# Crystal Lake Nutrient TMDL Final

Prepared for

Shingle Creek Watershed
Management Commission

Minnesota Pollution Control
Agency

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Wenck

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# Crystal Lake Nutrient TMDL Report

**Final**

**Wenck File #1240**

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**TMDL Summary Table**

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# TMDL Summary

**TMDL Summary Table**

| EPA/MPCA Required Elements | Summary | TMDL Page # |
|---|---|---|
| | but rather respond to long-term changes in annual load. | |
| **Reasonable Assurance** | Reasonable assurance is provided by the cooperative efforts of the Shingle Creek Watershed Commission, a joint powers organization with statutory responsibility to protect and improve water quality in the water resources in the Shingle Creek watershed in which these lakes are located, and by the member cities of this organization. In addition, the entire contributing area to these lakes is regulated under the NPDES program, and Minnesota's General Permit requires MS4s to amend their NPDES permit's Storm Water Pollution Prevention Plan within 18 months after adoption of a TMDL to set forth a plan to meet the TMDL wasteload allocation. | Section 10 |
| **Monitoring** | The Shingle Creek Watershed Management Commission periodically monitors these lakes and will continue to do so through the implementation period. | 10-3 |
| **Implementation** | This TMDL sets forth an implementation framework and general load reduction strategies that will be expanded and refined through the development of an Implementation Plan. | Section 9 |
| **Public Participation** | Public Comment period:<br>Meeting location:<br>Comments received: | 8-1 |

# TMDL Summary

This Total Maximum Daily Load (TMDL) study addresses a nutrient impairment in Crystal Lake (27-0034). The goal of this TMDL is to quantify the pollutant reductions needed to meet State water quality standards for nutrients.

Crystal Lake is located in the City of Robbinsdale, Hennepin County, Minnesota, in the Shingle Creek watershed. It is a highly used recreational water body with an active fishery and provides other aesthetic values as well. The drainage area to the lake is 1,237 acres of fully developed urban and suburban land. The drainage area is almost entirely in the City of Robbinsdale, with some contribution from the City of Minneapolis. Crystal Lake does not have a natural outlet; a pumping station is used under high water conditions to discharge into the City of Minneapolis storm sewer system. The storm sewer discharges into Shingle Creek, which ultimately discharges into the Mississippi River. Water quality is considered poor and not supportive of recreational activities, with frequent algal blooms.

Wasteload and Load Allocations to meet State standards indicate that average nutrient load reductions of 72% would be required to consistently meet standards under average precipitation conditions. Internal load management and reduction of phosphorus from urban runoff in the watershed by retrofitting BMPs (Best Management Practices) would have the most impact on reducing phosphorus load and improving water quality in Crystal Lake.

# Executive Summary

# 1.0 Introduction

## 1.1 PURPOSE

This Total Maximum Daily Load (TMDL) study addresses a nutrient impairment in Crystal Lake. The goal of this TMDL is to quantify the pollutant reductions needed to meet State water quality standards for nutrients in Crystal Lake. The Crystal Lake nutrient TMDL is being established in accordance with section 303(d) of the Clean Water Act, because the State of Minnesota has determined waters in Crystal Lake exceed the State established standards for nutrients.

This TMDL provides waste load allocations (WLAs) and load allocations (LAs) for Crystal Lake. Based on the current State standard for nutrients, the TMDL establishes a numeric target of 40 µg/L total phosphorus concentration for deep lakes in the North Central Hardwood Forest ecoregion.

## 1.2 PROBLEM IDENTIFICATION

Crystal Lake (DNR Lake # 27-0034), located in the city of Robbinsdale, was first placed on the State of Minnesota's 303(d) list of impaired waters in 2002. Crystal Lake was identified for impairment of aquatic recreation (e.g., swimming). Crystal Lake is a highly used water resource for fishing and provides aesthetic values. It is in a highly visible location adjacent to CSAH (County State Aid Highway) 81. Water quality does not meet state standards for nutrient concentrations.

# 2.0 Target Identification and Determination of Endpoints

## 2.1 IMPAIRED WATERS

The Minnesota Pollution Control Agency (MPCA) first included Crystal Lake on the 303(d) impaired waters list for Minnesota in 2002. The lake is impaired by an excess nutrient concentration, which inhibits aquatic recreation. The MPCA's projected schedule for TMDL completions, as indicated on the 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL. The project was scheduled to be completed in 2008. Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the water body; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

## 2.2 MINNESOTA WATER QUALITY STANDARDS AND ENDPOINTS

### 2.2.1 State of Minnesota Standards

Minnesota's standards for nutrients limit the quantity of nutrients which may enter waters. Minnesota's standards at the time of listing (Minnesota Rules 7050.0150(3)) stated that in all Class 2 waters of the State (i.e., "…waters…which do or may support fish, other aquatic life, bathing, boating, or other recreational purposes…") "…there shall be no material increase in undesirable slime growths or aquatic plants including algae…" In accordance with Minnesota Rules 7050.0150(5), to evaluate whether a water body is in an impaired condition the MPCA developed "numeric translators" for the narrative standard for purposes of determining which lakes should be included in the section 303(d) list as being impaired for nutrients. The numeric translators established numeric thresholds for phosphorus, chlorophyll-a, and clarity as measured by Secchi depth. Table 2.1 lists the thresholds for listing lakes on the 303(d) list of impaired waters in Minnesota that were in place when these lakes were listed.

**Table 2.1. Trophic status thresholds for determination of use support for lakes (Crystal Lake thresholds highlighted).**

| 305(b) Designation | Full Support | | | Partial Support to Potential Non-Support | | | |
|---|---|---|---|---|---|---|---|
| 303(d) Designation | Not Listed | | | Review | Listed | | |
| Ecoregion | TP (ppb) | Chl-a (ppb) | Secchi (m) | TP Range (ppb) | TP (ppb) | Chl-a (ppb) | Secchi (m) |
| Northern Lakes and Forests | < 30 | <10 | > 1.6 | 30 – 35 | > 35 | > 12 | < 1.4 |
| (Carlson's TSI) | (< 53) | (< 53) | (< 53) | (53-56) | (> 56) | (> 55) | (> 55) |
| North Central Hardwood Forests | **< 40** | **< 14** | **> 1.4** | 40 - 45 | > 45 | > 18 | < 1.1 |
| (Carlson's TSI) | **(<57)** | **(<57)** | **(<57)** | (57 – 59) | (> 59) | (> 59) | (> 59) |
| Western Cornbelt Plain and Northern Glaciated Plain | < 70 | < 24 | > 1.0 | 70 - 90 | > 90 | > 32 | < 0.7 |
| (Carlson's TSI) | (< 66) | (< 61) | (< 61) | (66 – 69) | (> 69) | (> 65) | (> 65) |

### 2.2.2 Endpoint Used in this TMDL

The numeric target used to list this lake was the numeric translator threshold phosphorus standard for Class 2B waters in the North Central Hardwood Forest ecoregion (40 µg/L) prior to adoption of new standards in 2008 (Table 2.1). Under the new standards, Crystal Lake is now considered a deep lake with a numeric target of 40 µg/L. Therefore, this TMDL presents load and wasteload allocations and estimated load reductions assuming an endpoint of 40 µg/L.

Although the TMDL is set for the total phosphorus standard, one of the two other eutrophication standards must be met: chlorophyll-a and Secchi depth (see Table 2.2). All three of these parameters were assessed in this TMDL to assure that the TMDL will result in compliance with State standards. As shown in Table 2.2 Crystal Lake numeric standards for chlorophyll-a and Secchi depth are 14 µg/L and 1.4 meters, respectively.

**Table 2.2. Numeric targets for Lakes in the North Central Hardwood Forest and Western Corn Belt Plain Ecoregions.**

| | Ecoregions | | | |
|---|---|---|---|---|
| | North Central Hardwood Forest | | Western Corn Belt Plains | |
| Parameters | Shallow[1] | Deep | Shallow[1] | Deep |
| Phosphorus Concentration (µg/L) | 60 | **40** | 90 | 65 |
| Chlorophyll-a Concentration (µg/L) | 20 | **14** | 30 | 22 |
| Secchi disk transparency (meters) | >1 | **>1.4** | >0.7 | >0.9 |

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

## 2.3 PRE-SETTLEMENT CONDITIONS

Another consideration when evaluating nutrient loads to lakes is the natural background load. Ultimately, the background load represents the load the lake would be expected to receive under natural, undisturbed conditions. This load can be determined using ecoregion pre-settlement nutrient concentrations as determined by diatom fossil reconstruction. Diatom inferred total phosphorus concentrations are presented in Table 2.3.

**Table 2.3. Pre-settlement total phosphorus concentrations based on water quality reconstructions from fossil diatoms.**

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

(MPCA 2002). All are the concentration at the 75th percentile.

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

A 2002 MPCA study reconstructed pre-settlement lake conditions based on diatom assemblages in soil cores from many different representative lakes across the state. Crystal Lake was not included in the study. Based on the diatom fossils, pre-settlement concentrations were approximately 26 μg/L for deep lakes in the North Central Hardwood Forests ecoregion. Another benchmark that may be useful in determining goals and load reductions are expected stream concentrations under natural or undisturbed conditions. Table 2.4 provides data from minimally impacted streams.

**Table 2.4. Interquartile range of summer mean concentrations by ecoregion for minimally impacted streams in Minnesota.**

| Region | Total Phosphorus (μg/L) | | |
|---|---|---|---|
| | 25th Percentile | 50th Percentile | 75th Percentile |
| North Central Hardwood Forest | 70 | 100 | 170 |

(McCollor and Heiskary 1993)

To achieve the predicted background load, average in-stream concentrations would need to be approximately 55 to 65 μg/L which is lower than the low end of the interquartile range (70 μg/L).

# 3.0 Watershed and Lake Characterization

## 3.1 LAKE AND WATERSHED DESCRIPTION

Almost the entire drainage area for the Crystal Lake watershed is located in the City of Robbinsdale (see Figures 3.1 and 3.2), although a portion is in the City of Minneapolis. The basin covers 1,237 acres, which is approximately four percent of the Shingle Creek watershed. Crystal Lake is a 89-acre basin with an average depth of 10 feet and a maximum depth of 39 feet (Table 3.1). The littoral zone covers 64 acres, which is 72% of the basin. The littoral zone is that portion of the lake that is less than 15 feet in depth, and is where the majority of the aquatic plants grow. Crystal Lake has approximately 15 storm sewer outfalls discharging into the lake (WSB & Associates, Inc. 2003). Crystal Lake has no natural outlet; the city operates a lift station to pump discharge into the City of Minneapolis storm sewer system, where it discharges downstream directly into Shingle Creek.

**Table 3.1. Crystal Lake morphometric characteristics.**

| Parameter | Crystal Lake |
|---|---|
| Surface Area (ac) | 89 |
| Average Depth (ft) | 10.0 |
| Maximum Depth (ft) | 39.0 |
| Volume (ac-ft) | 937 |
| Residence Time (years) | 1.0 |
| Littoral Area (ac) | 64 (72%) |
| Watershed (ac) | 1,237 |

## 3.2 LAND USE

The 2000 land use data are presented in Table 3.2 and Figure 3.3. The Crystal Lake watershed is a fully developed urban watershed. Little change from the 2000 land use conditions is expected. The Crystal Lake watershed is dominated by single-family residential land use, comprising 67% of the total for the watershed. Other land uses of significance within the Crystal Lake watershed are: parks & recreation (9%), water (6%), commercial (6%), and multi-family residential (6%).

**Table 3.2. 2000 land use in the Crystal Lake watershed.**

| Land Use | 2000 | |
|---|---|---|
| | Acres | Percent |
| Single Family Residential | 824 | 67% |
| Park, Recreation, Preserve, Golf | 107 | 9% |
| Water | 78 | 6% |
| Commercial | 76 | 6% |
| Multi Family Residential | 71 | 6% |
| Institutional | 42 | 3% |
| Highway | 33 | 3% |
| Undeveloped | 3 | 0.1% |
| Industrial & utility | 3 | 0.1% |
| TOTAL | 1,237 | 100.0% |

Source: Metropolitan Council, derived from city Comprehensive Plans.

The watershed is highly developed and is drained by a network of storm sewers discharging into several large outfalls into the lake. Stormwater treatment is minimal, mainly consisting of a few small ponds serving small developments. Hennepin County is completing a major reconstruction of CSAH 81 which began in 2006 and runs along the west shore of the lake. Some new treatment has been installed along with this project to treat runoff from the highway and part of the surrounding watershed. A few existing small ponds have been increased in size, and some swirl separators have been added upstream of some outfalls to treat small events.

## 3.3 RECREATIONAL USES

Crystal Lake provides a variety of recreational uses, including fishing and boating. There is a gravel boat launch in Lakeview Terrace Park located on the south shore of Crystal Lake. There are also shore fishing opportunities and fishing piers in both Terrace Lakeview Park on the south shore and Hollingsworth Park on the north shore of Crystal Lake. A significant share of the lakeshore is park or city-owned open space, including most of the south and west shores and the north shore. Both Lakeview Terrace Park on the south shore and Sanborn Park across the street from the north shore are large, recreational parks with ballfields, playgrounds, trails, and picnic facilities. A small neighborhood park, Sunset Park, is located on the east shore and contains a playground.

