Kohlman Lake Total Maximum Daily Load Report Final

Prepared for Ramsey Washington Metro Watershed District

January 2010

BARR

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Kohlman Lake
Total Maximum Daily Load Report
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EPA/MPCA Required Elements	**Summary**	**TMDL Page #**
Location	Upper Mississippi Drainage Basin, Maplewood, Minnesota, Ramsey County	10
303(d) Listing Information	**Waterbody: Kohlman Lake DNR ID 62-0006** Impaired Beneficial Use: Aquatic Recreation Impairment/TMDL Pollutant of Concern: Excessive Nutrients (Phosphorus) Priority Ranking: 2004 Target Start, 2008 Target Completion Original Listing Year: 2002	16
Applicable Water Quality Standards/Numeric Targets	**MPCA Shallow Lake Eutrophication Standards (North Central Hardwood Forest Ecoregion):** 60 µg/L Total Phosphorus 20 µg/L Chlorophyll *a* 1.0 m Secchi disc transparency Source: Minnesota Rule 7050.0222 Subp. 4. Class 2B Waters	16
Loading Capacity (expressed as daily load)	Total Phosphorus Loading Capacity for critical condition 6.31 lbs/day Critical condition summary: MPCA eutrophication standard is compared to the growing season (June through September) average. Daily loading capacity for critical condition is based on the total load during the growing season.	39
Wasteload Allocation (WLA)	See table below	40

Source	Permit #	Individual WLA (lbs/day)
Permitted Stormwater (MS4 Cities):	City of White Bear Lake (MS400060)	1.05
	City of Vadnais Heights (MS400057)	0.77
	City of Oakdale (MS400042)	0.33
	City of North St. Paul (MS400041)	2.51

EPA TMDL Summary Table		
EPA/MPCA Required Elements	**Summary**	**TMDL Page #**
	<table><tr><td></td><td>City of Maplewood (MS400032)</td><td>0.72</td></tr><tr><td></td><td>City of Little Canada (MS400029)</td><td>0.12</td></tr><tr><td></td><td>MnDOT (MS400170)</td><td>0.47</td></tr><tr><td></td><td>Ramsey County (MS400191)</td><td>0.04</td></tr><tr><td>Reserve Capacity</td><td></td><td>0</td></tr></table>	
Load Allocation (LA)	<table><tr><td>Non-point Sources</td><td>LA (lbs/day)</td></tr><tr><td>Internal Loading of Phosphorus from Lake Sediments and from curlyleaf pondweed senescence</td><td>0.23</td></tr><tr><td>Atmospheric Deposition of Phosphorus</td><td>0.06</td></tr></table>	41
Margin of Safety	The margin of safety for this TMDL is largely provided implicitly through use of calibrated input parameters and conservative modeling assumptions in the development of allocations.	42
Seasonal Variation	TP concentrations in the lake vary significantly during the growing season, generally peaking in August. The TMDL guideline for TP is defined as the growing season mean concentration (MPCA, 2004). Accordingly, existing and future water quality scenarios (under different management options) were evaluated in terms of the mean growing season TP.	46
Reasonable Assurance	The overall implementation plan (Section 7.0) is multifaceted, with various projects put into place over the course of many years, allowing for monitoring and reflection on project successes and the chance to change course if progress is exceeding expectations or is unsatisfactory.	46
Monitoring	The monitoring plan to track TMDL effectiveness is described in Section 6.0 of this TMDL report.	48

EPA TMDL Summary Table		
EPA/MPCA Required Elements	**Summary**	**TMDL Page #**
Implementation	1. The implementation strategy to achieve the load reductions described in this TMDL is summarized in Section 7.0 of this TMDL report. 2. A cost estimate of all of the activities involved in implementing this TMDL is described in Section 7.0 of this report.	50
Public Participation	On November 7, 2007 a TMDL stakeholders meeting was conducted between District staff and representatives from the various MS4 permittees that are responsible for loads within the Kohlman Lake watershed. Also, a 30-day public comment period was provided from August 31 to September 30, 2009, via a public notice published in the State Register.	56

Executive Summary

Kohlman Lake is currently listed on the Minnesota Pollution Control Agency's (MPCA) Draft 2008 303(d) Impaired Waters List due to excessive nutrients (phosphorus). Kohlman Lake is the most upstream of the four lakes that make up the Phalen Chain of Lakes in Maplewood, Little Canada and St. Paul, Minnesota. The lake has a surface area of 74 acres, a maximum depth of approximately 9 feet, and a mean depth of 4 feet. Most of the lake is less than 6 feet deep, with the littoral area covering the entire lake surface. Kohlman Lake is a fishing lake used primarily for motor boating, canoeing, fishing, picnicking, and aesthetic viewing. Kohlman Lake provides some limited wildlife habitat.

The Kohlman Lake watershed comprises a total of 7,484 acres and drains portions of the St. Paul suburbs of Gem Lake, White Bear Lake, Vadnais Heights, Maplewood, North St. Paul, Little Canada, and Oakdale. The population of the Kohlman Lake watershed is approximately 35,000 (from census tract data).

Kohlman Lake is located in the North Central Hardwood Forests ecoregion. The lake's historical growing season water quality (10-year average) compared to the MPCA's shallow lake eutrophication standards for this ecoregion are shown below.

The MPCA's projected schedule for Total Maximum Daily Load (TMDL) report completions, as indicated on Minnesota's 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL. The Kohlman Lake TMDL was scheduled to begin in 2004 and 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 waterbody; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

Table EX-1 Kohlman Lake 10-Year Average Water Quality Parameters

Water Quality Parameter	MPCA Shallow Lake Eutrophication Standards (North Central Hardwood Forest Ecoregion)	Kohlman Lake 10-year (1997-2006) Growing Season (June through September) Average
Total Phosphorus (µg/L)	60 µg/L	98 µg/L
Chlorophyll *a* (µg/L)	20 µg/L	34.5 µg/L
Secchi disc (m)	1.0 m	1.0 m

A significant source of background information for this TMDL report is the Ramsey Washington Metro Watershed District's *Phalen Chain of Lakes Strategic Lake Management Plan (SLMP): Improvement Options and Recommendations* (Barr Engineering Company, 2004) study, coupled with the follow-up studies recommended by the SLMP. The SLMP is included as an appendix to this report.

The TMDL equation is defined as follows:

TMDL = Wasteload Allocation (WLA) + Load Allocation (LA) + Margin of Safety (MOS) + Reserve Capacity.

For Kohlman Lake, the Load Capacity is 769 pounds (lbs) of total phosphorus (TP) per growing season.

The TMDL equation used to derive this Load Capacity for Kohlman Lake is:

Expressed as growing season (June through September) totals:

TMDL = 734 lbs. TP (WLA) + 35 lbs. TP (LA) + 0 lbs. TP (MOS) + 0 lbs. (Reserve Capacity) = 769 lbs per year

Expressed in daily terms (growing season load/122)

TMDL = 6.02 lbs/day (WLA) + 0.29 (LA) +0 (MOS) + 0 (Reserve Capacity) = 6.31 lbs per day, on average, over the growing season

The Wasteload Allocation represents a 22% reduction in the external load from the entire tributary area to Kohlman Lake. The external load TP reduction efforts will be focused within the lake's "Main" drainage district - a 25% TP reduction in the "Main" drainage district is necessary to meet the entire tributary load reduction. This external load reduction will be achieved through a series of BMP implementation projects and programs sponsored by the Ramsey-Washington Metro Watershed District.

The Load Allocation represents an 88% total phosphorus reduction. This will be achieved through a reduction in the lake's internal phosphorus load, by herbicide treatment of the curlyleaf pondweed and through chemical (alum) treatment to inactivate the sediment TP load.

The Margin of Safety is implicitly included in the equation as a result of calibrated modeling parameters, conservative modeling assumptions and the fact that the lake is being managed for the "worst-case scenario" water quality condition when wet, dry and average precipitation and internal load conditions are considered.

The Reserve Capacity is 0 lbs because ultimate land use conditions were used in modeling watershed loads and because the District's stormwater volume reduction standard for redeveloping areas assures that future loads will be equal to or less than loads under existing land use conditions.

1.0 Introduction

The Phalen Chain of Lakes (Figure 1) is located in the upper portion of the Mississippi River Basin and is comprised of: Kohlman Lake (DNR ID 62-0006), Gervais Lake (DNR ID 62-0007), Keller Lake (DNR ID 620010), and Lake Phalen (DNR ID 62-0013). These lakes are within the North Central Hardwood Forest Ecoregion. The Phalen Chain of Lakes and its tributary watershed cover areas in Maplewood, Little Canada, North St. Paul, St. Paul, Vadnais Heights, White Bear Lake, Gem Lake, Oakdale and are part of the Ramsey Washington Metro Watershed District (District).

The District is a special purpose unit of local government that manages water resources on a watershed basis and was established in 1975 under the Minnesota Watershed District Act. The Watershed Act provides Districts across Minnesota with planning, regulatory, and taxing authority to carry out water management activities within the watershed. The mission of the District is to protect and improve water resources and water related environments in the District. More information can be found about the District on their website (www.rwmwd.org).

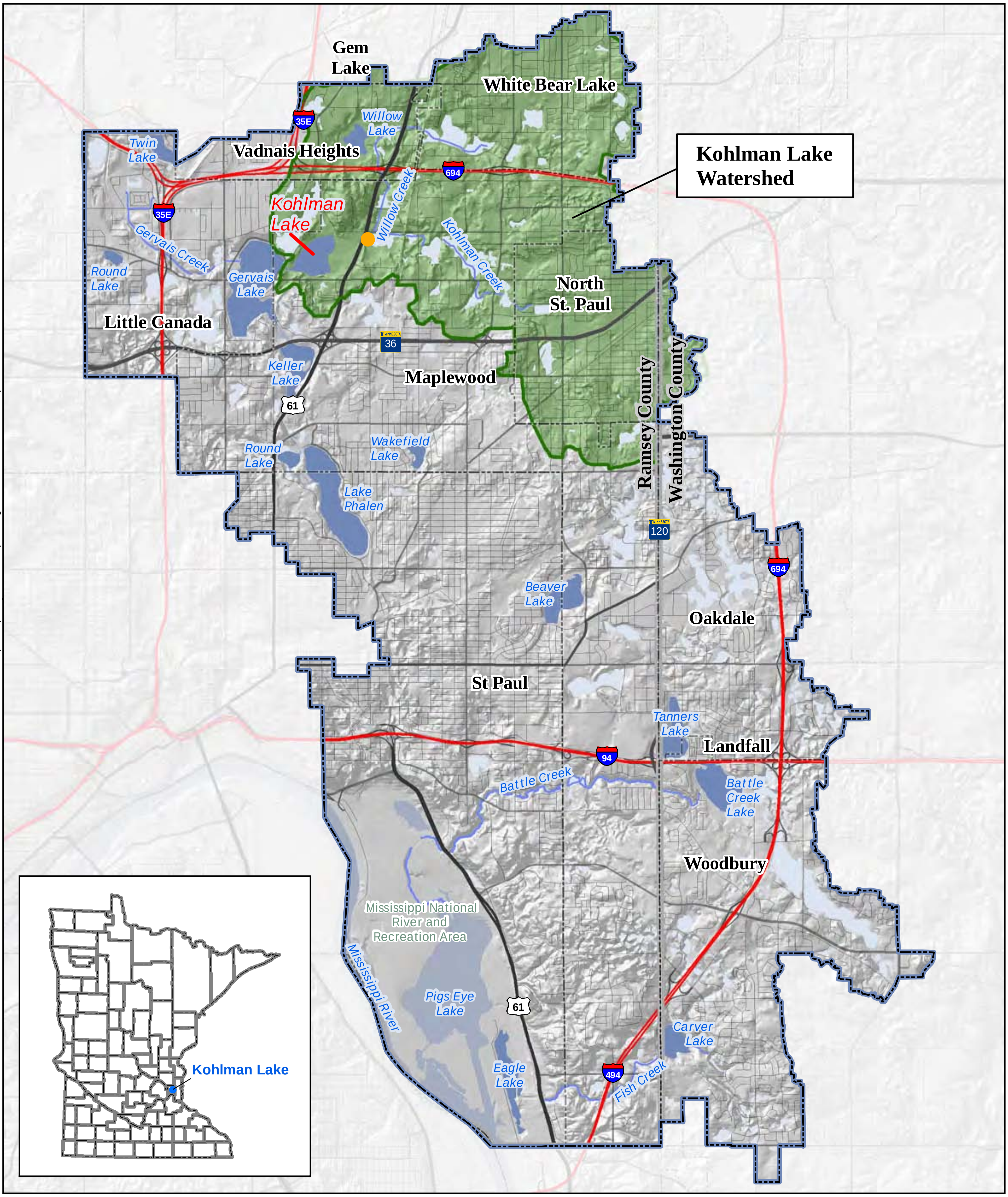
Kohlman Lake is currently listed on the Minnesota Pollution Control Agency's (MPCA) 2008 303(d) Impaired Waters List due to excessive nutrients (phosphorus) and requires a Total Maximum Daily Load (TMDL) report. The lake was first listed on the MPCA's 303(d) list in 2002. The TMDL report has a target start date of 2004 and a target completion date of 2008.

