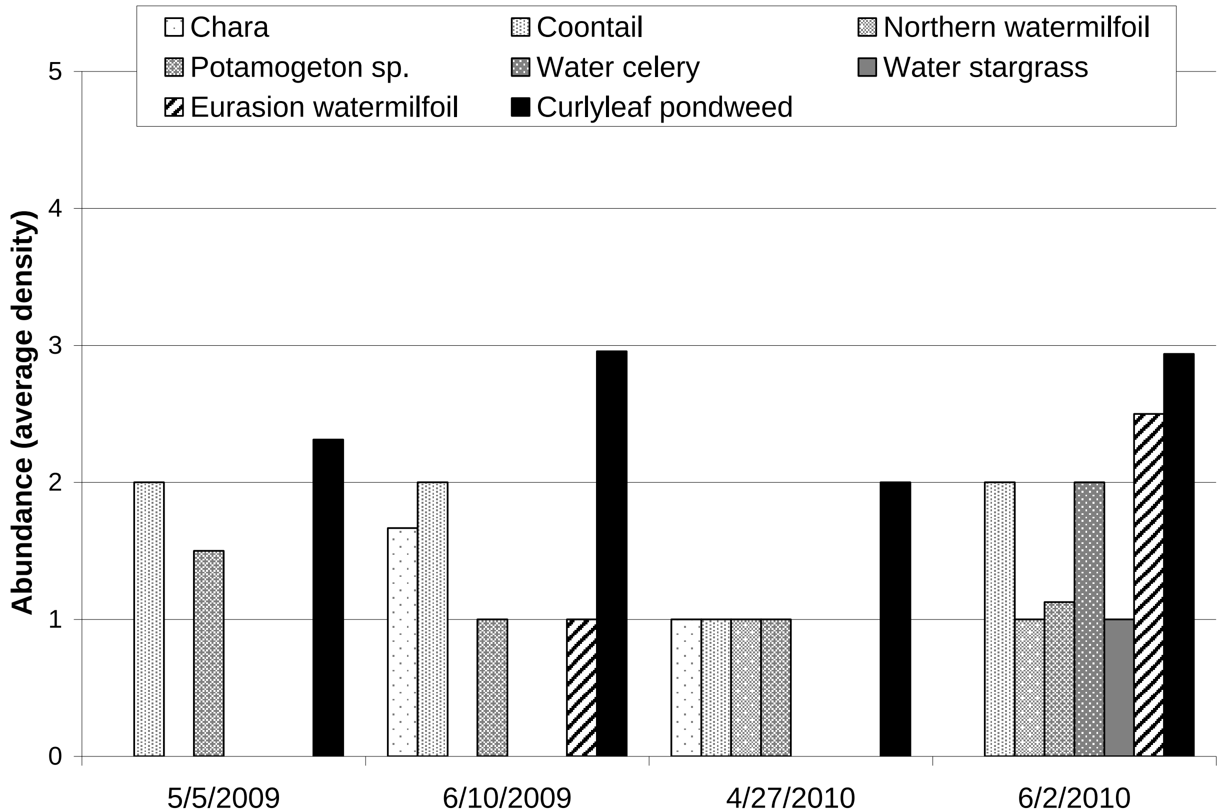


Figure 32. Macrophyte abundance as average density (low = 1 to high = 5), 2009-2010.

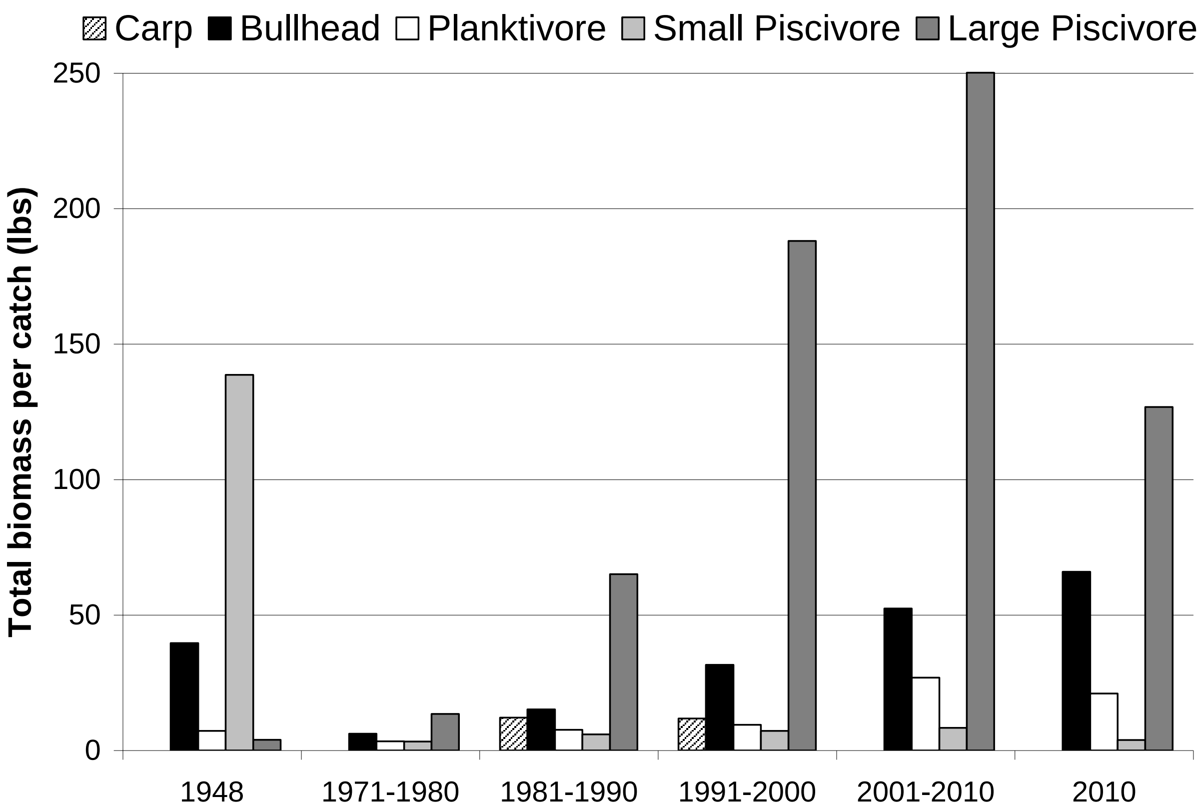


Figure 33. Fish biomass per catch (lbs) by trophic group (DNR) in Lower Prior Lake, 1948-2010.

Fish catch data were averaged by 10-year period and separated into the following groups: Carp (common carp); bullhead (yellow, brown, and black bullheads); Planktivore (bluegill, green sunfish, hybrid sunfish, and pumpkinseed); Small Piscivore (perch and black crappie); Large Piscivore (largemouth bass, northern pike, walleye).

2.2.5 Shoreline survey

Lower Prior Lake's shoreline vegetation was inventoried and separated into eight categories based on vegetation type and land use. The buffer width of this shoreline vegetation was quantified by distance from the lake's edge, up to 50 feet from the shoreline. Natural shoreline vegetation was categorized as "forest" or "native grass." A third category of natural shoreline also included "forest, with homes and hardscaping" which represents areas of forested canopy cover with homes and other structures in the understory.

Much of Lower Prior Lake's shoreline is composed of residential homes with a combination of the vegetation types "lawns" and "lawns with trees." Additional residential areas categorized as "beach" have a shoreline entirely composed of sandy beachfront.

A few minor erosion spots were also documented around the lake, mostly at culvert inlets. The most significant erosion site was in an undeveloped area identified as "grazed pasture," located at the northwest end of the lake. These erosion locations are also included in Figure 34 to show the relationship of the erosion location with respect to subwatershed boundaries and storm sewer infrastructure. Some of the erosion spots are located at or near stormsewer outfalls, while others are not. Scattered throughout are also several areas with "road" up to the edge of the shoreline.

68% of the shoreline is disturbed or developed (lawn, road, grazed pasture, and beach categories from Figure 34), the majority of which is residential lawns; 23% of the shoreline is natural (forest, forest with homes and hardscaping, and native grass); and 9% is lawns with trees.

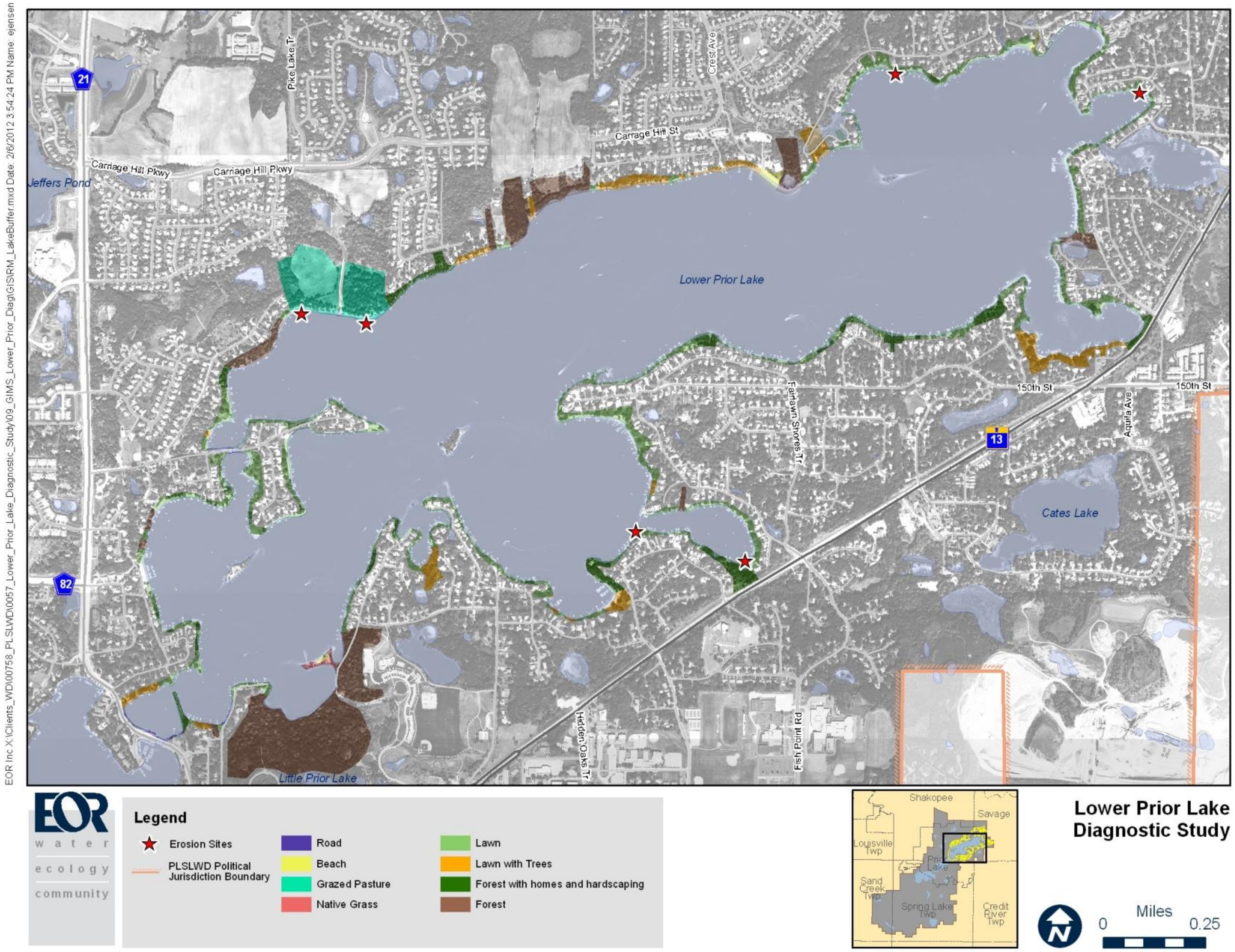


Figure 34. Shoreline vegetation and land cover

2.2.6 Watershed loading

Watershed phosphorus loading in the study area was estimated using the P8 model. Loading is reported as two different outputs: watershed loading ("basin loading") and loading exiting ponds and wetlands ("pond outlet loading"). Model outputs are shown graphically (Figure 35) and reported in table format in *Appendix B: P8 Model* . The maps show basin loading and pond outlet loading for each modeled subwatershed. The maps also categorize each watershed as having low or high TP loading rates per unit area (< 0.24 and > 0.24 lb/ac-yr, respectively). Land-locked subwatersheds were not modeled.

The modeling results indicate that the subwatersheds fall into one of three groups of existing phosphorus treatment:

1) No treatment: 688 acres (36% of project area)

   The only subwatersheds that do not receive any treatment before discharge to Lower Prior Lake are the ones in the direct drainage area (Figure 35), areas neither shaded in red or green, nor hatched in yellow).

2) Undersized treatment: 317 acres (16% of project area)

   Subwatersheds that are shaded red in Figure 35 have high modeled phosphorus loading rates relative to the other subwatersheds in the project area, likely due to undersized ponds.

3) Sufficient treatment: 580 acres (30% of project area)

   Subwatersheds that are shaded green in Figure 35 contain adequately sized ponds and wetlands to treat the watershed runoff.

In addition, a portion of the project area is land-locked (345 acres, 18% of modeled watershed) and does not contribute to surface areal phosphorus loading to Lower Prior Lake.

Table 12. P8 watershed phosphorus loading results

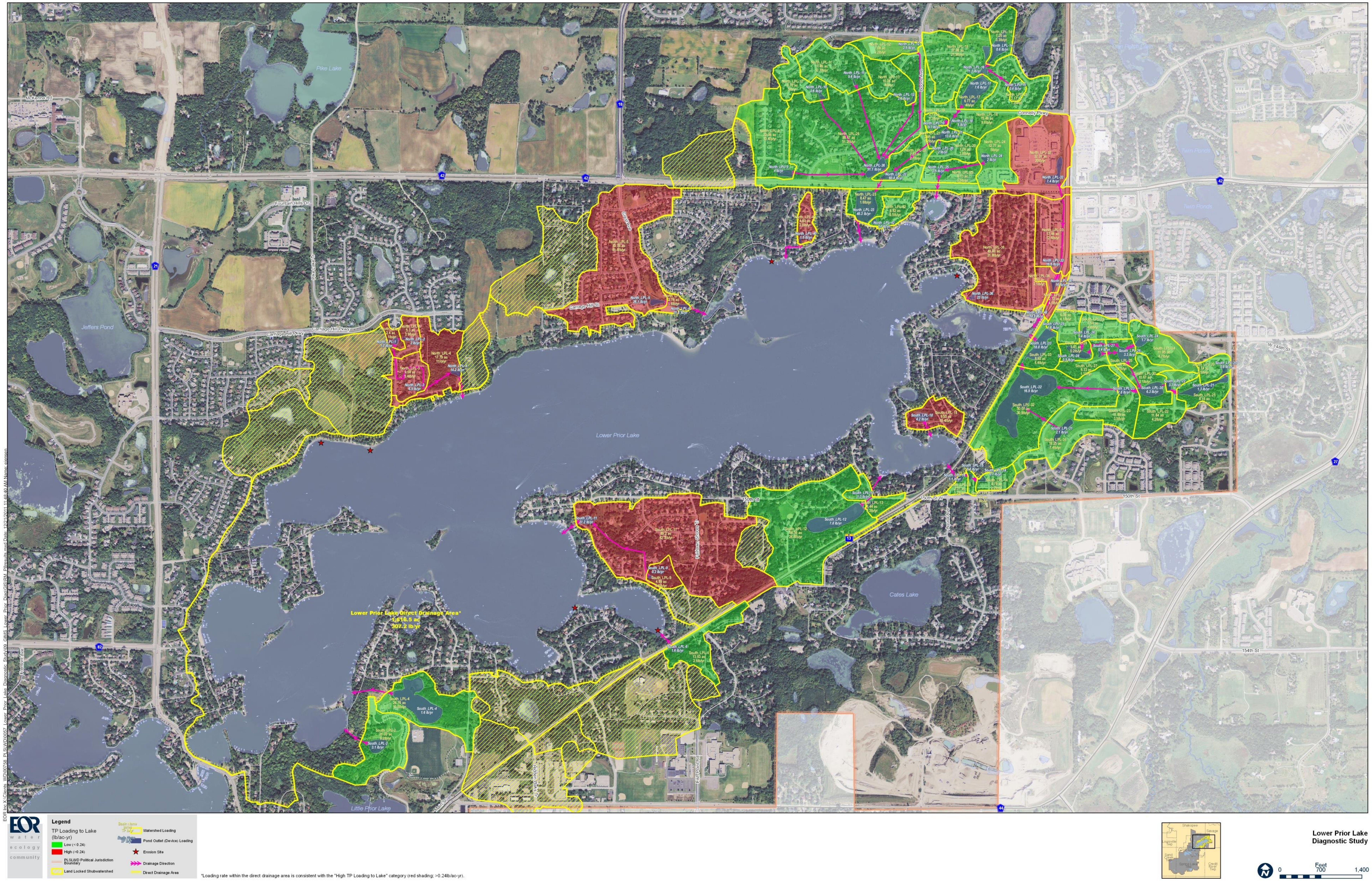
Subwatershed	Surface Area (ac)	Total P Load (lb/yr)	Areal P Load (lb/ac)	BMP Efficiency (%)
1) No Treatment:				
Direct Drainage	688	307.2	0.45	0
2) Undersized Treatment:				
North_LPL-4	35	14.2	0.40	22
North_LPL-6	68	21.6	0.32	24
North_LPL-36	50	23.0	0.46	44
North_LPL-40	5	1.5	0.30	6
North_LPL-48	56	18.8	0.34	63
South_LPL-11	94	27.2	0.29	62
South_LPL-18	10	4.2	0.44	20
Total	*317*			
3) Sufficient Treatment:				
North_LPL-23	261	48.3	0.19	36
North_LPL-25	21	3.5	0.17	28
South_LPL-2	21	3.1	0.15	68
South_LPL-4	27	1.6	0.06	38
South_LPL-6	14	1.6	0.12	35
South_LPL-12	65	7.8	0.12	39
South_LPL-16	8	1.1	0.14	57
South_LPL-33	163	18.8	0.12	0
Total	*580*			
Non-contributing:				
Landlocked	345			
Total Project Area:				
Total	*2,860*			

Model results were compared to 2011 data collected in the watershed by the Scott SWCD on behalf of the PLSLWD (Table 13). Synoptic monitoring occurred on three dates in the summer of 2011 and values monitored are generally within the same range as the concentrations reported in the model. The peak monitored phosphorus concentration of 552 µg/L at Site 6 is high and, although a single event means very little, this is a site to further investigate whether or not there is a high load from that subwatershed. See Figure 3 (page 15) for monitoring site locations.

Table 13. Watershed monitoring, 2011

Site	Date	Trans-parency (cm)	Dissolved Oxygen (mg/L)	Turbidity (FNU)	Flow (cfs)	Dissolved Ortho Phosphate * (µg/L)	Total Phosphorus (µg/L)
1	9-May-11	61.0	2.1	0.0	0.2	65	147
6	9-May-11	61.0	7.4	0.9	0.3	45	117
1	21-Jun-11	61.0	0.8	1.3	2.0	85	212
3	21-Jun-11	27.5	2.6	18.0	0.7	82	163
6	21-Jun-11	61.0	1.8	2.8	1.0	90	552
33	21-Jun-11	53.5	7.6	12.1	1.5	7	99
1	17-Aug-11	61.0	1.0	1.9	0.3	73	195
33	17-Aug-11	61.0	8.2	6.6	0.5	7	89
33	23-Aug-11	61.0	8.3	4.4	0.3		

*Dissolved ortho-phosphate represents dissolved inorganic phosphorus (phosphate)



*Loading rate within the direct drainage area is consistent with the "High TP Loading to Lake" category (red shading; >0.24lb/ac-yr).

Figure 35. P8 modeling results

2.3 Conclusions

This diagnostic study was conducted to provide information to protect the water quality of Lower Prior Lake and to ensure that the lake will remain a recreational lake suitable for fishing and swimming. This was accomplished by:

- Evaluating the spatial and temporal variability of water quality in Lower Prior Lake to determine if there are certain subwatersheds that lead to spatial variability of water quality within the lake.
- Comparing water quality in Lower Prior Lake to water quality in Upper Prior Lake to determine if the cause of poorer water quality during the later summer months is due to internal loading and/or ecological interactions within Lower Prior Lake or due to poor water quality from Upper Prior Lake.
- Identifying areas of highest phosphorus loading to Lower Prior Lake.

Water quality in Lower Prior Lake currently meets lake water quality standards. Except for higher algal abundance and lower transparency at Site 203, the water quality did not vary greatly among sites.

2.3.1 The water quality at Site 203 is influenced strongly by the water quality of Upper Prior Lake

Chl-*a* and Secchi transparency indicators of water quality were the worst at Site 203 and improved with increasing distance from Upper Prior Lake. Lower water quality at Site 203 was attributed to physical transport of algae and some phosphorus from Upper Prior Lake. Site 203 is located in the bay that directly receives water from Upper Prior Lake and discharges to the outlet channel of Lower Prior Lake. Upper Prior Lake has the greatest influence on water quality at Site 203 in Lower Prior Lake during spring and the beginning of summer when water levels are high and flow between Upper and Lower Prior lakes is greatest.

Internal phosphorus loading from the sediment may also contribute to lower water quality at Site 203 due to strong summer stratification, phosphorus accumulation in the bottom waters, and strong correlation between TP and Chl-*a*.

Site 203 Water Quality Goals

- Improve water quality of Upper Prior Lake.
- Reduce internal phosphorus loading from sediments.

2.3.2 The influence of Upper Prior Lake water quality on Lower Prior Lake decreases with increasing distance from Upper Prior Lake

Improved water quality in Upper Prior Lake will not necessarily impact water quality in most of Lower Prior Lake. Water quality in Lower Prior Lake further from the outlet of Upper Prior Lake than Site 203 is more greatly influenced by phosphorus loading from the watershed and internal loading from the sediments. The total drainage area of subwatersheds with high phosphorus loading rates (> 0.24 lb/ac) was 1934 acres, or 58%, of the project area. These areas should be the target of improvements to existing BMPs or construction of new BMPs to reduce the total phosphorus load from the watershed. Finally, while most of Lower Prior Lake stratified during the growing season and the bottom waters became devoid of oxygen, phosphorus accumulation in the bottom waters only occurred at Sites 101 and 206 in 2011. Internal phosphorus loading from the sediments is expected to have an influence on water quality in Lower Prior Lake in the Site 101 and Site 206 bays.

Lower Prior Lake Water Quality Goals

- Reduce phosphorus loading from the watershed by improving existing BMPs, constructing new BMPs in the direct drainage area, and improving shoreline buffers around the lake.
- Reduce internal phosphorus loading from sediments.

3 IMPLEMENTATION PLAN

3.1 Executive Summary

Location	BMP Type	P Removal [lb/yr]	Annual Cost-Benefit [$/lb]	Other Benefits					
				Involves Education	Beauty/ Natives	Reduces Erosion	Filters Pollutants	Reduces Volume	Provides Habitat
Shoreline	Residential rooftop disconnection	1.1	$1,263						
Shoreline	Shoreline buffers	2.6	$8,314						
Shoreline	Lawn management	1.3	$1,015						
SW-N1 SW-N2 SW-N3 SW-N4	Rain gardens 2 large infiltration areas Pond expansion	5.4	$929						
SW-N5 SW-N6	1 large infiltration area Parking lot storm drain rain gardens	11.7	$630						
SW-S9 SW-S11	Pond expansion Rain gardens 1 larger infiltration area	5.8	$1,454						
SW-N32 SW-N33 SW N34 SW-N48	Underground infiltration Swale Infiltration area	3.2	$5,043						
SW-10	Ditch checks	10.1	$46						
SW-S18	Rain gardens	0.3	$1,255						
SW-1	Rain gardens	1.8	$416						
SW-2	Rain gardens	1.6	$350						
SW-4	Rain gardens	1.8	$316						
SW-5	Rain gardens	0.4	$279						
SW-6	Rain gardens	0.5	$646						
SW-8	Rain gardens	2.7	$321						
SW-11	Rain gardens	1.5	$431						
SW-13	Infiltration area	2.3	$660						
SW-14	Rain gardens	7	$441						
SW-18	Rain gardens	2.3	$312						
SW-19	Rain gardens	3.2	$721						
SW-23	Rain gardens	0.6	$549						
SW-25	Rain gardens	9.1	$337						

The objective of the implementation plan was to identify specific load reduction activities needed to achieve the in-lake water quality, and information and education goals developed for Lower Prior Lake listed in Section 3.2 below. This plan sets forward a "menu" of potential implementation activities. In adopting this plan, the District is not committing to implement every activity evaluated here; rather, the information summarized here will help the District and its partners decide which implementation items to pursue, as opportunities and funding become available.

A balanced mix of public regional BMPs (pond expansions and large infiltration areas) and watershed-wide private projects (buffers and rain gardens) with a strong emphasis on education programs was chosen as primary components of a preliminary implementation plan to maintain water quality in Lower Prior Lake. Specifically, these include the following:

- Regional public projects
  - Infiltration areas and pond expansion in SW-N1/N2/N3/N4
  - Infiltration area and parking lot storm drain rain gardens in SW-N5/N6
  - Infiltration area and pond expansion in SW-S9/S11
  - Hwy 13 ditch checks in SW-10
- Watershed-wide private projects
  - Shoreline buffers
  - Raingarden implementation in SW-14 and SW-25
- Education programs
  - "Habitat for Watershed" neighborhood volunteer rain garden program
  - K-12 outreach programs

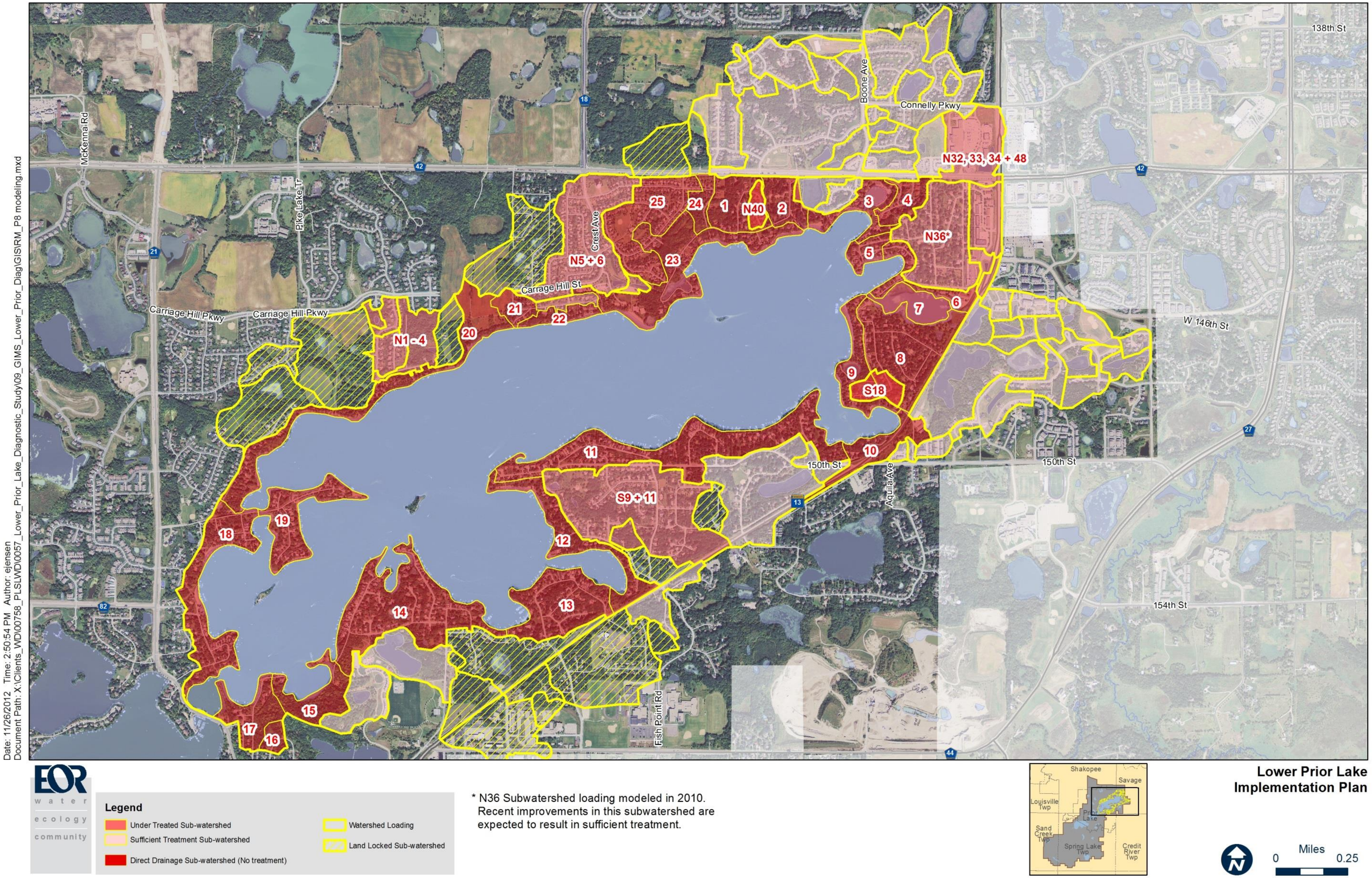
If all these projects were implemented, they would be expected to reduce 52 lb/year from the Lower Prior Lake watershed phosphorus load at a projected annual cost (2013-2015) of approximately $38,000 (Table 21).