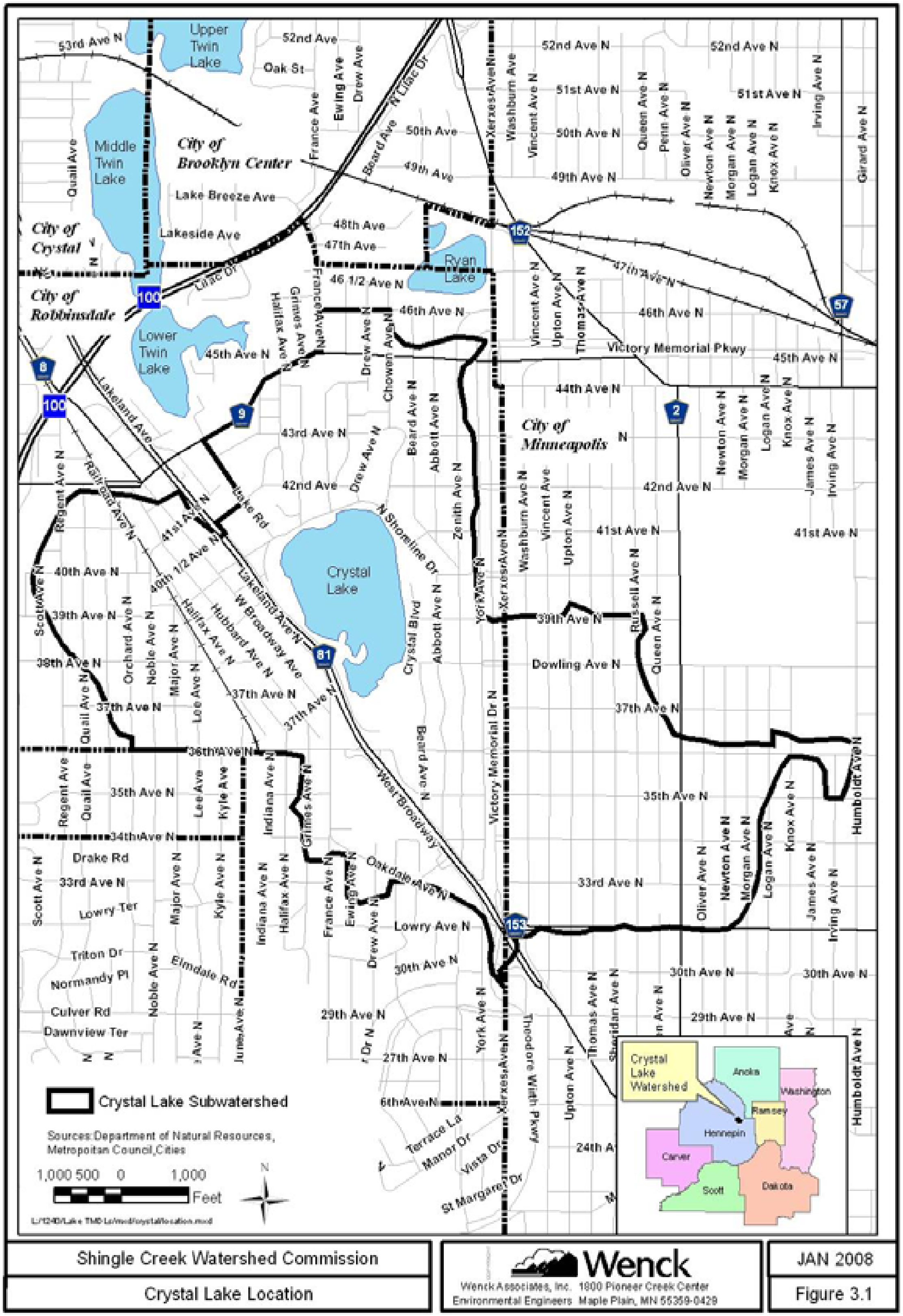


**Figure 3.1. Location map.**

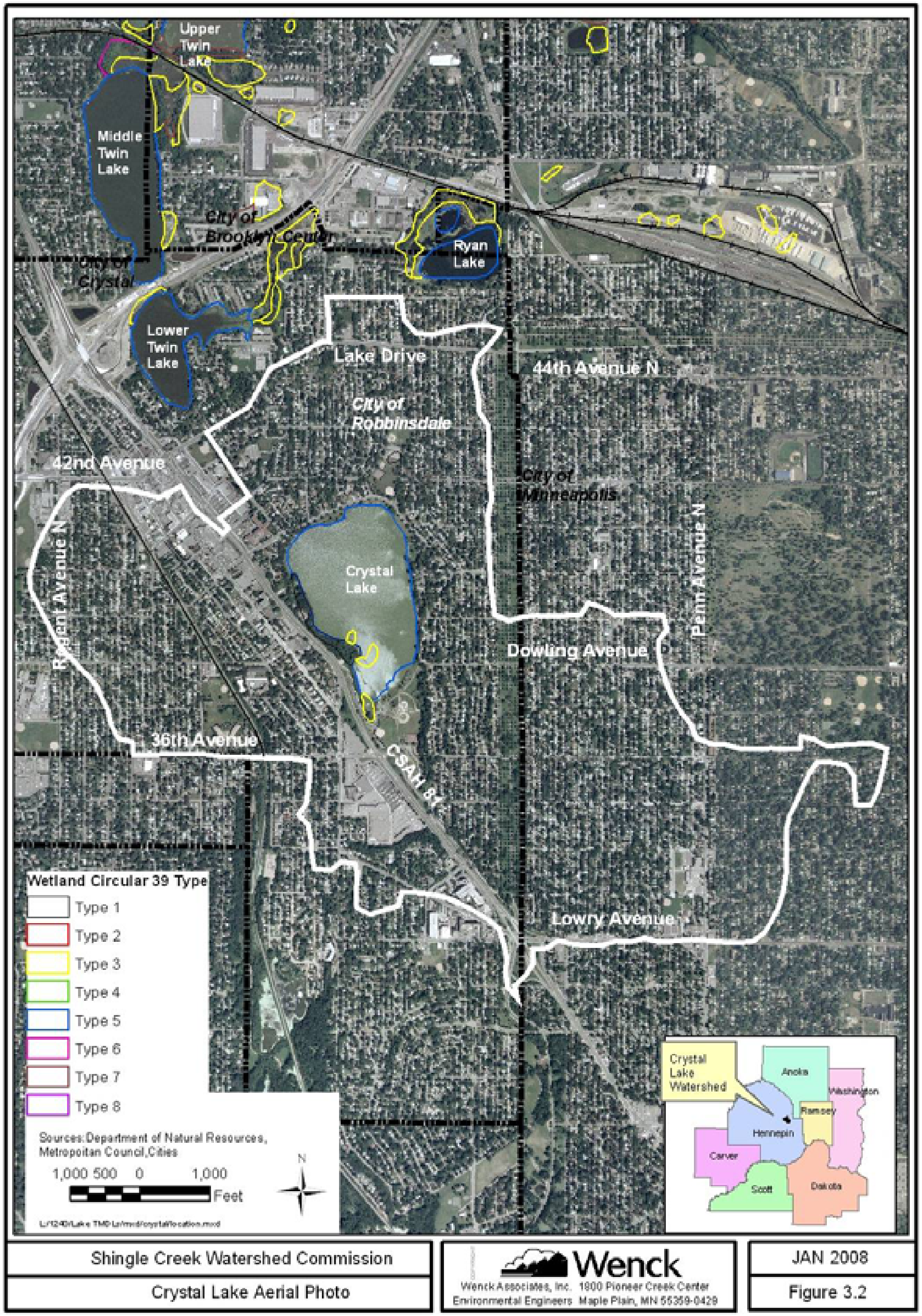


Figure 3.2. General drainage system.

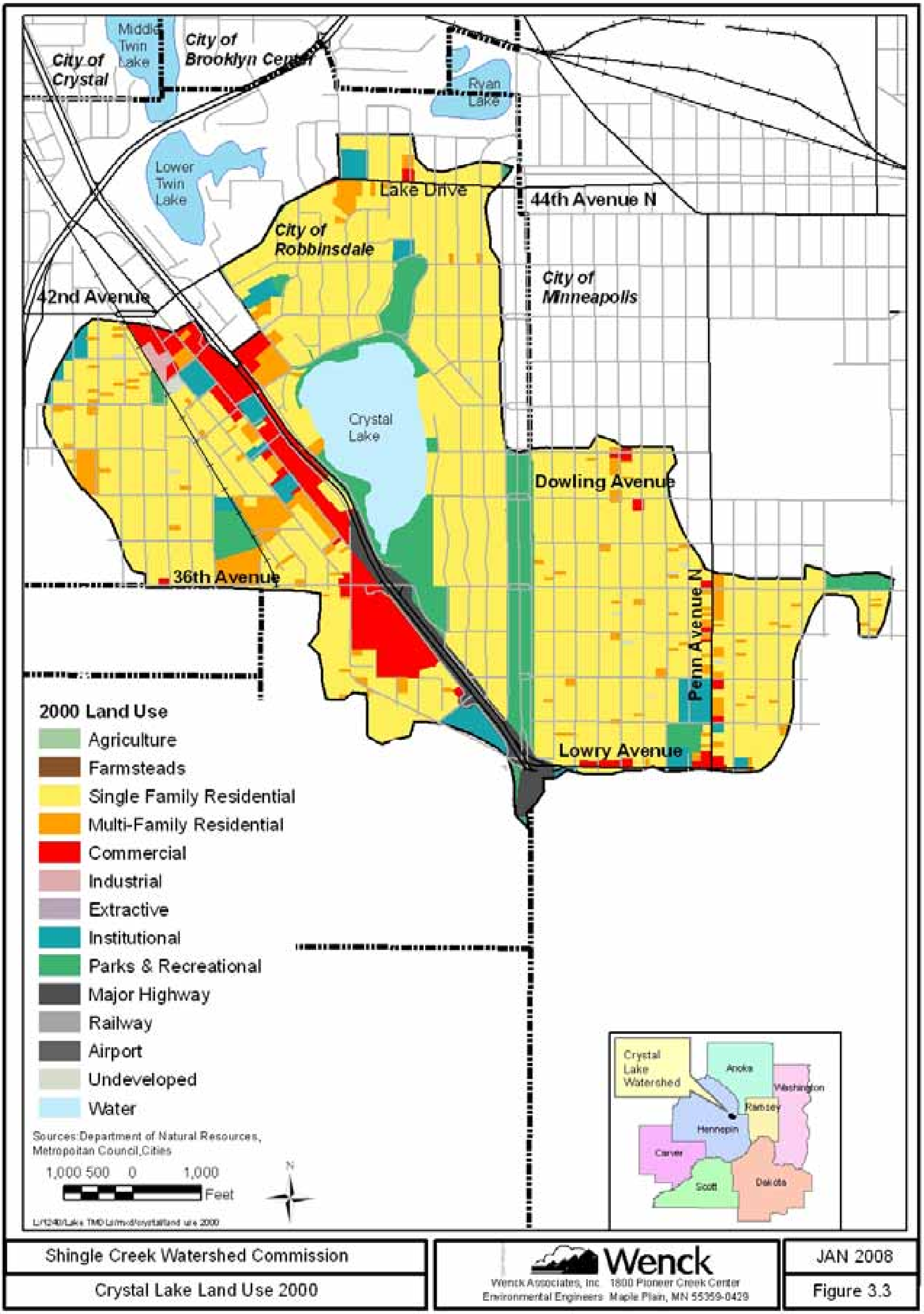


Figure 3.3. 2000 land use.

## 3.4 WATER CONDITION

### 3.4.1 Introduction

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

### 3.4.2 Historic Water Quality

Historic water quality is presented in Figure 3.4, Figure 3.5, and Figure 3.6. The summer average total phosphorus concentration ranges from 85 µg/L to 392 µg/L for the years in which measurements were taken. The largest phosphorus concentration was observed in 1988 when the artificial aeration system was used to prevent fish kills in the lake due to anaerobic conditions. The result of aeration is the disruption of the thermocline and the delivery of phosphorus from the hypolimnion to the epilimnion throughout the growing season. In recent years (2001, 2003), the total phosphorus concentration is approximately 100 µg/L. For comparison, the numeric standard for Crystal Lake is 40 µg/L total phosphorus.

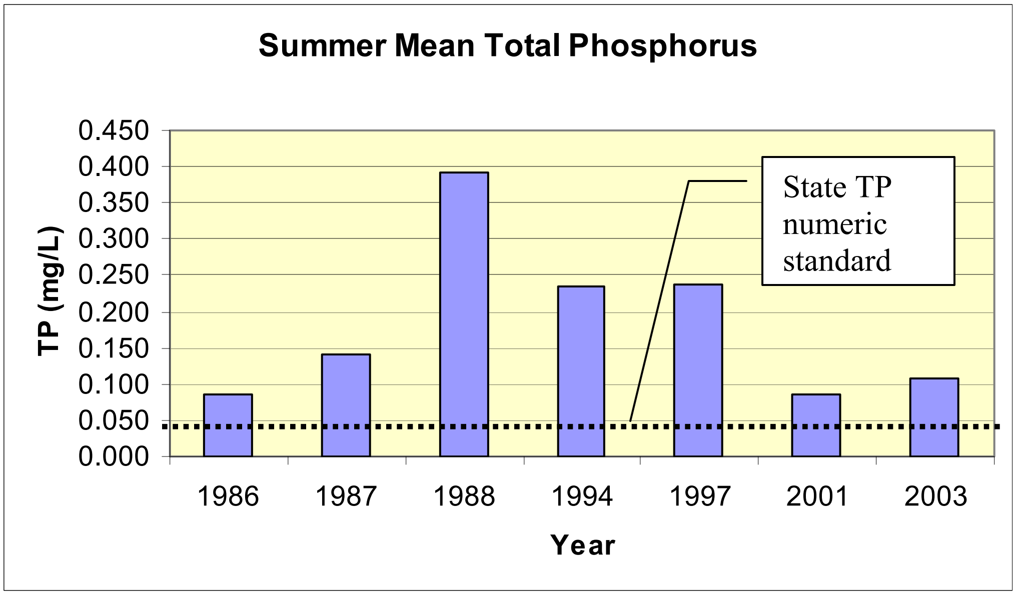


**Figure 3.4. Summer (June 1 –September 30) mean total phosphorus concentrations for Crystal Lake.**

Similar trends are observed in the chlorophyll-a concentration as was seen in the total phosphorus concentration. Chlorophyll-a ranged from approximately 30 µg/L to over 140 µg/L with the largest concentration observed in 1988 when the aeration system delivered nutrient rich hypolimnetic water to the epilimnion, resulting in significant algal blooms. In recent years, the chlorophyll-a concentration is approximately 30 to 40 µg/L. The numeric standard for Crystal Lake is 14 µg/L for chlorophyll-a.

