Schmidt, Pomerleau and Bass Lakes Nutrient TMDL

Wenck

Prepared for

Shingle Creek Watershed Management Commission

Minnesota Pollution Control Agency

July 2009

Schmidt, Pomerleau and Bass Lakes Nutrient TMDL

Wenck File #1240-22

Prepared for:

SHINGLE CREEK WATERSHED MANAGEMENT COMMISSION

MINNESOTA POLLUTION CONTROL AGENCY

Prepared by:

WENCK ASSOCIATES, INC.
1800 Pioneer Creek Center
P.O. Box 249
Maple Plain, Minnesota 55359-0249
(763) 479-4200

July 2009

Table of Contents

1.0 INTRODUCTION 1-1
1.1 Purpose 1-1
1.2 Problem Identification 1-1

2.0 TARGET IDENTIFICATION AND DETERMINATION OF ENDPOINTS 2-1
2.1 Impaired Waters 2-1
2.2 Minnesota Water Quality Standards and Endpoints 2-1
2.2.1 State of Minnesota Standards 2-1
2.2.2 End Points Used in this TMDL 2-2
2.3 Pre-settlement Conditions 2-2

3.0 WATERSHED AND LAKE CHARACTERIZATION 3-1
3.1 Lake and Watershed Description 3-1
3.2 Recreational Uses 3-6
3.2.1 Parks and Open Space 3-6
3.2.2 Other Recreation 3-6
3.3 Water Condition 3-6
3.3.1 Historic Water Quality 3-6
3.4 Fish Populations and Fish Health 3-8
3.4.1 Fish Populations 3-8
3.4.2 Fish Kills 3-9
3.4.3 Carp and Rough Fish 3-13
3.5 Aquatic Plants 3-13
3.5.1 Introduction 3-13
3.5.2 Littoral Zone 3-13
3.5.3 Aquatic Plants in the Bass Lake Chain 3-13
3.6 Shoreline Habitat and Conditions 3-14

4.0 NUTRIENT SOURCE ASSESSMENT 4-1
4.1 Introduction 4-1
4.2 Permitted Sources 4-1
4.2.1 Wastewater 4-1
4.2.2 Stormwater 4-1
4.3 Non-permitted Sources 4-2
4.3.1 Atmospheric Deposition 4-2
4.3.2 Internal Phosphorus Release 4-2

5.0 ASSESSMENT OF WATER QUALITY DATA 5-1
5.1 Introduction 5-1
5.2 Previous Studies and Monitoring on Schmidt, Pomerleau and Bass Lakes 5-1

Table of Contents (Cont.)

5.2.1 Citizen Assisted Monitoring Program (CAMP) and Other Monitoring 5-1
5.2.2 City of Plymouth Management Plans 5-1
5.2.3 Other Management Plans 5-1
5.3 Monitoring Parameters 5-2
5.3.1 Temperature and Dissolved Oxygen 5-2
5.3.2 Phosphorus and Nitrogen 5-2
5.3.3 Chlorophyll-a and Secchi Depth 5-2
5.4 Lake Monitoring Results 5-2
5.4.1 Schmidt Lake 5-2
5.4.1.1 Historical Data 5-2
5.4.1.2 Temperature and Dissolved Oxygen 5-3
5.4.1.3 Phosphorus 5-3
5.4.1.4 Chlorophyll-a 5-5
5.4.2 Pomerleau Lake 5-6
5.4.2.1 Historical Data 5-6
5.4.2.2 Temperature and Dissolved Oxygen 5-6
5.4.2.3 Phosphorus 5-6
5.4.2.4 Chlorophyll-a 5-8
5.4.3 Bass Lake 5-9
5.4.3.1 Historical Data 5-9
5.4.3.2 Temperature and Dissolved Oxygen 5-9
5.4.3.3 Phosphorus 5-10
5.4.3.4 Chlorophyll-a 5-11
5.5 Conclusions 5-12

6.0 LINKING WATER QUALITY TARGETS AND SOURCES 6-1
6.1 Introduction 6-1
6.2 Selection of Models and tools 6-1
6.2.1 SWMM Modeling 6-2
6.2.2 P8 Modeling 6-2
6.3 Current Phosphorus Budget Components 6-2
6.3.1 Tributary or Watershed Load 6-2
6.3.2 Atmospheric Load 6-2
6.3.3 Internal Loads 6-3
6.3.3.1 Schmidt Lake Internal Loads 6-4
6.3.3.2 Pomerleau Lake Internal Loads 6-5
6.3.3.3 Bass Lake Internal Loads 6-5
6.3.4 Lake Exchange 6-5
6.4 Current Phosphorus Budget 6-6
6.5 Water Quality Response Modeling 6-6

Table of Contents (Cont.)

6.5.1 Fit of the Model ... 6-7
6.6 Conclusions ... 6-8
6.6.1 Schmidt Lake ... 6-8
6.6.2 Pomerleau Lake ... 6-8
6.6.3 Bass Lake ... 6-8

7.0 TMDL ALLOCATION ... 7-1
7.1 Load and Wasteload Allocations ... 7-1
7.1.1 Allocation Approach ... 7-1
7.1.2 Critical Condition ... 7-2
7.1.3 Allocations ... 7-2
7.2 Rationale for Load and Wasteload Allocations ... 7-3
7.2.1 Modeled Historic Loads ... 7-3
7.2.2 Water Quality Response to Load Reductions ... 7-5
7.2.3 Phosphorus ... 7-5
7.2.4 Chlorophyll-a ... 7-6
7.2.5 Secchi Depth ... 7-7
7.3 Seasonal and Annual Variation ... 7-8
7.4 Margin of Safety ... 7-8
7.5 Reserve Capacity/Future Growth ... 7-9

8.0 PUBLIC PARTICIPATION ... 8-1
8.1 Introduction ... 8-1
8.2 Technical Advisory Committee ... 8-1
8.3 Stakeholder Meetings ... 8-1
8.4 Public Meetings ... 8-1

9.0 IMPLEMENTATION ... 9-1
9.1 Implementation Framework ... 9-1
9.1.1 The Shingle Creek Watershed Management Commission ... 9-1
9.1.2 Member Cities ... 9-2
9.2 Reduction Strategies ... 9-2
9.2.1 Annual Load Reductions ... 9-2
9.2.2 Actions ... 9-3
9.2.2.1 External Load Reductions ... 9-3
9.2.2.2 Internal Loads ... 9-4
9.3 Implementation Strategy ... 9-5

10.0 REASONABLE ASSURANCE ... 10-1

Table of Contents (Cont.)

10.1 Introduction 10-1
10.2 The Shingle Creek Watershed Management Commission 10-1
10.3 NPDES MS4 Stormwater permits 10-2
10.4 Monitoring 10-3
10.4.1 Monitoring Implementation of Policies and BMPs 10-3
10.4.2 Follow-up Monitoring 10-3

11.0 LITERATURE CITED 11-1

TABLES

Table 2.1. Impaired waters in the Bass Lake chain of lakes. 2-1
Table 2.2. Trophic status thresholds for determination of use support for lakes. 2-2
Table 2.3. Target end points used in this TMDL. 2-2
Table 2.4. Pre-settlement total phosphorus concentrations based on water quality reconstructions from fossil diatoms. 2-2
Table 2.5. Interquartile range of summer mean concentrations by ecoregion for minimally impacted streams in Minnesota. 2-3
Table 3.1. Lake characteristics. 3-1
Table 3.2. 2000 land use in the Schmidt Lake, Pomerleau Lake and Bass Lake watersheds. 3-2
Table 3.3. Fish species represented in DNR lake surveys. 3-8
Table 5.1. Historical summer average (June 1 through September 30) water quality conditions for Schmidt Lake. 5-3
Table 5.2. Historical summer average (June 1 through September 30) water quality conditions for Pomerleau Lake. 5-6
Table 5.3. Historical summer average (June 1 through September 30) water quality conditions for Bass Lake. 5-9
Table 6.1. Estimated total phosphorus load from atmospheric deposition by lake. 6-3
Table 6.2. Results of the mass balance at fall turnover for Schmidt Lake.. 6-4
Table 6.3. Results of the internal load assessment using an anoxic factor and release rate for Schmidt Lake. 6-4
Table 6.4. Results of the mass balance at fall turnover for Pomerleau Lake. 6-5
Table 6.5. Results of the internal load assessment using an anoxic factor and release rate for Bass Lake. 6-5
Table 6.6. Current total phosphorus budget for Schmidt, Pomerleau, and Bass Lakes. 6-6
Table 6.7. Model fit for Schmidt Lake. 6-7
Table 6.8. Model fit for Pomerleau Lake. 6-7
Table 6.9. Model fit for Bass Lake. 6-7
Table 7.1. Wasteload allocation by NPDES permitted facility for each lake. 7-1
Table 7.3. TMDL total phosphorus allocations expressed as daily loads. 7-2
Table 7.4. TMDL total phosphorus loads partitioned among the major sources. 7-3
Table 9.1. TMDL total phosphorus loads partitioned among the major sources. 9-2

FIGURES

Figure 3.1. Location map. 3-3
Figure 3.2. General drainage system. 3-4
Figure 3.3. 2000 land use. 3-5
Figure 3.4. Summer (June 1 –September 30) mean total phosphorus concentrations for the chain of lakes. 3-7

Table of Contents (Cont.)

Figure 3.5. Summer (June 1 –September 30) mean chlorophyll-a concentrations for the chain of lakes................ 3-7
Figure 3.6. Summer (June 1 –September 30) mean Secchi depth (meters) for the chain of lakes............................ 3-8
Figure 3.7. Fish abundance and biomass results from 1990 fish survey for Schmidt Lake.................................... 3-10
Figure 3.8. Fish abundance and biomass results from 1994 fish survey for Pomerleau Lake. 3-11
Figure 3.9. Fish abundance and biomass results from 1991 fish survey for Bass Lake.. 3-12
Figure 5.1. Surface total phosphorus concentrations and total precipitation for Schmidt Lake, summer 2004......... 5-4
Figure 5.2. Surface total phosphorus concentrations and total precipitation for Schmidt Lake, summer 2005......... 5-4
Figure 5.3. Surface chlorophyll-a and phosphorus concentrations in Schmidt Lake, summer 2004. 5-5
Figure 5.4. Surface chlorophyll-a and phosphorus concentrations in Schmidt Lake, summer 2005. 5-5
Figure 5.5. Dissolved oxygen profile of Pomerleau Lake. 5-6
Figure 5.6. Surface total phosphorus and total precipitation for Pomerleau Lake, summer 1999. 5-7
Figure 5.7. Surface phosphorus and total precipitation for Pomerleau Lake, summer 2001. 5-7
Figure 5.8. Surface chlorophyll-a and phosphorus concentrations in Pomerleau Lake, summer 1999. 5-8
Figure 5.9. Surface chlorophyll-a and phosphorus concentrations in Pomerleau Lake, summer 2001. 5-8
Figure 5.10. Dissolved oxygen profiles for Bass Lake in 1980. 5-10
Figure 5.11. Surface total phosphorus and total precipitation for Bass Lake, summer 1999.................................. 5-10
Figure 5.12. Surface total phosphorus and total precipitation for Bass Lake, summer 2001.................................. 5-11
Figure 5.13. Surface chlorophyll-a and phosphorus concentrations in Bass Lake, summer 1999........................... 5-11
Figure 5.14. Surface chlorophyll-a and phosphorus concentrations in Bass Lake, summer 2001. 5-12
Figure 6.1. Sediment phosphorus release rates by trophic condition (Nürnberg 1997). 6-3
Figure 7.1. Modeled annual load and load at the standard for Schmidt Lake. The percentages represent the reduction needed to meet the standard. 7-4
Figure 7.2. Modeled annual load and load at the standard for Pomerleau Lake. The percentages represent the reduction needed to meet the standard. 7-4
Figure 7.3. Modeled annual load and load at the standard for Bass Lake. The percentages represent the reduction needed to meet the standard. 7-5
Figure 7.4. Bass Lake total phosphorus concentration predicted for total phosphorus load reductions applied to all sources.. 7-5
Figure 7.5. In lake total phosphorus concentrations predicted for total phosphorus load reductions applied to all sources.. 7-6
Figure 7.6. Bass Lake chlorophyll-a concentration predicted for total phosphorus load reductions applied to all sources.. 7-6
Figure 7.7. In lake chlorophyll-a concentrations predicted for total phosphorus load reductions applied to all sources. 7-7
Figure 7.8. Bass Lake Secchi depth predicted for total phosphorus load reductions applied to all sources. 7-7
Figure 7.9. Secchi depth predicted for total phosphorus load reductions applied to all sources............................... 7-8

APPENDICES

A Models and Calculations Detail

TMDL Summary

<table>
<tr><th colspan="5">TMDL Summary Table</th></tr>
<tr><th>EPA/MPCA Required Elements</th><th colspan="3">Summary</th><th>TMDL Page #</th></tr>
<tr><td>Location</td><td colspan="3">Cities of Maple Grove and Plymouth in Hennepin County, Minnesota, in the Upper Mississippi River Basin.</td><td>3-1 – 3-2</td></tr>
<tr><td>303(d) Listing Information</td><td colspan="3">Bass 27-0098
Pomerleau 27-0100
Schmidt 27-0102
Schmidt, Pomerleau, and Bass Lakes were added to the 303(d) list in 2002 because of excess nutrient concentrations impairing aquatic recreation, as set forth in Minnesota Rules 7050.0150. This TMDL was prioritized to start in 2003 and be completed by 2012-2013.</td><td>2-1 – 2-2</td></tr>
<tr><td>Applicable Water Quality Standards/ Numeric Targets</td><td colspan="3">Criteria set forth in Minn. R. 7050.0150 (3) and (5). For Schmidt and Bass Lakes, which are shallow lakes, the target is a total phosphorus concentration of 60 µg/L or less. For Pomerleau Lake, the target is a total phosphorus concentration of 40 µg/L or less.</td><td>2-1 – 2-2</td></tr>
<tr><td rowspan="5">Loading Capacity (expressed as daily load)</td><td colspan="3">The loading capacity is the total maximum daily load for each of these conditions. The critical condition for these lakes is the summer growing season. The loading capacity is set forth in Table 7.2.</td><td rowspan="5">7-2 – 7-3</td></tr>
<tr><td colspan="3">Total maximum daily total phosphorus load (kg/day)</td></tr>
<tr><td colspan="2">Schmidt Lake</td><td>0.14</td></tr>
<tr><td colspan="2">Pomerleau Lake</td><td>0.09</td></tr>
<tr><td colspan="2">Bass Lake</td><td>1.19</td></tr>
<tr><td rowspan="5">Wasteload Allocation</td><td colspan="3">Portion of the loading capacity allocated to existing and future point sources.</td><td rowspan="5">7-2 – 7-3</td></tr>
<tr><td>Source</td><td>Permit #</td><td>Categorical WLA (kg/day)</td></tr>
<tr><td>Permitted Stormwater: Schmidt Lake</td><td>MS400112 - Plymouth</td><td>0.12</td></tr>
<tr><td>Permitted Stormwater: Pomerleau Lake</td><td>MS400112 - Plymouth</td><td>0.07</td></tr>
<tr><td>Permitted Stormwater: Bass Lake</td><td>MS400102-Maple Grove
MS400112-Plymouth
MS400138-Hennepin County
MS400170-MnDOT</td><td>1.12</td></tr>
<tr><td rowspan="4">Load Allocation</td><td colspan="3">The portion of the loading capacity allocated to existing and future nonpoint sources.</td><td rowspan="4">7-2 –7-3</td></tr>
<tr><td>Source</td><td colspan="2">Load Allocation (kg/day)</td></tr>
<tr><td colspan="3">Atmospheric Load</td></tr>
<tr><td>Schmidt Lake</td><td colspan="2">0.01</td></tr>
</table>

TMDL Summary

TMDL Summary Table			
EPA/MPCA Required Elements	**Summary**		**TMDL Page #**
	Pomerleau Lake	0.01	
	Bass Lake	0.06	
	Internal Load		
	Schmidt Lake	0.01	
	Pomerleau Lake	0.01	
	Bass Lake	0.01	
Margin of Safety	The margin of safety is implicit in each TMDL due to the conservative assumptions of the model and the proposed iterative nutrient reduction strategy with monitoring.		7-8 – 7-9
Seasonal Variation	Seasonal variation is accounted for by developing targets for the summer critical period where the frequency and severity of nuisance algal growth is greatest. Although the critical period is the summer, lakes are not sensitive to short-term changes but rather respond to long term changes in annual load.		7-8
Reasonable Assurance	Reasonable assurance is provided by the cooperative efforts of the Shingle Creek Watershed Commission, a joint powers organization with statutory responsibility to protect and improve water quality in the water resources in the Shingle Creek watershed in which these lakes are located, and by the member cities of this organization. In addition, the entire contributing area to these lakes is regulated under the NPDES program, and Minnesota's General Permit requires MS4s to amend their NPDES permit's Storm Water Pollution Prevention Plan within 18 months after adoption of a TMDL to set forth a plan to meet the TMDL wasteload allocation.		Section 10
Monitoring	The Shingle Creek Watershed Management Commission periodically monitors these lakes and will continue to do so through the implementation period.		10-3
Implementation	This TMDL sets forth an implementation framework and general load reduction strategies that will be expanded and refined through the development of an Implementation Plan.		Section 9
Public Participation	Public Comment period: Meeting location: Comment received:		

Executive Summary

This Total Maximum Daily Load (TMDL) study addresses nutrient impairments in Bass, Pomerleau, and Schmidt Lakes. The goal of this TMDL is to quantify the pollutant reductions needed to meet State water quality standards for nutrients in Schmidt Lake (27-0102), Pomerleau Lake (27-0100) and Bass Lake (27-0098).

These lakes are located in Hennepin County, Minnesota, in the Shingle Creek watershed, and specifically in the cities of Plymouth and Maple Grove. Bass and Schmidt Lakes are highly used recreational water bodies that support fishing and swimming as well as provide aesthetic values, while Pomerleau has limited public access. The drainage area to the lakes is 3,200 acres of mostly developed suburban land, with numerous large wetlands and a small remnant of agricultural land. The lake system discharges into Bass Creek, a tributary of Shingle Creek, which ultimately discharges into the Mississippi River.

Monitoring data indicate that the lakes are eutrophic, and experience significant algae blooms in late summer. The poor water quality in Schmidt, Pomerleau, and Bass Lakes appears to be primarily driven by phosphorus loading from the watershed although internal phosphorus loading also impacts the lakes, particularly for the shallower Schmidt and Bass Lakes. A 33 percent decrease in phosphorus load would be required for Bass Lake to consistently meet water quality standards. Schmidt Lake would require a 9 percent reduction and Pomerleau a 67 percent reduction.

Because the watershed that drains to Schmidt and Bass Lakes is almost completely developed, there are limited options for reducing external load. The area draining to Pomerleau Lake is undergoing land use conversion from agricultural to residential. Development rules require new development or redevelopment to provide treatment and manage stormwater volume. Additional Best Management Practices (BMPs) to treat stormwater will be incorporated where opportunities such as street reconstruction arise, and small practices such as rain gardens, native plantings, and reforestation will be encouraged to limit runoff and nutrient conveyance.

Aquatic plant management will target in-lake sources of nutrients and fishery management will be coordinated with the Minnesota Department of Natural Resources (DNR) to manage and maintain a beneficial community. The Shingle Creek Watershed Management Commission will work in partnership with the cities and other agencies in the watershed to prepare a more detailed Implementation Plan that will set forth specific strategies and priorities for achieving nutrient load reduction goals.

1.0 Introduction

1.1 PURPOSE

This Total Maximum Daily Load (TMDL) study addresses a nutrient impairment in Bass Lake and two lakes in its contributing watershed -- Schmidt and Pomerleau Lakes. The goal of this TMDL is to quantify the pollutant reductions needed to meet the water quality standards for nutrients in Schmidt, Pomerleau and Bass Lakes. The Schmidt, Pomerleau and Bass Lakes TMDL for nutrients is being established in accordance with Section 303(d) of the Clean Water Act because the State of Minnesota has determined waters in the Schmidt, Pomerleau and Bass Lakes exceed the State established standards for nutrients.

This TMDL provides waste load allocations (WLAs) and load allocations (LAs) for these three lakes. Based on the State standard for nutrients, the TMDL establishes a numeric target of 40 µg/L total phosphorus concentration for Pomerleau Lake and 60 µg/L total phosphorus for Schmidt and Bass Lakes.

1.2 PROBLEM IDENTIFICATION

Schmidt, Pomerleau and Bass Lakes were placed on the 2002 State of Minnesota's 303(d) list of impaired waters. Each was identified for impairment of aquatic recreation (swimming). Bass and Schmidt Lakes are highly used recreational water bodies with opportunities for fishing and swimming as well as providing habitat and aesthetic values, while Pomerleau has limited public access. Water quality does not meet state standards for nutrient concentrations and thus is not supportive of aquatic recreation.

Water quality is eutrophic and moderately degraded in all three lakes, with average Carlson's Trophic Status (TSI) of 64 for Pomerleau, 63 for Bass, and 61 for Schmidt. A TSI value of less than 57 is generally regarded as suitable water quality for swimming.

2.0 Target Identification and Determination of Endpoints

2.1 IMPAIRED WATERS

The Minnesota Pollution Control Agency (MPCA) first included Schmidt, Pomerleau, and Bass Lakes on the 2002 State of Minnesota 303(d) list of impaired waters list (Table 2.1). The lakes are impaired by excess nutrient concentrations, which inhibit aquatic recreation. The MPCA's projected schedule for TMDL completions, as indicated on the 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL. The project was scheduled to be completed in 2012-13. Ranking criteria for scheduling TMDL projects include, but are not limited to, impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the waterbody; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

Table 2.1. Impaired waters in the Bass Lake chain of lakes.

Lake	DNR Lake #	Listing Year	Affected use	Pollutant or Stressor	Target TMDL Completion
Bass	27-0098	2002	Aquatic recreation	Excess nutrients	2013
Pomerleau	27-0100	2002	Aquatic recreation	Excess nutrients	2012
Schmidt	27-0102	2002	Aquatic recreation	Excess nutrients	2012

2.2 MINNESOTA WATER QUALITY STANDARDS AND ENDPOINTS

2.2.1 State of Minnesota Standards

Minnesota's standards for nutrients limit the quantity of nutrients which may enter waters. Minnesota's standards at the time of listing (Minnesota Rules 7050.0150(3)) stated that in all Class 2 waters of the State (i.e., "…waters…which do or may support fish, other aquatic life, bathing, boating, or other recreational purposes…") "…there shall be no material increase in undesirable slime growths or aquatic plants including algae…" In accordance with Minnesota Rules 7050.0150(5), to evaluate whether a waterbody is in an impaired condition the MPCA developed "numeric translators" for the narrative standard for purposes of determining which lakes should be included in the section 303(d) list as being impaired for nutrients. The numeric translators established numeric thresholds for phosphorus, chlorophyll-a, and water clarity as measured by Secchi depth. Table 2.2 lists the thresholds for listing lakes on the 303(d) list of impaired waters in Minnesota that were in place when these lakes were listed.

Table 2.2. Trophic status thresholds for determination of use support for lakes.
Thresholds applicable at the time of listing are highlighted in bold.

305(b) Designation	Full Support			Partial Support to Potential Non-Support			
303(d) Designation	**Not Listed**			**Review**	**Listed**		
Ecoregion	**TP (ppb)**	**Chl-a (ppb)**	**Secchi (m)**	**TP Range (ppb)**	**TP (ppb)**	**Chl-a (ppb)**	**Secchi (m)**
North Central Hardwood Forests	**≤ 40**	**≤ 14**	**≥ 1.2**	40 - 45	> 45	> 18	< 1.1
(Carlson's TSI)	**(≤57)**	**(≤57≤)**	**(<57)**	(57 – 59)	(> 59)	(> 59)	(> 59)

2.2.2 End Points Used in this TMDL

The numeric target used to list these three lakes was the numeric translator threshold phosphorus standard for Class 2B waters in the North Central Hardwood Forest ecoregion (40 µg/L) prior to the adoption of new standards in 2008. However, since that time the state has adopted new standards for lakes meeting shallow lakes criteria. Schmidt and Bass Lakes are shallow lakes and are now subject to the revised total phosphorus target of 60 µg/L or greater (Minnesota Rules 7050). Pomerleau Lake is a deep lake and is subject to the 40 µg/L deep lake standard. Therefore, this TMDL presents load and wasteload allocations and estimated load reductions based on the end points presented in Table 2.3.

Although the TMDL is set for the total phosphorus standard, one of the two other eutrophication standards must be met: chlorophyll-a or Secchi depth (Table 2.3). All three of these parameters were assessed to assure that the TMDL will result in compliance with state standards.

Table 2.3. Target end points used in this TMDL.

	Total Phosphorus (µg/L) Standard	Chlorophyll-a (µg/L) Standard	Secchi Depth (m) Standard
Bass Lake	≤ 60	≤ 20	≥1.0
Schmidt Lake	≤ 60	≤ 20	≥1.0
Pomerleau Lake	≤ 40	≤ 14	≥1.4

2.3 PRE-SETTLEMENT CONDITIONS

Another consideration when evaluating nutrient loads to lakes is the natural background load. Ultimately, the background load represents the load the lake would be expected to receive under natural, undisturbed conditions. This load can be determined using ecoregion pre-settlement nutrient concentrations as determined by diatom fossil reconstruction. Diatom inferred total phosphorus concentrations are presented in Table 2.4.

Table 2.4. Pre-settlement total phosphorus concentrations based on water quality reconstructions from fossil diatoms.
All are the concentration at the 75th percentile (MPCA 2002).

	Ecoregions			
	North Central Hardwood Forest		**Western Corn Belt Plains**	
Parameter	**Shallow[1]**	**Deep**	**Shallow[1]**	**Deep**
Phosphorus concentration (µg/L)	47	26	89	56

[1] Shallow lakes are defined as lakes with a maximum depth of 15 feet or less, or with 80% or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants (littoral zone).

A 2002 MPCA study reconstructed pre-settlement lake conditions based on diatom assemblages in soil cores from many different representative lakes across the state. Pomerleau, Bass, and Schmidt Lakes were not included in the study. Based on the diatom fossils, pre-settlement concentrations were approximately 26 μg/L for deep lakes in the North Central Hardwood Forests ecoregion and 47 μg/L for shallow lakes.

Another benchmark that may be useful in determining goals and load reductions is expected stream concentration under natural or undisturbed conditions. Table 2.5 provides data from minimally impacted streams in the North Central Hardwood Forest ecoregion.

Table 2.5. Interquartile range of summer mean concentrations by ecoregion for minimally impacted streams in Minnesota.

Region	Total Phosphorus (μg/L)		
	25^{th} Percentile	**50^{th} Percentile**	**75^{th} Percentile**
North Central Hardwood Forest	70	100	170

(McCollor and Heiskary 1993).

To achieve the predicted background load, average in-stream concentrations for Bass, Schmidt, and Pomerleau Lakes would need to be approximately 90 to 100 μg/L, 100 to 110 μg/L, and 55 μg/L, respectively. The values for Bass and Schmidt are approximately equal to the 50^{th} percentile shown in Table 2.5 but the value for Pomerleau is significantly lower than the low end of the interquartile range (70 μg/L).

3.0 Watershed and Lake Characterization

3.1 LAKE AND WATERSHED DESCRIPTION

Almost the entire drainage area of these lakes is located within the city of Plymouth in the northwestern suburban Twin Cities metropolitan area, with a fraction located in the city of Maple Grove (See Figure 3.1). The Pomerleau Lake and Schmidt Lake subwatersheds drain through the Bass Lake subwatershed to Bass Lake (Figure 3.2). Bass Lake outlets through Bass Creek to Shingle Creek, which outlets into the Mississippi River. The area is almost fully developed, with a 2000 Census population of about 20,000.

Bass Lake is approximately 175 acres in size with an average depth of 10.1 feet. Approximately 82% of the surface area is littoral (i.e., less than 15 feet in depth) and, therefore, aquatic vegetation has a significant impact on the water quality in this shallow lake. Runoff from the watershed displaces the lake volume approximately twice per year, which provides a significant supply of nutrients to the lake regularly. There are about 7 storm sewer outfalls discharging into the lake as well as Bass Creek, which discharges into the lake at its south end and outlets through a control structure at its east side. Additional details for Bass Lake are provided in Table 3.1.

Pomerleau Lake is approximately 30 acres in size with an average depth of 10.9 feet. Approximately 66% of the surface area is littoral and, therefore, aquatic vegetation has an impact on the water quality in this deep lake. The residence time indicates that runoff from the watershed displaces the lake volume a little more than once per year. There appear to be no storm sewer outfalls directly discharging into Pomerleau Lake. Additional details for Pomerleau Lake are provided in Table 3.1.

Schmidt Lake is approximately 37 acres in size with an average depth of 5.5 feet. Approximately 92% of the surface area is littoral and, therefore, aquatic vegetation has a significant impact on the water quality in this shallow lake. Runoff from the watershed displaces the lake volume approximately twice per year, which provides a significant and regular supply of nutrients to the lake. There are about 8 storm sewer outfalls to the lake. Additional details for Schmidt Lake are provided in Table 3.1.

Table 3.1. Lake characteristics.

Parameter	Bass Lake	Pomerleau Lake	Schmidt Lake
Surface Area (ac)	175	30	37
Average Depth (ft)	10.1	10.9	5.5
Maximum Depth (ft)	31	26	27
Volume (ac-ft)	1,760	329	202
Residence Time (years)	0.47	0.73	0.50
Littoral Area (ac)	143 (82%)	19.8 (66%)	34 (92%)
Watershed (ac)	3,183	266	232

The Pomerleau Lake subwatershed is located in a developing area, with extensive wetlands and woodlands. The Schmidt Lake subwatershed is completely developed. The Bass Lake subwatershed is almost completely developed east of I-494, but west of I-494 there are tracts of undeveloped area, mainly wetlands, and some of the last remaining agriculture in the Shingle Creek watershed. The 2000 land use data are presented in Table 3.2 and Figure 3.3. Significant land uses in the watershed include single-family residential (36%); undeveloped (primarily wetland) at 24%; parks and recreation (12%), and agriculture (9%).

Table 3.2. 2000 land use in the Schmidt Lake, Pomerleau Lake and Bass Lake watersheds.

Land Use Class	Schmidt Lake		Bass Lake		Pomerleau Lake	
	Area	**Percent**	**Area**	**Percent**	**Area**	**Percent**
Single Family Residential	175	75%	1,148	36%	30	10%
Undeveloped	1	1%	770	24%	165	56%
Park, Rec, Preserve, Golf	14	6%	372	12%	27	9%
Agriculture, Farmstead	--	--	292	9%	45	15%
Water	42	1%	279	9%	--	--
Highway	--	--	109	3%	--	--
Multi-Family Residential	--	--	96	3%	--	--
Commercial/Industrial	--	--	97	3%	--	--
Institutional	--	--	19	1%	--	--
Total Area	232	100%	3,183	100%	266	100%

Source: Metropolitan Council as compiled from city Comprehensive Plans.