The MPCA's projected schedule for TMDL completions, as indicated on Minnesota's 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL. Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the waterbody; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

In 2004, the District completed a 3-year study that resulted in a Strategic Lake Management Plan (SLMP) for the Phalen Chain of Lakes and its watershed. The SLMP is entitled *Phalen Chain of Lakes Strategic Lake Management Plan: Improvement Options and Recommendations* (Barr Engineering Company, 2004). The purpose of the SLMP was to establish priorities and provide guidelines for the cities within the lakes' tributary watersheds, Ramsey County, the Ramsey-Washington Metropolitan Watershed District, and citizens to meet the water quality goals set for the Phalen Chain of Lakes.

As a part of the study, the District completed an inventory of all ponds and wetlands throughout the watershed tributary to Kohlman Lake and the remaining lakes in the Phalen Chain. Using the inventory, the District conducted an extensive survey of each pond and wetland, measuring available storage volumes, overflow elevations, and inlet and outlet pipelines and channels. The survey included measurements that allowed for the calculation of live storage volume, dead storage volume, overflow capacities, and potential inflows and outflows. In addition, the study evaluated the existing and future land uses throughout the tributary watershed. Also, the District conducted extensive monitoring of several lake inflow points and of the lakes themselves. All of this information was used to create and calibrate water quality models for the lakes and their watersheds. The District ran the calibrated water quality models using actual rainfall years that reflect wet, dry, and average precipitation conditions. The results of the modeling were used to identify watershed best management practices (BMPs) and in-lake management practices that would help achieve the goals for each lake. The District also estimated costs for various management practices and made recommendations for the most cost-effective improvements and practices. In addition, the SLMP contained recommendations for a number of feasibility studies aimed at determining which BMPs the District should ultimately pursue in order for the lakes to meet their water quality goals.

The SLMP is included in its entirety as Appendix A to this TMDL report. The SLMP and the conclusions of its subsequent feasibility studies provided the information needed to make the management decisions that are ultimately set forth in this TMDL report for Kohlman Lake.



District Legal Boundary

Kohlman Lake Watershed

Outlet of Kohlman Basin: Flow and Water Quality Monitoring Station

0 0.5 1 2
Miles

Figure 1
SITE LOCATION MAP
Kohlman Lake
Total Maximum Daily
Load Report

2.0 Description of the Water Body, Pollutant of Concern and Pollutant Sources

2.1 Overview of Kohlman Lake and Its Watershed

Kohlman Lake is a Minnesota Department of Natural Resources (DNR)-protected water (#62-0006) located in the city of Maplewood (Figure 2). The lake has a surface area of 74 acres, a maximum depth of approximately 9 feet, and a mean depth of 4 feet. Most of the lake is less than 6 feet deep, with the littoral area covering the entire lake surface (DNR Lake Data). By MPCA definition, Kohlman Lake is considered to be a shallow lake (a maximum depth of less than 15 feet and/or at least 80 percent of the lake less than 15 feet deep). The lake's tributary watershed area in comparison to the lake's surface area is relatively large (101:1). Kohlman Lake is a fishing lake used primarily for motor boating, canoeing, fishing, picnicking, and aesthetic viewing. Kohlman Lake provides some limited wildlife habitat.

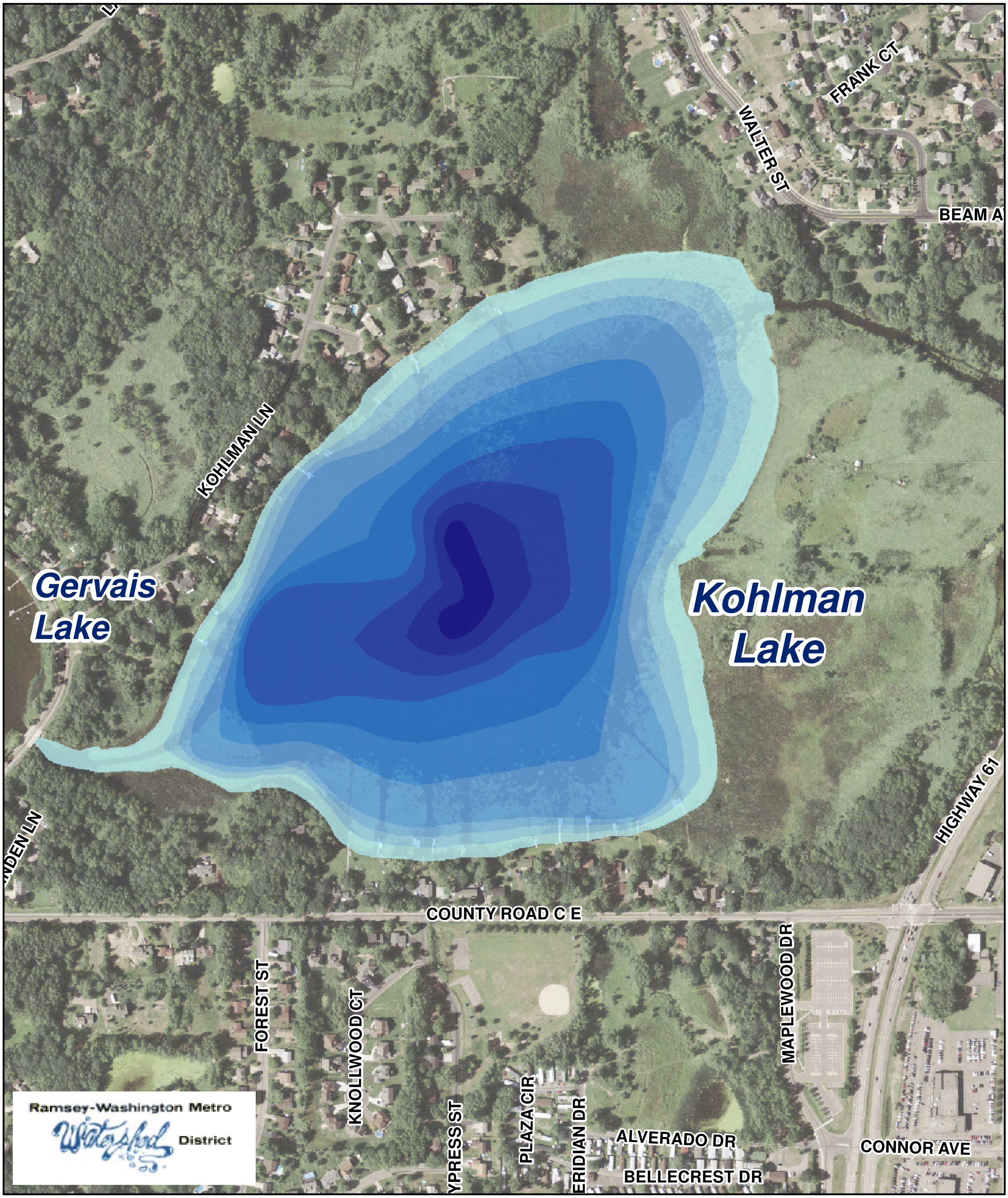
Kohlman Lake is polymictic; it mixes multiple times throughout the year. The lake stratifies only for short periods throughout the growing season, followed by destratification that mixes the water column. At times, this mixing can entrain phosphorus that is released from the lake sediment into the water column, making more phosphorus available to algae. Another internal source of phosphorus to Kohlman Lake is curlyleaf pondweed. This macrophyte proliferates in the early-summer and dies off in mid-summer, releasing substantial amounts of phosphorus into the water column.

The Kohlman Lake watershed comprises a total of 7,484 acres (excluding the lake surface area) and drains portions of the cities of Gem Lake, White Bear Lake, Vadnais Heights, Maplewood, North St. Paul, Little Canada, and Oakdale.

The Kohlman Lake watershed can be described in terms of four different "drainage districts." A drainage district is described here as a network of drainage areas whose runoff drains to a common point before entering the lake. Each Kohlman Lake drainage district is shown in Figure 3 and is described below:

- **Kohlman Lake Main Drainage District—**This 6,831-acre drainage district, located east of the lake, represents the majority of the Kohlman Lake watershed. Runoff from this drainage district flows through a series of ponds, wetlands and/or storm sewers; and, ultimately, Kohlman Basin (the wetland system directly upstream of the lake, located directly south of Beam Avenue and east of Highway 61) before reaching Kohlman Lake.

- **Kohlman Lake North Drainage District—**This 107-acre drainage district, north of the lake, represents a very small portion of the Kohlman Lake watershed. Runoff from this drainage district flows to a flow splitter, where low flows are routed to a wetland system that discharges to Kohlman Lake. High flows by-pass the splitter and discharge directly into Gervais Lake.
- **Kohlman Lake South Drainage District—**This 83-acre drainage district, south of the lake, also represents a very small portion of the Kohlman Lake watershed. Runoff from this drainage district is routed to two ponds, neither of which has constructed outlets—therefore, water from these ponds only flows to Kohlman Lake during high water conditions, when the ponds overtop. Under typical conditions, these ponds are landlocked.
- **Kohlman Lake Direct Drainage District—**This 463-acre drainage district consists of the area that drains directly to Kohlman Lake without passing through retention ponds or any significant pretreatment. The runoff from this area generally sheet flows directly into the lake with little or no treatment.