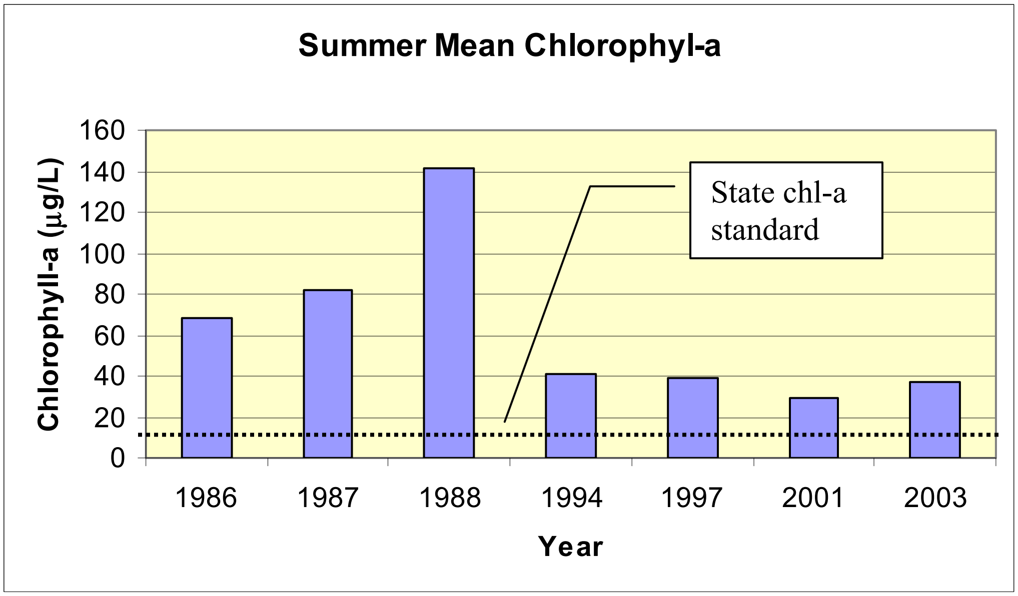


**Figure 3.5. Summer (June 1 –September 30) mean chlorophyll-a concentrations for Crystal Lake.**

Water clarity, as measured by Secchi depth measurements, was observed to follow similar trends as total phosphorus and chlorophyll-a concentration. Secchi depth ranged from approximately 0.3 meters to over 1.5 meters. The poorest clarity was observed in 1988 which coincides with the severe algal blooms observed in that year. Water clarity in recent years is approximately 1 meter. The numeric standard for Crystal Lake is 1.4 meters for clarity measured by Secchi depth.

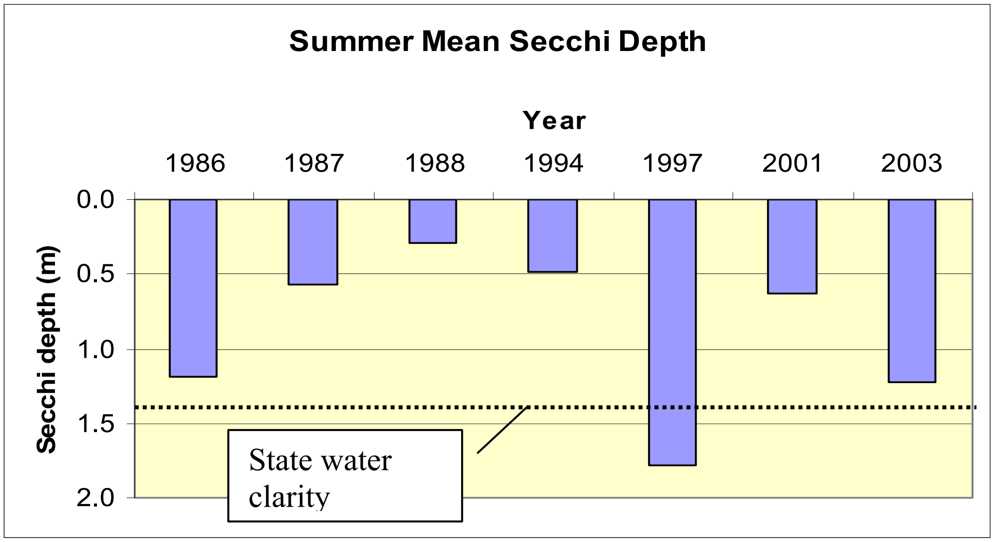


**Figure 3.6. Summer (June 1 –September 30) mean Secchi depth (meters) Crystal Lake.**

## 3.5 FISH POPULATIONS AND FISH HEALTH

### 3.5.1 Fish Populations

The lake is extensively used for fishing in both summer and winter. The results of the 1998 Minnesota Department of Natural Resources (DNR) fish survey for Crystal Lake (Figure 3.7 and Figure 3.8) revealed black crappie was the most abundant species, followed by bluegills and golden shiners. Northern Pike were the most abundant predator species with a few largemouth bass and tiger muskies also sampled. Biomass from the 1998 survey was dominated by black crappie and northern pike.

The most recent fish survey conducted by the DNR for Crystal Lake was in 2004 (Figure 3.7 and Figure 3.8). DNR stocking reports from 2004 indicate that tiger muskellunge fingerlings were stocked in Crystal Lake every two to four years between 1994 and 2001. The fish species collected during the 2004 fish survey include:

- Black Crappie
- Blue Gill
- Golden Shiner
- Northern Pike
- Tiger Muskellunge
- Walleye
- Yellow Perch
- Green Sunfish
- Hybrid Sunfish
- Largemouth Bass
- Pumpkin Seed
- White Sucker
- Yellow Bullhead

The most abundant species were bluegill and black crappie but average size for both species was small. The main predatory species collected during the 2004 survey were northern pike and largemouth bass. Northern Pike were less abundant in 2004 compared to the 1998 survey but the 2004 average weight was twice the average weight observed in 1998. Largemouth bass were not very abundant during the 2004 survey with five individuals collected, however the sample techniques used for these surveys are biased against the collection of largemouth bass and therefore are very conservative estimates of abundance. Largemouth bass size and growth were average for this lake class.

The fish community in Crystal Lake is relatively healthy overall for this lake class. There is a good mix of game fish, with prey species including bluegill, black crappie and yellow perch and predator species including northern pike, largemouth bass and a few tiger muskies. Furthermore, although some rough fish are present they are not abundant. Yellow bullheads were found in relatively low numbers in both 1998 and 2004, while black bullheads and carp were present in very small numbers in 1998 and not collected during the 2004 survey.

However there is some evidence of potential instability in the fish community. For example, the size structure of the bluegill and crappie populations is less than optimal with a lack of quality size fish (quality size fish are those most desired by anglers). The DNR suggests that “lakes that have good spawning habitat but not enough food can produce swarms of small adult sunfish that do not grow beyond four or five inches.” Another area of potential concern in the DNR 2004 fish survey was that a traditional northern pike spawning habitat was lost when a portion of the lake was filled in to create baseball fields. The 2004 survey found fewer but larger fish than the 1998 survey representing four age classes from four to seven years old. This may indicate that the pike in the lake are from year classes before the spawning area was lost and that recruitment of pike in recent years has been low (no one, two or three-year old fish were sampled).