These load reduction activities were chosen from a complete list of potential load reduction activities identified in the Lower Prior Lake watershed based on the following criteria:

- Phosphorus reduction cost-benefit ranking
- Other benefits such as wildlife benefits, aesthetic benefits, volume reduction
- Stakeholder interest
- Involvement of an education component, leading to long-term improvement in management practices by stakeholders.

Specific information on each load reduction activity can be found in Section 3.5 and in Appendix D. Load reduction activities that involve the City of Prior Lake are summarized in Appendix D.

Figure 36. Watershed phosphorus loading priority management areas and modeled P8 subwatersheds for Lower Prior Lake



* N36 Subwatershed loading modeled in 2010. Recent improvements in this subwatershed are expected to result in sufficient treatment.

3.2 Relevant Projects and Programs Implemented since the 1993 Feasibility Study

The following activities address recommendations in the 1993 feasibility study (see Section 1.1.3 for more details on the diagnostic and feasibility study that was conducted for Spring Lake, Upper Prior Lake, and Lower Prior Lake):

- A Minnesota-wide ban on phosphorus lawn fertilizer was established in 2005 to reduce the phosphorus runoff from high phosphorus fertilizers to Minnesota surface waters.
- PLSLWD's stormwater management and buffer rules are currently being updated in 2012 and are expected to include:
    - Rule D: Stormwater Management
    - Rule J: Buffers
- Spring and Upper Prior load reduction activities, which will affect phosphorus loading to parts of Lower Prior lake:
    - Installation of a FeCl injection system downstream of County Ditch 13 in 1998.
    - An Alum application in Spring Lake is currently planned for 2013 or 2014.
    - Agricultural incentive programs implemented in coordination with the Scott Soil and Water Conservation District.
- Aquatic plant management, specifically Curlyleaf Pondweed.

3.3 Proposed Load Reduction Activities

In this section, we will address the following load reduction approaches:

- "Habitat for Watershed" volunteer program
- K-12 outreach program
- Ponding
- Infiltration features
- Impervious disconnection
- Shoreline buffers
- Lawn management
- Source control

Each load reduction approach should be considered a potential activity that the PLSLWD (or another entity) may decide to pursue, based on available resources and organizational priorities.

At the end of this section, summaries of identified retrofit BMP opportunities by subwatershed and funding opportunities are presented.

3.3.1 ”Habitat for Watershed” neighborhood volunteer program

Stakeholders (specifically the PLSLWD CAC) expressed interest in forming a volunteer program to help residents in need (elderly, disabled, or poor) implement BMPs on their property. These programs could be targeted towards catchments identified in *Section 3.6.2 BMP Selection and Justification* as high priority for BMP implementation. Volunteers would be trained by professionals, and in turn would use their expertise in helping interested neighbors. Potential BMPs to implement could include impervious surface disconnection, rain barrels, yard management such as leaf pickup and mulching or composting, identification and repair of erosion, etc.

Phosphorus Reduction Benefit

Phosphorus reduction will be calculated on a case-by-case basis, as volunteers work with interested landowners.

Other Benefits

This program will provide an opportunity for engaged citizens to help and train others, helping to fill the gap between professional staff and interested parties (who are usually the recipients of activities, rather than implementers). It will open paths for education and dialog.

Estimated costs

Costs to organize a neighborhood volunteer program and material costs to construct volunteer rain gardens could be provided with grant monies obtained by the PLSLWD.

Implementation

Implementation of a neighborhood volunteer program will be directed by PLSLWD.

3.3.2 K-12 outreach program

Stakeholders also expressed interest in developing outreach programs for K-12 students in area schools. Children are an excellent way to involve parents and spark new behaviors. These programs could include components on rooftop disconnection, shoreline buffers, lawn management, and rain gardens.

Phosphorus Reduction Benefits

Phosphorus reduction benefit will likely be more long term and cumulative, coming out of changing opinions and behaviors regarding water quality.

Other Benefits

The program will increase engagement in water resources and improve overall understanding of the water cycle and water pollution. It will also provide enrichment opportunities for children.

Estimated costs

Costs to organize a K-12 outreach program would be incorporated in area schools environmental curriculum and/or PLSLWD education annual budgets.

Implementation

Implementation of a K-12 outreach program will be directed by PLSLWD and the environmental curriculum coordinator for area schools.

3.3.3 Sediment phosphorus inactivation

(Image from aquaticcontroltech.com)

Internal loading in lakes refers to the phosphorus load that originates in the bottom sediments and is released back into the water column. The phosphorus in the sediments was originally deposited in the lake sediments through the settling of particulates (attached to sediment that entered the lake from watershed runoff, or as phosphorus incorporated into biomass) out of the water column. Internal loading can occur through various mechanisms including anoxic (lack of oxygen) conditions in the overlying waters, physical disturbance by bottom-feeding fish such as carp and bullhead, physical disturbance due to wind mixing or boats, and phosphorus release from decaying curly-leaf pondweed.

One method to reduce the release of phosphorus from the sediment into the water column is to apply aluminum sulfate to the lake (alum treatment). Aluminum sulfate permanently binds with phosphorus through a chemical reaction, prohibiting phosphorus release during anoxic conditions. The alum strips phosphorus from the water column during application and also forms a layer on the surface of lake bottom sediments having the effect of 'capping' the sediment. Alum treatments are typically effective at sediment phosphorus inactivation for 5 to 10 years.

Phosphorus reduction benefits

We assumed that 75% of the internal load would be reduced through an alum treatment due to uncertainties in the estimation of internal loads and application of alum.

Other benefits

This treatment method is specifically for phosphorus reduction.

Estimated costs

The capital costs of an alum treatment ranges from tens of thousands to hundreds of thousands of dollars. Typical 30-year O&M cost-benefit ratios for alum treatments are less than $100 per lb. phosphorus removed; the estimated cost-benefit ratio for the planned Spring Lake alum treatment is between $16 and $25 per lb. phosphorus removed.

Site selection

While most of Lower Prior Lake stratified during the growing season and the bottom waters became devoid of oxygen, phosphorus accumulation in the bottom waters only occurred at Sites 203, 101, and 206 in 2011. Internal phosphorus loading from the sediments is expected to have an influence on water quality in Lower Prior Lake in the Sites 203, 101 and 206 bays.

Implementation

Implementation of sediment P inactivation will be directed by the PLSLWD.

O&M

Reapplication of alum at the end of the treatment lifespan, typically 5 to 10 years.

3.3.4 Stormwater ponds

Stormwater ponds perform rate control, retain watershed runoff, and reduce watershed phosphorus loading by promoting the settling of particulates and associated phosphorus loads. They typically have a high treatment volume, and some ponds provide additional volume control or phosphorus treatment via infiltration or filtration.

(Image from metrocouncil.org)

Phosphorus reduction benefits

The phosphorus reduction benefits of stormwater ponds were determined using the Program for Predicting Polluting Particle Passage thru Pits, Puddles, & Ponds (P8). Modeling assumptions for each pond by subwatershed can be found in Appendix D.

Other benefits

- Provides rate control for stormwater runoff
- Volume control (depending on design)
- Wildlife habitat

Estimated costs

Cost for pond retrofits included a base cost that included an estimate of mobilization, site clearing, and infrastructure improvements. This cost varied from site to site. In addition to this base cost, a rough estimate of cubic yards of excavation was multiplied by a unit cost of $15 per cubic yard. It should be noted that excavation unit costs can vary significantly depending on available disposal location and whether or not the material is considered contaminated by MPCA dredging guidelines. Costs assume that the material will not need to be landfilled.

Site selection

Because all subwatersheds in the study area are 100% developed, no new sites were identified for stormwater ponds . However, the existing ponds were reviewed for potential retrofit opportunities. Based on space constraints a determination was made as to whether pond expansion was possible to provide additional treatment volume. Maintenance needs were also identified during the site visits.

Implementation

Implementation of stormwater pond enhancements will be directed by the PLSLWD and the City of Prior Lake.

3.3.5 Infiltration Areas

Infiltration areas are vegetated depressions that collect, temporarily store, and infiltrate phosphorus-rich surface runoff into underlying soils. *Raingarden* typically refers to simple design and on-lot scale infiltration areas. Raingardens can be placed in a variety of locations including in yards, parking lot islands, road medians, and traffic islands. *Aboveground infiltration features* typically refers to large-scale features designed for infiltration of larger storm events. *Underground infiltration features* are underground excavations filled with clean granular stone or other void forming material that receive runoff and allow it to infiltrate into the native soil. All of these features require larger surface areas per treatment volume relative to stormwater ponds.

Phosphorus reduction benefits

The phosphorus reduction benefits of infiltration areas were determined using the Program for Predicting Polluting Particle Passage thru Pits, Puddles, & Ponds (P8). Modeling assumptions for each infiltration area by subwatershed can be found in Appendix D. Rain gardens were modeled for each subwatershed at maximum, mid-range, and minimum levels of total basin surface area. The maximum total surface area was determined based on field identification of the most feasible allowable space. P8 was then used to model the phosphorus removal efficiencies associated with each level of installation. Removal efficiencies below 10% are not reported.

Other benefits

- Provides rate control for stormwater runoff
- Reduces stormwater runoff volume
- Adds to property values (increases aesthetic appeal)
- Increases wildlife habitat (native vegetation)
- Provides public education through signage

Estimated costs

Cost for raingardens included a base cost of $1,000 per rain garden which includes things such as mobilization and curb cuts and then adding $7.50 per square foot which includes costs for excavation, soil amendments and plantings. Costs were further customized from there depending on special circumstances (e.g. retaining walls).

For larger surface infiltration features the same unit cost of $7.50 per square foot was used, however the base cost was modified based on a rough estimate of infrastructure needs to route the stormwater through the features.

Site selection

Infiltration features were sited based on space availability and ability to route drainage areas to these treatment features.

Rain gardens were best fit locations when it seemed to make sense for the watershed or neighborhood based on a quick walk through. Rain garden locations should not be interpreted to mean that these are the only areas that could accommodate rain garden features. Rain garden locations with the greatest contributing area should be investigated first. Locations that would be within the drainage area of another rain garden should be avoided. Optimal raingarden locations were chosen according to standard field protocol (APPENDIX X). In general, optimal sites are located just upgradient of storm drain inlets to capture the maximum amount of runoff from a roadway. In the absence of storm drain inlets, optimal locations were chosen based on contributing drainage area size and other factors. Optimal locations are near the lowest point of the drainage area and no other raingardens are proposed upgradient of an optimal site. Other potential sites are shown as alternatives, where raingardens could be installed if the optimal sites are not available. Other site factors considered included potential for conflict with utilities, land cover characteristics of the contributing drainage area, slope steepness, and existing landscaping.

Implementation

Implementation of infiltration areas will be directed by the PLSLWD and the City of Prior Lake. Please see *Appendix E: Raingarden Siting Methodology* for the recommended procedure to determine which identified raingarden locations to pursue.

3.3.6 Impervious Disconnection

Impervious disconnection is the process of directing flow from roof downspouts or impervious surfaces (such as parking lots and driveways) to pervious areas where stormwater runoff can infiltrate into the soil. This reduces the volume of stormwater and the amount of phosphorus that directly enters the storm sewer system. Small scale impervious disconnection typically involves downspout disconnection of residential roof runoff, while larger scale impervious disconnection typically involves routing pavement flow and commercial roof runoff to nearby infiltration areas.

(image from lowimpactdevelopment.org)

Phosphorus reduction benefits

The phosphorus reduction benefits of downspout disconnection were estimated based on the total impervious surface area of residential and commercial roofs, and commercial parking lots in the direct drainage area. The total treated area of these impervious surfaces was 12.5% of the total direct drainage area, and therefore the total treated watershed TP load by downspout disconnection was estimated at 12.5% of the direct drainage load (307.2 lb), or 38.4 lb. Infiltration of impervious runoff from impervious disconnection practices results in an estimated 50% reduction in phosphorus from the treated watershed load.

Other benefits

- Reduces stormwater runoff volume
- Incorporates stakeholder education

Estimated costs

Downspout disconnection of residential roof runoff is inexpensive. Materials such as elbows and extensions are readily available at home improvement stores. We estimated that the total cost for residential downspout disconnection was around $50 per home. This cost to homeowners could be offset by rebates from the PLSLWD. Construction costs for impervious disconnection of commercial roof or pavement runoff are higher, and include infrastructure costs needed to route water from impervious surfaces to areas of infiltration, and an estimated $7.50 per square foot of infiltration area for excavation, soil amendments and plantings. There are also additional education costs to encourage implementation of impervious disconnection among residential homeowners and business owners; these costs are estimated at $30/landowner/year, assuming funding and outreach are managed through the District's cost-share program.

Table 14 lists the phosphorus removal cost-benefits achieved under different implementation rates of residential rooftop disconnections in the direct drainage area of Lower Prior Lake. An implementation rate of 100% equates to rooftop disconnection implemented in every shoreline parcel (609 parcels total).

Table 14. Phosphorus removal cost-benefits for residential rooftop disconnections

Implementation Rate	Rooftop Disconnections [#]	P reduction [lb/yr]	Capital Costs [$]	Education Costs [$/yr]	30-yr Cost-Benefit [$/lb]
100%	609	11.4	$30,450	$18,270	$1,700
80%	487	9.1	$24,360	$14,610	$1,700
60%	365	6.8	$18,270	$10,950	$1,700
40%	244	4.5	$12,180	$7,320	$1,700
20%	122	2.3	$6,090	$6,660	$1,700
10%	61	1.1	$3,045	$1,830	$1,700

Site selection

Impervious surface areas of roads and rooftops were calculated in ArcGIS using satellite imagery. Approximately 25% of the total watershed area is covered by impervious surfaces. We estimated that half of this, or 12.5% of the total watershed area, is covered by directly connected roofs and pavement.

Implementation

Implementation of impervious disconnection practices will be directed by the PLSLWD.

3.3.7 Shoreline buffers

Buffers provide native vegetation with deep roots along lakeshores. Lakeshore buffers reduce phosphorus loads through reduced runoff velocities and increased settling of particulates, enhanced infiltration of water into the soil, and vegetative absorption of phosphorus in runoff. Buffers should be at least 15 feet wide and on average 25 feet wide for optimal benefits. (image from shorelinecreations.net)

Phosphorus reduction benefits

Lower Prior Lake has ~19 miles of unbuffered shoreline with over 500 different landowners. An average phosphorus removal rate for buffers is estimated at 50% with optimum width and no erosion. Because Lower Prior Lake currently meets water quality standards, buffers proposed in this implementation plan were estimated at 15 feet wide with a slight reduction in phosphorus removal benefits (~25%). In general, buffers treat the nearest 100 feet of upland surface runoff. The total treated area was calculated as the total length of unbuffered shoreline (101,402 feet) times the average treated width (100 feet), or 232.8 acres. The total treated area was 14% of the total direct drainage area, and therefore we estimated that the total treated watershed TP load by shoreline buffers was 14% of the direct drainage load (307.2 lb), or 44.2 lb.

Table 15 lists the phosphorus removal cost-benefits achieved under different implementation rates of shoreline buffers along the unbuffered portion of the Lower Prior Lake shoreline. An implementation rate of 100% equates to 15 feet wide buffers constructed along the entire length of unbuffered shoreline.

Other benefits

- Filters pollutants and sediment from runoff
- Protects shorelines from erosion
- Provides wildlife habitat
- Adds to property values (increases aesthetic appeal)
- Incorporates stakeholder education

Estimated costs

A good estimate is that shoreline buffers average around $3-$4 per square foot, depending on soil conditions and density and types of plants used (Coffman *et al.* 1999). Education costs include preparing, advertising, and running two workshops (see Section 3.5.1) to reach approximately 5% of lakeshore owners with unbuffered shorelines, including $300 per site visit for an average of 20 lakeshore owner attendees per workshop. Ongoing education costs are assumed to be $30/landowner/year, assuming funding and outreach are managed through the District's cost-share program.

Table 15. Phosphorus removal cost-benefits for shoreline buffers

Implementation Rate	Treated Area (ac)	Annual TP reduction (lb)	Capital Costs ($)	Education Costs ($/yr)	30-yr Cost-Benefit ($/lb)
100%	232.8	11.06	$6,084,120	$24,670	$20,560
80%	186.2	8.85	$4,867,296	$19,730	$20,560
60%	139.7	6.64	$3,650,472	$14,800	$20,560
40%	93.1	4.42	$2,433,648	$9,870	$20,560
20%	46.6	2.21	$1,216,824	$4,930	$20,560
10%	23.3	1.11	$608,412	$2,470	$20,560

Site selection

An analysis of aerial photography was used to determine shoreline vegetation type and was confirmed by a visual inspection of the shoreline (See Section 2.2.5 and Figure 34). Shorelines with beaches, lawns, lawns with trees, or along roads were considered unbuffered. The total length of unbuffered shoreline was measured in ArcMap at 101,402 feet.

Implementation

Implementation of shoreline buffers will be directed by the PLSLWD through the Stakeholder Education Program (See Section 3.5.1).

3.3.8 Lawn management

(image from beautifulbotany.com)

Phosphorus loading from lawns generally results from: a) the direct transport of grass clippings, leaves, and mulch into water bodies, b) erosion of exposed soil, or c) the application of phosphorus containing fertilizer to soils with high phosphorus content. To reduce phosphorus loading from lawns, leaves and grass clippings should be kept out of contact with watershed runoff, driveways, and streets and a healthy, dense stand of turf grass should be maintained to prevent erosion of the soil. Specifically, it is recommended to:

1. Leave grass clippings on the lawn as fertilizer to promote the growth of healthy, dense stands of turfgrass.
2. Use a phosphorus-free fertilizer and fertilize in the fall rather than the spring according to the recommendations published by the University of Minnesota Extension in the table below.
3. Mow higher (at least 2 ½ to 3 ½ inches) to shade out weeds.
4. Mow often and do not cut off more than one-third of the grass blade so clippings will filter into the grass and quickly decompose.
5. Keep leaves and grass clippings out of contact with watershed runoff by sweeping away from driveway and streets, spreading as mulch, composting, or hauling it away.

Table 16. Nitrogen recommendations for established lawns
(from Rosen et al. 2006. *Fertilizing Lawns*. University of Minnesota Extension, http://www.extension.umn.edu/distribution/horticulture/dg3338.html)

Maintenance practices	Nitrogen (N) to apply (lb. N/1000 ft2)	Timing of applications*
High-maintenance lawn		
(Irrigation, clippings removed)	4	Aug, Sept, mid-Oct, May-June
(Irrigation, clippings not removed)	3	Aug, mid-Oct, May-June
Low-maintenance lawn		
(No irrigation, clippings removed)	2	Aug, mid-Oct.
(No irrigation, clippings not removed)	1	Sept

*Assuming 1lb N per 1000 ft^2 of quickly available nitrogen is applied at each application.

Phosphorus reduction benefits

We conservatively assumed that every parcel in each lake watershed could have approximately 0.125 acres of well managed turfgrass with a 25% implementation rate (i.e., 25% of residents follow proper lawn management recommendations). Implementation of proper lawn management is primarily achieved through landowner education, such as workshops, Lake Associations, K-12 outreach programs, or distribution of turf grass resources available through the University of Minnesota and the Minnesota Department of Agriculture.

Other benefits

- Reduces soil erosion
- Incorporates stakeholder education

Estimated costs

Table 17 lists the phosphorus removal cost-benefits achieved under different implementation rates of lawn management in shoreline parcels of Lower Prior Lake. There is no cost to homeowners to implement proper lawn management. Education costs include preparing, advertising, and running two workshops per year (at $300/apiece) to reach approximately 5% of lakeshore owners, for an average of 20 lakeshore owner attendees per workshop.

Table 17. Phosphorus removal cost-benefits for lawn management practices

Implementation Rate	Treated Area (ac)	Annual TP reduction (lb)	Capital Costs ($)	Education Costs ($)	30-yr Cost-Benefit ($/lb)
100%	117.6	5.6	$0	$9,140	$1,600
80%	94.1	4.5	$0	$7,310	$1,600
60%	70.6	3.4	$0	$5,480	$1,600
40%	47.0	2.2	$0	$3,650	$1,600
20%	23.5	1.1	$0	$1,830	$1,600
10%	11.8	0.6	$0	$910	$1,600
5%	5.9	0.3	$0	$460	$1,600

Site selection

Proper lawn management is a priority for parcels within the direct drainage area of Lower Prior Lake due to the potential for direct contribution of lawn runoff from these parcels. However, lawn management in the rest of the Lower Prior Lake watershed is also important to reduce the watershed phosphorus load treated by other load reduction activities, such as sedimentation ponds and infiltration features.

Implementation

Implementation of proper lawn management will be directed by the PLSLWD through the Stakeholder Education Program (See Section 3.5.1).

3.3.9 BMP Cost-benefits

The capital (including design, construction, and contingencies) costs and annual operation and maintenance (O&M) costs were calculated for each retrofit BMP based on BMP surface area (infiltration areas) or cubic yards of sediment removal (pond retrofits). The following estimates were used:

- Construction Costs:
  - Rain gardens: $1,000 mobilization costs + $7.50/square foot + $1,000/retaining wall
  - Infiltration area: $2,000-7,500 mobilization cost + $7.50/square foot
  - Infiltration basin: $30,000 mobilization cost + $7.50/square
  - Underground infiltration basin: $22/cubic yard
  - Pond expansions: $5,000-15,000 mobilization costs + $15/cubic yard
  - Swales: $3,000 mobilization costs + $7.50/square foot
  - Ditch checks: $750/ditch check
- Design and Contingency Costs = 25% of Construction Costs
- Annual O&M Costs = 1% of Construction Costs

The 30-year O&M cost-benefit estimates listed in Table 18 should be used for planning purposes only. Additional feasibility and design studies will be necessary to determine specific costs for each project.

Table 18. BMP Retrofit Opportunities, Lower Prior Lake

			Phosphorus Reduction				*Other Benefits*				
Location	**Treated Area**	**TP Load**	**BMP Type**	**BMP surface area**	**Annual TP Reduction Benefits**	**Cost – Benefit[2]**	**Involves Education**	**Aesthetics and Property Value**	**Filters Pollutants**	**Reduces Volume**	**Provides Habitat**
	acres	lb/year		square feet	lb/year	$/lb					
Shoreline parcels	5.1	2.3	Residential rooftop disconnection[1]	--	1.1	1,263	X			X	
Shoreline parcels	23	10.3	Shoreline buffers[1]	--	2.6	8,314	X	X	X		X
Shoreline parcels	11.8	5.3	Lawn management[1]	--	1.3	1,015	X				
Undertreated SW-N1, N2, N3, N4	35.2	12.2	Rain gardens Rain gardens Infiltration area at Beach St. and Rosewood Rd. Infiltration area at Hemlock Cir. and Bluebird Tr. Pond expansion	1,350 2,850 1,500 300 8,700	5.4	929	X	X		X	X
Undertreated SW-N5, N6	67.9	26.2	Infiltration area at Amblewood Dr. and Crest Ave. Rain gardens around boat parking lot storm drains	14,375 450	11.7	630	X			X	X
Undertreated SW-N32, N33, N34, N48	56.0	17.9	Underground infiltration area in Rainbow parking lot Swale along Boudin St. NE (S of Commerce Ave.) Infiltration area by dental clinic	7,350 2,600 435	3.2	5,043				X	
Undertreated SW-S9, S11	94.1	21.6	Pond expansion in Fish Point Park Rain gardens Indian Ridge Park infiltration areas	54,000 1,950 4,900	5.8	1,454	X			X	X
Undertreated SW-S18	9.6	3.5	Rain gardens	480	0.3	1,137		X		X	X
Direct drainage SW-1	23.6	4.8	Rain gardens	1,000	1.8	416		X		X	X
Direct drainage SW-2	14.4	5	Rain gardens	780	1.6	350		X		X	X
Direct drainage SW-4	11.5	7.8	Rain gardens	800	1.8	316		X		X	X
Direct drainage SW-5	8.1	4.9	Rain gardens	155	0.4	279		X		X	X
Direct drainage SW-6	14.2	11	Rain gardens	300	0.5	646		X		X	X
Direct drainage SW-8	52.4	21	Rain gardens	1,170	2.7	321		X		X	X
Direct drainage SW-10	19.2	13.9	Ditch checks along County 13 (N of 150th St.)	19,170	10.1	46					
Direct drainage SW-11	74.9	40.6	Rain gardens	600	1.5	431		X		X	X
Direct drainage SW-13	39.2	17.9	Infiltration areas at Manor Dr. and Candy Cove Tr.	2,650	2.3	660		X		X	X
Direct drainage SW-14	69.6	27	Rain gardens	4,500	7.0	441		X		X	X
Direct drainage SW-18	43.1	20.2	Rain gardens	1,050	2.3	312		X		X	X
Direct drainage SW-19	27.3	7.2	Rain gardens	3,150	3.2	721		X		X	X
Direct drainage SW-23	53.3	15.9	Rain gardens	450	0.6	549		X		X	X
Direct drainage SW-25	41.3	29.5	Rain gardens	4,180	9.1	337		X		X	X
Total Phosphorus Reduction The following (direct drainage) subwatersheds had no modeled BMPs: 3, 7, 9, 10, 12, 15, 16, 17, 20, 21, 22, and 24.					**76.3**						

[1] Assuming an implementation rate of 10% with associated education costs to achieve a 10% implementation rate

[2] Accounts for TP reductions over 30-years, capital costs, and other costs

3.3.10 BMP Selection and Justification

A balanced mix of public regional BMPs (pond expansions and large infiltration areas) and watershed-wide private projects (buffers and rain gardens) with a strong emphasis on education programs should be chosen as primary components of an implementation plan to maintain water quality in Lower Prior Lake.

Specific information on each load reduction activity can be found in Section 3.3 and in Appendix D. Load reduction activities that involve the City of Prior Lake are summarized in Appendix D.