2006 Aerial Photography

Bathymetry Depth (feet)

9 - 9.5	7 - 8	3 - 4
8 - 9	6 - 7	2 - 3
	5 - 6	1 - 2
	4 - 5	0 - 1

0 250 500 1,000
Feet

Figure 2
KOHLMAN LAKE BATHYMETRY
Kohlman Lake Total Maximum Daily Load Report

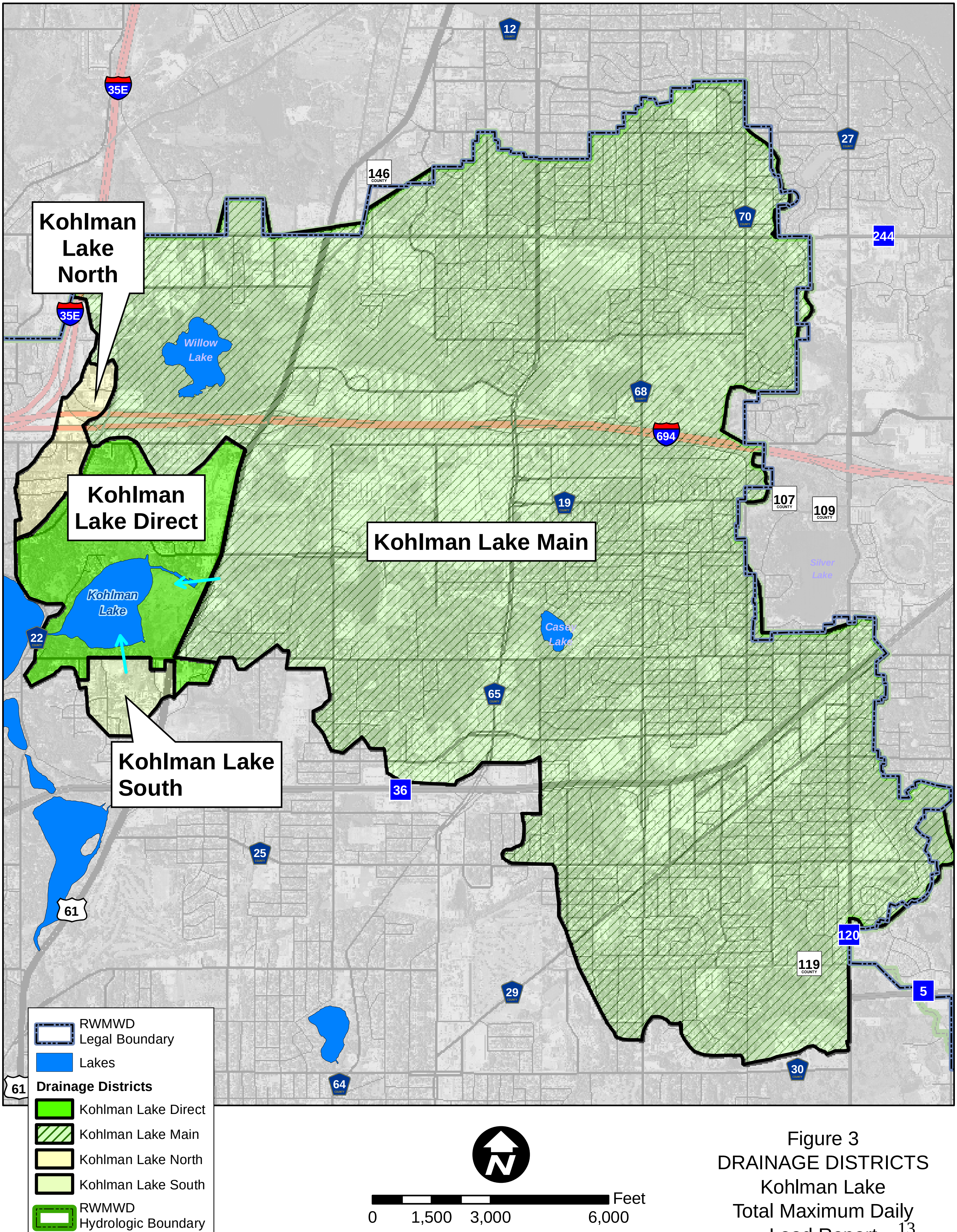


Figure 3
DRAINAGE DISTRICTS
Kohlman Lake
Total Maximum Daily
Load Report

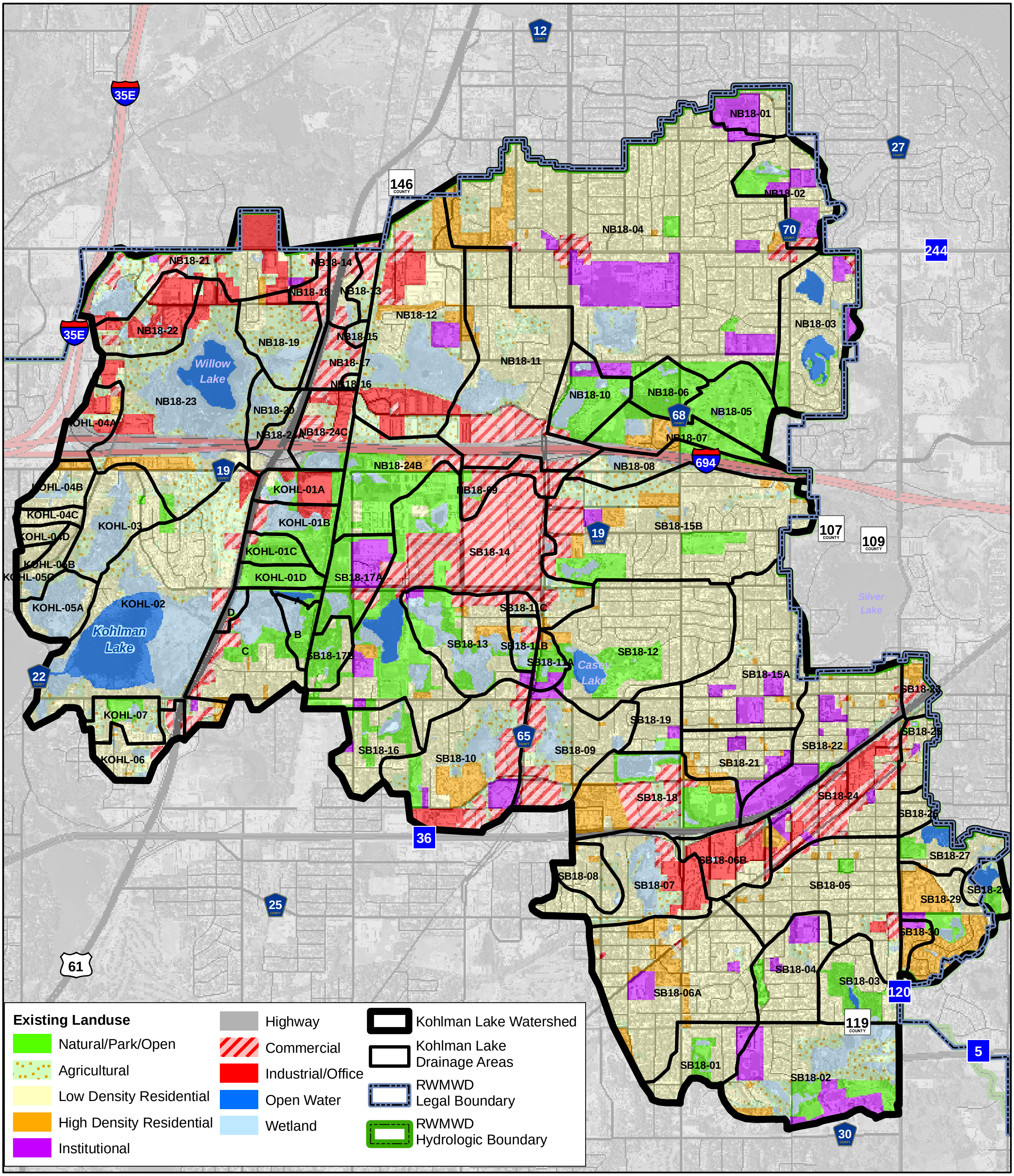
2.2 Kohlman Lake Pollutant of Concern and Pollutant Sources

The pollutant of concern in Kohlman Lake is phosphorus, measured as Total Phosphorus (TP). The Phalen Chain of Lakes' largest source of phosphorus is stormwater runoff from its tributary watershed. Figure 4 shows the land use used to model TP loads from the tributary watersheds for Kohlman Lake. P8 modeling is described in detail in Section 4.

The land uses in the Kohlman Lake tributary watershed can be summarized as follows:

- Low Density Residential (1-4 units per acre) 40.8%
- Natural/Park/Open/Agricultural 20.8%
- Commercial 8.9%
- Wetland 8.9%
- Institutional 5.2%
- High Density Residential (> 8 units per acre) 5.1%
- Industrial/Office 4.3%
- Highway 3.5%
- Open Water (including Kohlman Lake itself) 2.5%

In Kohlman Lake, other phosphorus sources are significant in affecting water quality- internal loads of phosphorus from the lake sediment and senescing macrophytes (curlyleaf pondweed). Carp excretion is also expected to contribute significantly to the lake's internal phosphorus load, although only rough, highly variable estimates of the TP load due to carp in Kohlman Lake have been made to date.



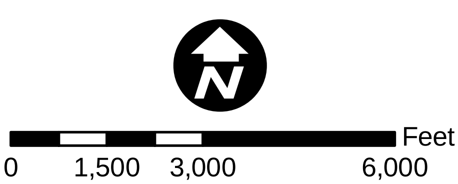


Figure 4
KOHLMAN LAKE WATERSHED
EXISTING LANDUSE
Kohlman Lake
Total Maximum Daily
Load Report

3.0 Description of Applicable Water Quality Standards and Numerical Water Quality Target

Impaired waters are listed and reported to the citizens of Minnesota and to the EPA in the 305(b) report and the 303(d) list, named after relevant sections of the Clean Water Act. Assessment of waters for the 305(b) report identifies candidates for listing on the 303(d) list of impaired waters. The purpose of the 303(d) list is to identify impaired water bodies for which a plan will be developed to remedy the pollution problem(s) (the TMDL—this document).

The basis for assessing Minnesota lakes for impairment due to eutrophication is the narrative water quality standard and assessment factors in Minnesota Rules 7050.0150. The MPCA has completed extensive planning and research efforts to develop quantitative lake eutrophication standards for lakes in different ecoregions of Minnesota that would result in achievement of the goals described by the narrative water quality standards. The MPCA's shallow lake eutrophication standards for the North Central Hardwood Forests ecoregion (Kohlman Lake's location) are shown in Table 1. To be listed as impaired by MPCA, the monitoring data must show that the standards for both total phosphorus (the causal factor) and either chlorophyll *a* or Secchi disc depth (the response factors) are not met (MPCA, 2004).

Table 1 MPCA Shallow Lake Eutrophication Standards for Total Phosphorus, Chlorophyll *a* and Secchi Disc (North Central Hardwood Forest Ecoregion)

303(d) Classification	**MPCA Shallow Lake Eutrophication Standard (North Central Hardwood Forests Ecoregion)**
Total Phosphorus (µg/L)	60
Chlorophyll-a (µg/L)	20
Secchi disc (m)	1.0

Source: Minnesota Rule 7050.0222 Subp. 4. Class 2B Waters

3.1 Historical Water Quality in Kohlman Lake

Kohlman Lake's historical (1981 to 2006) concentrations of TP, chlorophyll *a* (chl *a*) and Secchi disc (SD) are discussed below. This range of data was chosen for the SLMP to reflect more recent development conditions in the Phalen Chain of Lakes tributary watershed. 2002 was the last year evaluated in the SLMP. For the purposes of this TMDL report, *growing season mean* (June through September) concentrations of TP, chlorophyll *a* and Secchi disc were used to evaluate water quality in Kohlman Lake. This time period was chosen because it spans the months in which the lakes are most used by the public, and the months during which water quality is the most likely to suffer due to algal growths. For the SLMP, only *summer mean* (June through August) concentrations were evaluated.

Figures 5 through 7 show the growing season means (June through September) of Kohlman Lake's total phosphorus (TP), chlorophyll *a* (chl *a*), and Secchi disc (SD) measurements, respectively. Each column in each graph shows the number of readings (n) that resulted in the growing season average. For each sampling event, the measurements for TP, chl *a* and SD were taken at the same time from the same original water sample.

The mean surface water concentrations of TP in Kohlman Lake have ranged from 66 µg/L (in 2002) to 171 µg/L (in 1982) over the past 26 years, giving the lake a hypereutrophic classification. The *mean growing season* TP concentration over the last 10 years (1997 to 2006) is 98 µg/L.

The growing season average chl *a* concentrations have ranged from 12 µg/L (in 2002) to 74 µg/L (in 1996) over the past 26 years, giving the lake a hypereutrophic classification in some years and an eutrophic classification in others. The *mean growing season* chl *a* concentration over the last 10 years (1997-2006) is 34.5 µg/L.