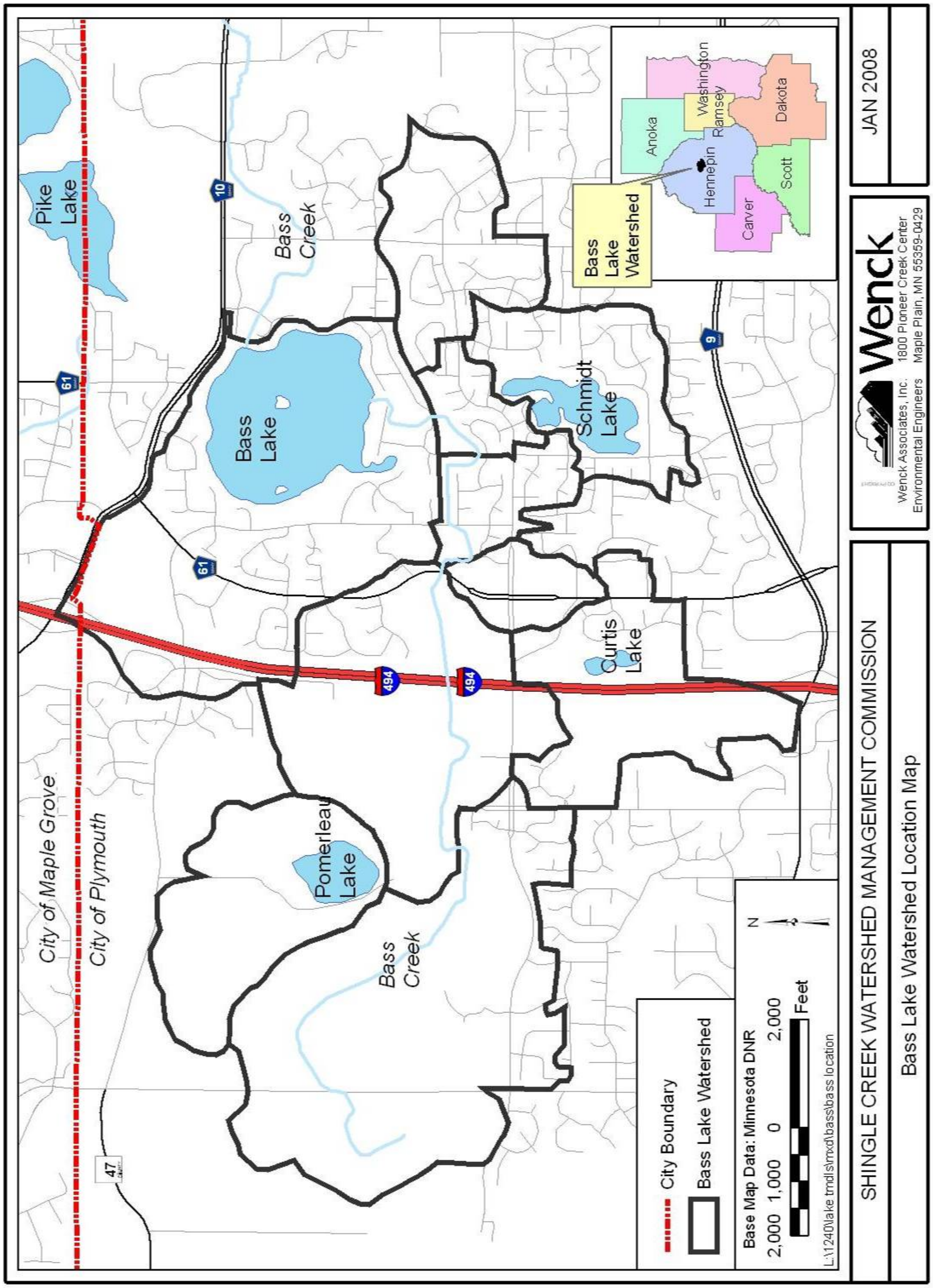


Figure 3.1. Location map.

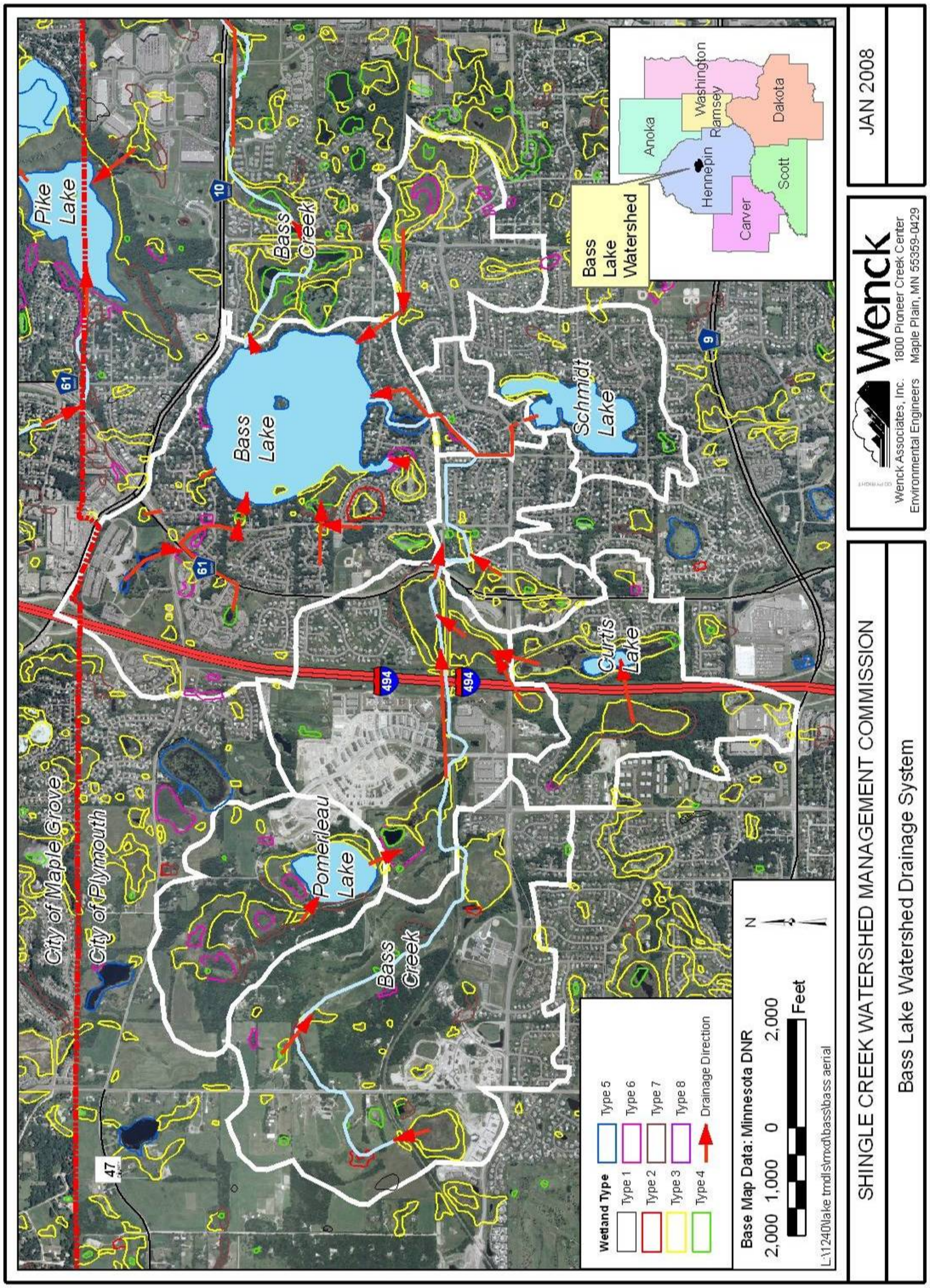


Figure 3.2. General drainage system.

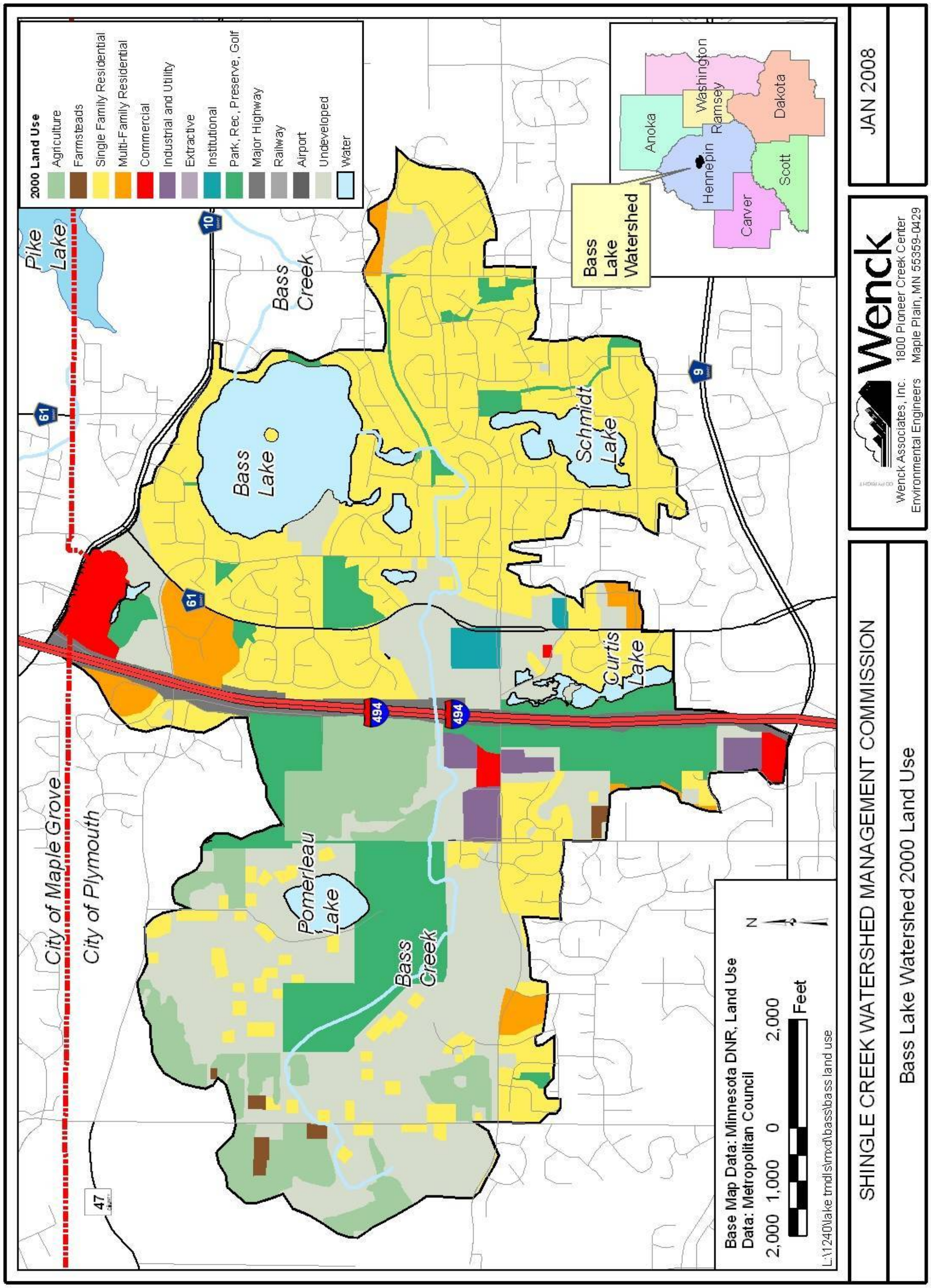


Figure 3.3. 2000 land use.

3.2 RECREATIONAL USES

3.2.1 Parks and Open Space

The largest open space in the watershed is the 18-hole Hampton Hills Golf Course in the upper watershed. Upper Bass Creek flows through the golf course's wetlands. Several wetland complexes adjacent to I-494, including Curtis Lake, provide additional open space. Several community parks and playlots are located within the watershed. Schmidt Lake Park is located on upper Schmidt Lake and provides a view of the lake, but no access. Timber Shores Park on the east side of Bass Lake is a large riparian wetland complex with walking trails.

3.2.2 Other Recreation

Boat access to Schmidt Lake is available from Larch Lane on the west side of the lake. Carry-in access is possible on Bass Lake at Timber Shores Park. No public swimming access is available on these lakes. A fishing pier is available at Timber Shores Park on the east side of Bass Lake.

A future regional trail linking Fish Lake Regional Park and Clifton French Regional Park is proposed to cross this watershed. The City of Plymouth maintains a network of on- and off-road trails, including several trails in this watershed.

3.3 WATER CONDITION

Water quality in Minnesota lakes is often evaluated using three associated parameters: total phosphorus, chlorophyll-a, and Secchi depth. Total phosphorus is typically the limiting nutrient in Minnesota's lakes, meaning that algal growth will increase with increases in phosphorus. There are cases where phosphorus is widely abundant and the lake becomes limited by nitrogen availability. Chlorophyll-a is the primary pigment in aquatic algae and has been shown to have a direct correlation with algal biomass. Because chlorophyll-a is a simple measurement, it is often used to evaluate algal abundance rather than doing expensive cell counts. Secchi depth is a physical measurement of water clarity taken by lowering a black and white disk until it can no longer be seen from the surface. Greater Secchi depths indicate less light-refracting particulates in the water column and better water quality. Conversely, high total phosphorus and chlorophyll-a concentrations point to poor water quality. Measurements of these three parameters are interrelated and can be combined into an index that describes water quality.

3.3.1 Historic Water Quality

Historic water quality is presented in Figure 3.4, Figure 3.5, and Figure 3.6. Historic summer average total phosphorus (TP) concentration in Schmidt, Pomerleau, and Bass Lakes ranges from 30 µg/L to 90 µg/L with the highest concentration occurring in Pomerleau Lake and the lowest concentration occurring in Schmidt Lake. The standards for Pomerleau Lake are 40 µg/L TP and 14 µg/L chlorophyll-a, and for Schmidt and Bass 60 µg/L TP and 20 µg/L chl-a.

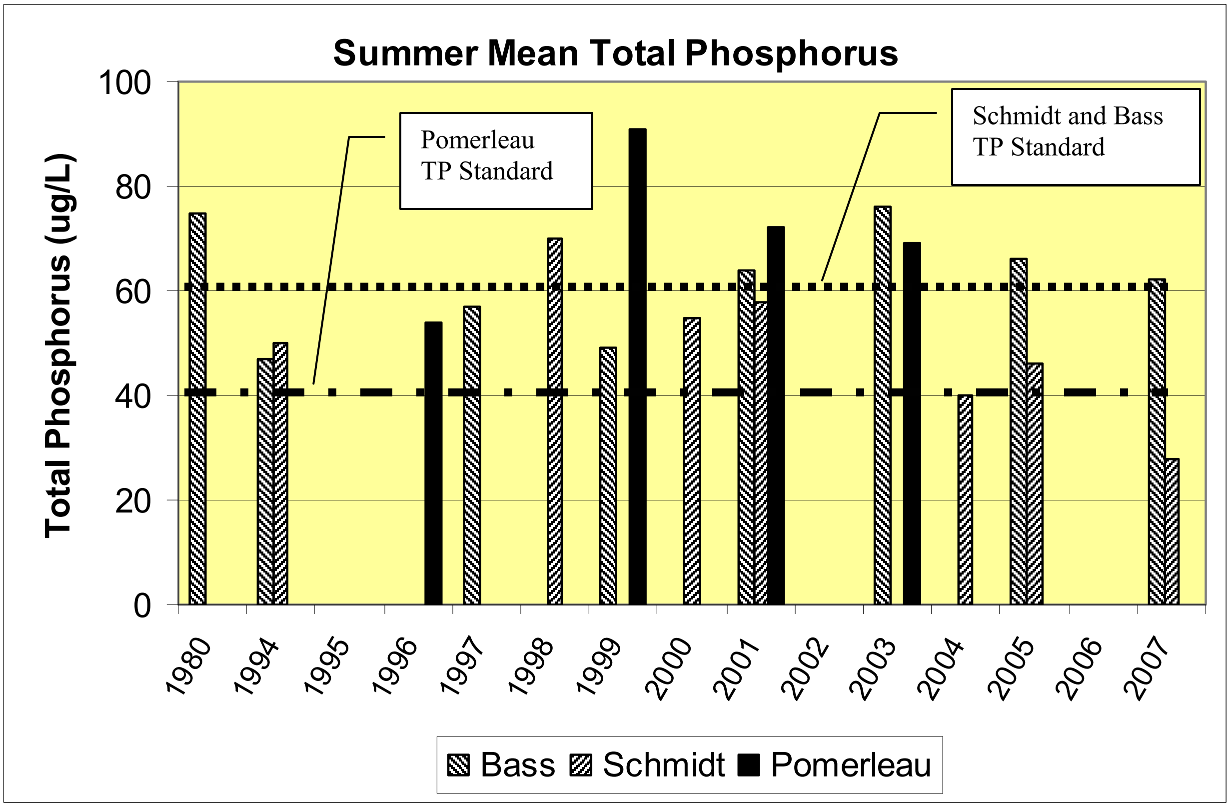


Figure 3.4. Summer (June 1 –September 30) mean total phosphorus concentrations for the chain of lakes.

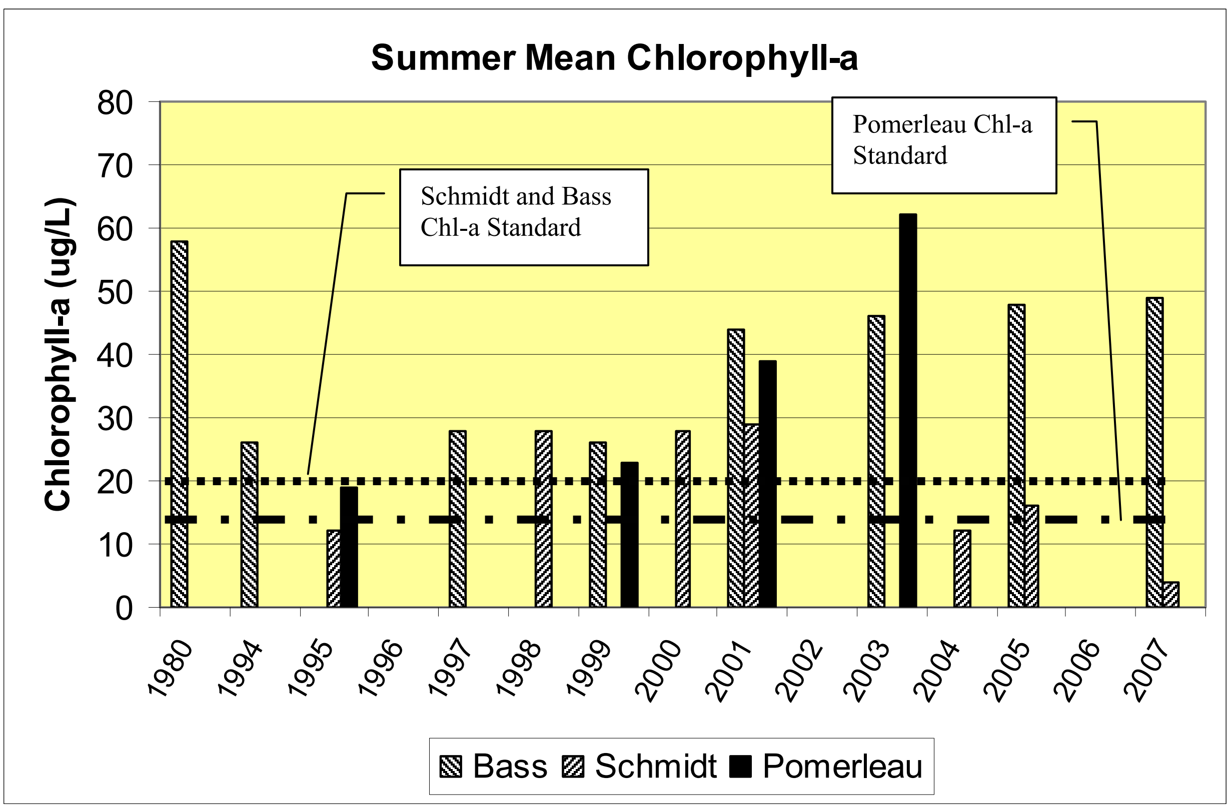


Figure 3.5. Summer (June 1 –September 30) mean chlorophyll-a concentrations for the chain of lakes

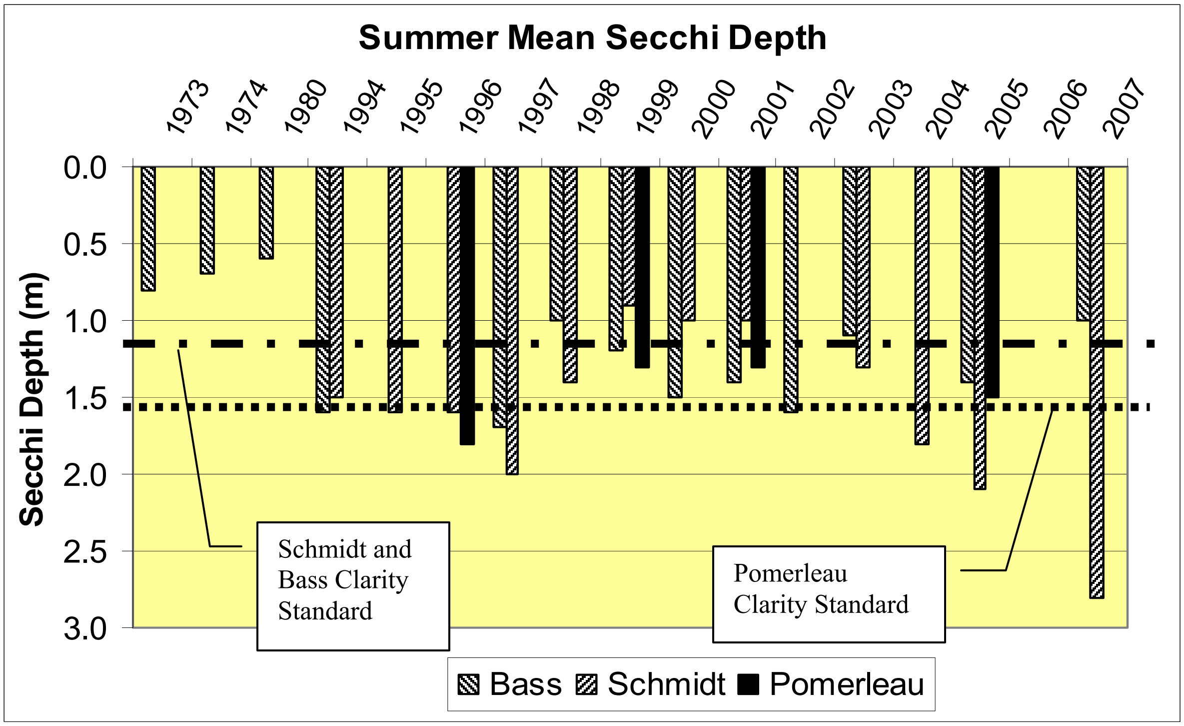


Figure 3.6. Summer (June 1 –September 30) mean Secchi depth (meters) for the chain of lakes.

Water clarity, as measured by Secchi depth measurements, was observed to follow similar trends as total phosphorus and chlorophyll-a concentrations. The Secchi depth standard for Pomerleau Lake is 1.4 meters or greater and for Schmidt and Bass Lakes is 1.0 meter or greater.

3.4 FISH POPULATIONS AND FISH HEALTH

3.4.1 Fish Populations

The Minnesota DNR conducted fish population surveys on Schmidt Lake (1990), Pomerleau Lake (1994), and Bass Lake (1991). Fish species captured during the survey at each lake include those listed below.

Table 3.3. Fish species represented in DNR lake surveys.

Fish Species	Schmidt Lake	Pomerleau Lake	Bass Lake
Black Bullhead	X	X	X
Black Crappie	X	X	X
Bluegill	X	X	X
Brown Bullhead			X
Common Carp			X
Golden Shiner			X
Green Sunfish		X	
Hybrid Sunfish	X		X
Largemouth Bass	X	X	X
Northern Pike	X		X
Pumpkinseed Sunfish	X		X
Walleye			X
White Crappie			X
White Sucker	X		X

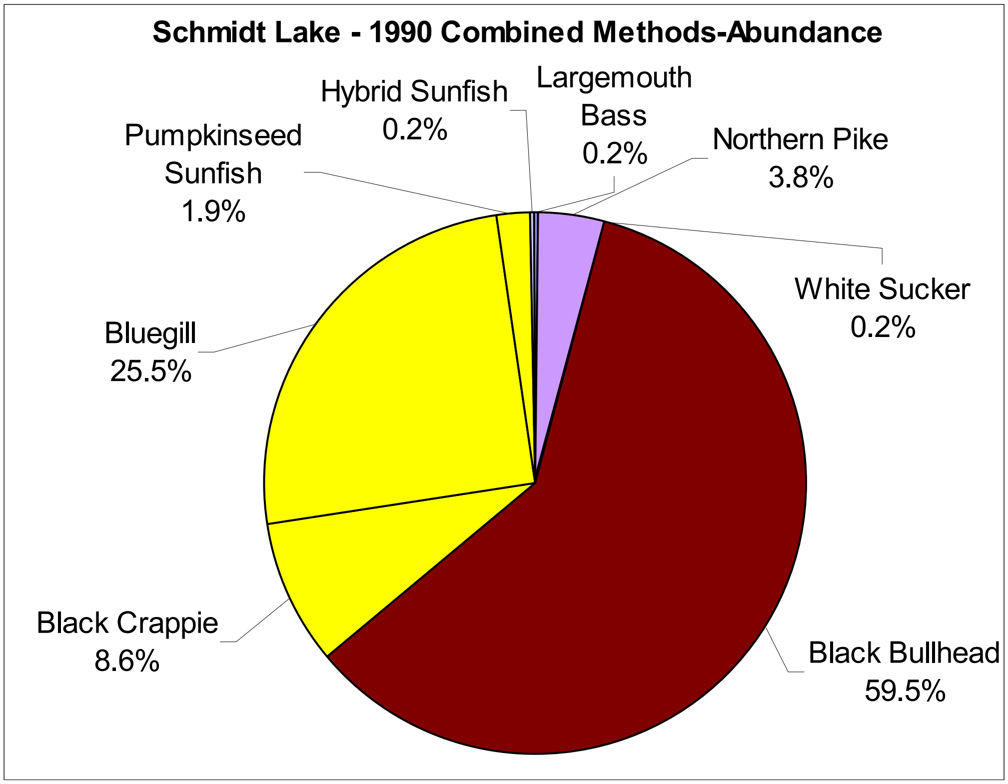
Of the three lakes discussed, the Schmidt Lake fish survey resulted in the smallest overall collection of fish in terms of total individuals and total biomass captured. The most abundant fish present in Schmidt Lake were black bullheads, followed by bluegills and black crappies. Both bluegills and black crappies were sampled near local averages in terms of abundance but individuals were small, averaging less than six inches in size. Northern pike and largemouth bass were the two predator species collected. The mean weight of the northern pike collected was 1.9 pounds, which is average for this size lake.

The Pomerleau Lake fish community is dominated by green sunfish in terms of total abundance and fish biomass. Green sunfish account for 94 percent of the total fish captured and 92 percent of the total fish biomass. The average size of the green sunfish measured was less than five inches. The only predator species captured was largemouth bass, which were the second most abundant fish in the survey. However, the average size of the largemouth bass was very small. The bluegill and black crappie populations were found to be low in Pomerleau Lake and the individuals captured were small in size for both species.

Bass Lake is the largest of the three lakes and had the largest and most diverse fish population. The most abundant species in Bass Lake are bluegill, black bullhead and black crappie. The average size of both the bluegills and black crappie was indicative of a panfish population that can be utilized by anglers. The main predator species in the lake is northern pike, but largemouth bass and walleye were also captured. The survey revealed that both northern pike and largemouth bass are re-establishing their populations in Bass Lake through natural reproduction. Northern pike accounted for the largest portion of total biomass at 29 percent. Common carp were not sampled in large numbers, with only five individuals captured, but still accounted for approximately 20 percent of the total fish biomass.

3.4.2 Fish Kills

Fish kills occur when dissolved oxygen (D.O.) levels are so low that fish begin to die from the lack of oxygen. Fish kills commonly occur during the summer or winter. Summer kills are the result of high productivity (algae and macrophytes) that eventually senesce and are subsequently broken down by bacteria. The breakdown by bacteria demands oxygen, which depletes D.O. in the water column. These conditions can result in a summer fish kill. Winter fish kills are the result of snow-covered ice that shades out photosynthesis under the ice. These conditions, coupled with a high sediment oxygen demand, can deplete the D.O. under the ice and result in a fish kill. There are no historical records of fish kills in Bass, Pomerleau, or Schmidt Lakes.