3.3.11 Funding Opportunities

It is anticipated that the PLSLWD, in collaboration with the City of Prior Lake, will apply for a follow-up Clean Water Partnership grant from the MPCA for implementation of some or all of the items identified in this plan. Other funding opportunities through MPCA, the Minnesota Board of Water and Soil Resources (BWSR), and other sources will be considered.

3.4 Implementation Monitoring and Evaluation

3.4.1 Monitoring Plan

We recommend bi-weekly monitoring during the growing season (May through September) to assess any changes in water quality associated with implementation of load reduction activities. Table 19 lists parameters of interest for each bay based on the major controls on water quality identified for each bay in the Diagnostic Study (*Section 2*). The focus of monitoring should be at Site 203, the bay receiving flow from Upper Prior Lake, and Site 101. These bays characterize most of the lake volume and they have been identified as potential internal loading sites. Basic water quality parameters should be monitored in the other two major bays, Sites 104 and 205, to identify changes in water quality due to changes in watershed loading. In the two minor bay, Sites 206 and 207, secchi depth should be monitored. Any major changes in Secchi depth in these two bays should commence monitoring of the TP and Chl-a as well.

Table 19. Bi-weekly monitoring recommendations for Lower Prior Lake

Bay	Water Quality Parameter	Monitoring Goal
203	TP Chl-a Secchi depth Temperature and dissolved oxygen profiles	To identify changes in water quality due to changes in Upper Prior Lake water quality (TP and Chl-a) and internal loading (temperature and dissolved oxygen profiles)
101	TP (surface and bottom) Chl-a Secchi depth Temperature and dissolved oxygen profiles	To identify changes in water quality due to changes in watershed loading (TP and Chl-a) and internal loading (temperature and dissolved oxygen profiles)
104 205	TP Chl-a Secchi depth	To identify changes in water quality due to changes in watershed loading
206 207	Secchi depth	To identify changes in water quality due to changes in watershed loading

3.5 Roles and Responsibilities of Project Participants

Prior Lake-Spring Lake Watershed District

- Organizing workshops
- Distributing informational mailings
- Organizing and hosting community education events
- Organizing and leading a neighborhood volunteer program
- Overseeing the design and implementation of sediment P inactivation, stormwater pond enhancements, infiltration areas, impervious disconnections, and shoreline buffers
- Coordinating Cost-Share programs, including providing technical assistance and maintenance costs as appropriate

City of Prior Lake

- Organizing and advertising community education events
- Assisting with the implementation of stormwater ponds and other public BMPs
- Long-term evaluation and maintenance of public BMPs

Scott SWCD

- Assisting with workshops

Engineering Consultant

- Designing and overseeing implementation of stormwater pond enhancements and infiltration areas

Prior Lake Citizens Advisory Committee, Homeowners and Business Owners

- Providing feedback on diagnostic study and implementation plan and future watershed activities
- Attending educational events
- Implementing stormwater retrofit BMPs

3.6 BMP Operation and Maintenance Plan

Long-term performance of watershed BMPs is ensured with proper operation and maintenance. Typical issues that are addressed through operation and maintenance are:

- Sedimentation or debris accumulation in the BMP, associated structures, or pretreatment areas
- Invasive vegetation
- Loss of slope stabilization materials
- Structural damage to embankments, weirs, or risers

Detailed operation and maintenance activities must be developed during the planning stages for all BMPs. Annual operation and maintenance costs for selected regional BMPs are ~$4,030 (not including private landowner projects) and are listed in Table 21 below.

3.7 Permits Required

Permits may be required from the municipality in which the activity is to take place (i.e. City of Prior Lake or City of Savage).

City of Prior Lake: Any person who shall undertake an operation in the City including mineral extraction, depositing of materials, or excavation of any materials on any upland, watercourse, or wetland, as defined in the City code, shall first make an application and obtain a permit from the City Engineer. For uplands, any operation that will result in removal or deposition (or a combination of both) exceeding either 500 square feet of surface area or a volume of 50 cubic yards requires a permit. For watercourses and wetlands, as designated in the City of Prior Lake Surface Water Management Plan, any operation, without respect to a minimum area or volume, requires a permit.

All land disturbing activities, whether or not they require a permit from the District, must be completed in compliance with the standards and criteria of the District's Rules and in conformance with best management practices.

Several regional BMPs identified in this implementation plan are expected to require a permit. The Prior Lake-Spring Lake Watershed District has developed a permit handbook, including permit applications and specific permit requirements. This handbook can be found on the PLSLWD website at: http://www.plslwd.org/permits.php.

Work below the Ordinary High Water elevation of Lower Prior Lake (903.9) requires a permit from the MN Department of Natural Resources, including any shoreline restoration work or removal of aquatic or emergent species.

3.8 Program Elements, Milestone Schedule, and Budget

A 10-year (2013-2022) implementation schedule and budget for priority implementation activities in the Lower Prior Lake watershed are summarized in Table 20 and Table 21.

Table 20. 10-year schedule (2013-2022) for priority implementation activities in Lower Prior Lake

Priority Implementation Activity	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Regional public projects	■	■	■							
Watershed-wide private projects	■	■	■	■	■	■	■	■	■	■
Workshops (shoreline buffers)	■	■	■							
Informational mailings	■	■	■							
Community events	■	■	■	■	■	■	■	■	■	■
Neighborhood volunteer rain garden program	■	■	■	■	■	■	■	■	■	■
K-12 outreach programs	■	■	■	■	■	■	■	■	■	■

Table 21. Estimated costs for priority implementation activities in Lower Prior Lake.

Priority Implementation Activity	Annual project costs ($)			
	2013	**2014**	**2015**	**2016-2022**
In-lake monitoring	5,500	5,500	5,500	5,500
Regional public projects*	3,784	4,030	4,030	4,030
Watershed-wide private projects	‡	‡	‡	‡
Workshops	20,000	20,000	20,000	
Informational mailings	1,500	1,500	1,500	
Community events	5,000	5,000	5,000	1,000
Neighborhood volunteer BMP program	1,000	1,000	1,000	1,000
K-12 outreach programs	1,000	1,000	1,000	1,000
Total	**37,784**	**38,030**	**38,030**	**12,530**

*The cost estimate for 2013 regional public projects does not include an anticipated $500,000 for an Alum treatment of Spring Lake, which will have benefits to Spring and Upper Prior lakes as well as portions of Lower Prior.

‡ - Costs provided by private individuals

Underlined - Initial 2 years of budget include funds to build demonstration projects, additional years include staff time only

3.9 References

Coffman, L.S., R. Goo and R. Frederick, 1999: Low impact development: an innovative alternative approach to stormwater management. Proceedings of the 26th Annual Water Resources Planning and Management Conference ASCE, June 6-9, Tempe, Arizona.

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4 APPENDIX A: 2011 MONITORING DATA

Table 22. 2011 monitoring data

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
25-Apr-11	203	0	0	1	7.64	11.4		8.09	433	2.7		29	1.1	56.4
25-Apr-11	203	1			7.26	11.3		8.11	432					
25-Apr-11	203	2			7.19	11.3		8.1	433					
25-Apr-11	203	3			7.05	11.4		8.12	434					
25-Apr-11	203	4			6.46	11.1		8.12	435					
25-Apr-11	203	5			6.32	10.8		8.11	434					
25-Apr-11	203	6			6.24	10.7		8.08	435					
25-Apr-11	203	7			6.22	10.5		8.06	435					
25-Apr-11	203	8			6.21	10.5		8.06	437					
25-Apr-11	203	9			6.22	10.3		8.08	442					
25-Apr-11	203	10			6.14	9.7		8	441					
25-Apr-11	203		10.5									22		
28-Apr-11	203		0	1							17.6			
10-May-11	203	0	0	1	12.63	13		8.68	478	2	11.4	21	0.83	
10-May-11	203	1			12.34	13.2		8.72	478					
10-May-11	203	2			11.73	13.1		8.72	477					
10-May-11	203	3			11.42	13.2		8.7	478					
10-May-11	203	4			10.96	13.2		8.65	477					
10-May-11	203	5			10.45	12.9		8.6	480					
10-May-11	203	6			9.15	13.1		8.6	481					
10-May-11	203	7			8.45	10.8		8.34	488					
10-May-11	203	8			8.27	10.5		8.33	489					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
10-May-11	203	9			8.15	10.3		8.31	490					
10-May-11	203	10			7.92	9.6		8.17	492					
10-May-11	203		10.7									31		
23-May-11	203	0	0	1	16.5	10.3		8.52	479	5.3	2.9	32	0.68	55
23-May-11	203	1			16.48	10.3		8.55	479					
23-May-11	203	2			16.45	10.3		8.54	480					
23-May-11	203	3			16.41	10.3		8.56	481					
23-May-11	203	4			14.75	10.5		8.5	483					
23-May-11	203	5			13.51	11		8.53	488					
23-May-11	203	6			12.05	8.8		8.35	487					
23-May-11	203	7			11.62	7.3		8.17	490					
23-May-11	203	8			10.4	5.7		8.03	492					
23-May-11	203	9			8.7	5.1		7.91	495					
23-May-11	203	10			8.22	3.5		7.79	497					
23-May-11	203		10.9									47		
6-Jun-11	203	0	0	1	22.97	10.3		8.5	493	3.5	5	14	0.7	56.1
6-Jun-11	203	1			21.36	10.7		8.54	488					
6-Jun-11	203	2			21.23	10.6		8.54	486					
6-Jun-11	203	3			20.41	10.7		8.54	481					
6-Jun-11	203	4			18.22	10.7		8.51	476					
6-Jun-11	203	5			17.38	9.5		8.42	486					
6-Jun-11	203	6			15.7	7.2		8.16	489					
6-Jun-11	203	7			13.26	4.1		7.87	494					
6-Jun-11	203	8			10.45	1.8		7.7	498					
6-Jun-11	203	9			9.3	0.9		7.63	500					
6-Jun-11	203	10			8.66	0.1		7.59	502					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
6-Jun-11	203		10.7									20		
20-Jun-11	203	0	0	1	21.57	8.5		8.41	486	3.5	7.3	15	0.89	
20-Jun-11	203	1			21.58	8.4		8.43	486					
20-Jun-11	203	2			21.48	8.4		8.44	486					
20-Jun-11	203	3			21.47	8.4		8.44	487					
20-Jun-11	203	4			20.8	7.7		8.4	490					
20-Jun-11	203	5			19.04	5.1		8.09	495					
20-Jun-11	203	6			16.32	1.8		7.85	499					
20-Jun-11	203	7			14.11	0.3		7.72	501					
20-Jun-11	203	8			11.9	0.1		7.63	503					
20-Jun-11	203	9			9.23	0.1		7.55	507					
20-Jun-11	203	10			8.87	0.1		7.51	509					
20-Jun-11	203		10.8									26		
29-Jun-11	203	0	0	1	22.02	8.1		8.37	491		3.9	17	0.87	55.7
29-Jun-11	203	1			22.02	8.2		8.38	491					
29-Jun-11	203	2			21.95	8.3		8.29	490					
29-Jun-11	203	3			21.16	7.9		8.39	487					
29-Jun-11	203	4			20.91	7.5		8.37	483					
29-Jun-11	203	5			20.1	5.3		8.15	489					
29-Jun-11	203	6			17.73	0.7		7.76	501					
29-Jun-11	203	7			14.61	0.1		7.71	504					
29-Jun-11	203	8			11.89	0.1		7.64	506					
29-Jun-11	203	9			10.33	0.1		7.61	508					
29-Jun-11	203	10			9.48	0.1		7.55	510					
29-Jun-11	203		10.9									31		
18-Jul-11	203	0	0	1	27.16	8.3		8.41	491	1.3	19	26	1.3	

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
18-Jul-11	203	1			26.85	8.4		8.43	491					
18-Jul-11	203	2			26.6	8		8.39	488					
18-Jul-11	203	3			26	7.4		8.34	484					
18-Jul-11	203	4			24.91	5.9		8.2	495					
18-Jul-11	203	5			23.24	1.8		7.87	497					
18-Jul-11	203	6			19.49	0.1		7.74	503					
18-Jul-11	203	7			15.8	0		7.69	509					
18-Jul-11	203	8			13.24	0		7.63	510					
18-Jul-11	203	9			11.23	0		7.59	512					
18-Jul-11	203	10			9.88	0		7.51	516					
18-Jul-11	203		10.5									32		
29-Jul-11	203	0	0	1	28.37	8.6	110.4	8.49	488	1.8	12	21	0.72	
29-Jul-11	203	1			28.23	8.5	109.3	8.54	488					
29-Jul-11	203	2			28.12	8.3	106.5	8.53	489					
29-Jul-11	203	3			28.07	8	102.5	8.5	489					
29-Jul-11	203	4			27.32	4.8	60.4	8.16	491					
29-Jul-11	203	5			24.64	0	0	7.69	494					
29-Jul-11	203	6			19.89	0	0	7.54	503					
29-Jul-11	203	7			16.25	0	0	7.52	509					
29-Jul-11	203	8			13.86	0	0	7.43	510					
29-Jul-11	203	9			11.38	0	0	7.37	512					
29-Jul-11	203	10			10.33	0	0	7.3	516					
29-Jul-11	203		10.7									30		
15-Aug-11	203	0	0	1	25.38	8.1	99.1	8.47	484	1.7	11	27	0.87	56
15-Aug-11	203	1			25.39	8.1	98.5	8.46	484					
15-Aug-11	203	2			25.38	8	97.6	8.45	484					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
15-Aug-11	203	3			25.37	8	97.6	8.44	484					
15-Aug-11	203	4			25.37	8	97.4	8.44	484					
15-Aug-11	203	5			24.71	5	60.2	8.1	485					
15-Aug-11	203	6			21.12	0.1	0.9	7.57	509					
15-Aug-11	203	7			16.48	0	0.3	7.5	518					
15-Aug-11	203	8			13.82	0	0.3	7.44	514					
15-Aug-11	203	9			11.6	0	0.3	7.4	516					
15-Aug-11	203	10			10.56	0	0.2	7.33	520					
15-Aug-11	203		10.5									38		57
29-Aug-11	203	0	0	1	24.41	7.2	86.3	8.22	478	2	9.3	16	0.59	
29-Aug-11	203	1			24.25	7.2	86.1	8.29	478					
29-Aug-11	203	2			24.18	7.2	86.1	8.3	478					
29-Aug-11	203	3			24.14	7.2	86	8.32	477					
29-Aug-11	203	4			24.13	7.2	85.8	8.32	477					
29-Aug-11	203	5			24.05	7.2	85.5	8.31	477					
29-Aug-11	203	6			22	0	0	7.65	500					
29-Aug-11	203	7			17.62	0	0	7.54	522					
29-Aug-11	203	8			13.87	0	0	7.47	516					
29-Aug-11	203	9			11.84	0	0	7.38	519					
29-Aug-11	203	10			10.64	0	0	7.24	524					
29-Aug-11	203		10.8									53		
13-Sep-11	203	0	0	1	22.93	7.3	85.1	8.34	476	2.6	6.7	21	1.2	58
13-Sep-11	203	1			22.92	7.3	85	8.31	476					
13-Sep-11	203	2			22.92	7.2	84	8.28	476					
13-Sep-11	203	3			22.91	7.1	82.8	8.26	476					
13-Sep-11	203	4			22.88	7.1	82.7	8.25	476					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
13-Sep-11	203	5			22.85	7.2	83.8	8.26	476					
13-Sep-11	203	6			21.65	0	0	7.74	488					
13-Sep-11	203	7			19.35	0	0	7.64	514					
13-Sep-11	203	8			14.75	0	0	7.55	524					
13-Sep-11	203	9			12.24	0	0	7.46	524					
13-Sep-11	203	10			10.69	0	0	7.35	533					
13-Sep-11	203		10.1									100		
26-Sep-11	203	0	0	1	16.82	7.6	78.4	7.9	480	1.9	8	17	0.98	
26-Sep-11	203	1			16.82	7.5	77.2	7.94	480					
26-Sep-11	203	2			16.82	7.4	76.4	7.96	480					
26-Sep-11	203	3			16.79	7.4	76.2	7.97	480					
26-Sep-11	203	4			16.77	7.4	76.1	7.98	480					
26-Sep-11	203	5			16.76	7.4	76	7.98	480					
26-Sep-11	203	6			16.73	7.3	75.2	7.98	480					
26-Sep-11	203	7			16.7	7	72	7.95	480					
26-Sep-11	203	8			16.65	6.8	70	7.93	479					
26-Sep-11	203	9			13.6	0.1	1	7.45	532					
26-Sep-11	203	10			10.96	0.1	1	7.24	540					
26-Sep-11	203		10.2									210		
11-Oct-11	203	0	0	1	17.36	8.5	88.7	8.24	479	3.2	9.3	19	0.75	
11-Oct-11	203	1			17.34	8.4	87.6	8.21	479					
11-Oct-11	203	2			17.31	8.4	87.6	8.19	479					
11-Oct-11	203	3			17.3	8.3	86.5	8.18	479					
11-Oct-11	203	4			17.29	8.3	86.5	8.16	479					
11-Oct-11	203	5			17.28	8.2	85.5	8.15	479					
11-Oct-11	203	6			17.18	8	83.2	8.12	479					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
11-Oct-11	203	7			16.99	6.7	69.4	8.02	481					
11-Oct-11	203	8			16.59	4.5	46.2	7.88	483					
11-Oct-11	203	9			15.88	2.4	24.4	7.73	486					
11-Oct-11	203	10			12.52	0.1	1	7.35	540					
11-Oct-11	203		10.1									200		
21-Oct-11	203	0	0	1	12.14	7.6	70.9	7.94	477	3.2	5.3	25	0.81	
21-Oct-11	203	1			12.14	7.4	69	7.9	477					
21-Oct-11	203	2			12.14	7.4	69	7.88	477					
21-Oct-11	203	3			12.14	7.4	69	7.86	477					
21-Oct-11	203	4			12.14	7.3	68.1	7.86	477					
21-Oct-11	203	5			12.13	7.3	68.1	7.84	477					
21-Oct-11	203	6			12.1	7.2	67.1	7.84	477					
21-Oct-11	203	7			12.09	7.2	67	7.83	477					
21-Oct-11	203	8			12.07	7.3	68	7.83	477					
21-Oct-11	203	9			12.06	7.4	69	7.84	477					
21-Oct-11	203	10			12.03	7.4	68.8	7.84	477					
21-Oct-11	203		10.2									24		
25-Apr-11	104	0	0	1	7.97	11.2		7.97	429	3.4		20	0.62	57.4
25-Apr-11	104	1			7.87	10.7		8	427					
25-Apr-11	104	2			7.18	10.7		8.02	427					
25-Apr-11	104	3			6.74	10.6		8.02	427					
25-Apr-11	104	4			6.56	10.4		8.04	427					
25-Apr-11	104	5			6.29	10.2		8	426					
25-Apr-11	104	6			6.07	10		8.02	427					
25-Apr-11	104	7			6.01	9.8		8.02	427					
25-Apr-11	104	8			5.98	9.8		7.98	428					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
25-Apr-11	104	9			5.96	9.7		7.98	428					
25-Apr-11	104	10			5.96	9.7		7.98	428					
25-Apr-11	104		10.5									49		
28-Apr-11	104		0	1							6.7			
10-May-11	104	0	0	1	11.5	11.8		8.44	471	2.5	6.8	15	0.66	
10-May-11	104	1			11.39	11.8		8.43	471					
10-May-11	104	2			11.23	11.7		8.42	471					
10-May-11	104	3			11.07	11.7		8.44	471					
10-May-11	104	4			10.6	11.8		8.45	472					
10-May-11	104	5			10.11	11.9		8.45	472					
10-May-11	104	6			9.64	12		8.45	473					
10-May-11	104	7			9.19	11.3		8.43	475					
10-May-11	104	8			8.83	10.8		8.31	475					
10-May-11	104	9			8.72	10.6		8.29	476					
10-May-11	104	10			8.23	9.7		8.17	477					
10-May-11	104		9									20		
23-May-11	104	0	0	1	16.04	9.9		8.38	474	6.4	6.1	30	0.61	55.6
23-May-11	104	1			16.02	9.8		8.37	474					
23-May-11	104	2			16.01	9.8		8.37	474					
23-May-11	104	3			16	9.8		8.38	474					
23-May-11	104	4			15.97	9.8		8.37	474					
23-May-11	104	5			13.84	9.8		8.3	478					
23-May-11	104	6			12.58	10.1		8.31	478					
23-May-11	104	7			11.21	9.4		8.18	479					
23-May-11	104	8			9.95	8		8.02	480					
23-May-11	104	9			9.21	7.5		7.95	480					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
23-May-11	104		8.1									22		
6-Jun-11	104	0	0	1	24.02	10.9		8.51	483	3.1	7.2	13	0.7	56.2
6-Jun-11	104	1			21.6	11.1		8.54	479					
6-Jun-11	104	2			20.8	11.1		8.55	476					
6-Jun-11	104	3			20.61	10.8		8.54	477					
6-Jun-11	104	4			19.54	11.2		8.55	475					
6-Jun-11	104	5			17.75	10.6		8.5	475					
6-Jun-11	104	6			16.58	10.1		8.41	477					
6-Jun-11	104	7			14.18	8.5		8.16	481					
6-Jun-11	104	8			10.74	5.8		7.93	486					
6-Jun-11	104	9			9.44	5.8		7.88	485					
6-Jun-11	104	10			8.59	4.4		7.76	485					
6-Jun-11	104		9									11		
20-Jun-11	104	0	0	1	21.57	8.9		8.55	475	4.1	6.2	16	0.47	
20-Jun-11	104	1			21.58	8.8		8.55	475					
20-Jun-11	104	2			21.57	8.8		8.55	475					
20-Jun-11	104	3			21.51	8.8		8.54	475					
20-Jun-11	104	4			21.38	8.6		8.52	477					
20-Jun-11	104	5			20.18	7.7		8.41	485					
20-Jun-11	104	6			18.55	6.5		8.19	483					
20-Jun-11	104	7			14.78	4.3		7.91	488					
20-Jun-11	104	8			12.06	2.6		7.77	490					
20-Jun-11	104	9			9.89	2.4		7.69	489					
20-Jun-11	104	10			9.05	1.3		7.63	490					
20-Jun-11	104		9.6									24		
29-Jun-11	104	0	0	1	21.78	8.5		8.42	477	4.2	3.6	13	0.86	55.7

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
29-Jun-11	104	1			21.75	8.4		8.43	477					
29-Jun-11	104	2			21.49	8.3		8.43	477					
29-Jun-11	104	3			20.89	8.2		8.43	477					
29-Jun-11	104	4			20.79	8		8.42	476					
29-Jun-11	104	5			20.74	7.8		8.4	477					
29-Jun-11	104	6			20.09	6.9		8.3	478					
29-Jun-11	104	7			16.75	3.8		7.94	486					
29-Jun-11	104	8			12.46	1.5		7.78	492					
29-Jun-11	104	9			10.28	1.3		7.69	490					
29-Jun-11	104	10			9.1	0.1		7.61	491					
29-Jun-11	104		10									21		
18-Jul-11	104	0	0	1	27.04	8.3		8.47	478	2.5	9.3	19	0.82	
18-Jul-11	104	1			26.78	8.3		8.46	477					
18-Jul-11	104	2			26.49	8.3		8.46	473					
18-Jul-11	104	3			26.14	8.1		8.45	472					
18-Jul-11	104	4			25.02	7.7		8.43	472					
18-Jul-11	104	5			24.39	6.5		8.31	474					
18-Jul-11	104	6			21.73	3.4		7.97	482					
18-Jul-11	104	7			18.25	1.1		7.68	486					
18-Jul-11	104	8			14.43	0		7.58	494					
18-Jul-11	104	9			11.89	0		7.54	493					
18-Jul-11	104	10			9.9	0		7.35	493					
18-Jul-11	104		9.3									23		
29-Jul-11	104	0	0	1	28.46	8.5	109.4	8.61	473	3.1	6.7	15	0.7	
29-Jul-11	104	1			28.37	8.5	109.4	8.61	473					
29-Jul-11	104	2			28.17	8.5	109.1	8.6	472					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
29-Jul-11	104	3			28.05	8.5	109	8.59	472					
29-Jul-11	104	4			27.59	8.1	103	8.45	474					
29-Jul-11	104	5			26.07	3.2	39.6	7.84	481					
29-Jul-11	104	6			22.73	0	0	7.59	481					
29-Jul-11	104	7			18.45	0	0	7.51	485					
29-Jul-11	104	8			14.75	0	0	7.42	491					
29-Jul-11	104	9			11.61	0	0	7.34	493					
29-Jul-11	104	10			10.99	0	0	7.33	494					
29-Jul-11	104		9									21		
15-Aug-11	104	0	0	1	25.48	8.3	101.7	8.52	469	2.9	6.7	25	0.56	57
15-Aug-11	104	1			25.48	8.2	100.1	8.53	469					
15-Aug-11	104	2			25.46	8.2	100.1	8.52	469					
15-Aug-11	104	3			25.42	8.2	100.1	8.52	469					
15-Aug-11	104	4			25.41	8.2	99.8	8.51	469					
15-Aug-11	104	5			25.27	7.3	88.6	8.41	470					
15-Aug-11	104	6			24.19	4.9	59.4	8.05	475					
15-Aug-11	104	7			19.63	0.1	1	7.69	486					
15-Aug-11	104	8			14.59	0	0.2	7.59	492					
15-Aug-11	104	9			12.26	0	0	7.54	497					
15-Aug-11	104	10			10.54	0	0	7.44	498					
15-Aug-11	104		9.1									32		58
29-Aug-11	104	0	0	1	24.61	7.8	93.8	8.38	466	4.1	5.3	15	0.74	
29-Aug-11	104	1			24.47	7.8	93.5	8.41	466					
29-Aug-11	104	2			24.29	7.8	93.2	8.41	466					
29-Aug-11	104	3			24.24	7.7	92	8.4	466					
29-Aug-11	104	4			24.22	7.6	91	8.4	466					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
29-Aug-11	104	5			24.15	7.2	85.8	8.34	466					
29-Aug-11	104	6			24.06	6.8	81	8.29	467					
29-Aug-11	104	7			20.98	0.6	6.8	7.73	483					
29-Aug-11	104	8			15.62	0	0	7.49	490					
29-Aug-11	104	9			12.49	0	0	7.45	496					
29-Aug-11	104	10			10.68	0	0	7.34	498					
29-Aug-11	104		9.6									26		
13-Sep-11	104	0	0	1	22.86	7.8	90.8	8.3	466	4.2	4	19	1.2	59
13-Sep-11	104	1			22.85	7.7	89.6	8.32	466					
13-Sep-11	104	2			22.82	7.7	89.5	8.32	466					
13-Sep-11	104	3			22.8	7.7	89.5	8.31	466					
13-Sep-11	104	4			22.79	7.6	88.3	8.3	466					
13-Sep-11	104	5			22.77	7.5	87.1	8.29	467					
13-Sep-11	104	6			22.66	7.4	85.9	8.26	467					
13-Sep-11	104	7			20.92	1.2	13.5	7.76	475					
13-Sep-11	104	8			17.49	0.1	1	7.57	491					
13-Sep-11	104	9			12.88	0	0	7.52	496					
13-Sep-11	104	10			11.26	0	0	7.5	502					
13-Sep-11	104		9.4									26		
26-Sep-11	104	0	0	1	17.08	7.6	78.9	8.05	473	2.6	5.3	18	0.81	
26-Sep-11	104	1			17.08	7.5	77.8	8.06	473					
26-Sep-11	104	2			17.07	7.5	77.8	8.06	473					
26-Sep-11	104	3			17.07	7.4	76.8	8.06	473					
26-Sep-11	104	4			17.06	7.4	76.8	8.06	473					
26-Sep-11	104	5			17.01	7.3	75.7	8.05	473					
26-Sep-11	104	6			16.98	7.1	73.5	8.03	473					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
26-Sep-11	104	7			16.92	6.5	67.3	7.97	474					
26-Sep-11	104	8			16.84	6.3	65.1	7.94	475					
26-Sep-11	104	9			16.03	4.1	41.6	7.74	478					
26-Sep-11	104	10			11.15	0.1	1	7.49	511					
26-Sep-11	104		9.4									33		
11-Oct-11	104	0	0	1	17.2	8.8	91.5	8.29	472	4.5	5.3	17	0.69	
11-Oct-11	104	1			17.16	8.7	90.3	8.26	472					
11-Oct-11	104	2			17.08	8.6	89.2	8.23	472					
11-Oct-11	104	3			17.04	8.5	88.2	8.22	472					
11-Oct-11	104	4			17.02	8.6	89.1	8.2	472					
11-Oct-11	104	5			16.98	8.4	87	8.19	472					
11-Oct-11	104	6			16.94	8.3	85.9	8.17	472					
11-Oct-11	104	7			16.7	7.5	77.2	8.08	473					
11-Oct-11	104	8			16.49	6.5	66.6	7.97	474					
11-Oct-11	104	9			16.08	5.7	57.9	7.92	475					
11-Oct-11	104	10			14.9	1.8	17.8	7.73	478					
11-Oct-11	104		9.1									19		
21-Oct-11	104	0	0	1	12.53	8.3	78	8	470	4.7	2.7	19	0.77	
21-Oct-11	104	1			12.51	8.2	77	8	470					
21-Oct-11	104	2			12.47	8.2	77	7.99	470					
21-Oct-11	104	3			12.42	8.1	76	7.98	470					
21-Oct-11	104	4			12.39	8.1	76	7.97	470					
21-Oct-11	104	5			12.37	8.1	75.9	7.97	470					
21-Oct-11	104	6			12.33	8.1	75.8	7.97	470					
21-Oct-11	104	7			12.31	8.1	75.8	7.96	470					
21-Oct-11	104	8			12.27	7.9	73.8	7.94	470					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
21-Oct-11	104	9			12.21	7.7	71.8	7.92	471					
21-Oct-11	104	10			12.17	7.8	72.8	7.92	471					
21-Oct-11	104		9.2									16		
25-Apr-11	101	0	0	1						3.6		16	0.79	57.1
25-Apr-11	101	1			7.05	10.7		7.93	426					
25-Apr-11	101	2			6.78	10.6		7.96	425					
25-Apr-11	101	3			6.66	10.6		7.98	425					
25-Apr-11	101	4			6.58	10.5		8	425					
25-Apr-11	101	5			6.5	10.3		8	425					
25-Apr-11	101	6			6.22	10.4		8.02	425					
25-Apr-11	101	7			6.22	10.4		8.01	425					
25-Apr-11	101	8			6.23	10.4		8.03	425					
25-Apr-11	101	9			6.23	10.4		8.03	425					
25-Apr-11	101	10			6.21	10.4		8.04	425					
25-Apr-11	101		10.2									34		
28-Apr-11	101		0	1							6.4			
10-May-11	101	0	0	1	11.5	11.5		7.92	472	3.6	4.8	16	0.89	
10-May-11	101	1			11.49	11.5		8.16	472					
10-May-11	101	2			11.23	11.5		8.27	472					
10-May-11	101	3			11.12	11.5		8.3	472					
10-May-11	101	4			11.04	11.4		8.32	472					
10-May-11	101	5			10.96	11.4		8.33	472					
10-May-11	101	6			10.8	11.3		8.33	472					
10-May-11	101	7			10.55	11.3		8.33	472					
10-May-11	101	8			10.46	11.2		8.31	472					
10-May-11	101	9			10.39	11.2		8.3	472					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
10-May-11	101	10			9.13	10.8		8.21	474					
10-May-11	101		10.5									21		
23-May-11	101	0	0	1	15.66	9.8		8.31	471	6.8	<4	42	0.73	55.4
23-May-11	101	1			15.64	9.7		8.27	471					
23-May-11	101	2			15.58	9.7		8.26	472					
23-May-11	101	3			15.53	9.7		8.26	472					
23-May-11	101	4			15.42	9.7		8.26	472					
23-May-11	101	5			13.95	9.8		8.23	474					
23-May-11	101	6			12.68	8.8		8.11	476					
23-May-11	101	7			12.5	8.4		8.09	476					
23-May-11	101	8			12.1	7.9		8.04	477					
23-May-11	101	9			11.5	7.1		7.98	478					
23-May-11	101	10			10.72	4.6		7.86	480					
23-May-11	101		10.5									43		
6-Jun-11	101	0	0	1	22.22	10.4		8.47	477	3.5	6.4	14	0.56	55.7
6-Jun-11	101	1			21.19	10.5		8.5	476					
6-Jun-11	101	2			20.78	10.7		8.5	477					
6-Jun-11	101	3			20.6	10.6		8.5	476					
6-Jun-11	101	4			18.85	11.1		8.52	474					
6-Jun-11	101	5			18.03	10.7		8.48	474					
6-Jun-11	101	6			17.5	10.1		8.4	475					
6-Jun-11	101	7			16.88	9.3		8.31	476					
6-Jun-11	101	8			15.64	7.7		8.1	478					
6-Jun-11	101	9			13.19	5.3		7.8	481					
6-Jun-11	101	10			11.55	1.7		7.66	486					
6-Jun-11	101		10.3									18		