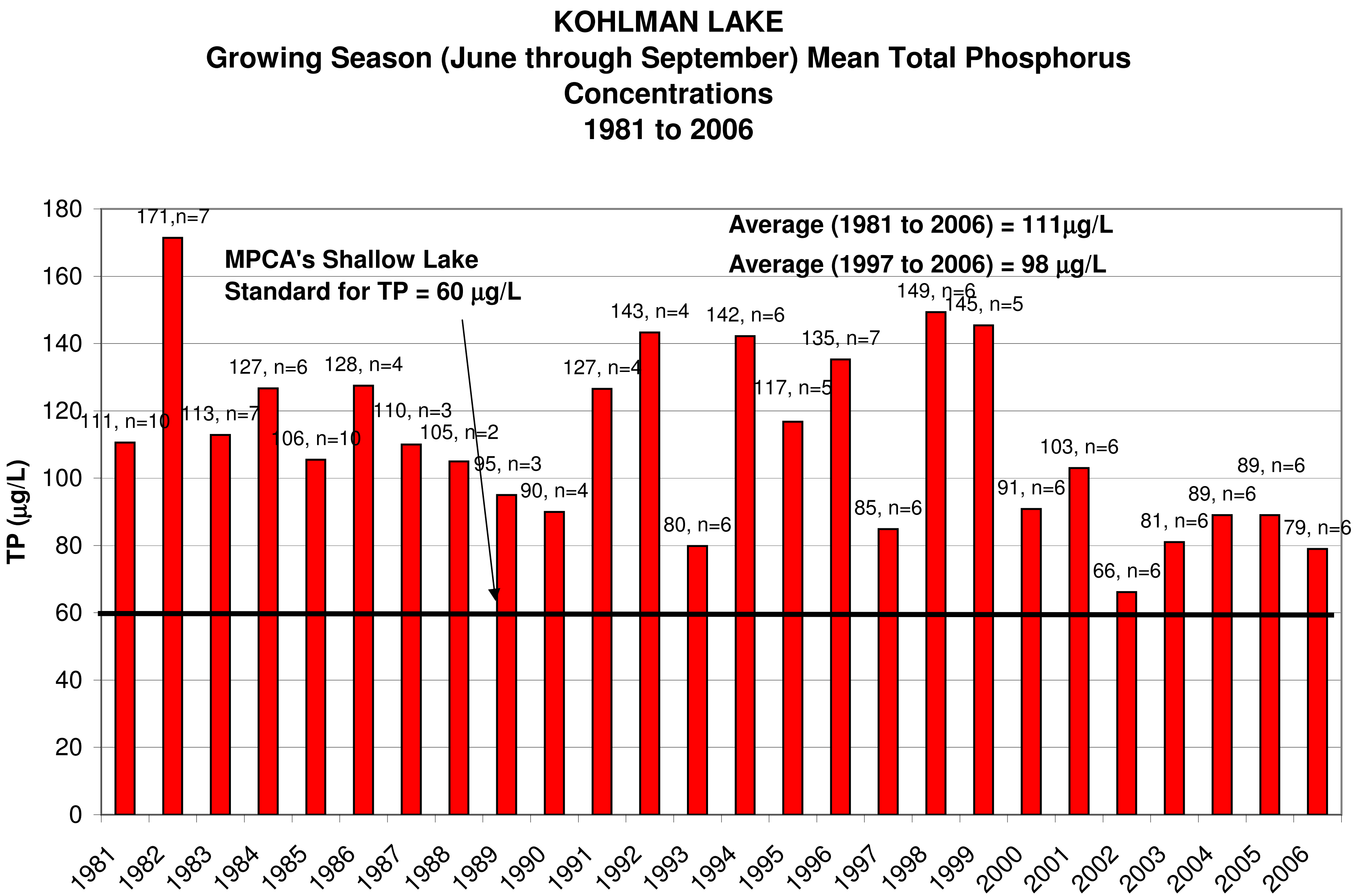
The growing season average SD measurements have ranged from 1.4 feet (in 1982) to 5.4 feet (in 2002) over the past 26 years, giving the lake a hypereutrophic classification in some years and a eutrophic classification in others. The *mean growing season* SD transparency over the last 10 years (1997-2006) is 3.2 feet (1.0 meter).

Figure 8 shows the relationship between SD and TP measurements taken throughout the year (1981-2006) in Kohlman Lake. At lower TP concentrations (less than 60 µg/L), changes in the lake's TP result in significant changes in the lake's transparency. At higher TP concentrations, changes in lake TP result in relatively smaller changes in the lake's transparency. This figure also shows the typical timing of higher and lower lake TP concentrations throughout the year in Kohlman Lake. Lower TP concentrations are typically seen in the late spring and early summer, while higher TP concentrations typically occur later in the summer months (typical of lakes with internal sources of phosphorus loading).

Figure 9 shows the relationship between chl *a* and TP concentrations throughout the year in Kohlman Lake. The relationship between growing season averages of chl *a* and TP are shown here in order to reduce some of the scatter in the data.

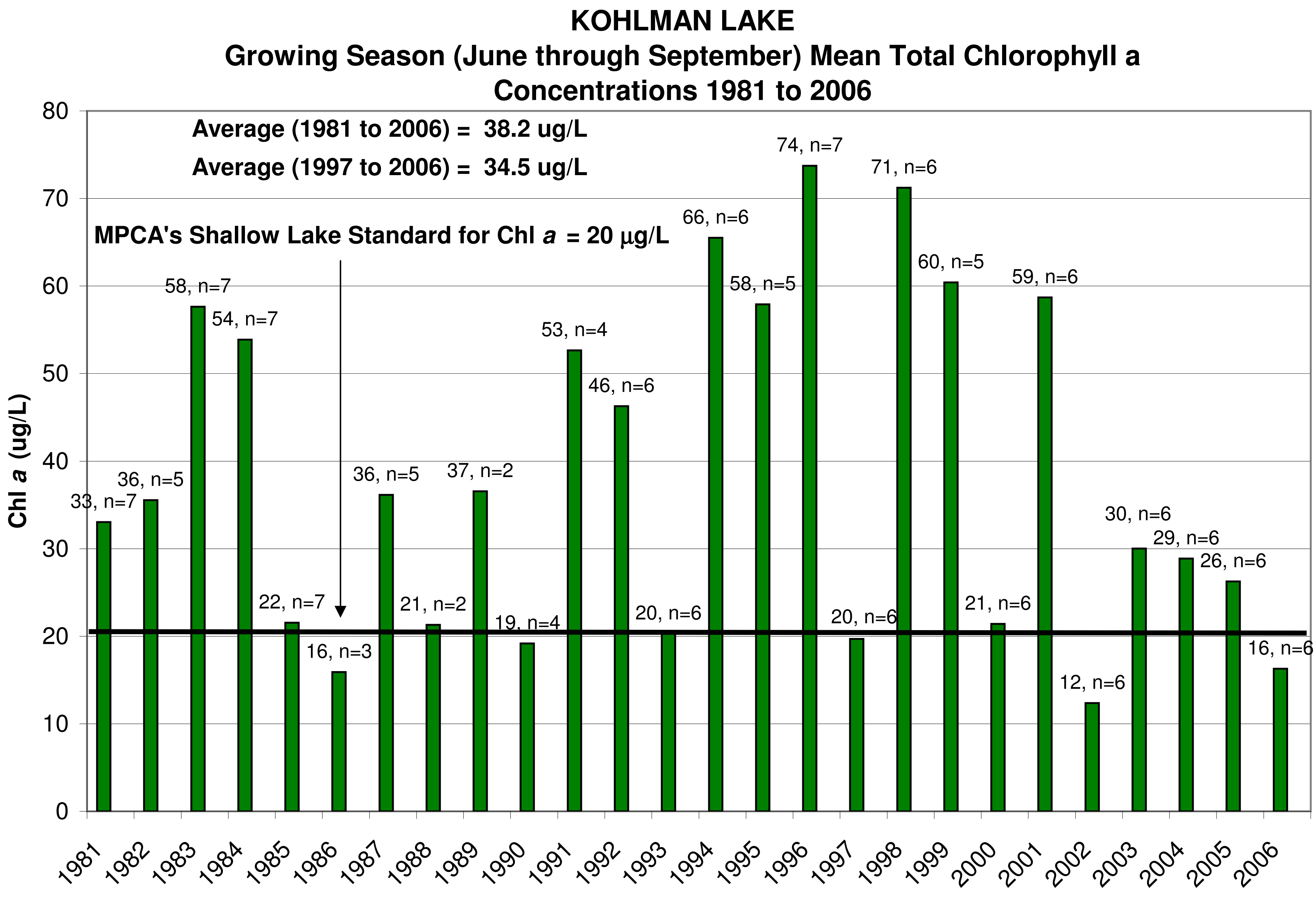
Isopleth diagrams represent the change in a parameter relative to depth and time. For a given time period, vertical isopleths indicate complete mixing and horizontal isopleths indicate stratification. Isopleth diagrams can be particularly useful in visually detecting the presence (or absence) of an internal load of phosphorus in a lake. In 2002, a more rigorous lake water quality survey provided enough samples to create isopleth diagrams of Kohlman Lake's TP concentrations, indicating the dynamic nature of TP in the lake throughout the growing season (Figure 10). The increase of phosphorus concentrations seen during the temporarily stratified conditions in late August and early September, 2002 indicate the presence of internal sediment loading in Kohlman Lake.

Figure 5



P:\Mpls\23 MN\62\2362797_MovedFromMpls_P\2362797\Conversion to TMDL report\Historical Water Quality\Kohlman_alldata TMDL thru 2006.xlsChrt_TP

Figure 6


KOHLMAN LAKE
Growing Season (June through September) Mean Total Chlorophyll a Concentrations 1981 to 2006
Average (1981 to 2006) = 38.2 ug/L
Average (1997 to 2006) = 34.5 ug/L
MPCA's Shallow Lake Standard for Chl *a* = 20 µg/L
Chl *a* (ug/L)
0
10
20
30
40
50
60
70
80
33, n=7
36, n=5
58, n=7
54, n=7
22, n=7
16, n=3
36, n=5
21, n=2
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30, n=6
29, n=6
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Figure 7

KOHLMAN LAKE
Growing Season (June through September) Mean Secchi Disc Transparencies
1981 to 2006