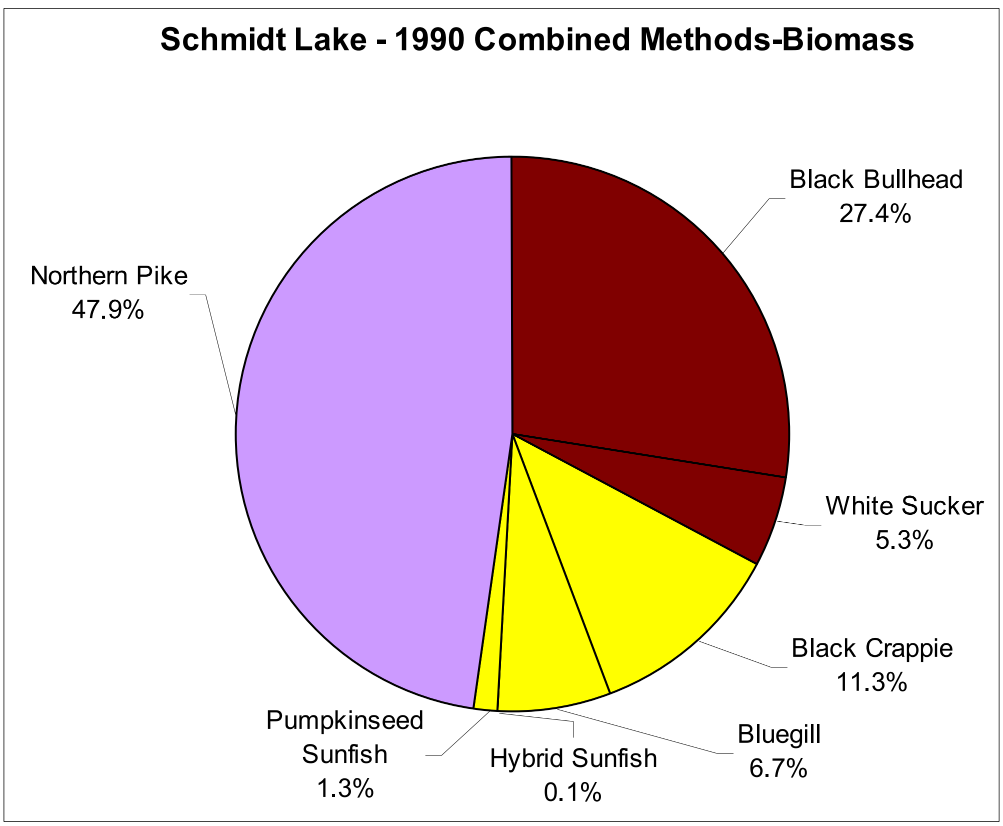
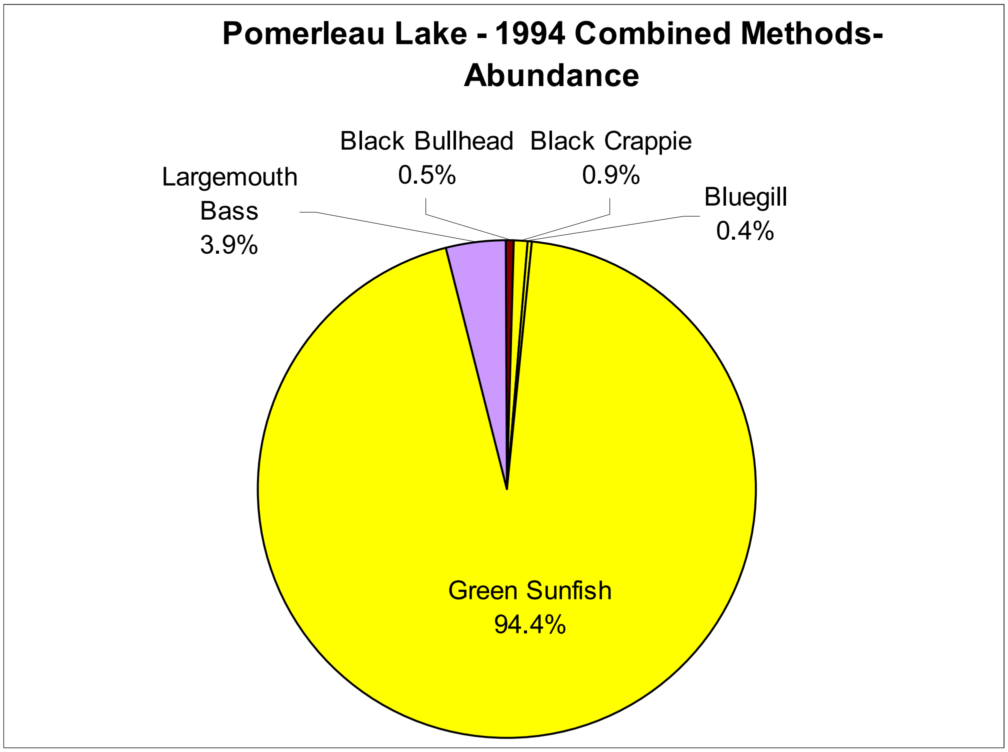


Figure 3.7. Fish abundance and biomass results from a 1990 fish survey for Schmidt Lake.



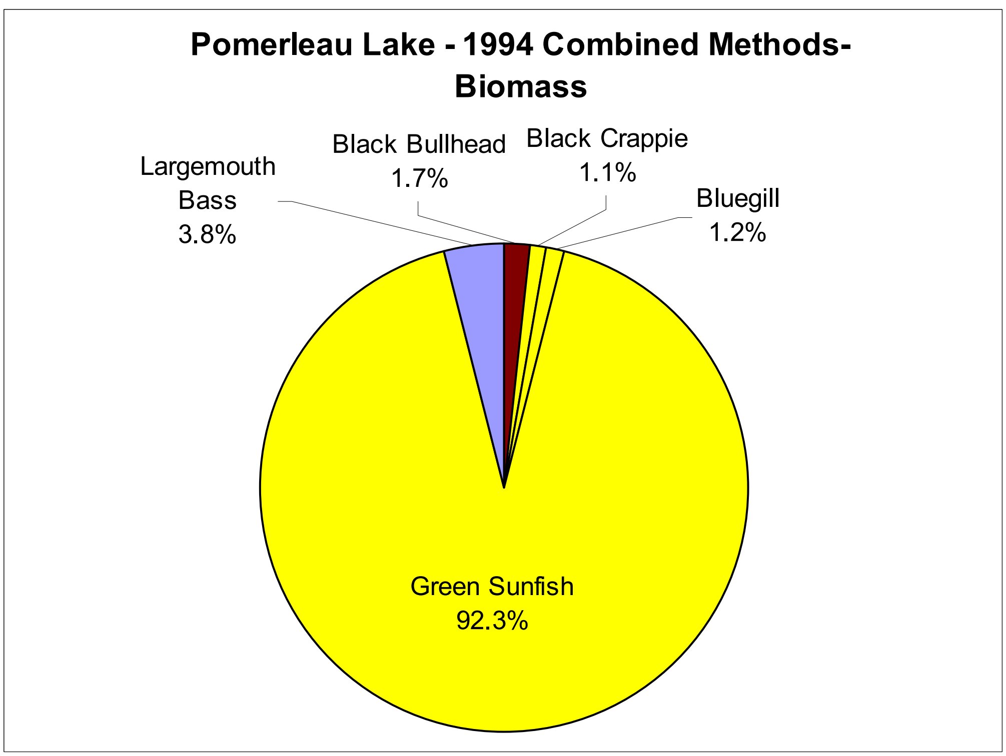
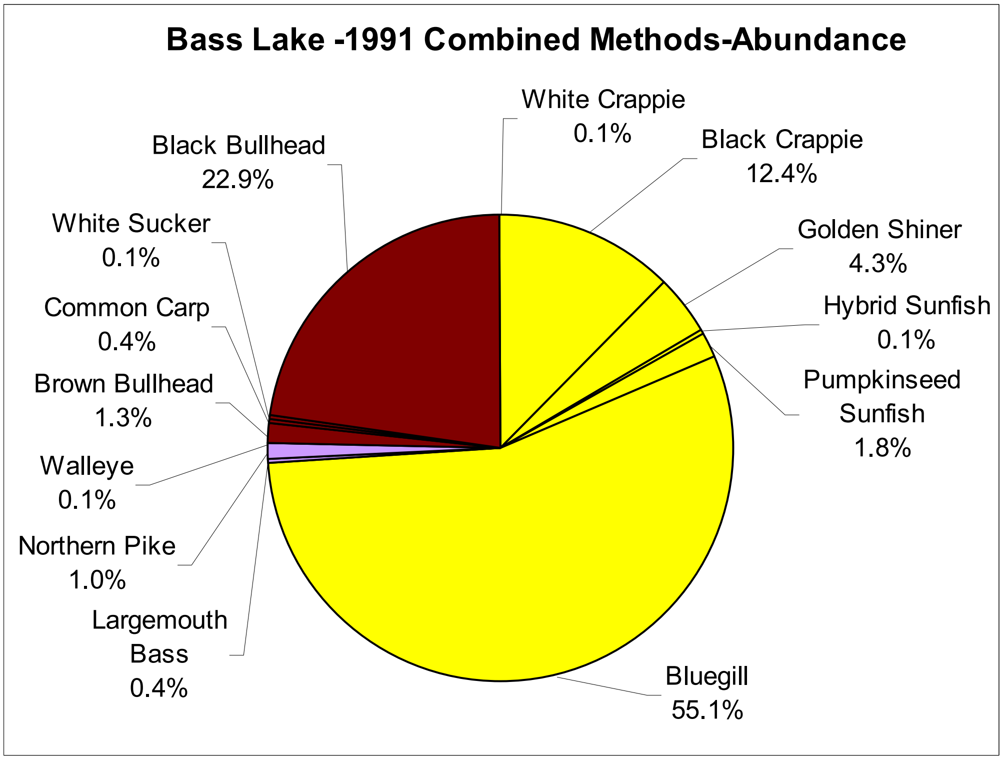


Figure 3.8. Fish abundance and biomass results from a 1994 fish survey for Pomerleau Lake.



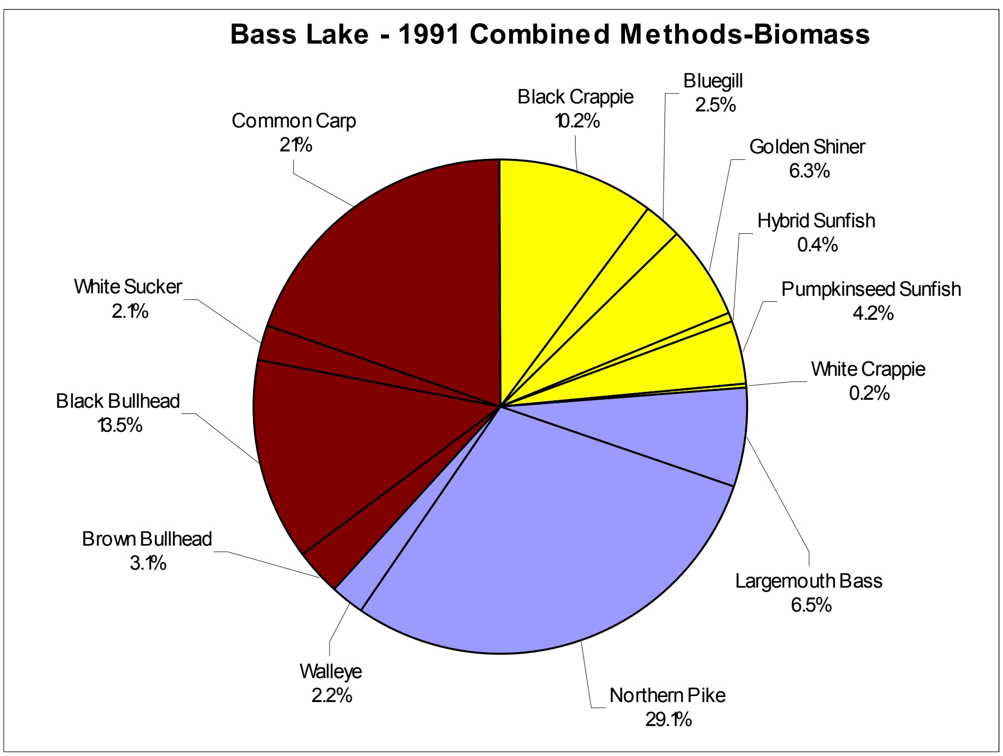


Figure 3.9. Fish abundance and biomass results from a 1991 fish survey for Bass Lake.

3.4.3 Carp and Rough Fish

Common carp have both direct and indirect effects on aquatic environments. Carp uproot aquatic macrophytes during feeding and spawning re-suspending bottom sediments and nutrients. These activities can lead to increased nutrients in the water column ultimately resulting in increased nuisance algal blooms. There are carp present in Bass Lake, but based on the number collected, the population is likely average to below average in size compared to areas lakes. The carp biomass in Bass Lake, however, is significant (~20%), indicating that the carp are large and could significantly disturb the lake bottom sediments. Carp may be present in either Schmidt or Pomerleau Lakes but none were collected from either lake during the most recent population survey. Black bullhead, a species of rough fish, was present in large numbers (~60%) and size (~27% biomass) in Schmidt Lake and could potentially disturb macrophyte beds and nutrient-rich sediments. Carp and rough fish management may be a key factor in managing nutrient levels in those lakes.

3.5 AQUATIC PLANTS

3.5.1 Introduction

Aquatic plants are beneficial to lake ecosystems providing spawning and cover for fish, habitat for macroinvertebrates, refuge for prey, and stabilization of sediments. However, in excess they limit recreation activities such as boating and swimming. Excess nutrients in lakes can lead aquatic weeds and exotics to take over a lake. Some exotics can lead to special problems in lakes. For example, Eurasian water milfoil can reduce plant biodiversity in a lake because it grows in great densities and out-competes all the other plants. Ultimately, this can lead to a shift in the fish community because these high densities favor panfish over larger game fish. Species such as curly-leaf pondweed can cause very specific problems by changing the dynamics of internal phosphorus loading. All in all, there is a delicate balance between the aquatic plant community in any lake ecosystem.

3.5.2 Littoral Zone

The littoral zone is defined as that portion of the lake that is less than 15 feet in depth and is where the majority of the aquatic plants are found. The littoral zone of the lake also provides the essential spawning habitat for most warmwater fish (e.g., bass, walleye and panfish). As shown in Table 3.1, the littoral areas in Bass, Pomerleau, and Schmidt Lakes are 82%, 66%, and 92%, of the surface area, respectively. Therefore, the aquatic vegetation will have a significant impact on the water quality in all three lakes.

3.5.3 Aquatic Plants in the Bass Lake Chain

No aquatic plant survey data is available for Bass or Pomerleau Lakes. The Bass Lake Improvement Association routinely contracts for aquatic plant chemical treatment to target curly-leaf pondweed, Eurasian water milfoil, and filamentous algae. Those application reports include information about species noted as present but do not note relative abundance or location.

A survey for Schmidt Lake conducted in 2004 found that about 66 percent of the lake bottom was colonized with submerged aquatic plants, with curly-leaf pondweed and coontail the dominant plants in the early summer. By late summer Eurasian water milfoil was more abundant but at low to moderate density. Chemical treatments for curly-leaf pondweed have been applied for several years and a comparison to a 1987 aquatic plant survey indicated that the overall abundance of the invasive plant has declined. However, Eurasian water milfoil, coontail and water celery have increased. An aquatic plant management plan has been developed for Schmidt Lake.

3.6 SHORELINE HABITAT AND CONDITIONS

The shoreline areas are defined as the areas adjacent to the lake edge with hydrophytic vegetation and water up to 1.5 feet deep or a water table within 1.5 feet from the surface. Natural shorelines provide water quality treatment, wildlife habitat and increased biodiversity of plants and aquatic organisms. Natural shoreline areas also provide aesthetic values and important habitat to fisheries including spawning areas and refugia.

Vegetated shorelines provide numerous benefits to both lakeshore owners and lake users including improved water quality, increased biodiversity, important habitat for both aquatic and terrestrial animals, and erosion stabilization resulting in reduced maintenance of the shoreline. Identifying projects where natural shoreline habitats can be restored or protected will enhance the overall lake ecosystem.

Limited data is available on shoreline conditions, as no shoreline condition surveys have been performed. Except for riparian wetland areas, the shoreline of these lakes is developed with single family residential land use featuring turfed lawns and little native vegetation.

4.0 Nutrient Source Assessment

4.1 INTRODUCTION

Understanding the sources of nutrients to a lake is a key component in developing a TMDL for lake nutrients. This section provides a brief description of the potential sources of phosphorus to the lakes.

4.2 PERMITTED SOURCES

4.2.1 Wastewater

Permitted wastewater sources can range from industrial effluent to municipal wastewater treatment plants. There are no wastewater treatment plant effluent discharges in the watershed. No known permitted wastewater sources are present in the Bass Lake subwatershed.

4.2.2 Stormwater

Phosphorus transported by stormwater represents one of the largest contributors of phosphorus to lakes in Minnesota. In fact, phosphorus export from urban watersheds rivals that of agricultural watersheds. Impervious surfaces in the watershed improve the efficiency of water moving to streams and lakes resulting in increased transport of phosphorus into local water bodies. Phosphorus in stormwater is a result of transporting organic material such as leaves and grass clippings, fertilizers, and sediments to the water body. All of these materials contain phosphorus which can impair local water quality. Consequently, stormwater is a high priority pollution concern in urban and urbanizing watersheds.

There are permitted stormwater sources in the Bass Lake subwatershed. National Pollution Discharge Elimination System (NPDES) Phase II permits for small municipal separate storm sewer systems (MS4s) have been issued to the member cities in the Shingle Creek watershed as well as Hennepin County and the Minnesota Department of Transportation (Mn/DOT). The MS4 cities, Hennepin County and MnDOT Metro District, are covered under the Phase II General NPDES Stormwater Permit – MNR040000. Not all the MS4s in the Shingle Creek watershed drain to the Bass Lake chain. The unique permit numbers assigned to the MS4s that discharge to the Bass Lake chain are as follows:

- Maple Grove – MS400102
- Plymouth – MS400112
- Hennepin County – MS400138
- MnDOT Metro District – MS400170

Storm sewer information was used to develop the lakeshed boundaries as shown in Figure 3.1. The following MS4s, while located in the Shingle Creek watershed, do not drain to the Bass Lake chain, and thus are not part of the Categorical Wasteload Allocation:

- Brooklyn Center – MS400006
- Brooklyn Park – MS400007
- Crystal – MS400012
- Minneapolis – MN0061018
- New Hope – MS400039
- Osseo – MS400043
- Robbinsdale – MS400046

4.3 NON-PERMITTED SOURCES

4.3.1 Atmospheric Deposition

Precipitation contains phosphorus that can ultimately end up in the lakes as a result of direct input on the lake surface or as a part of stormwater running off of impervious surfaces in the watershed. Although atmospheric inputs must be accounted for in development of a nutrient budget, direct inputs to the lake surface are impossible to control.

4.3.2 Internal Phosphorus Release

Internal phosphorus loading from lake sediments has been demonstrated to be an important aspect of the phosphorus budgets of lakes. However, measuring or estimating internal loads can be difficult. Large internal loads are the result of significant amounts of phosphorus in lake-bottom sediments that are released under specific conditions. Phosphorus can build up in lake-bottom sediments as part of the eutrophication process which can be accelerated and exacerbated by an increase in phosphorus load export from developing watersheds. Internal loading can be a result of sediment anoxia where poorly bound phosphorus is released in a form readily available for phytoplankton production. Internal loading can also result from sediment resuspension that may result from rough fish activity or prop wash from boat activity. Additionally, curly-leaf pondweed can increase internal loading because it senesces and releases phosphorus during the summer growing season (late June to early July). All of these factors affect internal phosphorus cycling in these lakes.

5.0 Assessment of Water Quality Data

5.1 INTRODUCTION

Water quality monitoring has been conducted in the Shingle Creek watershed since 1990 as a part of the CAMP program. Additionally, some cities have conducted monitoring on their own or as a partnership with the Three Rivers Park District. This section presents data for each of the lakes to characterize current conditions and diagnose key problems degrading current water quality.

5.2 PREVIOUS STUDIES AND MONITORING ON SCHMIDT, POMERLEAU AND BASS LAKES

5.2.1 Citizen Assisted Monitoring Program (CAMP) and Other Monitoring

All three lakes have been periodically monitored by volunteers sponsored and trained by the SCWMC through the Citizen Assisted Monitoring Program (CAMP) operated by Metropolitan Council Environmental Services (MCES). The CAMP program is a volunteer monitoring program where volunteers collect data and samples biweekly including samples for total phosphorus, total Kjeldahl nitrogen, and Secchi depth. The SCWMC has no professional monitoring program at this time. The City of Plymouth has worked cooperatively with the Three Rivers Park District to obtain occasional monitoring data on these lakes.

5.2.2 City of Plymouth Management Plans

As a part of its planning process, the City of Plymouth has conducted monitoring on Schmidt and Pomerleau Lakes through the Three Rivers Park District and private contractors. These efforts provide critical data including dissolved oxygen profiles, temperature profiles, and aquatic vegetation surveys. These data have been incorporated into the TMDL where appropriate.

5.2.3 Other Management Plans

The Bass Lake Improvement Association developed a management plan in 1982 and has been actively managing aquatic vegetation within the lake including the application of copper sulfate. However, it is important to note that the applications have been limited in area by DNR permits and do not constitute a lake-wide application.

The DNR also conducted a fisheries survey on the lake in 1991 that includes some limited water quality and vegetation data.

5.3 MONITORING PARAMETERS

5.3.1 Temperature and Dissolved Oxygen

Understanding lake stratification is important to the development of both the nutrient budget for a lake as well as ecosystem management strategies. Lakes that are dimictic (mix from top to bottom in the spring and fall) can have very different nutrient budgets than lakes that are completely mixed all year. Typically, temperature drives the stratification of a lake because water density changes with water temperature. However, the larger impact is usually a result of the dissolved oxygen profile. As cooler, denser water is trapped at the bottom of a lake, it can become devoid of oxygen affecting both aquatic organisms and the sediment biogeochemistry. Limited temperature and dissolved oxygen profile data suggest that Bass and Pomerleau Lakes are dimictic.

5.3.2 Phosphorus and Nitrogen

Lake algal production is typically limited by nutrient availability, specifically phosphorus and nitrogen. Minnesota lakes are almost exclusively limited by phosphorus; however excessive phosphorus can lead to nitrogen-limiting conditions. Phosphorus and nitrogen are measured to determine the availability of the nutrients for algal production. Dissolved and orthophosphorus are the most readily available forms of phosphorus while total phosphorus is a measure of all the phosphorus, bound and unbound. Nitrate is the most readily available form of nitrogen for algal production and total Kjeldahl nitrogen is a measure of all nitrogen in the water column.

5.3.3 Chlorophyll-a and Secchi Depth

Algal biomass can be measured directly by developing cell-by-cell counts and volumes. However, this is time-intensive and often expensive. Chlorophyll-a has been shown to be a representative estimation of algal biomass and is inexpensive and easy to analyze.

Secchi depth is also a predictor of algal production by measuring the clarity of lake water. This is accomplished by lowering a round disc shaded black and white over the shady side of the boat and recording the depth at which the disc is no longer visible.

5.4 LAKE MONITORING RESULTS

Following is a discussion of the lake monitoring results for Schmidt, Pomerleau, and Bass Lakes. The discussion is focused on specific monitoring years to present nutrient cycling dynamics in the lakes.

5.4.1 Schmidt Lake

5.4.1.1 Historical Data

Historical data for Schmidt Lake is presented in Table 5.1. In 2004, data was collected by the Three Rivers Park District as well as the CAMP program. Summer average total phosphorus concentrations ranged from 39 to 70 µg/L with summer averages typically better than the shallow lake standard of 60 µg/L. Chlorophyll-a data typically exceeded the State standard of 20 µg/L. Secchi depth typically met the shallow lake standard with the most recent data well above the 1 meter in depth standard. Historical data suggest that even though total phosphorus concentrations are typically good, severe algal blooms still occur.

Table 5.1. Historical summer average (June 1 through September 30) water quality conditions for Schmidt Lake.

Year	Total Phosphorus (µg/L)		Chlorophyll-a (µg/L)		Secchi Depth (m)	
	N	Mean	N	Mean	N	Mean
1994	10	50			12	1.5
1995			10	12	25	1.9
1996					17	1.6
1997					16	2.0
1998	8	70	8	28	8	1.4
1999					15	0.9
2000	8	55	8	28	16	1.0
2001	8	58	8	30	16	1.0
2002						
2003					16	1.3
2004*	7	68	7	20	7	2.0
2005*	8	52	8	15	8	2.6
2006						
2007	7	28	7	4	7	2.8
Average		54		20		1.6
Standard	60 or less		20 or less		1.0 or greater	

N=number of samples taken
*Three Rivers Park District data

5.4.1.2 Temperature and Dissolved Oxygen

Temperature and dissolved oxygen data were collected for Schmidt Lake in 2004 and 2005. Schmidt Lake demonstrated stratification with anoxia measured as shallow as 6 feet. This suggests that anoxia occurred in the shallow, weakly stratified areas of the lake. Due to the weak stratification, the phosphorus-rich water mixes easily into the photic zone of the lake. Temperature and dissolved oxygen conditions in Schmidt Lake demonstrate the potential for internal loading of phosphorus.

5.4.1.3 Phosphorus

Total phosphorus concentrations in 2004 and 2005 were typically 40 to 50 µg/L with a peak in mid-July to mid-August (see Figure 5.1 and Figure 5.2). Total phosphorus concentrations do not appear to vary with precipitation, however, both peaks occurred following drier periods suggesting internal loading may be causing the increase. Additionally, both peaks occurred in midsummer when anoxia occurred over the bottom sediments. Schmidt Lake demonstrates stratification in the summer. Because of the shallowness of Schmidt Lake, much of the sediment-released phosphorus may reach the water column prior to fall turnover.

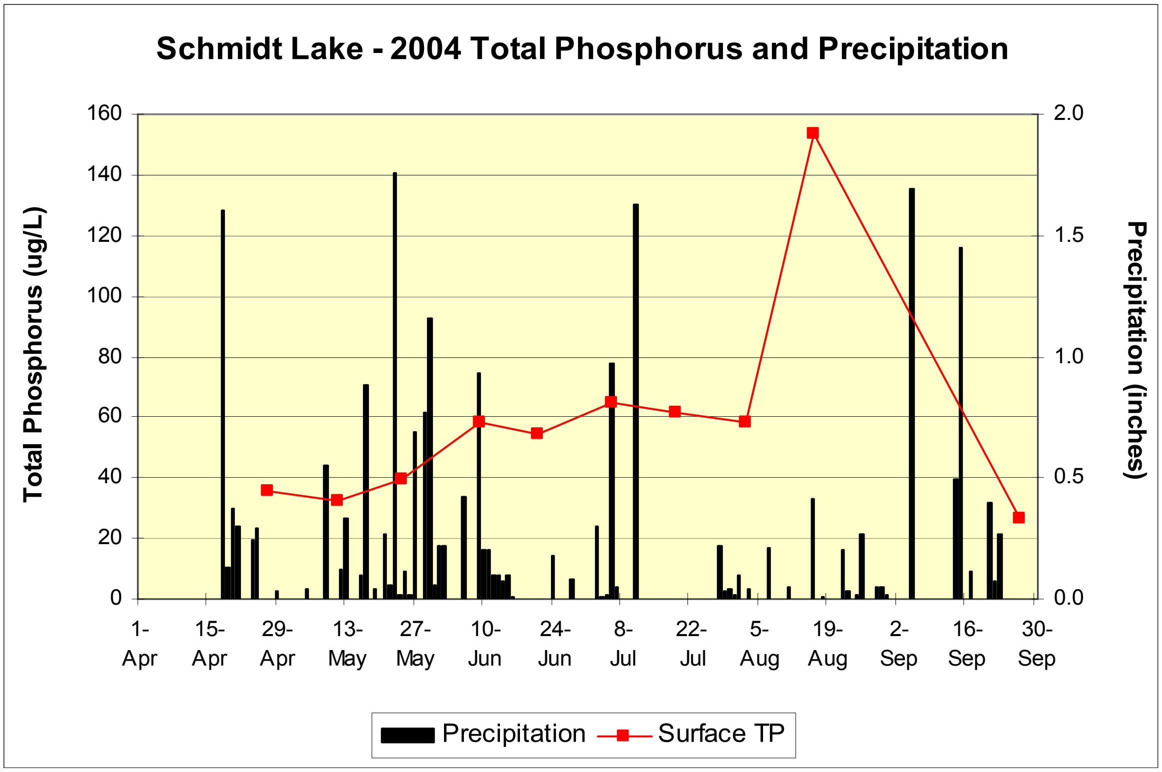


Figure 5.1. Surface total phosphorus concentrations and total precipitation for Schmidt Lake, summer 2004.

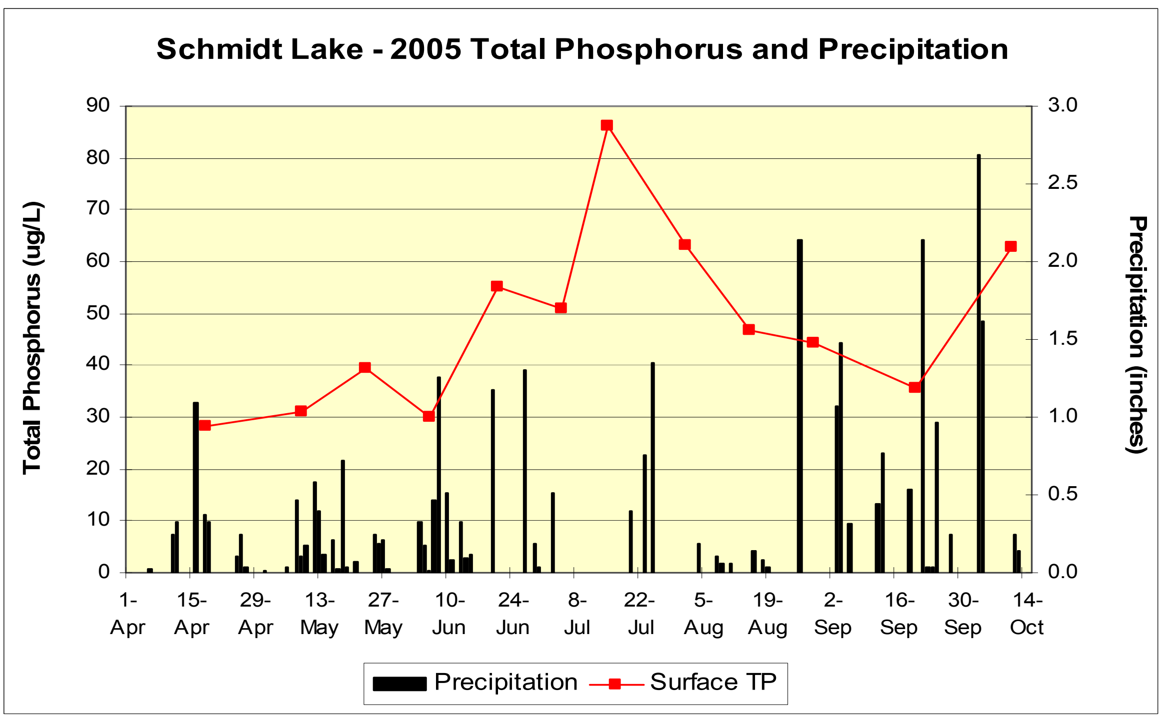


Figure 5.2. Surface total phosphorus concentrations and total precipitation for Schmidt Lake, summer 2005.

5.4.1.4 Chlorophyll-a

In 2004, Schmidt Lake demonstrated severe algal blooms in late June and early July lasting approximately one month. In 2005, chlorophyll concentrations were less severe, typically hovering around 20 µg/L.

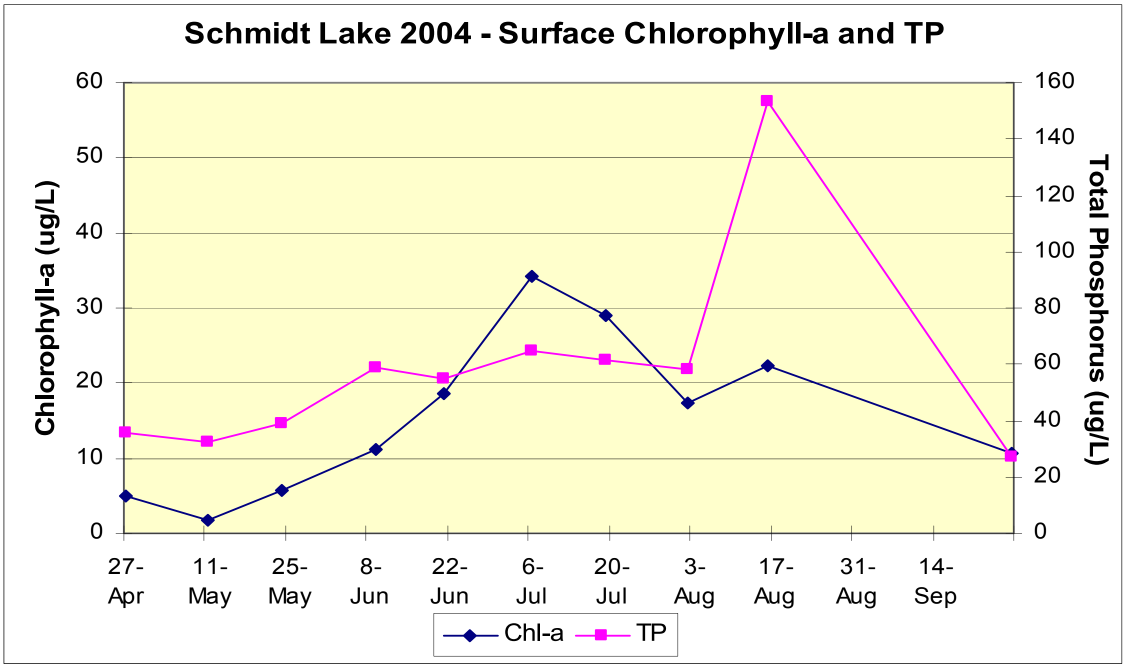


Figure 5.3. Surface chlorophyll-a and phosphorus concentrations in Schmidt Lake, summer 2004.