Date	**Site**	**Depth** (m)	**Upper Depth** (m)	**Lower Depth** (m)	**Water Temp.** (deg C)	**Dissolved oxygen** (mg/L)	**Dissolved oxygen** (%)	**pH**	**Spec. Cond.** (µS/cm)	**Secchi disk depth** (m)	**Chlorophyll a, corrected for pheophytin** (µg/L)	**Phosphorus, as P** (µg/L)	**Nitrogen, Kjeldahl** (mg/L)	**Chloride** (mg/L)
20-Jun-11	101	0	0	1	21.06	8.7		8.43	473	3.9	6.9	13	0.54	
20-Jun-11	101	1			21.06	8.7		8.45	473					
20-Jun-11	101	2			21.06	8.6		8.45	473					
20-Jun-11	101	3			21.06	8.6		8.46	473					
20-Jun-11	101	4			21.06	8.7		8.46	473					
20-Jun-11	101	5			21.06	8.7		8.46	473					
20-Jun-11	101	6			21.04	8.6		8.46	474					
20-Jun-11	101	7			18.8	6.7		8.12	482					
20-Jun-11	101	8			15.57	4.2		7.8	485					
20-Jun-11	101	9			13.93	0.5		7.52	490					
20-Jun-11	101	10			12.4	0.1		7.48	492					
20-Jun-11	101		10.3									44		
29-Jun-11	101	0	0	1	21.71	8.1		8.29	478	4.5	<4	12	0.85	55.3
29-Jun-11	101	1			21.72	8.1		8.34	478					
29-Jun-11	101	2			21.71	8.1		8.35	478					
29-Jun-11	101	3			21.7	8.1		8.35	478					
29-Jun-11	101	4			20.92	7.9		8.36	475					
29-Jun-11	101	5			20.76	7.8		8.36	476					
29-Jun-11	101	6			20.39	7.1		8.29	477					
29-Jun-11	101	7			19.18	5		8.04	481					
29-Jun-11	101	8			16.74	2.1		7.74	486					
29-Jun-11	101	9			14.68	0.2		7.61	489					
29-Jun-11	101	10			12.82	0.1		7.54	495					
29-Jun-11	101		10.6									41		
18-Jul-11	101	0	0	1	26.89	8.1		8.42	473	3.2	8	19	0.64	
18-Jul-11	101	1			26.68	8		8.43	473					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
18-Jul-11	101	2			26.61	8.1		8.42	473					
18-Jul-11	101	3			26.13	7.8		8.42	473					
18-Jul-11	101	4			25.12	7.2		8.35	472					
18-Jul-11	101	5			24.23	6		8.25	474					
18-Jul-11	101	6			22.29	4.1		7.92	481					
18-Jul-11	101	7			20.34	2.2		7.76	483					
18-Jul-11	101	8			18.2	0.3		7.6	486					
18-Jul-11	101	9			14.85	0		7.49	497					
18-Jul-11	101	10			13.81	0		7.42	502					
18-Jul-11	101		10.4									47		
29-Jul-11	101	0	0	1	28.05	8.1	103.1	8.45	470	3.5	5.3	20	0.61	
29-Jul-11	101	1			28	8.2	104.5	8.49	470					
29-Jul-11	101	2			27.94	8.2	104.3	8.51	470					
29-Jul-11	101	3			27.92	8.2	104.3	8.51	470					
29-Jul-11	101	4			27.85	8	101.8	8.5	470					
29-Jul-11	101	5			25.76	3.7	45.8	7.92	476					
29-Jul-11	101	6			23.43	0.3	3.2	7.7	478					
29-Jul-11	101	7			20.7	0	0	7.52	481					
29-Jul-11	101	8			18.53	1.7	18.4	7.41	482					
29-Jul-11	101	9			15.24	0	0	7.27	499					
29-Jul-11	101	10			14.01	0	0	7.24	505					
29-Jul-11	101		10.4									82		
15-Aug-11	101	0	0	1	25.5	8.2	100.3	8.58	468	2.8	5.3	26	0.59	57
15-Aug-11	101	1			25.5	8	97.7	8.52	468					
15-Aug-11	101	2			25.51	8.1	99	8.52	468					
15-Aug-11	101	3			25.44	8.1	98.6	8.51	469					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
15-Aug-11	101	4			25.38	8	97.7	8.5	469					
15-Aug-11	101	5			25.35	8	97.3	8.52	468					
15-Aug-11	101	6			25.12	7.2	88	8.41	470					
15-Aug-11	101	7			21.54	0.1	1.4	7.79	481					
15-Aug-11	101	8			18	0.1	0.7	7.63	478					
15-Aug-11	101	9			15.44	0	0.4	7.46	507					
15-Aug-11	101	10			13.93	0	0.4	7.35	513					
15-Aug-11	101		10.3									100		58
29-Aug-11	101	0	0	1	24.35	7.6	91.3	8.14	465	4.1	5.3	17	0.72	
29-Aug-11	101	1			24.35	7.6	91	8.25	465					
29-Aug-11	101	2			24.31	7.6	91	8.31	465					
29-Aug-11	101	3			24.3	7.6	91	8.33	465					
29-Aug-11	101	4			24.29	7.6	90.8	8.34	465					
29-Aug-11	101	5			24.29	7.5	89.7	8.34	465					
29-Aug-11	101	6			24.27	7.4	88.6	8.34	465					
29-Aug-11	101	7			23.44	3.9	45.7	7.85	472					
29-Aug-11	101	8			19.4	0	0	7.58	475					
29-Aug-11	101	9			15.72	0	0	7.5	514					
29-Aug-11	101	10			14.04	0	0	7.28	522					
29-Aug-11	101		10.3									120		
13-Sep-11	101	0	0	1	22.84	7.3	85.1	8.61	465	3.8	4	22	0.9	58
13-Sep-11	101	1			22.87	7.4	86.2	8.5	465					
13-Sep-11	101	2			22.87	7.4	86.1	8.44	466					
13-Sep-11	101	3			22.87	7.4	86	8.4	466					
13-Sep-11	101	4			22.87	7.4	86.2	8.36	465					
13-Sep-11	101	5			22.87	7.4	85.9	8.35	466					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
13-Sep-11	101	6			22.87	7.4	85.9	8.33	466					
13-Sep-11	101	7			22.87	7.4	86.1	8.32	466					
13-Sep-11	101	8			21.01	0.6	7	7.67	471					
13-Sep-11	101	9			16.88	0	0	7.52	516					
13-Sep-11	101	10			14.23	0	0	7.39	535					
13-Sep-11	101		10.3									290		
26-Sep-11	101	0	0	1	17.2	7.3	75.7	7.47	471	2.9	4	21	0.96	
26-Sep-11	101	1			17.21	7.2	75	7.69	471					
26-Sep-11	101	2			17.2	7.1	74.1	7.8	471					
26-Sep-11	101	3			17.19	7.1	73.9	7.83	471					
26-Sep-11	101	4			17.17	7.1	73.9	7.86	471					
26-Sep-11	101	5			17.14	7.1	73.9	7.88	471					
26-Sep-11	101	6			17.13	7.1	73.8	7.89	471					
26-Sep-11	101	7			17.1	7.1	73.7	7.9	471					
26-Sep-11	101	8			17.07	7.1	73.5	7.91	471					
26-Sep-11	101	9			17.06	7	72.6	7.92	471					
26-Sep-11	101	10			17.03	7	72.6	7.92	471					
26-Sep-11	101		10.1									22		
11-Oct-11	101	0	0	1	17.39	9	94.1	8.3	472	3.7	9.3	21	0.66	
11-Oct-11	101	1			17.39	8.9	92.9	8.27	472					
11-Oct-11	101	2			17.39	8.9	92.8	8.26	472					
11-Oct-11	101	3			17.39	8.8	91.9	8.25	472					
11-Oct-11	101	4			17.39	8.8	91.9	8.24	472					
11-Oct-11	101	5			17.38	8.7	90.9	8.23	472					
11-Oct-11	101	6			17.38	8.7	90.9	8.23	472					
11-Oct-11	101	7			17.38	8.8	91.8	8.22	472					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
11-Oct-11	101	8			17.36	8.7	90.9	8.22	472					
11-Oct-11	101	9			17.16	7.4	77	8.08	473					
11-Oct-11	101	10			16.98	5.9	61	7.95	475					
11-Oct-11	101		10									28		
21-Oct-11	101	0	0	1	12.77	8.2	77.5	8.15	469	4.2	5.3	17	0.78	
21-Oct-11	101	1			12.78	8.2	77.5	8.14	469					
21-Oct-11	101	2			12.78	8.2	77.5	8.11	469					
21-Oct-11	101	3			12.78	8.2	77.5	8.09	469					
21-Oct-11	101	4			12.78	8.2	77.6	8.09	469					
21-Oct-11	101	5			12.77	8.2	77.5	8.07	469					
21-Oct-11	101	6			12.77	8.2	77.6	8.06	469					
21-Oct-11	101	7			12.77	8.2	77.5	8.06	469					
21-Oct-11	101	8			12.77	8.2	77.5	8.05	469					
21-Oct-11	101	9			12.77	8.2	77.6	8.04	469					
21-Oct-11	101	10			12.77	8.2	77.5	8.04	469					
21-Oct-11	101		10.1									18		
25-Apr-11	205	0	0	1	7.72	10.3		7.94	421	3.6		16	0.94	57.8
25-Apr-11	205	1			7.63	10.2		7.99	421					
25-Apr-11	205	2			7.42	10.2		8	421					
25-Apr-11	205	3			7.16	10.2		8.03	422					
25-Apr-11	205	4			6.8	10.2		8.03	422					
25-Apr-11	205	5			6.7	10.1		8.04	423					
25-Apr-11	205	6			6.56	10.1		8.05	424					
25-Apr-11	205	7			6.4	10.1		8.07	424					
25-Apr-11	205	8			6.1	9.3		7.98	425					
25-Apr-11	205	9			6.11	7.6		7.85	423					

Date	**Site**	**Depth** (m)	**Upper Depth** (m)	**Lower Depth** (m)	**Water Temp.** (deg C)	**Dissolved oxygen** (mg/L)	**Dissolved oxygen** (%)	**pH**	**Spec. Cond.** (µS/cm)	**Secchi disk depth** (m)	**Chlorophyll a, corrected for pheophytin** (µg/L)	**Phosphorus, as P** (µg/L)	**Nitrogen, Kjeldahl** (mg/L)	**Chloride** (mg/L)
25-Apr-11	205		7.1									29		
28-Apr-11	205		0	1							3.7			
10-May-11	205	0	0	1	11.25	11.3		8.33	472	3.1	6	14	0.66	
10-May-11	205	1			11.13	11.3		8.33	472					
10-May-11	205	2			11	11.3		8.33	472					
10-May-11	205	3			10.78	11.3		8.33	472					
10-May-11	205	4			10.65	11.3		8.34	472					
10-May-11	205	5			9.98	11.3		8.33	472					
10-May-11	205	6			9.63	11.1		8.3	473					
10-May-11	205	7			9.55	10.9		8.28	473					
10-May-11	205	8			9.22	10.9		8.27	473					
10-May-11	205		7.2									19		
23-May-11	205	0	0	1	15.84	9.8		8.28	472	7.6	<2.1	28	0.57	55.8
23-May-11	205	1			15.83	9.6		8.29	473					
23-May-11	205	2			15.79	9.7		8.29	472					
23-May-11	205	3			15.71	9.7		8.3	472					
23-May-11	205	4			15.69	9.6		8.29	472					
23-May-11	205	5			15.67	9.5		8.3	472					
23-May-11	205	6			15.65	9.6		8.3	472					
23-May-11	205	7			14.28	9.7		8.25	475					
23-May-11	205	8			12.05	8.5		8.07	477					
23-May-11	205		7.2									27		
6-Jun-11	205	0	0	1	23.4	10.5		8.46	478	3.6	5.5	10	0.65	56.5
6-Jun-11	205	1			21.74	10.8		8.51	475					
6-Jun-11	205	2			20.78	11		8.52	475					
6-Jun-11	205	3			20.61	11		8.52	475					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
6-Jun-11	205	4			19.55	11.4		8.54	475					
6-Jun-11	205	5			18.6	11		8.52	474					
6-Jun-11	205	6			17.51	10.2		8.39	475					
6-Jun-11	205	7			16.68	9.2		8.27	476					
6-Jun-11	205	8			15.42	3.6		7.7	485					
6-Jun-11	205		7.2									15		
20-Jun-11	205	0	0	1	21.02	8.9		8.55	470	4	6.8	18	0.79	
20-Jun-11	205	1			21.01	8.8		8.54	474					
20-Jun-11	205	2			20.98	8.6		8.53	474					
20-Jun-11	205	3			20.97	8.6		8.52	474					
20-Jun-11	205	4			20.92	8.6		8.52	474					
20-Jun-11	205	5			19.63	7.2		8.33	479					
20-Jun-11	205	6			19.33	6.5		8.2	480					
20-Jun-11	205	7			17.74	4.8		7.95	484					
20-Jun-11	205	8			16.57	2.5		7.74	488					
20-Jun-11	205		7									17		
29-Jun-11	205	0	0	1	22.09	8.3		8.41	477	4.5	3.1	14	0.79	55.8
29-Jun-11	205	1			22.03	8.2		8.42	477					
29-Jun-11	205	2			21.71	8.2		8.42	476					
29-Jun-11	205	3			20.9	8.1		8.43	475					
29-Jun-11	205	4			20.78	7.8		8.39	475					
29-Jun-11	205	5			20.73	7.7		8.37	476					
29-Jun-11	205	6			20.58	7.5		8.36	476					
29-Jun-11	205	7			19.93	6		8.15	479					
29-Jun-11	205	8			17.93	2.1		7.76	486					
29-Jun-11	205		7.2									16		

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
18-Jul-11	205	0	0	1	28.29	8.4		8.43	472	3.3	5.3	19	0.86	
18-Jul-11	205	1			27.22	8.4		8.42	471					
18-Jul-11	205	2			27.05	8.5		8.41	471					
18-Jul-11	205	3			26.73	8.5		8.41	470					
18-Jul-11	205	4			25.67	7.6		8.21	466					
18-Jul-11	205	5			24.44	6.3		8.18	471					
18-Jul-11	205	6			22.25	3.9		7.76	481					
18-Jul-11	205	7			19.72	0.9		7.56	485					
18-Jul-11	205	8			18.5	0		7.44	488					
18-Jul-11	205		7.3									26		
29-Jul-11	205	0	0	1	28.48	8.5	109.6	8.59	466	3.7	4	14	0.64	
29-Jul-11	205	1			28.37	8.6	110.5	8.6	466					
29-Jul-11	205	2			28.15	8.5	109.2	8.6	466					
29-Jul-11	205	3			28	8.6	109.8	8.59	465					
29-Jul-11	205	4			27.62	7.7	97.7	8.45	468					
29-Jul-11	205	5			26.47	5.2	65.1	8.1	473					
29-Jul-11	205	6			23.88	0.9	10.5	7.58	478					
29-Jul-11	205	7			20.92	0.1	1	7.47	481					
29-Jul-11	205	8			18.72	0	0	7.4	487					
29-Jul-11	205		7									24		
15-Aug-11	205	0	0	1	25.91	8.5	104.8	8.55	464	3	6.7	25	0.81	57
15-Aug-11	205	1			25.84	8.4	103.4	8.55	464					
15-Aug-11	205	2			25.71	8.3	103.3	8.55	465					
15-Aug-11	205	3			25.57	8.4	102.5	8.53	465					
15-Aug-11	205	4			25.53	8.1	99.1	8.5	465					
15-Aug-11	205	5			25.22	7.1	86.3	8.39	466					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
15-Aug-11	205	6			24.83	5.5	66.5	8.11	470					
15-Aug-11	205	7			22.77	0.1	1.4	7.61	480					
15-Aug-11	205	8			18.92	0	0.3	7.49	495					
15-Aug-11	205		6.9									30		57
29-Aug-11	205	0	0	1	24.74	7.7	92.9	8.4	463	4.5	5.3	14	0.8	
29-Aug-11	205	1			24.7	7.6	91.5	8.41	463					
29-Aug-11	205	2			24.43	7.5	89.8	8.4	462					
29-Aug-11	205	3			24.39	7.4	88.5	8.39	462					
29-Aug-11	205	4			24.37	7.3	87.3	8.38	463					
29-Aug-11	205	5			24.36	7.1	85	8.35	463					
29-Aug-11	205	6			24.28	6.7	80.1	8.29	462					
29-Aug-11	205	7			23.92	5	59.4	8.06	466					
29-Aug-11	205	8			19.6	0.1	1	7.48	501					
29-Aug-11	205		6.9									18		
13-Sep-11	205	0	0	1	23.43	7.9	93	8.46	464	3.6	4	24	0.86	58
13-Sep-11	205	1			23.42	7.8	91.7	8.42	464					
13-Sep-11	205	2			23.31	7.8	91.6	8.39	464					
13-Sep-11	205	3			23.18	7.9	92.6	8.38	464					
13-Sep-11	205	4			23.13	7.9	92.5	8.37	464					
13-Sep-11	205	5			23.1	7.8	91.2	8.35	463					
13-Sep-11	205	6			23.05	7.7	90	8.33	464					
13-Sep-11	205	7			23	7.6	88.7	8.31	464					
13-Sep-11	205	8			21.46	0.1	1	7.79	478					
13-Sep-11	205		6.9									22		
26-Sep-11	205	0	0	1	16.92	7.8	80.7	8.12	469	3.1	5.3	20	0.76	
26-Sep-11	205	1			16.93	7.7	79.7	8.12	469					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
26-Sep-11	205	2			16.93	7.7	79.6	8.11	469					
26-Sep-11	205	3			16.92	7.7	79.6	8.11	469					
26-Sep-11	205	4			16.92	7.6	78.7	8.1	469					
26-Sep-11	205	5			16.92	7.6	78.7	8.1	469					
26-Sep-11	205	6			16.91	7.7	79.4	8.1	469					
26-Sep-11	205	7			16.91	7.7	79.6	8.1	469					
26-Sep-11	205	8			16.9	7.4	76.5	8.01	469					
26-Sep-11	205		6.9									17		
11-Oct-11	205	0	0	1	17.74	9.2	96.8	8.49	471	4.6	5.3	18	0.78	
11-Oct-11	205	1			17.66	9	94.6	8.43	471					
11-Oct-11	205	2			17.51	8.9	93	8.39	471					
11-Oct-11	205	3			17.43	8.8	92	8.35	471					
11-Oct-11	205	4			17.42	8.6	89.9	8.32	471					
11-Oct-11	205	5			17.4	8.5	88.8	8.3	471					
11-Oct-11	205	6			17.29	8	83.4	8.22	472					
11-Oct-11	205	7			17.17	7.5	78	8.15	472					
11-Oct-11	205		6.7									16		
21-Oct-11	205	0	0	1	12.34	9	84.3	8.11	467	5.9	5.3	13	0.6	
21-Oct-11	205	1			12.34	8.9	83.3	8.12	467					
21-Oct-11	205	2			12.33	8.9	83.3	8.12	467					
21-Oct-11	205	3			12.29	8.8	82.3	8.12	467					
21-Oct-11	205	4			12.24	8.8	82.2	8.12	467					
21-Oct-11	205	5			12.13	8.9	83	8.13	467					
21-Oct-11	205	6			12.02	8.9	82.8	8.14	467					
21-Oct-11	205	7			11.92	8.8	81.6	8.13	467					
21-Oct-11	205		6.7									14		

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
25-Apr-11	206	0	0	1	8.04	10.8		7.98	419	2.5		19	0.72	57.8
25-Apr-11	206	1			7.47	10.8		8.04	419					
25-Apr-11	206	2			7.13	10.8		8.07	419					
25-Apr-11	206	3			6.95	10.8		8.1	419					
25-Apr-11	206	4			6.36	10.7		8.13	419					
25-Apr-11	206	5			6.22	10.7		8.14	419					
25-Apr-11	206	6			6.02	10.4		8.14	419					
25-Apr-11	206	7			5.73	9.5		8.07	419					
25-Apr-11	206	8			5.12	7.8		7.97	421					
25-Apr-11	206	9			4.96	5.6		7.86	430					
25-Apr-11	206	10			5.07	0.1		7.52	630					
25-Apr-11	206		10									17		
28-Apr-11	206		0	1							8.8			
23-May-11	206	0	0	1	16.36	9.9		8.39	470	5.5	3.3	32	0.54	55.5
23-May-11	206	1			16.33	9.8		8.4	470					
23-May-11	206	2			16.05	9.8		8.39	471					
23-May-11	206	3			14.57	10.8		8.4	475					
23-May-11	206	4			11.72	14.7		8.63	469					
23-May-11	206	5			9.02	16.5		8.74	466					
23-May-11	206	6			7.52	14.2		8.56	469					
23-May-11	206	7			6.94	9.9		8.17	475					
23-May-11	206	8			6.65	6.9		7.96	482					
23-May-11	206	9			6.47	0.9		7.7	504					
23-May-11	206	10			6.27	0.2		7.53	599					
23-May-11	206		9.5									99		
20-Jun-11	206	0	0	1	21.91	9.1		8.57	467	4.2		14	0.62	