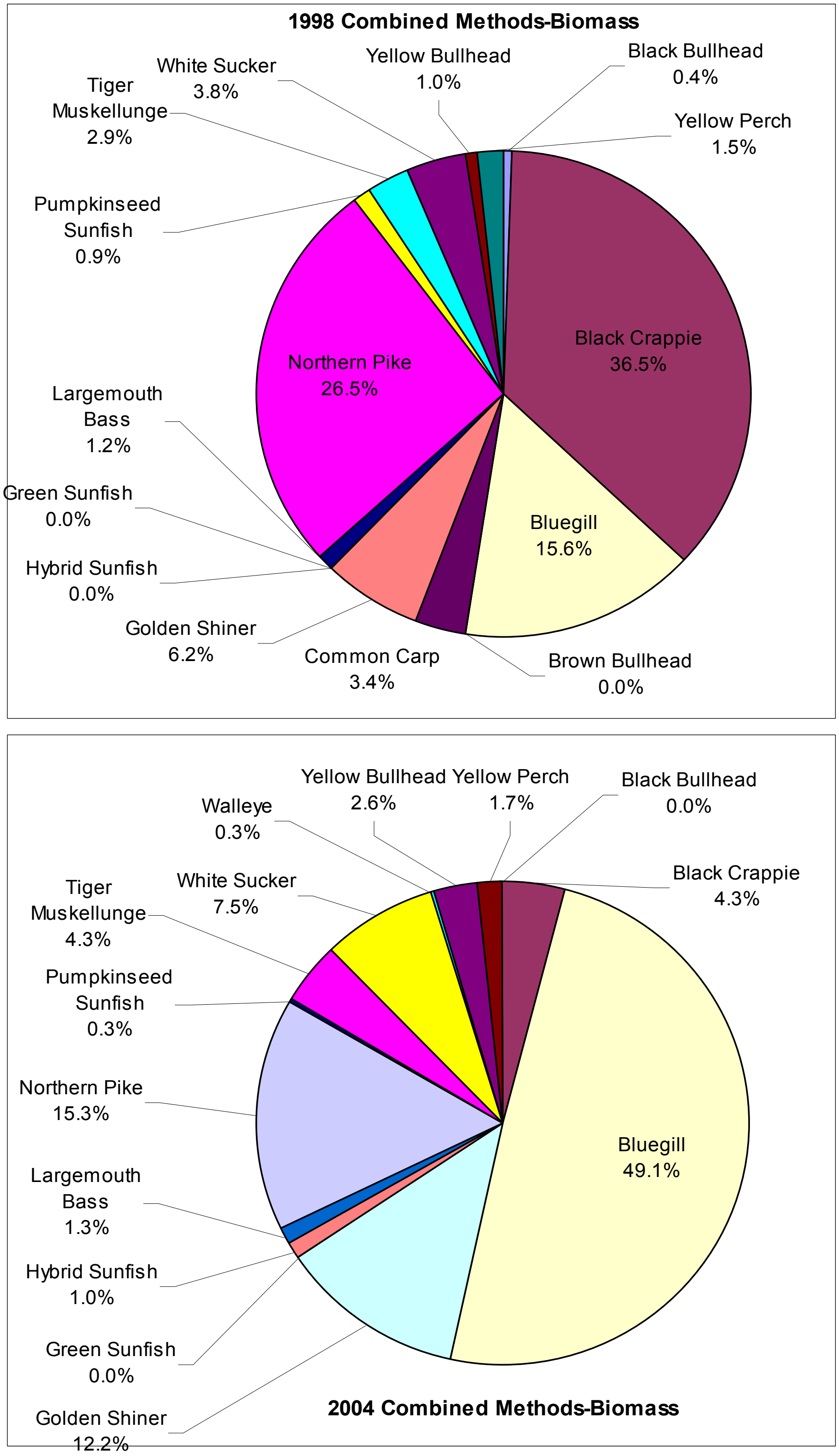


**Figure 3.7. 1998 and 2004 fish survey results for total fish biomass in Crystal Lake.**

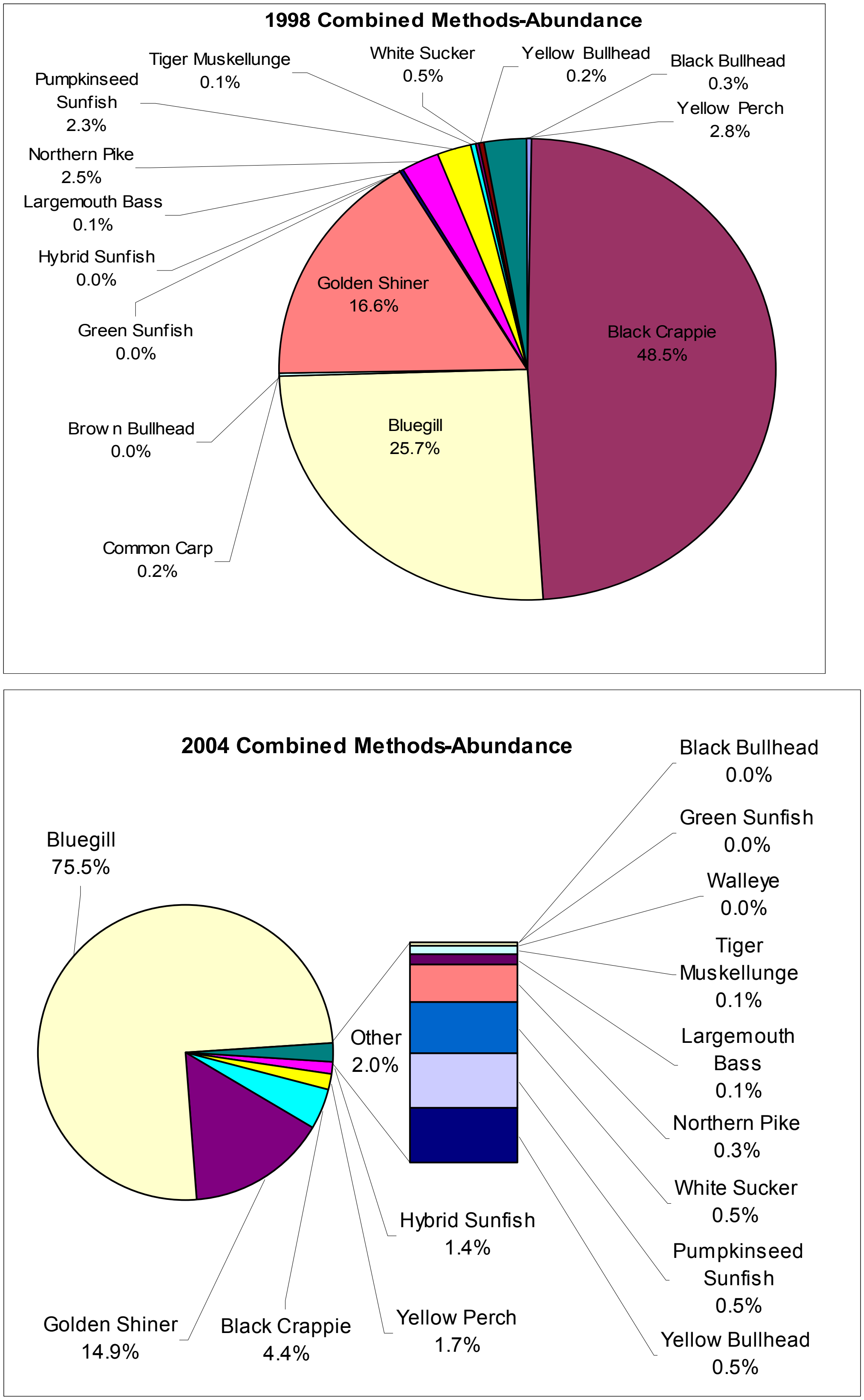


**Figure 3.8. 1998 and 2004 fish survey results for total fish abundance in Crystal Lake.**

### 3.5.2 Fish Kills

Fish kills occur when dissolved oxygen (DO) levels are so low that fish begin to die from the lack of oxygen. Fish kills commonly occur during the summer or winter. Summer kills are the result of high productivity (algae and macrophyte) that eventually senesce, and are subsequently broken down by bacteria. The breakdown by bacteria demands oxygen, which depletes DO in the water column. These conditions can result in a summer fish kill. Winter fish kills are the result of snow-covered ice that shades out photosynthesis under the ice. These conditions, coupled with a high sediment oxygen demand can deplete the DO under the ice and result in a fish kill. There are historical records of fish kills in Crystal Lake which prompted the installation of an artificial aeration system.

### 3.5.3 Carp

Common carp have both direct and indirect effects on aquatic environments. Carp uproot aquatic macrophytes during feeding and spawning that resuspends bottom sediments and nutrients. These activities can lead to increased nutrients in the water column ultimately resulting in increased nuisance algal blooms. There are carp and other rough fish present in Crystal Lake, but based on the number collected, the population is likely average to below average in size compared to area lakes.

## 3.6 AQUATIC PLANTS

### 3.6.1 Introduction

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

### 3.6.2 Littoral Zone

The littoral zone is defined as that portion of the lake that is less than 15 feet in depth and is where the majority of the aquatic plants are found. The littoral zone of the lake also provides the essential spawning habitat for most warm water fishes (e.g. bass, walleye, and panfish). Crystal Lake is approximately 72% littoral and should support a healthy aquatic plant community.

### 3.6.3 Aquatic Plants in Crystal Lake

No systematic aquatic plant survey data are available for Crystal Lake. A fisheries survey was conducted on Crystal Lake in 1991 that included limited water quality and vegetation data.

Anecdotal evidence from the Crystal Lake Task Force is that rooted aquatic plants on the north end of the lake around the fishing pier posed a problem for public use. Curly-leaf pondweed has been observed on Crystal Lake, as has Eurasian watermilfoil. Curly-leaf pondweed management occurred on Crystal Lake between 2001 and 2004. Approximately 8 acres along the northwest shoreline was treated with herbicide to reduce curly-leaf pondweed in 2001, 2002, and 2004. Approximately 4 acres was treated in 2003. No data are available on relative abundance.

## 3.7 SHORELINE HABITAT AND CONDITIONS

The shoreline areas are defined as the areas adjacent to the lakes edge with hydrophytic vegetation and water up to 1.5 feet deep or a water table within 1.5 feet from the surface. Shoreline areas should not be confused with shoreland areas which are defined as 1,000 feet upland from the Ordinary High Water (OHW). Natural shorelines provide water quality treatment, wildlife habitat, and increased biodiversity of plants and aquatic organisms. Natural shoreline areas also provide aesthetic values and important habitat to fisheries including spawning areas and refugia.

Vegetated shorelines provide numerous benefits to both lakeshore owners and lake users including improved water quality, increased biodiversity, important habitat for both aquatic and terrestrial animals, and stabilizing erosion resulting in reduced maintenance of the shoreline. Identifying projects where natural shoreline habitats can be restored or protected will enhance the overall lake ecosystem. Limited data are available on shoreline conditions, as no shoreline condition surveys have been performed. But for a few riparian wetlands, the shoreline of Crystal Lake is developed with single family residential and park uses, featuring turfed lawns and little native vegetation.

# 4.0 Nutrient Source Assessment

## 4.1 INTRODUCTION

Understanding the sources of nutrients to a lake is a key component in developing a TMDL for lake nutrients. In this section, we provide a brief description of the potential sources of phosphorus to the lake.

## 4.2 PERMITTED SOURCES

### 4.2.1 Wastewater

Permitted wastewater sources can range from industrial effluent to municipal wastewater treatment plants. There are no wastewater treatment plant effluent discharges in the watershed. No known permitted wastewater sources are present in the Crystal Lake subwatershed. Several Voluntary Industrial Cleanup program sites are located in the subwatershed, and two locations are sites of old dumps, including the general area of Sanborn Park on the north side of Crystal Lake.

### 4.2.2 Stormwater

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

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

- Minneapolis – MN0061018
- Robbinsdale – MS400046
- Hennepin County – MS400138

Stormwater discharges are regulated under NPDES, and allocations of nutrient reductions are considered wasteloads that must be divided among permit holders. Because there is not enough information available to assign loads to individual permit holders, the Wasteload Allocations are combined in this TMDL as Categorical Wasteload Allocations. The Load Allocation is allocated in the same manner including atmospheric deposition and internal loading. The relative proportions of these sources are presented in Section 9 of this report. Each permittee has agreed to implement BMPs to the maximum extent practicable. This collective approach allows for greater reductions for permit holders with more opportunities and less for those with greater constraints. The collective approach is to be outlined in an implementation plan.

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

- Brooklyn Center – MS400006
- Brooklyn Park – MS400007
- Crystal – MS400012
- Maple Grove – MS400102
- New Hope – MS400039
- Osseo – MS400043
- Plymouth – MS400112
- Mn/DOT Metro District – MS400170

## 4.3 NON-PERMITTED SOURCES

### 4.3.1 Atmospheric Deposition

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

### 4.3.2 Internal Phosphorus Release

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

# 5.0 Assessment of Water Quality Data

## 5.1 INTRODUCTION

Water quality monitoring has been conducted since 1994 as a part of the CAMP program. This section is focused on characterizing current conditions and diagnosing key problems degrading current water quality.

## 5.2 PREVIOUS STUDIES AND MONITORING ON CRYSTAL LAKE

### 5.2.1 Citizen Assisted Monitoring Program (CAMP)

Since 1990, the Shingle Creek Watershed Management Commission (SCWMC) has participated in the Citizens Assisted Monitoring Program (CAMP) operated by the Metropolitan Council Environmental Services (MCES). The CAMP program is a volunteer monitoring program where volunteers collect data and samples biweekly including samples for total phosphorus, total Kjeldahl nitrogen, and Secchi depth. The SCWMC has no professional monitoring program at this time. However, some of the member cities have conducted their own monitoring periodically on some of the lakes in the watershed.

### 5.2.2 Crystal Lake Management Plans

The City of Robbinsdale has periodically studied Crystal Lake, most recently with the development of a *Water Quality Management Plan for Crystal Lake* in 2003 (WSB & Associates, Inc. 2003). Several analyses have been performed over the years related to operation of the aeration system. These data have been incorporated into the TMDL where appropriate.

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

## 5.3 MONITORING PARAMETERS

### 5.3.1 Temperature and Dissolved Oxygen

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

### 5.3.2 Phosphorus and Nitrogen

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

### 5.3.3 Chlorophyll-a and Secchi Depth

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

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

## 5.4 LAKE MONITORING RESULTS

Following is a discussion of the lake monitoring results for Crystal Lake. The discussion is focused on specific monitoring years to present nutrient cycling dynamics in the lake.

### 5.4.1 Historical Data

Historical data for Crystal Lake is presented in Table 5.1. Data was collected through the CAMP program. Summer average total phosphorus concentrations ranged from 85 to 392 µg/L, significantly exceeding the state standard of 40 µg/L. The uncharacteristically large phosphorus concentrations observed in 1988, 1994, and 1997 are expected to be the result of the artificial aeration system used in Crystal Lake to prevent fish kills (WSB & Associates, Inc. 2003). Chlorophyll-a data typically exceeded the State standard of 14 µg/L. The Secchi depth measure of transparency has varied based on conditions, with a few years meeting or approaching the state standard of 1.4 meters. Historical data suggest that even when total phosphorus concentrations are typically good, severe algal blooms still occur.

**Table 5.1. Growing season (June 1 –September 30) lake water quality for Crystal Lake.**

| Year | Number of Samples | Chlorophyll-a (µg/L) | Kjeldahl Nitrogen (mg/L) | Total Phosphorus (mg/L) | Secchi Disk (m) |
|---|---|---|---|---|---|
| 1986[1] | 9 | 68 | 1.3 | 0.085 | 1.2 |
| 1987[1] | 9 | 82 | 1.4 | 0.141 | 0.6 |
| 1988 | 9 | 142 | 2.9 | 0.392 | 0.3 |
| 1994 | 8 | 41 | 1.7 | 0.234 | 0.5 |
| 1997 | 8 | 39 | 1.8 | 0.239 | 1.8 |
| 2001 | 4 | 29 | 1.1 | 0.085 | 0.6 |
| 2003 | 7 | 37 | 1.5 | 0.106 | 1.2 |

**[1] Artificial circulation system shut off.**

### 5.4.2 Temperature and Dissolved Oxygen

Temperature and dissolved oxygen profile data were collected for Crystal Lake in 1986, 1987, and 1988. Temperature profiles suggest stratification as shown in Figure 5.1. Dissolved oxygen (DO) concentration in Crystal Lake also demonstrates stratification with hypoxia (DO ≤ 2 mg/L) measured as shallow as 6.5 feet (Figure 5.2). Temperature and dissolved oxygen conditions in Crystal Lake demonstrate the potential for internal loading of phosphorus.