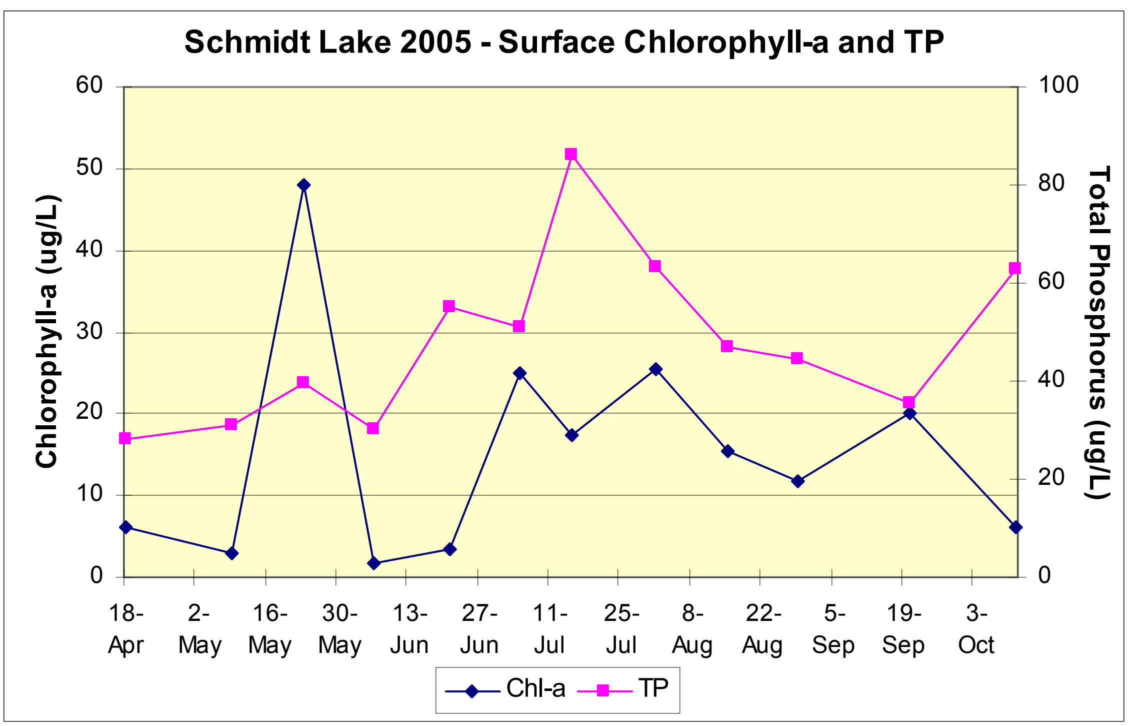


Figure 5.4. Surface chlorophyll-a and phosphorus concentrations in Schmidt Lake, summer 2005.

5.4.2 Pomerleau Lake

5.4.2.1 Historical Data

Only two good years of data were available for Pomerleau Lake - 1996 and 1999. Other years had too few observations to develop conclusions. Both of these years demonstrate exceedance of the State standards for total phosphorus, chlorophyll-a, and Secchi depth (1996 only).

Table 5.2. Historical summer average (June 1 through September 30) water quality conditions for Pomerleau Lake.

	Total Phosphorus (µg/L)		Chlorophyll-a (µg/L)		Secchi Depth (m)	
Year	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**
1996	7	54	7	19	7	1.8
1999	9	91	9	23	9	1.3
2001	4	73	4	39	4	1.3
2003	2	69	2	62	2	1.5
Average		74		28		1.5
Standard	40 or less		14 or less		1.4 or greater	

N=number of samples taken

5.4.2.2 Temperature and Dissolved Oxygen

Only one temperature and dissolved oxygen profile was available for Pomerleau Lake (Figure 5.5). The lake demonstrated stratified conditions with anoxia occurring as shallow as 13 feet.

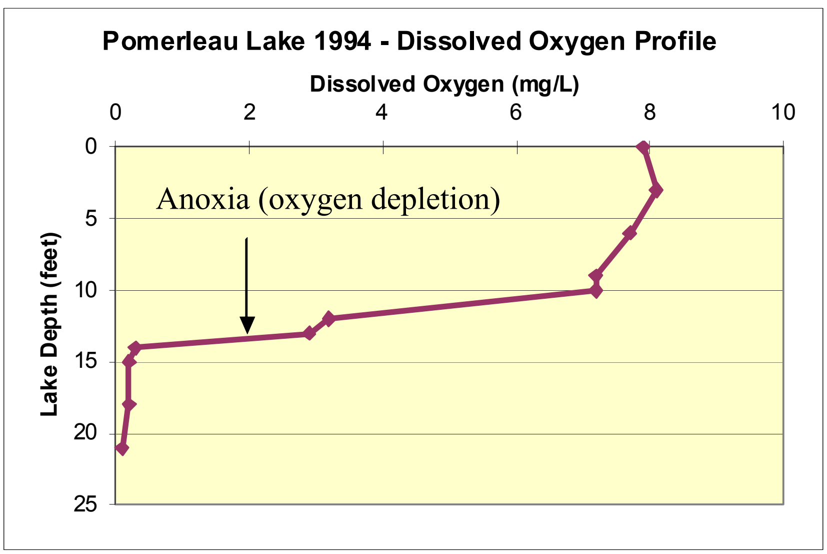


Figure 5.5. Dissolved oxygen profile of Pomerleau Lake.

5.4.2.3 Phosphorus

Total phosphorus concentrations were fairly constant throughout the summer period with increasing concentrations during the late summer to early fall period. The increase in total phosphorus is likely a result of a deepening thermocline and mixing of phosphorus-rich water into the surface waters. In 2001, high concentrations were in midsummer following a dry period, suggesting internal loading may be occurring.

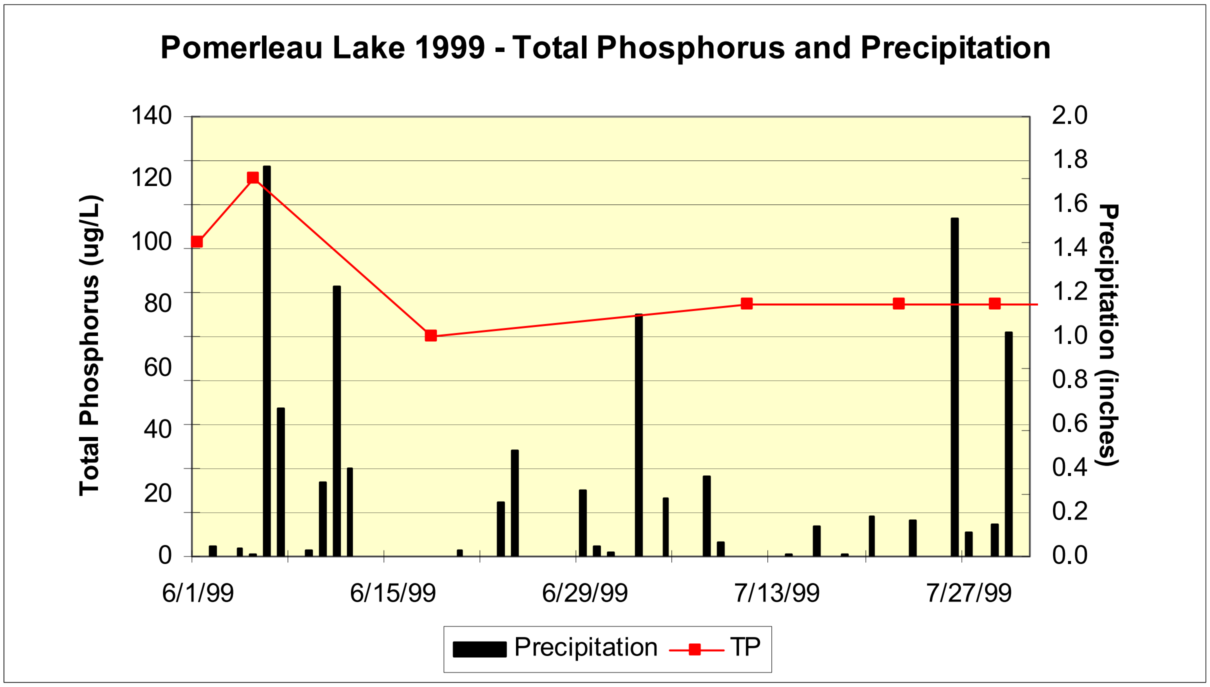


Figure 5.6. Surface total phosphorus and total precipitation for Pomerleau Lake, summer 1999.

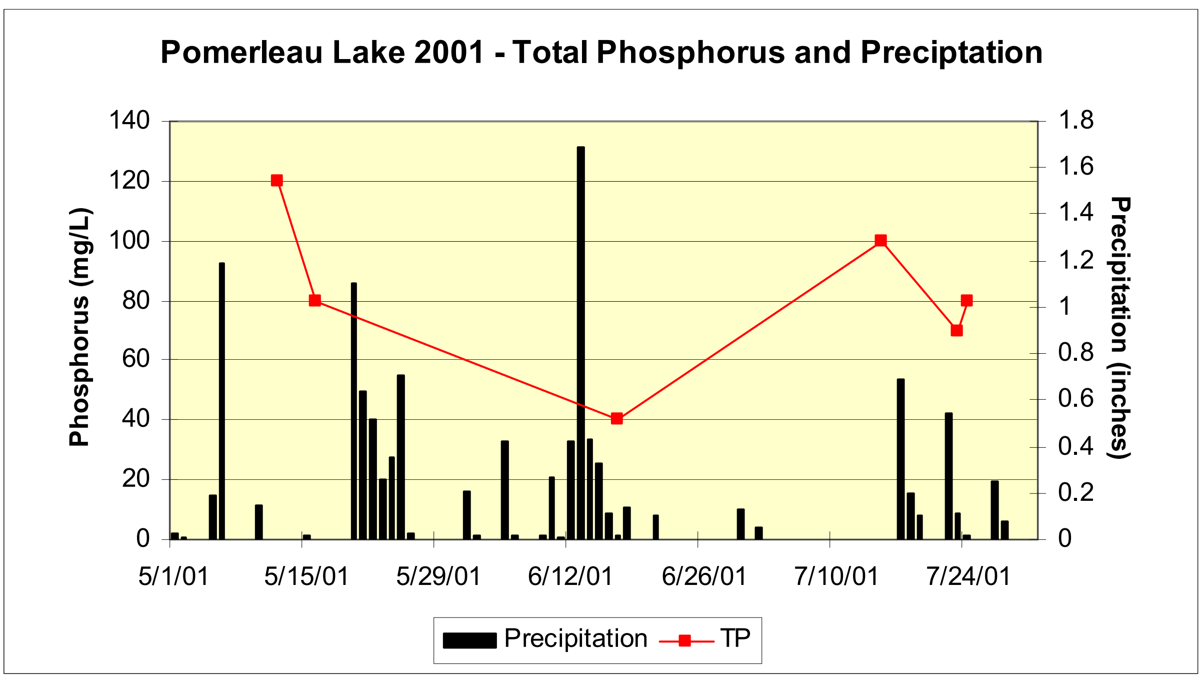


Figure 5.7. Surface phosphorus and total precipitation for Pomerleau Lake, summer 2001.

5.4.2.4 Chlorophyll-a

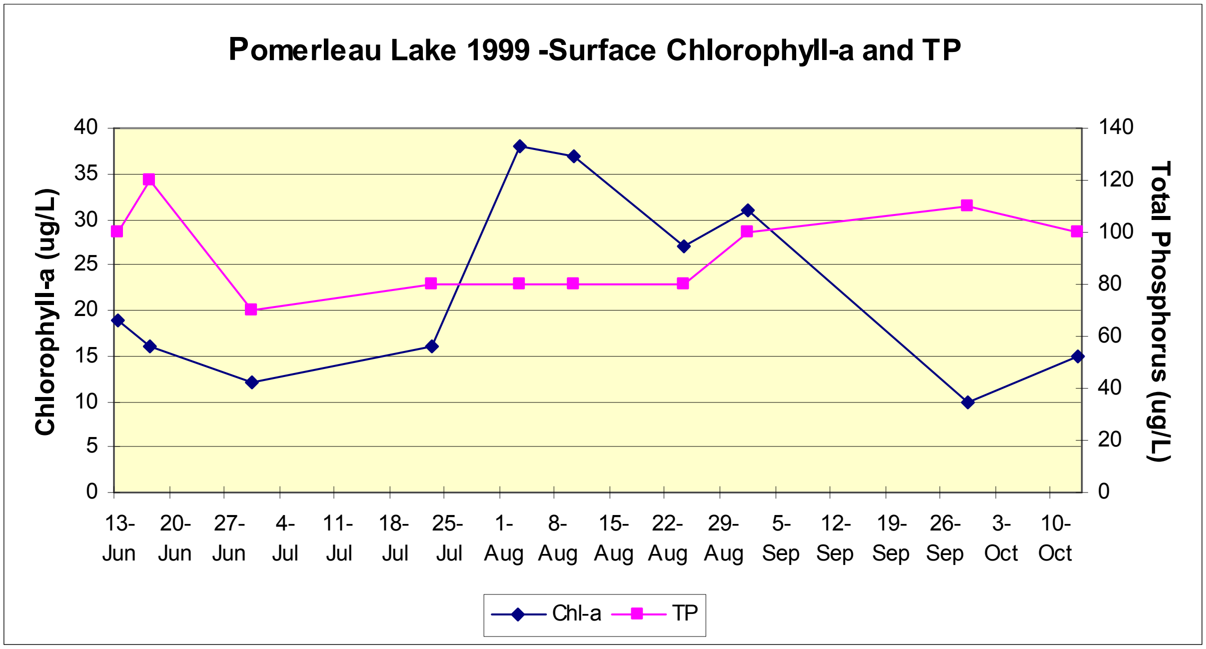


Figure 5.8. Surface chlorophyll-a and phosphorus concentrations in Pomerleau Lake, summer 1999.

In 1999 (Figure 5.8), Pomerleau Lake demonstrated severe algal blooms in August lasting approximately one month. In 2001 (Figure 5.9), the limited data indicate what appears to be an onset of another late summer algae bloom.

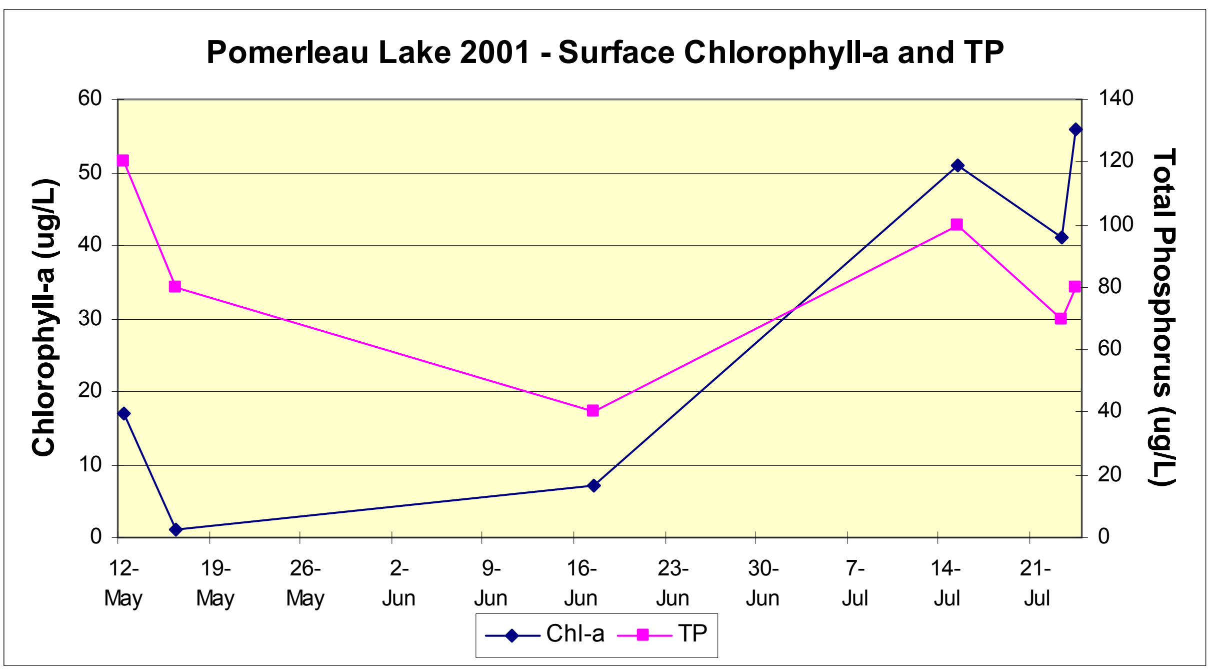


Figure 5.9. Surface chlorophyll-a and phosphorus concentrations in Pomerleau Lake, summer 2001.

5.4.3 Bass Lake

5.4.3.1 Historical Data

Historical summer averages for Bass Lake are presented in Table 5.3. Total phosphorus concentrations have been variable, in some years exceeding the State standards, and some years better than the State standard. Chlorophyll concentrations, however, were much more severe, with summer averages in the last ten years reaching 41 µg/L. Secchi depth appears to have improved significantly since the 1970s, and currently meets or is just less than the shallow lake standard of greater than one meter. Bass Lake does not consistently meet the State standards for at least two of the parameters, thus the Impaired Water listing.

Table 5.3. Historical summer average (June 1 through September 30) water quality conditions for Bass Lake.

	Total Phosphorus (µg/L)		Chlorophyll-a (µg/L)		Secchi Depth (m)	
Year	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**
1973					13	0.8
1974					14	0.7
1980	4	75	4	58	18	0.8
1994	12	47	12	26	12	1.6
1997	9	57	9	28	9	1.7
1998					9	1.0
1999	11	49	11	26	11	1.2
2000					12	1.5
2001	9	64	9	44	14	1.4
2002					11	1.6
2003	4	76	5	46	5	1.1
2004						
2005	10	74	10	57	10	1.1
2006						
2007	8	77	7	67	8	0.8
Average		62		41		1.2
Standard	60 or less		20 or less		1.0 or greater	

N=number of samples taken

5.4.3.2 Temperature and Dissolved Oxygen

The only temperature and dissolved oxygen profile data available for Bass Lake was collected in 1980 (Figure 5.10). These data demonstrate weak temperature stratification and anoxia as shallow as 9 feet in depth. These conditions demonstrate a strong potential for internal loading in Bass Lake.

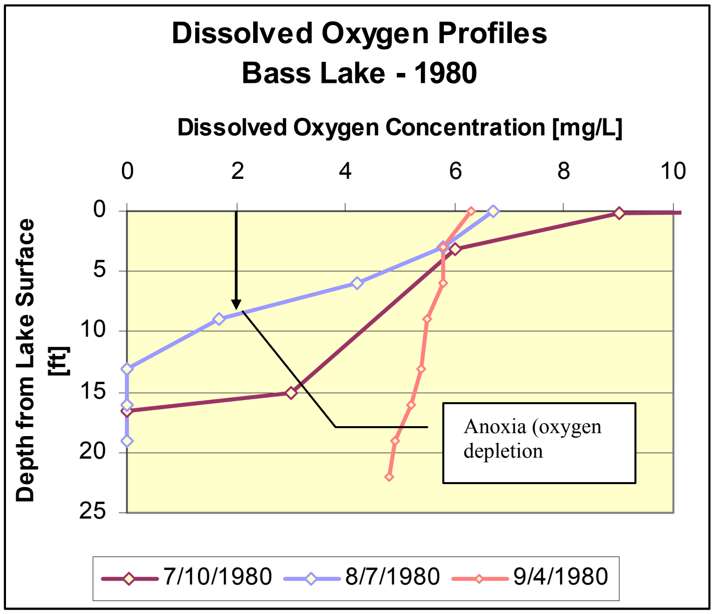


Figure 5.10. Dissolved oxygen profiles for Bass Lake in 1980.

5.4.3.3 Phosphorus

Total phosphorus concentrations in Bass Lake increased during the summer months (June and July) in both 1999 and 2001. No apparent patterns with precipitation exist. Total phosphorus concentrations peaked in late summer. Although the summer average concentration was below the State standard for shallow lakes, total phosphorus concentrations during late July and August were close to the standard, resulting in late summer severe algal blooms.

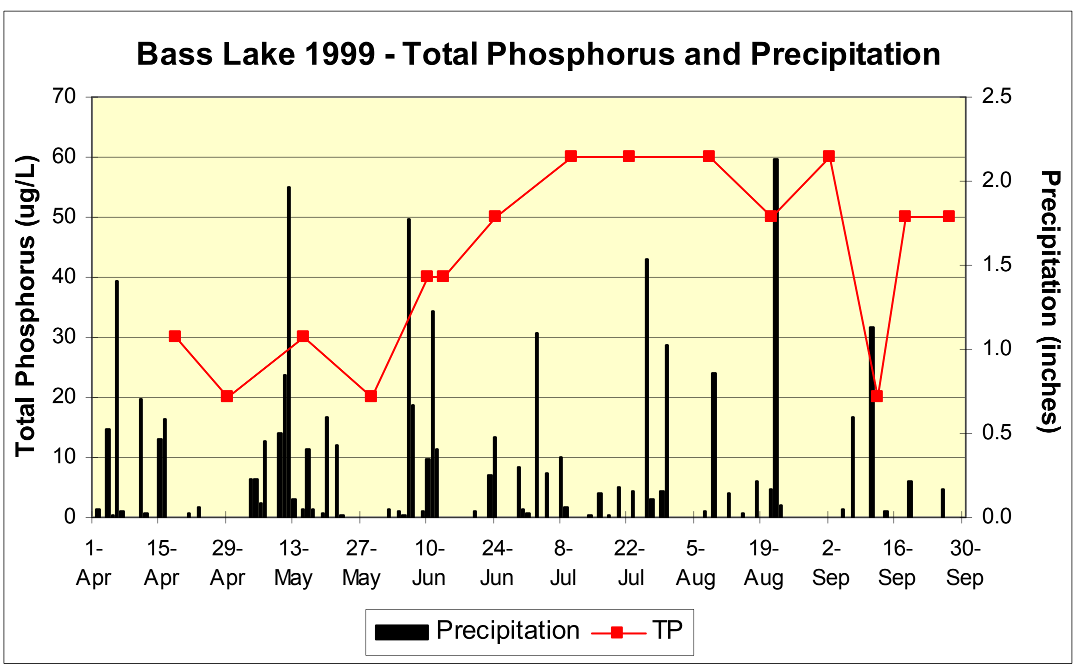


Figure 5.11. Surface total phosphorus and total precipitation for Bass Lake, summer 1999.

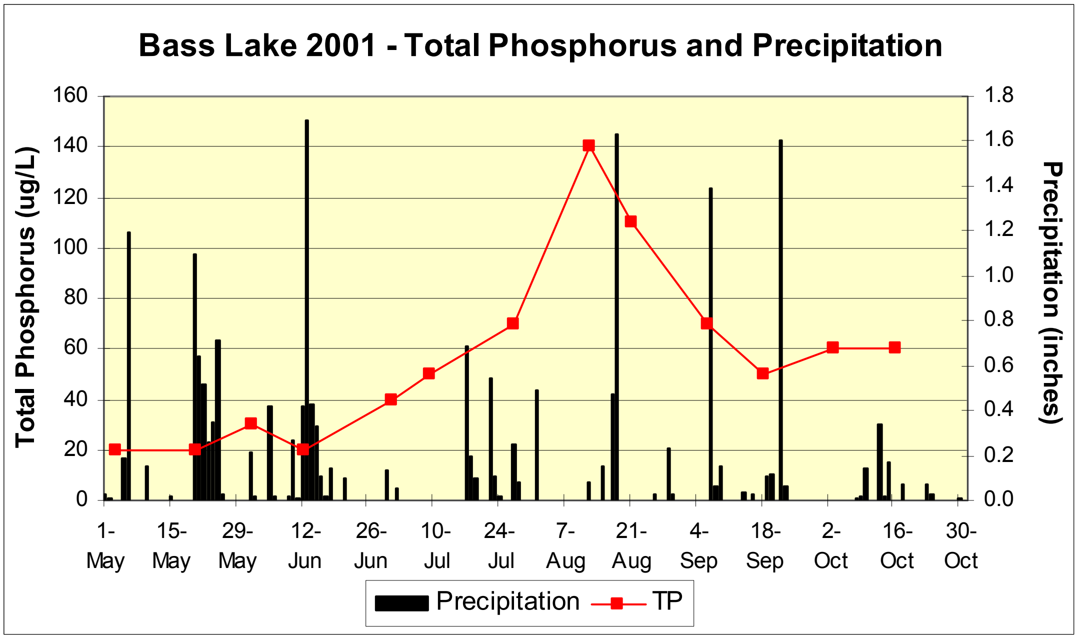


Figure 5.12. Surface total phosphorus and total precipitation for Bass Lake, summer 2001.

5.4.3.4 Chlorophyll-a

Chlorophyll-a concentrations in Bass Lake track well with total phosphorus concentrations, with peak blooms occurring late in the summer associated with the late season total phosphorus peak. Severe algal blooms in 1999 and 2001 occurred throughout the summer with chlorophyll-a concentrations above 20 µg/L during most of the summer.

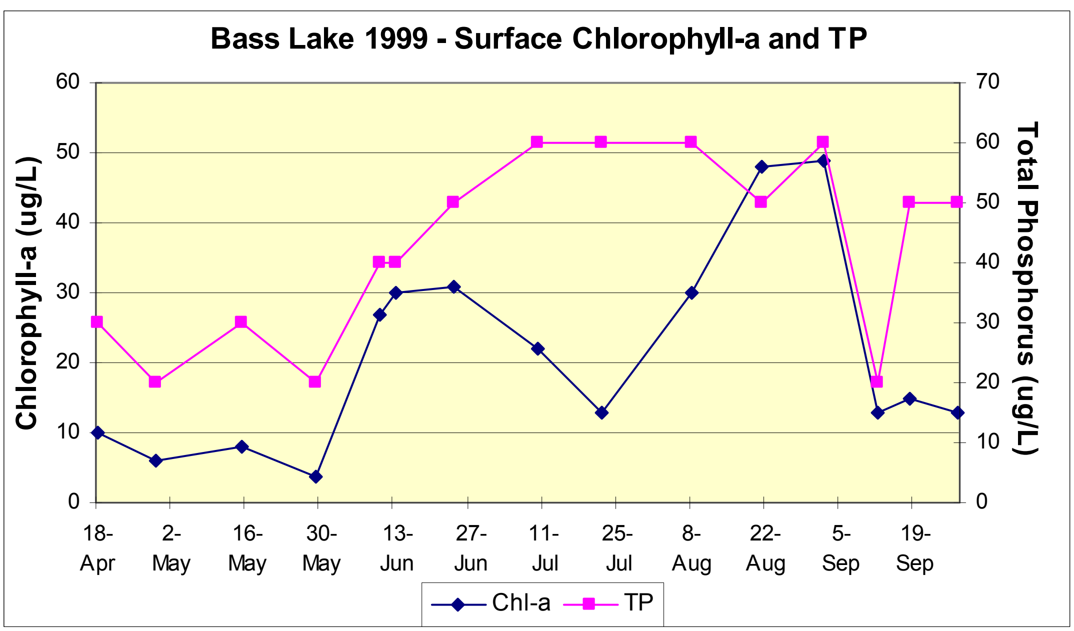


Figure 5.13. Surface chlorophyll-a and phosphorus concentrations in Bass Lake, summer 1999.

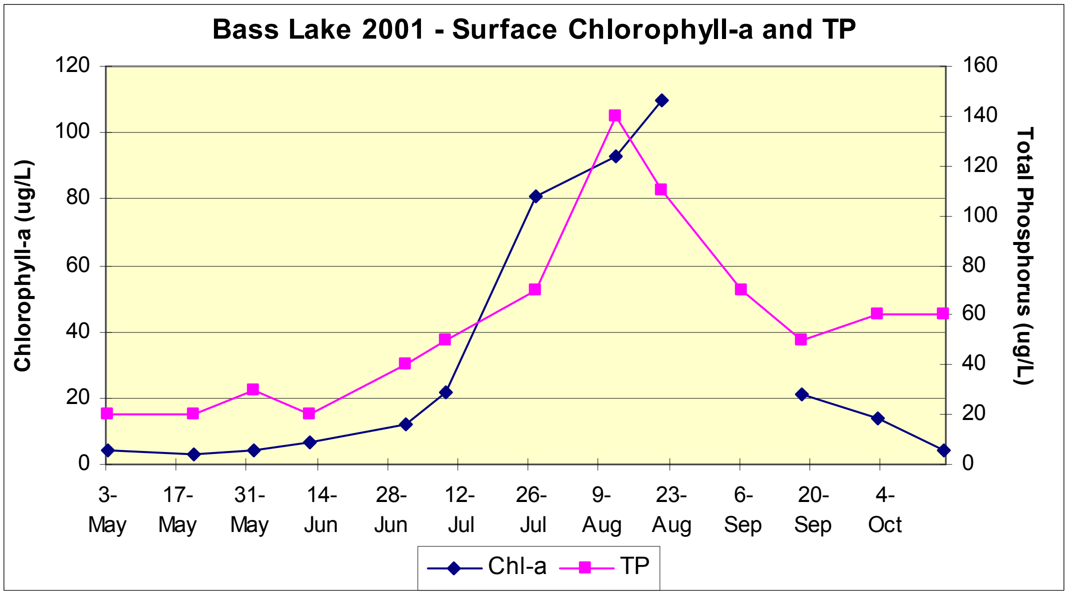


Figure 5.14. Surface chlorophyll-a and phosphorus concentrations in Bass Lake, summer 2001.

5.5 CONCLUSIONS

No clear patterns were present in Schmidt Lake; however, severe algal blooms occurred even though total phosphorus concentrations were typically around 60 µg/L.

No clear patterns were present in the Pomerleau Lake data. Total phosphorus concentrations were high throughout the summer season.