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
20-Jun-11	206	1			21.88	9.2		8.59	467					
20-Jun-11	206	2			21.69	8.9		8.6	468					
20-Jun-11	206	3			20.91	9.7		8.64	469					
20-Jun-11	206	4			18.82	9.7		8.56	473					
20-Jun-11	206	5			14.02	15		8.69	472					
20-Jun-11	206	6			9.87	13.1		8.51	475					
20-Jun-11	206	7			8.16	7.8		8.12	483					
20-Jun-11	206	8			7.38	1		7.84	499					
20-Jun-11	206	9			7	0.1		7.7	528					
20-Jun-11	206	10			6.73	0.1		7.52	589					
20-Jun-11	206		9.3									56		
18-Jul-11	206	0	0	1	27.64	8.6		8.51	455	3.5	6.7	18	1.2	
18-Jul-11	206	1			27.24	8.8		8.53	454					
18-Jul-11	206	2			26.9	8.7		8.51	455					
18-Jul-11	206	3			25.83	8.7		8.52	454					
18-Jul-11	206	4			24.4	8.1		8.44	449					
18-Jul-11	206	5			19.07	11.2		8.41	476					
18-Jul-11	206	6			13.84	12.7		8.4	480					
18-Jul-11	206	7			10.09	9.9		8.14	485					
18-Jul-11	206	8			8.37	1.2		7.75	503					
18-Jul-11	206	9			7.51	0.1		7.66	535					
18-Jul-11	206	10			7.11	0		7.26	578					
18-Jul-11	206		9.3									96		
15-Aug-11	206	0	0	1	25.89	9	110.6	8.67	445	4.2	2.7	25	0.59	56
15-Aug-11	206	1			25.74	9	110.3	8.67	445					
15-Aug-11	206	2			25.7	9	110.3	8.68	444					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
15-Aug-11	206	3			25.66	9	110.3	8.66	444					
15-Aug-11	206	4			25.18	8.4	102.4	8.59	446					
15-Aug-11	206	5			22.04	5.8	66.5	8.05	473					
15-Aug-11	206	6			16.75	4.4	45.3	7.81	485					
15-Aug-11	206	7			12.7	1.2	11	7.53	493					
15-Aug-11	206	8			9.76	0.3	2.9	7.51	504					
15-Aug-11	206	9			8.31	0.1	1	7.41	535					
15-Aug-11	206	10			7.5	0.1	0.7	7.15	599					
15-Aug-11	206		9.3									130		71
13-Sep-11	206	0	0	1	23.19	9	105.4	8.62	440	6.5	2.7	18	1.1	58
13-Sep-11	206	1			23.05	9	105.2	8.62	440					
13-Sep-11	206	2			22.95	8.9	103.8	8.63	440					
13-Sep-11	206	3			22.89	8.9	103.6	8.62	439					
13-Sep-11	206	4			22.75	8.8	102	8.61	439					
13-Sep-11	206	5			22.41	8.3	95.9	8.56	442					
13-Sep-11	206	6			19.09	5.1	55	8.1	480					
13-Sep-11	206	7			15.21	0.9	9	7.84	493					
13-Sep-11	206	8			11.92	0.3	2.8	7.73	507					
13-Sep-11	206	9			9.13	0.1	1	7.3	564					
13-Sep-11	206	10			8.06	0	0	7.26	616					
13-Sep-11	206		9									110		
11-Oct-11	206	0	0	1	17.65	9.3	97.6	8.44	457	6.3	4	20	0.69	
11-Oct-11	206	1			17.46	9.3	97.3	8.43	458					
11-Oct-11	206	2			17.39	9.3	97.1	8.42	457					
11-Oct-11	206	3			17.34	9	93.9	8.39	457					
11-Oct-11	206	4			16.84	9.2	95.1	8.41	454					

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
11-Oct-11	206	5			16.48	8.9	91.2	8.41	453					
11-Oct-11	206	6			16.13	7.9	80.4	8.31	455					
11-Oct-11	206	7			15.33	4.5	45	8	466					
11-Oct-11	206	8			13.68	0.1	1	7.79	493					
11-Oct-11	206	9			10.33	0.1	1	7.34	587					
11-Oct-11	206		8.9									86		
10-May-11	207	0	0	1	12.01	11.2		8.27	472	2.8	4.7	15	0.67	
10-May-11	207	1			11.7	11.2		8.26	472					
10-May-11	207	2			10.97	11.1		8.26	472					
10-May-11	207	3			10.35	11.4		8.26	472					
10-May-11	207		2.3									15		
6-Jun-11	207	0	0	1	24.78	10.5		8.54	476	>3	4.8	16	0.75	56.5
6-Jun-11	207	1			22.06	11.5		8.55	473					
6-Jun-11	207	2			20.32	12		8.58	473					
6-Jun-11	207	3			19.11	13.5		8.58	466					
6-Jun-11	207		2									24		
29-Jun-11	207	0	0	1						>3	3.6	20	0.97	56.1
29-Jun-11	207	1			22.89	8.5		8.36	477					
29-Jun-11	207	2			22.6	8.3		8.37	477					
29-Jun-11	207	3			21.49	8.3		8.39	475					
29-Jun-11	207		2									16		
29-Jul-11	207	0	0	1	29.04	8.6	112	8.56	458	2.75	4	22	0.57	
29-Jul-11	207	1			28.45	8.7	112.2	8.52	457					
29-Jul-11	207	2			28.13	8.4	107.5	8.46	456					
29-Jul-11	207		2									33		
29-Aug-11	207	0	0	1	24.8	7.5	90.4	8.3	457	2.7	2.7	15	0.78	

Date	Site	Depth (m)	Upper Depth (m)	Lower Depth (m)	Water Temp. (deg C)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)	pH	Spec. Cond. (µS/cm)	Secchi disk depth (m)	Chlorophyll a, corrected for pheophytin (µg/L)	Phosphorus, as P (µg/L)	Nitrogen, Kjeldahl (mg/L)	Chloride (mg/L)
29-Aug-11	207	1			24.12	6.7	79.9	8.19	456					
29-Aug-11	207	2			23.75	6.5	77	8.17	456					
29-Aug-11	207	2.7			23.74	6.7	79.2	8.17	456					
29-Aug-11	207		1.7									17		
26-Sep-11	207	0	0	1	16.52	8.3	85.2	8.18	470	2.7		19	0.93	
26-Sep-11	207	1			16.51	8.1	83.1	8.18	470					
26-Sep-11	207	2			16.45	8	82.1	8.17	470					
26-Sep-11	207	2.7			16.46	8	82	8.18	470					
26-Sep-11	207		1.7									17		
21-Oct-11	207	0	0	1	11.42	9.3	85.1	8.16	468	2.6	2.7	19	0.7	
21-Oct-11	207	1			10.41	9.9	88.6	8.24	468					
21-Oct-11	207	2			10.04	9.8	87.1	8.23	469					
21-Oct-11	207	2.6			10.01	9.7	86.1	8.24	469					
21-Oct-11	207		1.6									15		

5 APPENDIX B: P8 MODEL INPUT AND RESULTS

Table 23. P8 watershed model input

Watershed Label	Total Area acres	Outflow Device	Percol Device	Pervious Curve Number	Indirect Imperv Fraction	Pervious Load Factor	Directly Connected UnSwept Areas				Directly Connected Swept Areas				Street Sweeping Parameters			
							Imperv Fraction	Depress Storage inches	Runoff Coef	Imperv Load Factor	Imperv Fraction	Depress Storage inches	Runoff Coef	Imperv Load Factor	Start Date MMDD	Stop Date MMDD	Sweep Effic	Sweep Freq 1/week
Lower Prior Lake Direct Drainage	1616.5	LPL_out	none	69	0	1	0.09	0.02	1	1	0.6	0	1	0	101	1231	0	0
North_LPL-1	2.4	North_LPL-1_out	none	69	0	1	0.22	0.02	1	1	0.09	0	1	0	101	1231	0	0
North_LPL-2	5.3	North_LPL-2_out	none	69	0	1	0.3	0.02	1	1	0.01	0	1	0	101	1231	0	0
North_LPL-3	9.68	North_LPL-3_out	none	69	0	1	0.27	0.02	1	1	0	0	1	0	101	1231	0	0
North_LPL-4	17.79	North_LPL-4_out	none	69	0	1	0.3	0.02	1	1	0.01	0	1	0	101	1231	0	0
North_LPL-5	65.09	North_LPL-5_out	none	69	0	1	0.31	0.02	1	1	0.01	0	1	0	101	1231	0	0
North_LPL-6	2.76	North_LPL-6_out	none	69	0	1	0.28	0.02	1	1	0.16	0	1	0	101	1231	0	0
North_LPL-9	22.86	North_LPL-9_out	none	69	0	1	0.22	0.02	1	1	0.03	0	1	0	101	1231	0	0
North_LPL-10	9.76	North_LPL-10_out	none	69	0	1	0.25	0.02	1	1	0.02	0	1	0	101	1231	0	0
North_LPL-11	17.89	North_LPL-11_out	none	69	0	1	0.29	0.02	1	1	0	0	1	0	101	1231	0	0
North_LPL-12	7.08	North_LPL-12_out	none	69	0	1	0.22	0.02	1	1	0.01	0	1	0	101	1231	0	0
North_LPL-13	10.06	North_LPL-13_out	none	69	0	1	0.19	0.02	1	1	0.02	0	1	0	101	1231	0	0
North_LPL-14	7.25	North_LPL-14_out	none	69	0	1	0.22	0.02	1	1	0.26	0	1	0	101	1231	0	0
North_LPL-15	2.17	North_LPL-15_out	none	69	0	1	0.3	0.02	1	1	0.11	0	1	0	101	1231	0	0
North_LPL-16	37.98	North_LPL-16_out	none	69	0	1	0.28	0.02	1	1	0.02	0	1	0	101	1231	0	0
North_LPL-17	6.77	North_LPL-17_out	none	69	0	1	0.29	0.02	1	1	0.49	0	1	0	101	1231	0	0
North_LPL-18	15.46	North_LPL-18_out	none	69	0	1	0.3	0.02	1	1	0.01	0	1	0	101	1231	0	0
North_LPL-19	2.13	North_LPL-19_out	none	69	0	1	0.3	0.02	1	1	0.01	0	1	0	101	1231	0	0
North_LPL-20	7.06	North_LPL-20_out	none	69	0	1	0.26	0.02	1	1	0.01	0	1	0	101	1231	0	0
North_LPL-21	2.95	North_LPL-21_out	none	69	0	1	0.19	0.02	1	1	0.3	0	1	0	101	1231	0	0
North_LPL-22	7.57	North_LPL-22_out	none	69	0	1	0.17	0.02	1	1	0.08	0	1	0	101	1231	0	0
North_LPL-23	8.47	North_LPL-23_out	none	69	0	1	0.09	0.02	1	1	0.46	0	1	0	101	1231	0	0
North_LPL-24	12.77	North_LPL-24_out	none	69	0	1	0.19	0.02	1	1	0.03	0	1	0	101	1231	0	0
North_LPL-25	8.13	North_LPL-25_out	none	69	0	1	0.21	0.02	1	1	0.02	0	1	0	101	1231	0	0
North_LPL-26	88.67	North_LPL-26_out	none	69	0	1	0.28	0.02	1	1	0.02	0	1	0	101	1231	0	0
North_LPL-32	32.31	North_LPL-32_out	none	69	0	1	0.3	0.02	1	1	0.04	0	1	0	101	1231	0	0

Watershed Label	Total Area acres	Outflow Device	Percol Device	Pervious Curve Number	Indirect Imperv Fraction	Pervious Load Factor	Directly Connected UnSwept Areas				Directly Connected Swept Areas				Street Sweeping Parameters			
							Imperv Fraction	Depress Storage inches	Runoff Coef	Imperv Load Factor	Imperv Fraction	Depress Storage inches	Runoff Coef	Imperv Load Factor	Start Date MMDD	Stop Date MMDD	Sweep Effic	Sweep Freq 1/week
North_LPL-33	17.44	North_LPL-33_out	none	69	0	1	0.35	0.02	1	1	0.01	0	1	0	101	1231	0	0
North_LPL-34	3.51	North_LPL-34_out	none	69	0	1	0.43	0.02	1	1	0.06	0	1	0	101	1231	0	0
North_LPL-36	49.83	North_LPL-36_out	none	69	0	1	0.31	0.02	1	1	0	0	1	0	101	1231	0	0
North_LPL-40	4.93	North_LPL-40_out	none	69	0	1	0.26	0.02	1	1	0.02	0	1	0	101	1231	0	0
North_LPL-42	6.82	North_LPL-42_out	none	69	0	1	0.39	0.02	1	1	0.03	0	1	0	101	1231	0	0
North_LPL-48	2.72	North_LPL-48_out	none	69	0	1	0.73	0.02	1	1	0.03	0	1	0	101	1231	0	0
South_LPL-2	21.33	South_LPL-2_out	none	69	0	1	0.21	0.02	1	1	0.07	0	1	0	101	1231	0	0
South_LPL-4	26.76	South_LPL-4_out	none	69	0	1	0.19	0.02	1	1	0.28	0	1	0	101	1231	0	0
South_LPL-6	13.63	South_LPL-6_out	none	69	0	1	0.09	0.02	1	1	0	0	1	0	101	1231	0	0
South_LPL-9	4.86	South_LPL-9_out	none	69	0	1	0.06	0.02	1	1	0.03	0	1	0	101	1231	0	0
South_LPL-11	89.2	South_LPL-11_out	none	69	0	1	0.23	0.02	1	1	0.05	0	1	0	101	1231	0	0
South_LPL-12	58.59	South_LPL-12_out	none	69	0	1	0.22	0.02	1	1	0.08	0	1	0	101	1231	0	0
South_LPL-13	6.44	South_LPL-13_out	none	69	0	1	0.25	0.02	1	1	0.04	0	1	0	101	1231	0	0
South_LPL-14	4.78	South_LPL-14_out	none	69	0	1	0.22	0.02	1	1	0.05	0	1	0	101	1231	0	0
South_LPL-15	1.33	South_LPL-15_out	none	69	0	1	0.3	0.02	1	1	0.12	0	1	0	101	1231	0	0
South_LPL-16	2.01	South_LPL-16_out	none	69	0	1	0.28	0.02	1	1	0.12	0	1	0	101	1231	0	0
South_LPL-18	9.55	South_LPL-18_out	none	69	0	1	0.53	0.02	1	1	0.06	0	1	0	101	1231	0	0
South_LPL-20	4.74	South_LPL-20_out	none	69	0	1	0.26	0.02	1	1	0.06	0	1	0	101	1231	0	0
South_LPL-21	8.16	South_LPL-21_out	none	69	0	1	0.19	0.02	1	1	0.21	0	1	0	101	1231	0	0
South_LPL-22	11.84	South_LPL-22_out	none	69	0	1	0.17	0.02	1	1	0.02	0	1	0	101	1231	0	0
South_LPL-23	11.89	South_LPL-23_out	none	69	0	1	0.14	0.02	1	1	0.04	0	1	0	101	1231	0	0
South_LPL-24	11.95	South_LPL-24_out	none	69	0	1	0.19	0.02	1	1	0.04	0	1	0	101	1231	0	0
South_LPL-25	4.94	South_LPL-25_out	none	69	0	1	0.21	0.02	1	1	0.17	0	1	0	101	1231	0	0
South_LPL-26	7.56	South_LPL-26_out	none	69	0	1	0.28	0.02	1	1	0.05	0	1	0	101	1231	0	0
South_LPL-27	6.33	South_LPL-27_out	none	69	0	1	0.08	0.02	1	1	0.02	0	1	0	101	1231	0	0
South_LPL-28	3.81	South_LPL-28_out	none	69	0	1	0.02	0.02	1	1	0.26	0	1	0	101	1231	0	0
South_LPL-29	6.08	South_LPL-29_out	none	69	0	1	0.33	0.02	1	1	0.04	0	1	0	101	1231	0	0
South_LPL-30	10.67	South_LPL-30_out	none	69	0	1	0.14	0.02	1	1	0.17	0	1	0	101	1231	0	0
South_LPL-31	16.25	South_LPL-31_out	none	69	0	1	0.22	0.02	1	1	0.06	0	1	0	101	1231	0	0
South_LPL-32	50.07	South_LPL-32_out	none	69	0	1	0.3	0.02	1	1	0.28	0	1	0	101	1231	0	0
South_LPL-33	8.92	South_LPL-33_out	none	69	0	1	0.35	0.02	1	1	0.3	0	1	0	101	1231	0	0

Table 24. Contributing area device inputs

Watershed	Device Name	Out Type	Diameter or Length (ft)	Coefficient	Downstream Device	Particle Removal Factor	Bottom Elevation	Bottom (ac)	Permanent Pool (ac)	Permanent Pool Volume (ac-ft)	Permanent Pool Infiltration Rate (in/hr)	Flood Pool (ac)	Flood Pool Depth (in)	Flood Pool Volume (ac-ft)	Flood Pool Infiltration Rate (in/hr)
Drainage Area		*From city GIS layers and As-built surveys*	*Diameter of culverts assumed as oriface diameter*	*Default (0.6 for orifice, 3.2 for weir)*	*Routing from city stormsewer*	*Initially set to 1, used for calibration*	*Zero*	*Assumes 4:1 slopes for ponds and 10:1 slopes for wetlands below the Permanent Pool Area where as-builts were not available*	*Pond or wetland surface area from GIS*	*Assumes 5' max Depth for ponds, 3' max depth for wetlands where as-builts were not available*	*Assumes zero as default, adjusted based on calibration*	*Assumed 4:1 slopes above NWL where as-builts were not available*	*Depth is 1' greater than the outlet size if orifice, 1' total if weir.*	*Assumes 4:1 sideslopes*	*Assumes zero as default, adjusted based on calibration*
Lower Prior Lake Direct Drainage	LPL_out	Pipe	NA	NA	Out	0	0	NA	NA	NA	NA	NA	NA	NA	NA
North_LPL-1	North_LPL-1_out	Orifice	12	0.6	North_LPL-3_out	1	0.0	0.16	0.21	0.55	0.00	0.26	24	0.47	0.00
North_LPL-10	North_LPL-10_out	Orifice	15	0.6	North_LPL-26_out	1	1006.0	0.22	0.22	0.01	0.00	0.41	27	5.70	0.00
North_LPL-11	North_LPL-11_out	Orifice	21	0.6	North_LPL-26_out	1	995.6	0.08	0.08	0.01	0.00	0.45	33	4.10	0.00
North_LPL-12	North_LPL-12_out	Orifice	15	0.6	North_LPL-26_out	1	1006.0	0.07	0.08	0.01	0.00	0.24	27	1.20	0.00
North_LPL-13	North_LPL-13_out	Orifice	21	0.6	North_LPL-26_out	1	964.0	0.00	0.21	0.01	0.00	0.45	33	1.98	0.00
North_LPL-14	North_LPL-14_out	Orifice	36	0.6	North_LPL-16_out	1	0.0	1.62	1.90	8.79	0.00	2.38	48	8.56	0.00
North_LPL-15	North_LPL-15_out	Orifice	12	0.6	North_LPL-17_out	1	0.0	0.18	0.24	0.63	0.00	0.30	24	0.54	0.00
North_LPL-16	North_LPL-16_out	Orifice	15	0.6	North_LPL-17_out	1	931.6	0.64	0.75	3.47	0.00	0.94	27	1.90	0.00
North_LPL-17	North_LPL-17_out	Orifice	15	0.6	North_LPL-21_out	1	0.0	2.81	3.31	15.31	0.00	4.14	27	8.38	0.00
North_LPL-18	North_LPL-18_out	Weir	10	3.2	North_LPL-21_out	1	914.0	0.01	0.11	1.75	0.00	0.22	12	12.50	0.00
North_LPL-19	North_LPL-19_out	Orifice	24	0.6	North_LPL-21_out	1	914.0	0.01	0.02	0.16	0.00	0.04	36	0.20	0.00
North_LPL-2	North_LPL-2_out	Orifice	24	0.6	North_LPL-1_out	1	0.0	0.04	0.05	0.13	0.00	0.06	36	0.17	0.00
North_LPL-20	North_LPL-20_out	Orifice	24	0.6	North_LPL-21_out	1	913.0	0.02	0.04	0.62	0.00	0.14	36	0.20	0.00
North_LPL-21	North_LPL-21_out	Orifice	18	0.6	North_LPL-22_out	1	0.0	0.66	0.88	2.31	0.00	1.10	30	2.48	0.00
North_LPL-22	North_LPL-22_out	Orifice	42	0.6	North_LPL-23_out	1	0.0	0.47	0.63	1.65	0.00	0.79	54	3.20	0.00
North_LPL-23	North_LPL-23_out	Orifice	27	0.6	LPL_out	1	0.0	2.92	3.90	10.24	0.00	4.88	39	14.27	0.00
North_LPL-24	North_LPL-24_out	Orifice	12	0.6	North_LPL-25_out	1	0.0	0.29	0.39	1.02	0.00	0.49	24	0.88	0.00
North_LPL-25	North_LPL-25_out	Orifice	24	0.6	LPL_out	1	946.0	0.16	0.19	0.88	0.00	0.24	36	0.65	0.00
North_LPL-26	North_LPL-26_out	Orifice	30	0.6	North_LPL-22_out	1	905.0	0.31	1.35	1.62	0.00	1.73	42	7.50	0.00
North_LPL-3	North_LPL-3_out	Orifice	12	0.6	North_LPL-4_out	1	0.0	0.01	0.01	0.03	0.00	0.01	24	0.02	0.00
North_LPL-32	North_LPL-32_out	Orifice	18	0.6	North_LPL-33_out	1	940.0	1.16	1.37	6.34	0.00	1.71	30	3.85	0.00
North_LPL-33	North_LPL-33_out	Orifice	44	0.6	North_LPL-34_out	1	918.0	0.13	0.15	0.69	0.00	0.19	56	0.79	0.00
North_LPL-34	North_LPL-34_out	Orifice	48	0.6	North_LPL-48_out	1	916.0	0.19	0.22	1.02	0.00	0.28	60	1.25	0.00
North_LPL-36	North_LPL-36_out	Orifice	24	0.6	LPL_out	1	0.0	0.15	0.18	0.83	0.00	0.22	36	0.60	0.00
North_LPL-4	North_LPL-4_out	Orifice	18	0.6	LPL_out	1	903.5	0.05	0.10	0.30	0.00	0.30	30	0.40	0.00
North_LPL-40	North_LPL-40_out	Orifice	12	0.6	LPL_out	1	916.9	0.02	0.11	0.10	0.00	0.15	24	0.10	0.00
North_LPL-42	North_LPL-42_out	Orifice	12	0.6	North_LPL-23_out	1	904.0	0.10	0.20	0.45	0.00	0.30	24	0.50	0.00

Watershed	Device Name	Out Type	Diameter or Length (ft)	Coefficient	Downstream Device	Particle Removal Factor	Bottom Elevation	Bottom (ac)	Permanent Pool (ac)	Permanent Pool Volume (ac-ft)	Permanent Pool Infiltration Rate (in/hr)	Flood Pool (ac)	Flood Pool Depth (in)	Flood Pool Volume (ac-ft)	Flood Pool Infiltration Rate (in/hr)
Drainage Area		*From city GIS layers and As-built surveys*	*Diameter of culverts assumed as oriface diameter*	*Default (0.6 for orifice, 3.2 for weir)*	*Routing from city stormsewer*	*Initially set to 1, used for calibration*	*Zero*	*Assumes 4:1 slopes for ponds and 10:1 slopes for wetlands below the Permanent Pool Area where as-builts were not available*	*Pond or wetland surface area from GIS*	*Assumes 5' max Depth for ponds, 3' max depth for wetlands where as-builts were not available*	*Assumes zero as default, adjusted based on calibration*	*Assumed 4:1 slopes above NWL where as-builts were not available*	*Depth is 1' greater than the outlet size if orifice, 1' total if weir.*	*Assumes 4:1 sideslopes*	*Assumes zero as default, adjusted based on calibration*
North_LPL-48	North_LPL-48_out	Orifice	48	0.6	LPL_out	1	0.0	0.06	0.07	0.32	0.00	0.09	60	0.40	0.00
North_LPL-5	North_LPL-5_out	Orifice	42	0.6	North_LPL-6_out	1	0.0	0.37	0.44	2.04	0.00	0.55	54	2.23	0.00
North_LPL-6	North_LPL-6_out	Orifice	36	0.6	LPL_out	1	919.0	0.40	0.45	1.20	0.00	0.56	48	3.00	0.00
North_LPL-9	North_LPL-9_out	Orifice	15	0.6	North_LPL-26_out	1	962.0	0.53	0.62	2.87	0.00	0.78	27	1.58	0.00
South_LPL-11	South_LPL-11_out	Orifice	15	0.6	LPL_out	1	0.0	0.40	0.47	2.17	0.00	0.59	27	1.19	0.00
South_LPL-12	South_LPL-12_out	Orifice	36	0.6	LPL_out	1	0.0	4.23	4.98	23.03	0.00	6.23	48	22.42	0.00
South_LPL-13	South_LPL-13_out	Orifice	15	0.6	South_LPL-12_out	1	912.0	0.05	0.28	0.62	0.00	0.30	27	0.90	0.00
South_LPL-14	South_LPL-14_out	Orifice	15	0.6	South_LPL-15_out	1	916.0	0.20	0.23	1.06	0.00	0.29	27	0.59	0.00
South_LPL-15	South_LPL-15_out	Orifice	18	0.6	South_LPL-16_out	1	901.9	0.14	0.16	0.74	0.00	0.20	30	0.45	0.00
South_LPL-16	South_LPL-16_out	Orifice	18	0.6	LPL_out	1	916.0	0.20	0.24	1.11	0.00	0.30	30	0.68	0.00
South_LPL-18	South_LPL-18_out	Orifice	12	0.6	LPL_out	1	0.0	0.47	0.55	2.54	0.00	0.69	24	1.24	0.00
South_LPL-2	South_LPL-2_out	Orifice	15	0.6	LPL_out	1	0.0	1.04	1.39	3.65	0.00	1.74	27	3.52	0.00
South_LPL-20	South_LPL-20_out	Orifice	18	0.6	South_LPL-21_out	1	917.6	0.26	0.30	1.39	0.00	0.38	30	0.85	0.00
South_LPL-21	South_LPL-21_out	Orifice	18	0.6	South_LPL-22_out	1	0.0	1.30	1.74	4.57	0.00	2.17	30	4.89	0.00
South_LPL-22	South_LPL-22_out	Orifice	18	0.6	South_LPL-30_out	1	909.0	0.25	0.29	1.34	0.00	0.36	30	0.81	0.00
South_LPL-23	South_LPL-23_out	Orifice	18	0.6	South_LPL-32_out	1	902.5	0.43	0.51	2.36	0.00	0.64	30	1.44	0.00
South_LPL-24	South_LPL-24_out	Weir	10	3.2	South_LPL-25_out	1	0.0	0.38	0.51	1.34	0.00	0.64	12	0.58	0.00
South_LPL-25	South_LPL-25_out	Orifice	15	0.6	South_LPL-30_out	1	0.0	0.64	0.85	2.23	0.00	1.06	27	2.15	0.00
South_LPL-26	South_LPL-26_out	Orifice	15	0.6	South_LPL-28_out	1	894.0	0.01	0.41	2.00	0.00	0.52	27	1.05	0.00
South_LPL-27	South_LPL-27_out	Orifice	15	0.6	South_LPL-25_out	1	901.0	0.09	0.10	0.46	0.00	0.13	27	0.26	0.00
South_LPL-28	South_LPL-28_out	Orifice	15	0.6	South_LPL-25_out	1	0.0	0.75	1.00	2.63	0.00	1.25	27	2.53	0.00
South_LPL-29	South_LPL-29_out	Orifice	24	0.6	South_LPL-33_out	1	896.0	0.20	0.23	1.06	0.00	0.29	36	0.78	0.00
South_LPL-30	South_LPL-30_out	Orifice	24	0.6	South_LPL-23_out	1	0.0	1.36	1.81	4.75	0.00	2.26	36	6.11	0.00
South_LPL-31	South_LPL-31_out	Orifice	15	0.6	South_LPL-32_out	1	925.0	0.89	1.05	4.86	0.00	1.31	27	2.66	0.00
South_LPL-32	South_LPL-32_out	Orifice	24	0.6	South_LPL-33_out	1	0.0	8.27	11.03	28.95	0.00	13.79	36	37.23	0.00
South_LPL-33	South_LPL-33_out	Weir	10	3.2	LPL_out	1	0.0	2.24	2.64	12.21	0.00	3.30	12	2.97	0.00
South_LPL-4	South_LPL-4_out	Orifice	18	0.6	LPL_out	1	0.0	6.34	7.46	34.50	0.00	9.32	30	20.98	0.00
South_LPL-6	South_LPL-6_out	Orifice	36	0.6	LPL_out	1	0.0	0.03	0.04	0.11	0.00	0.05	48	0.18	0.00
South_LPL-9	South_LPL-9_out	Orifice	15	0.6	LPL_out	1	0.0	0.12	0.14	0.65	0.00	0.18	27	0.36	0.00