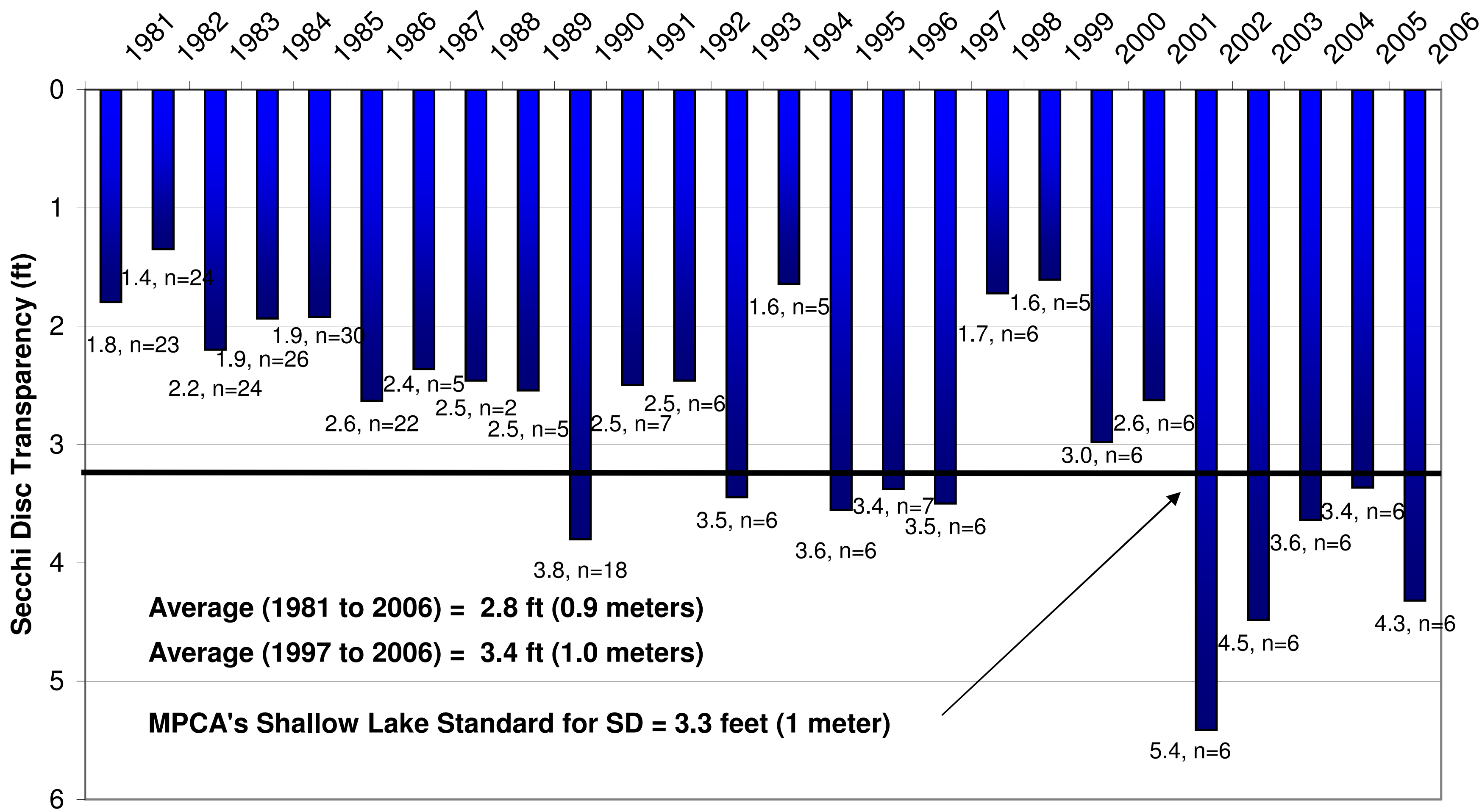
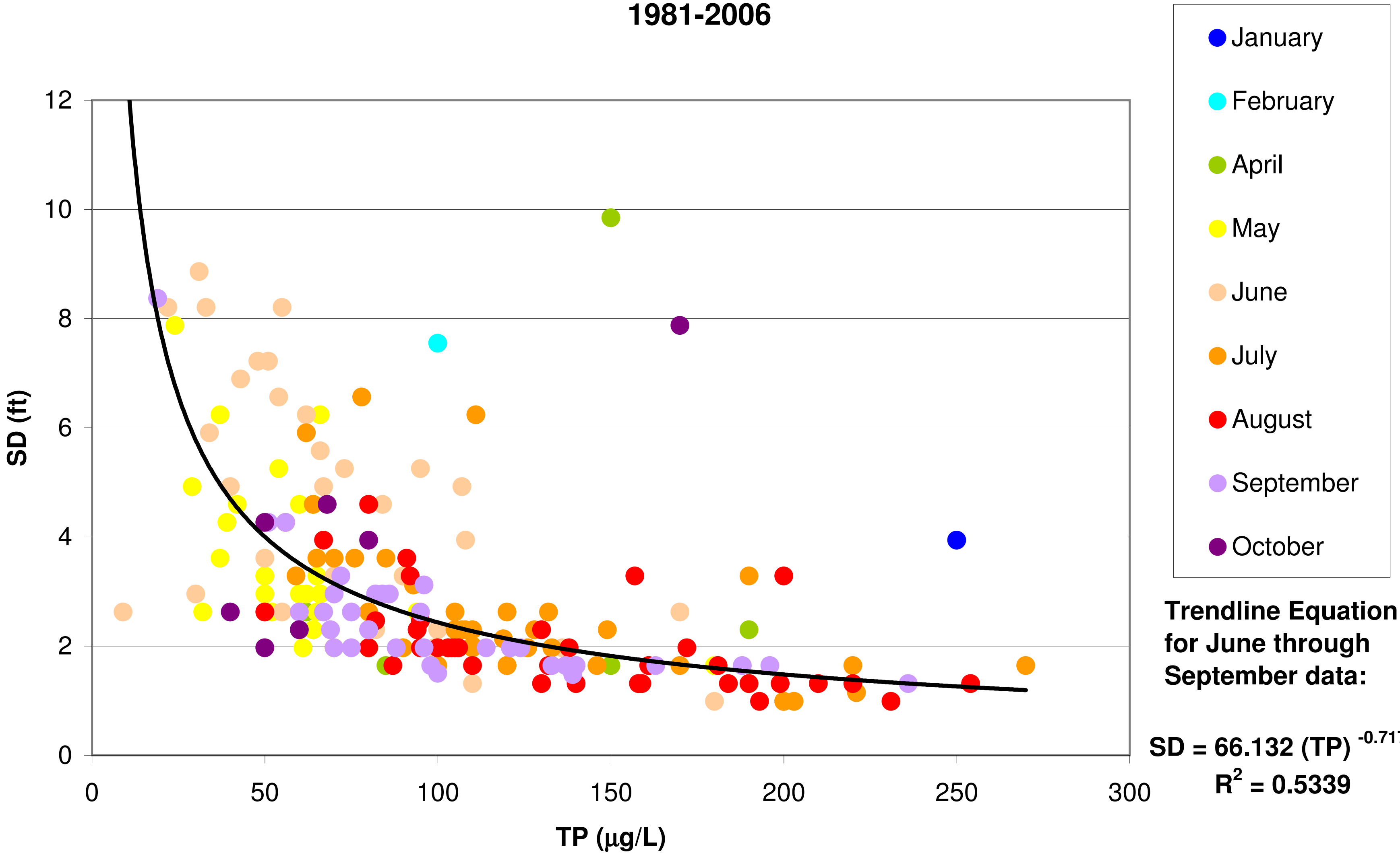


Figure 8

KOHLMAN LAKE
Secchi Disc Transparency-Total Phosphorus Relationship
1981-2006



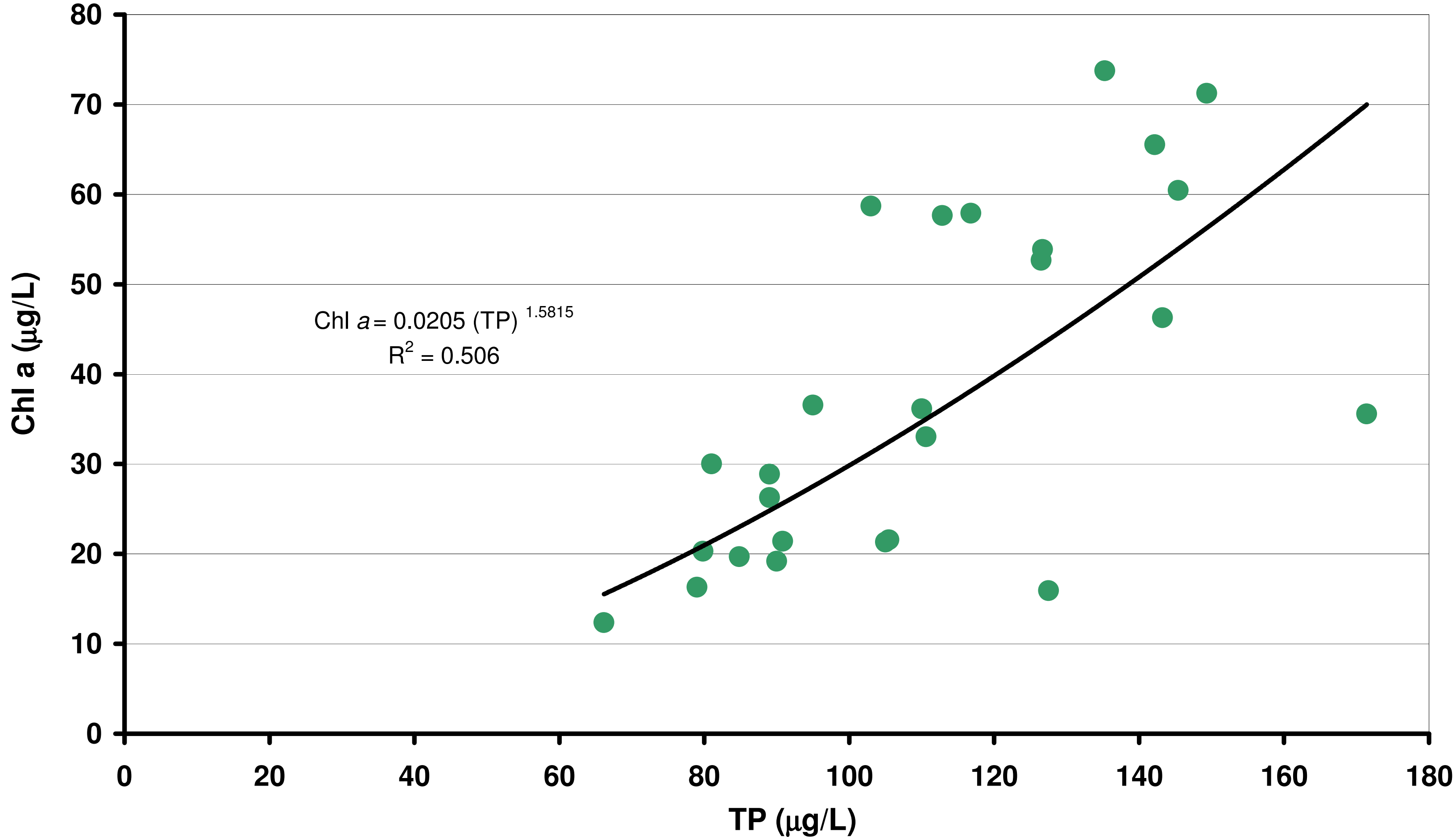
Trendline Equation for June through September data:

$SD = 66.132\ (TP)^{-0.7171}$

$R^2 = 0.5339$

Figure 9

KOHLMAN LAKE
Relationship Between
Growing Season Average Total Phosphorus and
Growing Season Average Chlorophyll *a* Concentrations
1981-2006 data