Bass Lake demonstrated mid and late summer severe algal blooms as a result of increasing phosphorus concentrations throughout the summer. The cause of the steady phosphorus concentrations throughout the summer is unclear, however, the presence of carp and curly-leaf pondweed likely contribute to the issue.

6.0 Linking Water Quality Targets and Sources

6.1 INTRODUCTION

A detailed nutrient budget for Schmidt, Pomerleau and Bass Lakes can be a useful tool for identifying management options and their potential effects on water quality. Additionally, lake response models can be developed to understand the response of other variables such as chlorophyll-a and Secchi depth. Through this knowledge managers can make educated decisions about how to allocate restoration dollars and efforts as well as the resultant effect of such efforts.

6.2 SELECTION OF MODELS AND TOOLS

Modeling was completed using three independent platforms including SWMM, P8, and model equations extracted from BATHTUB.

The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. SWMM calculates stormwater runoff by catchment area, and routes it through pipes, channels, and storage/treatment devices, tracking the quantity and quality of runoff generated within each subcatchment. SWMM was first developed in 1971, and is widely used throughout the world (http://www.epa.gov/ednnrmrl/models/swmm/index.htm).

P8 (Program for Predicting Polluting Particle Passage through Pits, Puddles, & Ponds) is a public domain (http://wwwalker.net/p8/), industry standard model developed to assess pollutant loading in urban watersheds. P8 was developed using National Urban Runoff Program (NURP) data and provides loading estimates based on data collected as a part of the NURP program.

The U.S. Army Corps of Engineers' BATHTUB model predicts eutrophication-related water quality conditions (e.g., phosphorus, nitrogen, chlorophyll-a, and transparency) using empirical relationships previously developed and tested for reservoir applications. The Canfield-Bachmann natural lake model, which was developed for northern temperate lakes, was selected from the suite of BATHTUB relationships to model lake phosphorus concentration response. Other models from the suite were used to predict chlorophyll-a and transparency.

SWMM was used to develop watershed hydraulics and runoff volumes through calibration to collected data. The P8 model was subsequently calibrated to match the watershed runoff volumes developed from the SWMM model. Watershed loads were calculated using P8 (50^{th} percentile particle file) for each of the subwatersheds. Watershed loads were entered into the BATHTUB model equations in a spreadsheet to predict lake effects.

6.2.1 SWMM Modeling

The Shingle Creek Watershed Management Commission developed the XP-SWMM model during the development of the *Shingle Creek Chloride TMDL* (Wenck 2007). The calibrated model was used to predict annual runoff volumes for each lake watershed. More details on the calibration of the XP-SWMM model can be found in the Shingle Creek Chloride TMDL report (http://www.pca.state.mn.us/water/tmdl/project-shinglecreek-chloride.html).

6.2.2 P8 Modeling

Watershed loads were estimated using the P8 model for urban watersheds (Walker 1990). The model is based on National Urban Runoff Program studies and is widely used in the State of Minnesota for assessing runoff from urban watersheds. The P8 model was calibrated to match annual runoff volumes predicted by the calibrated XP-SWMM model as reported in the *Shingle Creek Chloride TMDL* (Wenck 2007). No ponds or wetlands were explicitly included in the model, but since the model is calibrated to in-lake data, it implicitly reflects all the BMPs in place in the watershed at the time the data was collected. Some of the lake load is a result of internal loading, which has been estimated externally of the model. The P8 results give a relative sense of watershed nutrient dynamics and provide a tool for future evaluation of watershed BMPs.

6.3 CURRENT PHOSPHORUS BUDGET COMPONENTS

A phosphorus budget that sets forth the current phosphorus load contributions from each potential source was developed using the modeling and collected data described above. Following is a brief description of the budget components and how these values were developed.

6.3.1 Tributary or Watershed Load

The tributary load from stormwater runoff from the watershed was developed using the P8 model calibrated to the SWMM runoff volumes (see Section 6.2). Particle data that represents the median for particle sedimentation developed during the National Urban Runoff Program studies was used for development of the loads. P8 results are shown in Appendix A for each lake.

6.3.2 Atmospheric Load

Atmospheric inputs of phosphorus from wet and dry deposition are estimated using rates set forth in the MPCA report "Detailed Assessment of Phosphorus Sources to Minnesota Watersheds," (Barr Engineering, 2004) and are based on annual precipitation. The values used for dry (< 25 inches), average, and wet precipitation years (>38 inches) for atmospheric deposition are 24.9, 26.8, and 29.0 kg/km^2-year, respectively. The atmospheric load (kg/year) for each lake was calculated by multiplying the lake area (km^2) by the atmospheric deposition rate (kg/km^2-year). The watershed is small enough that it is unlikely that there are significant geographic differences in rainfall intensity and amounts across the watershed.

Table 6.1. Estimated total phosphorus load from atmospheric deposition by lake.

Lake	Lake Area (km^2)	TP Deposition Rate ($kg/km^2/yr$)	Annual Atmospheric Load (kg)
Pomerleau	0.12	26.8	3.2
Schmidt	0.15	26.8	4.0
Bass	0.78	26.8	20.9

6.3.3 Internal Loads

Internal phosphorus loading from lakes has been demonstrated to be an important aspect of the phosphorus budgets of lakes. However, measuring or estimating internal loads can be difficult, especially in shallow lakes that may mix many times throughout the year. Internal loads were estimated independently for each of the basins. Two methods were used to calculate internal loads for the lakes. The first method applied was to calculate a mass balance change at fall turnover. The change in the total phosphorus concentration was assumed to be a direct result of hypolimnetic phosphorus mixing with epilimnetic water at turnover. The second method applies an anoxic factor (Nürnberg 2004), which estimates the period where anoxic conditions exist over the sediments. In the case of shallow lakes, this can be estimated from lake geomorphology and lake TP concentrations (Nürnberg 2004). The anoxic factor is expressed in days but is normalized over the area of the lake. For example, if the depth of oxygen depletion (<2 mg/L D.O.) was 6 meters, then the number of days was multiplied by the anoxic area at that depth and divided by the entire area of the lake. A release rate was then selected based upon the eutrophic state of the lake. The selected release rates were a range based on previous lake studies (Nürnberg 1997, Figure 6-1).

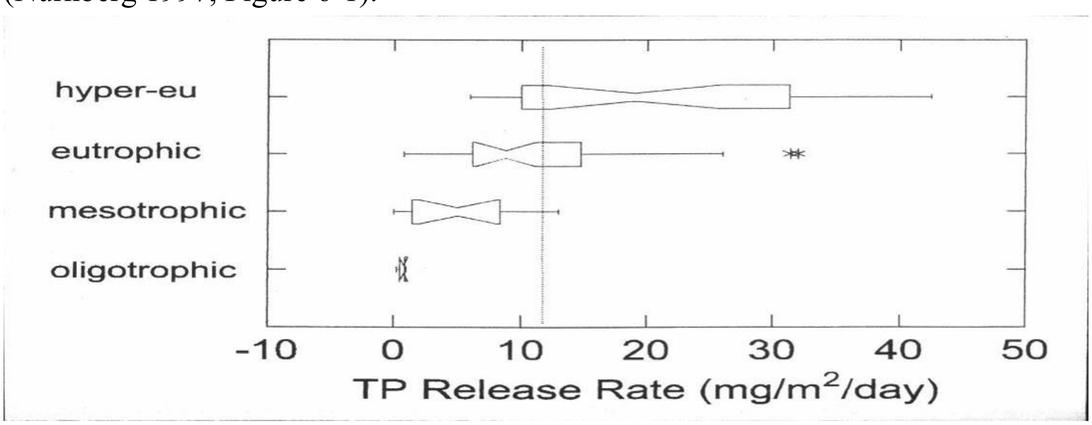


Figure 6.1. Sediment phosphorus release rates by trophic condition (Nürnberg 1997).

However, it is important to note that these estimates are used to give an estimate of the role of internal loading in lakes. The Canfield-Bachmann model used to estimate lake response in this TMDL is based on empirical relationships with lakes that demonstrate some internal loading. Consequently, the external load estimated is partially in lieu of internal loading. As an additional margin of safety, this TMDL is developed with load reductions applied to the watershed to meet the standard and a load reduction estimated for the internal loading.

6.3.3.1 Schmidt Lake Internal Loads

Mass balance changes at fall turnover resulted in an estimated internal load of 7 to 24 kilograms, as shown in Table 6.2 below.

Table 6.2. Results of the mass balance at fall turnover for Schmidt Lake.

Date	TP (µg/L)	Volume (m^3)	TP Mass (kg)	TP Internal Load (kg)
8/2/2004	58	248,953	14.4	24
8/16/2004	154	248,953	38.3	
9/20/2005	36	248,953	9.0	7
10/11/2005	63	248,953	15.7	

An anoxic factor was calculated for 2004 and 2005 using dissolved oxygen profile data collected by the Three Rivers Park District on behalf of the City of Plymouth (Table 6.3). Using this methodology, the internal load was estimated between 17 and 53 kg. An alternative approach is to calculate an anoxic factor using the water quality and morphology of the lake (Nürnberg 2004). This estimated a much longer anoxic period and resulted in an internal load estimate of 40 to 101 kilograms of phosphorus. However, in-lake monitoring data and the P8 modeled watershed load suggest that the actual internal load is less than that estimate. Schmidt Lake has the *potential* to have a significant internal load that could increase in-lake phosphorus concentrations during the summer.

Table 6.3. Results of the internal load assessment using an anoxic factor and release rate for Schmidt Lake.

Year	Release Rate ($mg/m^2/day$)[1]	Anoxic Factor (days)[2]	Gross Load ($mg/m^2/summer$)	Gross Load (kg)
2004	6	19	117	17
	9	19	175	26
	15	19	292	43
2005	6	24	143	21
	9	24	215	32
	15	24	358	53
Shallow Lake[3]	6	46	274	40
	9	46	411	61
	15	46	686	101

[1]Estimated from Figure 6-1 Nürnberg 1997).
[2]Calculated from dissolved oxygen profiles.
[3]Anoxic factor predicted based on lake phosphorus concentration and lake morphology.

For purposes of establishing the current phosphorus budget, the internal load was estimated by difference. The BATHTUB model was used to estimate the total load corresponding to the observed in-lake total phosphorus concentrations for 1999 and 2001. The P8 watershed load and the estimated atmospheric load were subtracted from the total to obtain the internal load. This process was done iteratively until an internal load of 5.5 kg/year was found to result in a good model fit for both years (see Appendix A for BATHTUB output).

6.3.3.2 Pomerleau Lake Internal Loads

Little data was available for estimating internal loads in Pomerleau Lake. The lake does demonstrate summer stratification and anoxia over bottom sediments. However, there is little or no change in total phosphorus concentrations at fall turnover, suggesting that the internal load during that period is relatively small in comparison to the lake volume (Table 6.4).

Table 6.4. Results of the mass balance at fall turnover for Pomerleau Lake.

Date	TP (μg/L)	Volume (m^3)	TP Mass (kg)	TP Internal Load (kg)
9/15/1996	40	405,862	16.2	4
9/27/1996	50	405,862	20.3	
9/1/1999	100	405,862	40.6	4
9/29/1999	110	405,862	44.6	

Based on a dissolved oxygen profile collected in 1994, an anoxic factor was estimated using an estimated 60-day period of anoxia over approximately 9 acres. That anoxic factor and a release rate of 6 mg/m^2/summer (approximately the mid point of release rates observed in mesotrophic lakes) was used to estimate an internal load of 13.1 kg/year.

6.3.3.3 Bass Lake Internal Loads

No dissolved oxygen profile data was available for Bass Lake to develop an anoxic factor. To estimate the anoxic factor, the shallow lake equation was applied to the lake (Nürnberg 2004). However, since Bass Lake is a deeper shallow lake, this is likely an overestimate of the anoxic period and internal load. Based on these data, Bass Lake has the potential to demonstrate internal loads ranging from 104 to 518 kilograms during the summer period (see Table 6.5). Since greater than 80% of the lake area is 15 feet in depth, a healthy native plant community would likely mitigate much of this internal loading. Because the P8 estimated watershed loads were high for Bass Lake, the internal load was assumed to be minimal. However, data suggest that under certain environmental conditions internal loading does occur in the lake.

Table 6.5. Results of the internal load assessment using an anoxic factor and release rate for Bass Lake.

Year	Release Rate (mg/m^2/day)[1]	Anoxic Factor (days)	Gross Load (mg/m^2/summer)	Gross Load (kg)
Shallow Lake[2]	3	44	132	104
	9	44	397	311
	15	44	662	518

[1]Estimated from Figure 6-1 (Nürnberg 1997).
[2]Anoxic factor predicted based on lake phosphorus concentration and lake morphology.

6.3.4 Lake Exchange

Lakes or bays can exchange nutrients through either advective exchange (water moving through) or diffusive exchange (molecules moving along a gradient). Since each of these lakes is connected through channels and pipes, no diffusive change is occurring. However, nutrients exported from an upstream lake were routed to the downstream lake in their entirety as a conservative assumption. It is likely that some of these nutrients are lost prior to entering the downstream waterbody.

6.4 CURRENT PHOSPHORUS BUDGET

The current conditions phosphorus budget was developed using the P8 model results (Section 6.2), the internal load evaluation (Section 6.3.3) and the BATHTUB model. Phosphorus budgets were developed for 1999 and 2001 (Table 6.6) and averaged to obtain a current phosphorus budget.

Table 6.6. Current total phosphorus budget for Schmidt, Pomerleau, and Bass Lakes.

	Source	Source	1999 Annual TP Load (kg/yr)	2001 Annual TP Load (kg/yr)	Average Annual TP Load (kg/yr)
Schmidt Lake	Wasteload	Watershed Load	41.5	51.8	46.6
		Upstream Load	-	-	-
	Load	Atmospheric Load	4.0	4.0	4.0
		Internal Load	5.5	5.5	5.5
		TOTAL LOAD	**51.0**	**61.3**	**56.1**
Pomerleau Lake	Wasteload	Watershed Load	73.6	84.0	78.8
		Upstream Load	-	-	-
	Load	Atmospheric Load	3.2	3.2	3.2
		Internal Load	13.1	13.1	13.1
		TOTAL LOAD	**90.0**	**100.4**	**95.1**
Bass Lake	Wasteload	Watershed Load	495.7	664.4	580.1
		Upstream Load	50.5	61.7	52.7
	Load	Atmospheric Load	20.9	20.9	20.9
		Internal Load	<1.0	<1.0	1.0
		TOTAL LOAD	**567.1**	**747.0**	**654.7**

The budget suggests that external load is the driving force in each of these lakes. Partitioning between external and internal loads is difficult, especially with the limited data sets available for these lakes. Rather, evidence is presented for the role of an internal load in these lakes. In all three of these lakes, internal load is likely secondary to the watershed loads. However, once target watershed loads have been met, the internal load will need to be re-evaluated.

6.5 WATER QUALITY RESPONSE MODELING

The BATHTUB model was developed using the P8 loads and runoff volumes. Two years were modeled to validate the assumptions of the model. Several models (subroutines) are available for use within the BATHTUB model. The selection of the subroutines is based on past experience in modeling lakes in Minnesota and is focused on subroutines that were developed based on data from natural lakes. The Canfield-Bachmann natural lake model was chosen for the phosphorus model. Since channels and pipes connect the lakes, diffusive exchange of nutrients is expected to be minimal. The model was set so that no diffusive exchange would occur. The chlorophyll-a response model used was model 1 from the BATHTUB package, which accounts for nitrogen, phosphorus, light, and flushing rate. Secchi depth was predicted using the VS, CHLA &

TURBIDITY equation. For more information on these model equations, see the BATHTUB model documentation (Walker 1999). Model coefficients are also available in the model for calibration or adjustment based on known cycling characteristics. The coefficients were left at the default values except for the Secchi/chl-a slope, which was decreased from 0.025 to 0.015 based on the relationship from Minnesota lakes (MPCA 2004). No initial calibration factors were applied to any of the lakes except for the export of phosphorus from upstream lakes if they exist in the watershed.

6.5.1 Fit of the Model

Model fit for each of the lakes is presented in Tables 6.7, 6.8, and 6.9. The model fits reasonably well for both 1999 and 2001 for all of the lakes. The model over-predicted phosphorus in Bass Lake, which may be a result of directly including loads from the outfalls of both Schmidt and Pomerleau Lakes. Discharge from both of these lakes travels a considerable distance prior to reaching Bass Lake –particularly Pomerleau Lake which is conveyed through Bass Creek - and much of the phosphorus may be attenuated prior to reaching the lake.

Table 6.7. Model fit for Schmidt Lake.

Year	Variable	Predicted Mean	Observed Mean
2001	Total Phosphorus (µg/L)	62	58
	Chlorophyll-a (µg/L)	30	30
	Secchi Depth (meters)	1.0	1.0
1999	Total Phosphorus (µg/L)	60	55
	Chlorophyll-a (µg/L)	29	28
	Secchi Depth (meters)	1.2	1.3

Table 6.8. Model fit for Pomerleau Lake.

Year	Variable	Predicted Mean	Observed Mean
2001	Total Phosphorus (µg/L)	75	73
	Chlorophyll-a (µg/L)	39	39
	Secchi Depth (meters)	1.3	1.3
1999	Total Phosphorus (µg/L)	78	91
	Chlorophyll-a (µg/L)	35	23
	Secchi Depth (meters)	1.1	1.3

Table 6.9. Model fit for Bass Lake.

Year	Variable	Predicted Mean	Observed Mean
2001	Total Phosphorus (µg/L)	72	64
	Chlorophyll-a (µg/L)	36	44
	Secchi Depth (meters)	1.6	1.4
1999	Total Phosphorus (µg/L)	66	49
	Chlorophyll-a (µg/L)	32	27
	Secchi Depth (meters)	1.1	1.2

6.6 CONCLUSIONS

6.6.1 Schmidt Lake

Schmidt Lake appears to exceed state shallow lake TP standards mainly in wet precipitation years. Estimated internal loads demonstrate the potential for internal loading to account for 10 to 50% of the overall load in Schmidt Lake. Only small external phosphorus load reductions are required for the Schmidt Lake watershed and management should focus on in-lake controls to address the severe algae blooms that occur even when the TP standard is met. Additional data is necessary to adequately characterize internal loads.

6.6.2 Pomerleau Lake

Pomerleau Lake water quality is likely controlled by watershed runoff; however, the lake does have the potential for internal loading. Presently, the internal load appears to be small. An imbalanced fishery is likely contributing to the algal blooms, which are often higher than expected based on the total phosphorus concentrations. Restoration efforts should focus on the external loads and restoring a balanced fishery. Additional data is necessary to adequately characterize internal loads.

6.6.3 Bass Lake

Bass Lake has reasonably good water quality, yet experiences severe algal blooms. Although watershed controls are the biggest need, it may be necessary to also implement in-lake controls. The lake demonstrates some internal loading; however, it is difficult to determine its role in water quality. Consequently, restoration efforts should focus on controlling the external load while reestablishing the biological integrity of the lake. Additional data is necessary to adequately characterize internal loads.

7.0 TMDL Allocation

7.1 LOAD AND WASTELOAD ALLOCATIONS

Nutrient loads in this TMDL are set for phosphorus since this is typically the limiting nutrient for nuisance aquatic plants. This TMDL is written to solve the TMDL equation for numeric targets of 40 µg/L of total phosphorus for Pomerleau Lake and 60 µg/L of total phosphorus for Bass and Schmidt Lakes. This TMDL presents load and wasteload allocations for each of these lakes and estimated load reductions to achieve those end points.

7.1.1 Allocation Approach

Stormwater discharges are regulated under the National Pollution Discharge Elimination System (NPDES), and are considered wasteloads. Because there is not enough information available to assign loads to individual permit holders, the Wasteload Allocations are combined in this TMDL as Categorical Wasteload Allocations (see Table 7.1) assigned to all permitted dischargers in the contributing watershed. There are no known industrial dischargers in the watershed. The pollutant load from construction stormwater is considered to be less than one percent of the TMDL and difficult to quantify. Consequently, the WLA also includes pollutant loading from construction stormwater sources.

The Load Allocation is allocated in the same manner as the WLA and includes atmospheric deposition and internal loading. Each permittee ("MS4") has committed to implement Best Management Practices (BMPs) to reduce nutrient loading to each lake. The MS4s cooperated in developing the TMDL and Implementation Plan and will continue to work together through the ongoing Commission Technical Advisory Committee (TAC) to identify and implement BMPs either individually or in collaboration. This collective approach allows for greater reductions for some permit holders with greater opportunity and less for those with greater constraints. The collective approach is to be outlined in an Implementation Plan. Construction stormwater activities are considered in compliance with provisions of the TMDL if they obtain a Construction General Permit under the NPDES program and properly select, install, and maintain all BMPs required under the permit, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit.

Table 7.1. Wasteload allocation by NPDES permitted facility for each lake.

NPDES Permit Number	Pomerleau	Schmidt	Bass
MS400102-Maple Grove	N/A	N/A	Categorical WLA
MS400112-Plymouth	Categorical WLA	Categorical WLA	Categorical WLA
MS400138-Hennepin	N/A	N/A	Categorical WLA
MS400170-MnDOT	N/A	N/A	Categorical WLA

N/A = Not applicable – does not drain to lake.

7.1.2 Critical Condition

The critical condition for these lakes is the summer growing season. Minnesota lakes typically demonstrate impacts from excessive nutrients during the summer recreation season (June 1 - September 30) including excessive algal blooms and fish kills. Lake goals have focused on summer-mean total phosphorus, Secchi transparency and chlorophyll-a concentrations, which have been linked to user perception (Heiskary and Wilson 2005). The lake response models have focused on the summer growing season as the critical condition. Also, these lakes tend to have relatively short residence times and, therefore, respond to summer growing season loads.

7.1.3 Allocations

The loading capacity is the total maximum daily load. The TMDL was developed using an inverted Canfield-Bachmann model to calculate the predicted load at the State total phosphorus standard. Hydrologic inputs were derived from P8 and XP-SWMM to determine residence time for each of the lakes. For Bass and Pomerleau Lakes, an average runoff year (1999) was selected to determine the loading capacity of the lake. Schmidt Lake appears to exceed the State standard only in wet years, so a wet year (2001) was selected to determine the loading capacity of the lake. Models and calculation details are provided in Appendix A.

The TMDL was apportioned into wasteload and load allocations as follows. Atmospheric deposition load was calculated as described in section 6.3.2. As atmospheric load is impossible to control on a local basis, no reduction in that source was assumed for the TMDL. For Pomerleau and Schmidt Lakes, an equal reduction approach was applied to the remaining watershed and internal load using the overall reduction required for the lakes to meet State standards, as shown in Appendix A.

For Bass Lake the TMDL includes a nominal 5.0 kg/year internal load. The load allocation is the sum of the internal and atmospheric load. The wasteload allocation was then calculated as the difference between the TMDL and the load allocation. The load from upstream lakes was calculated as the modeled phosphorus outflow from Schmidt and Pomerleau at the TMDL loads using the spreadsheet model in Appendix A. The watershed load was calculated as the difference between the total wasteload allocation and the load from upstream lakes.

For all the lakes, the wasteload, internal load, and atmospheric load allocations were divided by 365.25 days per year (to account for leap year) to convert the annual load to a daily load. The load and wasteload allocations are shown in Table 7.2. Allocations by source are provided in Table 7.3. These allocations will guide the development of an Implementation Plan and necessary reductions.

Table 7.2. TMDL total phosphorus allocations expressed as daily loads.

Lake	Wasteload TP Allocation (kg/day)[1]	Load Allocation (kg/day)	Margin of Safety	Total Phosphorus TMDL (kg/day)
Schmidt Lake	0.12	0.02	Implicit	0.14
Pomerleau Lake	0.07	0.02	Implicit	0.09
Bass Lake	1.12	0.07	Implicit	1.19

[1]The wasteload allocation is allocated to NPDES-permitted facilities in accordance with Table 7.1.

Table 7.3. TMDL total phosphorus loads partitioned among the major sources.

	Allocation	Source	Current TP Load		Total Phosphorus TMDL		Load Reduction
			(kg/day)	(kg/year)	(kg/day)	(kg/year)	(kg/year)
Schmidt Lake	Wasteload	Watershed	0.13	46.6	0.12	42.0	4.6
	Load	Atmospheric	0.01	4.0	0.01	4.0	0
		Internal	0.02	5.5	0.01	5.0	0.5
			0.16	**56.1**	**0.14**	**51.0**	**5.1**
Pomerleau Lake	Wasteload	Watershed	0.22	78.8	0.07	23.8	55.0
	Load	Atmospheric	0.01	3.2	0.01	3.2	0
		Internal	0.04	13.1	0.01	4.0	9.1
			0.27	**95.1**	**0.09**	**31.0**	**64.1**
Bass Lake	Wasteload	Watershed	1.59	580.1	1.03	374.8	205.3
		Upstream Load	0.14	52.7	0.09	35.3	17.4
	Load	Atmospheric	0.06	20.9	0.06	20.9	0
		Internal	<0.01	1.0	0.01	5.0	N/A*
			1.79	**654.7**	**1.19**	**436.0**	**218.7**

*There is not enough information to calculate a current internal load for Bass Lake, so a "placeholder load" of 1.0 kg/year was used for the budget. The TMDL load of 5.0 is a reasonable nominal internal load for this lake at goal. The actual internal load reduction is unknown at this time.

7.2 RATIONALE FOR LOAD AND WASTELOAD ALLOCATIONS

The TMDL presented here is developed to be protective of the aquatic recreation beneficial use in lakes. However, there is no loading capacity *per se* for nuisance aquatic plants. Consequently, to understand the impacts of the phosphorus loads to the lakes, a water quality response model was utilized to predict the water quality after load reductions were implemented. Utilization of this approach allows for a better understanding of potential lake conditions under numerous load scenarios. The following sections describe the results from the water quality response modeling.

7.2.1 Modeled Historic Loads

Using the Canfield-Bachmann equation, historic loads and load reductions were calculated for each of the lakes. These calculations provide some insight into the assimilative capacity of the lake under different hydrologic conditions as well as over time. Additionally, these results provide a sense for the level of effort necessary to achieve the TMDL and whether that TMDL will be protective of the water quality standard.

Schmidt Lake met the shallow lake standard for phosphorus in four out of the last six monitored years (Figure 7.1). However, several of those years exceeded the chlorophyll-a standard for shallow lakes. Only small reductions in phosphorus loads are required to meet the phosphorus standard. Since Schmidt Lake is a shallow lake, the next step in restoring water quality is addressing the in-lake processes such as invasive aquatic vegetation, internal loading and fisheries conditions.

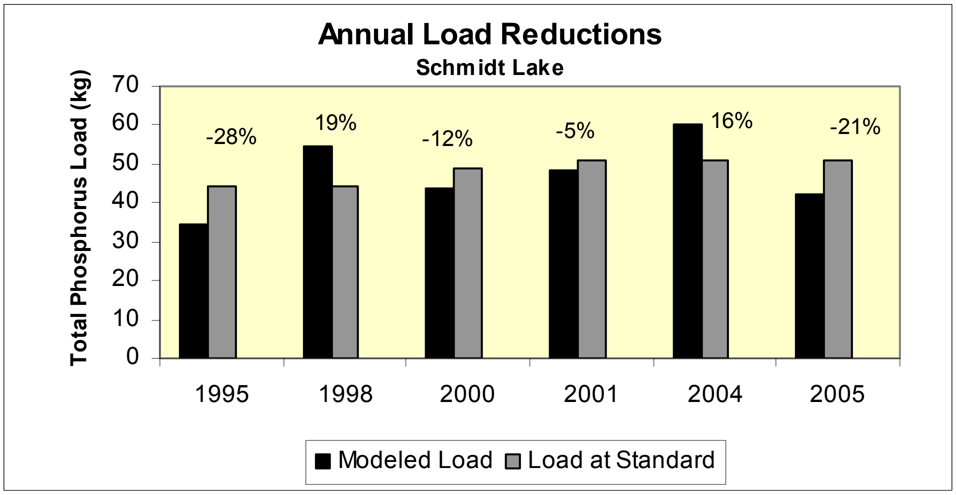


Figure 7.1. Modeled annual load and load at the standard for Schmidt Lake. The percentages represent the reduction needed to meet the standard.

Pomerleau Lake requires a 35 to 70% reduction in phosphorus loading to meet the State standard for deep lakes (Figure 7.2). Reductions in external sources of phosphorus will be required for in-lake management activities to be fully effective. Pomerleau Lake will require a significant effort in watershed BMPs to reduce the phosphorus loads to meet the State standards.

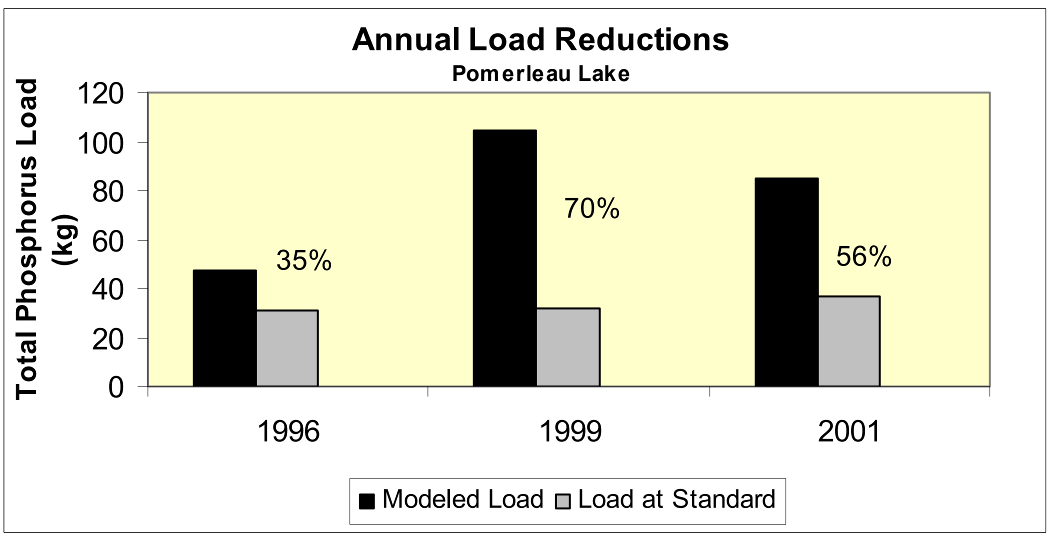


Figure 7.2. Modeled annual load and load at the standard for Pomerleau Lake. The percentages represent the reduction needed to meet the standard.

Bass Lake met the State phosphorus standard for shallow lakes in three out of the four years monitored (Figure 7.3). However, significant nuisance algal blooms occurred in the lake in all of these years, with summer average chlorophyll concentrations above 25 µg/L. These results suggest that, although some effort is still required in reducing external phosphorus loads from the watershed, equal effort should be placed on in-lake efforts to manage water quality in Bass Lake.