Table 25. P8 watershed model results

Watershed Pollutant Loads			Device Pollutant Loading					
Watershed	Total Loading (lb/yr)		Device	TP Concentration Out (µg/l)	Total Loading Out of Device (lb/yr)		Pollutant Removal Efficiency (%)	
	TSS	TP			TSS	TP	TSS	TP
Lower Prior Lake Direct Drainage	97,505	307.2	LPL_out	0.056	122,038	503.6	NA	NA
North_LPL-1_out	346	1.1	North_LPL-1_out	0.109	164	1.7	76%	43%
North_LPL-2_out	1,041	3.3	North_LPL-2_out	0.186	367	2.0	64%	38%
North_LPL-3_out	1,712	5.4	North_LPL-3_out	0.226	1,561	6.9	17%	4%
North_LPL-4_out	3,496	11.0	North_LPL-4_out	0.207	2,725	14.2	46%	20%
North_LPL-5_out	13,216	41.6	North_LPL-5_out	0.188	4,769	26.1	64%	37%
North_LPL-6_out	506	1.6	North_LPL-6_out	0.140	2,856	21.6	45%	22%
North_LPL-9_out	3,295	10.4	North_LPL-9_out	0.105	406	4.0	87%	58%
North_LPL-10_out	1,598	5.0	North_LPL-10_out	0.182	597	3.6	63%	29%
North_LPL-11_out	3,398	10.7	North_LPL-11_out	0.281	2,097	9.6	38%	10%
North_LPL-12_out	1,021	3.2	North_LPL-12_out	0.219	467	2.5	54%	22%
North_LPL-13_out	1,252	4.0	North_LPL-13_out	0.180	474	2.8	62%	29%
North_LPL-14_out	1,045	3.3	North_LPL-14_out	0.025	34	0.6	95%	67%
North_LPL-15_out	426	1.3	North_LPL-15_out	0.075	32	0.4	91%	64%
North_LPL-16_out	6,966	21.9	North_LPL-16_out	0.108	1,432	11.3	79%	49%
North_LPL-17_out	1,286	4.0	North_LPL-17_out	0.056	383	7.6	83%	41%
North_LPL-18_out	3,038	9.6	North_LPL-18_out	0.131	762	5.0	74%	45%
North_LPL-19_out	419	1.3	North_LPL-19_out	0.153	107	0.7	74%	46%
North_LPL-20_out	1,202	3.8	North_LPL-20_out	0.154	316	2.0	73%	44%
North_LPL-21_out	367	1.2	North_LPL-21_out	0.065	972	13.8	49%	15%
North_LPL-22_out	843	2.7	North_LPL-22_out	0.113	7,280	60.4	25%	10%
North_LPL-23_out	500	1.6	North_LPL-23_out	0.085	3,617	48.3	54%	24%
North_LPL-24_out	1,590	5.0	North_LPL-24_out	0.106	198	2.0	87%	58%
North_LPL-25_out	1,119	3.5	North_LPL-25_out	0.109	364	3.5	71%	36%
North_LPL-26_out	16,263	51.2	North_LPL-26_out	0.167	7,959	51.1	61%	31%
North_LPL-32_out	6,349	20.0	North_LPL-32_out	0.099	693	7.4	88%	59%
North_LPL-33_out	3,998	12.6	North_LPL-33_out	0.144	2,560	16.5	45%	17%
North_LPL-34_out	988	3.1	North_LPL-34_out	0.122	1,995	16.0	43%	18%

Watershed Pollutant Loads		
Watershed	Total Loading (lb/yr)	
	TSS	TP
North_LPL-36_out	10,118	31.8
North_LPL-40_out	840	2.6
North_LPL-42_out	1,742	5.5
North_LPL-48_out	1,300	4.1
South_LPL-2_out	2,935	9.2
South_LPL-4_out	3,331	10.5
South_LPL-6_out	805	2.6
South_LPL-9_out	192	0.6
South_LPL-11_out	13,440	42.3
South_LPL-12_out	8,444	26.6
South_LPL-13_out	1,055	3.3
South_LPL-14_out	689	2.2
South_LPL-15_out	261	0.8
South_LPL-16_out	369	1.2
South_LPL-18_out	3,314	10.4
South_LPL-20_out	807	2.5
South_LPL-21_out	1,016	3.2
South_LPL-22_out	1,319	4.2
South_LPL-23_out	1,091	3.5
South_LPL-24_out	1,488	4.7
South_LPL-25_out	680	2.1
South_LPL-26_out	1,387	4.4
South_LPL-27_out	332	1.1
South_LPL-28_out	50	0.2
South_LPL-29_out	1,314	4.1
South_LPL-30_out	979	3.1
South_LPL-31_out	2,342	7.4
South_LPL-32_out	9,837	30.9
South_LPL-33_out	2,044	6.4

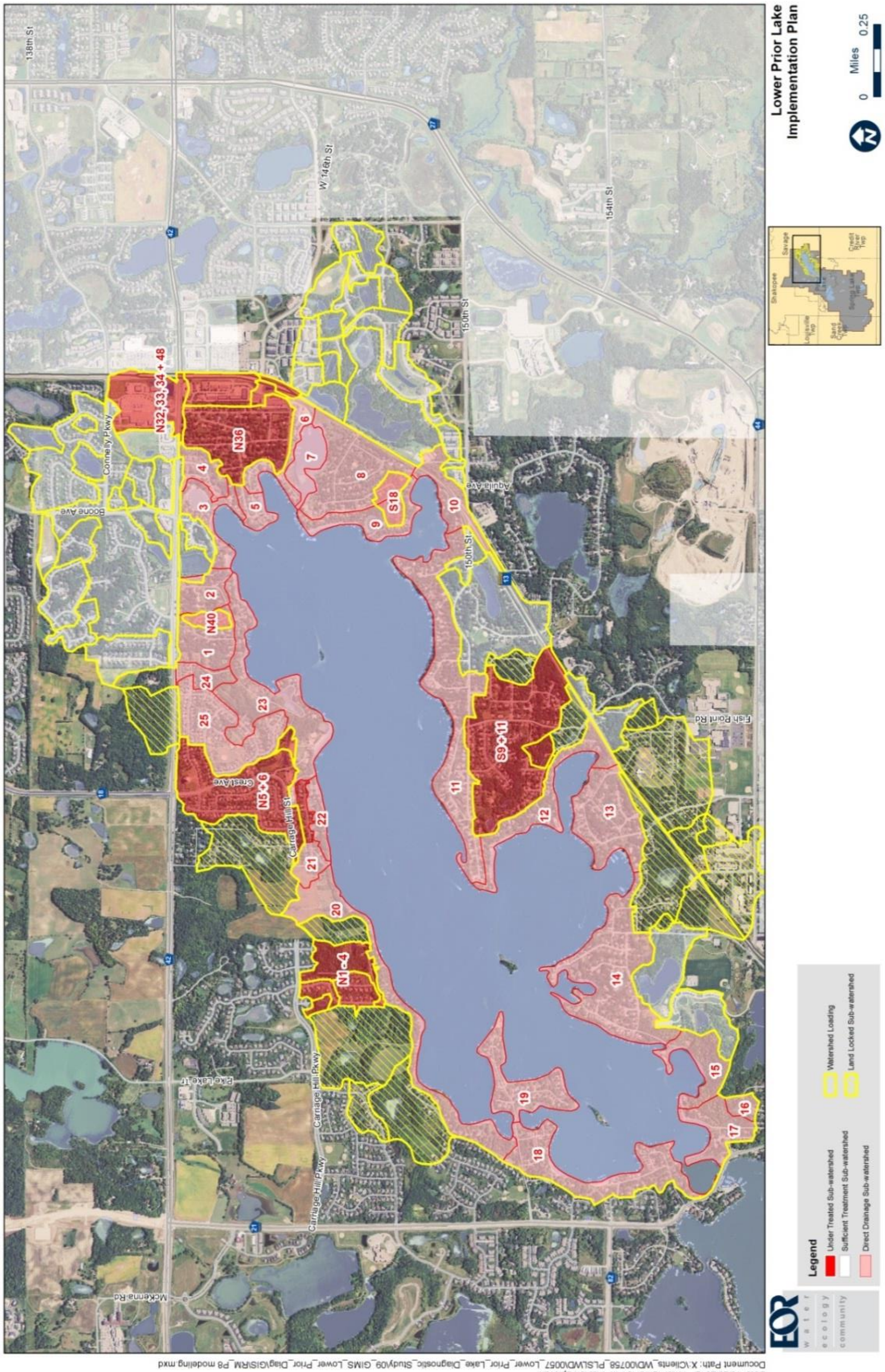
Device Pollutant Loading					
Device	TP Concentration Out (µg/l)	Total Loading Out of Device (lb/yr)		Pollutant Removal Efficiency (%)	
		TSS	TP	TSS	TP
North_LPL-36_out	0.226	4,820	23.0	52%	28%
North_LPL-40_out	0.156	221	1.5	74%	44%
North_LPL-42_out	0.141	372	2.7	78%	49%
North_LPL-48_out	0.131	2,601	18.8	21%	6%
South_LPL-2_out	0.080	225	3.1	91%	63%
South_LPL-4_out	0.020	88	1.6	95%	68%
South_LPL-6_out	0.179	278	1.6	65%	38%
South_LPL-9_out	0.052	10	0.2	93%	64%
South_LPL-11_out	0.081	4,779	27.2	64%	35%
South_LPL-12_out	0.061	535	7.8	92%	62%
South_LPL-13_out	0.108	136	1.3	86%	58%
South_LPL-14_out	0.083	60	0.7	90%	62%
South_LPL-15_out	0.070	57	0.8	81%	39%
South_LPL-16_out	0.063	71	1.1	82%	39%
South_LPL-18_out	0.110	436	4.2	86%	57%
South_LPL-20_out	0.078	65	0.8	90%	63%
South_LPL-21_out	0.043	63	1.3	93%	57%
South_LPL-22_out	0.069	342	3.3	75%	37%
South_LPL-23_out	0.056	509	7.8	63%	18%
South_LPL-24_out	0.095	157	1.7	89%	60%
South_LPL-25_out	0.057	172	3.3	80%	32%
South_LPL-26_out	0.086	127	1.4	89%	61%
South_LPL-27_out	0.088	32	0.4	89%	60%
South_LPL-28_out	0.039	23	0.9	84%	28%
South_LPL-29_out	0.110	179	1.6	85%	57%
South_LPL-30_out	0.051	311	6.3	78%	30%
South_LPL-31_out	0.069	159	2.1	92%	64%
South_LPL-32_out	0.045	869	16.9	91%	53%
South_LPL-33_out	0.045	909	18.8	69%	20%

6 APPENDIX C: CITY OF PRIOR LAKE BMP AND MAINTENANCE SUMMARY

A summary of potential redevelopment and maintenance opportunities for the City of Prior Lake that were identified during the stormwater retrofit assessment are summarized below. Note that the term "subwatershed" is equivalent to the use of the term "catchment" from past Prior Lake assessments. The redevelopment opportunities are listed below by subwatershed location. For details of the proposed activities and locations see Appendix D.

Treatment Area	Subwatersheds	Activity
Undertreated	N1, N2, N3, N4	Expand existing N4 ponding & repair outlet pipe.
Undertreated	N5, N6	Infiltration in Crest Ave. park, flat curbs on Crest Ave. Maintenance of existing ponds suggested.
Undertreated	N32, N33, N34, N48	Impervious disconnection, underground storage/pervious pavement
Undertreated	S9, S11	Infiltration in park; reconfiguration/expansion of pond in NW corner
Direct Drainage	1, 2	Curbless streets
Direct Drainage	10	Ditch checks along HW 13
Direct Drainage	13	Infiltration at Candy Cove & Manor

7 APPENDIX D: MODELED BMPS BY SUBWATERSHED


Lower Prior Lake
Implementation Plan
Miles
0
0.25
Legend
Under Treated Sub-watershed
Sufficient Treatment Sub-watershed
Direct Drainage Sub-watershed
Watershed Loading
Land Locked Sub-watershed
N32, 33, 34 + 48
N36
N40
N5 + 6
N1 - 4
S9 + 11
S18
Date: 10/25/2012 Time: 12:16:46 PM Author: apievan
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7.1 BMP Selection and Justification

Table 29 summarizes the complete list of identified and modeled watershed BMPs in the undertreated and direct drainage subwatersheds of Lower Prior Lake. Phosphorus reduction benefits, capital costs, O&M costs, other benefits, and stakeholder input were used to select priority projects. Watershed management practices (or, retrofit BMP opportunities) identified in each subwatershed are described in Section 3.6.1 and later in this Appendix.

7.1.1 Retrofit BMP Opportunities by Subwatershed

This section summarizes all identified BMP opportunities for all subwatersheds. Undertreated subwatersheds were split into northern subwatersheds and southern subwatersheds, with subwatershed numbers beginning with SW-N and SW-S, respectively. Subwatersheds with no treatment are located in the direct drainage area of the lake and have a separate numbering system without letters.

Infiltration features were sited based on space availability and ability to route drainage areas to these treatment features. Rain gardens were best fit locations when it seemed to make sense for the watershed or neighborhood based on a quick walk through. Rain garden locations should not be interpreted to mean that these are the only areas that could accommodate rain garden features. Rain garden locations with the greatest contributing area should be investigated first. Locations that would be within the drainage area of another rain garden should be avoided. See *Appendix E:Raingarden Siting Methodology* for a more complete implementation methodology.

Because all subwatersheds in the study area are 100% developed, no new sites were identified for stormwater ponds. However, the existing ponds were reviewed for potential retrofit opportunities. Based on space constraints a determination was made as to whether pond expansion was possible to provide additional treatment volume.

For the undertreated portion of the Lower Prior watershed, subwatersheds that outlet through the same subwatershed (e.g., N1, N2, and N3 all drain to N4) were modeled as one group. As a result, BMPs identified in a group of subwatersheds were modeled as a BMP treatment train, where downstream BMPs receive pre-treated runoff from upstream BMPs. The total phosphorus load reductions from all identified retrofit BMP opportunities in a subwatershed group were reported at the subwatershed outlet. The following (direct drainage) subwatersheds had no modeled BMPs: 3, 7, 9, 10, 12, 15, 16, 17, 20, 21, 22, and 24.

Rain gardens

Rain garden opportunities were identified in 14 subwatersheds and modeled in P8 to determine their phosphorus reduction benefits. The locations of these rain gardens are shown in this appendix. This does not imply that rain gardens in other locations are not feasible or beneficial, but they may require additional infrastructure or provide lower phosphorus reduction benefits than the rain gardens modeled in this implementation plan. A summary of the phosphorus reductions achieved from these rain gardens and ditch checks in subwatershed 10 are summarized in Table 29 with the treatment level with an optimum phosphorus cost-benefit highlighted in bold.

Table 29. Infiltration opportunities in Lower Prior Lake subwatersheds

Subwatershed	**Treatment Level***	**P Removal Efficiency (%)**	**Total surface area (sq. ft.)**	**Total phosphorus reduction [lb/yr]**	**30-year O&M Cost-Benefit [$/lb]**
Undertreated SW-S18	Max	20	1,200	0.7	1,255
	Min	**9**	**480**	**0.3**	**1,137**
Direct drainage SW-1	Max	53	3,300	3.8	622
	Mid	**25**	**1,000**	**1.8**	**416**
	Min	11	450	0.6	549
Direct drainage SW-2	Max	43	1,350	2.2	449
	Mid	**31**	**780**	**1.6**	**350**
	Min	12	235	0.6	324
Direct drainage SW-4	Max	29	1,350	2.3	407
	Mid	**23**	**800**	**1.8**	**316**
	Min	10	330	0.8	289
Direct drainage SW-5	Max	18	450	0.9	538
	Min	**8**	**155**	**0.4**	**279**
Direct drainage SW-6	**Max**	**5**	**300**	**0.5**	**646**
Direct drainage SW-8	Max	26	2,850	5.4	568
	Min	**13**	**1,170**	**2.7**	**321**
Direct drainage SW-10 (Ditch checks)	**Max**	**73**	**19,170**	**10.1**	**46**
	Mid	53	7,510	7.4	25
	Min	29	2,470	4.0	15
Direct drainage SW-11	**Max**	**4**	**600**	**1.5**	**431**
Direct drainage SW-14	**Max**	**26**	**4,500**	**7.0**	**441**
	Min	11	1,390	3.1	324
Direct drainage SW-18	**Max**	**11**	**1,050**	**2.3**	**312**
Direct drainage SW-19	**Max**	**22**	**3,150**	**3.2**	**721**
	Min	10	1,200	1.4	627
Direct drainage SW-23	**Max**	**4**	**450**	**0.6**	**549**
Direct drainage SW-25	Max	56	10,050	16.4	458
	Mid	**31**	**4,180**	**9.1**	**337**
	Min	19	2,500	5.6	330

*Max = Maximum; Mid = Mid-range; Min = Minimum

7.2 Undertreated Subwatersheds N1, N2, N3, and N4

7.2.1 Phosphorus Reduction Benefits

Two retrofit BMP opportunities were identified in the undertreated subwatersheds N1, N2, N3, and N4 (Figure 37):

1. Infiltration area at Beach St. and Rosewood Rd. (1,500 sq. ft.)
2. Pond expansion in SW-N4 (8,700 sq. ft.)

In addition, there are 29 locations for rain gardens (150 sq. ft. each) identified in these subwatersheds. Implementation of rain gardens should begin with the 300 sq. ft. rain garden on the south side of Hemlock Circle. Site conditions are similar for all other rain gardens and should be implemented with an even distribution along Rosewood Road and Bluebird Trail in each subwatershed. These BMPs remove an estimated 5.4 lb TP per year from the load to Lower Prior Lake.

7.2.2 P8 Modeling Assumptions

- Existing ponds were modeled to account for some phosphorus reduction benefits from regular maintenance by the City to remove sediment in-fill. Existing average pond depths were estimated to be between 2.6 and 3 feet deep, with sediment removal to 4 feet depth based on NURP design standards. No surveying was conducted to determine actual pond depths.
- Rain gardens and infiltration areas were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
  - 60% of the N2 watershed draining to N2 rain gardens
  - 80% of the N3 watershed draining to the N3 rain gardens and infiltration features
  - 100% of the N4 watershed draining directly to pond SW-N4 pond expansion

7.2.3 General Subwatershed Observations

- Areas along Bluebird Trail and Rosewood appeared to be very conducive to rain garden retrofits with the exception of boulevard areas adjacent to sidewalks. Two areas were identified as having space for slightly larger rain garden/infiltration features. However, these areas are located on residential lots, and concern for loss of yard space may limit the size of these features. A neighborhood rain garden project with enough resident participation could significantly reduce runoff and loading from these residential streets.
- The ponding area located in the southwest portion of N4 receives all drainage from N1, N2, N3 and N4. This pond could potentially be expanded to provide additional treatment volume. Clearing of trees and/or wetland impacts would need to be considered prior to expansion. At a minimum, the need for maintenance excavation should be investigated. One of the adjacent landowners indicated that the outlet pipe on the lake side has been tipped up from ice heaving and may need some repairs as well.

Figure 37. BMP retrofit opportunities in Lower Prior Lake subwatersheds N1, N2, N3, and N4

7.3 Undertreated Subwatersheds N5 and N6

7.3.1 Phosphorus Reduction Benefits

Two retrofit BMP opportunities were identified in the undertreated subwatersheds N5 and N6 (Figure 38):

1. Infiltration area at Amblewood Dr. and Crest Ave. (14,375 sq. ft.)
2. Three small infiltration features (150 sq. ft. each) around trailer parking lot storm drains

The phosphorus load reductions for these subwatersheds assume regular maintenance for sediment infill removal in the two existing stormwater ponds. These BMPs remove an estimated 11.7 lb TP per year from the load to Lower Prior Lake.

7.3.2 P8 Modeling Assumptions

- Existing ponds were modeled to account for some phosphorus reduction benefits that will be received from regular maintenance by the City to remove sediment in-fill. Existing pond depths were estimated to be 1 foot and 3 feet deep (SW-N5 and SW-N6, respectively), with sediment removal to 4 feet depth based on NURP design standards. No surveying was conducted to determine actual pond depths.
- Infiltration areas were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
  - 40% of the N5 watershed draining to the Amblewood Dr. infiltration area
  - 2.5 % of the N5 watershed draining to the three small infiltration areas

7.3.3 General Subwatershed Observations

- What appeared to be underutilized open space in the park east of Crest Avenue could potentially accommodate a large infiltration basin. A feasibility assessment would need to be conducted to determine how much drainage area could be routed to this feature and how much infrastructure improvements would be needed. This feature could potentially reduce volumes and loading to the downstream ponds which appear to be undersized for the size of the watershed. If this park infiltration area were deemed infeasible, there is opportunity for infiltration features along a significant stretch of Crest Avenue. Although some opportunities exist, much of the drainage area is not conducive to neighborhood rain gardens due to steep slopes and trees. It is recommended that the more regional features be pursued first. Other redevelopment potential includes converting to flat curbs along Crest Avenue.
- There are three existing curb cuts located around the DNR boat trailer parking lot. These areas currently lack treatment storage. However they could be easily retrofitted to rain gardens to provide treatment and education value in this high visibility area.
- The existing ponds, although deep in the surrounding landscape, appear to provide only a small amount of actual treatment volume (storage below the outlet). It appeared from a visual inspection that maintenance of the basins may be needed. It is recommended that the owner of these basins assess the storage volume relative to the original design to determine if maintenance excavation is needed.

Figure 38. BMP retrofit opportunities in Lower Prior Lake subwatersheds N5 and N6

7.4 Undertreated Subwatersheds N32, N33, N34, and N48

7.4.1 Phosphorus Reduction Benefits

Three retrofit BMP opportunities were identified in the undertreated subwatersheds N32, N33, N34, and N48 (Figure 39):

1. Underground infiltration area in the grocery store parking lot (7,350 sq. ft.)
2. Infiltration area by the dental clinic off Commerce Ave. (435 sq. ft.)
3. Vegetated swale along Boudin St. NE, south of Commerce Ave. (2,600 sq. ft.)

These BMPs remove an estimated 3.2 lb TP per year from the load to Lower Prior Lake.

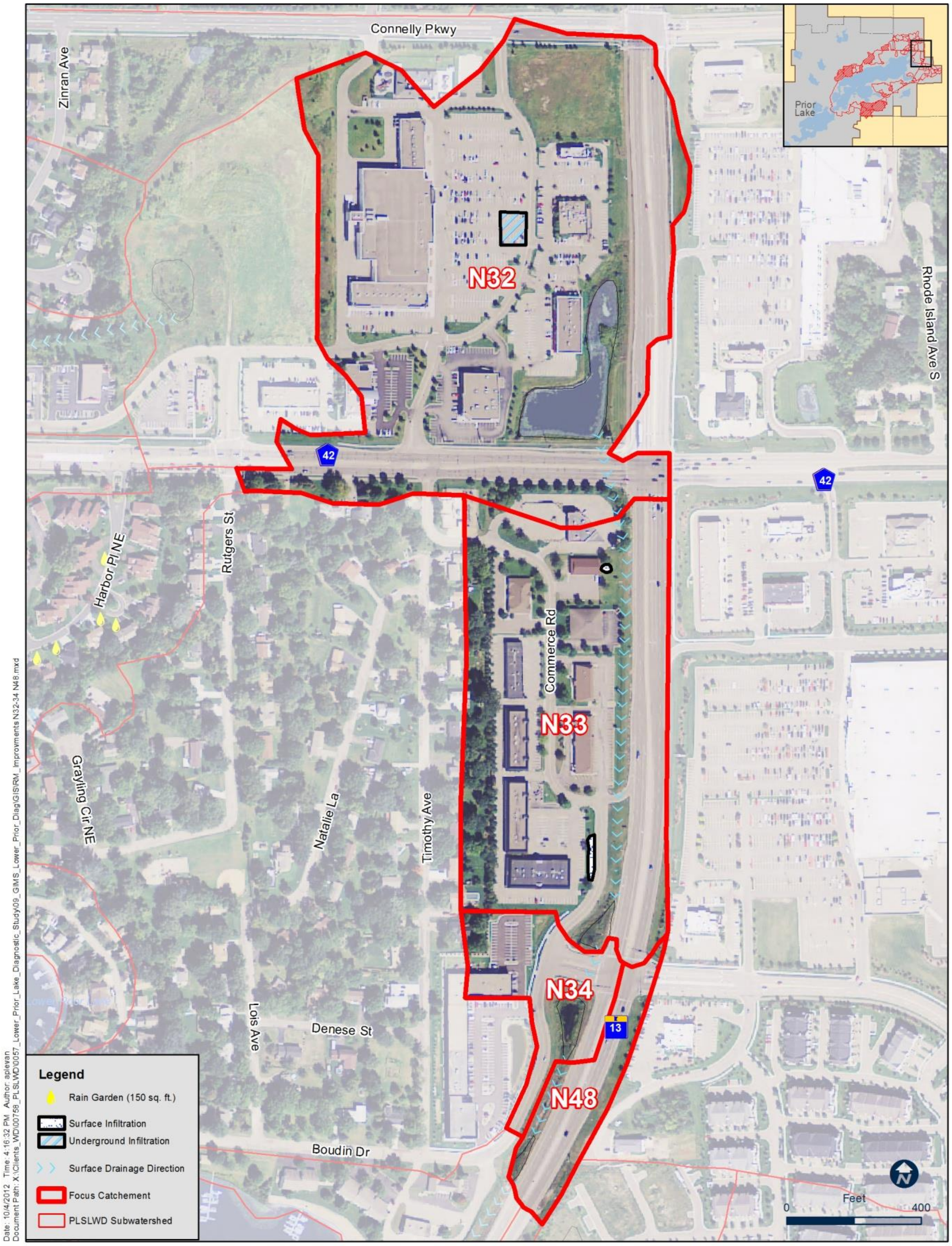
7.4.2 P8 Modeling Assumptions

- The average depth of the existing pond areas was assumed to be 4 feet deep based on NURP design standards. No surveying was conducted to determine actual pond depths.
- Infiltration areas were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
    - 13% of the N32 watershed draining to the underground infiltration area
    - 2% of the N33 watershed draining to the small infiltration area
    - 20% of the N33 watershed draining to the vegetated swale

7.4.3 General Subwatershed Observations

- These subwatersheds are highly impervious with some existing treatment ponds. There did not appear to be any obvious maintenance needs for the existing ponds.
- Redevelopment opportunities are limited due to the lack of open space. Disconnection of impervious areas, where feasible, could provide some small benefits. The green space identified in the north east portion of the N33 subwatershed could be used to create a small infiltration feature to route rooftop water from the adjacent building (gutters would need to be installed). The green space located along Commerce Avenue in the southern portion of N33 could possibly be used to treat a small amount of the adjacent paved surfaces. Other small disconnections could be considered on a lot by lot basis, however space availability is very limited and it would require working with each individual landowner.
- With the limited amount of green space available, underground features or pervious pavements could be considered during reconstruction of site parking lots if additional treatment is desired in the subwatershed. Although similar features could be incorporated anywhere in the watershed, one example was included that would provide treatment for the grocery store parking lot located in N32. This example is an underground chamber system that would capture and infiltrate stormwater.

Figure 39. BMP retrofit opportunities in Lower Prior Lake subwatersheds N32, N33, N34, and N48



7.5 Undertreated Subwatersheds S9 and S11

7.5.1 Phosphorus Reduction Benefits

Two retrofit BMP opportunities were identified in the undertreated subwatersheds S11 and S9 (Figure 40):

1. Infiltration area in Indian Ridge Park (4,900 sq. ft.)
2. Pond expansion in Fish Point Park (54,000 sq. ft.)

In addition, there are 13 locations for rain gardens (150 sq. ft. each) identified in these subwatersheds. Site conditions are similar for all rain gardens and should be implemented with an even distribution throughout the subwatershed. These BMPs remove an estimated 5.8 lb TP per year from the load to Lower Prior Lake.

