Long and Ringo Lakes Excess Nutrients Total Maximum Daily Load

Hawk Creek Watershed Project
Minnesota Pollution Control Agency
2011

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Table of Contents

List of Tables 4

List of Figures 5

List of Appendices 6

TMDL Summary Table 7

Executive Summary 10

1.0 Introduction and Watershed Background 12

1.1 Purpose 12

1.2 Problem Statement and 303(d) Listings 12

1.3 Description of Long and Ringo Lakes Watersheds 12

1.4 Climate Summary 15

1.5 Soil and Geological Summary 15

1.6 Water Quality Sampling Protocol 15

1.7 Long Lake 17

1.7.1 Long Lake Morphology 17

1.7.2 Long Lake Water Quality and Sampling Results 18

1.7.3 Fisheries, Aquatic Vegetation, and Substrate Surveys 28

1.8 Ringo Lake 29

1.8.1 Ringo Lake Morphology 29

1.8.2 Ringo Lake Water Quality Data and Sampling Results 30

1.8.3 Fisheries, Aquatic Vegetation, and Substrate Surveys 36

1.9 Ringo Lake Outlet 36

1.9.1 Ringo Lake Outlet Water Quality Data and Sampling Results 36

2.0 Narrative and Numeric Water Quality Standards 37

3.0 Phosphorus Source Inventory 38

4.0 Linking Water Quality Goals and Phosphorus Sources 41
4.1 Lake Modeling 41
4.1.1 Long Lake 42
4.1.2 Ringo Lake 44
5.0 Phosphorus TMDL and Load Allocations 46
5.1 Total Maximum Daily Load Formula 46
5.2 Wasteload Allocations (WLA) 46
5.3 Load Allocations (LA) 47
5.4 Margin of Safety (MOS) 47
5.5 Reserve Capacity (RC) 47
5.6 Phosphorus Total Maximum Daily Loads for Long and Ringo Lake 48
5.7 Seasonal Variation 48
6.0 Public Participation 49
7.0 Implementation Strategy 50
7.1 External Loading Reduction Strategies 50
7.1.1 Urban/Residential 50
7.1.2 Agriculture/Gravel Operations 51
7.2 Internal Loading Reduction Strategies 51
7.3 Monitoring Plan 52
7.4 Reasonable Assurance 53
8.0 References 54

List of Tables

Table 1. Land Use Summary for Long and Ringo Lakes. 14

Table 2. Lake and Stream Sampling Site Locations. 16

Table 3. Long Lake Morphometric Characteristics. 17

Table 4. Annual Water Quality Parameter Means for Long Lake 2008-2009. 22

Table 5. Carlson's Trophic State Index for Long Lake 2008 – 2009. 28

Table 6. Ringo Lake Morphometric Characteristics. 29

Table 7. Annual Water Quality Parameter Means for Ringo Lake 2008-2009. 33

Table 8. Carlson's Trophic State Index (TSI) for Ringo Lake 2008 – 2009. 36

Table 9. Annual Water Quality Parameter Means for Ringo Lake Outlet 2008-2009. 37

Table 10. Livestock Facilities in the Long and Ringo Lakes Watersheds. 39

Table 11. Summary of Livestock in the Long and Ringo Lakes Watersheds. 39

Table 12. Long Lake Observed In-lake Parameter Concentrations and Model Predictions. 44

Table 13. Ringo Lake Observed In-lake Parameter Concentrations and Model Predictions. 45

List of Figures

Figure 1. Long and Ringo Lakes Sampling Sites, 2008-2009. 16

Figure 2. Long Lake Bathymetric Map. 18

Figure 3. Water Temperature Profile for Long Lake Site 203 (2008). 19

Figure 4. Water Temperature Profile for Long Lake Site 201 (2009). 19

Figure 5. Dissolved Oxygen Profile for Long Lake Site 201 (2008). 20

Figure 6. Dissolved Oxygen Profile for Long Lake Site 203 (2009). 20

Figure 7. Long Lake Site 201 (2008) Secchi Water Clarity, Total Phosphorus and Chlorophyll-a vs. date.. 23

Figure 8. Long Lake Site 201 (2009) Secchi Water Clarity, Total Phosphorus and Chlorophyll-a vs. date.. 23

Figure 9. Long Lake Site 203 (2008) Secchi Water Clarity, Total Phosphorus and Chlorophyll-a vs. date.. 24

Figure 10. Long Lake Site 203 (2009) Secchi Water Clarity, Total Phosphorus and Chlorophyll-a vs. date. 24

Figure 11. Long Lake Sites 201 and 203 Combined (2008) Mean Secchi Water Clarity, Total Phosphorus and Chlorophyll-a vs. date. 25

Figure 12. Long Lake Sites 201 and 203 Combined (2009) Mean Secchi Water Clarity, Total Phosphorus and Chlorophyll-a vs. date. 25

Figure 13. Long Lake Summer Mean Secchi Transparency, 1975 - 2009. 26

Figure 14. Carlson's Trophic State Index 27

Figure 15. Ringo Lake Bathymetric Map. 30

Figure 16. Water Temperature Profile for Ringo Lake 2008. 31

Figure 17. Water Temperature Profile for Ringo Lake 2009. 31

Figure 18. Dissolved Oxygen Profile for Ringo Lake 2008. 32

Figure 19. Dissolved Oxygen Profile for Ringo Lake 2009. 32

Figure 20. Ringo Lake (2008) Secchi Water Clarity, Total Phosphorus and Chlorophyll-a vs. date. 34

Figure 21. Ringo Lake (2009) Secchi Water Clarity, Total Phosphorus and Chlorophyll-a vs. date. 35

Figure 22. Ringo Lake Summer Mean Secchi Transparency, 2003, 2007 - 2009. 35

List of Appendices

1. Temperature Profiles for Long Lake.
2. Dissolved Oxygen Profiles for Long Lake.
3. Minnesota Department of Natural Resources, Fisheries Management Standard Lake Reports for Long and Ringo Lake.
4. List of Acronyms and Abbreviations

TMDL Summary Table

EPA/MPCA Required Elements	Summary	TMDL Page #
Location	Long and Ringo Lakes are located in the Hawk Creek Watershed, Kandiyohi County, just north of the city of Willmar, Minnesota (HUC-07020004)	12-13
303(d) Listing Information	• Long Lake (34-0192), Ringo Lake (34-0172) • Impaired Beneficial Use: Aquatic Recreation (Minn. R. pt. 7050.0222) • Impairment/TMDL Pollutant of Concern: Excess Nutrients (Total Phosphorus) • Priority set to complete by 2011 • Original listing year: Long Lake (2002), Ringo Lake (2010) • Target Start: Long Lake (2007) and Ringo Lake (2008) • Target Completion: Long Lake (2011) and Ringo Lake (2011)	12
Applicable Water Quality Standards/ Numeric Targets	The North Central Hardwood Forest (NCHF) Ecoregion water quality standards for shallow lakes are: Total Phosphorus (≤60 µg/L), Chlorophyll-a (≤20 µg/L), and Secchi Transparency (≥1.0 m). (Minn. R. 7050.0222, subp. 4 and subp. 4a).	12, 37-38
Loading Capacity (expressed as daily load)	The phosphorus loading capacity is the Total Maximum Daily Load for the critical condition. Long Lake = 8.16 lbs/day, Ringo Lake = 1.96 lbs/day The critical condition for Long Lake and Ringo Lake is the summer growing season (June-Sept.) when water quality and phosphorus loading are worst. Setting the TMDL based on these conditions will be protective during the entire year.	46
Wasteload Allocation	Waste load allocations (WLA) in this watershed are limited to potential construction stormwater, and industrial stormwater activities in relation to sand and gravel operations. For the purposes of this TMDL, the one year	46-47

	average construction rate (0.2%) is rounded up to a 1% WLA rate for both lakes. To account for waste loads associated with industrial stormwater, an allocation 5.5% of the total watershed portion of the TMDL load is assigned to the Industrial Stormwater WLA in the Long Lake Watershed, and 6.2% was assigned to the Ringo Lake Watershed. The combined Construction Stormwater and Industrial Stormwater WLA for Long Lake is 6.5% and Ringo Lake is 7.2%. Long Lake Total Phosphorus WLA = 0.48 lbs/day Ringo Lake Total Phosphorus WLA = 0.13 lbs/day	
Load Allocation	Existing and future nonpoint sources accounted for in this load allocation (LA) include: phosphorus contributions from all watershed land uses, direct atmospheric loading, and internal loading. Long Lake Total Phosphorus LA = 6.87 lbs/day Ringo Lake Total Phosphorus LA = 1.64 lbs/day	47
Margin of Safety	A 10% Margin of Safety (MOS) is built into the Long and Ringo Lakes TMDL to help account for uncertainty, effectively lowering the phosphorus target from the ecoregion standard of 60 µg/L to 54 µg/L . Long Lake Total Phosphorus MOS = 0.81 lbs/day Ringo Lake Total Phosphorus MOS = 0.20 lbs/day	47
Seasonal Variation	Total Phosphorus (TP) concentrations in lakes can vary considerably during the growing season, generally peaking during mid-late summer. The MPCA eutrophication water quality guideline for assessing TP is defined as the growing season mean concentration (MPCA, 2004). The BATHTUB model was used to calculate the LA and WLA, incorporating mean growing season TP values. TP loadings were calculated to meet the water quality standards during the summer growing season, the most critical period of the year. Calibration to this critical period will provide adequate protection during times of the year with reduced loading.	48-49

Reasonable Assurance	Several agencies and non-profit groups are currently working toward the goal of reducing phosphorus runoff within the Long and Ringo Lakes Watershed. These include Hawk Creek Watershed Project, Natural Resources Conservation Service, Soil & Water Conservation District, Kandiyohi County, Long Lake Association, and the MPCA, as well as private citizens and landowners. Funding and technical assistance is currently available to assist land and home owners with a variety of best management practices (BMPs) that will, if implemented, reduce phosphorus loading to Long and Ringo Lakes.	53
Monitoring	Effectiveness monitoring of Long Lake, Ringo Lake, and their tributaries will be conducted following a period of implementation. Effectiveness monitoring methodology and sampling sites will be consistent with the parameters established during this TMDL assessment (see Long Lake Nutrient TMDL Assessment and Implementation Plan Development Project Quality Assurance Project Plan).	52
Implementation	A detailed Implementation Plan including estimated number of practices and expenses will be developed through the Long/Ringo Lakes Technical Committee. The Implementation Strategy described here will provide the framework for the Long and Ringo Lakes TMDL Implementation Plan. Cost estimates of each practice are included.	50
Public Participation	The Hawk Creek Watershed Project hosted six meetings with a stakeholder group between August 2008 and June 2011. This group was made up of volunteers from the general public, representing varied interests such as lake associations, home owners, agriculture, and public resource management agencies. Meetings were held to inform the public about the TMDL process, data collection, and to solicit input on the TMDL draft report prior to submittal to the EPA. Additional comments were received during the official public comment period from April 18 to May 18, 2011. See Section 6 for additional details about public participation.	49

Executive Summary

Long Lake and Ringo Lake are currently listed on the Minnesota Pollution Control Agency's (MPCA) 2010 303(d) Impaired Waters List due to excessive nutrients, specifically phosphorus. Both of these lakes require a Total Maximum Daily Load (TMDL) report. Long Lake was originally listed in 2002, and Ringo Lake was originally listed in 2010. The designated uses for both lakes are for aquatic recreation (boating, swimming, fishing, etc.). This TMDL study assesses the pollutant source inventories and subsequent pollutant reduction strategies required to reach the North Central Hardwood Forest (NCHF) ecoregion phosphorus standard of ≤60 µg/L.

Excessive phosphorus levels can have significant negative effects on lake water clarity, biology, and aesthetics. Measured phosphorus levels in both Long and Ringo Lakes are typical of lakes with frequent severe nuisance algae blooms (Heiskary and Wilson, 2008), dominated by blue-green algae which has been linked to illness in people and death of animals. Increased phosphorus levels will also stimulate excess rooted vegetation growth. As excess vegetation dies and is decomposed, anoxic conditions are created that have negative effects on aquatic communities. Loss of native plant communities can impact wildlife species through loss of habitat. Native plant communities provide spawning and shelter areas for fish as well as feeding areas for a variety of wildlife. Aesthetic qualities of lakes are also lost due to decreased water clarity and frequent algae blooms.

The Long and Ringo Lake watersheds are located within the NCHF ecoregion about three miles north of the city of Willmar in Kandiyohi County. Located on the northern edge of the Hawk Creek Watershed, Ringo Lake (MNDNR Lake ID# 34-0172) is a 735-acre lake with a watershed area of 4,368 acres, which flows through a wetland complex then to Long Lake (MNDNR ID# 34-0192), a 1,568-acre lake with a watershed area of 8,372 acres. Land use in the watersheds of Long and Ringo Lakes are typical of other watersheds in the NCHF ecoregion. Land use is divided among agriculture, Conservation Reserve Program, urban, wooded, and pasture/grasslands, with no single land use dominating the landscape. Long and Ringo Lakes are moderately developed lakes used for a variety of recreational activities including fishing, swimming, boating, and some hunting.

A Lake Assessment Program (LAP) Study was conducted in 1997 on Long Lake. At that time, the in-lake phosphorus level was 51 µg/L. Data collected during this TMDL study revealed that total phosphorus in Long Lake had increased to 113 µg/L in 2008 and 141 µg/L in 2009, far exceeding the ecoregion standard.

In 2008, the Hawk Creek Watershed Project (HCWP), with assistance from the MPCA, initiated a TMDL assessment project for Long and Ringo Lakes. The HCWP collected water quality information on Long and Ringo Lakes in 2008 and 2009. Public meetings were held to introduce the TMDL process to the public and to secure volunteers for a stakeholder committee.

The TMDL required for Long and Ringo Lakes to meet the NCHF ecoregion's phosphorus standard are:

TMDL = WLA + LA + MOS

Long Lake TMDL = WLA + LA + MOS

(daily) 8.16 lbs/day = 0.48 lbs/day + 6.87 lbs/day + 0.81 lbs/day

3.71 kg/day = 0.22 kg/day + 3.12 kg/day + 0.37 kg/day

(annual) 2,979.2 lbs/yr = 174.2 lbs/yr + 2,507.1 lbs/yr + 297.9 lbs/yr

1,354.2 kg/yr = 79.2 kg/yr + 1,139.6 kg/yr + 135.4 kg/yr

Ringo Lake TMDL = WLA + LA + MOS

(daily) 1.96 lbs/day = 0.13 lbs/day + 1.64 lbs/day + 0.20 lbs/day

0.89 kg/day = 0.06 kg/day + 0.74 kg/day + 0.09 kg/day

(annual) 715.9 lbs/yr = 46.40 lbs/yr + 597.90 lbs/yr + 71.59 lbs/yr

325.4 kg/yr = 21.09 kg/yr + 271.77 kg/yr + 32.54 kg/yr

Where WLA is the wasteload allocation, LA is the load allocation, and MOS is the margin of safety. These terms are fully addressed in Section 5.

The current estimated phosphorus load for Long Lake is 11,447 pounds per year (lbs/yr) (5,203 kilograms per year (kg/yr)). To reach the target total in-lake phosphorus concentration of 60 µg/L, minus 10 percent for MOS, a reduction of 8,468 lbs/yr (3,849 kg/yr) is required. Phosphorus loading for Ringo Lake is currently 2,464 lbs/yr (1,120 kg/yr), to reach the target in-lake phosphorus concentration of 60 µg/L, including a 10 percent MOS, a reduction of 1,749 lbs/yr (795 kg/yr) is required. Reductions from each source will be required to effectively reduce loading to target levels. Reductions from both external and internal sources have been identified. Some external sources include cultivated lands, Conservation Reserve Program (CRP), pasture/grasslands, urban runoff, woodlands, and failing septic systems. External phosphorus sources are typically delivered through stormwater runoff, though phosphorus from failing septic systems would be delivered regardless of rainfall intensity or frequency. Strategies to reduce internal loading (i.e. loading from phosphorus already in the lake) will need to be developed based primarily on fisheries and vegetation management as well as potential reductions of boating activity in sensitive areas. Other internal loading treatment methods will need to be considered in the Implementation Plan but could include chemical treatment of in-lake phosphorus.

1.0 Introduction and Watershed Background

1.1 Purpose

The primary goal of this TMDL study is to determine the level of phosphorus reduction required to meet current water quality standards for Long and Ringo Lakes. Long Lake was listed as impaired for excessive nutrients on the section 303(d) list in 2002; Ringo Lake was placed on the 303(d) list for excessive nutrients in 2010. This document outlines the extent of these reductions and the strategies to improve in lake conditions.

1.2 Problem Statement and 303(d) Listings

Water quality data collected by the MPCA and citizen monitoring data collected through the Citizen Lake Monitoring Program (CLMP) indicate that both Long and Ringo Lakes are not meeting the phosphorus standard for the NCHF ecoregion. The water quality standard for shallow lakes in the NCHF ecoregion are: ≤60 µg/l for Total Phosphorus, ≤20 µg/l for Chlorophyll-a, and ≥1.0 meter for Secchi readings as a summer average (Heiskary and Wilson 2008., Minn. R. ch. 7050.0222, subp. 4 and subp. 4a). Data summaries, from 2008-2009, discussed in section 1.7, indicate an increase in the level of phosphorus in Long Lake as compared to a 1997 Long Lake Assessment Study (Gillingham et al. 1997). Long and Ringo Lakes, both considered shallow lakes, are used for recreational activities, including fishing, swimming, boating, and some hunting. In addition, there is significant residential development along portions of the Long Lake shoreline. Though Ringo Lake has some development, it is not as significant as the development on Long Lake.

303(d) Listings – The designated beneficial use for Long and Ringo Lakes is aquatic recreation and the pollutant stressor is excess nutrients. The impairment for Long Lake is based on water quality data collected from 1991-2000, and the Ringo Lake impairment is based on water quality data collected from 1999-2008. Long Lake was listed as impaired for excessive nutrients on the section 303(d) list in 2002; Ringo Lake was added to the section 303(d) list for excessive nutrients in 2010.