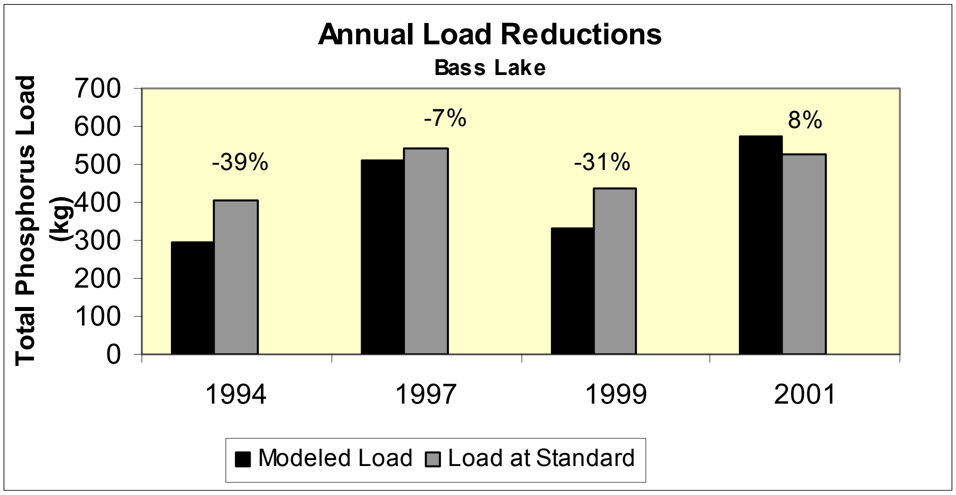


Figure 7.3. Modeled annual load and load at the standard for Bass Lake. The percentages represent the reduction needed to meet the standard.

7.2.2 Water Quality Response to Load Reductions

Using the previously described BATHTUB water quality response model, total phosphorus and chlorophyll-a concentrations were predicted for load reductions in 5% increments. These predicted responses can be used to develop goals for load reductions with an understanding of the overall water quality benefits.

7.2.3 Phosphorus

The modeled response to phosphorus load reductions in all basins is presented in Figures 7.4 and 7.5. Schmidt Lake requires a 9% reduction to meet the standard while Pomerleau and Bass Lakes require a 67% and 33% reduction respectively.

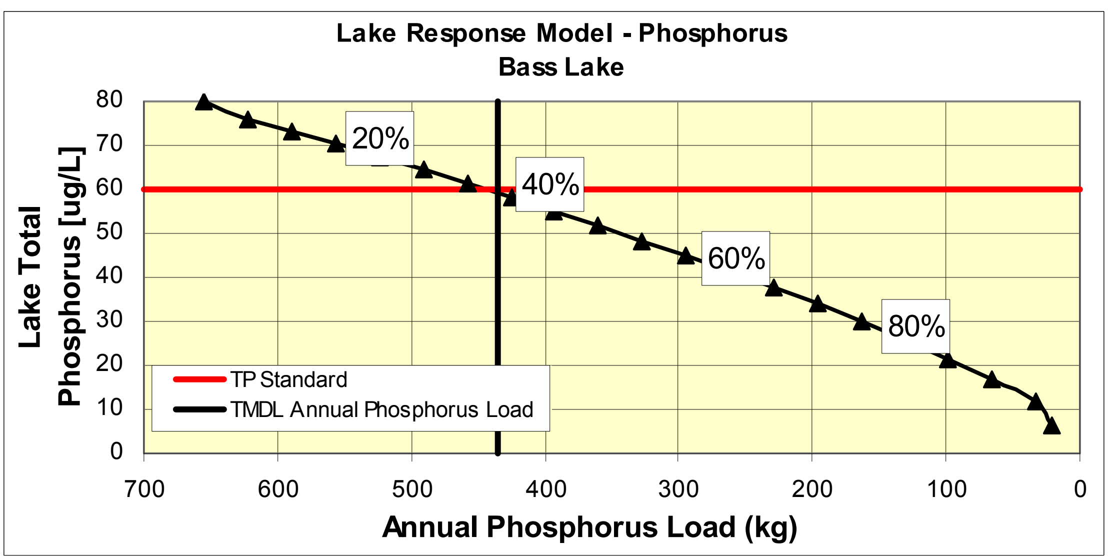


Figure 7.4. Bass Lake total phosphorus concentration predicted for total phosphorus load reductions applied to all sources.

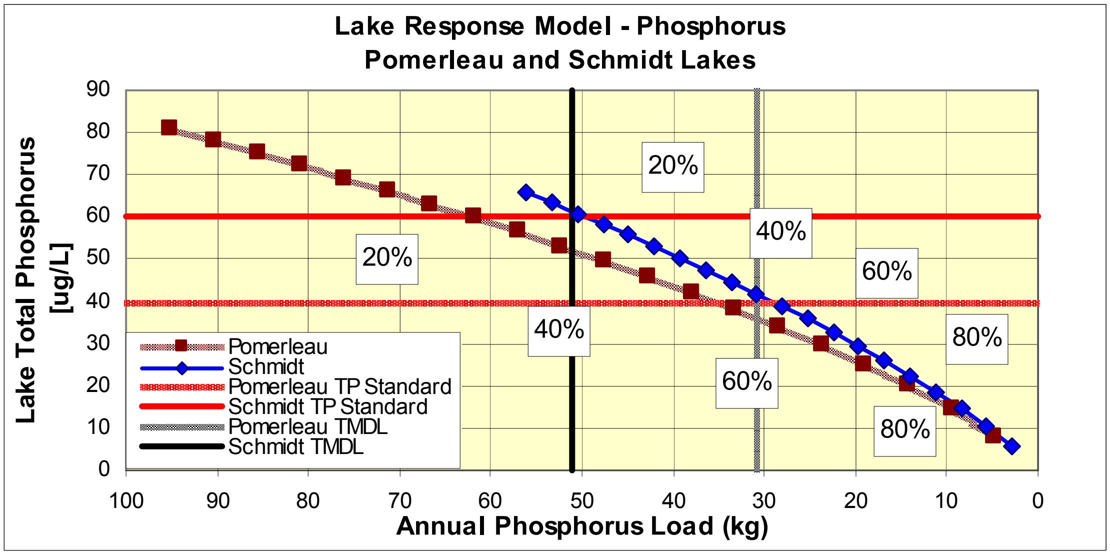


Figure 7.5. In lake total phosphorus concentrations predicted for total phosphorus load reductions applied to all sources.

7.2.4 Chlorophyll-a

Modeled chlorophyll-a concentrations with each load reduction are presented in Figures 7.6 and 7.7. The model predicts much larger reductions in phosphorus to meet the chlorophyll-a standard, ranging from a 40 to 70% in phosphorus loading. However, these lakes may respond to biological manipulations to reintroduce higher levels of zooplankton grazing to control algal blooms.

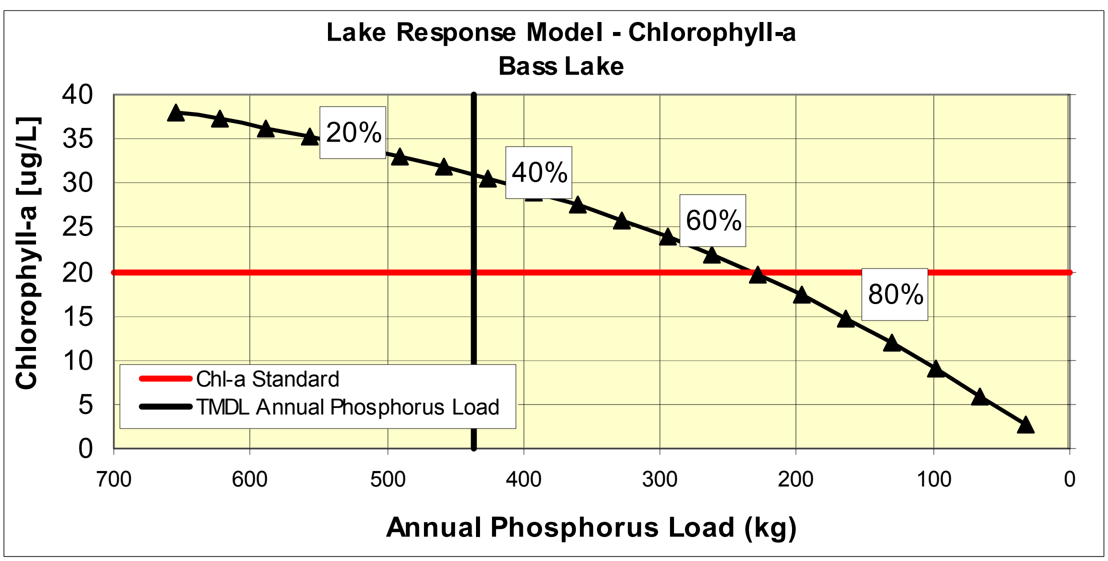


Figure 7.6. Bass Lake chlorophyll-a concentration predicted for total phosphorus load reductions applied to all sources.

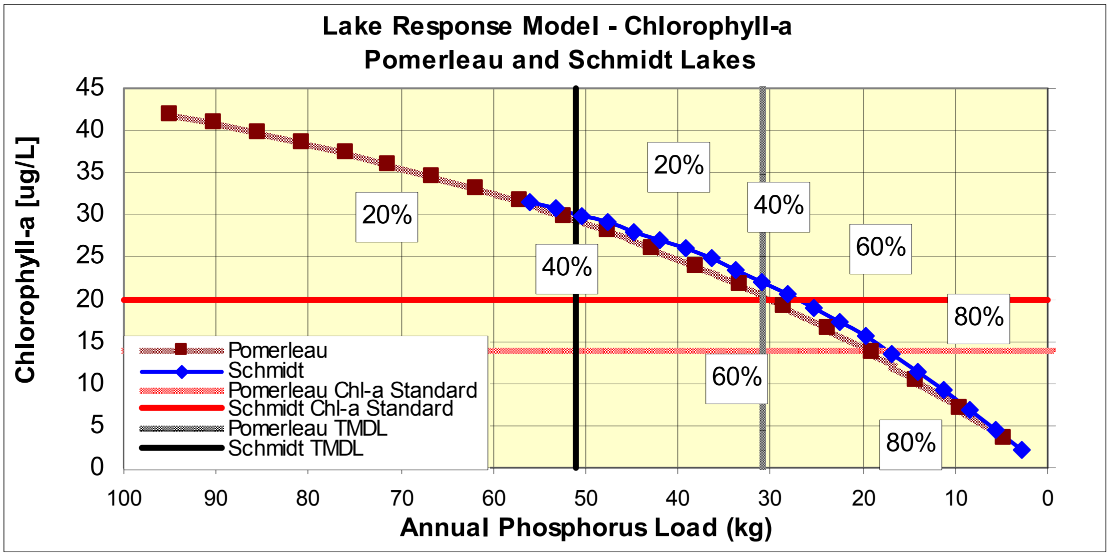


Figure 7.7. In lake chlorophyll-a concentrations predicted for total phosphorus load reductions applied to all sources.

7.2.5 Secchi Depth

The response in water clarity is presented in Figures 7.8 and 7.9. Bass Lake should meet water clarity standards with the proposed reductions, while Schmidt and Pomerleau should either meet or be very close to the standard. Additional measures including aquatic plant and fishery management may need to be taken to improve water clarity in Schmidt and Pomerleau Lakes.

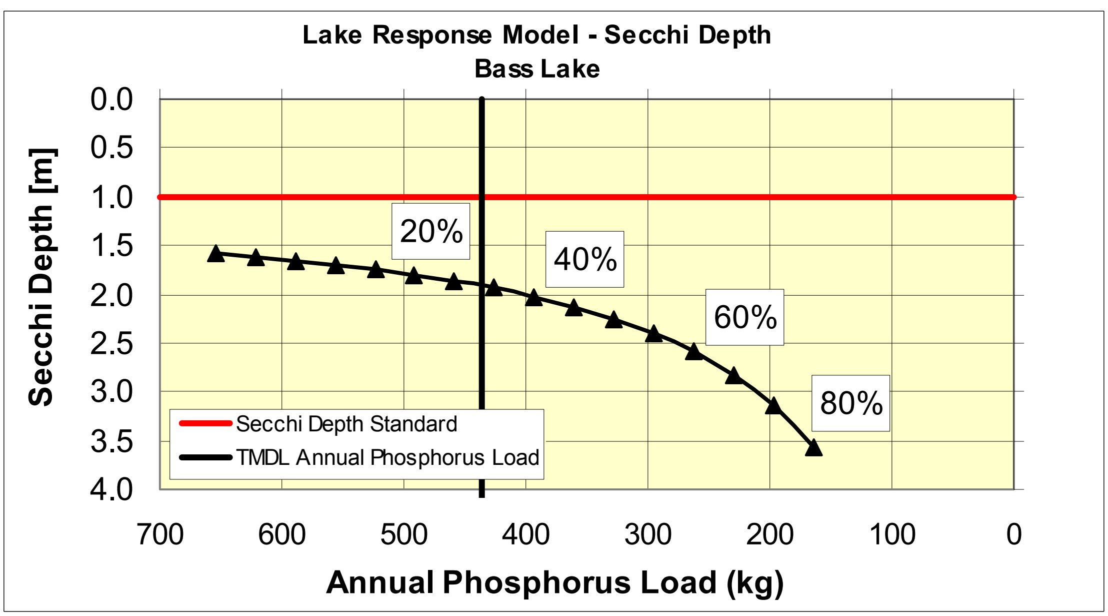


Figure 7.8. Bass Lake Secchi depth predicted for total phosphorus load reductions applied to all sources.

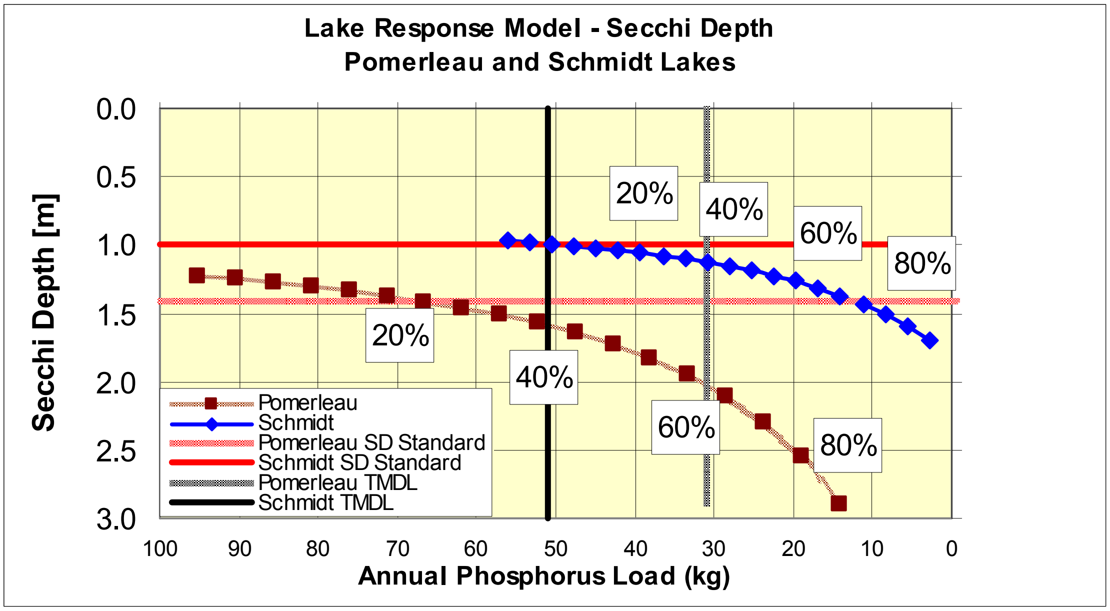


Figure 7.9. Secchi depth predicted for total phosphorus load reductions applied to all sources.

7.3 SEASONAL AND ANNUAL VARIATION

The daily load reduction targets in this TMDL are calculated from the current phosphorus budget for each of the lakes. The budget is an average of several years of monitoring data and includes both wet and dry years. BMPs designed to address excess loads to the lakes will be designed for these average conditions; however, the performance will be protective of all conditions. For example, a stormwater pond designed for average conditions may not perform at design standards for wet years; however the assimilative capacity of the lake will increase due to increased flushing. Additionally, in dry years the watershed load will be naturally down, allowing for a larger proportion of the load to come from internal loading. Consequently, averaging across several modeled years addresses annual variability in lake loading.

Seasonal variation is accounted for through the use of annual loads and developing targets for the summer period when the frequency and severity of nuisance algal growth will be the greatest. Although the critical period is the summer, lakes are not sensitive to short term changes in water quality; rather, lakes respond to long-term changes such as changes in the annual load. Therefore, seasonal variation is accounted for in the annual loads. Additionally, by setting the TMDL to meet targets established for the most critical period (summer), the TMDL will inherently be protective of water quality during all the other seasons.

7.4 MARGIN OF SAFETY

A margin of safety has been incorporated into this TMDL by using conservative assumptions. These were utilized to account for an inherently imperfect understanding of the lake system and to ultimately ensure that the nutrient reduction strategy is protective of the water quality standard.

Conservative modeling assumptions included applying sedimentation rates from the Canfield-Bachmann model that likely under-predicts the sedimentation rate for shallow lakes. The sedimentation rate refers to the loss of phosphorus from the water column as a result of settling. This can occur as algae die and settle, as organic material settles, or as algae are grazed by zooplankton. Zooplankton grazing plays a large role in algal and subsequent phosphorus sedimentation in shallow lakes (Meijer et al. 1994). However, the Canfield-Bachmann equation does not account for the higher sedimentation rates in healthy shallow lake systems as a result of increased zooplankton grazing. Consequently, the model-predicted phosphorus concentrations will be higher than expected because they do not account for the additional loss of phosphorus from the water column from that zooplankton grazing. Although Pomerleau Lake is not defined as a shallow lake, it is 66% littoral, making it likely that the lake acts more similarly to a shallow lake than a deep lake.

Secondly, the Canfield-Bachmann model was used to match data by only adjusting the loads and not applying calibration factors. It is likely that the sedimentation rates used in the model are conservatively low for most Minnesota lakes because of the relatively shallow nature of these lakes. Finally, an additional margin of safety is provided by developing load allocations for the summer season when lake water quality is worst and most sensitive to loads.

7.5 RESERVE CAPACITY/FUTURE GROWTH

The watersheds for these lakes are all fully covered by MS4 communities and are included in the Wasteload Allocation. The watershed is almost entirely developed and most of the development projects that occur are redevelopment or small infill projects. No new NPDES sources are anticipated in these watersheds, therefore, no portion of the Wasteload Allocation is being held in reserve.

Future growth will not affect this TMDL. Additionally, the Shingle Creek Watershed Management Commission has rules in place for development and redevelopment that are protective of water quality. Consequently, future development will have to meet watershed requirements that will contribute to pollution reductions in this TMDL.

8.0 Public Participation

8.1 INTRODUCTION

As a part of the strategy to achieve implementation of the necessary allocations, the Shingle Creek Watershed Management Commission (SCWMC) seeks stakeholder and public engagement and participation regarding their concerns, interests, and questions regarding the development of the TMDL. Specifically, meetings were held for a Technical Advisory Committee representing key stakeholders. Additionally, the SCWMC reviewed the TMDL with City Councils and citizens advisory committees at meetings to which lake association members were invited.

8.2 TECHNICAL ADVISORY COMMITTEE

A technical advisory committee was established so that interested stakeholders could be involved in key decisions involved in developing the TMDL. Stakeholders represented on the Technical Advisory Committee include local cities, Minnesota DNR, the Metropolitan Council, Hennepin County, the U.S. Geological Survey (USGS), Three Rivers Park District, and the Minnesota Pollution Control Agency. All meetings were open to interested individuals and organizations. Technical Advisory Committee meetings to review this and other lake TMDLs in the watershed were held on December 8, 2005, February 9, 2006, March 9, 2006, and June 27, 2007.

8.3 STAKEHOLDER MEETINGS

The preliminary results of the TMDL were presented to the City of Plymouth Environmental Quality Committee on March 8, 2006. This citizen commission invited lake association members and other interested parties to attend this meeting. The TMDL and the preliminary Implementation Plan were presented to the Environmental Quality Committee on June 11, 2008.

8.4 PUBLIC MEETINGS

The general TMDL approach and general results of TMDLs were presented to six City Councils in May and July 2006. Additional public comment will be taken as part of the public comment period.

9.0 Implementation

9.1 IMPLEMENTATION FRAMEWORK

9.1.1 The Shingle Creek Watershed Management Commission

The SCWMC is committed to improving water quality in the Shingle Creek watershed. To this end, the SCWMC completed a Water Quality Plan and adopted it as a Major Plan Amendment to its Watershed Management Plan. A number of activities are detailed in the Management Plan over the next ten years, including developing individual management plans for water resources.

The Shingle Creek Water Quality Plan (WQP):
- Sets forth the Commissions' water quality goals, standards, and methodologies in more detail than the general goals and policies established in the Second Generation Watershed Management Plan.
- Provides philosophical guidance for completing water resource management plans and TMDLs; and
- Provides direction for the ongoing water quality monitoring programs that will be essential to determine if the TMDLs and implementation program are effectively improving water quality.

The Water Quality Plan is composed of four parts:
- A monitoring plan to track water quality changes over time;
- Detailed management plans for each resource to lay out a specific plan of action for meeting water quality goals;
- A capital improvement plan; and
- An education and public outreach plan.

This WQP charts the course the Commission will take to meet its Second Generation Watershed Management Plan goals to protect and improve water quality and meet Commission and State water quality standards. While the Plan lays out a series of activities and projects, implementation will occur as the Commission's and cities' budgets permit. The Commission as part of the Major Plan Amendment process also revised its cost share formula to provide for Commission participation in the cost of TMDL implementation projects.

The Commission has received significant grant funding from the Minnesota Pollution Control Agency, the Board of Water and Soil Resources, the Metropolitan Council, and the Department of Natural Resources to undertake planning and demonstration projects. The Commission intends to continue to solicit funds and partnerships from these and other sources to supplement the funds provided by the nine cities having land in the Shingle Creek watershed.

The Shingle Creek Watershed Management Commission's Second Generation Watershed Management Plan provides for development of individual management plans for each of the high priority water resources in the watershed over the next several years. In its Work Plan and Capital Improvement Program (CIP) the Commission set up a process and budgeted resources to systematically work in partnership with its member cities to develop lake management plans that will meet both local and watershed needs and to do so in a consistent manner across the watershed.

9.1.2 Member Cities

Because the Commission is a Joint Powers Organization, it relies on the cities to implement most programs and construct capital improvements. Under the Joint Powers Agreement, cities agree to use their best efforts to carry out directives of the Commission in its exercise of the powers and duties set forth in statute and administrative rule for the protection of water resources. Each city has in place a Local Water Management Plan to address watershed and city goals and objectives; those local plans are periodically updated to reflect resource management plans and adopt or revise strategies for water resource management.

9.2 REDUCTION STRATEGIES

9.2.1 Annual Load Reductions

The focus in implementation will be on reducing the annual phosphorus loads to the lakes through structural and nonstructural Best Management Practices. Table 7.3 above, which establishes the daily and annual TMDL loads, is replicated as Table 9.1 below.

Table 9.1. TMDL total phosphorus loads partitioned among the major sources.

	Allocation	Source	Current TP Load		Total Phosphorus TMDL		Load Reduction
			(kg/day)	(kg/year)	(kg/day)	(kg/year)	(kg/year)
Schmidt Lake	Wasteload	Watershed	0.13	46.6	0.12	42.0	4.6
	Load	Atmospheric	0.01	4.0	0.01	4.0	0
		Internal	0.02	5.5	0.01	5.0	0.5
			0.16	**56.1**	**0.14**	**51.0**	**5.1**
	9% Load Reduction Required						
Pomerleau Lake	Wasteload	Watershed	0.22	78.8	0.07	23.8	55.0
	Load	Atmospheric	0.01	3.2	0.01	3.2	0
		Internal	0.04	13.1	0.01	4.0	9.1
			0.27	**95.1**	**0.09**	**31.0**	**64.1**
	67% Load Reduction Required						
Bass Lake	Wasteload	Watershed	1.59	580.1	1.03	374.8	205.3
		Upstream Load	0.14	52.7	0.09	35.3	17.4
	Load	Atmospheric	0.06	20.9	0.06	20.9	0
		Internal	<0.01	1.0	0.01	5.0	N/A*
			1.79	**654.7**	**1.19**	**436.0**	**218.7**
	33% Load Reduction Required						

9.2.2 Actions

Restoration options for lakes are numerous with varying rates of success. Consequently, each technology must be evaluated in light of our current understanding of physical and biological processes in that lake. Much of the watershed draining to these lakes is fully developed, and options for reducing external nutrient loads are limited and will likely be costly to implement. Following is a description of potential actions for controlling nutrients in these lakes that will be further developed in the Schmidt-Pomerleau-Bass Lakes Implementation Plan. The estimated total cost of implementing these and other potential BMPs ranges from $500,000 to $3,000,000.

9.2.2.1 External Load Reductions

The Bass Lake watershed is mostly developed, with some infill development east of I-494 and some potential development opportunities west of I-494. New development and redevelopment that meet certain thresholds will be required to provide pretreatment of stormwater prior to discharge into the lakes, Bass Creek and the other water resources in the watershed. Small, incremental reductions are also possible through retrofit as redevelopment occurs and through the implementation of Best Management Practices (BMPs) throughout the subwatershed.

Maximize load reduction through development and redevelopment. As redevelopment occurs, areas with little or no treatment will be required to meet current water quality standards. It may be possible to "upsize" water quality treatment BMPs for both development and redevelopment projects to increase treatment efficiency beyond the minimum required by the City and Commission to maximize the amount of load reduction achieved. The public cost of "upsizing" would be dependent on the specific BMPs, negotiations with developers, etc., but could range from $10,000-500,000 each. In 2001, Plymouth commissioned a Hydrologic and Hydraulic study of its "2020 Urban Expansion Area," which includes parts of the upper Bass Lake watershed. This study made recommendations regarding future management and regulatory strategies as the area develops and converts agricultural and golf course uses to higher density uses.

Protect high-value wetlands to prevent phosphorus export. Numerous high-value wetlands, especially in the upper watershed, serve as phosphorus and sediment traps. As development occurs in the upper watershed, there is the potential to discharge stormwater to them, altering their hydroperiod and natural assimilative characteristics and converting the wetlands from nutrient sinks to nutrient sources. The City of Plymouth has a wetland classification scheme in place and regulates certain development requirements based on wetland functions and values.

Increase infiltration and filtration in the lakeshed. Encourage the use of rain gardens, native plantings and reforestation as means to increase infiltration and evapotranspiration and reduce runoff conveying pollutant loads to the lake. The City of Plymouth has installed three rain gardens in the Schmidt Lake watershed to provide treatment and infiltration. The cost of this strategy varies depending on the BMP and may range from $500 for a single property owner installing an individual rain garden to retrofitting parks and open space with native vegetation rather than mowed turf at a cost of $10,000. The Education and Outreach Committee of the Watershed Commission regularly provides education and outreach information on these topics to member cities for publication in city newsletters, neighborhood and block club fliers, and the city's website.

Target street sweeping. Identify key areas for more frequent street sweeping. The entire Schmidt Lake watershed is in Plymouth's Priority Sweeping program. Nearly all of the area draining to this lake chain is located in the City of Plymouth, and the City should evaluate whether additional sweeping in the areas draining directly to the other lakes would be beneficial.

Retrofit BMPs. Much, but not all, of the watershed was developed with treatment controls, generally in the form of stormwater detention ponds. As opportunities arise, retrofit water quality treatment through a variety of Best Management Practices including detention ponds, native plantings, sump manholes, swirl separators, and trash collectors. These small practices are effective in removing debris, leaf litter, and other potential pollutants. Depending on the type of BMP, location, easement requirements, and other factors, costs can range from $5,000 for a sump manhole to $250,000 or more for a detention pond. The number of BMPs necessary to achieve the required phosphorus load reduction is unknown and is dependent on the types of opportunities that arise. As part of the Schmidt Lake Management Plan, Plymouth has installed catch basin inserts at six locations to filter runoff and trap debris. Five sump manholes allow debris to settle out of the storm sewer flow, where it is mechanically removed by sewer vacuum. These small practices are effective in removing debris, leaf litter, and other potential pollutants.

Encourage shoreline restoration. Most property owners maintain a turfed edge to the shoreline. Encourage property owners to restore their shoreline with native plants to reduce erosion and capture direct runoff and to limit removal of beneficial vegetation that is perceived to be a nuisance or undesirable. The city should consider demonstration projects in city parks and open spaces. Residential property shoreline totals about 25,700 linear feet on Bass and Schmidt Lakes, with the balance of the shoreline composed of riparian wetlands. Ideally about 75 percent of the residential shoreline would be native vegetation, with about 25 percent available for lake access. Accomplishing this goal would require restoration of about 19,275 feet of shoreline at a cost of about $600,000 to $1,000,000.

Conduct education and outreach awareness programs. Educate property owners in the subwatershed about proper fertilizer use, low-impact lawn care practices, and other topics to increase awareness of sources of pollutant loadings to the lakes and encourage the adoption of good individual property management practices. Lakeshore property owners should be educated about aquatic vegetation management practices and how they relate to beneficial biological communities and water quality. Both Bass Lake and Schmidt Lake have active lake associations that have provided education opportunities in the past and are interested in continuing and expanding that function.

9.2.2.2 Internal Loads

The primary option for the control of internal loading is likely to be biological manipulation. This would include an integrated plan to manage the aquatic vegetation, fish, and zooplankton communities to reduce nutrient loads and maintain a level of water clarity that is desirable both aesthetically and for maintenance of a fishery.

Vegetation management. Curly-leaf pondweed and Eurasian water milfoil have been chemically treated in both Schmidt and Bass Lakes. Management activities that address phosphorus sources such as curly-leaf pondweed should be continued. Chemical treatments applied for at least three to five years in a row may be necessary to limit growth of this phosphorus source. The estimated cost of this treatment is $35,000 per treatment.

Conduct aquatic plant survey and prepare vegetation management plan. An aquatic vegetation management plan has been developed for Schmidt Lake. Aquatic vegetation surveys and management plans should be prepared for Bass and Pomerleau Lakes as well. As BMPs are implemented and water clarity improves, the aquatic vegetation community will change. Surveys should be updated periodically and vegetation management plans amended to take into account appropriate management activities for that changing community. The cost of a survey and management plan is about $10,000 per lake.

Manage fish populations. Partner with the DNR to monitor and manage the fish population to maintain a beneficial community.

9.3 IMPLEMENTATION STRATEGY

The load allocations in the TMDL represent aggressive goals for nutrient reductions for Pomerleau Lake and more attainable goals for Schmidt and Bass Lakes. Consequently, implementation will be conducted using adaptive management principles. Adaptive management is appropriate because it is difficult to predict the lake response that will occur from implementing strategies with the paucity of information available to demonstrate expected reductions. Future technological advances may alter the course of actions detailed here. Continued monitoring and “course corrections” responding to monitoring results are the most appropriate strategies for attaining the water quality goals established in this TMDL.