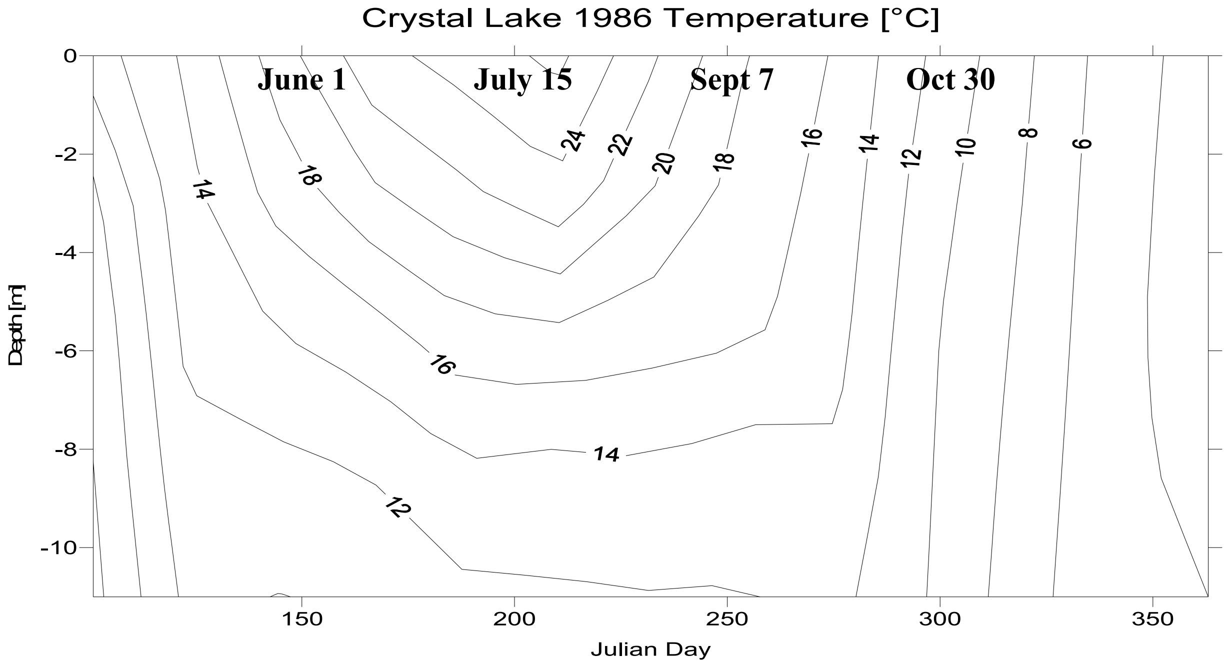


**Figure 5.1. Temperature isoplot for Crystal Lake in 1986.**

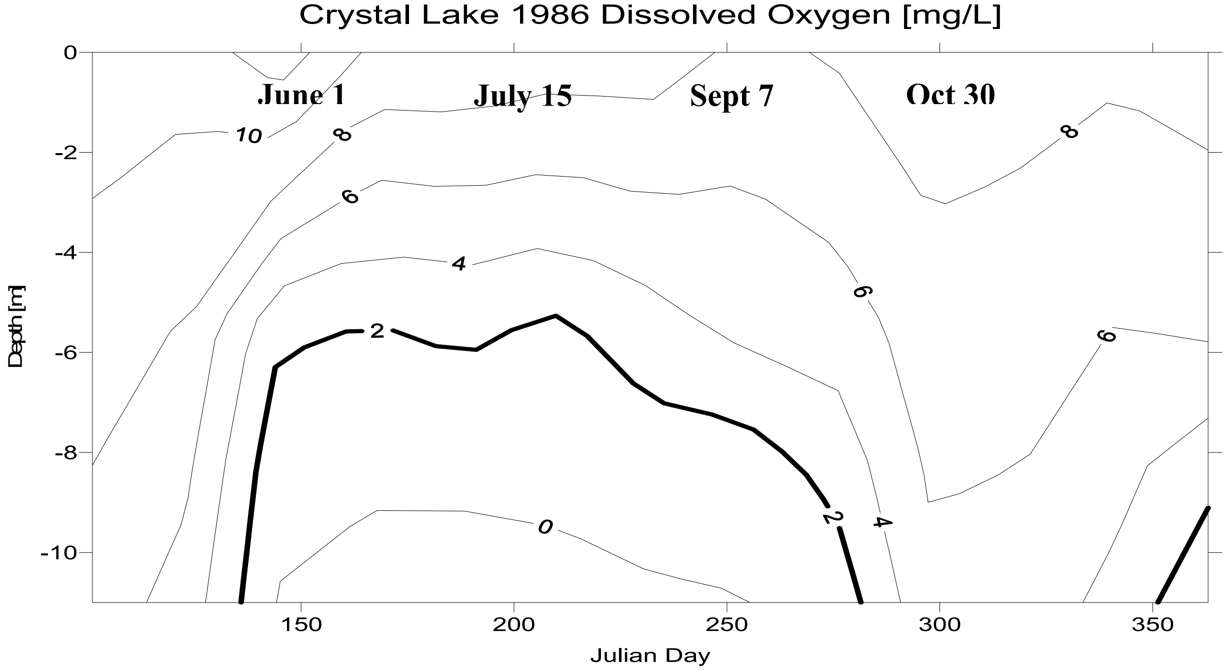


**Figure 5.2. Dissolved oxygen isoplot for Crystal Lake in 1986.**

### 5.4.2.1 Phosphorus

Total phosphorus concentrations in 2001 were typically 60-100 µg/L, peaking in early June and then again in mid-July (Figure 5.3). Total phosphorus concentrations do not appear to vary with precipitation, however, both peaks occurred following dryer periods suggesting internal loading may be causing the increase. Additionally, both peaks occurred in midsummer when anoxia occurred over the bottom sediments. Crystal Lake demonstrates stratification in the summer.

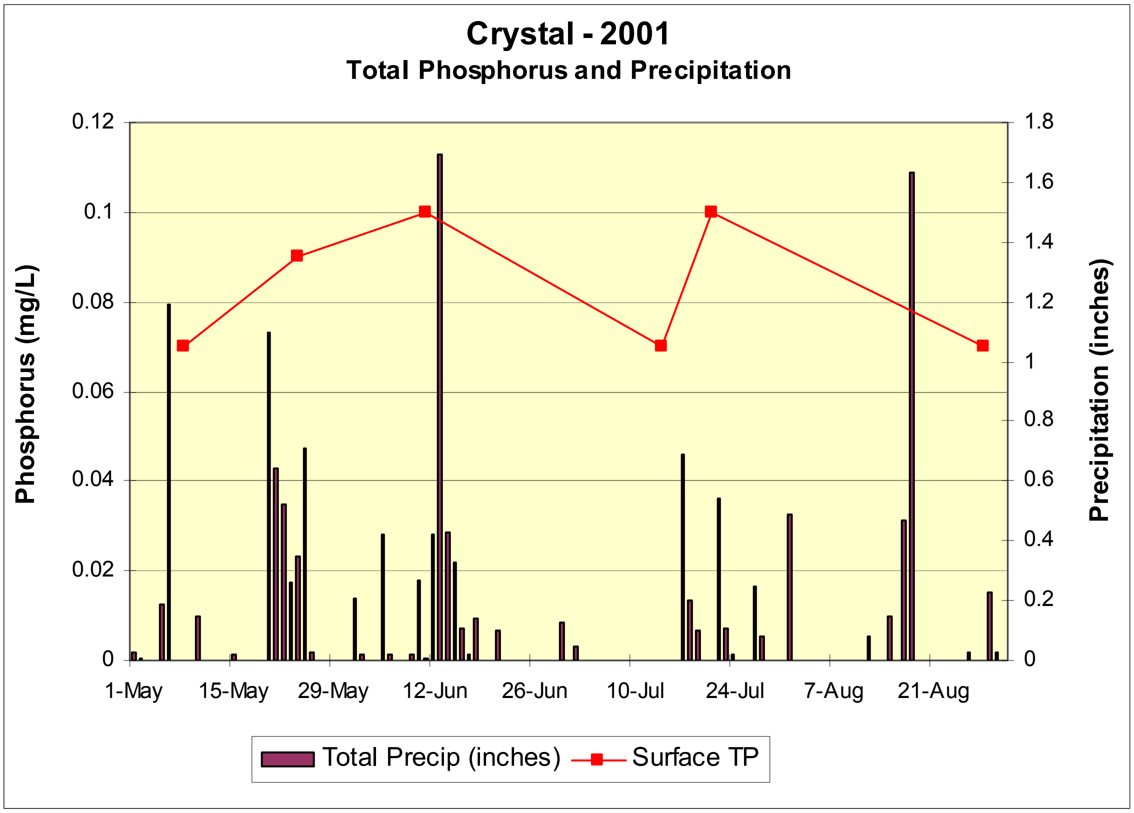


**Figure 5.3. Surface total phosphorus concentrations and total precipitation for Crystal Lake in 2001.**

### 5.4.2.2 Chlorophyll-a

In 2001, chlorophyll-a concentration varied between approximately 20 and 45 µg/L and demonstrated a similar trend as total phosphorus concentration. Peak algae blooms were observed in late May and late July as shown in Figure 5.4.

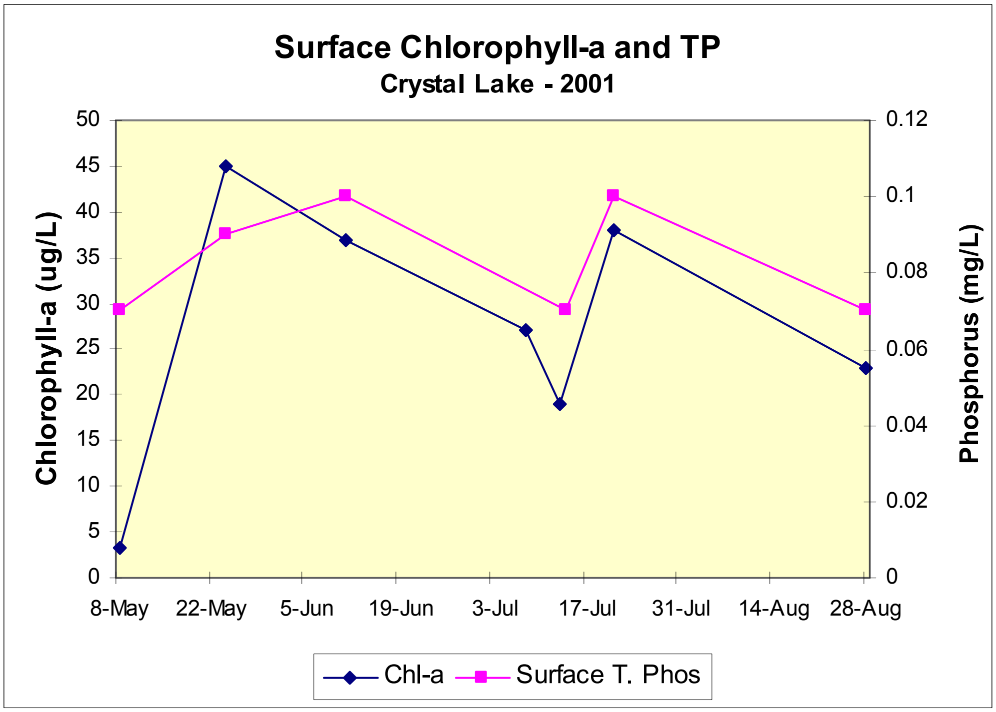


**Figure 5.4. Chlorophyll-a and phosphorus concentrations in Crystal Lake for 2001.**

## 5.5 CONCLUSIONS

Algal blooms and total phosphorus peak concentrations were observed during early and late summer in Crystal Lake with average concentrations greater than the state standards (40 µg/L for phosphorus and 14 µg/L for chlorophyll-a). Stratification and a significant anoxic layer are observed during the summer and are indications that internal loading could be a significant portion of the phosphorus budget in Crystal Lake.

# 6.0 Linking Water Quality Targets and Sources

## 6.1 INTRODUCTION

A detailed nutrient budget can be a useful tool for identifying management options and their potential effects on water quality. Additionally, lake response models can be developed to understand how different lake variables respond to changes in nutrient loads. Through this knowledge, managers can make educated decisions about how to allocate restoration dollars and efforts as well as understand the resultant effect of such efforts. At the time this report was written, only data through 2003 was available for model calibration.

## 6.2 SELECTION OF MODELS AND TOOLS

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

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

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

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

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

### 6.2.1 SWMM Modeling

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

### 6.2.2 P8 Modeling

Watershed loads were estimated using the P8 model for urban watersheds (Walker 1990). The model is based on National Urban Runoff Program studies and is widely used in the State of Minnesota for assessing runoff from urban watersheds. The P8 model was calibrated to match annual runoff volumes predicted by the calibrated XP-SWMM model as reported in the Shingle Creek Chloride TMDL (Wenck 2007). However, due to budgetary and data constraints, no ponds or wetlands were included in the model. Consequently, the P8 model represents a likely overestimate of watershed loads because treatment devices were not included in the model. With the lack of data for calibrating runoff concentrations, the P8 model was compared to in-lake data to validate the runoff calculations. Some of the lake load is a result of internal loading, which has been estimated externally from the model. The P8 results give a relative sense of watershed nutrient dynamics and provide a tool for future evaluation of watershed BMPs.

## 6.3 CURRENT PHOSPHORUS BUDGET COMPONENTS

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

### 6.3.1 Tributary or Watershed Load

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

### 6.3.2 Atmospheric Load

Atmospheric inputs of phosphorus from wet and dry deposition are estimated using rates set forth in the MPCA report “Detailed Assessment of Phosphorus Sources to Minnesota Watersheds” (Barr Engineering, 2004), and are based on annual precipitation. The values used for dry (< 25 inches), average, and wet precipitation years (>38 inches) for atmospheric deposition are 24.9, 26.8, and 29.0 kg/km$^2$-year, respectively. These values are equivalent to 0.222, 0.239, and 0.259 pounds/acre-year for dry, average, and wet years in English units, respectively. The atmospheric load (kg/year) for Crystal Lake was calculated by multiplying the lake area (km$^2$) by the atmospheric deposition rate (kg/km$^2$-year). For example, in an average precipitation year the atmospheric load to Crystal Lake would be 26.8 kg/km$^2$-year times the lake surface area (0.36 km$^2$), which is 9.7 kg/year. The watershed is small enough that it is unlikely that there are significant geographic differences in rainfall intensity and amounts across the watershed.

### 6.3.3 Internal Loads

Internal phosphorus loading from lakes has been demonstrated to be an important aspect of the phosphorus budgets of lakes. However, measuring or estimating internal loads can be difficult, especially in shallow lakes that may mix many times throughout the year. Two methods were used to estimate the internal load for Crystal Lake. In both methods, the anoxic factor (Nürnberg 2004), which estimates the period where anoxic conditions exist over the sediments, is estimated from the dissolved oxygen profile data obtained in 1986 and 1987 because more recent data is not available. The anoxic factor is expressed in days but is normalized over the area of the lake. For example, if the depth of oxygen depletion (<2 mg/L DO) was 6 meters for 14 days, the corresponding area of anoxia is approximately 10 hectares for Crystal Lake. The anoxic factor can then be calculated as the number of anoxic days multiplied by the area of anoxia and dividing by the total lake area (36 hectares), which results in an anoxic factor of approximately 3.9 days for this 14-day period.

The sediment phosphorus release rate was calculated differently in the two methods used to estimate internal load which are described below. For reference, the sediment phosphorus release rates for varying trophic status are provided in Figure 6.1 (Nürnberg 1997). It is important to note that these methods are used to give an estimate of the role of internal loading in lakes. The Canfield-Bachmann model used to estimate lake response in this TMDL is likely based on empirical relationships with lakes that demonstrate some internal loading. Consequently, the external load estimated is partially in lieu of internal loading. As an additional margin of safety, this TMDL is developed with load reductions applied to the watershed to meet the standard and a load reduction estimated for the internal loading.