TMDL Priority Ranking – The Long Lake and Ringo Lake watersheds were given a priority ranking for TMDL development due to the impairment impacts on public health and aquatic life, the public value of the impaired water resource, the likelihood of completing the TMDL in an expedient manner, the inclusion of a strong base of existing data and the restorability of the water body, the technical capability and the willingness of local partners to assist with the TMDL, and the appropriate sequencing of TMDLs within a watershed or basin. Long and Ringo Lakes are a popular location for aquatic recreation, including boating, swimming, fishing and hunting. Water quality degradation has lead to efforts to improve the water quality within the Long and Ringo watersheds, and to the development of a TMDL.

1.3 Description of Long and Ringo Lakes Watersheds

Long Lake (MNDNR Lake ID# 34-0192) and Ringo Lake (MNDNR Lake ID# 34-0172), both located in Kandiyohi County, are in the headwaters region of the Hawk Creek Watershed (HUC - 07020004), approximately three miles north of the city of Willmar. Minnesota is divided into seven ecoregions, with varying soils, topography, vegetation and land use. Kandiyohi County is bisected by two ecoregions, the NCHF to the north and the Western Corn Belt Plains (WCP) to the south. Data gathered from representative, minimally-impacted reference lakes within the NCHF ecoregion serve as a basis for comparing the water quality and characteristics of other lakes within the same ecoregion (Heiskary and Wilson 2008, Heiskary and Wilson 2005). The characteristics of the Long and Ringo Lakes watersheds are typical of watersheds in the NCHF ecoregion.

Ringo Lake is 735 acres with a watershed size of 4,368 acres that flows into Long Lake, a 1,568-acre lake with a watershed of 8,372 acres, which includes all of Ringo Lake and its watershed. Ringo Lake, situated to the northeast of Long Lake, flows through a wetland prior to outletting into Long Lake and subsequently into Hawk Creek, eventually flowing to the Minnesota River. Long Lake has only one inlet via Ringo Lake and the wetland between the lakes. Flow from this site is frequent though water levels in the wetland are occasionally low enough to restrict or stop flow into Long Lake. Water quality from the wetland is generally poor, with high phosphorus levels; this will be discussed further in section 1.9. West Twin Lake outlets to Ringo Lake, though this site did not flow during this study. It is likely that this site only flows during spring runoff and extreme rain events.

Long and Ringo Lakes watersheds consists of a variety of land uses including row crops, CRP, urban/residential, wooded areas, wetlands, and lakes. Land use in both watersheds is typical of the NCHF Ecoregion. Long Lake, Ringo Lake, King Lake, East and West Twin Lakes, Henderson Lake, and Carlson Lakes, as well as several wetlands, are located in the Long Lake Watershed.

The land use within the watershed of Long Lake is very diverse without a particular land use standing out as dominant (Table 1). Water and wetland uses account for 41 percent of the land use in the Long Lake watershed. The percentage of forested land, 12 percent, is typical for the NCHF ecoregion. Cultivated areas account for approximately 12 percent of the land use in this watershed and are generally used for production of corn and soybeans. CRP lands account for 7 percent (571 acres), down from 1,400 acres during the 1997 Lake Assessment Program (LAP) study (Gillingham et al. 1997). There is very little pasture in the watershed (4 percent). Table 1 shows a combined value for pasture, grass, and hay of about 12 percent (1,004 acres).

Urban land use, including homes, lawns, roadways, and related infrastructure, account for about 13 percent of the watershed, with most of the urban lands in the near-shore area of the lake or in business developments in the eastern portion of the watershed. The amount of land classed as urban has not changed significantly since 1997, although the intensity of use has increased. The number of lake homes increased from 67 in 1991 (Gillingham et al. 1997) to 84 in 2009. Not only has the above ground urban land use intensified, but since lake homes are not connected to municipal sewage treatment, each additional home has a subsurface sewage treatment system (SSTS). Additionally, there are several moderately-sized gravel pits making up about 3 percent of the Long Lake watershed.

The Ringo Lake watershed, a sub-watershed of Long Lake, is similar in land use breakdown to the Long Lake watershed (Table 1). Land currently in cultivation is 496 acres (11 percent) and CRP accounts for 386 acres (9 percent). Water and wetlands again make up a significant portion of the watershed with 35 percent (1,509 acres). Most of the gravel pits are within the Ringo sub-watershed, making up

4 percent of Ringo's watershed land use. Although home construction and development have increased on Ringo Lake, they have not increased at the same rate as Long Lake. Currently about 15 percent of Ringo's watershed is categorized as urban developed.

Table 1. Land Use Summary for Long and Ringo Lakes.

Land Use Category	Cultivated % (acres)	CRP % (acres)	Urban % (acres)	Wooded % (acres)	Open Water/ Wetland % (acres)	Pasture/Grass/ Hay/Idle Grass % (acres)	Gravel Pit % (acres)
Ringo Lake	11 (496)	9 (386)	15(640)	15 (655)	35 (1509)	11 (506)	4 (177)
Long Lake[1]	12 (1037)	7 (571)	13 (1087)	12 (973)	41 (3430)	12 (1004)	3 (271)
NCHF[2]	22-50%	NA[3]	2-9%	6-25%	14-30%	11-25%	NA[4]

[1] Ringo Lake land use values are included as part of the Long Lake Watershed.
[2] Inter-quartile ranges for NCHF ecoregion (Heiskary and Wilson, 2005).
[3] CRP is included in Pasture/Grass/Hay/Idle Grass estimate.
[4] Gravel Pits were not measured in the ecoregion summary.

Numerous other lakes in the watershed continue to be developed. There are no municipal sources of phosphorus in the watershed. Septic compliance continues to be a concern related to increased lakeshore development. Maintenance and repair of existing systems and proper installation of new systems will be a key element to ensure that pollution will not be transmitted to the lakes.

Demographics of Long and Ringo Lakes – The populations of all lakes in this watershed have increased over the past few decades. Along with general population increases, there seems to be a concurrent trend towards more year-round homes rather than seasonal cabins increasing lake shore use and adding stress to existing septic systems. There were an estimated 67 homes on Long Lake in 1991 (Gillingham et al. 1997). Currently there are 84 'first tier' (i.e. homes with lake shore frontage) homes, 176 'second tier' homes, homes within one-quarter mile of the lake shore, and additional 'third tier' homes further than one-quarter mile from the lake. These second and third tier homes have likely increased at a higher rate than those with lake shore frontage for all lakes in the watershed. The total number of residences within the Long Lake watershed is 445. The current population of the watershed is estimated to be approximately 1,125. This number is based on the number of homes and an average household size of 2.53 (U.S. Census Bureau, 2000, Kandiyohi County, Minnesota).

Future Growth/Reserve Capacity – The trend towards increased development of lakeshore is common on Minnesota lakes. Increased development of Long and Ringo Lakes is anticipated, though it is difficult to estimate how fast this development will take place. Several other lakes in the vicinity are already heavily developed. Conversion of CRP and pasture lands to cultivation may also be a continuing trend, though depending on commodity prices and available conservation practices, this is a trend that could quickly reverse.

1.4 Climate Summary

The average annual precipitation for the Long and Ringo Lakes watershed is 28.21 inches, based on precipitation data collected in the city of Willmar about 3 miles south of Long Lake (Climatography of the United States). Total annual precipitation during 2008 was 27.98 inches, which was very close to the average (Minnesota Climatology Working Group, 2008). Total precipitation during 2009 was somewhat higher at 31.16 inches, though it is important to note that 6.91 inches fell during the month of October (Minnesota Climatology Working Group, 2009) and would have had no effect on water quality or quantity during the TMDL study. Growing season precipitation, from May to September annually, was 16.07 inches and 15.15 inches during 2008 and 2009 respectively (Minnesota Climatology Working Group, 2008/2009).

1.5 Soil and Geological Summary

Long and Ringo Lakes were formed from ice-blocks in till deposits of the Des Moines Lobe, the most recent glacial lobe (Goebel and Walton, 1979). The watershed consists of the Wadenill-Sunburg-Delft and Koronis-Hawick-Sunburg soil associations. Most of these soils are suitable for cultivation and hay crops, though slope which ranges from 2-35 percent limits cultivation of some areas (Giencke, 1987). Watershed soils consist primarily of Wadenill-Sunburg loams and Sunburg-Wadenill complexes with higher slopes. The soils with low slope are well suited to cultivation; however, those with higher slopes present a high risk of erosion (Giencke, 1987). Shallow ditches and tile lines located throughout the watershed convey runoff from the watershed to the lakes. Most of this drainage is private.

1.6 Water Quality Sampling Protocol

Water quality data were collected by the HCWP staff at four locations, twice monthly from June through September during 2008 and 2009. Two in-lake sites were selected on Long Lake: site 201 located in a deep portion of the lake just north of the island and site 203 located approximately mid-way between the island and the southwest lake shore (Figure 1). One mid-lake sampling location was monitored on Ringo Lake (Figure 1). To monitor inflow to Long Lake, two sites were selected: stream site 1 (Ringo Lake outlet) was located at the outflow of a large wetland that receives flow from Ringo Lake and subsequently flows into Long Lake. The monitoring site was located within one-quarter mile upstream of Long Lake. The second site was selected to monitor flow coming from West Twin Lake; however, no samples were taken due to lack of flow. Table 2 outlines specific sampling locations.

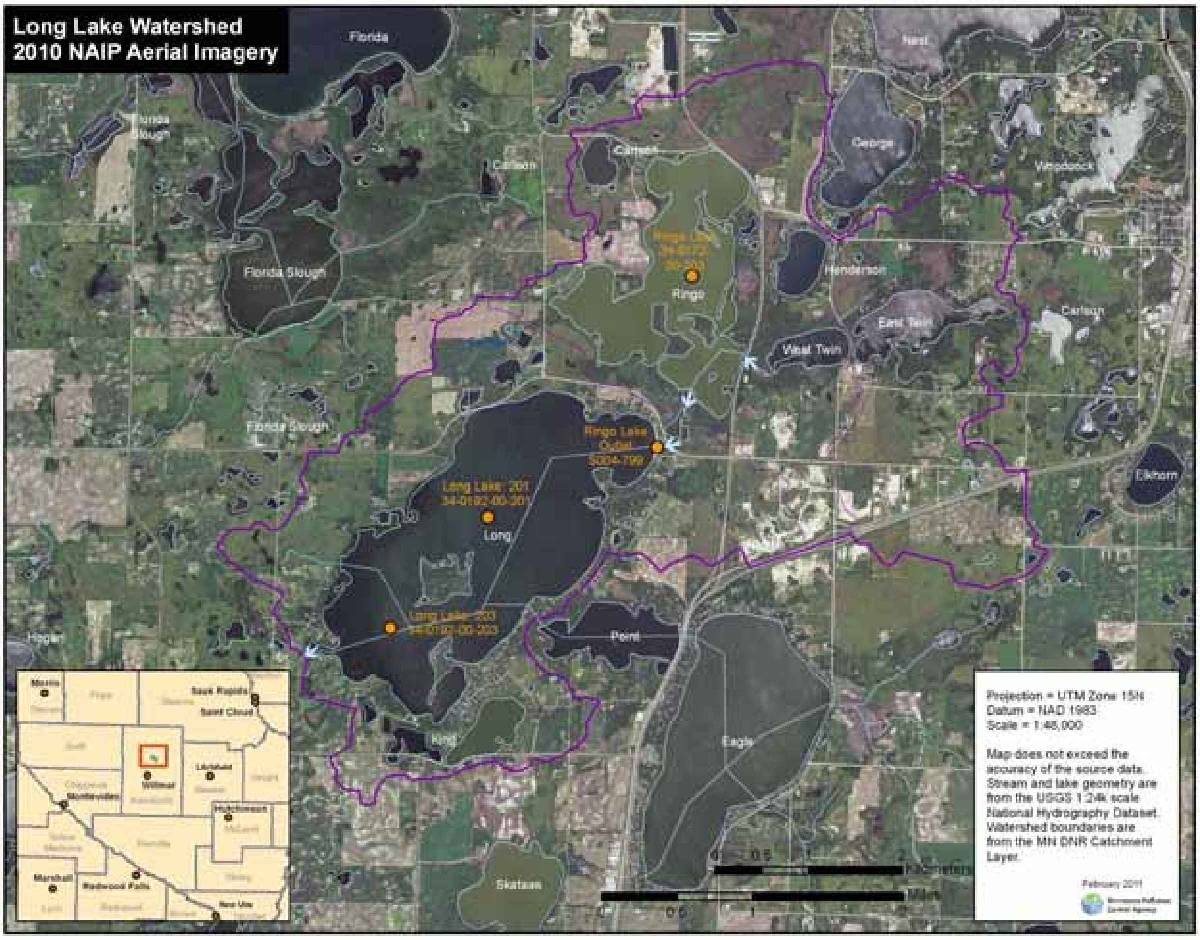


Figure 1. Long and Ringo Lakes Sampling Sites, 2008-2009.

Table 2. Lake and Stream Sampling Site Locations.

Lake/Stream	Site Code	Location	County	STORET ID
Long Lake	203	West Side	Kandiyohi	34-192
Long Lake	201	East Side	Kandiyohi	34-192
Ringo Lake	203	Middle	Kandiyohi	34-172
Ringo Lake Outlet	RL-01	Sec. 7, Green Lake Township	Kandiyohi	S004-799

Sampling and laboratory procedures are described in detail in the Long Lake Nutrient TMDL Assessment and Implementation Plan Development Project Quality Assurance Project Plan (September 2008). Laboratory analysis was performed by ERA Laboratories, Duluth, Minnesota, following Environmental Protection Agency (EPA) approved methods. Lake samples were analyzed for total phosphorus (TP), ortho phosphorus (OP), chlorophyll-a (Chl-a), total suspended solids (TSS), total suspended volatile solids (TSVS), total Kjeldahl nitrogen (TKN), nitrate-nitrite nitrogen (N_2N_3), alkalinity, color, and chloride.

Parameters sampled in the field include pH, turbidity, temperature, dissolved oxygen (DO), Secchi disk transparency, and field observations. The Ringo Lake Outlet site followed the same sampling schedule and lab analysis and included TP, OP, Chl-a, TSS, TSVS, TKN, N_2N_3, alkalinity, color, and chloride. Field parameters included pH, turbidity, temperature, DO, t-tube transparency, and user visual perception. Additional data from research projects including the 1997 LAP study and CLMP Secchi disk measurements were also used as comparisons and to provide additional background information, though these data were not used in TMDL calculations or modeling. All data used are stored in the STORET database.

1.7 Long Lake

1.7.1 Long Lake Morphology

Long Lake is approximately 1,568 acres with a watershed size of 8,372 acres. The maximum depth of Long Lake is about 16 feet (4.9 meters) with an average depth of 9.5 feet (2.9 meters) (Table 3). Although the maximum depth is relatively deep for a shallow lake, the littoral area (i.e. lake area less than 15 feet deep) of the lake is about 1,489 acres (i.e. the lake is defined by vast shallow areas) (Figure 2). Long Lake has only one major tributary, which flows from Ringo Lake through a wetland on the northeast edge of the lake (Figure 2). Long Lake also has a relatively large fetch (1.5 miles), and there are few forested areas to mitigate the effects of prevailing northwest winds. A 47-acre island is situated near the south end of Long Lake. The level of Long Lake during 2008-2009 varied seasonally but was consistently slightly below the Ordinary High Water Level of 1,165.4 feet above sea level (Minnesota DNR Lake Water Level Report). The Ordinary High Water Level is defined as the highest water level that has been maintained for a sufficient period of time to leave evidence upon the landscape, typically where natural vegetation changes from predominantly aquatic to predominantly terrestrial. Lake level has been recorded at this site from 1949 to the present. Additional watershed details are presented in Table 3.

Table 3. Long Lake Morphometric Characteristics.

Parameter	**Measurement**
Lake Area	1,568 acres (635 ha)
Mean Depth	9.6 feet (2.9 m)
Max Depth	16 feet (4.9 m)
Volume	14,841 acre-ft (18.3 hm^3)
Littoral Area	1,489 acres
Fetch	1.5 mile (2.1 km)
Watershed Area (total with lake) Watershed Area (without lake)	8,372 Acres (3,389 ha) 6,804 Acres (2,755 ha)
Shore Length	12.44 miles

Figure 2. Long Lake Bathymetric Map.

1.7.2 Long Lake Water Quality and Sampling Results

Monitoring Results and Lake/Stream Conditions 2008-2009

Thermal stratification and Dissolved Oxygen Profiles – Temperature profiles taken at sites on Long Lake did not indicate thermal stratification at either sampling location during 2008 or 2009. Representative temperature profiles for Long Lake site 201 and 203 are shown in Figures 3-4, all other temperature profiles are located in Appendix 1. DO profiles indicated that DO levels were generally above the 5 milligram per liter (mg/L) threshold needed for adequate game fish survival. There were, however, several occasions when DO fell below 5 mg/L. These were, however, limited to samples near the lake bottom and may have been influenced by lake sediments. Lake sediments can influence DO level through decomposition of organic material contained in the sediment, thereby consuming oxygen and releasing nutrients including phosphorus. Typical DO readings were between 6 and 10 mg/L (Figures. 5-6). Additional DO profiles are located in Appendix 2.