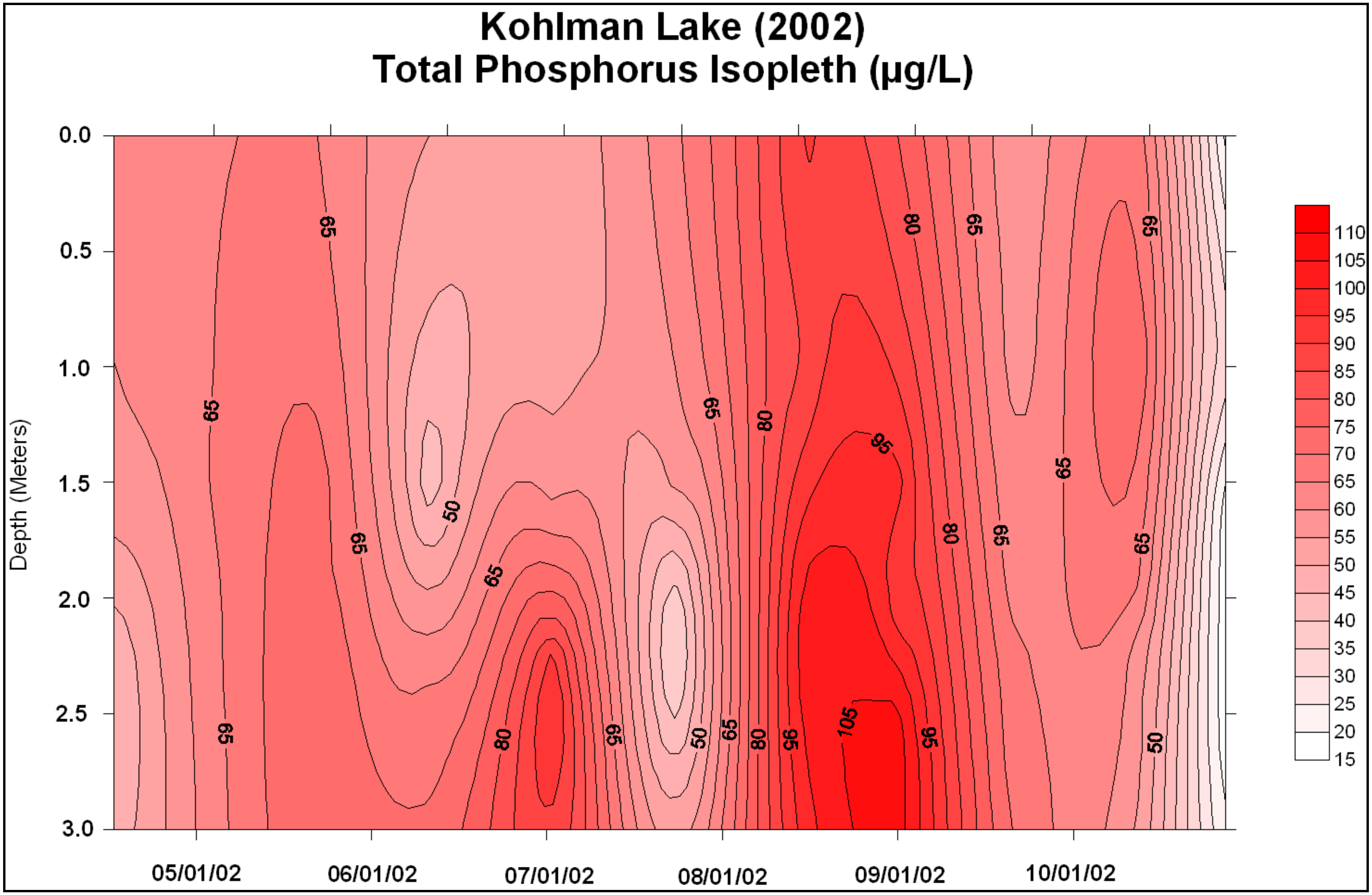


Figure 10 Kohlman Lake 2002 Isopleth Diagram for Total Phosphorus

Table 2 summarizes this historical water quality information compared to the recommended shallow lake listing criteria. Because the causal water quality factor (TP) and one of the response factors (chlorophyll *a*) exceed the Listing Criteria on average over the last 10 years, Kohlman Lake is listed as “Non-Supporting” on the 2004 305(b) list and as “Impaired” on the 303(d) list (Kohlman Lake was first listed in 2002.)

Table 2 Kohlman Lake Historical Nutrient Related Water Quality Parameters

Water Quality Parameter	MPCA’s Shallow Lake Eutrophication Standards (North Central Hardwood Forest Ecoregion)	Kohlman Lake Historical (1981-2006) Growing season Average	Kohlman Lake 10-Year (1997-2006) Growing season Average
Total Phosphorus (µg/L)	60	111	98
chlorophyll *a* (µg/L)	20	38.2	34.5
Secchi disc (m)	1.0	0.9	1.0

4.0 Source Assessment and Reduction Options

4.1 Water Quality Modeling of the Phalen Chain of Lakes Watersheds

Water quality modeling provided the means to estimate the TP sources to each lake in the Phalen Chain and their effect on lake water quality. Water quality modeling was two-fold, involving:

- A stormwater runoff model (P8 Urban Catchment Model; IEP, Inc., 1990) that estimated the water and TP loads from each lake's tributary watershed
- An in-lake mass balance model that took the water and TP loads from each lake's watershed and generated the resultant lake TP concentration

The P8 Urban Catchment Model and the in-lake mass balance model are described in more detail below.

4.1.1 P8 Urban Catchment Model

The P8 (Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds) Urban Catchment (computer) Model (Version 2.4) was used to estimate watershed flow and total phosphorus loads from each lake's tributary watershed. All existing BMPs in the watershed were incorporated into the model. The model was calibrated to monitoring data and the model results were used to estimate the water and phosphorus loads reaching each lake over a range of climatic conditions. The model and its supporting information can be downloaded from the internet at http://wwwalker.net/p8/.

P8 is a useful diagnostic tool for evaluating and designing watershed improvements and BMPs because it can estimate the treatment effect of several different kinds of potential BMPs. P8 tracks stormwater runoff as it carries phosphorus across watersheds and incorporates the treatment effect of detention ponds, infiltration basins, flow splitters, etc. on the TP loads that ultimately reach downstream water bodies. P8 accounts for phosphorus attached to a range of particulate sizes, each with their own settling velocity, tracking their removal accordingly.

P8 also uses long-term climatic data so that watershed runoff and BMPs can be evaluated for varying hydrologic conditions. In this study, P8 was used to generate a range of water and phosphorus loadings from each lake's watershed during three different water years (October 1 through September 30) with varying climatic conditions: a wet year (2001-02: 41.7 inches of precipitation); a dry year (1988-89: 26.6 inches of precipitation); and a year with near-average precipitation (2000-01: 34.4 inches of precipitation)[1].

It is not always clear whether a wet, dry or average year will result in the highest lake TP concentration. For example, wet years result in larger volumes of runoff to the lakes; if the runoff has high phosphorus concentrations, a wet year will result in a higher lake phosphorus concentration. If the runoff has low phosphorus concentrations, a wet year will likely result in a relatively lower lake phosphorus concentration. The impact of internal phosphorus loads are also affected by climatic conditions. Larger volumes of runoff entering the lake can "flush out" the lake, moving the elevated mass of phosphorus, due to internal loading, out of the system. The converse can be true of dry years; the impact of internal phosphorus loads may be magnified as phosphorus released from the sediment remains in the water column longer. Therefore, by evaluating a range of climatic conditions, a more realistic range of potential lake TP concentration estimates can be made.

P8-estimated runoff volumes and phosphorus loads were calibrated using observed flow and water quality data collected by RWMWD staff from April to September, 2002. Figure 11 shows the location of the monitoring station. FLUX was used to estimate the overall water and TP loads from the outlet of Kohlman Basin over the monitoring period. P8 water volumes and TP loads were calibrated to within 5 percent of the observed values calculated by FLUX from the monitoring data. A storm event-based look at the agreement between P8 results and monitoring data was also used in calibrating the P8 model. P8 tracked the flow of water and particles over the tributary watershed and through ponds and wetlands on a 10 minute time step. Detailed information on the input and calibration parameters used for the Kohlman Lake watershed P8 model can be found in the SLMP (Appendix A of this TMDL report).

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[1] There are two reasons why the average year precipitation used in this study may appear higher than expected. During the 2001-2002 water year, the rainfall measured at gauges close to the Phalen Chain of Lakes was 2% higher than the rainfall measured at the Minneapolis-St. Paul International Airport. Also, only precipitation depths from 1981 to 2002 were used in calculating the average precipitation for this study. Because the last several years have been relatively wet, the average precipitation depth defined for this study is higher than an average precipitation depth calculated from a longer period of record.

Key input parameters used in the P8 model of Kohlman Lake's watershed were:

- Drainage area information: size, impervious area (both directly and indirectly connected), depression storage

- Bathymetry of ponds and wetlands within the watershed

- Hourly precipitation, obtained from the Minneapolis-St. Paul airport, adjusted by the rainfall depths observed at more local gauges

Key calibration parameters in modeling the Kohlman Lake watershed were:

- Particle composition: (TP Particle Fraction 1 = 52,000 mg/kg, TP Particle Fraction 2 through 4 = 12,000 mg/kg)

- Growing season antecedent moisture conditions AMC-II = 1.4, AMC-III 100

- Particle removal scale factor for detention ponds and wetlands based on the depth of the waterbody: 0.3 if the waterbody was less than two feet deep, 0.6 if the waterbody was between 2 and 3 feet deep and 1.0 if the waterbody was 3 or more feet deep

4.1.2 In-Lake Mass Balance Modeling of Kohlman Lake

In-lake modeling for Kohlman Lake was accomplished through the creation of a daily time-step mass balance model that tracked the flow of water and phosphorus through the lake over a range of climatic conditions. Essentially, a modified version of Vollenweider's (1969) mass balance equation was used:

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

Where:

$\bar{z}$	=	average lake depth in meters
ρ	=	flushing rate in yr^{-1}
σ	=	sedimentation rate in yr^{-1}
L	=	areal loading rate in $mg/(m^2*yr)$
$Lint$	=	internal loading rate in $mg/(m^2*yr)$

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

Key input parameters to the in-lake model included the external load of total phosphorus (from the watershed only) obtained from P8 model output for wet (2001-02), dry (1988-89), and average (2000-01) water years. Also, daily values for average lake depth, lake volume, and the flushing rate were calculated using a daily water balance in an Excel spreadsheet that incorporated P8 output for watershed inflows, observed daily precipitation data, observed lake level measurements, and daily evaporation rates that were estimated using the Meyer Model (Barr Engineering Company, undated) for the wet, dry, and average precipitation years.

Key calibration parameters for the in-lake model included selection of the apparent sedimentation rate and estimation of the net internal load that affects the lake's surface waters during the growing season. The internal load from Kohlman Lake's sediments is intermittent. Lake mixing and anoxic conditions in Kohlman Lake can create an environment in the lake that is conducive to internal loads at times. At other times, the lake does not experience a significant internal load. Isopleth diagrams and monitoring data provided useful information in determining when the lake experienced an internal load of phosphorus and when it did not.

The sedimentation rates for Kohlman Lake were calibrated using in-lake TP monitoring data from stratified (non-internally loaded) periods. At these times, the in-lake model only allows changes in the phosphorus concentration in the surface waters of the lake to be affected by sedimentation, flushing and incoming external loads of phosphorus from the watershed and atmosphere.

Internal load could be estimated for destratified (internally loaded) periods by calculating the difference between the predicted lake TP (using the sedimentation rate that assumes no internal load) and the observed lake TP. In this manner, a predictive model could be created and used to evaluate the effects of current and potential future CIPs. The selection of these parameters is discussed in greater detail, below.

2006 Aerial Photography

Flow Monitoring Locations

Flow Direction

Kohlman Lake Watershed

Kohlman Lake Drainage Areas

0 500 1,000 2,000

Feet

Figure 11
CONTINUOUS FLOW AND WATER QUALITY MONITORING STATION
Kohlman Lake Total Maximum Daily Load Report

Calibrating the Apparent Sedimentation Rate

The term $\bar{Z}^*\sigma$ is an apparent sedimentation rate in m/yr that can be assumed to fall within the range cited by O'Melia (1974). Sedimentation rates were calibrated for the wet (0.100 m/day), dry (0.050 m/day), and average (0.075 m/day) summers in the lake during periods when the lake was assumed to have only negligible internal TP loads. O'Melia cites a range from 0 to over 20 m/day; the rates that the fit to models in his 1974 paper, however, fall on the low end of this range, from 0.1 to 0.27 m/day.

A linear regression evaluating the relationship between the lake's summer overflow rate (q_s in m/day) during the wet, dry and average years and their corresponding calibrated sedimentation rates were performed. For Kohlman Lake, higher overflow rates resulted in higher calibrated sedimentation rates. The equation relating Kohlman Lake's summer overflow rate and calibrated sedimentation rates for each of the modeled years is:

$$\bar{Z}^*\sigma = 0.0648\mathrm{Ln}(q_s) + 0.2298$$

Calibrating the Internal Load of Phosphorus from the Lake's Sediments

For the SLMP, internal load was calculated by deduction, using the in-lake mass balance model at times when TP and dissolved oxygen (DO) isopleth diagrams (charts of TP or DO over depth and time in the lakes) indicated the presence of an internal load.