Based on this understanding of the appropriate standards for lakes, this TMDL has been established with the intent to implement all the appropriate activities that are not considered greater than extraordinary efforts. It is expected that it may take 10-20 years to implement BMPs and load-reduction activities. If all of the appropriate BMPs and activities have been implemented and the lakes still do not meet the current water quality standards, the TMDL will be reevaluated and the Shingle Creek Watershed Management Commission will begin a process with the MPCA to develop more appropriate site-specific standards for the lakes. The process will be based on the MPCA’s methodology for determining site-specific standards.

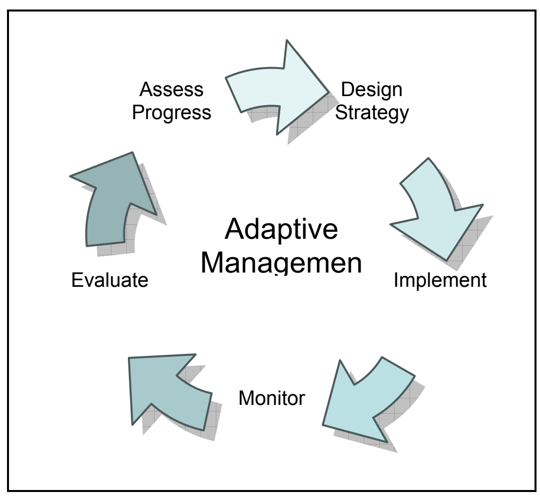


Figure 9.1. Adaptive management.

10.0 Reasonable Assurance

10.1 INTRODUCTION

When establishing a TMDL, reasonable assurances must be provided demonstrating the ability to reach and maintain water quality endpoints. Several factors control reasonable assurance, including a thorough knowledge of the ability to implement BMPs as well as the overall effectiveness of the BMPs. This TMDL establishes aggressive goals for the reduction of phosphorus loads to Pomerleau Lake but more achievable goals for Bass and Schmidt Lakes. There are few if any examples where the levels of reduction necessary for Pomerleau Lake have been achieved when the sources were primarily nonpoint source in nature, especially in suburban watersheds.

TMDL implementation will be carried out on an iterative basis so that course corrections based on periodic monitoring and reevaluation can adjust the strategy to meet the standard. After the first phase of nutrient reduction efforts, reevaluation will identify those activities that need to be strengthened or other activities that need to be implemented to reach the standards. This type of iterative approach is more cost effective than over-engineering to conservatively inflated margins of safety (Walker 2003). Implementation will also address in-lake problems such as invasive plant species (curly-leaf pondweed) and invasive fish (carp and rough fish). These practices go beyond the traditional nutrient controls and provide additional protection for lake water quality.

10.2 THE SHINGLE CREEK WATERSHED MANAGEMENT COMMISSION

The Shingle Creek Watershed Management Commission was formed in 1984 using a Joint Powers Agreement developed under authority conferred to the member communities by Minnesota Statutes 471.59 and 103B.201 through 103B.251. The Metropolitan Surface Water Management Act (Chapter 509, Laws of 1982, Minnesota Statute Section 473.875 to 473.883 as amended) establishes requirements for preparing watershed management plans within the Twin Cities Metropolitan Area.

Minnesota Rules Chapter 8410 requires watershed management plans to address eight management areas and to include specific goals and policies for each. Strategies and policies for each goal were developed to serve as a management framework. To implement these goals, policies, and strategies, the Commissions have developed the Capital Improvement Program and Work Plan discussed in detail in the Second Generation Plan (SCWMC 2004). In 2007 the Commission adopted a Water Quality Plan, revised Capital Improvement Program, and Cost Sharing Policy to further progress toward meeting water quality goals.

The philosophy of the Joint Powers Agreement is that the management plan establishes certain common goals and standards for water resources management in the watershed, agreed to by the nine cities having land in the watershed, and implemented by those cities with activities at both the Commission and local levels. TMDLs developed for water bodies in the watershed will be used as guiding documents for developing appropriate goals, policies, and strategies and ultimately sections of the Capital Improvement Program and Work Plan.

The Commission has received significant grant funding from the Minnesota Pollution Control Agency, the Board of Water and Soil Resources, the Metropolitan Council, and the Department of Natural Resources to undertake planning and demonstration projects. The Commission intends to continue to solicit funds and partnerships from these and other sources to supplement the funds provided by the nine cities having land in the watershed. It is expected that the Commission will continuously update the annual Capital Improvement Programs (CIPs) as a part of its annual budget process.

10.3 NPDES MS4 STORMWATER PERMITS

NPDES Phase II stormwater permits are in place for each of the member cities in the watershed as well as Hennepin County and Mn/DOT. Under the stormwater program, permit holders are required to develop and implement a Stormwater Pollution Prevention Program (SWPPP; MPCA, 2004). SWPPPs identify Best Management Practices (BMPs) and measurable goals associated with each of six specified minimum control measures.

Within the Bass Lake chain of lakes watershed, two cities, Hennepin County and MnDOT Metro District are covered under the Phase II General NPDES Stormwater Permit – MNR040000. The unique permit numbers assigned to the MS4s that drain to the chain of lakes are as follows:

- Maple Grove – MS400102
- Plymouth – MS400112
- Hennepin County – MS400138
- MnDOT Metro District – MS400170

Stormwater discharges are regulated under NPDES and allocations are considered wasteloads. Because there is not enough information available to assign loads to individual permit holders, the Wasteload Allocations are combined in this TMDL as Categorical Wasteload Allocations (see Table 7.1). There are no known industrial dischargers in the watershed. The pollutant load from construction stormwater is considered to be less than one percent of the TMDL and difficult to quantify. Consequently, the WLA includes pollutant loading from construction stormwater sources.

According to federal regulations, NPDES permit requirements must be consistent with the assumptions and requirements of an approved TMDL and associated Wasteload Allocations. See 122.44(d)(1)(vii)(B). To meet this regulation, Minnesota's proposed MS4 permit requires the following:

> “If a USEPA-approved **TMDL(s)** has been developed, you must review the adequacy of your Storm Water Pollution Prevention Program to meet the **TMDL's Waste Load Allocation** set for storm water sources. If the **Storm Water Pollution Prevention Program** is not meeting the applicable requirements, schedules and objectives of the **TMDL**, you must modify your **Storm Water Pollution Prevention Program**, as appropriate, within 18 months after the TMDL is approved.”

MS4s contributing stormwater to the lakes will comply with this requirement during the implementation planning period of the TMDL. The Implementation Plan will identify specific BMP opportunities sufficient to achieve their load reduction and the individual SWPPPs will be modified accordingly as a product of this plan. Construction stormwater activities are considered in compliance with provisions of the TMDL if they obtain a Construction General Permit under the NPDES program and properly select, install, and maintain all BMPs required under the permit, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit.

In this TMDL the Load Allocation is also allocated in the same manner as the WLA. Each permittee has committed to implement Best Management Practices (BMPs) to reduce nutrient loading to each lake. The MS4s cooperated in developing the TMDL and Implementation Plan and will continue to work together through the ongoing Commission Technical Advisory Committee (TAC) to identify and implement BMPs either individually or in collaboration. This collective approach allows for greater reductions for some permit holders with greater opportunity and less for those with greater constraints. The collective approach is to be outlined in an Implementation Plan developed by the Shingle Creek Watershed Management Commission.

10.4 MONITORING

10.4.1 Monitoring Implementation of Policies and BMPs

The SCWMC will evaluate progress toward meeting the goals and policies outlined in the Second Generation Plan in their Annual Report. Success will be measured by completion of policies and strategies, or progress toward completion of policies and strategies. The Annual Report will then be presented to the public at the Commission’s annual public meeting. The findings of the Annual Report and the comments received from the member cities and the public will then be used to formulate the work plan, budget, CIP and specific measurable goals and objectives for the coming year as well as to propose modifications or additions to the management goals, policies, and strategies. At the end of each five year period the Commission will evaluate the success of BMP implementation in reducing the total phosphorus concentration in the Bass Lake chain and will reconvene the Technical Advisory Committee to determine if adjustments to the Implementation Plan are necessary.

10.4.2 Follow-up Monitoring

The SCWMC monitors water quality in local lakes through the funding of special studies and citizen volunteer efforts. Additional monitoring is proposed in the Commission’s Water Quality

Plan in an effort to ensure the quality of data. Schedules of monitoring activities are identified in the Shingle Creek Water Quality Plan (SCWMC 2007). Results of all monitoring will be included in their annual water quality monitoring report. These three lakes will be periodically monitored by the Shingle Creek Watershed Management Commission (SWMC) through the CAMP program. The CAMP program is operated by Metropolitan Council Environmental Services (MCES) and is a volunteer monitoring program. Citizen volunteers collect data and samples biweekly.

11.0 Literature Cited

Barr Engineering. 2004. Detailed Assessment of Phosphorus Sources in Minnesota Watersheds. Minnesota Pollution Control Agency, St. Paul, Minnesota. <<http://www.pca.state.mn.us/hot/legislature/reports/phosphorus-report.html>>.

Heiskary, S.A. and C.B. Wilson. 2005. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment. Minnesota Pollution Control Agency, St. Paul, Minnesota.

McCollor, S. and S. Heiskary. 1993. Selected water-quality characteristics of the seven ecoregions of Minnesota. Minnesota Pollution Control Agency. St. Paul, MN.

MCES. 1981. "A Study of the Water Quality of 60 Lakes in the Seven County Metropolitan Area." Metropolitan Council Report. Publication No. 01-81-047

Meijer, M.-L., Ven Nes, E.H., Lammens, E.H.R.R., and Gulati, R.D. 1994. The consequences of a drastic fish stock reduction in the large and shallow Lake Wolderwijd, The Netherlands – Can we understand what happened? Hydrobiologia, 276:31-42.

Minnesota Pollution Control Agency (MPCA). 2002. Water Quality Reconstruction from Fossil Diatoms: Applications for Trend Assessment, Model Verification, and Development of Nutrient Criteria for Lakes in Minnesota, USA. Minnesota Pollution Control Agency, St. Paul, Minnesota.

MPCA. 2004. Guidance Manual for Assessing the Quality of Minnesota Surface Waters, 2004. Minnesota Pollution Control Agency, St. Paul, Minnesota.

Nürnberg, G. 1997. Coping with water quality problems due to hypolimnetic anoxia in central Ontario lakes. Water Quality Research Journal of Canada. 32 (2) pp 391-405.

Nürnberg, G. K. 2004. "Quantified Hypoxia and Anoxia in Lakes and Reservoirs." The Scientific World Journal 4: 42-54.

Shingle Creek Watershed Management Commission. 2004. “Second Generation Watershed Management Plan.” Wenck Report 1240-01.

Shingle Creek Watershed Management Commission. 2007. Water Quality Plan. Wenck Report 1240-23.

Walker, W.W. 1990. P8 Urban Catchment Model. << http://wwwalker.net/p8/>>

Walker, William W. 1999. Simplified Procedures for Eutrophication Assessment and Prediction: User Manual. USACE Report w-96-2.

Walker, William W. 2003. Consideration of Variability and Uncertainty in Phosphorus Total Maximum Daily Loads for Lakes. J. Water Resour. Plng. and Mgmt., Volume 129, Issue 4, pp. 337-344 (July/August 2003).

Wenck Associates, Inc. 2007. Shingle Creek Chloride TMDL. Wenck Report 1240-34

Appendix A

Models and Calculations Detail

MODELING AND CALCULATION DETAIL

The attached tables and model runs provide detail of modeling performed for this TMDL.

TMDL Table 6.6, Current Total Phosphorus Budget
P8 modeling was performed for each lake. For each lake in this Appendix A there is a Table 1 that shows P8 Results for the period 1992 - 2003. This table shows the P8 runoff flow and load in acre-feet and pounds, cubic hectometers and kilograms. This table also shows acre-feet of runoff calculated using the Shingle Creek Watershed Commission's calibrated SWMM model.

TMDL Table 6.6 presents annual phosphorus budgets for 1999 and 2001. Those years were used to calibrate the water quality response model. The P8 values were used in the existing conditions models and in establishing the TMDLs as described below.

TMDL Table 6.1 shows the calculation of atmospheric deposition load for the lakes. Section 6.3 of the TMDL describes the estimation of internal loads for the lakes. For each lake in this Appendix A there is a Table 2 that summarizes Lake Morphometry characteristics that were used in the estimation of atmospheric and internal loads.

For Bass Lake, a BATHTUB model was used to estimate phosphorus sedimentation and phosphorus outflow. It was assumed that the entire outflow load from Schmidt and Pomerleau Lakes would be transported downstream to Bass Lake.

The average annual load in Table 6.6 was calculated as follows. The watershed load was averaged between the two years; the atmospheric and internal loads were assumed to be constant; and the Bass Lake upstream load was calculated using the BATHTUB spreadsheet in Table 1, Current Phosphorus Budget.

TMDL Tables 6.7, 6.8, and 6.9, Model Fit
Model fit for the years 1999 and 2001 was calculated using the BATHTUB interface. Output of those model runs is attached as Table 2. "Segment Balances" shows the inputs to the model, while "Diagnostics" compares the observed TP, chl-a, and Secchi depth values to the predicted values.

TMDL Tables 7.2 and 7.3, TMDL Total Phosphorus Allocations
Inverted Canfield Bachmann equations were used to calculate the TMDL. For each lake in this Appendix A there is a Table 3 that shows Inverted Canfield Bachmann Calculations. This table shows how the loads were reverse-calculated under existing conditions and at the appropriate TP standard. As the TMDL Sections 7.1 and 7.2 discuss, the TMDL for Bass and Pomerleau Lakes was established using the 1999 flow conditions, representative of an average precipitation year. Because Schmidt Lake appears to exceed the state TP standard only in wet years, 2001 flow, representative of a wet year, was used to reverse calculate the load at standard.

The total TP TMDL for Schmidt and Pomerleau Lakes was partitioned as shown in the table below. These loads were entered into the BATHTUB spreadsheet shown in Table 3, TMDL Loads, to obtain the load from upstream lakes for Bass Lake.

The total TP TMDL for Bass Lake was partitioned by difference. The upstream load, atmospheric load, and a constant 5.0 kg/yr internal load was subtracted from the TMDL to obtain the watershed load.

Calculation method to allocate the TMDL to WLA and LA for Pomerleau and Schmidt Lakes.

	Pomerleau		**Schmidt**	
Step 1: Subtract the atmospheric deposition load from the total load for both the current total phosphorus load and the TMDL total load	Current 95.1 -3.2 91.9	TMDL 31.0 -3.2 27.8	Current 56.1 -4.0 52.1	TMDL 51.0 -4.0 47.0
Step 2: Compute the required load reduction	(91.9 - 27.8)/91.9 = 0.697		(52.1- 47.0)/52.1 = 0.098	
Step 3: Apply the reduction to the current wasteload to obtain the TMDL WLA	78.8 * (1-0.697) = 23.8 = TMDL WLA		46.6 * (1-0.098) = 42.0 = TMDL WLA	
Step 4: Apply the percent reduction to the current internal load to obtain the TMDL internal load	13.1 * (1-0.697) = 4.0 = TMDL internal load		5.5 * (1-0.098) = 5.0 = TMDL internal load	

Table 1: Current Phosphorus Budget Average of 1999 and 2001			Pomerleau	Schmidt	Bass
Modeled Parameter	**Option & Equation**		**Lake Model**	**Lake Model**	**Lake Model**
Internal Phosphorus Load	**kg**		**13.1**	**5.5**	**1.0**
Atmospheric Phosphorus Load			**3.2**	**4.0**	**20.9**
Tributary Load			**78.8**	**46.6**	**580.1**
Load from Upstream Lake			**-**	**-**	**52.7**
Total Phosphorus Load			**95.1**	**56.1**	**654.7**
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION	Canfield & Bachmann 1980 f(W,Q,V) $P = P_i/(1+CP*a*P_i^b*T^c)$				
	CP	[--]	*1.00*	*1.00*	*1.00*
	a	[--]	0.162	0.162	0.162
	b	[--]	0.458	0.458	0.458
	c	[--]	0.542	0.542	0.542
	W= total P load (inflow + atm.)	[kg/yr]	95	56	655
	Q=lake outflow	$[10^6 m^3/yr]$	0.37	0.33	3.76
	V=lake volume (modeled)	$[10^6 m^3]$	0.41	0.25	2.20
	T = V/Q	[yr]	1.11	0.76	0.59
	P_i = W/Q	[ug/l]	257	170	174
Modeled In-Lake [TP]		**[ug/l]**	**81.0**	**69.0**	**76.1**
Observed In-Lake [TP], May to September					
CHL-A MODEL	**N, P, Flushing (Walker 1999)**				
	B= CB Bx /[(1+0.025 Bx				
	CB as used to calibrate		**1.0**	**1.0**	**1.0**
	P Total Phosphorus	**[ug/l]**	**81**	**69**	**76**
	N Total Nitrogen	**[ug/l]**	**1930**	**1040**	**1220**
	Zmix Mixing Depth	**m**	**3.3**	**1.7**	**2.8**
Q/V	**Fs Flushing Rate**	**year-1**	**0.9**	**1.3**	**1.7**
	S Secchi Depth	**(m)**	**1.3**	**1.0**	**1.4**
(1/s)-0.025B	**a Non algal turbidity**	**m-1**	**0.2**	**0.6**	**0.1**
	Xpn		**71.1**	**50.5**	**57.9**
	Bx		**67.3**	**42.8**	**51.3**
	G		**0.47**	**0.25**	**0.41**
	B		**41.9**	**32.5**	**38.0**
Observed In-Lake [CHL-A]			**38.8**	**29.5**	**43.7**
SECCHI MODEL	chla & turbidity				
	CS as used to calibrate	[--]	*1.00*	*1.00*	*1.00*
Calibrated In-Lake SD		**[m]**	**1.23**	**0.96**	**1.59**
Observed In-Lake [SD]			**1.30**	**1.00**	**1.40**
MODELED PHOSPHORUS OUTFLOW	W-(Sedimentation)	**[kg/yr]**	**30**	**23**	**286**
MODELED PHOSPHORUS SEDIMENTATION	$CP*a*(Wp/V)^b*[TP]*V$	**[kg/yr]**	**65**	**33**	**368**

Table 2: BATHTUB Model Run Output

Segment Balances 1999

File:T:\1240\Lake TMDLs\Models and Data\Bass Schmidt Pomerleau\Bass 1999.btb

Segment Mass Balance Based Upon Predicted Concentrations

Component:TOTAL P — Segment: 1 Bass

Trib Type Location	Flow hm3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m3
1 1 Bass	3.2	67.1%	495.7	87.4%	153
PRECIPITATION	0.9	17.8%	20.9	3.7%	24
TRIBUTARY INFLOW	3.2	67.1%	495.7	87.4%	153
ADVECTIVE INFLOW	0.7	15.1%	50.5	8.9%	69
***TOTAL INFLOW	4.8	100.0%	567.1	100.0%	118
ADVECTIVE OUTFLOW	4.3	88.7%	283.3	50.0%	66
***TOTAL OUTFLOW	4.3	88.7%	283.3	50.0%	66
***EVAPORATION	0.5	11.3%	0.0	0.0%	
***RETENTION	0.0	0.0%	283.8	50.0%	

Hyd. Residence Time = 0.5103 yrs
Overflow Rate = 5.5 m/yr
Mean Depth = 2.8 m

Component:TOTAL P — Segment: 2 Schmidt

Trib Type Location	Flow hm3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m3
2 1 Schmidt	0.3	63.7%	41.5	81.4%	143
PRECIPITATION	0.2	36.3%	4.0	7.9%	24
INTERNAL LOAD	0.0	0.0%	5.5	10.7%	
TRIBUTARY INFLOW	0.3	63.7%	41.5	81.4%	143
***TOTAL INFLOW	0.5	100.0%	51.0	100.0%	112
ADVECTIVE OUTFLOW	0.3	76.9%	21.0	41.1%	60
***TOTAL OUTFLOW	0.3	76.9%	21.0	41.1%	60
***EVAPORATION	0.1	23.1%	0.0	0.0%	
***RETENTION	0.0	0.0%	30.0	58.9%	

Hyd. Residence Time = 0.7286 yrs
Overflow Rate = 2.3 m/yr
Mean Depth = 1.7 m

Component:TOTAL P — Segment: 3 Pomerleau

Trib Type Location	Flow hm3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m3
3 1 Pomerleau	0.3	71.4%	73.6	81.8%	223
PRECIPITATION	0.1	28.6%	3.2	3.6%	24
INTERNAL LOAD	0.0	0.0%	13.1	14.6%	
TRIBUTARY INFLOW	0.3	71.4%	73.6	81.8%	223
***TOTAL INFLOW	0.5	100.0%	90.0	100.0%	195
ADVECTIVE OUTFLOW	0.4	81.8%	29.5	32.8%	78
***TOTAL OUTFLOW	0.4	81.8%	29.5	32.8%	78
***EVAPORATION	0.1	18.2%	0.0	0.0%	
***RETENTION	0.0	0.0%	60.5	67.2%	

Hyd. Residence Time = 1.0444 yrs
Overflow Rate = 3.2 m/yr
Mean Depth = 3.3 m
Bass Lake

Table 2: BATHTUB Model Run Output

Diagnostics 1999

File: T:\1240\Lake TMDLs\Models and Data\Bass Schmidt Pomerleau\Bass 1999.btb

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 4 Area-Wtd Mean

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	66.6	0.27	64.3%	54.7		55.8%
TOTAL N MG/M3	1357.7		68.2%	1357.7		68.2%
C.NUTRIENT MG/M3	55.4	0.19	70.8%	47.3		63.7%
CHL-A MG/M3	31.8	0.33	94.4%	26.2		90.9%
SECCHI M	1.1	0.21	50.9%	1.2		56.5%
ORGANIC N MG/M3	915.5	0.29	90.2%			
TP-ORTHO-P MG/M3	62.8	0.33	78.2%			
ANTILOG PC-1	783.2	0.44	81.2%	549.2		73.1%
ANTILOG PC-2	15.3	0.16	95.1%	14.3		93.6%
(N - 150) / P	18.1	0.28	53.5%	22.9		66.8%
INORGANIC N / P	128.5	12.23	93.0%			
TURBIDITY 1/M	0.4	0.15	34.9%	0.4	0.15	34.9%
ZMIX * TURBIDITY	1.2	0.18	10.2%	1.2	0.18	10.2%
ZMIX / SECCHI	2.5	0.22	12.9%	2.2	0.09	9.3%
CHL-A * SECCHI	35.0	0.20	95.9%	32.1		94.7%
CHL-A / TOTAL P	0.5	0.27	92.0%	0.5		93.0%
FREQ(CHL-a>10) %	94.0	0.07	94.4%	89.2		90.9%
FREQ(CHL-a>20) %	66.9	0.28	94.4%	55.0		90.9%
FREQ(CHL-a>30) %	41.5	0.49	94.4%	29.9		90.9%
FREQ(CHL-a>40) %	24.9	0.67	94.4%	16.1		90.9%
FREQ(CHL-a>50) %	15.0	0.82	94.4%	8.9		90.9%
FREQ(CHL-a>60) %	9.2	0.96	94.4%	5.0		90.9%
CARLSON TSI-P	64.7	0.06	64.3%	61.5		55.8%
CARLSON TSI-CHLA	64.5	0.05	94.4%	62.6		90.9%
CARLSON TSI-SEC	58.6	0.05	49.1%	57.1		43.5%

Segment: 1 Bass

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	66.2	0.29	64.0%	49.0		51.0%
TOTAL N MG/M3	1400.0		69.9%	1400.0		69.9%
C.NUTRIENT MG/M3	55.9	0.20	71.2%	44.3		60.7%
CHL-A MG/M3	31.9	0.34	94.4%	26.5		91.1%
SECCHI M	1.1	0.22	50.4%	1.2		55.5%
ORGANIC N MG/M3	917.2	0.29	90.2%			
TP-ORTHO-P MG/M3	63.1	0.34	78.3%			
ANTILOG PC-1	790.0	0.45	81.4%	563.6		73.8%
ANTILOG PC-2	15.2	0.17	94.9%	14.2		93.4%
(N - 150) / P	18.9	0.29	56.1%	25.5		72.4%
INORGANIC N / P	155.7	12.79	95.2%			
TURBIDITY 1/M	0.4	0.20	35.6%	0.4	0.20	35.6%
ZMIX * TURBIDITY	1.2	0.23	11.3%	1.2	0.23	11.3%
ZMIX / SECCHI	2.6	0.23	14.4%	2.3	0.12	11.0%
CHL-A * SECCHI	34.7	0.22	95.8%	31.8		94.6%
CHL-A / TOTAL P	0.5	0.28	92.1%	0.5		94.5%
FREQ(CHL-a>10) %	94.1	0.07	94.4%	89.7		91.1%
FREQ(CHL-a>20) %	67.1	0.29	94.4%	55.7		91.1%

FREQ(CHL-a>30) %	41.6	0.51	94.4%	30.5		91.1%
FREQ(CHL-a>40) %	25.0	0.69	94.4%	16.5		91.1%
FREQ(CHL-a>50) %	15.0	0.85	94.4%	9.1		91.1%
FREQ(CHL-a>60) %	9.2	0.99	94.4%	5.2		91.1%
CARLSON TSI-P	64.6	0.06	64.0%	60.3		51.0%
CARLSON TSI-CHLA	64.6	0.05	94.4%	62.7		91.1%
CARLSON TSI-SEC	58.8	0.05	49.6%	57.4		44.5%

Segment: 2 Schmidt

	Predicted Values--->			Observed Values--->		
Variable	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	59.9	0.27	59.8%	55.0		56.1%
TOTAL N MG/M3	960.0		47.3%	960.0		47.3%
C.NUTRIENT MG/M3	44.8	0.15	61.2%	42.6		58.8%
CHL-A MG/M3	29.2	0.32	93.0%	27.5		91.9%
SECCHI M	1.2	0.19	55.2%	1.3		58.8%
ORGANIC N MG/M3	853.1	0.27	87.5%			
TP-ORTHO-P MG/M3	57.4	0.32	75.3%			
ANTILOG PC-1	617.4	0.40	76.0%	549.6		73.1%
ANTILOG PC-2	15.8	0.15	95.6%	15.3		95.1%
(N - 150) / P	13.5	0.28	36.8%	14.7		41.7%
INORGANIC N / P	42.0	12.95	63.6%			
TURBIDITY 1/M	0.4		31.6%	0.4		31.6%
ZMIX * TURBIDITY	0.7		2.4%	0.7		2.4%
ZMIX / SECCHI	1.4	0.19	1.9%	1.3		1.4%
CHL-A * SECCHI	34.9	0.18	95.9%	35.2		96.0%
CHL-A / TOTAL P	0.5	0.28	92.4%	0.5		93.0%
FREQ(CHL-a>10) %	92.2	0.08	93.0%	90.7		91.9%
FREQ(CHL-a>20) %	61.8	0.31	93.0%	58.1		91.9%
FREQ(CHL-a>30) %	36.2	0.53	93.0%	32.6		91.9%
FREQ(CHL-a>40) %	20.7	0.71	93.0%	18.0		91.9%
FREQ(CHL-a>50) %	12.0	0.86	93.0%	10.1		91.9%
FREQ(CHL-a>60) %	7.1	0.99	93.0%	5.8		91.9%
CARLSON TSI-P	63.2	0.06	59.8%	61.9		56.1%
CARLSON TSI-CHLA	63.7	0.05	93.0%	63.1		91.9%
CARLSON TSI-SEC	57.5	0.05	44.8%	56.4		41.2%

Segment: 3 Pomerleau

	Predicted Values--->			Observed Values--->		
Variable	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	78.0	0.30	70.6%	91.0		76.2%
TOTAL N MG/M3	1580.0		76.2%	1580.0		76.2%
C.NUTRIENT MG/M3	65.3	0.21	77.5%	72.3		81.1%
CHL-A MG/M3	34.8	0.33	95.6%	22.9		87.7%
SECCHI M	1.1	0.20	48.6%	1.3		59.6%
ORGANIC N MG/M3	982.5	0.29	92.4%			
TP-ORTHO-P MG/M3	68.0	0.33	80.6%			
ANTILOG PC-1	946.2	0.45	84.9%	455.4		68.2%
ANTILOG PC-2	15.5	0.14	95.2%	13.7		92.5%
(N - 150) / P	18.3	0.31	54.4%	15.7		45.4%
INORGANIC N / P	59.7	2.52	75.9%			
TURBIDITY 1/M	0.4		34.6%	0.4		34.6%
ZMIX * TURBIDITY	1.4		15.1%	1.4		15.1%
ZMIX / SECCHI	3.1	0.20	23.5%	2.5		13.8%
CHL-A * SECCHI	36.5	0.18	96.4%	29.8		93.5%
CHL-A / TOTAL P	0.4	0.28	90.2%	0.3		65.3%
FREQ(CHL-a>10) %	95.6	0.05	95.6%	84.8		87.7%

Table 2: BATHTUB Model Run Output

FREQ(CHL-a>20) %	72.0	0.24	95.6%	46.3	87.7%
FREQ(CHL-a>30) %	47.1	0.44	95.6%	22.8	87.7%
FREQ(CHL-a>40) %	29.6	0.62	95.6%	11.3	87.7%
FREQ(CHL-a>50) %	18.5	0.76	95.6%	5.8	87.7%
FREQ(CHL-a>60) %	11.7	0.89	95.6%	3.1	87.7%
CARLSON TSI-P	67.0	0.07	70.6%	69.2	76.2%
CARLSON TSI-CHLA	65.4	0.05	95.6%	61.3	87.7%
CARLSON TSI-SEC	59.3	0.05	51.4%	56.2	40.4%

Table 2: BATHTUB Model Run Output

Segment Balances 2001

File:T:\1240\Lake TMDLs\Models and Data\Bass Schmidt Pomerleau\Bass 2001.btb

Segment Mass Balance Based Upon Predicted Concentrations

Component:TOTAL P — Segment: 1 Bass

Trib Type Location	Flow hm3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m3
1 1 Bass	4.4	71.5%	664.4	88.9%	151
PRECIPITATION	0.9	13.9%	20.9	2.8%	24
TRIBUTARY INFLOW	4.4	71.5%	664.4	88.9%	151
ADVECTIVE INFLOW	0.9	14.6%	61.7	8.3%	69
***TOTAL INFLOW	6.2	100.0%	747.0	100.0%	121
ADVECTIVE OUTFLOW	5.6	91.1%	402.0	53.8%	72
***TOTAL OUTFLOW	5.6	91.1%	402.0	53.8%	72
***EVAPORATION	0.5	8.9%	0.0	0.0%	
***RETENTION	0.0	0.0%	345.0	46.2%	

Hyd. Residence Time = 0.3893 yrs
Overflow Rate = 7.2 m/yr
Mean Depth = 2.8 m

Component:TOTAL P — Segment: 2 Schmidt

Trib Type Location	Flow hm3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m3
2 1 Schmidt	0.4	69.2%	51.8	84.5%	140
PRECIPITATION	0.2	30.8%	4.0	6.6%	24
INTERNAL LOAD	0.0	0.0%	5.5	8.9%	
TRIBUTARY INFLOW	0.4	69.2%	51.8	84.5%	140
***TOTAL INFLOW	0.5	100.0%	61.3	100.0%	115
ADVECTIVE OUTFLOW	0.4	80.4%	26.6	43.3%	62
***TOTAL OUTFLOW	0.4	80.4%	26.6	43.3%	62
***EVAPORATION	0.1	19.6%	0.0	0.0%	
***RETENTION	0.0	0.0%	34.7	56.7%	