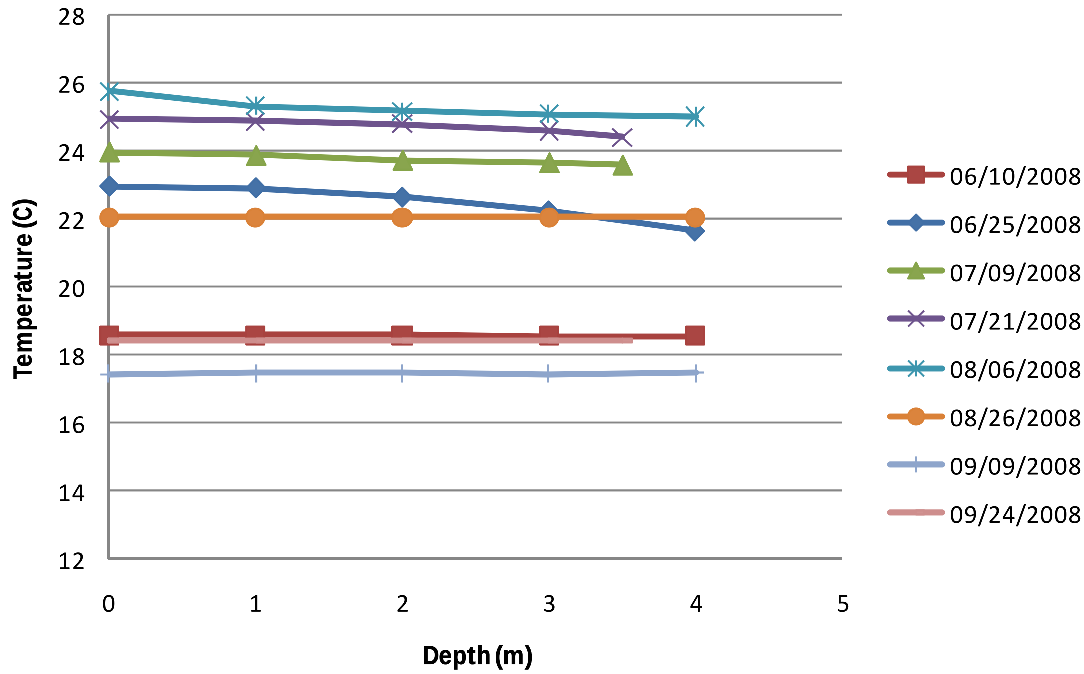


Figure 3. Water Temperature Profile for Long Lake Site 203 (2008).

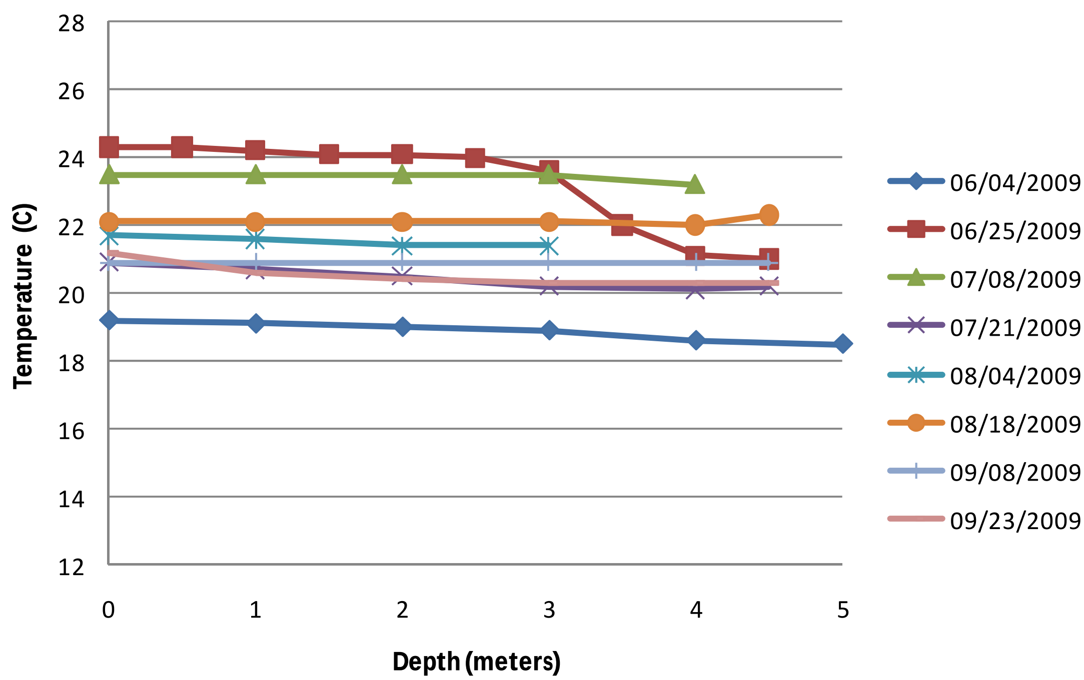


Figure 4. Water Temperature Profile for Long Lake Site 201 (2009).

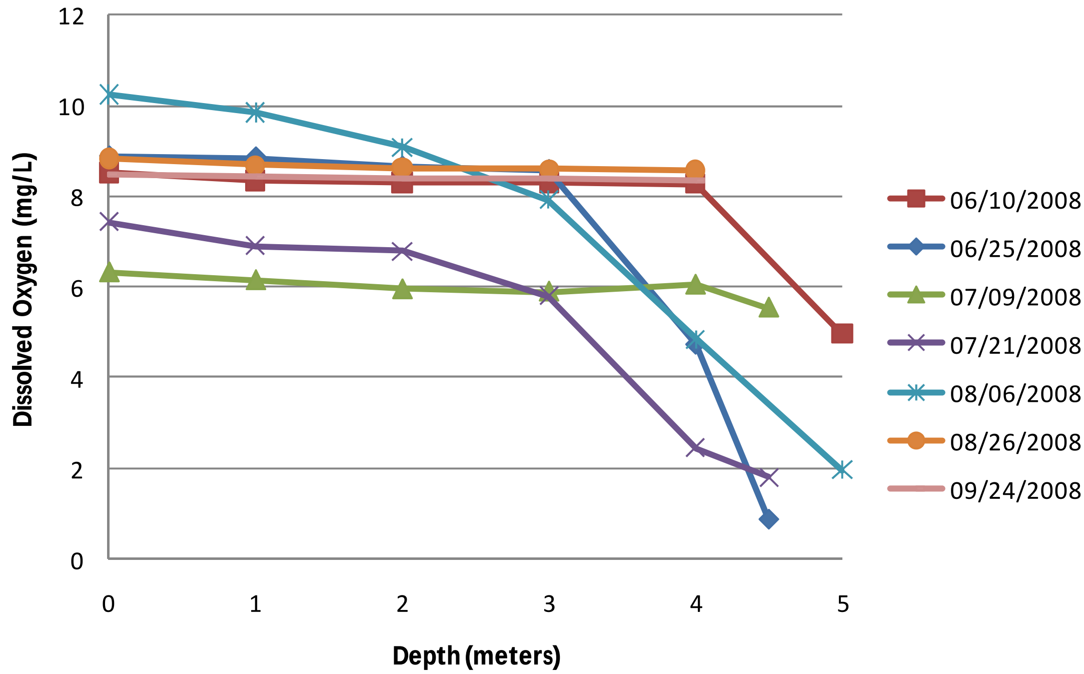


Figure 5. Dissolved Oxygen Profile for Long Lake Site 201 (2008).

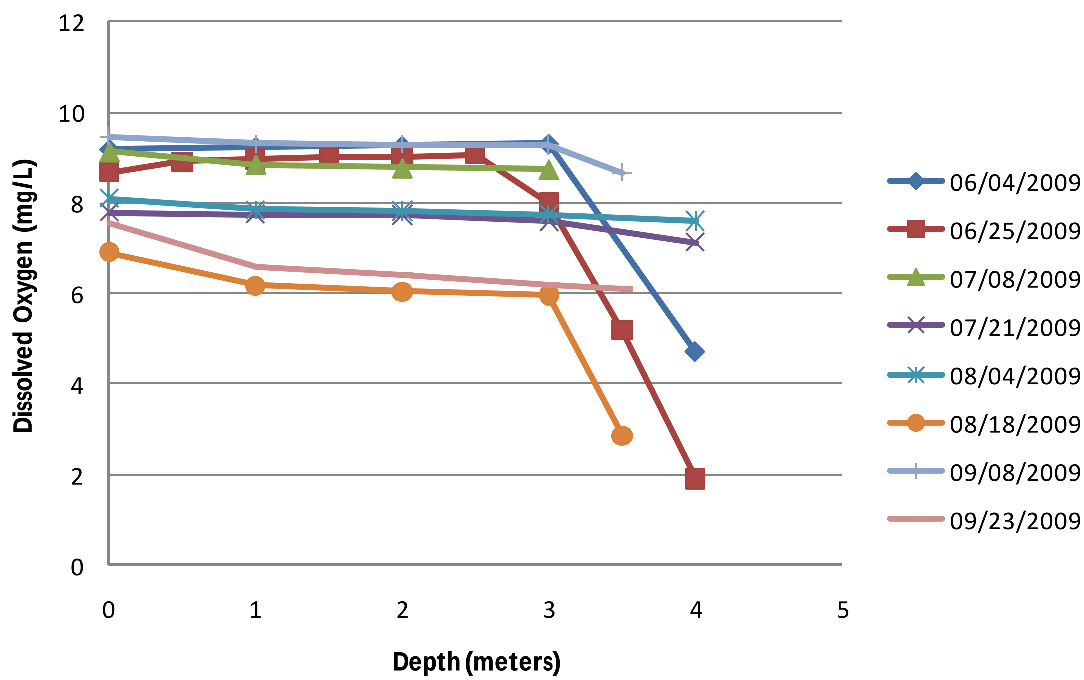


Figure 6. Dissolved Oxygen Profile for Long Lake Site 203 (2009).

Total Phosphorus (TP) – TP means for Long Lake during 2008 were 106 µg/L and 121 µg/L for sites 201 and 203, respectively. Mean phosphorus during 2009 increased slightly to 143 µg/L and 139 µg/L for sites 201 and 203, respectively. These values are well in excess of the ecoregion standard of 60 µg/L. TP concentrations ranged from 65 µg/L to 181 µg/L, all samples exceeded the ecoregion standard, most by a factor of 2. The 1997 LAP study reported average TP of 56 µg/L and 45 µg/L for two sampling sites on Long Lake. Annual means for water quality parameters are presented in Table 4.

Total Nitrogen (TN) – TN, the sum of TKN and nitrate-nitrite, averaged 1.73 mg/L and 1.82 mg/L for site 201 and 203, respectively, during 2008. Average TN was similar in 2009 at both site 201 (1.77 mg/L) and site 203 (1.67 mg/L). Mean TN for all Long Lake sites was 1.77 mg/L and 1.72 mg/L for 2008 and 2009, respectively (Table 4). The TN:TP ratio for Long Lake is about 14:1. Although phosphorus is still the limiting nutrient, the ratio is not consistent with similar lakes in this ecoregion (Heiskary and Wilson, 2005) or with the 1997 LAP study that reported a ratio of 30:1. The change in ratio is due primarily to a marked increase in TP, rather than a decrease in TN.

Chlorophyll-a – During 2008, chlorophyll-a concentrations ranged from 1 µg/L to 39 µg/L with a mean of 15 µg/L. Results during 2009 were similar with a range from 3µg/L to 34 µg/L and a mean of 11 µg/L. Chlorophyll concentrations of 10-20 µg/L are related to mild algal blooms while concentrations greater than 30 µg/L are linked to severe algal blooms (Heiskary and Walker, 1988). Nineteen percent of samples were greater than 20 µg/L and 9 percent were greater than 30 µg/L. Mean chlorophyll-a during both study years were within the typical range (5-22 µg/L) for the NCHF ecoregion, though the maximum for 2008 was above what is typical for the ecoregion (Table 4). Additionally, there were several other chlorophyll-a measurements that were near the maximum values.

Secchi disk transparency – Secchi disk transparency can be influenced by other parameters including color, TSS, and algae. TSS averaged 8.3 mg/L and 7.1 mg/L during 2008 and 2009, respectively, slightly higher than ecoregion norms (Table 4). Color averaged about 27 and 24 Pt-Co Units for 2008 and 2009, respectively. Mean color was higher than the accepted ecoregion values.

Mean Secchi disk readings of 1.77 meters (m) and 1.97 m during 2008 and 2009, respectively, were well within the 1.5-3.2 m range typical of this ecoregion and were both above the standard of 1 m. Water clarity early in the season was generally very good, followed by lower clarity during the summer months when water temperature and algal growth peaked (Figures 7-12), a pattern typical for lakes in this ecoregion.

Table 4. Annual Water Quality Parameter Means for Long Lake 2008-2009.

Parameter Means	Long Lake 2008	Long Lake 2009	Long Lake Mean 2008 – 2009	Typical Range for NCHF Ecoregion[1]	Ecoregion Standard
Total Phosphorus (µg/L)	113	141	127	23-50	<60
Chlorophyll a (µg/L)					
Mean	15	11	13	5-22	<20
Maximum	39	34	39	7-37	
Secchi disk (m)	1.77	1.97	1.87	1.5-3.2	>1.0
Total Kjeldahl Nitrogen (mg/L)	1.71	1.70	1.70	<0.60-1.2	
Nitrate-nitrite Nitrogen (mg/L)	0.06	0.02	0.04	<0.01	
Total Nitrogen (mg/L)	1.77	1.72	1.74		
Alkalinity (mg/L)	325	329	327	75-150	
Color (Pt-Co Units)	27	24	26	10-20	
pH	8.7	8.8	8.7	8.6-8.8	
Chloride (mg/L)	25	28	27	4-10	
Total Suspended Solids (mg/L)	8.3	7.1	7.7	2-6	
Conductivity (umhos/cm)	652	680	667	300-400	
TN:TP Ratio	16:1	12:1	14:1	25:1 – 35:1	

[1] Heiskary and Wilson, 2005.

Secchi disk transparency, TP, and Chlorphyll-a measurements followed a typical pattern for lakes in this region with TP and Chlorophyll-a generally increasing through the season while transparency decreased (Figures 7-12). One interesting feature is that transparency consistently peaked during the latter half of June, with the earlier June samples slightly less. This may be due to peak nutient uptake from rooted vegetation limiting early season algal blooms. Water clarity generally declined during the summer and rebounded slightly during September.

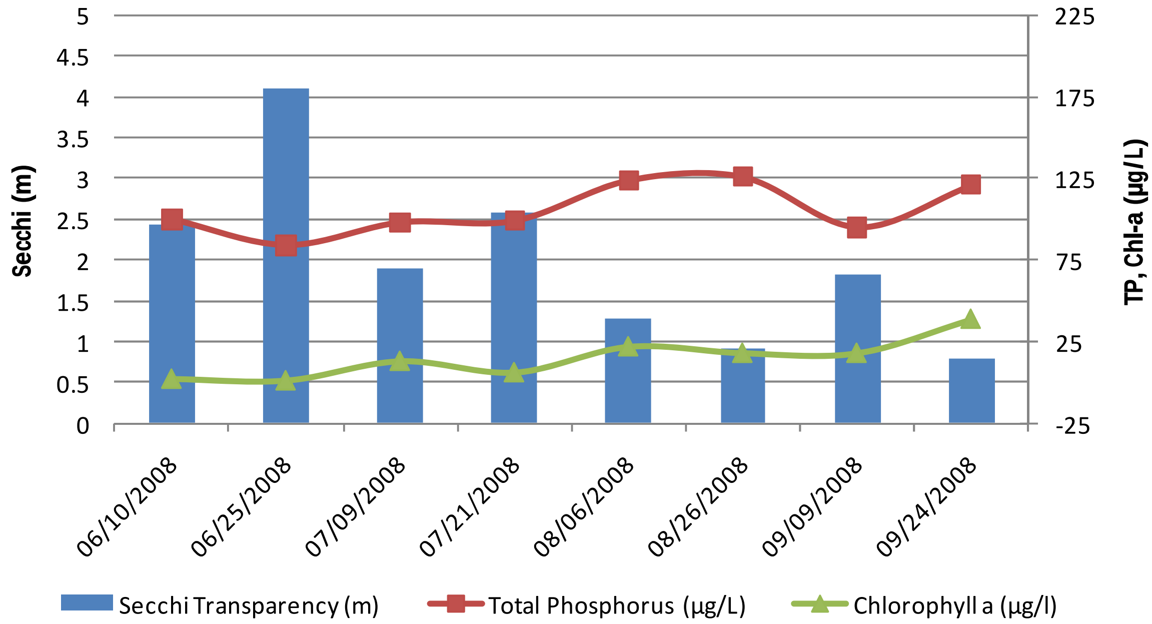


Figure 7. Long Lake Site 201 (2008) Secchi Water Clarity, Total Phosphorus and Chlorophyll-a vs. date.

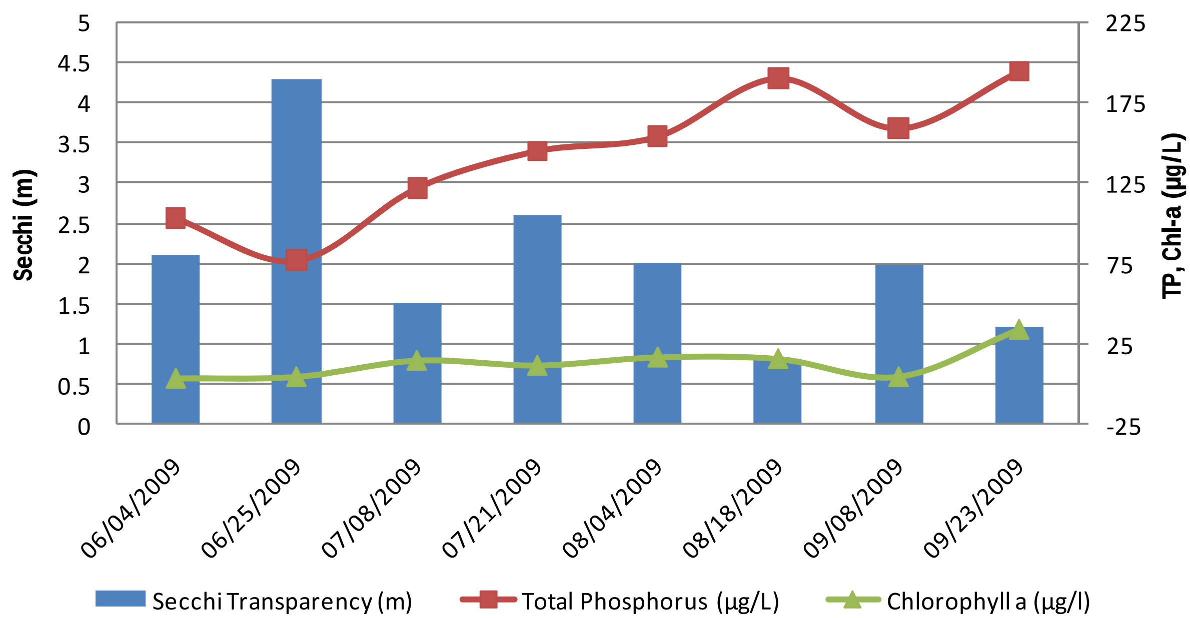


Figure 8. Long Lake Site 201 (2009) Secchi Water Clarity, Total Phosphorus and Chlorophyll-a vs. date.