In 2005, sediment cores from Kohlman Lake were collected and analyzed for mobile phosphorus (mobile P content). Knowing the mobile P concentration and depth distribution, a regression equation relating mobile P and the maximum possible sediment TP release rate was used to estimate sediment release rate of TP during anoxic conditions at the sediment surface. This method is presented in a research article by Pilgrim et al. (2007). This maximum possible release rate was compared to the rate calculated by deduction to confirm that the deduced load was reasonable.

Also, a recent macrophyte survey indicates the potential for internal phosphorus loading from curlyleaf pondweed in Kohlman Lake. The implementation section of this TMDL report shows how this new information will be explored further, to shed more light upon the magnitude of internal phosphorus load in Kohlman Lake and to identify management options.

4.2 Modeling Results

P8 and in-lake modeling of the Phalen Chain tributary watershed generated useful data that:

- Characterized the existing watershed loadings
- Estimated the performance of existing BMPs and
- Indicated where future BMPs should be located

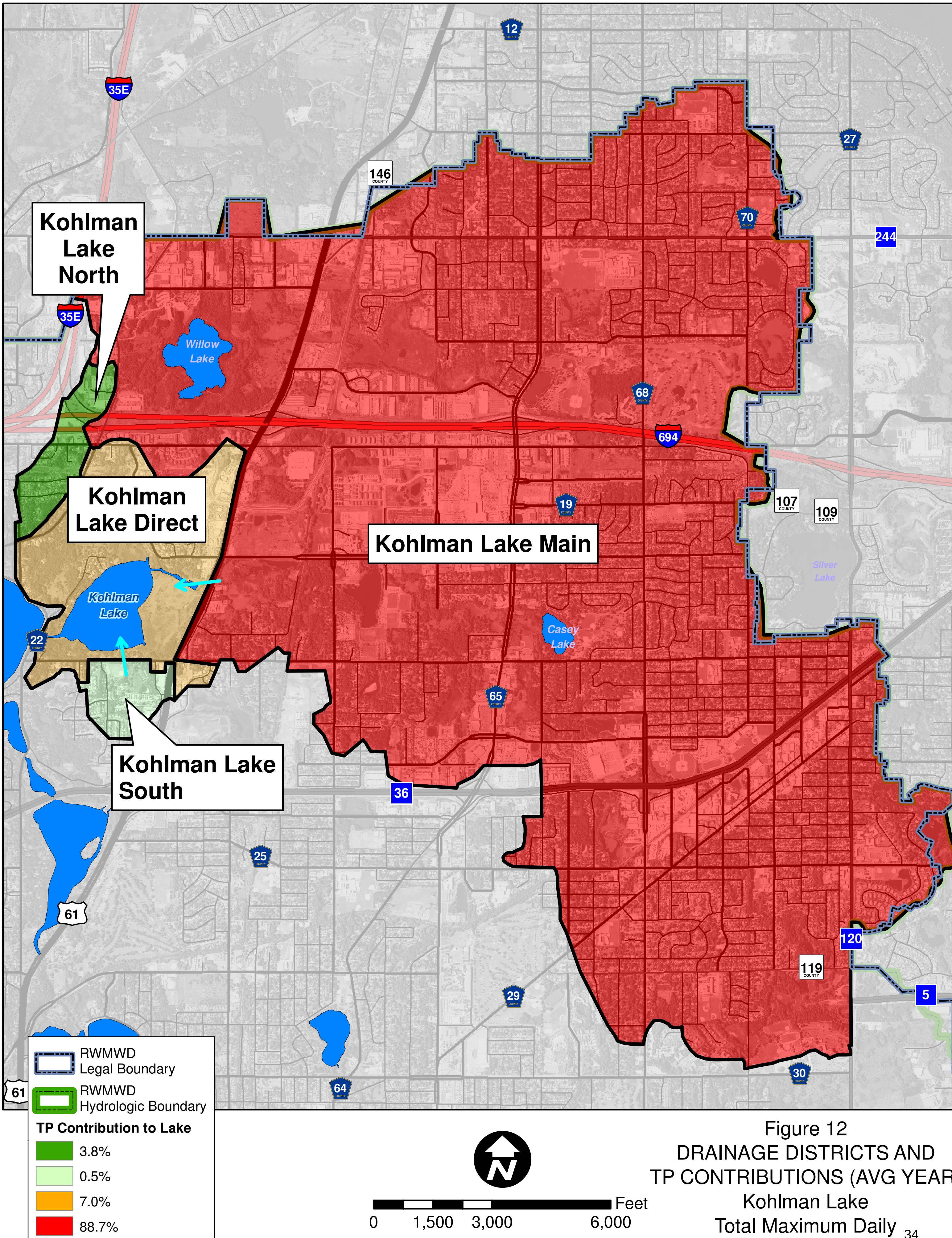
Many different types of figures were created for Kohlman Lake's watershed to highlight different information (see the SLMP, Appendix A).

For example, Figure 12 shows the different drainage districts in the Kohlman Lake watershed and the percent of the annual TP load that each drainage district contributes to the lake during an average year of precipitation. It should be noted that each drainage district's TP contribution is after any TP treatment that currently occurs within the drainage district. Also, any internal load of phosphorus from Kohlman Lake itself is not factored into these percentages.

Table 3 presents the existing water, external and internal TP budgets in Kohlman Lake that were calculated for Kohlman Lake using the P8 and in-lake models.

Table 3 Water, Total Phosphorus and Net Internal Load Budgets in Kohlman Lake for Wet, Dry and Average Precipitation Conditions

Precipitation Year	Water Load Over the Growing Season (AF)	External Total Phosphorus Load Over the Growing Season (lbs)	Internal Total Phosphorus Load Over the Growing Season (lbs)
Wet (Calibration Year) (2002)	4,868	2,317	65
Dry (1989)	1,639	666	70
Average (2001)	2,185	943	283



Barr Footer: Date: 6/24/2008 11:23:50 AM File: I:\Client\Rwmwd\District\Workorders\MS4\KohlmanLake\Maps\Reports\TMDL Report\Figure 12 Kohlman Lake Drainage Districts and TP Contributions.mxd User: TJA

Figure 12
DRAINAGE DISTRICTS AND TP CONTRIBUTIONS (AVG YEAR)
Kohlman Lake Total Maximum Daily Load Report

The magnitude of the lake's internal load value was verified by measuring the release rate of TP from Kohlman Lake sediment and calculating the potential TP load from senescing curlyleaf pondweed (based on curlyleaf pondweed growths observed in the lake in June, 2005). This information was obtained as a part of the Internal Phosphorus Load Study that was completed for the lakes in 2005 (Barr, 2005). In this study, the maximum possible loading rate of mobile phosphorus from Kohlman Lake sediment was estimated to be 9.7 $mg/m^2/day$. This loading rate was applied to the growing season months (122 days), to come up with an existing, combined internal phosphorus load of 780 lbs per year from the lake's sediments. The loading rate of phosphorus from senescing curlyleaf pondweed in the lake was estimated to be 1.54 $mg/m^2/day$. This loading rate was applied only to the months of July, August and September (the months of curlyleaf senescence- 91 days), to come up with an existing, combined internal phosphorus load of 92 lbs. This existing internal load (a total of 872 lbs) can be considered a maximum in any given growing season, regardless of the level of precipitation. Table 4 compares this maximum internal TP load to the internal loads deduced for the three precipitation scenarios in the in-lake model. These results are reasonable, given the different degrees of lake mixing (or not observed) in the lake over the three different growing seasons.

Table 4 Maximum Measured Internal TP Load, and Estimated Internal TP Loads in Kohlman Lake for Wet, Dry and Average Precipitation Conditions

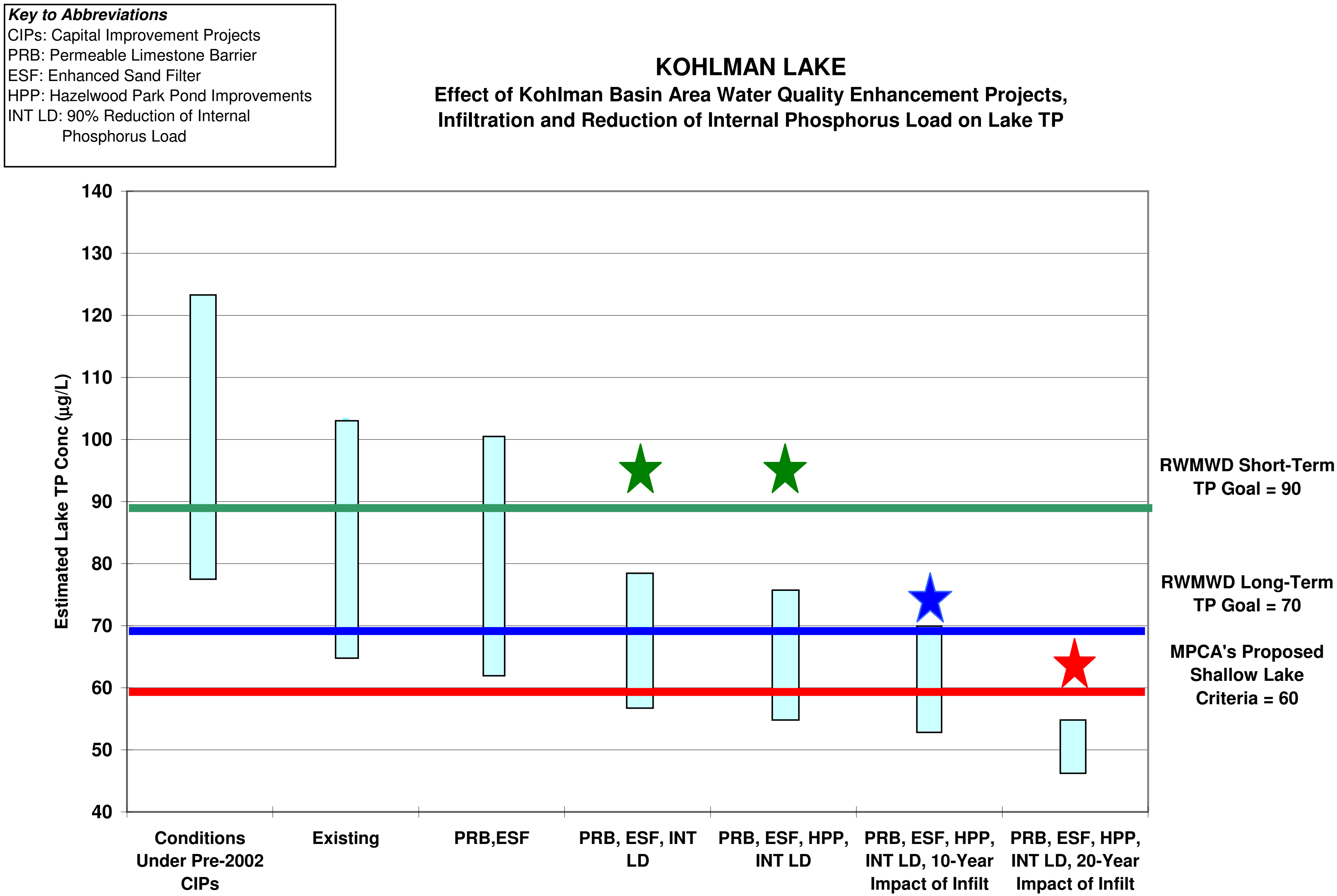
Scenario	Internal Total Phosphorus Load Over the Growing Season (lbs)	Percent of Maximum Measured Internal Load (%)
Maximum Measured (From Sediment Analysis and Macrophyte Survey)	872	100
Wet (2002)	65	7
Dry (1989)	70	8
Average (2001)	283	32

After the P8 model and in-lake water quality model were created and calibrated, they were used predictively to evaluate the effect of different BMPs on in-lake TP concentration. Many factors were taken into consideration in determining where to concentrate load reduction efforts, such as: the seasonality of the TP loads, particulate nature of the loads and location of the loads. Detailed information regarding these considerations can be found in the Phalen Chain of Lakes SLMP (Appendix A).