7.5.2 P8 Modeling Assumptions

- Existing ponds were modeled to account for some phosphorus reduction benefits from regular maintenance by the City to remove sediment in-fill. Existing average pond depths were estimated to be 3 feet deep, with sediment removal to 4 feet depth based on NURP design standards. No surveying was conducted to determine actual pond depths.
- Rain gardens and infiltration areas were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
  - 10% of the S11 watershed draining to the large infiltration area and rain gardens
  - 80% of the S11 watershed draining to the expanded S11 ponds

7.5.3 General Subwatershed Observations

- Areas near Lost Horizon Circle and Maves Trail appeared to be conducive to rain garden retrofits, however much of the rest of the watershed was limited by steep slopes or limited space. Based on a quick walk through, sites that appeared to be best fit for rain gardens were identified. This should not be interpreted to mean that other lots could not be utilized for rain gardens should landowners be interested.
- Areas within the park near the corner of Indian Ridge Circle and Fairlawn Shore Trail appeared to be conducive for infiltration features. A determination of drainage area that could be delivered to these features would be needed. However, based on grades it appears that there is potential to pick up a decent amount of drainage area from the west. The park area identified for infiltration features appeared to be getting minimal use, but the City would need to determine if this area could be repurposed.
- The existing pond located in the northwest corner of the watershed receives all upstream drainage before discharging west to the lake. There are several options that could be explored for this pond, including expanding the pond to the east and/or incorporating an additional wetland treatment cell upstream of the pond along the existing drainage ditch. Wetland impacts would need to be assessed for the addition of the wetland treatment cell. At a minimum, an assessment of maintenance needs should be done by the owner with removal of accumulated sediment as needed.

Figure 40. BMP retrofit opportunities in Lower Prior Lake subwatersheds S9 and S11

7.6 Undertreated Subwatershed S18

7.6.1 Phosphorus Reduction Benefits

There are 8 locations for rain gardens (150 sq. ft. each) identified in this subwatershed (Figure 41). The target number of rain gardens for this subwatershed based on a cost-benefit analysis is three rain gardens. The priority locations of these rain gardens are highlighted in blue in Figure 41. However, some drainage from the subwatershed will likely be missed by only implementing these 3 rain gardens. These BMPs remove an estimated 0.7 lb TP per year from the load to Lower Prior Lake.

7.6.2 P8 Modeling Assumptions

- The average depth of the existing pond area was assumed to be 4 feet deep based on NURP design standards. No surveying was conducted to determine actual pond depths.
- Rain gardens were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
    - 50% of the watershed draining to the rain gardens

7.6.3 General Subwatershed Observations

- Rain gardens could be scattered in this small watershed to provide added infiltration and water quality treatment.
- Runoff is currently routed to an existing wetland area. This wetland was very green from algae during the site visit.

Figure 41. BMP retrofit opportunities in Lower Prior Lake subwatershed S18

7.7 Direct Drainage Subwatersheds 1 and 2

7.7.1 Phosphorus Reduction Benefits

There are 30 locations for rain gardens (29 at 150 sq. ft. each; 1 at 300 sq. ft.) identified in these subwatersheds (Figure 42). The target number of rain gardens for these subwatersheds based on a cost-benefit analysis is 7 rain gardens in SW-1 and 5 rain gardens in SW-2. Priority locations for these rain gardens are highlighted in blue in Figure 42 to catch most of the subwatershed drainage. These BMPs remove an estimated 3.7 lb TP per year from the load to Lower Prior Lake.

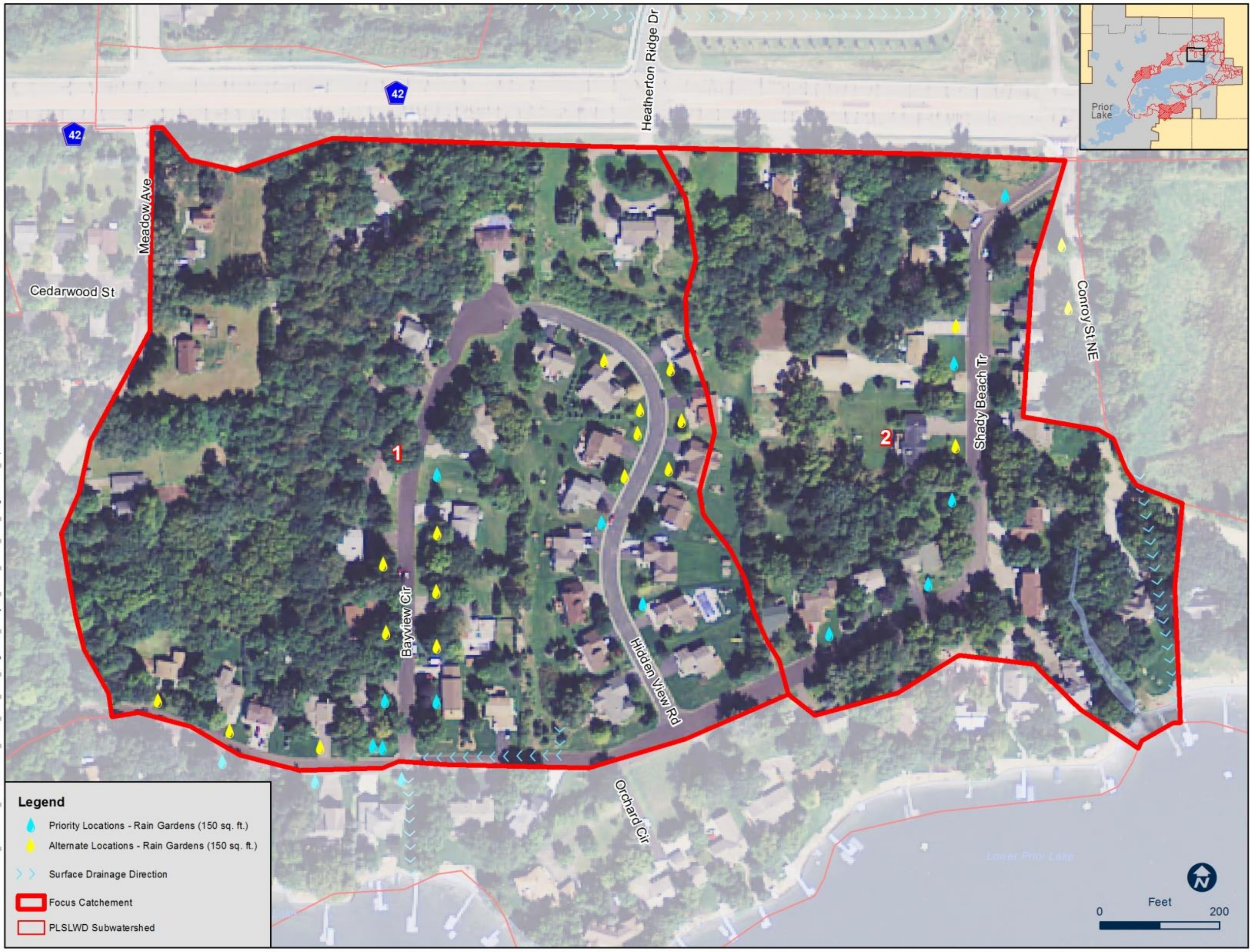
7.7.2 P8 Modeling Assumptions

- Existing ponds were modeled to account for some phosphorus reduction benefits from regular maintenance by the City to remove sediment in-fill. Existing average pond depths were estimated to be 3 feet deep, with sediment removal to 4 feet depth based on NURP design standards. No surveying was conducted to determine actual pond depths.
- Rain gardens were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
    - 80% of the SW-1 watershed draining to the SW-1 rain gardens
    - 60% of the SW-2 watershed draining to the SW-2 rain gardens

7.7.3 General Subwatershed Observations

- Subwatersheds 1 and 2 appear to be good candidates for neighborhood rain garden retrofits. Based on a quick walk through, numerous sites that appeared to be a good fit for rain gardens were identified. This should not be interpreted to mean that other lots could not be utilized for rain gardens should landowners be interested.
- The existing treatment pond was quite small and only treated Hidden View road. Options for improvements were limited based on space constraints.
- A potential redevelopment opportunity in these subwatersheds is to convert to curbless streets.

Figure 42. BMP retrofit opportunities in Lower Prior Lake subwatersheds 1 and 2



7.8 Direct Drainage Subwatershed 4

7.8.1 Phosphorus Reduction Benefits

There are 7 locations for rain gardens (5 at 150 sq. ft. each; 2 at 300 sq. ft. each) identified in this subwatershed (Figure 43). The target number of rain gardens for this subwatershed based on a cost-benefit analysis is 5 rain gardens. Priority locations for these rain gardens are highlighted in blue in Figure 43. Implementation of rain gardens should begin with the 300 sq. ft. rain garden at the end of Harborview Circle NE. The other 300 sq. ft. rain garden along Harbor Place NE requires a retaining wall and is not priority. Site conditions are similar for all other rain gardens and should be implemented with an even distribution. These BMPs remove an estimated 2.3 lb TP per year from the load to Lower Prior Lake.

7.8.2 P8 Modeling Assumptions

- Rain gardens were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
    - 40% of the watershed draining to the rain gardens

7.8.3 General Subwatershed Observations

- Several opportunities for rain gardens exist in this townhome development. Based on a quick walk through, sites that appeared to be best fit for rain gardens were identified. This should not be interpreted to mean that other lots could not be utilized for rain gardens should landowners be interested. Additional areas in back or side yards could likely be considered for rooftop disconnection.

Figure 43. BMP retrofit opportunities in Lower Prior Lake subwatershed 4

7.9 Direct Drainage Subwatershed 5

7.9.1 Phosphorus Reduction Benefits

There are 3 locations for rain gardens (150 sq. ft. each) identified in this subwatershed (Figure 44). The target number of rain gardens for this subwatershed based on a cost-benefit analysis is 1 rain garden. These BMPs remove an estimated 0.9 lb TP per year from the load to Lower Prior Lake.

7.9.2 P8 Modeling Assumptions

- Rain gardens were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
  - 30% of the watershed draining to the rain gardens

7.9.3 General Subwatershed Observations

- A few opportunities for rain gardens exist along Rutgers Street NE. Based on a quick walk through, sites that appeared to be best fit for rain gardens were identified. This should not be interpreted to mean that other lots could not be utilized for rain gardens should landowners be interested.

Figure 44. BMP retrofit opportunities in Lower Prior Lake subwatershed 5

7.10 Direct Drainage Subwatershed 6

7.10.1 Phosphorus Reduction Benefits

There are 2 locations for rain gardens (150 sq. ft. each) identified in this subwatershed (Figure 45). Site conditions are similar for both rain gardens. These BMPs remove an estimated 0.5 lb TP per year from the load to Lower Prior Lake.

7.10.2 P8 Modeling Assumptions

- Rain gardens were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
    - 10% of the watershed draining to the rain gardens

7.10.3 General Subwatershed Observations

- Limited opportunities exist for rain gardens. Based on a quick walk through, sites that appeared to be best fit for rain gardens were identified. This should not be interpreted to mean that other lots could not be utilized for rain gardens should landowners be interested.

Figure 45. BMP retrofit opportunities in Lower Prior Lake subwatershed 6

7.11 Direct Drainage Subwatershed 8

7.11.1 Phosphorus Reduction Benefits

There are 19 locations for rain gardens (150 sq. ft. each) identified in this subwatershed (Figure 46). The target number of rain gardens for this subwatershed based on a cost-benefit analysis is 8 rain gardens. These BMPs remove an estimated 5.4 lb TP per year from the load to Lower Prior Lake.

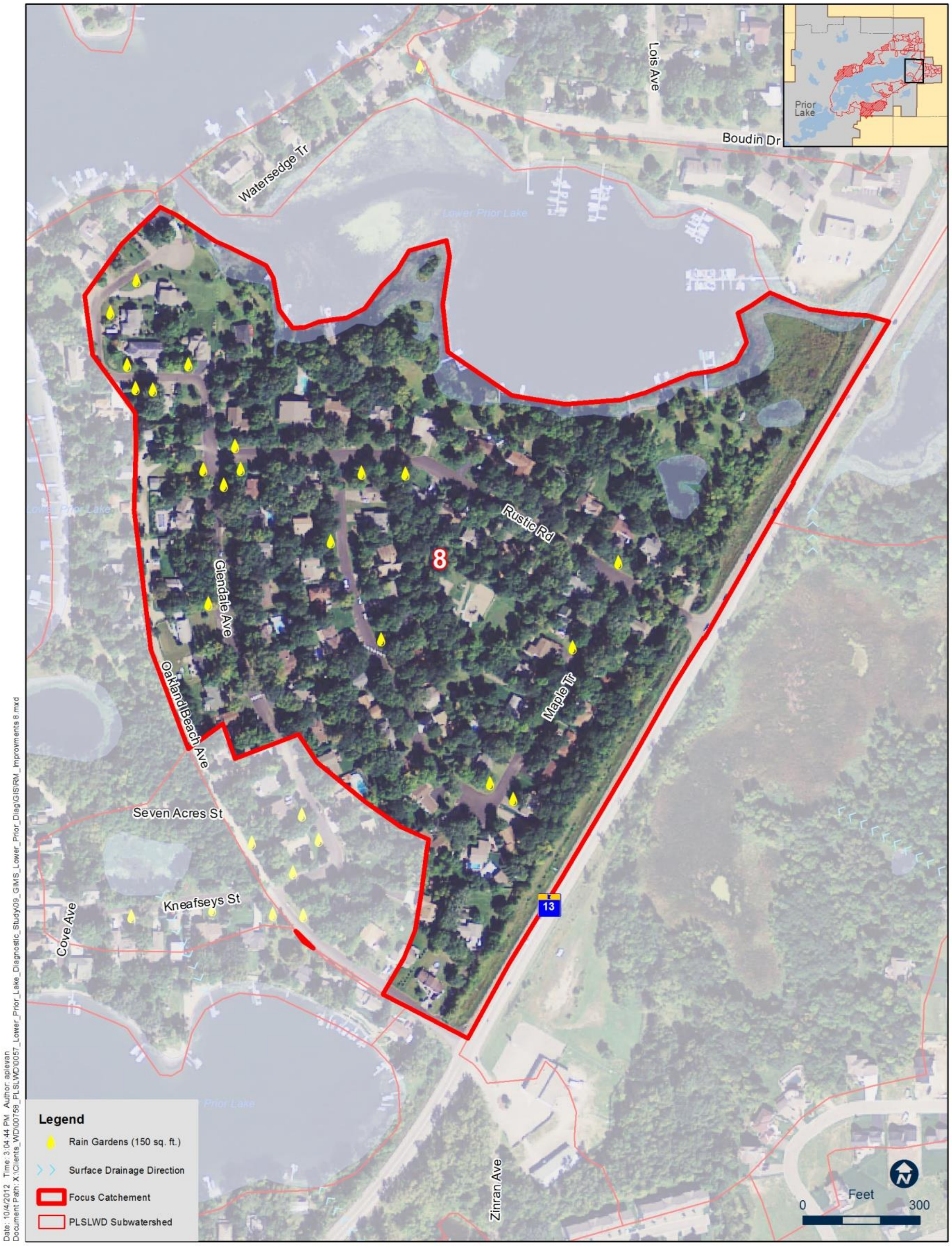
7.11.2 P8 Modeling Assumptions

- Rain gardens were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
    - 50% of the watershed draining to the rain gardens

7.11.3 General Subwatershed Observations

- Numerous opportunities exist for rain gardens throughout the watershed. Based on a quick walk through, sites that appeared to be best fit for rain gardens were identified. This should not be interpreted to mean that other lots could not be utilized for rain gardens should landowners be interested.

Figure 46. BMP retrofit opportunities in Lower Prior Lake subwatershed 8



7.12 Direct Drainage Subwatershed 10

7.12.1 Phosphorus Reduction Benefits

One retrofit BMP opportunity was identified in the direct drainage subwatershed 10 (Figure 47):

1. Construction of ditch checks (12 total) along both sides of County 13 between 150th St. S.E. and Oakland Beach Ave. S.E.

These BMPs remove an estimated 10.1 lb TP per year from the load to Lower Prior Lake.

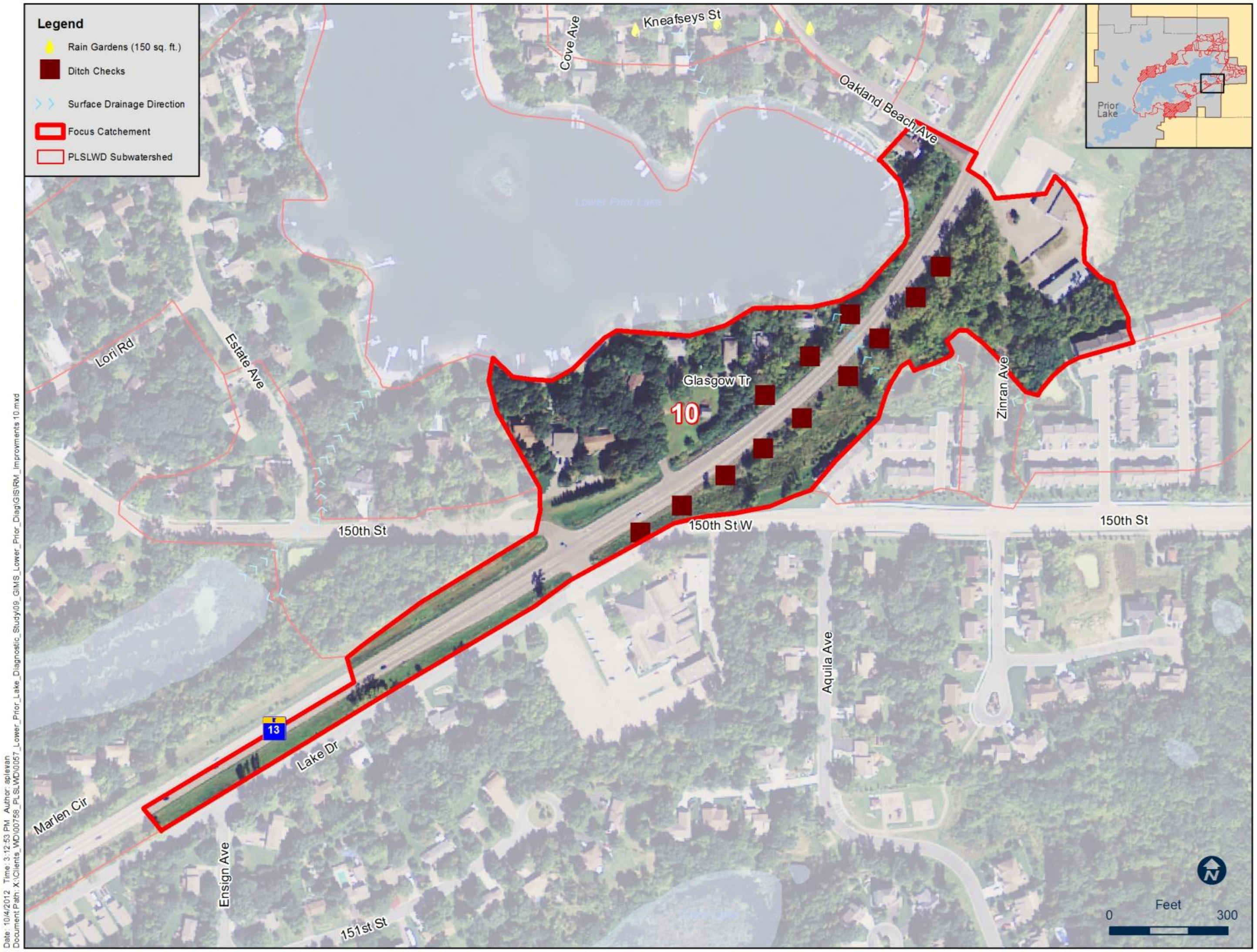
7.12.2 P8 Modeling Assumptions

- Ditch checks were designed with two feet of ponding depth and a total ponding area of 19,341 sq. ft.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
    - 80% of the watershed draining to the ditch checks

7.12.3 General Subwatershed Observations

- Stormwater runoff from Highway 13 and adjacent drainage areas flow to road side ditches that flow parallel to Highway 13 and eventually discharge into Prior Lake. Ditch checks could potentially be installed along these drainage ways to store water and provide sedimentation and water quality treatment prior to discharge to Prior Lake. Coordination with the road authority would be required.

Figure 47. BMP retrofit opportunities in Lower Prior Lake subwatershed 10



7.13 Direct Drainage Subwatershed 11

7.13.1 Phosphorus Reduction Benefits

There are 4 locations for rain gardens (150 sq. ft. each) identified in this subwatershed (Figure 48). Site conditions are similar for all rain gardens and should be implemented with an even distribution throughout the subwatershed. These BMPs remove an estimated 1.5 lb TP per year from the load to Lower Prior Lake.

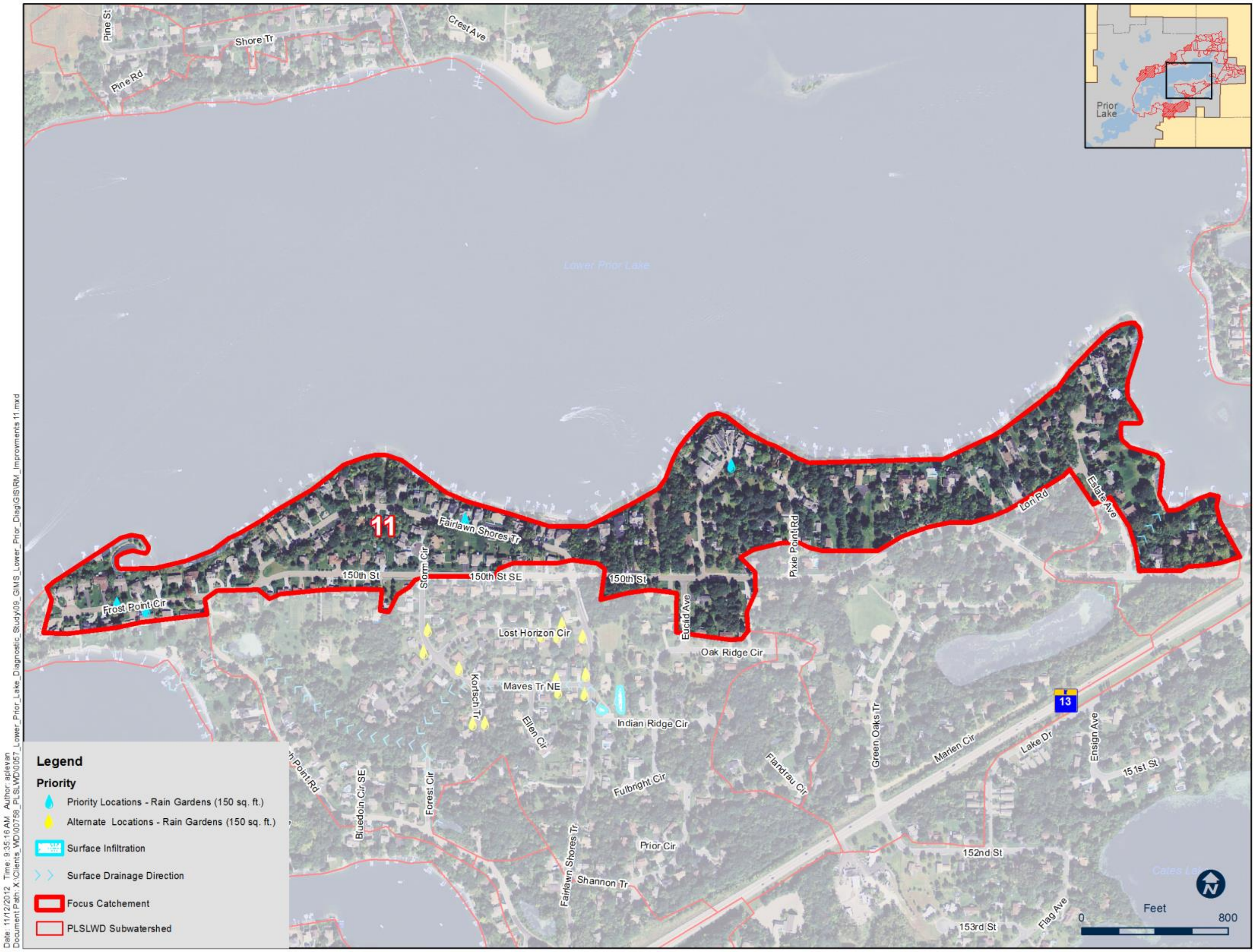
7.13.2 P8 Modeling Assumptions

- Rain gardens were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
    - 15% of the watershed draining to the rain gardens

7.13.3 General Subwatershed Observations

- Limited opportunities exist for rain gardens. Based on a quick walk through, sites that appeared to be best fit for rain gardens were identified. This should not be interpreted to mean that other lots could not be utilized for rain gardens should landowners be interested.

Figure 48. BMP retrofit opportunities in Lower Prior Lake subwatershed 11



7.14 Direct Drainage Subwatershed 13

7.14.1 Phosphorus Reduction Benefits

One retrofit BMP opportunity was identified in the direct drainage subwatershed 13 (Figure 49):

1. Infiltration area at Manor Dr. and Candy Cove Tr. (2,500 sq. ft.)

In addition, there is one ideal location for a rain garden (150 sq. ft.) identified in this subwatershed. These BMPs remove an estimated 2.3 lb TP per year from the load to Lower Prior Lake.