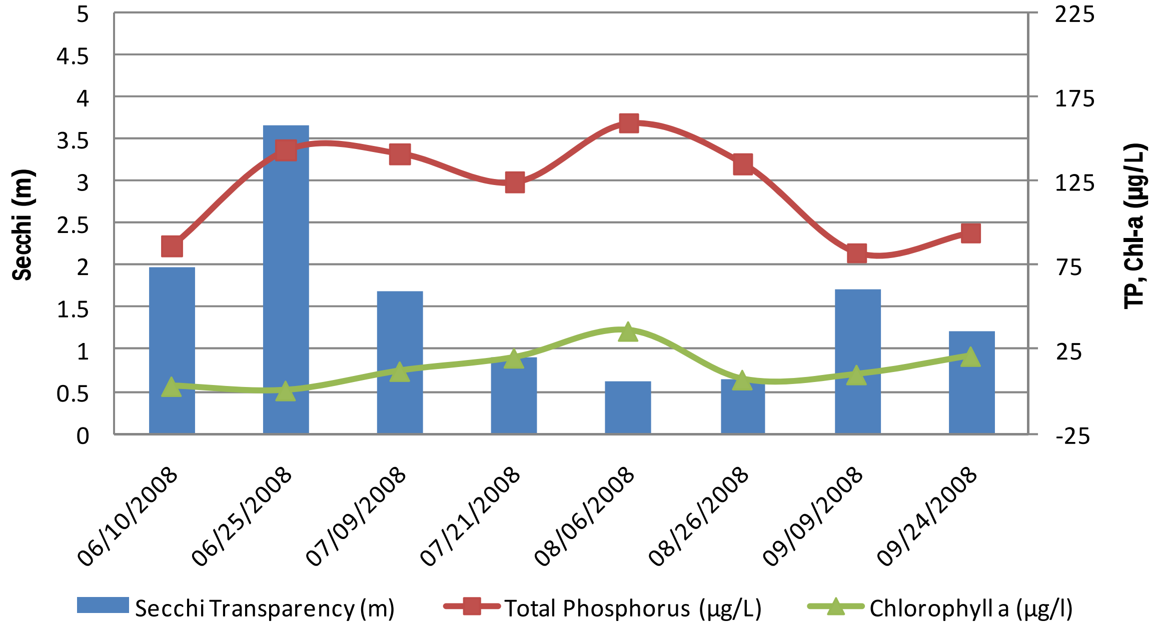


Figure 9. Long Lake Site 203 (2008) Secchi Water Clarity, Total Phosphorus and Chlorophyll-a vs. date.

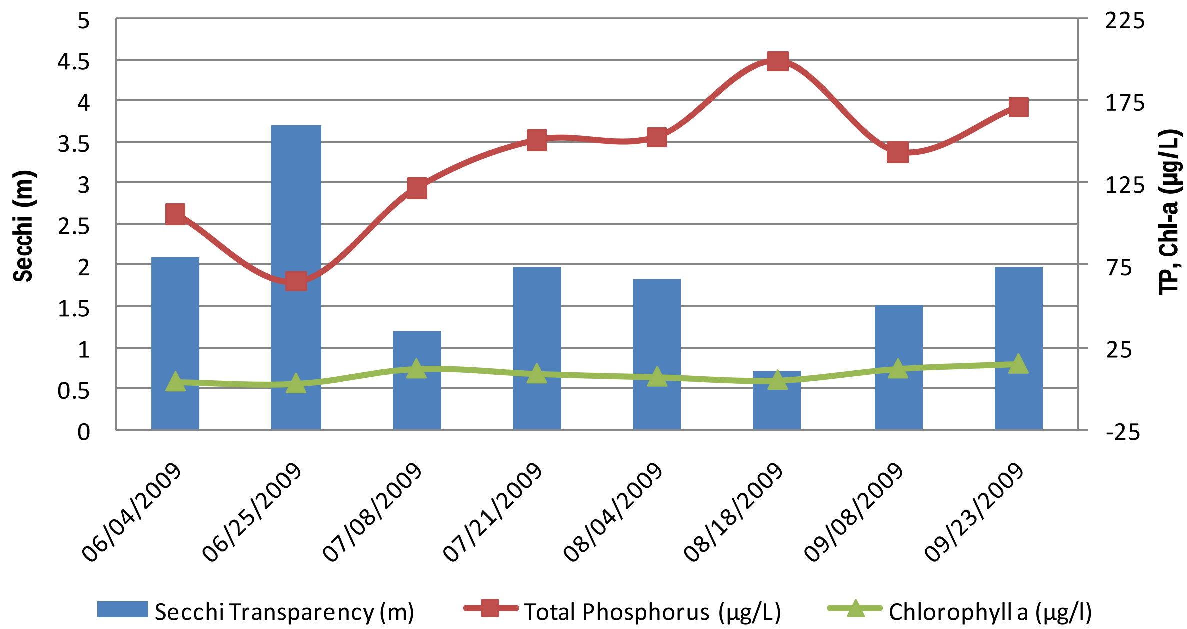


Figure 10. Long Lake Site 203 (2009) Secchi Water Clarity, Total Phosphorus and Chlorophyll-a vs. date.

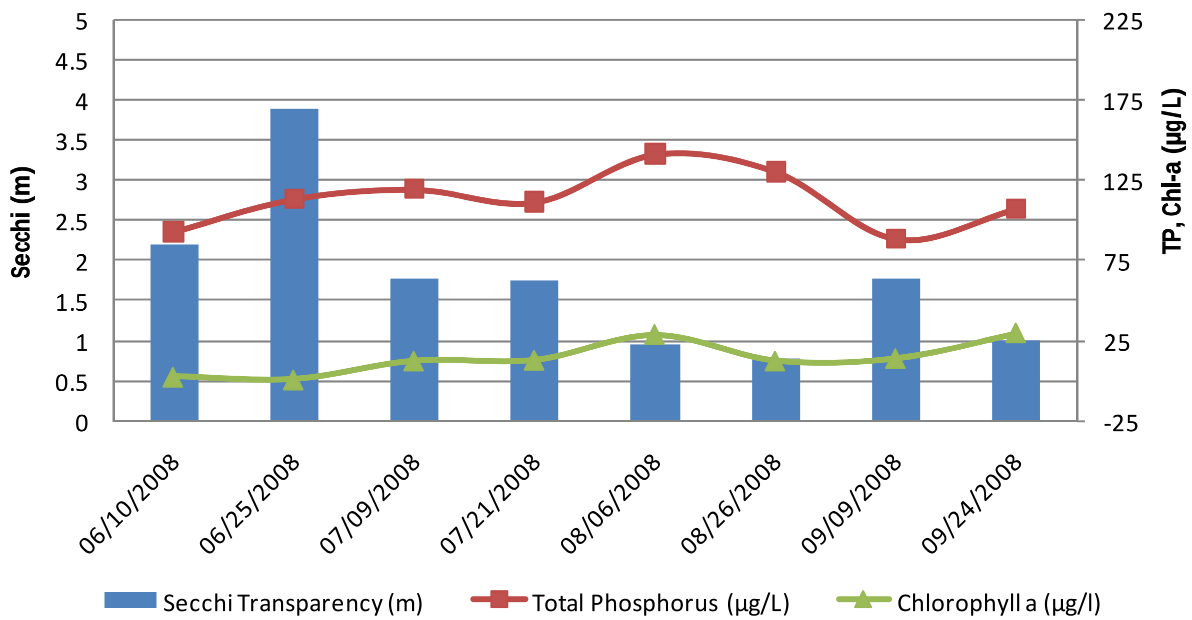


Figure 11. Long Lake Sites 201 and 203 Combined (2008) Mean Secchi Water Clarity, Total Phosphorus and Chlorophyll-a vs. date.

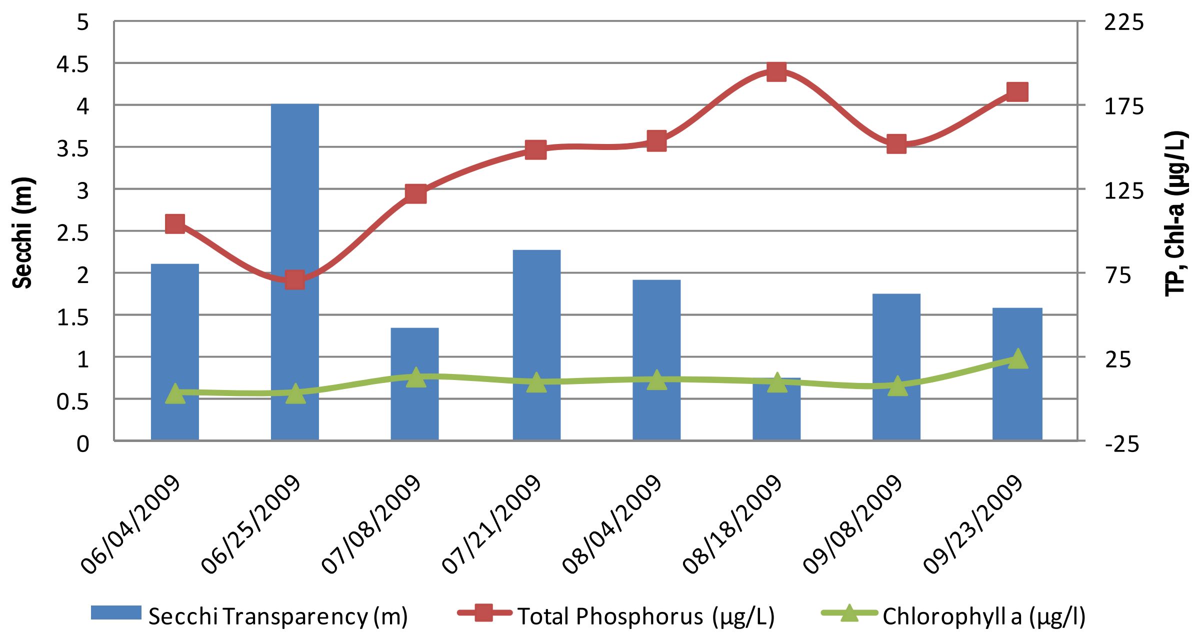


Figure 12. Long Lake Sites 201 and 203 Combined (2009) Mean Secchi Water Clarity, Total Phosphorus and Chlorophyll-a vs. date.

Long term transparency collected from 1975-2009 does show some variability and would indicate that transparency was worse in the 1970s than in the 1990s-2000s. The difference, however, is not significant over the entire period (Figure 13). Transparency data were collected by several cooperating groups including; CLMP (1975-1978, 1991-1997, 1999-2007), MPCA (1992, 1997), and HCWP (2008-2009).

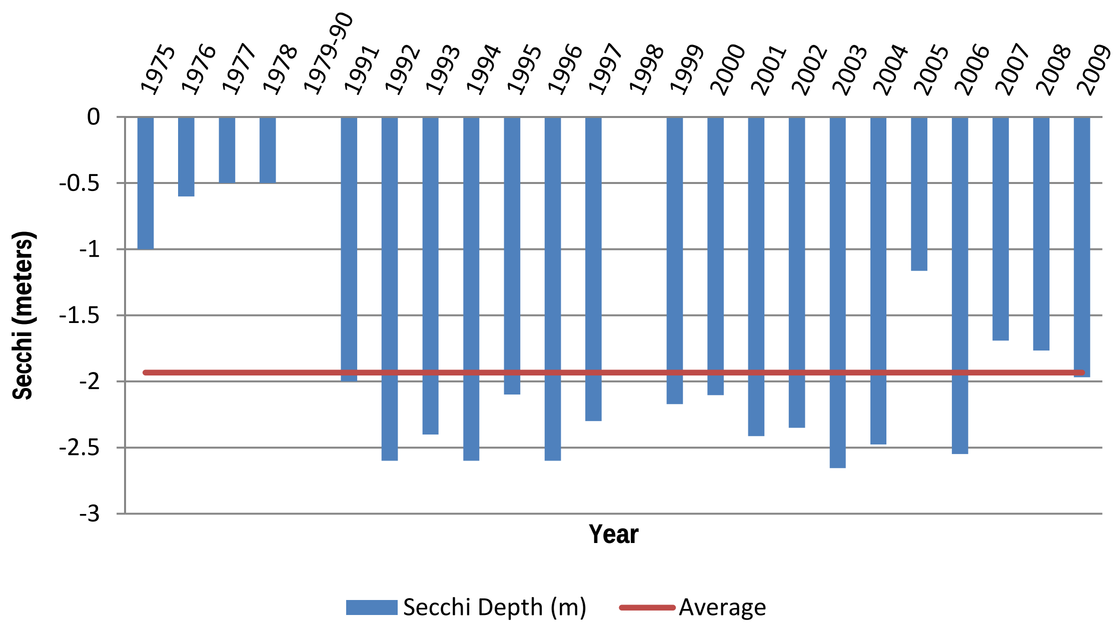


Figure 13. Long Lake Summer Mean Secchi Transparency, 1975 - 2009.

Water clarity seems to be relatively good despite high TP values. However, as indicated by Heiskary and Wilson, 2008, TP values in the range of 90-120 µg/L can be indicative of a system that can quickly change from a clear water state to a turbid water state with frequent, severe nuisance algal blooms. Measured phosphorus levels in Long Lake were within or in excess of this range in both 2008 and 2009. Once this transition has been made, it can be difficult to reverse the process. There may also be biological processes that are limiting algal production in this system.

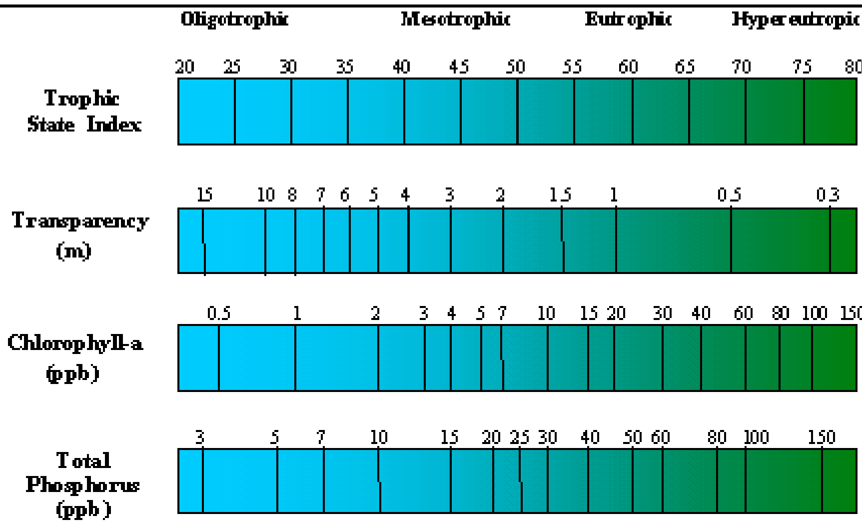
Good water clarity is difficult to maintain with excessive phosphorus though there is evidence that zooplankton communities can influence water clarity (Hanson and Butler, 1994). Zooplankton samples were collected to determine if the zooplankton populations were 'biologically' maintaining water clarity despite high TP values. In fact, sample collection during 2010 indicated a population structure of *Daphnia pulex* that could explain this phenomenon (Hanson and Butler, 1994). These conditions may be related to a healthy game fish population that is cropping small zooplanktivorous fish reducing predatory stress on the *Daphnia* that feed on phytoplankton responsible for reduced water clarity, primarily green algae and some blue-green algae (*Microcystis* species). The stability of this biological community is not certain. In the presence of such high TP values, it is imperative that we strive to better understand and maintain these conditions to prevent a turbid condition in Long Lake. Ringo Lake did not exhibit zooplankton populations similar to Long Lake.

Trophic State Index – Trophic State Index (TSI), a measure of TP, Chl-a, and transparency, is used to gauge general lake condition (Carlson, 1977). A TSI score is used to classify a lake into one of four categories: Oligotrophic, Mesotrophic, Eutrophic, or Hypereutrophic. A description of Carlson's TSI is included in Figure 14.

Figure 14. Carlson's Trophic State Index

Carlson's Trophic State Index
RE Carlson

TSI < 30	Classic Oligotrophy: Clear water, oxygen throughout the year in the hypolimnion, salmonid fisheries in deep lakes.
TSI 30 - 40	Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.
TSI 40 - 50	Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.
TSI 50 - 60	Lower boundary of classical eutrophy: decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.
TSI 60 - 70	Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.
TSI 70 - 80	Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.
TSI > 80	Algal scums, summer fish kills, few macrophytes, dominance of rough fish.



After Moore, 1. And K. Thornton, [Ed.]1988. Lake and Reservoir Restoration Guidance Manual. USEPA>EPA 440/5-88-002.

A TSI value was calculated for each pertinent parameter, and an overall TSI was generated from the mean of the combined values. TSI values were calculated for each site per year and a combined 'whole lake' value for each year. The Long Lake TSI value for 2008 was 61, similar to a value of 60 during 2009 (Table 5). Although there was some variability between sites and years, Secchi TSI (TSIS) was consistently lower than either Chl-a TSI (TSIC) or TP TSI (TSIP). This lake would be consistently considered eutrophic based on Chl-a TSI, TSIS, and the overall TSI score. TP TSI, however, was much higher than either the Chl-a or Secchi component subsequently driving the overall score into the upper eutrophic range and into the hyper-eutrophic range if scored independently.

Table 5. Carlson's Trophic State Index for Long Lake 2008 – 2009.

	Carlson's TSI		
	Long Lake 2008	**Long Lake 2009**	**Long Lake 2008-2009**
TP TSIP	72	76	74
Chl-a TSIC	57	54	56
Secchi TSIS	52	50	51
TSI Mean	61	60	60

1.7.3 Fisheries, Aquatic Vegetation, and Substrate Surveys

In Lake Resources: Fisheries, Aquatic Vegetation, and Substrate

The Minnesota Department of Natural Resources (MN DNR) conducted a fisheries, vegetation, and substrate survey during the 2009 field season. Results indicate a healthy game fish population. The surveys also do not indicate a rough fish population that dominates the system. A detailed report is included in Appendix 3 (MN DNR Standard Lake Survey Report, Long Lake). MN DNR substrate surveys indicate that the lake bottom is dominated by sand and gravel. Muck, the substrate most likely to be re-suspended and contribute to internal loading of TP was listed as rare according to MN DNR substrate transect surveys (MN DNR Standard Lake Survey Report, Long Lake).