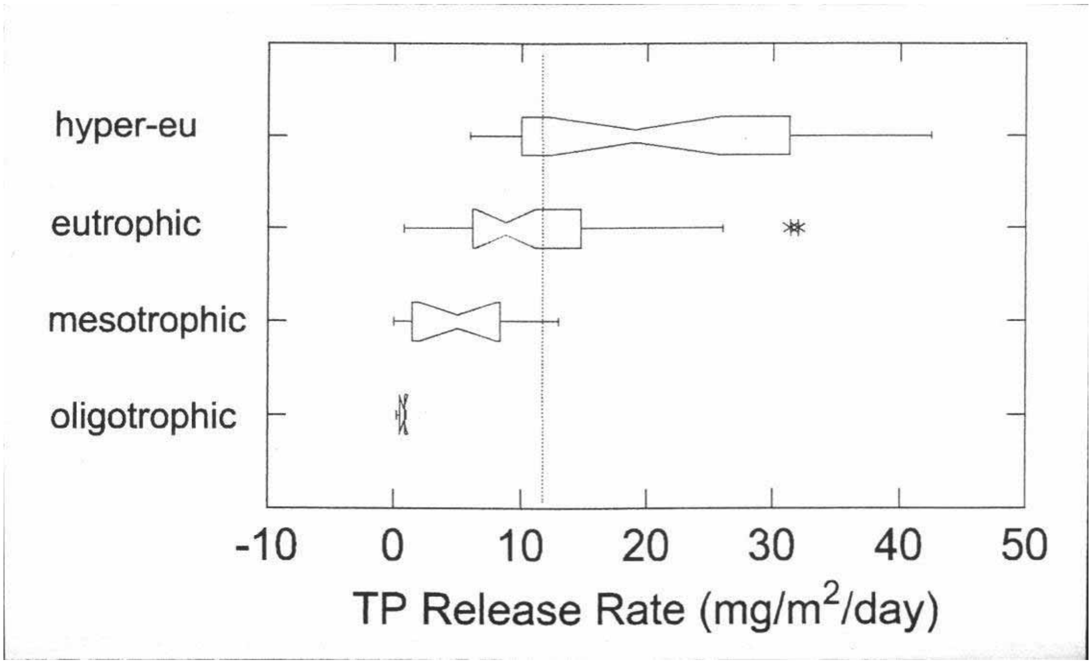


**Figure 6.1. Sediment phosphorus release rates by trophic condition.**

**(Nürnberg 1997)**

### 6.3.3.1 Crystal Lake Internal Loads

The first method for estimating internal load in Crystal Lake is based on mass balance of phosphorus in the lake. The sediment phosphorus release rate was estimated from hypolimnetic phosphorus concentration and anoxic water volume. The mass of phosphorus in the anoxic layer is assumed to be a direct result of phosphorus release from lake-bottom sediments. An anoxic factor was calculated for 1986 and 1987 using dissolved oxygen profile data and is estimated from the areal extent and number of days of anoxia, normalized for the entire lake area as described above. The internal load as estimated by mass balance of the anoxic layer within Crystal Lake is, on average, approximately 125 kg (Table 6.1).

**Table 6.1. Results of the mass balance for Crystal Lake.**

| Year | Release Rate ($mg/m^2/day$) | Anoxic Factor (days) | Gross Load ($mg/m^2/summer$) | Gross Load (kg) |
|---|---|---|---|---|
| 1986 | 12.1 | 28 | 339 | 122 |
| 1987 | 11.6 | 31 | 360 | 130 |

Another method for estimating internal load is based on an area-weighted release rate and anoxic factor. The release rate was measured from sediment cores taken from the lake-bottom sediments in 2007 and analyzed for phosphorus release. The results indicate that oxic and anoxic release rates for phosphorus release from Crystal Lake are 6.4 $mg/m^2$-day and 19.8 $mg/m^2$-day, respectively. The area-weighted average release rate for the entire lake using 6.4 $mg/m^2$-day in the littoral area (assumed to be oxic) and 19.8 $mg/m^2$-day in the remainder of the lake (assumed to be anoxic) is approximately 10.1 $mg/m^2$-day. The anoxic factor was calculated separately for the shallow and deep areas of the lake and the area-weighted anoxic factor for Crystal Lake is approximately 35.3 days. The internal load as estimated from the measured release rates area-weighted for the entire lake (10.1 $mg/m^2$-day) and the anoxic factor estimated from dissolved oxygen profiles (35.3 days) is approximately 129 kg (Table 6.2).

**Table 6.2. Results of the internal load assessment using an anoxic factor and release rate for Crystal Lake.**

| | Release Rate ($mg/m^2/day$) | Anoxic Factor (days) | Gross Load ($mg/m^2/summer$) | Gross Load (kg) |
|---|---|---|---|---|
| Shallow Area | 6.4 | 5.8 | 37 | 13 |
| Deep Area | 19.8 | 112 | 2,220 | 801 |
| Area-weighted average | 10.1 | 35.3 | 357 | 129 |

The area-weighted method for estimating internal load is based on measured release rates and anoxic factors calculated from measured data. The mass balance method for estimated internal load confirmed that the average internal load is approximately 129 kg/year as estimated by the area-weighted average. The area-weighted average release rate (10.1 $mg/m^2$-day) and anoxic factor (35.3 days) are used for the phosphorus budget for Crystal Lake.

## 6.4 CURRENT PHOSPHORUS BUDGET

The current conditions phosphorus budget was developed using the P8 model results (Section 6.2), the internal load evaluation Section 6.3.3 and the BATHTUB model. Phosphorus budgets were developed for 2001 and 2003 (Table 6.3) because these are the only recent years in which data is available for calibration of the model. The average model-predicted phosphorus budget for 1999-2003 is also provided in Table 6.3. The results of the lake response modeling can be found in Appendix A.

**Table 6.3. Total phosphorus budget for Crystal Lake.**

| Source | Source | 2001 Annual TP Load (kg/yr) | 2003 Annual TP Load (kg/yr) | Average Load (1999-2003, kg/yr) |
|---|---|---|---|---|
| Wasteload | Watershed Load | 229 | 161 | 223.2 |
| Load | Atmospheric Load | 10 | 10 | 10.0 |
| | Internal Load | 129 | 129 | 128.8 |
| | TOTAL LOAD | 368 | 299 | 362.0 |

Partitioning between external and internal loads is difficult, especially with the limited data set available for this lake. The nutrient budget, however, suggests that the watershed and internal loads are significant for Crystal Lake.

## 6.5 WATER QUALITY RESPONSE MODELING

The BATHTUB model was developed using the P8 loads and runoff volumes. Two years were modeled to validate the assumptions of the model. Several models (subroutines) are available for use within the BATHTUB model. The selection of the subroutines is based on past experience in modeling lakes in Minnesota and is focused on subroutines that were developed based on data from natural lakes. The Canfield-Bachmann natural lake model was chosen for the phosphorus model. The chlorophyll-a response model used was model 1 from the BATHTUB package, which accounts for nitrogen, phosphorus, light, and flushing rate. Secchi depth was predicted using the “VS. CHLA & TURBIDITY” equation. For more information on these model equations, see the BATHTUB model documentation (Walker 1999). Model coefficients are also available in the model for calibration or adjustment based on known cycling characteristics and the coefficients were left at the default values. No initial calibration factors were applied.

## 6.6 FIT OF THE MODEL

Model fit for Crystal Lake is presented in Table 6.4. The model fit reasonably well for both 2001 and 2003 for all parameters. The model over-predicted phosphorus in 2001 but under-predicted in 2003 indicating that the model is a reasonable average prediction. Chlorophyll-a is over-predicted in both years, indicating that the target reductions are conservative. Water clarity (Secchi depth) is over-predicted in 2001 and under-predicted in 2003, indicating that the model is a reasonable average prediction.

**Table 6.4. Model fit for Crystal Lake.**

| Year | Variable | Predicted Mean | Observed Mean |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 2001 | Total Phosphorus (µg/L) | 93 | 85 |
| | Chlorophyll-a (µg/L) | 38 | 29 |
| | Secchi Depth (meters) | 1.0 | 0.6 |
| | | | |
| 2003 | Total Phosphorus (µg/L) | 93 | 106 |
| | Chlorophyll-a (µg/L) | 44 | 37 |
| | Secchi Depth (meters) | 0.9 | 1.2 |

The model was used to estimate total phosphorus concentration in Crystal Lake for 1992 through 2003 as shown in Figure 6.2 (See also Appendix A). The model fit is reasonable for 2001 and 2003 as described above.

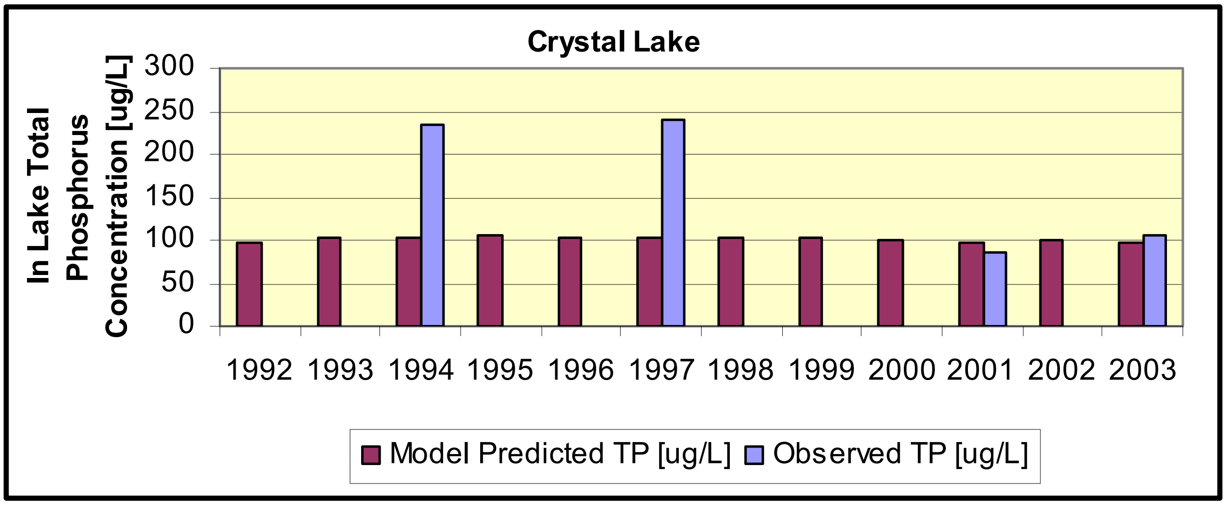


**Figure 6.2. Model-predicted total phosphorus concentration in Crystal Lake for 1992 – 2003.**

The model, however, significantly under-predicted total phosphorus concentration in 1994 and 1997. The artificial aeration system likely entrained a significant phosphorus load from the hypolimnion to the epilimnion (WSB & Associates, Inc. 2003) in these years. The aeration system is believed to not be operating efficiently in 2001 and 2003 which resulted in a lower mass of hypolimnetic phosphorus being delivered to the surface. The additional load that would account for the discrepancy between the model-predicted and observed total phosphorus concentration in 1994 and 1997 is approximately 1,000 kg. Analysis of hypolimnetic total phosphorus concentration indicates that between 3,000 and 5,000 kg of total phosphorus mass can be present in the anoxic layer. Only a portion of this load would be needed to account for the large total phosphorus concentrations observed in 1994 and 1997.

## 6.7 CONCLUSIONS

Overall, Crystal Lake is hypereutrophic with both internal and external loads contributing to phosphorus load to the lake. Curly-leaf pondweed and Eurasian watermilfoil are also present in Crystal Lake but the abundance is unknown and therefore it is unclear to what extent this vegetation is contributing to the nutrient cycling in Crystal Lake. External loads represent approximately 62% of the total phosphorus load to Crystal Lake. Conclusions from the modeling and source assessment are as follows:

1. External load is a significant source to Crystal Lake and must be part of any management or implementation plan.
2. Internal load is also a significant source to Crystal Lake and must be part of any management or implementation plan. It is unclear to what extent carp, rough fish, and curly-leaf pondweed contribute to internal recycling of nutrients.
3. Artificial aeration of lake-bottom sediments is used in Crystal Lake and may negatively impact water quality.

# 7.0 TMDL Allocation

## 7.1 LOAD AND WASTELOAD ALLOCATIONS

Nutrient loads in this TMDL are set for phosphorus, since this is typically the limiting nutrient for nuisance aquatic plants. This TMDL is written to solve the TMDL equation for a numeric target of 40 μg/L of total phosphorus. This TMDL presents load and wasteload allocations and estimated load reductions to achieve this endpoint.

### 7.1.1 Allocation Approach

Stormwater discharges are regulated under NPDES, and allocations of nutrient reductions are considered wasteloads. Because there is not enough information available to assign loads to individual permit holders, the Wasteload Allocations are combined in this TMDL as Categorical Wasteload Allocations (WLA) (see Table 7.1) assigned to all permitted dischargers in the contributing lakeshed. There are no known industrial dischargers in the watershed. The pollutant load from construction stormwater is considered to be less than 1 percent of the TMDL and difficult to quantify. Consequently, the WLA includes pollutant loading from construction stormwater sources.

The Load Allocation is allocated in the same manner as the WLA, and includes atmospheric deposition and internal loading. The relative proportions of these sources are presented in Section 9 of this report. Each permittee has agreed to implement BMPs to the maximum extent practicable. This collective approach allows for greater reductions for some permit holders with greater opportunity and less for those with greater constraints. The collective approach is to be outlined in an implementation plan. Construction stormwater activities are considered in compliance with provisions of the TMDL if they obtain a Construction General Permit under the NPDES program and properly select, install, and maintain all BMPs required under the permit, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit.

**Table 7.1. Wasteload allocation by NPDES permitted facility.**

| NPDES Permit Number | Allocation |
|---|---|
| MN0061018-Minneapolis | Categorical WLA |
| MS400046-Robbinsdale | Categorical WLA |
| MS400138-Hennepin | Categorical WLA |

### 7.1.2 Critical Condition

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

### 7.1.3 Allocations

The loading capacity is the total maximum daily load. The total maximum daily load was calculated in the following manner. Atmospheric deposition load was calculated as described in section 6.3.2 to be 10 kg/yr. As atmospheric load is impossible to control on a local basis, no reduction in that source was assumed for the TMDL.