Hyd. Residence Time = 0.5930 yrs
Overflow Rate = 2.9 m/yr
Mean Depth = 1.7 m

Component:TOTAL P — Segment: 3 Pomerleau

Trib Type Location	Flow hm3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m3
3 1 Pomerleau	0.4	76.1%	84.0	83.7%	200
PRECIPITATION	0.1	23.9%	3.2	3.2%	24
INTERNAL LOAD	0.0	0.0%	13.1	13.1%	
TRIBUTARY INFLOW	0.4	76.1%	84.0	83.7%	200
***TOTAL INFLOW	0.6	100.0%	100.4	100.0%	182
ADVECTIVE OUTFLOW	0.5	84.8%	35.1	35.0%	75
***TOTAL OUTFLOW	0.5	84.8%	35.1	35.0%	75
***EVAPORATION	0.1	15.2%	0.0	0.0%	
***RETENTION	0.0	0.0%	65.3	65.0%	

Hyd. Residence Time = 0.8436 yrs
Overflow Rate = 3.9 m/yr
Mean Depth = 3.3 m

Table 2: BATHTUB Model Run Output

Diagnostics 2001

File: T:\1240\Lake TMDLs\Models and Data\Bass Schmidt Pomerleau\Bass 2001.btb

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 4 Area-Wtd Mean

Variable		Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P	MG/M3	70.6	0.26	66.7%	64.2		62.7%
TOTAL N	MG/M3	1275.4		64.7%	1275.4		64.7%
C.NUTRIENT	MG/M3	55.9	0.16	71.3%	52.6		68.6%
CHL-A	MG/M3	35.7	0.31	95.9%	41.1		97.2%
SECCHI	M	1.5	0.27	65.8%	1.3		60.8%
ORGANIC N	MG/M3	983.5	0.28	92.4%			
TP-ORTHO-P	MG/M3	63.4	0.34	78.5%			
ANTILOG PC-1		753.1	0.44	80.4%	774.4		81.0%
ANTILOG PC-2		20.4	0.10	98.6%	20.8		98.7%
(N - 150) / P		15.9	0.26	46.0%	17.4		51.4%
INORGANIC N / P		61.3	2.86	76.7%			
TURBIDITY	1/M	0.2	0.07	7.1%	0.2	0.07	7.1%
ZMIX * TURBIDITY		0.4	0.10	0.3%	0.4	0.10	0.3%
ZMIX / SECCHI		1.8	0.27	5.1%	2.0	0.09	7.0%
CHL-A * SECCHI		53.0	0.12	99.0%	55.4		99.2%
CHL-A / TOTAL P		0.5	0.28	93.2%	0.6		96.9%
FREQ(CHL-a>10)	%	95.8	0.04	95.9%	97.1		97.2%
FREQ(CHL-a>20)	%	73.1	0.22	95.9%	79.4		97.2%
FREQ(CHL-a>30)	%	48.7	0.40	95.9%	57.3		97.2%
FREQ(CHL-a>40)	%	31.1	0.56	95.9%	39.3		97.2%
FREQ(CHL-a>50)	%	19.7	0.70	95.9%	26.7		97.2%
FREQ(CHL-a>60)	%	12.6	0.82	95.9%	18.1		97.2%
CARLSON TSI-P		65.5	0.06	66.7%	64.1		62.7%
CARLSON TSI-CHLA		65.6	0.05	95.9%	67.0		97.2%
CARLSON TSI-SEC		54.6	0.07	34.2%	56.0		39.2%

Segment: 1 Bass

Variable		Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P	MG/M3	71.7	0.27	67.3%	64.0		62.6%
TOTAL N	MG/M3	1220.0		62.1%	1220.0		62.1%
C.NUTRIENT	MG/M3	55.9	0.16	71.2%	52.0		68.1%
CHL-A	MG/M3	36.3	0.31	96.0%	43.7		97.7%
SECCHI	M	1.6	0.29	69.8%	1.4		63.4%
ORGANIC N	MG/M3	990.7	0.29	92.6%			
TP-ORTHO-P	MG/M3	62.4	0.36	78.0%			
ANTILOG PC-1		726.8	0.46	79.7%	784.7		81.3%
ANTILOG PC-2		21.9	0.09	99.0%	22.5		99.1%
(N - 150) / P		14.9	0.27	42.4%	16.7		49.0%
INORGANIC N / P		24.8	2.36	42.8%			
TURBIDITY	1/M	0.1	0.20	1.1%	0.1	0.20	1.1%
ZMIX * TURBIDITY		0.2	0.23	0.0%	0.2	0.23	0.0%
ZMIX / SECCHI		1.7	0.30	4.2%	2.0	0.12	6.8%
CHL-A * SECCHI		58.1	0.11	99.3%	61.2		99.4%
CHL-A / TOTAL P		0.5	0.28	93.2%	0.7		97.5%
FREQ(CHL-a>10)	%	96.2	0.04	96.0%	98.1		97.7%
FREQ(CHL-a>20)	%	74.3	0.21	96.0%	82.9		97.7%

FREQ(CHL-a>30) %	49.9	0.40	96.0%	61.7		97.7%
FREQ(CHL-a>40) %	32.0	0.56	96.0%	43.3		97.7%
FREQ(CHL-a>50) %	20.4	0.70	96.0%	29.9		97.7%
FREQ(CHL-a>60) %	13.1	0.82	96.0%	20.6		97.7%
CARLSON TSI-P	65.8	0.06	67.3%	64.1		62.6%
CARLSON TSI-CHLA	65.8	0.05	96.0%	67.7		97.7%
CARLSON TSI-SEC	53.2	0.08	30.2%	55.2		36.6%

Segment: 2 Schmidt

	Predicted Values--->			Observed Values--->		
Variable	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	61.8	0.26	61.1%	58.0		58.4%
TOTAL N MG/M3	1040.0		52.3%	1040.0		52.3%
C.NUTRIENT MG/M3	47.5	0.16	63.9%	45.7		62.1%
CHL-A MG/M3	29.8	0.32	93.3%	29.5		93.1%
SECCHI M	1.0	0.17	43.6%	1.0		46.0%
ORGANIC N MG/M3	881.5	0.27	88.8%			
TP-ORTHO-P MG/M3	63.2	0.30	78.3%			
ANTILOG PC-1	725.8	0.39	79.6%	739.5		80.0%
ANTILOG PC-2	13.7	0.16	92.4%	13.3		91.6%
(N - 150) / P	14.4	0.26	40.4%	15.3		44.0%
INORGANIC N / P	158.5	1.51	95.4%			
TURBIDITY 1/M	0.6		49.3%	0.6		49.3%
ZMIX * TURBIDITY	1.0		7.3%	1.0		7.3%
ZMIX / SECCHI	1.8	0.17	4.5%	1.7		3.8%
CHL-A * SECCHI	28.5	0.21	92.6%	29.5		93.3%
CHL-A / TOTAL P	0.5	0.27	92.2%	0.5		93.3%
FREQ(CHL-a>10) %	92.7	0.07	93.3%	92.4		93.1%
FREQ(CHL-a>20) %	63.0	0.30	93.3%	62.4		93.1%
FREQ(CHL-a>30) %	37.4	0.51	93.3%	36.8		93.1%
FREQ(CHL-a>40) %	21.6	0.69	93.3%	21.2		93.1%
FREQ(CHL-a>50) %	12.6	0.84	93.3%	12.3		93.1%
FREQ(CHL-a>60) %	7.5	0.97	93.3%	7.3		93.1%
CARLSON TSI-P	63.6	0.06	61.1%	62.7		58.4%
CARLSON TSI-CHLA	63.9	0.05	93.3%	63.8		93.1%
CARLSON TSI-SEC	60.7	0.04	56.4%	60.0		54.0%

Segment: 3 Pomerleau

	Predicted Values--->			Observed Values--->		
Variable	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	75.0	0.29	69.1%	73.0		68.0%
TOTAL N MG/M3	1930.0		84.7%	1930.0		84.7%
C.NUTRIENT MG/M3	66.9	0.23	78.4%	65.5		77.6%
CHL-A MG/M3	39.2	0.34	96.8%	38.8		96.7%
SECCHI M	1.3	0.27	59.1%	1.3		59.6%
ORGANIC N MG/M3	1064.2	0.31	94.4%			
TP-ORTHO-P MG/M3	70.1	0.37	81.4%			
ANTILOG PC-1	958.7	0.51	85.1%	751.1		80.4%
ANTILOG PC-2	19.4	0.11	98.2%	19.6		98.3%
(N - 150) / P	23.7	0.30	68.8%	24.4		70.2%
INORGANIC N / P	177.4	7.35	96.4%			
TURBIDITY 1/M	0.2		9.3%	0.2		9.3%
ZMIX * TURBIDITY	0.6		1.9%	0.6		1.9%
ZMIX / SECCHI	2.6	0.27	14.2%	2.5		13.8%
CHL-A * SECCHI	50.4	0.13	98.8%	50.4		98.8%
CHL-A / TOTAL P	0.5	0.27	93.8%	0.5		94.2%
FREQ(CHL-a>10) %	97.1	0.04	96.8%	97.0		96.7%

Table 2: BATHTUB Model Run Output

FREQ(CHL-a>20) %	78.1	0.20	96.8%	77.6	96.7%
FREQ(CHL-a>30) %	54.8	0.39	96.8%	54.2	96.7%
FREQ(CHL-a>40) %	36.5	0.56	96.8%	36.0	96.7%
FREQ(CHL-a>50) %	24.1	0.71	96.8%	23.6	96.7%
FREQ(CHL-a>60) %	15.9	0.83	96.8%	15.5	96.7%
CARLSON TSI-P	66.4	0.06	69.1%	66.0	68.0%
CARLSON TSI-CHLA	66.6	0.05	96.8%	66.5	96.7%
CARLSON TSI-SEC	56.4	0.07	40.9%	56.2	40.4%

Table 3: TMDL Loads Pomerleau and Bass (1999) and Schmidt (2001)			Pomerleau	Schmidt	Bass
Modeled Parameter	**Option & Equation**		**Lake Model**	**Lake Model**	**Lake Model**
Internal Phosphorus Load	**kg**		**4.0**	**5.0**	**5.0**
Atmospheric Phosphorus Load			**3.2**	**4.0**	**20.9**
Tributary Load			**23.8**	**42.0**	**374.8**
Load from Upstream Lake					**35.3**
Total Phosphorus Load			**31.0**	**51.0**	**436.0**
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION	Canfield & Bachmann 1980 f(W,Q,V) $P = P_i/(1+CP*a*P_i^b*T^c)$				
	CP	[--]	*1.00*	*1.00*	*1.00*
	a	[--]	0.162	0.162	0.162
	b	[--]	0.458	0.458	0.458
	c	[--]	0.542	0.542	0.542
	W= total P load (inflow + atm.)	[kg/yr]	31	51	436
	Q=lake outflow	$[10^6 m^3/yr]$	0.33	0.37	3.24
	V=lake volume (modeled)	$[10^6 m^3]$	0.41	0.25	2.20
	T = V/Q	[yr]	1.24	0.68	0.68
	P_i = W/Q	[ug/l]	94	138	135
Modeled In-Lake [TP]		**[ug/l]**	**38.2**	**61.2**	**60.1**
Observed In-Lake [TP], May to September					
CHL-A MODEL	**N, P, Flushing (Walker 1999)** **B= CB Bx /[(1+0.025 Bx**				
	CB as used to calibrate		**1.0**	**1.0**	**1.0**
	P Total Phosphorus	**[ug/l]**	**38**	**61**	**60**
	N Total Nitrogen	**[ug/l]**	**1930**	**1040**	**1220**
	Zmix Mixing Depth	**m**	**3.3**	**1.7**	**2.8**
Q/V	**Fs Flushing Rate**	**year-1**	**0.8**	**1.5**	**1.5**
	S Secchi Depth	**(m)**	**1.3**	**1.0**	**1.4**
(1/s)-0.025B	**a Non algal turbidity**	**m-1**	**0.2**	**0.6**	**0.1**
	Xpn		**37.0**	**47.2**	**49.8**
	Bx		**28.3**	**39.1**	**42.0**
	G		**0.47**	**0.25**	**0.41**
	B		**21.6**	**30.0**	**32.6**
Observed In-Lake [CHL-A]			**38.8**	**29.5**	**43.7**
SECCHI MODEL	chla & turbidity				
	CS as used to calibrate	[--]	*1.00*	*1.00*	*1.00*
Calibrated In-Lake SD		**[m]**	**1.95**	**0.99**	**1.82**
Observed In-Lake [SD]			**1.30**	**1.00**	**1.40**
MODELED PHOSPHORUS OUTFLOW	W-(Sedimentation)	**[kg/yr]**	**13**	**23**	**195**
MODELED PHOSPHORUS SEDIMENTATION	$CP*a*(Wp/V)^b*[TP]*V$	**[kg/yr]**	**18**	**28**	**241**

Schmidt Lake Table 1
P8 Results

Precip (n)	Year	P8 Flow (ac-ft)	P8 Load (lbs)
35	1992	277.66	100.54
37	1993	278.57	108.85
30	1994	216.67	86.274
33	1995	236.44	95.416
29	1996	221.61	86.405
34	1997	304.42	159.5
31	1998	237.37	91.178
31	1999	237.02	92.004
35	2000	282.92	121.13
35	2001	301.07	114.35
43	2002	348.62	139.34
25	2003	196.48	77.8

Year	Precip (in)	SWMM (ac-ft)	P8 Flow (ac-ft)	% diff	TP-P8 (lbs)	TP-ICB (lbs)	% diff
1992	35	272	278	2%	101		
1993	37	254	279	9%	109		
1994	30	126	217	42%	86		
1995	33	225	236	5%	95	76	20%
1996	29	188	222	15%	86		
1997	34	256	304	16%	160		
1998	31	195	237	18%	91	121	-33%
1999	31	202	237	15%	92		
2000	35	249	283	12%	121	107	12%
2001	35	478	301	-59%	114	133	-16%
2002	43	334	349	4%	139		
2003	25	190	196	3%	78		

ICB = Inverted Canfield Bachmann
SWMM = Shingle Creek SWMM model calibrated in the Shingle Creek Chloride TMDL

Precip (in)	Year	P8 Flow (hm3)	P8 Load (kg)	TP (ug/L)	
35	1992	0.34	46	133	
37	1993	0.34	49	144	
30	1994	0.27	39	146	
33	1995	0.29	43	148	
29	1996	0.27	39	143	
34	1997	0.38	72	193	
31	1998	0.29	41	141	
31	1999	0.29	42	143	Average
35	2000	0.35	55	157	
35	2001	0.37	52	140	
43	2002	0.43	63	147	Wet
25	2003	0.24	35	146	Dry

Schmidt Lake Table 2
Lake Morphometry

Depth	Depth Segment	Acres	Volume (ac-ft)	Bottom Area	% Lake Area	m3	Liters	m2	Km2	z
0		36.35						147,108	0.15	1.69
5	0-5	13.31	119.43	23.0	63.4	147,327	147,326,771	53,866		
10	5-10	4.84	43.63	8.5	23.3	53,819	53,819,171	19,587		
15	10-15	2.91	19.17	1.9	5.3	23,650	23,650,369	11,777		
20	15-20	2.15	12.60	0.8	2.1	15,546	15,546,274	8,701		
25	20-25	0.76	6.98	1.4	3.8	8,611	8,611,238	3,076		
TOTAL			201.81		98	248,954	248,953,823	97,007		

Schmidt Lake Table 3
Inverted Canfield Bachmann Calculation

EXISTING

Total Watershed Loads

		ICB Load (kg)	Modeled TP Average	Measured TP Average	L Average	z (m)	p (1/yr)	o Average	Volume (ac-ft)	Water Load (ac-ft)	Residence Time (yr)	Inflow Concen-tration (ug/L)	Lake Surface Area (km2)
	1995	34	50	50	229.8	1.7	1.17050	1.53262	202	236	0.9	118	0.15
	1998	55	70	70	365.4	1.7	1.17510	1.89546	202	237	0.9	187	0.15
	2000	44	55	55	290.5	1.7	1.40059	1.70646	202	283	0.7	125	0.15
	2001	49	58	58	323.8	1.7	1.49045	1.79335	202	301	0.7	131	0.15
	2004	60	68	68	400.9	1.7	1.49045	1.97775	202	301	0.7	162	0.15
	2005	42	52	52	280.1	1.7	1.49045	1.67820	202	301	0.7	113	0.15

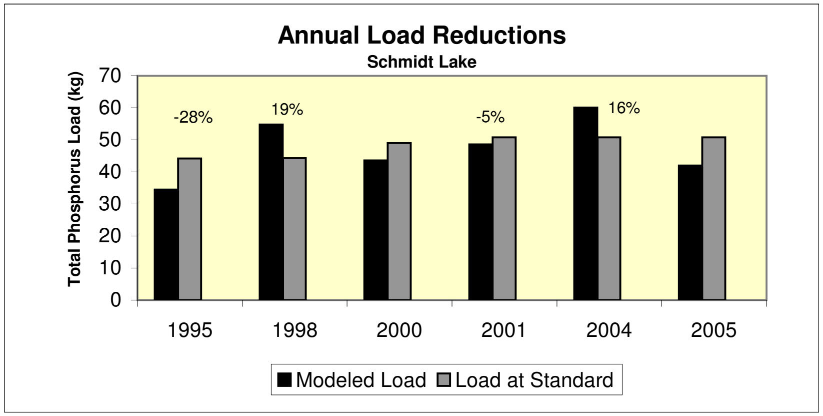
		P8 Load (kg)											
Average	1999	42	57		278.2	1.7	1.173267	1.673013	202	237	0.9	143	0.15
Wet	2002	63	66		421.4	1.7	1.727723	2.023311	202	349	0.6	147	0.15
Dry	2003	35	55		235.3	1.7	0.970297	1.549332	202	196	1.0	146	0.15

AT STANDARD

Total Watershed Loads

		ICB Load (kg)	Modeled TP Average	Measured TP Average	L Average	z (m)	p (1/yr)	o Average	Volume (ac-ft)	Water Load (ac-ft)	Residence Time (yr)	Inflow Concen-tration (ug/L)	Lake Surface Area (km2)
	1995	44	60	60	294.6	1.7	1.170495	1.717297	202	236	0.9	151	0.15
	1998	44	60	60	295.2	1.7	1.175099	1.719026	202	237	0.9	151	0.15
	2000	49	60	60	326.5	1.7	1.400594	1.800174	202	283	0.7	140	0.15
	2001	51	60	60	338.8	1.7	1.490446	1.830931	202	301	0.7	137	0.15
	2004	51	60	60	338.8	1.7	1.490446	1.830931	202	301	0.7	137	0.15
	2005	51	60	60	338.8	1.7	1.490446	1.830931	202	301	0.7	137	0.15
Average	1999	44	60	60	294.9	1.7	1.173267	1.718351	202	237	0.9	151	0.15
Wet	2002	56	60	60	370.9	1.7	1.727723	1.908461	202	349	0.6	129	0.15
Dry	2003	40	60	60	266.2	1.7	0.970297	1.639514	202	196	1.0	165	0.15

Year	Load	Load at Standard	% Reduction
1995	34	44	-28%
1998	55	44	19%
2000	44	49	-12%
2001	49	51	-5%
2004	60	51	16%
2005	42	51	-21%



Pomerleau Lake Table 1
P8 Results

Precip (in)	Year	P8 Flow (ac-ft)	P8 Load (lbs)
35	1992	311.96	170.26
37	1993	315.58	193.7
30	1994	248.68	161.28
33	1995	269.48	176.58
29	1996	253.56	159.13
34	1997	354.39	241.83
31	1998	272.22	167.28
31	1999	266.98	162.09
35	2000	326.61	199.22
35	2001	342.72	186.86
43	2002	393.24	225.09
25	2003	219.81	126.93

Year	Precip (in)	SWMM (ac-ft)	P8 Flow (ac-ft)	% diff	TP-P8 (lbs)	TP-ICB (lbs)	% diff	
1992	35	335	312	-7%	170			
1993	37	311	316	1%	194			
1994	30	245	249	2%	161			
1995	33	275	269	-2%	177			
1996	29	230	254	10%	159	105	34%	
1997	34	315	354	13%	242			
1998	31	239	272	14%	167			
1999	31	247	267	8%	162	230	-42%	Average
2000	35	305	327	7%	199			
2001	35	312	343	10%	187	187		
2002	43	408	393	-4%	225			Wet
2003	25	236	220	-7%	127			Dry

Precip (in)	Year	P8 Flow (hm3)	P8 Load (kg)	TP (ug/L)
35	1992	0.38	77	201
37	1993	0.39	88	226
30	1994	0.31	73	238
33	1995	0.33	80	241
29	1996	0.31	72	231
34	1997	0.44	110	251
31	1998	0.34	76	226
31	1999	0.33	74	223
35	2000	0.40	90	224
35	2001	0.42	85	200
43	2002	0.49	102	210
25	2003	0.27	58	212

Precipitation at New Hope

Average 224

ICB = Inverted Canfield Bachmann

SWMM = Shingle Creek SWMM model calibrated in the Shingle Creek Chloride TMDL

Pomerleau Lake Table 2
Lake Morphometry

Depth	Depth Segment	Acres	Volume (ac-ft)	Bottom Area	% Lake Area	m3	Liters	m2	Km2	z
0		30.52			100			123,514	0.12	3.29
5	0-5	23.33	134.22	7.19	23.56	165,580.32	165,580,317.12			
10	5-10	13.53	91.04	9.80	32.11	112,314.20	112,314,201.08			
15	10-15	9.76	57.97	3.77	12.35	71,511.72	71,511,718.46			
20	15-20	4.95	36.10	4.81	15.76	44,535.06	44,535,058.25			
25	20-25	0.11	9.66	4.84	15.86	11,920.67	11,920,672.93			
TOTAL			329.00			405,861.97	405,861,967.85			

Pomerleau Lake Table 3
Inverted Canfield Bachmann Calculation

EXISTING

Total Watershed Loads

		ICB Load (kg)	Modeled TP Average	Measured TP Average	L Average	z (m)	p (1/yr)	o Average	Volume (ac-ft)	Water Load (ac-ft)	Residence Time (yr)	Inflow Concen-tration (ug/L)	Lake Surface Area (km2)
Years With	1996	48	54	54	396.3	3.3	0.77204	1.45188	329	254	1.3	152	0.12
Actual WQ	1999	104	91	91	868.1	3.3	0.81155	2.07922	329	267	1.2	316	0.12
Data	2001	85	73	73	708.3	3.3	1.04255	1.89428	329	343	1.0	201	0.12

		P8 Load (kg)											
Average	1999	74	72		616.7	3.3	0.81155	1.77778	329	267	1.2	225	0.12
Wet	2002	102	79		850.0	3.3	1.19453	2.05925	329	393	0.8	210	0.12
Dry	2003	58	65		483.3	3.3	0.66565	1.59009	329	219	1.5	215	0.12

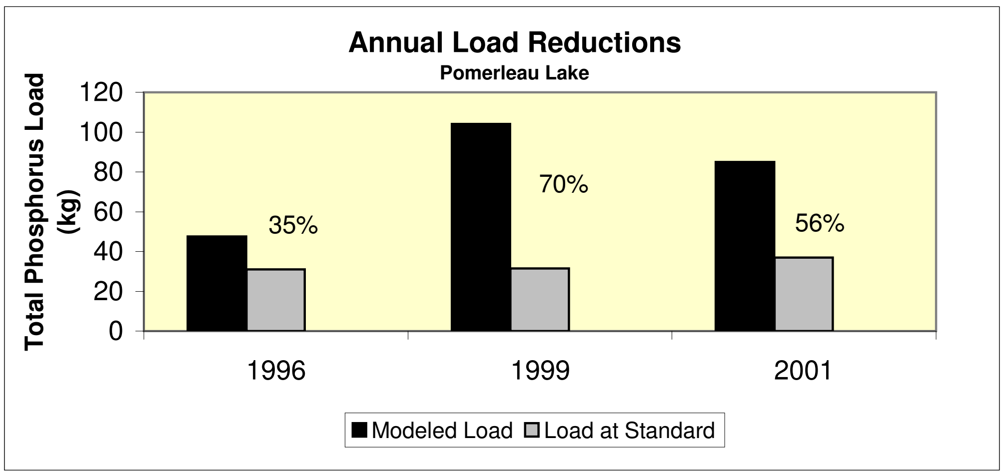
AT STANDARD

Total Watershed Loads

		ICB Load (kg)	Modeled TP Average	Measured TP Average	L Average	z (m)	p (1/yr)	o Average	Volume (ac-ft)	Water Load (ac-ft)	Residence Time (yr)	Inflow Concen-tration (ug/L)	Lake Surface Area (km2)
	1996	31	40	40	258.3	3.3	0.77204	1.19348	329	254	1.3	99	0.12
	1999	31	40	40	262.5	3.3	0.81155	1.20226	329	267	1.2	96	0.12
	2001	37	40	40	308.3	3.3	1.04255	1.29422	329	343	1.0	87	0.12
Average	1999	31	40		262.5	3.3	0.81155	1.20226	329	267	1.2	96	0.12
Wet	2002	40	40		335.2	3.3	1.19453	1.34463	329	393	0.8	83	0.12
Dry	2003	29	40		240.3	3.3	0.66565	1.15448	329	219	1.5	107	0.12

Year	Load	Load at Standard	% Reduction
1996	48	31	35%
1999	104	31	70%
2001	85	37	56%
Average	74	31	57%
Wet	102	40	61%
Dry	58	29	50%

residual 129



Bass Lake Table 1
P8 Results

Year	P8 Flow (ac-ft)	P8 Load (lbs)
1992	3109.3	1223.645
1993	3077.8	1294.618
1994	2327.1	997.576
1995	2518.9	1114.795
1996	2444.4	1016.418
1997	3730.2	2327.08
1998	2638.8	1080.948
1999	2628.7	1093.73
2000	3299.7	1592.421
2001	3548.6	1458.931
2002	3966.3	1749.92
2003	2178.3	918.0635

Year	Precip (in)	SWMM (ac-ft)	P8 Flow (ac-ft)	% diff	TP-P8 (lbs)	TP-ICB (lbs)	% diff
1992	35	3126	587	-1%	1223.645		
1993	37	2886	453	7%	1294.6175		
1994	30	2184	506	7%	997.576	644	55%
1995	33	2548	461	-1%	1114.795		
1996	29	2136	1056	14%	1016.418		
1997	34	2967	490	26%	2327.08	1,121	108%
1998	31	2217	496	19%	1080.948		
1999	31	2720	722	-3%	1093.7295	734	49%
2000	35	2833	662	16%	1592.421		
2001	35	3122	794	14%	1458.931	1,260	16%
2002	43	3787	416	5%	1749.92		
2003	25	2220	0	-2%	918.0635		

ICB = Inverted Canfield Bachmann
SWMM = Shingle Creek SWMM model calibrated in the Shingle Creek Chloride TMDL

Year	P8 Flow (hm3)	P8 Load (kg)	TP (ug/L)	
1992	3.84	555	145	
1993	3.80	587	155	
1994	2.87	453	158	
1995	3.11	506	163	
1996	3.02	461	153	
1997	4.60	1056	229	
1998	3.26	490	151	
1999	3.24	496	153	Average
2000	4.07	722	177	
2001	4.38	662	151	
2002	4.89	794	162	Wet
2003	2.69	416	155	Dry
		Average	163	

Bass Lake Table 2
Lake Morphometry

Depth	Depth Segment	Acres	Volume (ac-ft)	Bottom Area	% Lake Area	m3	Liters	m2	Km2	z
0		193.27			100.0			782,164	0.78	2.78
10	0-10	65.22	1235.87	128.05	66.3	1,524,598.31	1,524,598,307.35	263,945		
20	10-20	23.91	428.73	41.31	21.4	528,891.07	528,891,073.63	96,764		
30	20-30	0.73	96.06	23.18	12.0	118,500.78	118,500,779.26	2,954		
				0.73	0.4	-	-	363,663		
TOTAL			1760.67			2,171,990.16				

Bass Lake Table 3
Inverted Canfield Bachmann Calculation

EXISTING

Total Watershed Loads

	Year	ICB Load (kg)	Modeled TP Average	Measured TP Average	L Average	z (m)	p (1/yr)	o Average	Volume (ac-ft)	Water Load (ac-ft)	Residence Time (yr)	Inflow Concen-tration (ug/L)	Lake Surface Area (km2)
Years With	1994	292	47	47	374.7	2.8	1.32141	1.52561	1,761	2,327	0.8	102	0.78
Actual	1997	508	57	57	651.8	2.8	2.11811	1.96603	1,761	3,730	0.5	110	0.78
WQ	1999	333	49	49	427.1	2.8	1.49290	1.61990	1,761	2,629	0.7	103	0.78
Data	2001	572	64	64	732.9	2.8	2.01533	2.07445	1,761	3,549	0.5	131	0.78

	Year	P8 Load (kg)	Modeled TP Average	Measured TP Average	L Average	z (m)	p (1/yr)	o Average	Volume (ac-ft)	Water Load (ac-ft)	Residence Time (yr)	Inflow Concen-tration (ug/L)	Lake Surface Area (km2)
Average	1999	496	66		635.9	2.8	1.49290	1.94387	1,761	2,629	0.7	153	0.78
Wet	2002	794	78		1017.9	2.8	2.25230	2.41132	1,761	3,966	0.4	162	0.78
Dry	2003	416	63		533.3	2.8	1.23697	1.79342	1,761	2,178	0.8	155	0.78

AT STANDARD

Total Watershed Loads

	Year	ICB Load (kg)	Modeled TP Average	Measured TP Average	L Average	z (m)	p (1/yr)	o Average	Volume (ac-ft)	Water Load (ac-ft)	Residence Time (yr)	Inflow Concen-tration (ug/L)	Lake Surface Area (km2)
	1994	405	60	60	519.8	2.8	1.32141	1.77236	1,761	2,327	0.8	141	0.78
	1997	543	60	60	696.3	2.8	2.11811	2.02631	1,761	3,730	0.5	118	0.78
	1999	436	60	60	558.5	2.8	1.49290	1.83176	1,761	2,629	0.7	134	0.78
	2001	526	60	60	674.0	2.8	2.01533	1.99632	1,761	3,549	0.5	120	0.78
Average	1999	436	60		558.5	2.8	1.49290	1.83176	1,761	2,629	0.7	134	0.78
Wet	2002	566	60		725.2	2.8	2.25230	2.06448	1,761	3,966	0.4	116	0.78
Dry	2003	390	60		500.5	2.8	1.23697	1.74190	1,761	2,178	0.8	145	0.78

Year	Load	Load at Standard	% Reduction
1994	292	405	-39%
1997	508	543	-7%
1999	333	436	-31%
2001	572	526	8%