1.8 Ringo Lake

1.8.1 Ringo Lake Morphology

Ringo Lake is approximately 735 acres with a watershed size of 4,368 acres. The maximum depth is about 10 feet (3.1 meters) with an average depth of 4.1 feet (1.3 meters) (Table 6). Ringo Lake has a maximum fetch of 2.0 miles, and there are few forested areas to mitigate the effects of prevailing northwest winds. The level of Ringo Lake during 2008-2009 varied seasonally but was consistently slightly below the Ordinary High Water Level of 1,166.4 feet above sea level (MN DNR Lake Water Level Report, Ringo Lake). The Ordinary High Water Level is defined as the highest water level that has been maintained for a sufficient period of time to leave evidence upon the landscape, typically where natural vegetation changes from predominantly aquatic to predominantly terrestrial. Lake Level has been recorded at this site from 1948 to the present.

Additional watershed details are presented in Table 6 and Figure 15.

Table 6. Ringo Lake Morphometric Characteristics.

Parameter	**Measurement**
Lake Area	735 acres (298 ha)
Mean Depth	4.1 feet (1.3 m)
Max Depth	10 feet (3.1 m)
Volume	3,001 acre-ft (3.7 hm^3)
Littoral Area	735 acres
Fetch	2.0 miles (km)
Watershed Area (total with lake) Watershed Area (without lake)	4,368 Acres (1,768 ha) 3,633 Acres (1,471 ha)
Shore Length	9.56 miles

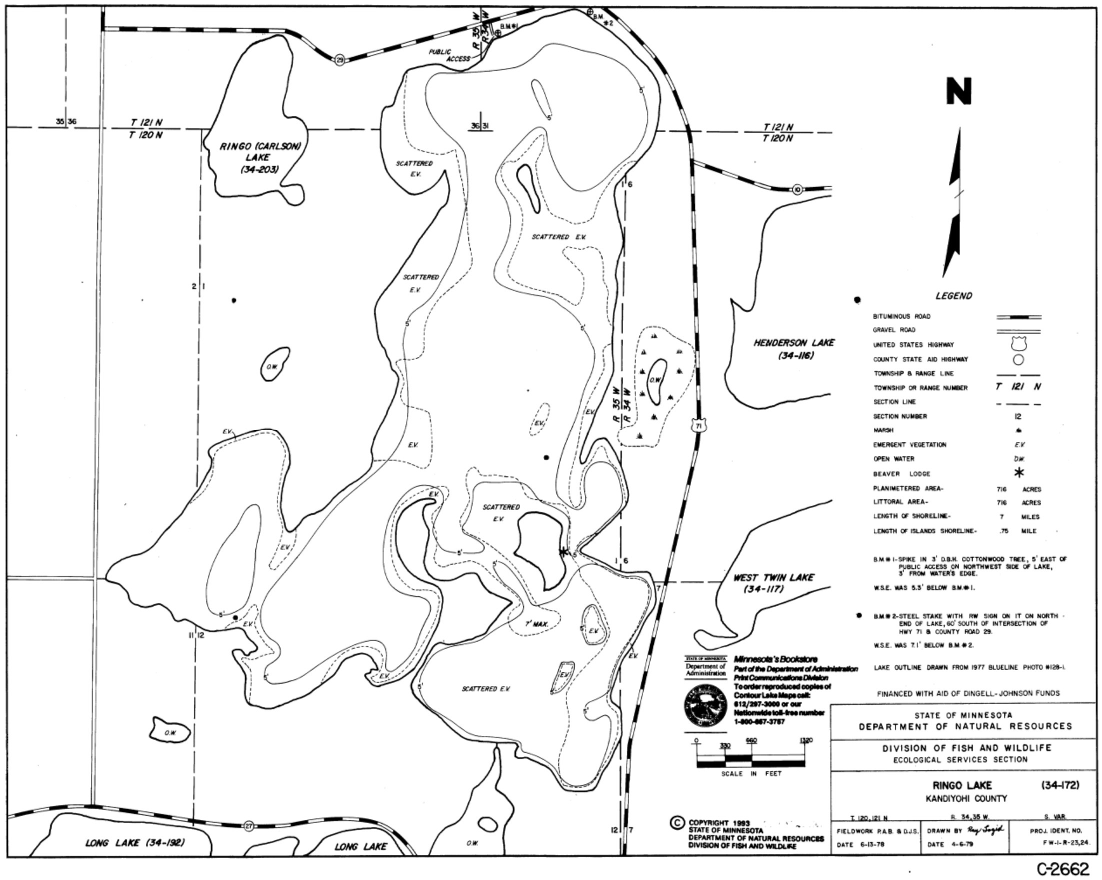


Figure 15. Ringo Lake Bathymetric Map.

1.8.2 Ringo Lake Water Quality Data and Sampling Results

Thermal stratification and Dissolved Oxygen Profiles – Temperature profiles taken at sites on Ringo Lake did not indicate thermal stratification during 2008 or 2009. The temperature profiles for Ringo Lake are shown in Figures 16 and 17 for 2008 and 2009, respectively. Because Ringo Lake is shallow and windswept, thermal stratification is not expected, as stratification is uncommon in lakes exhibiting similar physical characteristics. DO profiles indicated that DO levels were generally above 5 mg/L, which is the threshold needed for adequate game fish survival. DO did fall below 5 mg/L on several occasions; however, these instances were limited to samples near the lake bottom and may have been influenced by lake sediments. Lake sediments can influence DO level through decomposition of organic material contained in the sediment, thereby consuming oxygen and releasing nutrients including phosphorus. Typical DO readings fell between 7 and 12 mg/L (Figures 18-19).

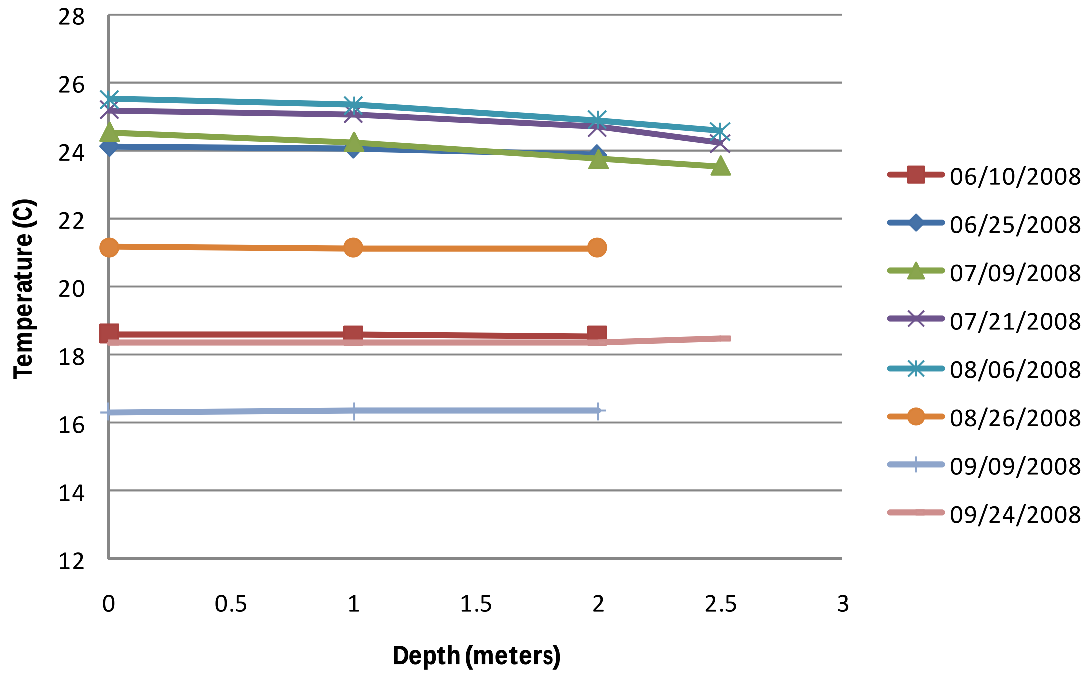


Figure 16. Water Temperature Profile for Ringo Lake 2008.

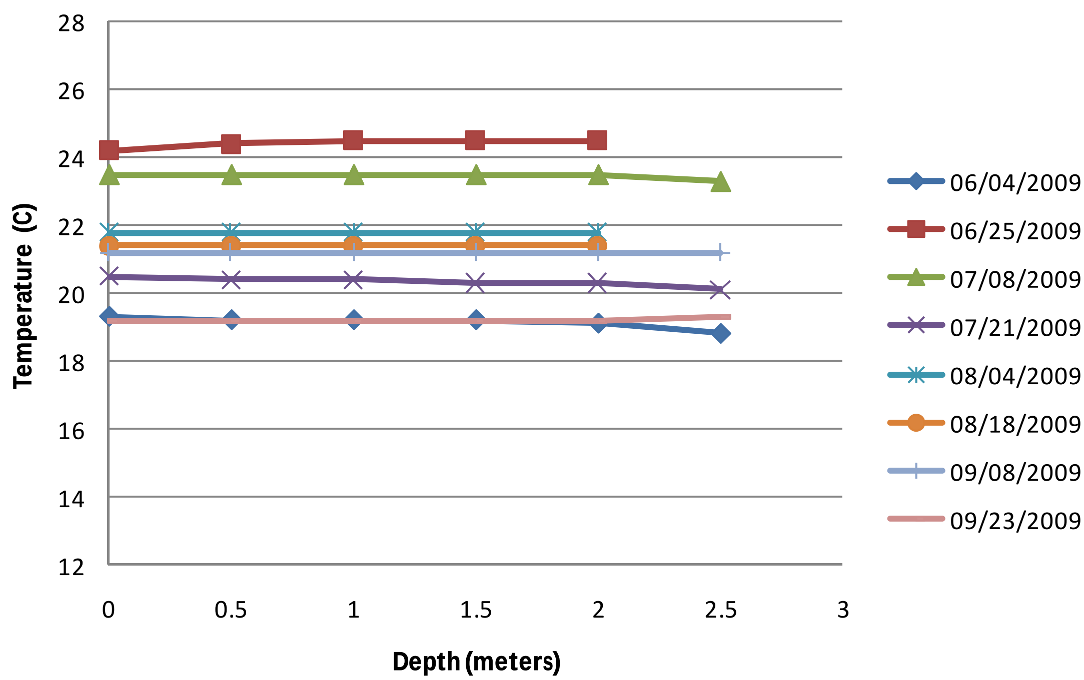


Figure 17. Water Temperature Profile for Ringo Lake 2009.

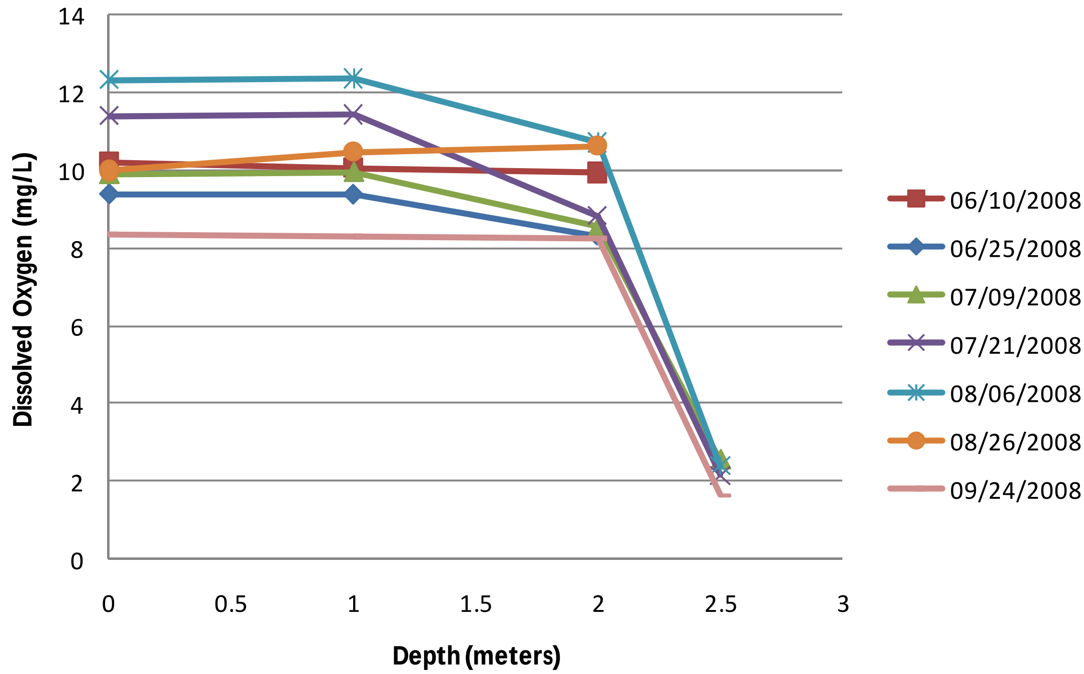


Figure 18. Dissolved Oxygen Profile for Ringo Lake 2008.

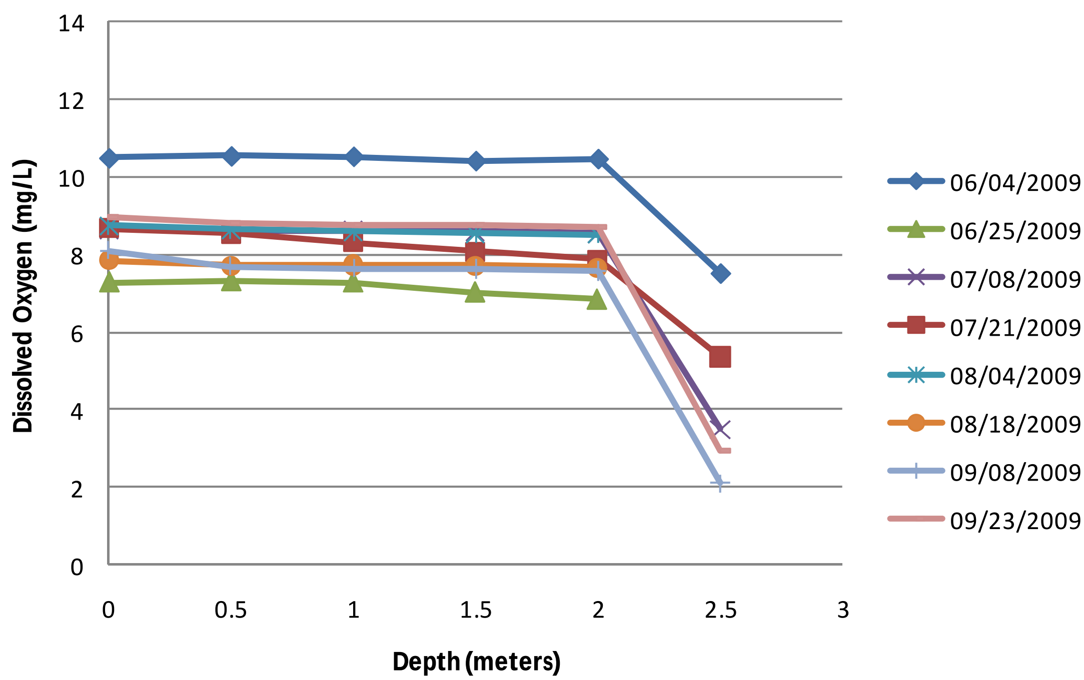


Figure 19. Dissolved Oxygen Profile for Ringo Lake 2009.

Total Phosphorus – Mean TP for Ringo Lake was 114 µg/L during 2008. Mean phosphorus during 2009 increased slightly to 135 µg/L (Table 7). These values are well in excess of the ecoregion standard of 60 µg/L. TP concentrations ranged from 44 µg/L to 155 µg/L. Like Long Lake, nearly all samples exceeded the ecoregion standard, most by a factor of 2. Water quality parameters are summarized in Table 7.

Total Nitrogen (TN) – TN, the sum of TKN and nitrate-nitrite, averaged 2.71 mg/L during 2008. Average TN was similar in 2009 at 2.83 mg/L. TN values in Ringo Lake were consistently about 1 mg/L higher than in Long Lake. The TN:TP ratio for Ringo Lake is about 22:1. Phosphorus continues to be the limiting nutrient in Ringo Lake, although the ratio falls just outside the range typical for lakes of this region. The TN:TP ratio for Ringo Lake is much closer to typical than Long Lake; however, this is due to higher TN levels, not lower TP levels.

Chlorophyll-a – During 2008, chlorophyll-a concentrations ranged from 15 µg/L to 90 µg/L with an average of 56 µg/L. Results during 2009 were similar with a range from 20 µg/L to 54 µg/L and an average of 45 µg/L. Chlorophyll concentrations of 10-20 µg/L are related to mild algal blooms while concentrations greater than 30 µg/L are linked to severe algal blooms (Heiskary and Walker, 1988). Ninety-four percent of samples were greater than 20 µg/L and 88 percent were greater than 30 µg/L. Mean chlorophyll-a concentrations during both study years were well above the typical range for the NCHF ecoregion (Table 7).

Table 7. Annual Water Quality Parameter Means for Ringo Lake 2008-2009.

Parameter Means	Ringo Lake 2008	Ringo Lake 2009	Ringo Lake Mean 2008 – 2009	Typical Range for NCHF Ecoregion[1]	Ecoregion Standard
Total Phosphorus (µg/L)	114	135	125	23-50	<60
Chlorophyll a (µg/L)					
Mean	56	45	50	5-22	<20
Maximum	90	54	90	7-37	
Secchi disk (m)	0.23	0.22	0.22	1.5-3.2	>1.0
Total Kjeldahl Nitrogen (mg/L)	2.66	2.83	2.74	<0.60-1.2	
Nitrate-nitrite Nitrogen (mg/L)	0.05	0.01	0.03	<0.01	
Total Nitrogen (mg/L)	2.71	2.83	2.77		
Alkalinity (mg/L)	178	184	181	75-150	
Color (Pt-Co Units)	24	25	24	10-20	
pH	9.0	8.9	8.9	8.6-8.8	
Chloride (mg/L)	22	21	22	4-10	
Total Suspended Solids (mg/L)	76.6	60.5	68.6	2-6	
Conductivity (umhos/cm)	379	397	390	300-400	
TN:TP Ratio	24:1	21:1	22:1	25:1 – 35:1	

[1] Heiskary and Wilson, 2005.