As described in section 3.3.3.1, current internal load was estimated to be approximately 10.1 mg/m$^2$/day. The TMDL assumed that at goal the sediment phosphorus release rate would be low, as is found in oligotrophic or the low end of mesotrophic lakes (see figure 6.1). The current anoxic factor and a release rate of 1.0 mg/m$^2$/day was used to calculate an internal load of 13 kg/yr at goal. Finally, these two loads and the P8 annual runoff by year were entered into the Canfield-Bachmann equation to calculate the maximum watershed load allowable to achieve an in-lake concentration of 40 µg/L TP, the applicable standard for Crystal Lake. A summary and details by year of these calculations and model inputs are shown in Appendix A.

The wasteload allocation for the TMDL was calculated by averaging the watershed load at goal for 2001 and 2003, two recent years for which calibrated SWMM model data is available to calibrate the P8 model runoff. As can be seen in Appendix A, the watershed load in 2001 for goal conditions was estimated to be 92 kg/L and in 2003 to be 66 kg/L, which average to 79 kg/year. The watershed, internal, and atmospheric loads were summed and divided by 365.25 days per year (to account for leap year) to convert the annual load to a daily load.

The load and wasteload allocations are shown in Table 7.2. As additional data become available after US EPA approval of the TMDL, WLAs for individual permitted sources may be modified, provided the overall WLA does not change. Modifications in individual WLAs will be public noticed. These allocations will guide the development of an implementation plan and necessary reductions.

**Table 7.2. Crystal Lake TMDL total phosphorus allocations expressed as daily loads (average of model years 2001 and 2003).**

| Wasteload TP Allocation (kg/day)[1] | Load TP Allocation (kg/day) | Margin of Safety | Total Phosphorus TMDL (kg/day) |
|---|---|---|---|
| 0.22 | 0.06 | Implicit | 0.28 |

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

Load allocations by source are provided in Table 7.3. No reduction in atmospheric loading is targeted. The remaining load reductions were applied based on our understanding of the lakes as well as output from the model (Appendix A).

**Table 7.3. TMDL total phosphorus daily loads partitioned among the major sources for Crystal Lake assuming a TP standard of 40 μg/L.**

| | Source | Total Maximum Daily TP Load (kg/day) |
|---|---|---|
| Wasteload | Watershed Load | 0.22 |
| Load | Atmospheric Load | 0.03 |
| | Internal Load | 0.03 |
| | **TOTAL LOAD** | **0.28** |

Annual total maximum loads are provided in Tables 7.4 and 7.5. The loading capacity provided in Tables 7.4 and 7.5 is based on the average model-predicted results for the years in which calibration data is available (2001, 2003).

**Table 7.4. Crystal Lake TMDL total phosphorus allocations expressed as annual loads (average of model years 2001 and 2003).**

| Wasteload TP Allocation (kg/yr)[1] | Load TP Allocation (kg/yr) | Margin of Safety | Total Phosphorus TMDL (kg/yr) |
|---|---|---|---|
| 79 | 23 | Implicit | 102 |

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

**Table 7.5. TMDL total phosphorus annual loads partitioned among the major sources for Crystal Lake assuming a TP standard of 40 μg/L.**

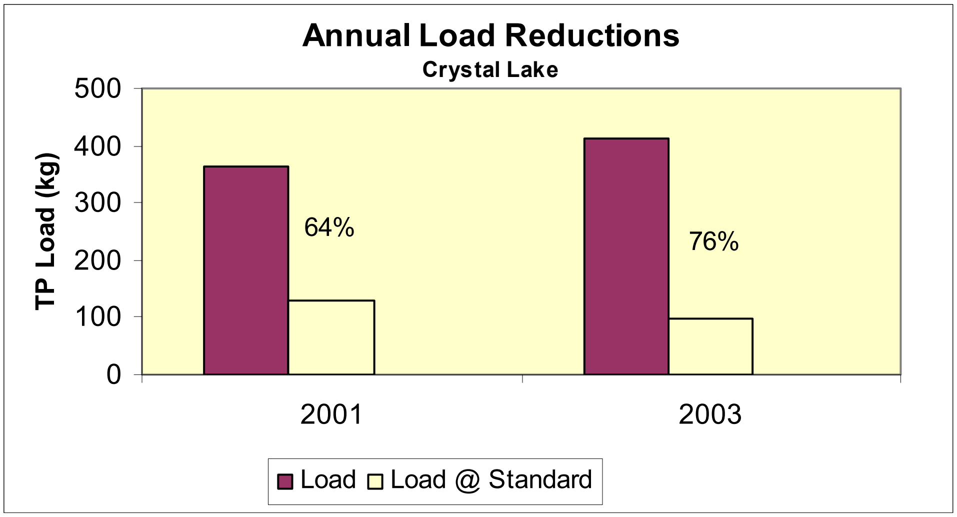
| | Source | Total Maximum Daily TP Load (kg/yr) |
|---|---|---|
| Wasteload | Watershed Load | 79 |
| Load | Atmospheric Load | 10 |
| | Internal Load | 13 |
| | **TOTAL LOAD** | **102** |

## 7.2 RATIONALE FOR LOAD AND WASTELOAD ALLOCATIONS

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

### 7.2.1 Modeled Historic Loads

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



The percentages represent the reduction needed to meet the standard.

**Figure 7.1. Modeled annual load and load at the standard for Crystal Lake.**

For two years with monitoring data, Crystal Lake required a 64 and 76% reduction in total annual phosphorus loads (Figure 7.1) to meet the numeric total phosphorus standard of 40 µg/L. Much of this load is likely external load with a significant contribution from internal loading. Reductions in phosphorus will be required for in-lake management activities to be fully effective. Crystal Lake will require a significant effort in watershed BMPs to reduce the phosphorus loads to meet the State standards. Annual total phosphorus values can be found in Tables 9.1 and 9.2 and in Appendix A.

### 7.2.2 Water Quality Response to Load Reductions

Using the previously described BATHTUB water quality response model, total phosphorus and chlorophyll-a concentrations were predicted for load reductions in 5% increments for 2003. These predicted responses can be used to develop goals for load reductions with an understanding of the overall water quality benefits.

### 7.2.3 Phosphorus

The modeled response to phosphorus load reductions for 2003 is presented in Figure 7.2 as an average year because the precipitation in 2003 (27.1 inches) is similar to the 30-year normal (28.3 inches). The model indicates a phosphorus load reduction of about 72% would be required to achieve a total phosphorus concentration of 40 µg/L, which would meet the state standard.

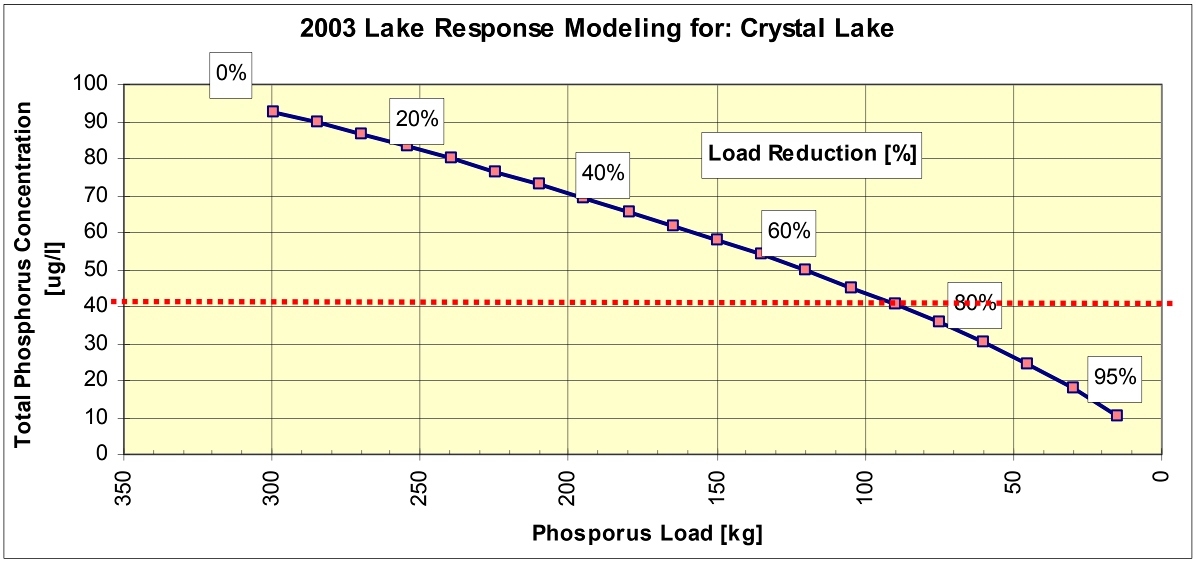


**Figure 7.2. In-lake total phosphorus concentrations predicted for total phosphorus load reductions applied to all sources.**

### 7.2.4 Chlorophyll-a

Modeled chlorophyll-a concentrations with each load reduction for 2003 are presented in Figure 7.3. A 72% reduction in total phosphorus load will result in a chlorophyll-a concentration in Crystal Lake of approximately 21 µg/L which would not meet the state standard of 14 µg/L. Additional management activities may be required to get the chlorophyll-a concentration to meet the standard.

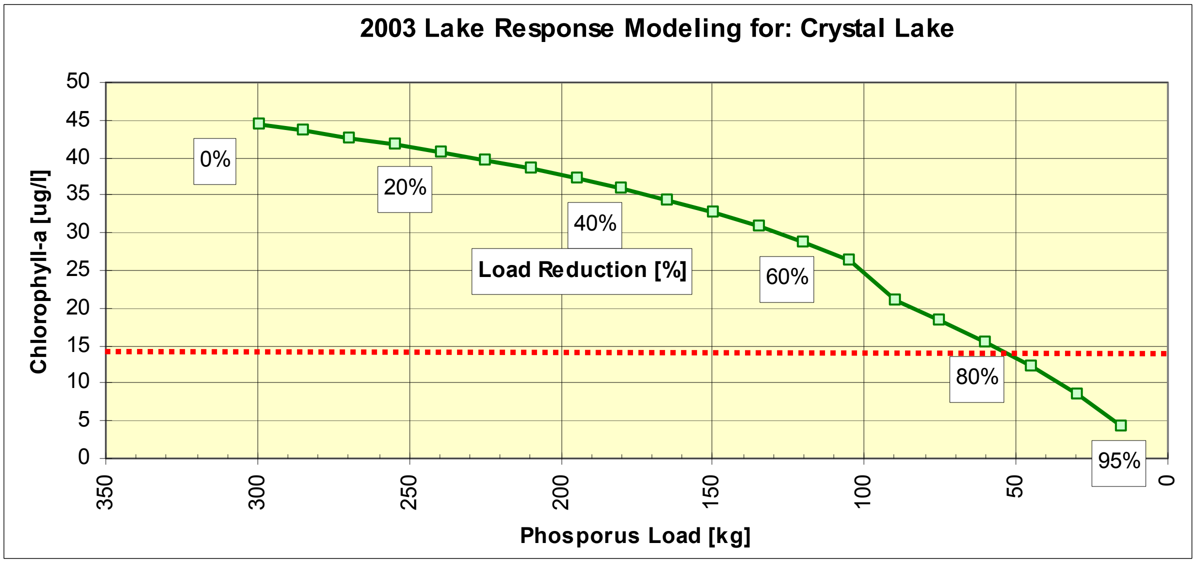


**Figure 7.3. In-lake chlorophyll-a concentrations predicted for total phosphorus load reductions applied to all sources.**

### 7.2.5 Secchi Depth

The response in water clarity for 2003 is presented in Figure 7.4. A 72% reduction in total phosphorus load will result in a Crystal Lake Secchi depth of approximately 1.8 meters, which will meet the state standard.

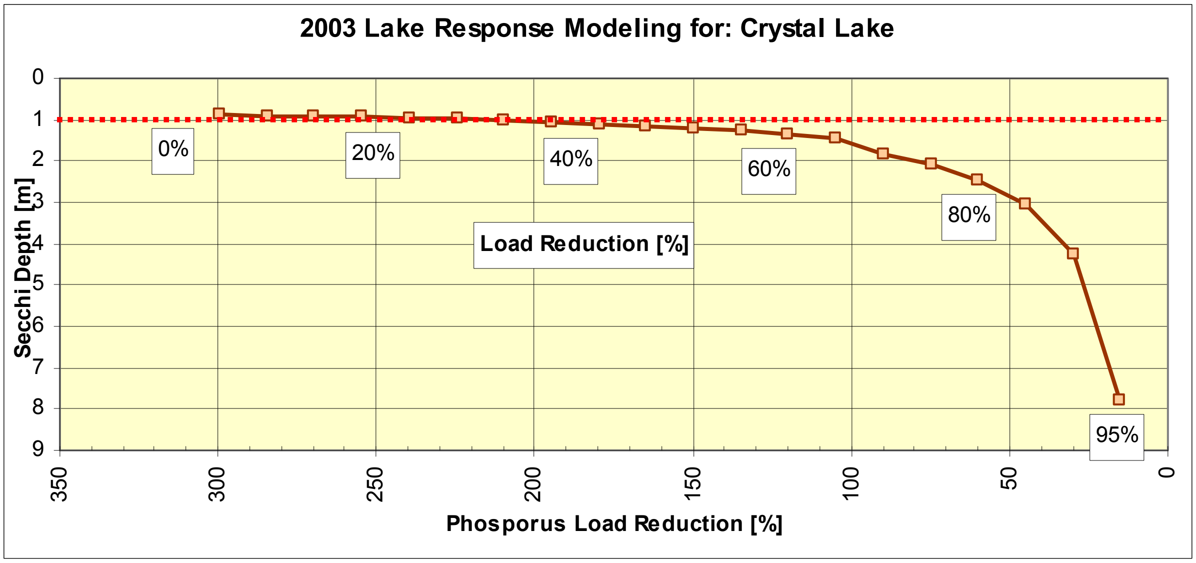


**Figure 7.4. Secchi depth predicted for total phosphorus load reductions applied to all sources.**

## 7.3 SEASONAL AND ANNUAL VARIATION

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

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

## 7.4 MARGIN OF SAFETY

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

Conservative modeling assumptions included applying sedimentation rates from the Canfield-Bachmann model that likely under-predicts the sedimentation rate for shallow lakes. Zooplankton grazing plays a large role in algal and subsequent phosphorus sedimentation in shallow lakes. However, the Canfield-Bachmann equation does not account for the expected higher sedimentation rates expected in healthy shallow lake systems. Although Crystal Lake is not defined as a shallow lake, it is 72% littoral, making it more likely to act similar to a shallow lake than a deep lake.