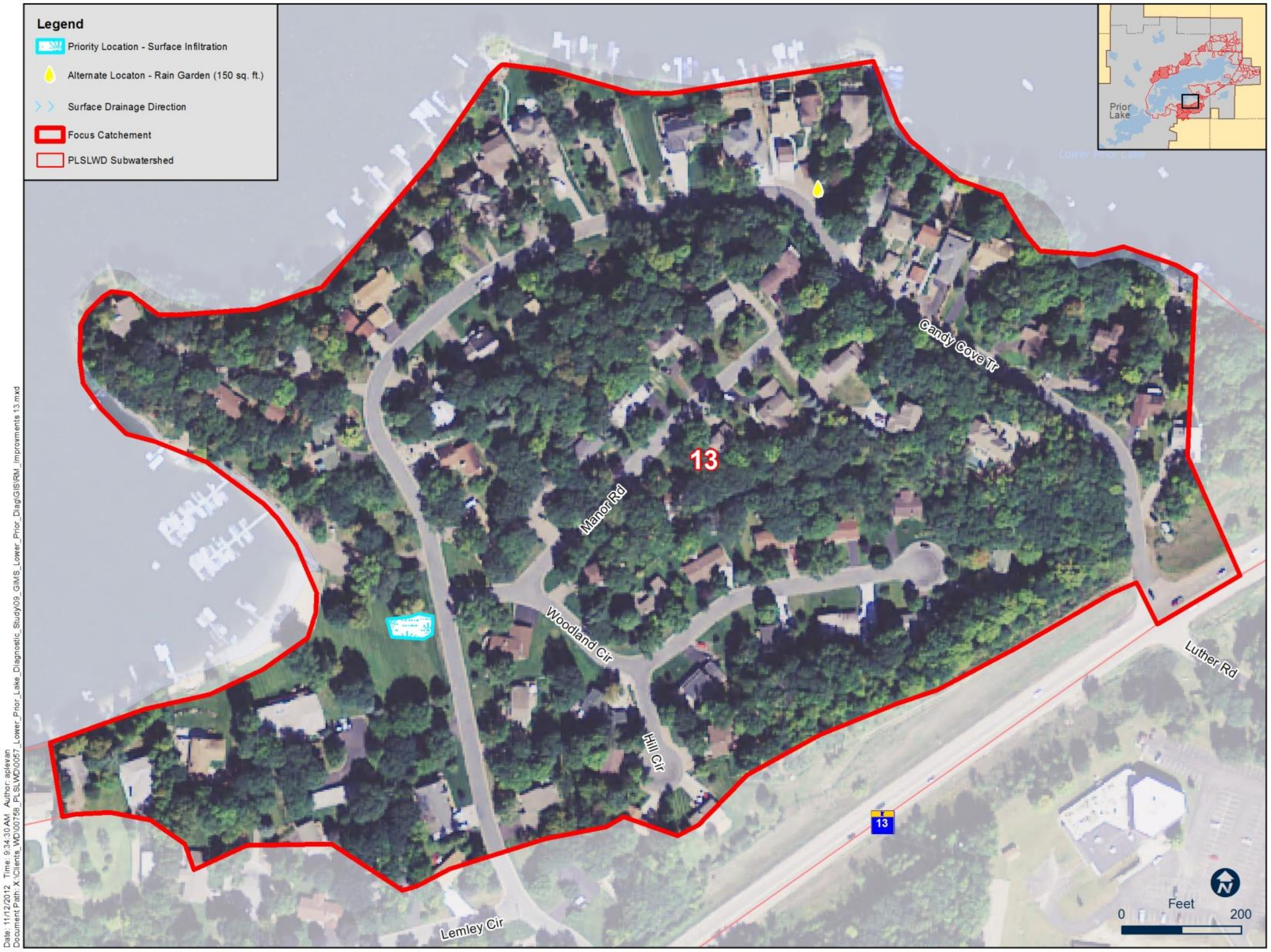
7.14.2 P8 Modeling Assumptions

- Rain gardens and infiltration areas were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
    - 40% of the watershed draining to the rain garden and large infiltration area

7.14.3 General Subwatershed Observations

- Limited opportunities were identified for rain gardens within the watershed. However, it appeared that a larger infiltration basin could potentially be constructed in the open space located near the intersection of Candy Cove Trail SE and Manor Road SE. A determination of the existing land use and ownership would first need to be determined, along with an assessment of the infrastructure improvements that would be required to route water to this location.

Figure 49. BMP retrofit opportunities in Lower Prior Lake subwatershed 13



7.15 Direct Drainage Subwatershed 14

7.15.1 Phosphorus Reduction Benefits

There are 26 locations for rain gardens (22 at 150 sq. ft. each; 4 at 300 sq. ft. each) identified in this subwatershed (Figure 50). Based on drainage patterns and even distribution, implementation of rain gardens should begin with the rain gardens highlighted in blue in Figure 50, followed by the rain gardens highlighted in yellow, then red. These BMPs remove an estimated 7.0 lb TP per year from the load to Lower Prior Lake.

7.15.2 P8 Modeling Assumptions

- Rain gardens were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
    - 35% of the watershed draining to the rain gardens

7.15.3 General Subwatershed Observations

- Numerous opportunities exist for rain gardens throughout the watershed. Based on a quick walk through, sites that appeared to be best fit for rain gardens were identified. This should not be interpreted to mean that other lots could not be utilized for rain gardens should landowners be interested.

Figure 50. BMP retrofit opportunities in Lower Prior Lake subwatershed 14

7.16 Direct Drainage Subwatershed 18

7.16.1 Phosphorus Reduction Benefits

There are 6 locations for rain gardens (5 at 150 sq. ft. each; 1 at 300 sq. ft. each) identified in this subwatershed (Figure 51). Implementation of rain gardens in this subwatershed should begin with the 300 sq. ft. rain garden located near the southern end of Calmut Avenue. Site conditions are similar for all other rain gardens. These BMPs remove an estimated 2.3 lb TP per year from the load to Lower Prior Lake.

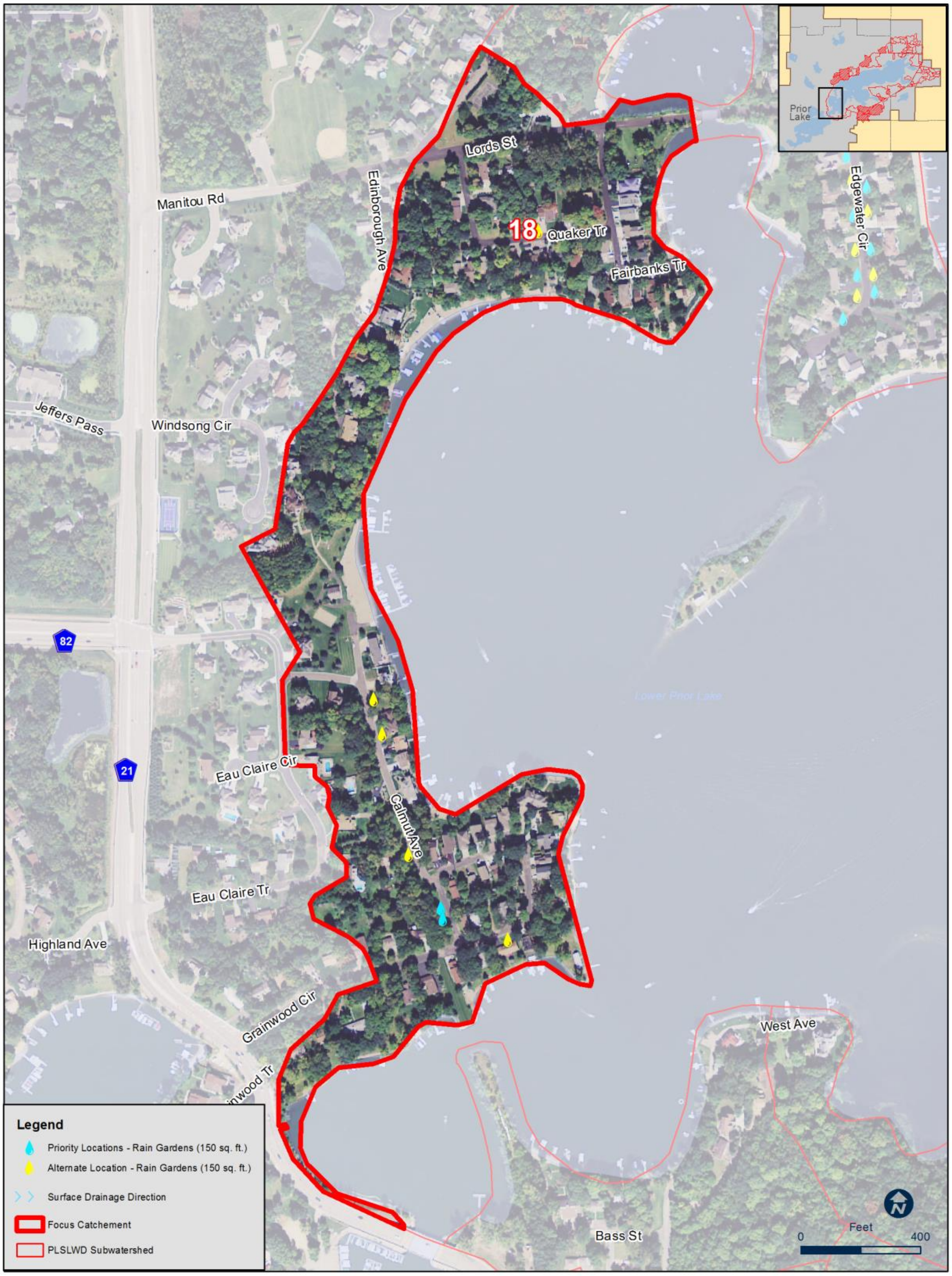
7.16.2 P8 Modeling Assumptions

- Rain gardens were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
    - 25% of the watershed draining to the rain gardens

7.16.3 General Subwatershed Observations

- A few scattered opportunities for rain gardens exist within the watershed. Based on a quick walk through, sites that appeared to be best fit for rain gardens were identified. Many of the sites were limited by street grades and/or limited space.

Figure 51. BMP retrofit opportunities in Lower Prior Lake subwatershed 18



Date: 11/12/2012 Time: 9:32:16 AM Author: aplevan
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7.17 Direct Drainage Subwatershed 19

7.17.1 Phosphorus Reduction Benefits

There are 21 locations for rain gardens (150 sq. ft. each) identified in this subwatershed (Figure 52). Site conditions are similar for all rain gardens and should be implemented with an even distribution throughout the subwatershed. An example of this rain garden spacing is shown in blue in Figure 52. These BMPs remove an estimated 3.2 lb TP per year from the load to Lower Prior Lake.

7.17.2 P8 Modeling Assumptions

- Rain gardens were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
    - 50% of the watershed draining to the rain gardens

7.17.3 General Subwatershed Observations

- Numerous opportunities for rain gardens exist throughout the watershed. This subwatershed would be suited for a neighborhood rain garden project, particularly along Edgewater Circle. Based on a quick walk through, sites that appeared to be best fit for rain gardens were identified. This should not be interpreted to mean that other lots could not be utilized for rain gardens should landowners be interested.

Figure 52. BMP retrofit opportunities in Lower Prior Lake subwatershed 19

7.18 Direct Drainage Subwatershed 23

7.18.1 Phosphorus Reduction Benefits

There are 3 locations for rain gardens (150 sq. ft. each) identified in this subwatershed (Figure 53). Site conditions are similar for all rain gardens. These BMPs remove an estimated 0.6 lb TP per year from the load to Lower Prior Lake.

7.18.2 P8 Modeling Assumptions

- Rain gardens were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
    - 5% of the watershed draining to the rain gardens

7.18.3 General Subwatershed Observations

- Some opportunities for rain gardens exist along Shady Beach Trail NE. Based on a quick walk through, sites that appeared to be best fit for rain gardens were identified. This should not be interpreted to mean that other lots could not be utilized for rain gardens should landowners be interested.

Figure 53. BMP retrofit opportunities in Lower Prior Lake subwatershed 23

7.19 Direct Drainage Subwatershed 25

7.19.1 Phosphorus Reduction Benefits

There are 63 locations for rain gardens (59 at 150 sq. ft. each; 4 at 300 sq. ft. each) identified in this subwatershed (Figure 54). The target number of rain gardens for this subwatershed based on a cost-benefit analysis is 28 rain gardens. Priority locations for these rain gardens are highlighted in blue, yellow, and red in Figure 54, in order of decreasing priority. The priority rain gardens are larger rain gardens located in the park. The locations of the first tier of alternate rain gardens were chosen based on an even distribution throughout the subwatershed. The second tier of alternate rain gardens was also chosen based on an even distribution throughout the subwatershed, however these rain gardens require retaining walls. Any rain gardens implemented beyond those 28 should be evenly distributed throughout the subwatershed. These BMPs remove an estimated 16.4 lb TP per year from the load to Lower Prior Lake.

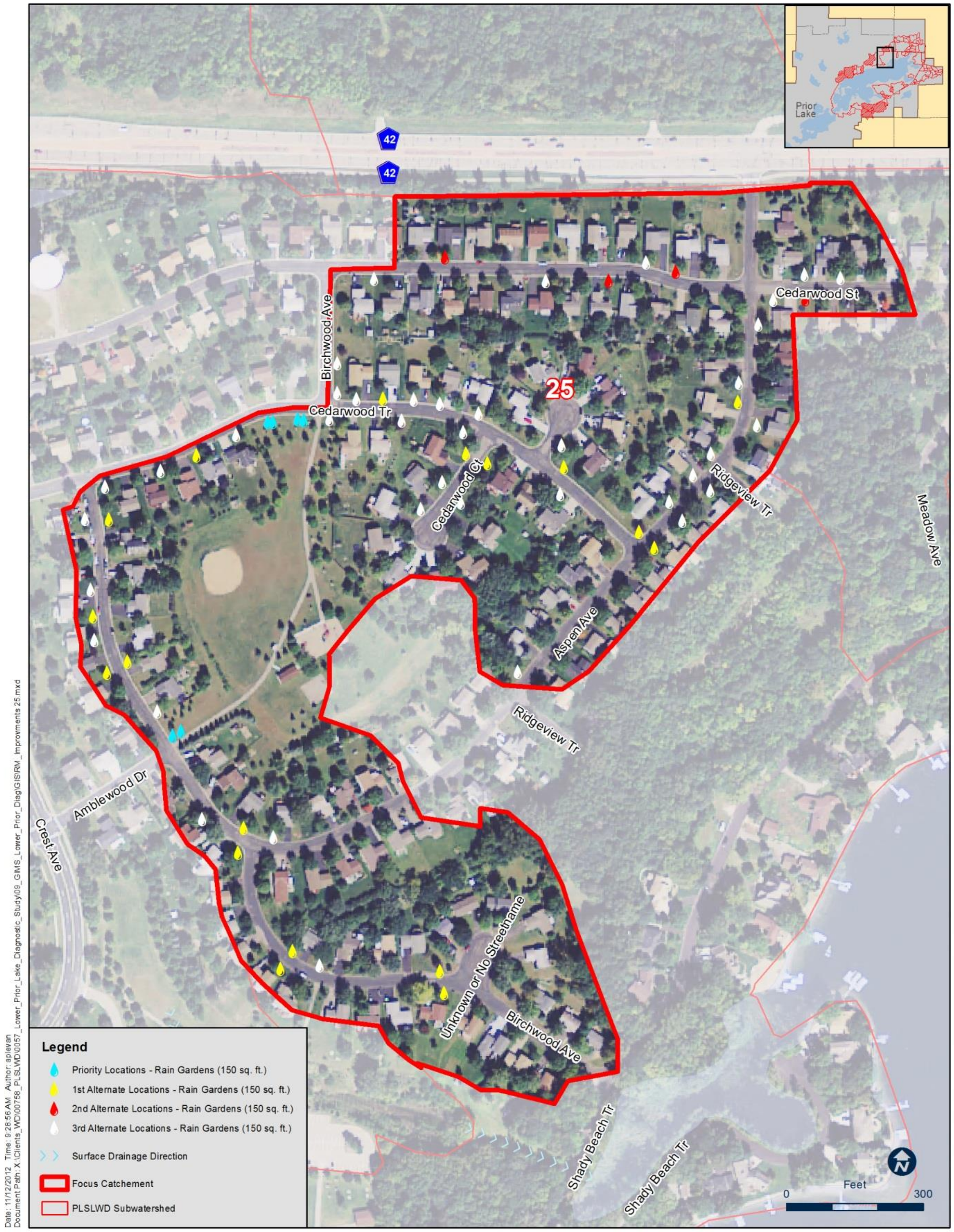
7.19.2 P8 Modeling Assumptions

- Rain gardens were designed with one foot of ponding depth, two feet of amended soil with 30% voids (modeled as an average depth of 1.6 feet, 100% voids, and an infiltration rate of 0.3 in/hr), and the surface areas specified in the preceding section.
- Curve number was estimated as 69 based on soil and parcel size.
- Connections between features were modeled as weirs with overland flow.
- Contributing watershed loads to each feature were modified based on site topography, with:
    - 75% of the watershed draining to the rain gardens

7.19.3 General Subwatershed Observations

- Numerous opportunities for rain gardens exist throughout the watershed. Based on a quick walk through, sites that appeared to be best fit for rain gardens were identified. This should not be interpreted to mean that other lots could not be utilized for rain gardens should landowners be interested. The sites along Cedarwood Street would likely need retaining walls due to the grade of the yards. Rain gardens located in the park could be increased in size depending on the amount of drainage area that could be routed to them.

Figure 54. BMP retrofit opportunities in Lower Prior Lake subwatershed 25



8 APPENDIX E: RAINGARDEN SITING METHODOLOGY

The following describes the stormwater BMP retrofitting process as it pertains to the directly-connected areas not studied by EOR, Inc., surrounding Lower Prior Lake. It does describe that work conducted by EOR, Inc. for those areas with existing stormwater pond treatment. In as such, this is not an exhaustive list of tasks associated with a complete subwatershed assessment for retrofitting stormwater BMPs. For an exhaustive process, please refer to *Manual 3: Urban Stormwater Retrofit Practices Manual* of the Center for Watershed Protection's Urban Subwatershed Manual Series.

8.1 Step 1 – Delineation and definition of pipesheds

8.1.1 Purpose

Define logical drainage areas of interest to investigate for retrofitting potential. In some case, it may make sense to merge pipesheds so as to make modeling more efficient (i.e, when the land cover is relatively homogeneous, there is no existing treatment and it appears that there will be a mostly uniform approach (selection of BMP type) to retrofitting).

8.1.2 Process

1. Define surface drainage using LIDAR data (*see* Nat Kale's notes).
2. Use stormwater inlet and outfall GIS data to modify delineations into pipesheds (*see* Nat Kale's notes).
3. Proof and edit automated delineation process via manual manipulation of vertices where appropriate.
    a. Depending on how detailed the modeling is going to be, one could choose to define pipesheds including the backyard areas not draining to the street inlets or to delineate a fully separate "donut" catchment area surrounding the lake.
    b. It will be likely that vertices will need to be moved relative to impervious cover drainage behavior. Roof tops in the front of homes typically drain to the street and as long as the side and backyards are not connected to the inlet/outlet system the front of the house does, those areas should be considered as a different catchment area.
4. Classify soils GIS data into hydrologic groups A, B, C, D
5. Define land cover constituents
    a. For the Lower Prior study, the 2006 Met Council raster layer for impervious cover was used to generate impervious surface acreages for each pipeshed. The finished pipesheds were used to clip a shapefile of the Met Council raster data and the Field Calculator was used to calculate acres of impervious cover.
    b. For future studies I recommend either one of the following two scenarios
        i. PLSLWD-generated impervious cover (*see* Nat Kale's notes) can be clipped using the finished catchment (or pipeshed) polygons and resulting total acres of impervious can be generated.
        ii. Each catchment's land use can be defined using WinSLAMM land use codes and the resulting impervious amounts can be looked up in their definitions. The WinSLAMM Standard Land Use files were created by

digitizing all land cover types in several cities in Wisconsin then filed verified. Each land cover (or "source area") was broken up into various hydrologic response types such as indirectly-connected. Directly connected, surface roughness (in the case of streets), etc. for a refined description of impervious and impervious makeup in average conditions for 26 land uses. Depending on which water quality model one selects (Steps 2 and 6), simply adopting WinSLAMM codes or pulling information from its standard land use files may be appropriate.

8.2 Step 2 – Water quality base model (existing conditions)

8.2.1 Purpose

Estimate existing pollutant loading to the receiving water body from each defined catchment.

8.2.2 Process

1. For the Lower Prior Lake Diagnostic study, EOR's P8 model for the Treated Areas was adopted to build new models for the directly-connected areas (those areas with no water quality treatment located between upland and receiving water body).
    a. Particle, water quality, ET/Snowmelt, temperature and precipitation files for all preserved as well as all settings associated with them, both systemic and watershed or device specific.
    b. New watersheds ("pipesheds" or "catchments" as described above) were created by entering the calculated acreages.
    c. The pervious areas CN of 69 was kept constant between watersheds, as was done in the EOR model.
    d. Depressional storage was kept constant, as well, at 0.02 regardless of topographical or surface pitting variability.
    e. If an open water body was present within the watershed (pipeshed), it was accounted for under "Vacuum Swept Directly-Connected Impervious" as the fraction (expressed as a coefficient) of its areal acreage within the watershed. This process was utilized by EOR and is described in their description of process.
    f. As per EOR's process, impervious cover was not broken into Indirect and Direct fractions (in this context, "directly" and "indirectly connected" does NOT refer to an area's relationship to the receiving water body. It refers to whether the impervious area drains directly to the stormwater conveyance system or if it first runs across a pervious area).
    g. The representative water year of 10/1/1958 – 9/30/1959 was kept consistent with EOR with 1 pass through starting at 6/1/1958 to "warm up" the model (build more accurate pond sediment, chemical and hydrologic conditions prior to the first recorded storm event during the water year).

   h. Similarly, EOR's settings for rainfall breakpoint (0.8), time steps per hour (*n*=12), minimum inter-event time (10), max. continuity error (2%), air temp offset (0) and precipitation scale factor (1) were retained.

2. For future studies,
   a. I would recommend using the PLSLWD-generated impervious cover data in conjunction with WinSLAMM Standard Land Use file source area definitions to generate impervious area values. If WinSLAMM is used, this would involve sub-sampling a few representative land use areas in the District and developing some standard rations of direct and indirect areas. If P8 is used, one can reference the P8 help file (while in the Watershed screen) to look up appropriate settings for indirect and direct impervious areas based on WinSLAMM land use classifications.
   b. I would analyze PLSLWD rainfall data to identify "dry," "average" and "wet" year representative water years (10/1 – 9/31) and generate a custom rainfall data set for each (see P8 help file on this process under the General screen). Using a representative year is much faster when running iterations or Design Tune. Having Dry, Avg, and Wet year info is also very handy when investigating watershed behavior or when dealing with permits or cost share design considerations based on what event you're holding applicant accountable for. It is sometimes easiest to simply run the entire extent of the rainfall data record and read results from the Annual columns in P8 reports. P8 generates annual results by running the extent of the precipitation record (by leaving start, keep and finish values blank in the General screen) then divides to total sum of the loading for that period by the number of years within the precipitation data set to get the average 9considered the "average" year). This is one way to generate the "average" year and is, perhaps, the most accurate. Another way is to compare the resulting rainfall inches of this average model to that of the PLSLWD record for annual precipitation and select that particular sub-set year for the average year, as it will run faster than the complete record.

8.3 Step 3 – Desktop review for retrofitting indicators

8.3.1 Purpose

Investigate remote indicators of areas conducive to, or restrictive of, stormwater BMP retrofits. This process potentially eliminates some catchments (pipesheds) from further review, thereby initiating the retrofit selection process.

8.3.2 Process

1. For the PLSWLD portion of work in the Lower Prior Diagnostic study, we were only investigating areas without existing stormwater quality infrastructure (i.e., those areas with no treatment; directly-connected to the lake via either surface flow or via storm sewer pipes).

2. Typically, the investigator follows the following procedures, as mostly was done for the PLSWD area with the exception of investigating modification of existing storm water ponds, as none occurred in our study area. The investigator uses GIS and aerial imagery to look for the following opportunities, each of which is conducive to a certain suite of BMP's to retrofit (guidance on what to look for, within each of the following areas in terms of where retrofits are possible and not recommended, as well as which particular BMP's are appropriate for each area, see the CWP Manual 3; such a list is provided under Step 4 as well):
    a. Existing ponds
    b. Above roadway culverts
    c. Below outfalls
    d. Within conveyance systems
    e. Within right of way
    f. Large parking lots
    g. Public lands
3. In this study, several pipesheds were eliminated from further review given that they
    a. Showed no indicators (a-g, above) of areas conducive to retrofitting, and/or
    b. Had too limited of a spatial capacity to accommodate retrofits, and/or
    c. Had hydrologic or geologic limiting factors that would drive the cost of retrofitting too high while reducing performance of the BMPs
4. Each of the remaining pipesheds is then slated for the review of the above areas as well as keeping an eye open for all possibilities (see Step 4) as there is high likelihood opportunities will arise that were missed via the rapid, remote method.

8.4 Step 4 – Field retrofit recon

8.4.1 Purpose

Visit catchments/pipesheds not eliminated in Step 3 for parcel-level review of applicability for various BMP's and to record site variables that may influence the cost and performance of recommended practices.

8.4.2 Process

1. As mentioned earlier, there were no existing water quality or rate control stormwater features to visit within the PLSLWD study area. Had there been, the very first place to look for the lowest-hanging fruit are such facilities. All existing ponds and wetlands should be investigated for the following potential retrofits, in order of preference
    a. Raise or hydraulically modify the outlet structure to increase storage volume and/or ponding time (especially advantageous in ponds that allow infiltration)
    b. Add a filter bench (e.g., iron-enhanced sand filter) as the primary outlet
    c. Over-excavate bottom of pond to a point greater than 6-ft (shallower ponds are subject to re-scour and decreased WQ performance)

   d. Modification of inlet/outlet layout (if inlet is directly in-line with outlet, decreased performance results via short-circuiting)
   e. Modify the shape of the pond to optimize length to width ratio (see Manual 3 for guidance), and/or add more square footage to the existing cell
   f. Add a sediment forebay to the structure
   g. Add multiple cells (2 or more treatment cells) to the system
   h. Meander the flow path to lengthen ponding duration and to optimize particle to plant contact time
2. As there were no stormwater ponds to analyze, the PLSLWD analysis started by first investigating the potential for new regional servicing systems that could treat more than 5 acres of runoff area
   a. Extended Detention Ponds
   b. Dry Ponds and neighborhood scale bioretention basins
   c. New wetlands
   d. Filter beds and recreational field modification to handle runoff
   e. Modification of conveyance swales to water quality swales
3. Next, sites were investigated for placement of smaller-scaled BMPs, treating areas under 5 acres, typically from the following families of practices (with various sub-designs dependent on site and treatment area)
   a. Curbline disconnects to natural open space areas not sensitive to stormwater runoff
   b. Bioretention
   c. Filtration
   d. Infiltration
   e. Swales
   f. Permeable surfaces
   g. Water harvesting, reuse, evaporation
4. The optimal sites for the placement of specific BMPs are recorded considering site limitations of variables that may affect design and performance. Every optimal site is recorded so that should one site owner not agree to the placement of a stormwater BMP on their property, the next best location can be determined for canvassing efforts.
   a. Optimal sites were defined as those occurring immediately above catch basins provided:
      i. The drainage area leading to the site was a minimum of 5 properties in total
      ii. There was no catch basin within 5 properties uphill of the site
      iii. The site required either no retaining walls or only partial walls
      iv. The proximity of the BMP was such that allows for a sub-surface drain tile to be core drilled and fitted into the catch basin structure so that a draw down option is provided as insurance

v. The site had no physically-limiting conditions that would drive up costs beyond reason or drive down performance

b. In addition, optimal sites also were identified that were not immediately proximal to catch basins but still
   i. Had sufficient drainage areas to service and
   ii. Had no physical site-limiting constraints on the design in terms of cost or performance

8.5 Step 5 – Mapping ideal locations

8.5.1 Purpose

Effectively visually communicate the ideal possible locations of the various BMP retrofits recommended by the study.

8.5.2 Process

1. Select a unique symbol for each BMP family type (*see* list in Step 4)
2. Each sub-family design gets a color code that also should reflect the preferred, or best professional judgment on performance value, options. In this study, that meant the following:
   a. For facilities that fell under Bioretention, we used a Diamond shape for street-side, right of way curb-cut raingardens that will rely primarily on infiltration as their principle mechanism for pollutant removal. Other designs might have included fully filtering or both filtering and infiltrating, which did occur in this study. In as such, the sub-family became a question of whether the cell would require a retaining wall or could be connected to a catch basin structure via an underdrain. The Curb-Cut Bioretention types found in this study, in order of preference, were as follows and ranged from the highest priority being green to the lowest, optimal locations for such BMP's being red:
      i. Type A – Those connected via underdrain to catch basins and with no walls
      ii. Type B – Those connected via underdrain to catch basins and with partial walls
      iii. Type C – Those not connected to catch basins and with no walls
      iv. Type D – Those not connected to catch basins and with partial walls
   b. For areas conducive to slight modification of conveyance swales, we used a cross symbol signifying theoretical placement of check dams. The idea for these sites is that the placement of check dams will slow water enough to temporarily pond a first flush sized event in a newly-graded infiltration/filtration bed. The grades should be step-down in nature with the dams acting as level spreaders or notched weirs. The final design of such structures will need signoff from a certified engineer for the areas identified in this study, but should be straight forward.