Secchi disk transparency – Secchi disk transparency can be affected by other parameters including color, TSS, and algae. TSS averaged 76.6 mg/L and 60.5 mg/L during 2008 and 2009, respectively. These values are much higher than ecoregion norms (Table 7). Color averaged about 24 and 25 Pt-Co Units for 2008 and 2009, respectively. Mean color was near or slightly above typical ecoregion values (Table 7).

Mean Secchi disk readings of 0.23 m and 0.22 m during 2008 and 2009 respectively were well below the 1.5-3.2 m range typical of this ecoregion and were both below the standard of 1 m. Water clarity varied slightly during the season, although it was consistently poor.

Water clarity seems to be relatively poor, consistent with high TP values. Water clarity may have already negatively responded to high TP values changing from a clear water state to a turbid water state. Figures 20 – 21 detail Ringo Lake TP, Secchi, and Chl-a observations.

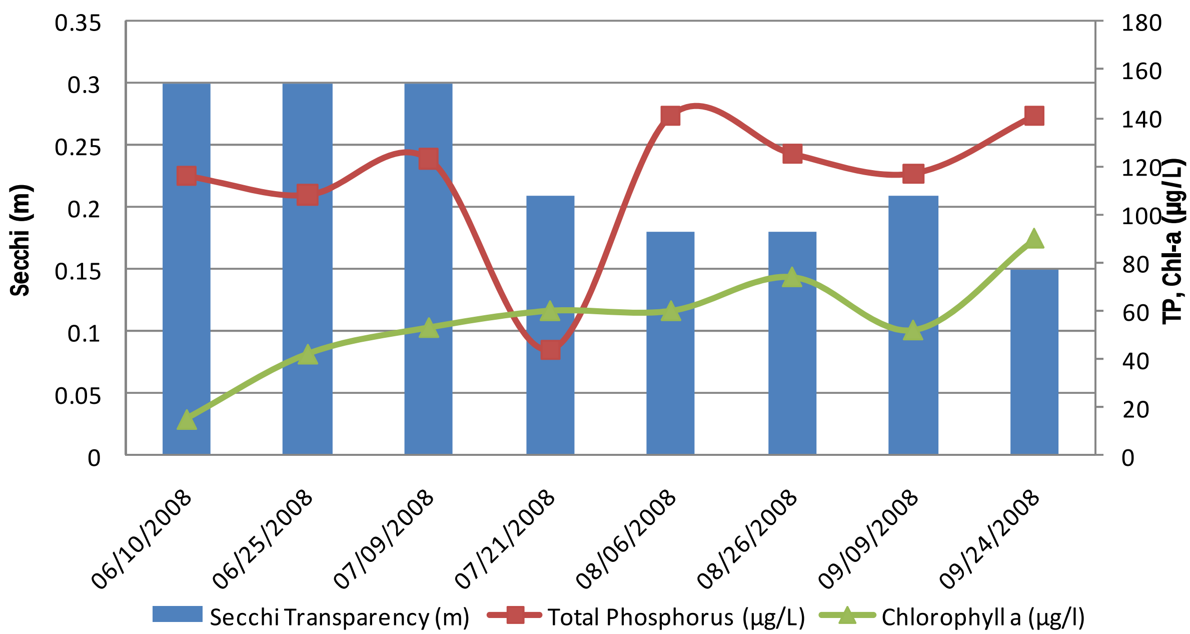


Figure 20. Ringo Lake (2008) Secchi Water Clarity, Total Phosphorus and Chlorophyll-a vs. date.

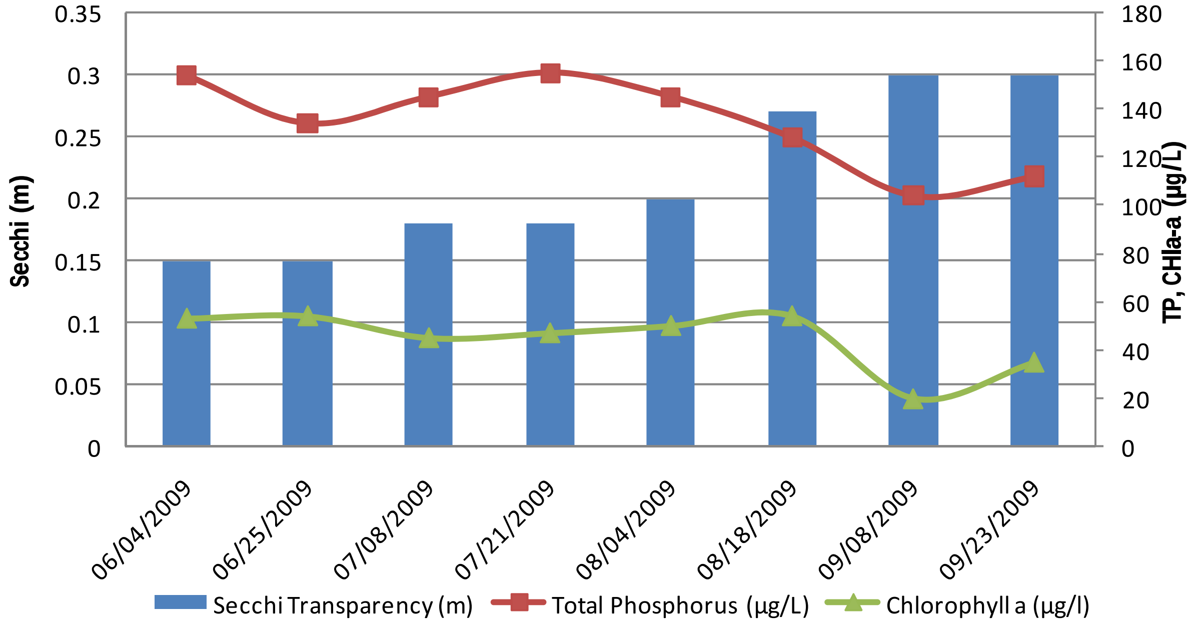


Figure 21. Ringo Lake (2009) Secchi Water Clarity, Total Phosphorus and Chlorophyll-a vs. date.

Ringo Lake transparency data are limited to data collected from 2003-2009. These limited data do not provide enough information to indicate the presence or absence of trends in transparency. Data collected from 2003-2009 are shown in Figure 22. Transparency data were collected by several cooperating groups, including CLMP (2003, 2007) and HCWP (2008-2009).

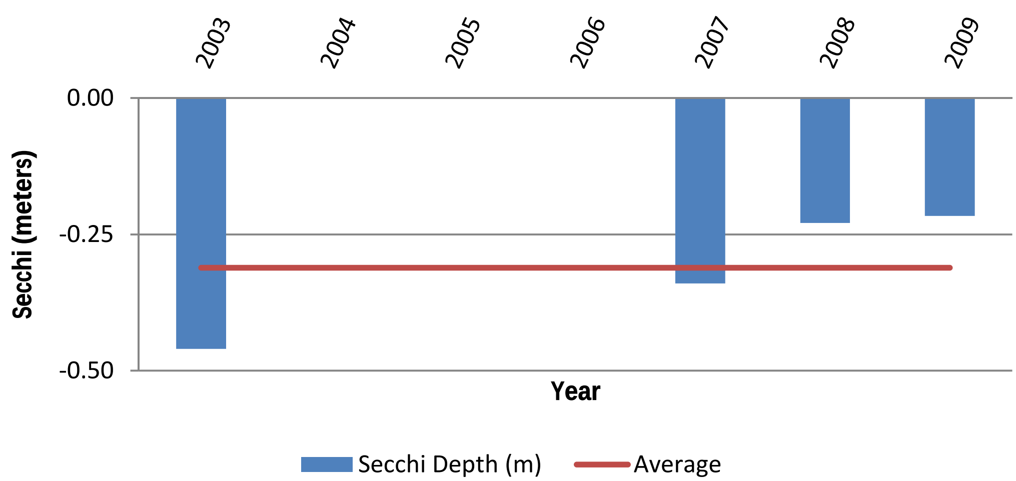


Figure 22. Ringo Lake Summer Mean Secchi Transparency, 2003, 2007 - 2009.

Trophic State Index – Trophic State Index (TSI), a measure of TP, Chl-a, and transparency, is used to gauge general lake condition. A TSI value was calculated for each pertinent parameter and an overall TSI was generated from the mean of the combined values. TSI values were calculated for each year. Ringo Lake TSI value was 75 for both 2008 and 2009 (Table 8). Although there was some variability between years, TSIS was higher than either Chl-a TSI (TSIC) or TP TSI (TSIP). This lake would be consistently considered hyper-eutrophic based on Chl-a TSI, TSIS, TP TSI, and the overall TSI score.

Table 8. Carlson's Trophic State Index (TSI) for Ringo Lake 2008 – 2009.

	Carlson's TSI		
	Ringo Lake 2008	**Ringo Lake 2009**	**Ringo Lake 2008-2009**
TP TSIP	73	75	74
Chl-a TSIC	70	68	69
Secchi TSIS	81	82	82
TSI Mean	75	75	75

1.8.3 Fisheries, Aquatic Vegetation, and Substrate Surveys

In Lake Resources: Fisheries

The MN DNR conducted a fisheries survey during the 2009 field season. Results indicate a healthy game fish population. The surveys also do not indicate a rough fish population that dominates the system. A detailed report is included in Appendix 3 (MN DNR Standard Lake Survey Report, Ringo Lake). Vegetation and substrate surveys were not conducted on Ringo Lake. Observations by the HCWP staff indicate that the lake bottom is dominated by muck and clay. There appears to be limited emergent and submergent vegetation.

1.9 Ringo Lake Outlet

Prior to outletting into Long Lake, Ringo Lake flows through a wetland. As discussed in section 1.6, the outlet of Ringo Lake was monitored on a schedule following that of the Lakes. Data were collected in an effort to determine the influence that Ringo Lake and its outflow may have on the water quality of Long Lake. Flow measurements were not collected.

1.9.1 Ringo Lake Outlet Water Quality Data and Sampling Results

It is likely that water quality outflow from the Ringo Lake Outlet monitoring site has an effect on the water quality of Long Lake. Mean TP measured at the Ringo Lake Outlet during 2008 was 291 µg/L and 211 µg/L in 2009 (Table 9), much higher than measured in either Long or Ringo Lake. There are multiple reasons why the TP at the outlet were so high. A likely cause is rough fish activity. On several occasions the water near the outlet had been agitated by rough fish activity. TSS concentrations followed a similar pattern as TP, being much higher than the lake samples, and would support the idea that fish activity is re-suspending sediments and phosphorus. It is also possible that this wetland has exceeded its capacity to assimilate phosphorus and is thus exporting it to Long Lake. It is important to note that no flow data were collected at this site, and without such data, it is not possible to determine the mass of phosphorus that is exported. Table 9 outlines additional water quality data for the Ringo Lake Outlet.

Table 9. Annual Water Quality Parameter Means for Ringo Lake Outlet 2008-2009.

Parameter Means	Ringo Lake Outlet 2008	Ringo Lake Outlet 2009	Ringo Lake Outlet Mean 2008 – 2009
Total Phosphorus (µg/L)	291	211	251
Chlorophyll a (µg/L)			
Mean	84	35	48
Maximum	110	60	
Total Kjeldahl Nitrogen (mg/L)	4.00	3.15	3.56
Nitrate-nitrite Nitrogen (mg/L)	0.04	0.02	0.13
Total Nitrogen (mg/L)			
Alkalinity (mg/L)	206.4	210.9	208.6
Color (Pt-Co Units)			
pH	8.8	8.6	8.7
Chloride (mg/L)	22	21	21
Total Suspended Solids (mg/L)	101.8	46.8	74.3
Conductivity (umhos/cm)	414	437	425
TN:TP Ratio			

2.0 Narrative and Numeric Water Quality Standards

Minnesota's water quality standards include both a narrative standard and numeric values for TP, chlorophyll-a, and Secchi transparency, and vary depending upon the ecoregion and lake depth. Both Long and Ringo Lakes are considered shallow lakes within the NCHF ecoregion. The numeric eutrophication standards for a class 2B shallow lake in the NCHF ecoregion are TP (≤60 µg/L), chlorophyll-a (≤20 µg/L), and Secchi transparency (≥1.0 m) (Minn. R. ch. 7050.0222, subp. 4 and subp. 4a). These standards are used in conjunction with the narrative standard which states "The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable."(Minn. R. ch. 7050.0222, subp. 4). Water quality standards are considered compliant by meeting mean summer condition (June-September) standards. Narrative eutrophication standards for Class 2B shallow lakes also state that the TP and either chlorophyll-a or the Secchi disk be met to be considered in compliance. Long Lake currently meets both the Chlorophyll-a and the Secchi disk standard, therefore, Long Lake will be in compliance when the TP standard is met. Ringo Lake currently does not meet any of the eutrophication standards. Ringo Lake will be in compliance when the

TP standard and either the Chlorophyll-a or Secchi disk standards are met. The efforts set forth by this TMDL are in agreement with current water quality narrative and numeric standards.

3.0 Phosphorus Source Inventory

- Livestock
- Cropland/CRP
- Urban
- Aerial
- Shoreline Erosion
- Failing Septic
- Wildlife (including rookery)
- Internal Loading (vegetation, wave action, fish, rookery)

There are several known sources of phosphorus, both external and internal, that can effect water quality of Long and Ringo Lakes. These sources include livestock, cropland/CRP, urban/residential runoff, shoreline erosion, failing or inadequate SSTS, aerial and dryfall deposition, and wildlife. Internal loading may include contribution from wildlife as well as sediment re-suspension through wave action and biological processes. The phosphorus source assessment is based on land use and livestock data and a range of documented P-delivery coefficients.

Individual Phosphorus Source Assessments

Point Sources – The potential point sources to the Long Lake and Ringo Lake watersheds are:

Construction Stormwater – Loads from construction stormwater are considered to be a small percent of the total WLA and are difficult to quantify, but phosphorus can be delivered through debris and sediment that is disturbed during the construction process. Disturbed soil at construction sites is easily mobilized and exported during rain events. This TMDL assumes that no more than 1 percent of the watershed would be under construction at any time (see section 5.2 for details).

Industrial stormwater – Loads from industrial stormwater activities in this watershed are limited to sand and gravel operations, and are covered under the General Sand and Gravel General Permit (MNG490000) (see section 7.1.2). Phosphorus at these sites can be delivered by wind erosion, dust from mining activities, and pit dewatering. This TMDL assumes that approximately 5.5 percent of the uplands in the Long Lake Watershed and 6.2 percent of the Ringo Lake Watershed uplands are gravel pits.

Nonpoint Sources – The potential nonpoint sources to the Long Lake and Ringo Lake watersheds are:

Forest – Forested land accounts for about 12 percent of the Long Lake watershed and 15 percent of the Ringo Lake watershed. Runoff from forested land can include decomposing vegetation and organic soils. A range of P delivery coefficients (0.1-0.15 kg/ha) were used to model phosphorus inputs.

Agricultural – Agricultural land comprises 12 percent of the land in the Long Lake watershed and 11 percent of the Ringo Lake watershed. A range of P delivery coefficients ranging from 0.2-0.8 kg/ha were used to estimate loading from agricultural lands. This estimate includes only land that is under annual cultivation. Land that is in grass, hay, or pasture was estimated separately. Runoff from agricultural lands can include livestock wastes, fertilizers, soil particles, and organic material from agronomic crops.

Livestock – Livestock numbers are based on information supplied by the Kandiyohi feedlot officer. There are no National Pollutant Discharge Elimination System (NPDES) registered feedlots in the Long Lake watershed. There are a few smaller feedlots (turkey), and a number of other landowners that have a small amount of livestock. Some livestock were not inventoried by Kandiyohi County (e.g. owners of one or two horses). These livestock were counted by HCWP staff. Since the method of obtaining this inventory involved visual inspection, it is likely that livestock numbers are slightly underestimated and unlikely that they were overestimated. Currently, there are a total of nine livestock facilities in the Long Lake watershed ranging from 2 to 270 animal units (Table 10), with a total of 457 animal units (Table 11). A range of livestock produced phosphorus was calculated and a conservative delivery ratio (10 percent) was used. Livestock can contribute phosphorus to the watershed through runoff at feeding, holding, and manure storage areas as well as direct loading if allowed access to streams or lakes. Additional runoff can occur through upland manure applications.

Table 10. Livestock Facilities in the Long and Ringo Lakes Watersheds.

Operator	Livestock Type (Au)	Watershed	Animal Units
1	Sheep (15), Horses (2)	Ringo	17
2	Beef Cattle	Ringo	50
3	Horses	Ringo	30
4	Turkeys	Long	270
5	Beef Cattle	Long	56
6	Beef Cattle (18),Horses (1)	Ringo	19
7	Horses	Long	2
8	Horses	Ringo	10
9	Sheep	Ringo	3

Table 11. Summary of Livestock in the Long and Ringo Lakes Watersheds.

Livestock Type	Ringo (Au)	Long (Au)*
Beef	68	124
Horse	43	45
Sheep	18	18
Turkey	0	270
Total	129	457

* Long Lake includes livestock from the Ringo Lake watershed.

Pasture/Open – This category combines several limited land uses including pasture, CRP, idle grasslands, hayland, and any state or federal program lands managed as grasslands. The range of phosphorus coefficients was 0.2-0.4 kg/ha. Surface runoff can deliver phosphorus from manure deposited on uplands by livestock and wildlife. Runoff also includes phosphorus from dislodged vegetation and soil loss.

Urban/Residential (surface runoff, lake homes) – Runoff from lake homes can be a significant source of phosphorus. Runoff from yards can include fertilizer, leaf and grass litter, pet waste, and numerous other sources of phosphorus. Urban runoff coefficients used range from 0.5-1.25 kg/ha.