Secondly, the Canfield-Bachmann model was used to match data by only adjusting the loads and not applying calibration factors. It is likely that the sedimentation rates used in the model are conservatively low for Minnesota lakes providing an additional margin of safety.

## 7.5 RESERVE CAPACITY/FUTURE GROWTH

The watershed for this lake is fully covered by MS4s and the watershed load is included in the Wasteload Allocation. Land use in the Crystal Lake watershed did not change significantly between 1997 and 2000. The watershed is essentially built out, and a vast majority of the development projects that occur are redevelopment. There was an increase of about 80 acres in park space and almost 125 acres of vacant land was converted between 1997 and 2000. No new NPDES sources are anticipated in these watersheds, therefore no portion of the Wasteload Allocation is being held in reserve.

Future growth will not affect this TMDL. The Shingle Creek Watershed Management Commission has standards in place that require development and redevelopment to limit new stormwater runoff, and to provide treatment of that runoff.

# 8.0 Public Participation

## 8.1 INTRODUCTION

As a part of the strategy to achieve implementation of the necessary allocations, the SCWMC seeks stakeholder and public engagement and participation regarding their concerns, hopes, and questions regarding the development of the TMDL. Specifically, meetings were held for a Technical Advisory Committee representing key stakeholders. Additionally, the SCWMC reviewed the TMDL with City Councils and citizens advisory committees at meetings to which Crystal Lake Task Force members were invited.

## 8.2 TECHNICAL ADVISORY COMMITTEE

A technical advisory committee was established so that interested stakeholders could be involved in key decisions involved in developing the TMDL. The Technical Advisory Committee includes stakeholder representatives from local cities, Minnesota DNR, the Metropolitan Council, the United States Geological Survey (USGS) and the Minnesota Pollution Control Agency. All meetings were open to interested individuals and organizations. Technical Advisory Committee meetings to review this and other lake TMDLs in the watershed were held on December 8, 2005, February 10, 2006, March 9, 2006, and June 27, 2007.

## 8.3 STAKEHOLDER MEETINGS

A task force of citizens, city staff, and agency representatives provided guidance to the city of Robbinsdale in the development of the Crystal Lake Management Plan, and the findings and recommendations of that Plan have been incorporated into this TMDL where appropriate. A public meeting was held August 14, 2008 to review the findings of this TMDL and to take public input in the development of the implementation plan. Lakeshore residents, members of the task force, and the general public in both Robbinsdale and Minneapolis were invited to attend.

## 8.4 PUBLIC MEETINGS

The general TMDL approach and general results of TMDLs were presented to the Robbinsdale City Council on May 2, 2006, and to six other City Councils in May and July 2006. Additional public comment will be taken as part of the public comment period.

# 9.0 Implementation

## 9.1 IMPLEMENTATION FRAMEWORK

### 9.1.1 The Shingle Creek Watershed Management Commission

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

The Shingle Creek Water Quality Plan (WQP):

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

The Water Quality Plan is composed of four parts:

- A monitoring plan to track water quality changes over time;
- Detailed management plans for each resource to lay out a specific plan of action for meeting water quality goals;
- A capital improvement plan; and
- An education and public outreach plan.

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

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

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

### 9.1.2 Member Cities

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

## 9.2 REDUCTION STRATEGIES

### 9.2.1 Annual Load Reductions

The focus in implementation will be on reducing the annual phosphorus loads to the lake through structural and nonstructural Best Management Practices. The Total Maximum Daily Load established for Crystal Lake is shown in Table 9.1 for various annual precipitation conditions.

**Table 9.1. Total phosphorus TMDL allocation for Crystal expressed as annual loads (average of model years 2001 and 2003).**

| Wasteload TP Allocation (kg/yr)[1] | Load TP Allocation (kg/yr) | Margin of Safety | Total Phosphorus TMDL (kg/yr) |
|---|---|---|---|
| 79 | 23 | Implicit | 102 |

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

Load allocation by source is provided in Table 9.2 as based on the average model-predicted results for the years in which calibration data is available (2001, 2003). No reduction in atmospheric loading is targeted because this source is impossible to control on a local basis.

**Table 9.2. TMDL total phosphorus loads partitioned among the major sources.**

|  | Source | Total Maximum Daily TP Load (kg/yr) |
|---|---|---|
| Wasteload | Stormwater Load | 79 |
| Load | Atmospheric Load | 10 |
|  | Internal Load | 13 |
|  | **TOTAL LOAD** | **102** |

### 9.2.2 Actions

Restoration options for lakes are numerous with varying rates of success. Consequently, each technology must be evaluated in light of our current understanding of physical and biological processes in that lake. The watershed draining to Crystal Lake is fully developed, and options for reducing external nutrient loads are limited and will likely be costly to implement. Following is a description of potential actions for controlling nutrients in the Crystal Lake watershed that will be further developed in the Crystal Lake Implementation Plan. The estimated total cost of implementing these and other potential BMPs ranges from $500,000 to $5,000,000.

#### 9.2.2.1 External Loads

The Crystal Lake watershed is fully developed with minimal existing water quality treatment, and limited opportunities are available to reduce external loading. Small, incremental reductions are possible through retrofit as redevelopment occurs and through the implementation of Best Management Practices (BMPs) throughout the subwatershed.

*Maximize load reduction through redevelopment.* As redevelopment occurs, areas with little or no treatment will be required to meet current water quality standards. It may be possible to “upsize” water quality treatment BMPs to increase treatment efficiency beyond the minimum required by city and commission requirements to maximize the amount of load reduction achieved. Incorporating BMPs to bring a redevelopment site to Watershed Commission treatment standards would be at the developer’s cost. The public cost of upsizing to provide additional treatment- for example oversizing a treatment pond- would be dependent on the specific BMPs, negotiations with developers, etc., but could range from $10,000 to $500,000.

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

*Target street sweeping.* Identify key areas and target those areas for more frequent street sweeping. Consider replacing mechanical street sweepers with more efficient regenerative air sweepers. Dustless sweepers cost $150,000-200,000, about twice the cost of traditional broom sweepers. As the drainage area to Crystal Lake encompasses both Robbinsdale and Minneapolis, each city should consider how to accomplish this within the context of their street sweeping program.

*Retrofit BMPs.* As opportunities arise, retrofit water quality treatment through a variety of Best Management Practices including detention ponds, native plantings, sump manholes, swirl separators, and trash collectors. These small practices are effective in removing debris, leaf litter, and other potential pollutants. Depending on the type of BMP, location, easement requirements, and other factors, costs can range from $5,000 for a sump manhole to $250,000 or more for a detention pond. The number of BMPs necessary to achieve the required phosphorus load reduction is unknown and is dependant on the types of opportunities that arise. In 2008 the City of Robbinsdale is installing water quality manholes and a neighborhood rain garden as part of street improvements in the Victory View neighborhood northeast of Crystal Lake.

*Encourage shoreline restoration.* Most property owners, including the city, maintain a turfed edge to the shoreline. Property owners should be encouraged to restore their shoreline with native plants to reduce erosion and capture direct runoff. The city should consider demonstration projects in city parks and open spaces. Based on the amount of developed shoreline on Crystal Lake, shoreline restoration could cost from $100,000 to $250,000.

*Conduct education and outreach awareness programs.* Educate property owners in the subwatershed about proper fertilizer use, low-impact lawn care practices, and other topics to increase awareness of sources of pollutant loadings to Crystal Lake and encourage the adoption of good individual property management practices.

#### 9.2.2.2 Internal Loads

Several options could be considered to manage internal sources of nutrients.

*Hypolimnetic withdrawal.* This option would require pumping nutrient-rich water from the hypolimnion to an external location where it could be chemically treated, and discharged through a constructed wetland treatment system outletting to the lake. The estimated cost of such a system is $1 million, plus an estimated $50,000 annual operating cost for electricity and treatment chemicals.

*Hypolimnetic aeration.* This option uses a specialized pump to circulate water from the hypolimnion to keep it aerated and reduce the potential for anoxic conditions that lead to sediment phosphorus release. The estimated cost of this option is $500,000, plus an estimated $25,000 annual operating cost for electricity.

*Chemical treatment.* Following implementation of BMPs to reduce external nutrient load sources, it may be feasible to chemically treat the lake with alum to remove phosphorus from the water column as well as bind it in sediments. Such a treatment is estimated to cost about $150,000.

*Vegetation management.* Curly-leaf pondweed is a nuisance in Crystal Lake. Chemical treatments applied for at least three to five years in a row may be necessary to limit growth of this phosphorus source. The estimated cost of such treatment is $10,000 annually.

*Aeration system management.* The existing aeration system should be managed to avoid circulating nutrient-rich water.

#### 9.2.2.3 Other Strategies

*Conduct an aquatic plant survey and prepare a vegetation management plan.* Aquatic plants should periodically be surveyed on Crystal Lake to track changes in the plant community and monitor growth and extent of nuisance species such as Eurasian watermilfoil and curly-leaf pondweed. The cost of a survey and management plan is about $10,000.

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

## 9.3 IMPLEMENTATION STRATEGY

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

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

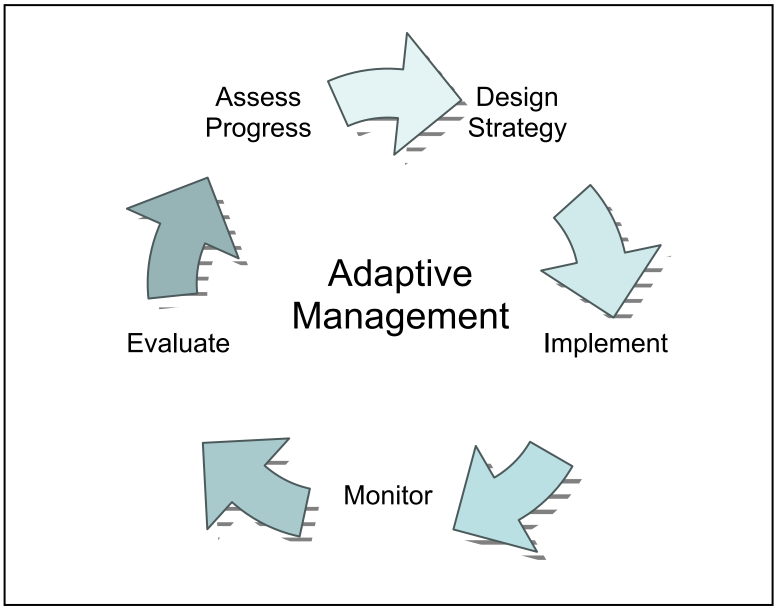


**Figure 9.1. Adaptive management.**

# 10.0 Reasonable Assurance

## 10.1 INTRODUCTION

When establishing a TMDL, reasonable assurances must be provided demonstrating the ability to reach and maintain water quality endpoints. Several factors control reasonable assurance, including a thorough knowledge of the ability to implement BMPs as well as the overall effectiveness of the BMPs. This TMDL establishes aggressive goals for the reduction of phosphorus loads to Crystal Lake. In fact, there are few examples where these levels of reductions have been achieved where the sources were primarily stormwater in nature, especially in suburban watersheds.

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

## 10.2 THE SHINGLE CREEK WATERSHED MANAGEMENT COMMISSION

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

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

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

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

## 10.3 NPDES MS4 STORMWATER PERMITS

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

Within the Crystal Lake watershed, the City of Minneapolis has an individual NPDES permit for Stormwater – NPDES Permit # MN 0061018. Robbinsdale and Hennepin County are covered under the Phase II General NPDES Stormwater Permit – MNR040000. The unique permit numbers assigned to the MS4s that drain to Crystal Lake are as follows:

- Minneapolis – MN0061018
- Robbinsdale – MS400046
- Hennepin County – MS400138

Stormwater discharges are regulated under NPDES, and allocations of nutrient reductions are considered wasteloads that must be divided among permit holders. Because there is not enough information available to assign loads to individual permit holders, the Wasteload Allocations are combined in this TMDL as Categorical Wasteload Allocations (see Table 7.1). There are no known industrial dischargers in the watershed. The pollutant load from construction stormwater is considered to be less than 1 percent of the TMDL and difficult to quantify. Consequently, the WLA includes pollutant loading from construction stormwater sources.

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

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

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

In this TMDL the Load Allocation is also allocated in the same manner as the WLA. Each stakeholder has agreed to implement BMPs to the maximum extent practicable. This collective approach allows for greater reductions for some permit holders with greater opportunity and less for those with greater constraints. The collective approach is to be outlined in an implementation plan developed by the Shingle Creek Watershed Management Commission.

## 10.4 MONITORING

### 10.4.1 Monitoring Implementation of Policies and BMPs

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

### 10.4.2 Follow-up Monitoring

The SCWMC monitors water quality in local lakes through the funding of special studies and citizen volunteer efforts. Additional monitoring is proposed in the Commission's Water Quality Plan in an effort to ensure the quality of data. Schedules of monitoring activities are identified in the Shingle Creek Water Quality Plan (SCWMC 2007). Results of all monitoring will be included in their annual water quality monitoring report.

Crystal Lake will be periodically monitored by the CAMP program through the Shingle Creek Watershed Management Commission (SCWMC). The CAMP program is operated by MCES and is a volunteer monitoring program. Citizen volunteers collect data and samples biweekly.

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