Inadequate SSTS – Based on Kandiyohi County installation records, approximately 51 of 84 (61 percent compliant) homes on Long Lake have compliant SSTS, 6 of 22 (27 percent compliant) homes on Ringo Lake have compliant systems. Upon further inspection, it is likely that many of the failing systems would be 'straight pipe' septic systems. Though the age and construction of straight pipe septic systems vary widely, they typically consist of an underground settling tank with a piped outflow discharging at or near the most convenient waterway. The settling tank provides for limited solids separation. It is also likely that several of the homes were once seasonal cabins and have systems that are not adequately sized to treat a year-round residence. Without individual inspections it is difficult to know for certain what effect failing systems are having on lake phosphorus levels. Models incorporate a soil retention coefficient of 0 to 100 percent. A coefficient of 30 percent retention was used based on county compliance records and knowledge of local systems. It is also important to note that the models only incorporate homes along the lake shore, not all homes in the watershed. This may slightly underestimate the effect of failing rural septics on these lakes.

Wetland/Open Water – Wetlands and open water comprise a significant portion of the watershed, approximately 35 percent of the Long Lake watershed and 41 percent of the Ringo Lake Watershed. The phosphorus delivery coefficient used for wetlands and open water was 0.1 kg/ha. Wetlands can export phosphorus through suspended solids as well as organic debris that flow through the waterways.

Aerial – Direct aerial deposition to the surface of the lake was based on regional values and is responsible for a portion of phosphorus loading to Long and Ringo Lakes. The atmospheric export coefficients used a range from 0.3-0.5 kg/ha.

Rookery – Long Lake is unique in that it is home to a large wildlife nesting island. Based on a nest count during May 2010, the island is home to about 1,230 waterbird nests (pers. comm. Linda Wires, U of M, unpublished data). Nest counts resulted in 747 double-crested cormorants (*Phalocrocorax auritus*), 243 great blue herons (*Ardea herodias*), 233 great egrets (*Casmerodius albus*), and 7 black-crowned night herons (*Nycticorax nycticorax*) (pers. comm. Linda Wires, U of M, unpublished data). This presents a significant challenge when estimating load. A general wildlife estimate can be calculated based on regional values; however limited local research exists on the effects, if any, of colonial nesting water birds on water quality. It is also uncertain at which levels loading from water birds should be considered internal (i.e. eating fish and depositing fecal matter into the same lake) or external (i.e. eating fish from separate lake and depositing fecal matter into Long Lake). Further complicating the issue is a lack of knowledge of food species selection. For example, if waterbirds are feeding on game fish, water quality may be negatively affected; however, if water birds are feeding on rough fish, they could have a positive effect on water quality. Recognizing that P contributions from the nesting island must be estimated, a formula based on population, internal/external loading ratio, and fecal P concentration was developed. Calculations were based on scientific literature and tailored to local conditions based upon assistance from non-game biologists from the MN DNR and University of Minnesota. Delivery of phosphorus from the rookery island and other wildlife would be through surface runoff and direct deposition. It is also important to note that most of the nesting occurs on the interior island, rather than the perimeter which may minimize surface runoff. There is a robust vegetative understory that is consuming nutrients and may act as an additional barrier to runoff.

Based upon waterbird cormorant and heron breeding and nesting behavior, a nest count of 1,230, and an average fledging rate of three young per nest, there may at times be as many as 6,150 birds on the island. Young of the year were counted as 0.5 in regard to fecal production to account for seasonal growth. This would be the equivalent of 4,305 birds. The island is used from approximately April 15 to September 15.

Internal Loading – Internal loading can come from a wide variety of sources including re-suspension of sediments due to wave action, rough fish mixing, wildlife activity, boating, and biological processes that release phosphorus. The soil substrate types and frequencies on Long Lake would not indicate a situation that is conducive to significant sediment re-suspension though some is likely. Ringo Lake appears to be more susceptible to this form of internal loading due to incidental observations of soil substrates.

4.0 Linking Water Quality Goals and Phosphorus Sources

4.1 Lake Modeling

Overview

Three models were employed to predict lake response to watershed conditions and determine levels of reductions that are required to meet existing water quality standards. These models include Minnesota Lake Eutrophication Analysis Procedure (MINLEAP), Reckhow-Simpson (Reckhow and Simpson, 1980.), and BATHTUB (Walker, 1999). Each model is successively more complex, each taking into account more environmental factors and providing more predictive power. Each model will predict anticipated levels of TP, Chlorophyll-a, and Secchi transparency based on current land use and environmental influences. They may also be used to estimate “what if” scenarios based on changing land use conditions, which can help determine which management practices can be used to most effectively improve water quality. Local land use data and ecoregion values were used to calibrate each model. MINLEAP and Reckhow-Simpson models are used primarily as supporting evidence and to gauge general watershed health, neither model was used for development of the TMDL formula or phosphorus loading estimates. The BATHTUB model was used exclusively for all TMDL calculations, for estimating current loading conditions and for determining required loading reductions.

MINLEAP Model - The MINLEAP program is designed to predict eutrophication in Minnesota lakes based on watershed area, depth, and ecoregion. The primary use for MINLEAP is to estimate lake conditions based on minimal data, potentially identifying lakes with severe problems. Since MINLEAP relies only on ecoregion watershed data, it is important to note that individual lakes can vary widely from ecoregion norms. Ecoregion land use values and phosphorus export coefficients are used to predict runoff and average stream phosphorus concentration. The program calculates water and phosphorus balances and uses empirical models to predict lake phosphorus, Chlorophyll-a, and transparency. Program outputs included statistical comparisons of observed and predicted phosphorus, Chlorophyll-a, and transparency, uncertainty estimates, and estimates of Chlorophyll-a interval frequencies (nuisance frequencies), for observed and predicted conditions. For the purposes of this TMDL, MINLEAP is used only as a basic assessment tool and to provide supporting information. The MINLEAP model is described in detail by Wilson and Walker, (1989), and Heiskary and Wilson, (2005).

The Chiaudani/Vighi regression method was run in conjunction with the MINLEAP model. The model predicts the natural background TP concentration based on a regression equation developed by Vighi and Chiaudani. TP is estimated as a function of lake alkalinity and mean depth. This model generally works well for headwater lakes and may not work well for extremely shallow lakes or lakes that are naturally eutrophic due to lake morphological conditions. Vighi and Chiaudani, (1985), describe this model in detail.

Reckhow-Simpson Model – The Reckhow-Simpson, though it incorporates detailed watershed specific land use values, was used as a basic watershed assessment, similar to MINLEAP. Reckhow-Simpson incorporates the Canfield-Bachman equations and relies on the user to select and input the appropriate land use values and phosphorus export coefficients (Heiskary and Wilson, 1994). Unlike MINLEAP, the Reckhow-Simpson model incorporated land use data specific to the Long and Ringo Lake watersheds, these include runoff, precipitation and evaporation rates, local land use, and livestock estimates. Output includes estimated phosphorus loading rates for each land use, predicted in-lake phosphorus, and water residence time. For the purposes of this TMDL, the Reckhow-Simpson model was used only as a basic assessment tool and to provide supporting information.

BATHTUB Model – BATHTUB can be used as both a diagnostic and predictive tool. BATHTUB, the most sophisticated of the models, incorporates local land use data and provides more flexibility in predicting the effects of implementation strategies. BATHTUB also provides more calculation options to better suit specific lake and watershed characteristics. BATHTUB predicts eutrophic water quality conditions for TP, TN, Chl-a, and transparency as well as other parameters. The BATHTUB model also provides significant predictive options to assess the impacts of changes in water and nutrient loading. The BATHTUB model was the model selected to calculate all loading in relation to the TMDL formula and recommended reductions. The BATHTUB model can also be used to estimate the effects of land use changes as part of the implementation plan.

4.1.1 Long Lake

MINLEAP – MINLEAP was used to estimate lake conditions that would be expected based on ecoregion land use, precipitation, and related physical parameters. MINLEAP estimated that the mean summer phosphorus concentration of Long Lake would be 38 µg/L, much lower than the measured mean of 127 µg/L. A t-statistic of 2.64 also suggests that this is a significant difference ($p<0.05$) when compared to the measured values. MINLEAP estimates that Long Lake retains about 92 percent of the phosphorus that enters the system. MINLEAP predicted a total P load of 598 kg/yr (1,315.6 lb/yr). A Chiaudani/Vighi regression model using alkalinity and lake morphometry to predict TP was run in conjunction with MINLEAP (Vighi and Chiaudani, 1985). Chiaudani/Vighi predicted an in-lake TP value of 36 µg/L, within the MINLEAP predicted range. MINLEAP provides a prediction of Chlorophyll-a of 13.1 µg/L compared to the measured value of 13.0 µg/L. A t-test revealed no significant difference ($p>0.05$). Secchi transparency was predicted at 1.7 m compared to the measured value of 1.9 m with no statistically significant differences ($p>0.05$). Model results are summarized in Table 12.

MINLEAP estimated basic lake hydrology based upon lake morphology and watershed characteristics. Long Lake's aerial water load is estimated at 0.20 meters per year with a lake outflow of 1.25 hm^3/yr. Water residence time is predicted between 14-15 years.

Reckhow-Simpson – As with MINLEAP, the Reckhow-Simpson model was used to estimate what lake conditions would be expected, based on given watershed conditions. The Reckhow-Simpson model, however, used locally measured land use and livestock values along with local precipitation data (Minnesota Climatology Working Group, 2008/2009) and a range of P export coefficients to predict TP, Chl-a, and Secchi transparency along with estimates of livestock contributed phosphorus. Ecoregion values were not used. Reckhow-Simpson predicted a TP concentration ranging from 46-67 µg/L, Chl-a ranging from 17.7-30.6 µg/L, and Secchi transparency of 1.4-1.0 m. These are comparable to the MINLEAP estimates of 38 µg/L TP, 13.1 µg/L Chl-a, and 1.7 m Secchi. Total watershed phosphorus load estimates ranged from 2,101-4,035 lbs/yr (955 – 1,834 kg/yr). Reckhow-Simpson also predicts the effect of livestock contributed phosphorus on the watershed. Under certain conditions, livestock can contribute significantly to phosphorus production. The livestock portion of the Reckhow-Simpson model was incorporated to evaluate the level of livestock contributed phosphorus. This portion of the model is based on varying phosphorus delivery rates. With the livestock contribution included, the model predicts an adjusted TP load of 2,974-4,618 lbs/yr (1,352-2,099 kg/yr). Adjusted in-lake TP is predicted between 56-73 µg/L.

BATHTUB – The third model, BATHTUB, gives an estimate of expected lake water quality based upon local watershed conditions. BATHTUB predicted 54.6 µg/L TP, 26.3 µg/L Chl-a, and 1.2 m Secchi transparency, again, very close to the values predicted by MINLEAP and Reckhow-Simpson. BATHTUB predicted a total watershed phosphorus load of 2,521 lbs/yr (1,146 kg/yr), within the range of the Reckhow-Simpson estimate. Although each lake model used a slightly different method to calculate in-lake phosphorus concentrations they all estimated similar values. Table 12 summarizes Long Lake model predictions.

Table 12. Long Lake Observed In-lake Parameter Concentrations and Model Predictions.

Model	Observed	MINLEAP	Chiaudani/ Vighi	Reckhow/ Simpson	Reckhow/ Simpson[1]	BATHTUB
TP (µg/L)	127	38	36	46-67	56-73	55
Chl-a (µg/L)	13	13.1	na	17.7-30.6	na	26.3
Secchi (m)	1.9	1.7	na	1.0-1.4	na	1.2
Phosphorus Load (lbs/yr)	na	1,316	na	2,101-4,035	2,974-4,618	2,521

[1] Includes estimate of livestock contribution.

BATHTUB TMDL load estimates – In addition to estimating lake water quality that would be expected based upon local watershed conditions, the BATHTUB model was used to estimate current loading and the loading rate required to meet water quality standards (i.e. the TMDL formula). Based on a measured in-lake phosphorus concentration of 127 µg/L, the current total estimated phosphorus load to Long Lake is 11,447 lbs/yr (5,203 kg/yr). To reach the NCHF ecoregion standard of 60 µg/L, TP load would need to be reduced to the Loading Capacity of 2,979 lbs/yr (1,354 kg/yr), a 74 percent reduction. The BATHTUB model predicted a significant portion of the total loading comes from internal sources. Based the BATHTUB model's residence time calculation of 14 years, it is likely that internally loaded phosphorus is not flushed out on a frequent basis. The BATHTUB model indicates that the lake may retain as much as 95 percent of the phosphorus that enters the system. BATHTUB estimated that internal loading is responsible for 78 percent (8,925 lbs/yr, 4,057 kg/yr) of current total loading. External loading would account for 18.4 percent (2,101 lbs/yr, 955 kg/yr) and precipitation would be 3.7 percent (418 lbs/yr, 190 kg/yr) of the current total loading. BATHTUB, however, does not account for loading from failing septic systems, which would be indirectly included in the internal loading estimate. Narrative eutrophication standards for Class 2B shallow lakes require that the TP and either Chlorophyll-a or the Secchi disk standard be met to be considered in compliance. Long Lake currently meets both the Chlorophyll-a and the Secchi disk standard, therefore, Long Lake will be in compliance when the TP standard is met.

4.1.2 Ringo Lake

MINLEAP – Based on ecoregion values, MINLEAP estimated that the mean summer phosphorus concentration of Ringo Lake would be 57 µg/L, much lower than the measured mean of 125 µg/L. A t-statistic also suggests that this may not be a significant difference ($p<0.05$) when compared to the measured values. MINLEAP estimates that Ringo Lake retains about 86 percent of the phosphorus that enters the system. MINLEAP predicted a TP load of 673 lbs/yr (306 kg/yr). A Chiaudani/Vighi regression model using alkalinity and lake morphometry to predict TP was run in conjunction with MINLEAP (Vighi and Chiaudani, 1985). Chiaudani/Vighi predicted an in-lake TP value of 38.6 µg/L. MINLEAP provides a prediction of Chlorophyll-a concentration of 24 µg/L compared to the measured value of 50.3 µg/L. A t-test did not reveal a significant difference. The predicted Secchi transparency of 1.2 m was significantly different than the measured value of 0.2 (t-statistic = 3.54; p<0.05). Model results are summarized in Table 13.

MINLEAP estimates basic lake hydrology based upon lake morphology and watershed characteristics. Ringo Lake's aerial water load is estimated at 0.26 m/yr with a lake outflow of 0.76 hm3/yr. Water residence time is predicted at about 5 years.

Reckhow-Simpson – The Reckhow-Simpson model used measured land use and livestock values along with local precipitation data (Minnesota Climatology Working Group, 2008/2009) and a range of P export coefficients to predict TP, Chl-a, and Secchi transparency along with estimates of livestock contributed P. Reckhow-Simpson predicted a TP concentration ranging from 67-103 µg/L, Chl-a ranging from 30.6-57.4 µg/L, and Secchi transparency of 1.0-0.7 m. These are comparable to the MINLEAP estimates of 57 µg/L TP, 24.0 µg/L Chl-a, and 1.2 m Secchi. Total watershed phosphorus load estimates ranged from 1,045-2,088 lbs/yr (475-949 kg/yr). Reckhow-Simpson also predicts the effect of livestock contributed phosphorus on the watershed. Under certain conditions, livestock can contribute significantly to phosphorus production. The livestock portion of the Reckhow-Simpson model was incorporated to evaluate the level of livestock contributed phosphorus. This portion of the model is based on varying phosphorus delivery rates. With the livestock contribution included, the model predicts an adjusted TP load of 1,536-2,572 lbs/yr (698-1,169 kg/yr). Adjusted to account for livestock, the in-lake TP concentration is predicted between 85-117 µg/L.

BATHTUB – The third model, BATHTUB, predicted 88.3 µg/L TP, 34.0 µg/L Chl-a, and 0.2 m Secchi transparency. The TP value predicted by BATHTUB is within of the range predicted by the other models. BATHTUB predicted a total watershed phosphorus load of 1,366 lbs/yr (621 kg/yr), within the range of the Reckhow-Simpson estimate. Although each lake model used a slightly different method to calculate in-lake phosphorus concentrations, they all estimated similar values. Table 13 summarizes Ringo Lake model predictions.

Table 13. Ringo Lake Observed In-lake Parameter Concentrations and Model Predictions.

Model	Observed	MINLEAP	Chiaudani/ Vighi	Reckhow/ Simpson	Reckhow/ Simpson[1]	BATHTUB
TP (µg/L)	125	57	38.6	67-103	85-117	88
Chl-a (µg/L)	50.3	24.0	na	30.6-57.4	na	34.0
Secchi (m)	0.2	1.2	na	0.7-1.0	na	0.2
Phosphorus Load(lbs/yr)	na	673	na	1,045-2,088	1,536-2,572	1,366

[1] Includes estimate of livestock contribution.

BATHTUB TMDL load estimates – In addition to estimating lake water quality that would be expected based upon local watershed conditions, the BATHTUB model was used to estimate current loading and the loading rate required to meet water quality standards (i.e. the TMDL formula). Based on a measured in-lake phosphorus concentration of 125 µg/L, the current total estimated phosphorus load to Ringo Lake is 2,463.6 lbs/yr (1,119.8 kg/yr). To reach the NCHF ecoregion standard of 60 µg/L, the TP load would need to be reduced to the loading capacity of 715.9 lbs/yr (325.4 kg/yr), a 71 percent reduction. Similar to Long Lake, BATHTUB predicted that a significant portion of Ringo Lake's total loading comes from internal sources. Based on a residence time of 5 years (BATHTUB), it is likely that internally loaded phosphorus is not flushed out on a frequent basis. The BATHTUB model indicates that the lake may retain as much as 92 percent of the phosphorus that enters the system. BATHTUB estimates that internal loading is responsible for 45 percent (1,098 lbs/yr, 499 kg/yr) of total loading. External loading would account for 48 percent (1,168 lbs/yr, 531 kg/yr) and precipitation would account for 8 percent (196 lbs/yr, 89 kg/yr) of the total loading. BATHTUB, however, does not account for loading from failing septic systems, which would be indirectly included in the internal loading estimate. Narrative eutrophication standards for Class 2B shallow lakes require that the TP and either Chlorophyll-a or the Secchi disk be met to be considered in compliance. Ringo Lake currently does not meet any of the eutrophication standards. Ringo Lake will be in compliance when the TP standard and either the Chlorophyll-a or Secchi disk standards are met.

5.0 Phosphorus TMDL and Load Allocations

5.1 Total Maximum Daily Load Formula – A TMDL formula was calculated for both Long and Ringo Lakes based on the sum of three factors, WLA, LA, and a MOS. All TMDL formulas are based on the critical condition for Long Lake and Ringo Lake, the summer growing season, when water quality and phosphorus loading are worst. Setting the TMDL based on these conditions will be protective during the entire year.

Loading Capacity: Long Lake = 8.16 lbs/day (3.7 kg/day), Ringo Lake = 1.96 lbs/day (0.89 kg/day)

TMDL = WLA + LA + MOS

5.2 Wasteload Allocations (WLA) – WLAs include all municipal sources of phosphorus, though there are no MS4 permitted areas within the watershed. This could include city or community wastewater treatment facilities, stormwater outlets, or individually permitted private facilities. The watersheds of Long and Ringo Lakes do not have any publically or privately owned facilities of this nature. The only stormwater runoff would be from roads and individual tracts of land and would be accounted for in the LA consequently. A small WLA was included for potential construction stormwater and industrial stormwater runoff. The WLA, based on potential construction, is derived from a survey of construction stormwater permits from 2005-2010. This survey revealed only two permits within the Long Lake watershed totaling 67.6 acres. This equates to 1.4 percent of the uplands over a five-year period or 0.2 percent over a one-year period. For the purposes of this TMDL, the one-year average construction rate (0.2 percent) is rounded up to a 1 percent stormwater construction WLA rate. This assumes that no more than 1 percent of the watershed would be under construction at any time. This 1 percent rate is also applied to the Ringo Lake Watershed.

Industrial stormwater activities in this watershed are limited to sand and gravel operations, and are covered under the General Sand and Gravel General Permit (MNG490000) (see section 7.1.2). Although they are permitted operations, an industrial stormwater allocation is necessary. This allocation is based on the percentage of uplands that are occupied by active gravel pits. Approximately 5.5 percent of the uplands in the Long Lake Watershed and 6.2 percent of the Ringo Lake Watershed uplands are gravel pits. Since sand and gravel operations are permitted, it is assumed that proper BMPs are in place limiting stormwater runoff. However, even with adequate BMPs, there invariably are still impacts in terms of phosphorus loads due to industrial activities. To account for waste loads associated with industrial stormwater, an allocation 5.5 percent of the total watershed portion of the TMDL load is assigned to the industrial stormwater WLA in the Long Lake Watershed, and 6.2 percent was assigned to the Ringo Lake Watershed. The combined construction stormwater and industrial stormwater WLA for Long Lake is 6.5 percent and Ringo Lake is 7.2 percent.

WLA: Long Lake = 0.48 lbs/day (0.22 kg/day), Ringo Lake = 0.13 lbs/day (0.06 kg/day)

5.3 Load Allocations (LA)

– Typical LA account for a variety of non-point sources of phosphorus which may include runoff from yards, agricultural lands, conservation lands, direct aerial deposition, and internal loading. Load allocations based on land use category and/or sources individually are small and have thus been combined for this TMDL. Additionally, non-point source reduction programs are voluntary in nature. Identification of individual LA may not result in increased implementation. All sources of phosphorus as addressed in section 3 are pertinent and will be addressed through implementation activities. Internal loading will be reduced as a result of reduced watershed loading.

WL: Long Lake = 6.87 lbs/day (3.12 kg/day), Ringo Lake = 1.64 lbs/day (0.74 kg/day)

5.4 Margin of Safety (MOS)

– A 10 percent MOS is built into the Long and Ringo Lakes TMDL to help account for uncertainty, effectively lowering the phosphorus target ecoregion standard of 60 µg/L by 10 percent (54 µg/L). The MOS of 0.81 lbs/day (0.37 kg/day) of phosphorus for Long Lake and 0.20 lbs/day (0.09 kg/day) of phosphorus for Ringo Lake is based on the BATHTUB lake model. Several methods give us confidence in a conservative MOS including: 1) conservative modeling assumptions, 2) TMDL based on critical conditions (June-Sept. sampling), and 3) an adaptive management approach to implementation, based on future monitoring results. A 10 percent MOS was incorporated into this TMDL to account for potential uncertainty in the understanding of these aquatic systems and limitation of data collected over two years.

5.5 Reserve Capacity (RC)

– RC is a portion of load set aside for future growth or changes in the watershed. The Long and Ringo Lake watersheds are in a rural portion of Kandiyohi County with no municipalities. With the exception of potential lakeshore development, significant development is not anticipated. Any planned development within the Long and Ringo Lake watersheds must take into account practices to avoid increasing phosphorus loading, and should reduce phosphorus loads where possible.

Therefore, there is no explicit RC with the exception of development covered under an NPDES permit. Future growth will be allowed; however, any future growth or development must be accomplished without increasing the phosphorus loads to Long and Ringo Lakes. Low impact development, stormwater BMPs, and other upland BMPs will be necessary to reduce phosphorus loads while allowing for concurrent development. Recommendations for lakeshore development practices that will meet water quality goals will be outlined in an implementation plan.

In the case of WLA, the stormwater component was rounded up from 0.2 percent to 1 percent. This will provide additional RC in the event that there are periods of construction greater than anticipated.

5.6 Phosphorus Total Maximum Daily Loads for Long and Ringo Lake

Long Lake TMDL = WLA + LA + MOS

BATHTUB

(daily) 8.16 lbs/day = 0.48 lbs/day + 6.87 lbs/day + 0.81 lbs/day

3.71 kg/day = 0.22 kg/day + 3.12 kg/day + 0.37 kg/day

(annual) 2,979.2 lbs/yr = 174.2 lbs/yr + 2,507.1 lbs/yr + 297.9 lbs/yr

1,354.2 kg/yr = 79.2 kg/yr + 1,139.6 kg/yr + 135.4 kg/yr

Ringo Lake TMDL = WLA + LA + MOS

BATHTUB

(daily) 1.96 lbs/day = 0.13 lbs/day + 1.64 lbs/day + 0.20 lbs/day

0.89 kg/day = 0.06 kg/day + 0.74 kg/day + 0.09 kg/day

(annual) 715.9 lbs/yr = 46.40 lbs/yr + 597.90 lbs/yr + 71.59 lbs/yr

325.4 kg/yr = 21.09 kg/yr + 271.77 kg/yr + 32.54 kg/yr

5.7 Seasonal Variation

Water quality monitoring in Long and Ringo Lakes suggest that in-lake TP concentrations vary significantly during the growing season (June-Sept.), generally peaking in mid-late summer and consistently exceeding the NCHF shallow lake eutrophication standard (see section 1.7.2 and 1.8.2). The MPCA eutrophication water quality guideline for assessing TP is defined as the growing season (June-Sept.) mean concentration. Accordingly, water quality scenarios were evaluated in terms of the mean growing season TP.

The BATHTUB model was used to calculate the LA and WLA, incorporating mean growing season TP values. TP loadings were calculated to meet the water quality standards during the summer growing season, the most critical period of the year. Calibration to this critical period will provide adequate protection during times of the year with reduced loading.

6.0 Public Participation

The HCWP hosted six meetings with a stakeholder committee between August 2008 and June 2011. This group was made up of volunteers from the general public, representing varied interests. Stakeholder meeting attendees included lake association members, lakeshore and watershed home owners, agriculture, Kandiyohi County Commissioners, UFWS, MN DNR, and the MPCA. Meetings were held to inform the public about the TMDL process, data collection, and to solicit input on the TMDL draft. Attendees were solicited through personal invitations to each residence in the Long and Ringo Lake watersheds. Meeting notifications were also posted in the larger Hawk Creek Watershed Newsletter, Hawk Creek website, and the MPCA website.

The initial stakeholder committee meeting held on April 16, 2009, introduced the TMDL process and focused on reviewing water quality data from the 1997 Long Lake LAP Study. Basic watershed land use information was also provided for discussion. This meeting invited citizens to share their concerns about the lakes and questions about what types of new of data would be collected. Initial public concerns included fisheries resources and the large rookery island on Long Lake. A brief evaluation was distributed for the purpose of obtaining additional information about the lake and citizens concerns about the lakes. A follow up meeting was scheduled for May 19, 2009, to provide more information and to give more residents the opportunity to be involved. A status report of the Long and Ringo Lake Fisheries was presented by Bruce Gilbertson, MN DNR. The HCWP reviewed their role in the TMDL process and outlined the water quality assessments that were being conducted. Additional questions were fielded in regard to the rookery island, gravel operations, feedlots, and failing septic systems.

A meeting on June 29, 2010, was held to review the data collected during the 2008-2009 sampling seasons. The data were presented, reviewed, and discussed. Updated watershed land use information was also presented along with the livestock use assessment. This meeting also served to invite more people to participate in the stakeholder committee.

Meeting four was held on November 18, 2010, to review the modeling results and the draft TMDL assessment report prior to submittal to the EPA. Each meeting attendee was provided a draft of the TMDL to review. Comments were requested by December 14, 2010.

Public comments were received on several occasions. Questions and comment on the TMDL process and water quality data were received at each meeting. A draft of the TMDL was provided to the stakeholder group prior to the EPA's review at the November 18, 2010, meeting. Comments on this draft were received and discussed at a meeting held December 14, 2010. Several comments were received and incorporated in the draft submitted to the EPA in January 2011. Additional comments were received during the official public comment period from April 18 – May 18, 2011. A final meeting was held on

April 28, 2011, during the public comment period. This meeting was held to answer questions about the draft TMDL and to encourage formal public comments.

7.0 Implementation Strategy

A detailed implementation plan, including estimated number of practices and expenses, will be developed by the Long Lake and Ringo Lake Technical Committee. This committee will be facilitated by the HCWP and be comprised of resource professionals involved in watershed management, including the MN DNR, MPCA, USFWS, SWCD, Kandiyohi County, and BWSR. These agencies will be responsible for providing the technical expertise to land and home owners who install BMPs. In addition, these agencies are responsible for management of public lands and waters within the watershed. An adaptive management approach will be used to tailor BMP implementation to match changing technologies and to update management techniques as water quality data are updated. The implementation strategy described here will provide the framework for the Long and Ringo Lakes TMDL implementation plan.

7.1 External Loading Reduction Strategies

Several proven methods have been developed to reduce phosphorus from non-point sources. Since there are currently no municipal P sources, these practices can be broken down into two basic non-point source categories: urban/residential and agricultural/gravel operations.

7.1.1 Urban/Residential

Urban and residential practices would include those that reduce runoff from lakeshore homes and residences within the watershed. These practices could include shoreland buffers, rain gardens, lawn fertilizer reductions, vegetation management, and permeable pavement. Continued residential development of lakeshore through construction and increased runoff, has the potential to add phosphorus to the system. Low impact practices and lakeshore BMPs should be utilized for any new lakeshore development. Practices on the homeowner scale often vary widely in cost (i.e. $500 for a small rain garden to $5,000 for permeable pavement). Assuming that 50 percent of homeowners are in need of BMPs, the cost to install could be as much as $145,750. Small business would have similar options as homeowners to reduce surface runoff from parking lots and green spaces. These would include pervious pavement, rain gardens, and stormwater settling basins. Estimates to establish BMPs to promote infiltration at business sites would cost approximately $41,250.

Non-compliant septic systems can be a significant source of phosphorus to the lakes. Compliance levels can be improved by increasing the rate at which systems are inspected and repaired. Currently, Kandiyohi County requires inspection and repair/replacement only when the property is sold. Once inspected, the county requires that the system be brought up to code. Increased inspection would increase the compliance rate. The HCWP and Kandiyohi County have been very successful in providing low interest loans to assist in paying for SSTS upgrades. Although non-compliant systems contribute to phosphorus loading, they do not receive an allocation in the TMDL formulas because they are an illegal source and should have zero discharge. Another option would be to tie lakeshore waste in to a local municipal wastewater treatment facility. Although this is not a current option, it may be incorporated at sometime in the future. According to estimates, there are 49 non-compliant systems that need to be upgraded. Based on an average system cost of $8,500, the cost to upgrade lakeshore homes could be as much as $416,500. If this effort is completed watershed wide, the cost would be $1,776,500.

7.1.2 Agriculture/Gravel Operations

Methods to reduce phosphorus contributions from agricultural land have been well developed. BMPs that reduce soil loss and minimize nutrient loss from fertilizers and manure would be effective methods to reduce phosphorus loading to the lakes. Practices could include stream and shoreland buffers, gully stabilizations, nutrient management planning, manure runoff controls, livestock exclusion fencing, wetland restorations, and changes in livestock management. It will also be important to maintain grasslands and CRP which are currently trending downward in the watershed as grasslands are converted to row crop production.

The HCWP has inventoried current agricultural land use and livestock numbers. Although generally well managed, sites and practices that could be improved have been identified. All agricultural non-point BMPs are implemented on volunteer participation basis and the HCWP, NRCS, SWCD, and other groups currently have funds to assist land and livestock owners in implementing a wide variety of BMPs. Agricultural and livestock related BMPs range widely in expense from $500 for an alternative tile intake to well over $100,000 for feedlot upgrades. Implementation of several BMPs would have an estimated cost of $95,000.

Non-agricultural industry in this watershed is limited to small gravel operations. The gravel industry could reduce phosphorus loss through dust abatement and reducing or relocating their dewatering sites.

The stormwater WLA includes loads from construction stormwater. Loads from construction stormwater are considered to be a small percentage of the total WLA and are difficult to quantify. 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, including any applicable additional BMPs required in Appendix A of the Construction General Permit for discharges to impaired waters, or meet local construction stormwater requirements if they are more restrictive than requirements of the state general permit. Industrial stormwater activities are considered in compliance with provisions of the TMDL if they obtain an industrial stormwater general permit or general sand and Gravel general permit (MNG490000) under the NPDES program and properly select, install and maintain all BMPs required under the permit.

7.2 Internal Loading Reduction Strategies

Internal loading reduction methods are often much more expensive, and if reductions in the watershed are not realized, build-up of internal loading will likely reoccur. Long term goals to reduce internal loading must be paired with efforts to reduce loading from external sources. Due to long residence times and high phosphorus retention values, both Long and Ringo Lakes are subject to load build-up over several years with infrequent flushing of nutrients. This is indicated by the lower phosphorus values reported in the 1997 Long Lake LAP Study. These lakes may be building internal load over nearly a decade; therefore, external loading must continue to be managed to reduce the negative effects of internal loading (i.e. low transparency, algal blooms) between such infrequent lake flushing events. Management of fisheries resources to maintain healthy game fish population which limits rough fish (i.e. carp, bullheads, fathead minnows) can also reduce the amount of internal phosphorus.

Management of in-lake vegetation can influence internal loading rates. A detailed vegetation survey of Long and Ringo Lakes should be conducted followed by development of a vegetation management plan designed to limit internal phosphorus loading and increase water clarity.

Though neither Long nor Ringo Lakes are known for significant boating activity, boat traffic in shallow areas and vegetated areas can contribute to re-suspension of phosphorus. Traffic patterns should be evaluated and pertinent no wake zones should be established.

Estimating costs for internal loading reduction is much more difficult. Implementing the previously mentioned projects requires development of long term plans and maintenance of complex biological communities. Cost to develop and execute plans could easily exceed $500,000.

Other methods to reduce internal loading do exist. These could include chemical treatment to remove phosphorus from the water column, binding it to lake sediments. Treatment with alum has been used successfully on some lakes, though the feasibility and expense of such treatment on Long and Ringo Lakes would have to be further evaluated. Treatment with alum can be cost prohibitive and external sources would continue to 're-load' the lake if not reduced accordingly. There are additional methods to reduce internal phosphorus loading, though some are experimental in nature ranging from addition of iron filings to lake draw-downs.

7.3 Monitoring Plan

Effectiveness monitoring of Long Lake, Ringo Lake, and their tributaries will be conducted following a period of implementation. Methodology and sampling sites would follow those utilized during this assessment (see Long Lake Nutrient TMDL Assessment and Implementation Plan Development Project Quality Assurance Project Plan). The basic monitoring plan would be to collect DO and temperature profiles, along with pH and conductivity twice monthly from June through September, and to analyze surface water sample for TP, Chl-a, and Secchi transparency at a minimum of every third year. Secchi transparency collection should be tracked on a continuous basis through the CLMP to provide data for evaluation of long term trends. The data collected from this sampling would give citizens and the MPCA the information necessary to determine the current trophic state and to assess the effectiveness of watershed BMP implementation. At this time, depending on funding availability, it is anticipated that either the HCWP or the MPCA will be responsible for further water quality monitoring. There are no plans at this time to continue phytoplankton or zooplankton sampling. Needs for fisheries assessments will determined by the MN DNR. Results of continuing monitoring will be used to reassess and redirect watershed restoration activities as needed.

7.4 Reasonable Assurance

Several agencies and non-profit groups are currently working toward the goal of reducing phosphorus runoff within the Long and Ringo Lake Watersheds. These include HCWP, NRCS, SWCD, Kandiyohi County, Long Lake Association, and the MPCA, as well as private citizens and landowners. Funding and technical assistance is currently available to assist land and home owners with a variety of BMPs that will, if implemented, reduce phosphorus loading to Long and Ringo Lakes. These groups also have a long history of effectively working cooperatively with private citizens to implement beneficial practices within their respective priority areas.

The HCWP and the MPCA will be responsible for monitoring and data collection to assess changes in water quality as part of an effectiveness monitoring program. Results of any monitoring will be provided to the Long and Ringo Lakes technical and stakeholder committees.

The Long and Ringo Lakes technical committee will be formed to complete an implementation plan that will provide a detailed plan to implement BMPs within the Long and Ringo Lake watersheds that will return the lakes to meeting water quality standards. A completed implementation plan is anticipated by June 2011. Future meetings of the Long and Ringo Lakes technical committee will be facilitated by the HCWP and will be in conjunction with the Hawk Creek Watershed Technical Committee which meets on a regular basis. Meetings of the stakeholder and technical committees will track the progress of watershed restoration and TP reductions. Feedback from the technical committee will be integral in implementing BMPs that will lead to phosphorus reductions to the target lakes.

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