Figure 13 shows the impact of several capital improvement project (CIP) options on in-lake TP concentrations, under wet, dry and average precipitation conditions. For Kohlman Lake, reduction of phosphorus from Kohlman Basin's outflows and an in-lake treatment of the internal load are required to bring TP concentration in the lake to below 60 µg/L during the wet, dry and average precipitation years modeled for the SLMP.

All of the lake concentrations (except for existing conditions) presented in Figure 13 were obtained through the modeling described in Section 4.1 of this report. The TP concentration in the lake that is achieved as a result of each management scenario is represented as a bar in order to convey the range of phosphorus concentrations predicted for the different precipitation years. The top of each bar represents the lake TP concentration during the average year of precipitation- this was the most critical condition.

It should be noted that each precipitation year had not only a different external load of phosphorus, but also a different internal load. The internal load assigned to each model run under existing conditions (wet, dry or average precipitation years) was based on the internal load that was calculated in the calibrated in-lake model for that year. The internal load assigned to different management scenarios depended on the nature of the management scenario. If the scenario involved no change to the lake's internal load, the internal load calculated in the calibrated in-lake model for that year was applied. If the scenario did involve a reduction in the lake's internal load, the existing conditions internal load was reduced accordingly in the scenario's in-lake model.



Key to Abbreviations
CIPs: Capital Improvement Projects
PRB: Permeable Limestone Barrier
ESF: Enhanced Sand Filter
HPP: Hazelwood Park Pond Improvements
INT LD: 90% Reduction of Internal Phosphorus Load
KOHLMAN LAKE
Effect of Kohlman Basin Area Water Quality Enhancement Projects, Infiltration and Reduction of Internal Phosphorus Load on Lake TP
Estimated Lake TP Conc (µg/L)
140
130
120
110
100
90
80
70
60
50
40
RWMWD Short-Term TP Goal = 90
RWMWD Long-Term TP Goal = 70
MPCA's Proposed Shallow Lake Criteria = 60
Conditions Under Pre-2002 CIPs
Existing
PRB,ESF
PRB, ESF, INT LD
PRB, ESF, HPP, INT LD
PRB, ESF, HPP, INT LD, 10-Year Impact of Infilt
PRB, ESF, HPP, INT LD, 20-Year Impact of Infilt

4.3 Reduction Options

There are multiple actions that are shown in Figure 13 that are needed to reduce phosphorus concentrations in Kohlman Lake to meet the MPCA's shallow lakes TMDL requirement of 60 µg/L. The District's short and long term goals are also shown on this figure. These goals are intended to be met as the watershed and in-lake improvements are implemented in a stepwise manner. The District's short term goal (90 µg/L) will be met with the implementation of:

- Permeable limestone barriers (PRB) in Kohlman Basin—designed to reduce external phosphorus loading by providing sorption sites via binding with calcium
- Enhanced sand filter (ESF) in a new commercial area upstream of Kohlman Basin—designed to reduce external phosphorus loading through physical filtration and phosphorus binding with iron
- Internal load reduction measures (INT LD) within Kohlman Lake—designed to reduce internal phosphorus loading through phosphorus binding with aluminum and curlyleaf pondweed reduction

To reach the District's long term goal of 70 µg/L, project implementation includes:

- 10 years of infiltration project implementation—designed to reduce external phosphorus loading through runoff infiltration, and, if needed,
- Hazelwood Park Pond improvements (HPP)—designed to reduce external phosphorus loading through increased biological uptake and burial in a wetland system. This project is an optional project that would be implemented if the infiltration projects are not successful.

An additional 10 years of infiltration projects (20 years total) will reduce phosphorus levels in Kohlman Lake to the point that the lake is expected to meet the 60 µg/L phosphorus requirement. As Figure 13 shows, the estimated lake phosphorus concentration will meet the goals stated above under the wet, dry, and average precipitation conditions for the lake (the range shown by the bar for each condition). Further discussion about implementation of these phosphorus reduction options can be found in Section 7.

5.0 TMDL Allocation Analysis

A TMDL is defined as follows (EPA 1999):

TMDL = WLA + LA + MOS + Reserve Capacity

Where:

WLA	=	Wasteload Allocation to Point Sources
LA	=	Load Allocation to NonPoint Sources
MOS	=	Margin of Safety
Reserve Capacity	=	Load set aside for future allocations from growth or changes

This section will define each of the terms in this equation for Kohlman Lake and will discuss seasonal variation and reasonable assurances that the TMDL for the lake will be pursued.

Of the three precipitation scenarios evaluated in this study, the one resulting in the worst water quality in Kohlman Lake was the "average" precipitation scenario (the growing season of 2001). During that growing season, the watershed phosphorus load and the lake's internal load of phosphorus combined to produce higher concentrations than in the other growing seasons modeled for this study (1989- the dry precipitation year and 2002- the wet precipitation year).

While it is true that the wet year precipitation scenario results in a greater TP load to the lake, it does not result in a higher lake TP concentration. In this scenario, the TP is diluted and the lake's high flushing rate decreases the lake's internal load. During the dry year precipitation scenario, the wasteload from the watershed is lower, but lake mixing conditions during that growing season were such that any internally loaded phosphorus from the lake did not reach the lake's upper layers as much as it did during the average year scenario.

For this reason, the wasteload and load allocations presented in this TMDL are based on the management scenario required to bring the lake's growing season average TP concentration to below 60 µg/L during the average precipitation scenario. Also, because it is a year of average precipitation, it serves as a fair baseline to set wasteload allocations for municipalities. It is reasonable to expect that, on average, the cities and other entities with MS4s in the Kohlman Lake watershed will have existing watershed TP loads on the order of the ones modeled during the growing season of 2001.

5.1 Wasteload Allocations to Point Sources

All of Kohlman Lake's allocated watershed loads are expressed as wasteload allocations because the communities and governmental entities in these areas are all defined as cities and other entities with Municipal Separate Storm Sewer Systems (MS4s), requiring National Pollutant Discharge Elimination System (NPDES) permits for discharge of stormwater. As Table 5 shows, all of the wasteload reduction occurs in the "Main Drainage District" - this is due to the fact that nearly all project implementation is expected to occur within this drainage district.

Figure 14 shows the different MS4 entities that make up the Kohlman Lake tributary watershed. The permit numbers associated with each of these entities are included below:

- City of White Bear Lake (MS400060)
- City of Vadnais Heights (MS400057)
- City of Oakdale (MS400042)
- City of North St. Paul (MS400041)
- City of Maplewood (MS400032)
- City of Little Canada (MS400029)
- MnDOT (MS400170)
- Ramsey County (MS400191)

The wasteload allocations for each of the MS4 communities in the Kohlman Lake Watershed are shown in Table 6. Wasteload allocations for new construction, redevelopment and/or all other related land disturbances are considered to be minimal because they are regulated under the District's permitting program. Therefore, loads from construction, redevelopment and/or other related land disturbances can be considered to be included in the WLAs for the cities.

A search of the MPCA's water quality discharge permit database indicates only one industrial facility with the potential for a phosphorus discharge in the watershed. The H.B. Fuller Company - Willow Lake (NPDES Permit No. MN0051811) discharges once-through, noncontact cooling water through a small pond to Willow Lake, which then outlets upgradient of Kohlman Lake. No chemical additives are used. The source of the cooling water is a well that draws from the Prairie du Chien-Jordan aquifer. No phosphorus monitoring data are currently available to determine whether the discharge is a contributing source to the lake requiring a wasteload allocation. However, this discharge is expected to contain concentrations of phosphorus comparable to those in nearby Prairie du Chien-Jordan wells monitored as part of the MPCA's ambient groundwater monitoring network, and would therefore not be considered a contributing phosphorus source requiring a wasteload allocation. Therefore, this TMDL does not assign a wasteload allocation to this facility. The H.B. Fuller Company has agreed with the MPCA to conduct sampling of their well in the spring of 2010 and further evaluate the phosphorus concentration associated with its discharge. Should the MPCA determine that the discharge is a contributing source requiring an individual wasteload allocation the TMDL's wasteload allocations will be revised to include H.B. Fuller.

By design, the modeling process is based on drainage areas and not municipal boundaries. Therefore, existing wasteloads were initially calculated by drainage area and then applied to each MS4. If a specific drainage area was intersected by a municipal boundary, wasteloads were calculated based on the relative amount of directly connected impervious area in each MS4 within the drainage area (indirectly connected impervious areas were not considered). Throughout the Kohlman Lake Watershed, there are many ponds and wetlands that currently provide reduction of TP loads that would otherwise enter the lake. Credit for these removals was applied to the MS4 in which the pond or wetland was located.

The remaining TP to be removed by each MS4 (in order to meet the 25% reduction of wasteload required in the Main Drainage District) was based on the relative amount of TP supplied to the lake under existing conditions (cities with a higher TP load under existing conditions were expected to reduce a greater amount of TP).

5.2 Load Allocations to Nonpoint Sources

The load allocations for Kohlman Lake that are presented in Table 6 are attributable to the internal and atmospheric loads of phosphorus to Kohlman Lake.

Atmospheric phosphorus loads were estimated assuming a 0.3 kg/ha/yr rate (6.6 pounds during the growing season).

The reduction in the lake's internal load was based on modeling for the average year of precipitation. During this year, the largest impact from internal load was observed (Tables 3 and 4). The maximum possible internal load calculated for the lake (872 lbs) was not used as a base for the load allocation because it was deemed unrealistically high (the surface waters of the lake receive only a fraction of this maximum internal load due to the intermittent nature of mixing in the lake).

Modeling results indicated that if the internal load observed during the average precipitation year was reduced by 90%, and wasteload allocations, as described above, were met, the average growing season average TP in Kohlman Lake would be less than 60 µg/L.

5.3 Margin of Safety

The error involved in any modeling exercise can be significant. However, the calibration process used in the Phalen Chain of Lakes SLMP minimized the errors associated with erroneous assumptions. Therefore, the margin of safety for this TMDL is largely provided implicitly through use of calibrated input parameters and conservative modeling assumptions in the development of allocations. The calibration of input parameters is discussed in Section 4.1 of this report.

Examples of conservative modeling assumptions used in this study are described below.

- A range of climatic conditions (wet, dry and average precipitation years) were used to provide a range of water and TP loads, and their resulting effect on lake TP, that could be expected under different management scenarios. Load reduction strategies that allow the lake to meet the eutrophication criteria are based on the critical conditions that would produce the highest lake TP concentrations.

- P8 water volumes and TP loads were calibrated to within 5 percent of the observed values calculated by FLUX from the monitoring data during the calibration year. To offset this and other errors implicit in the lake modeling for this study, the management scenario that is ultimately recommended in this TMDL report results in a lake phosphorus concentration that is 8% lower than the eutrophication standard. As Figure 13 shows, the recommended management scenario during a wet year of precipitation and maximum internal phosphorus load results in a maximum growing season average of 55 µg/L TP- 5 µg/L below the standard of 60 µg/L.

5.4 Reserve Capacity

Because the tributary watershed of Kohlman Lake is essentially fully developed, existing conditions can be considered ultimate land use conditions. No significant future growth or change is expected in the watershed. Although redevelopment is expected in some areas, zoning laws ensure similar types of development, and the District's permitting requirements dictate that there is no net increase in TP loads after development. Further, in 2006, the District instituted their new rules for all permitted projects within the District boundary. One of the new rules now requires storm water volume reduction for every permitted project. (A permit is necessary for all projects that disturb an acre or more.) The volume reduction rule requires that infiltration practices be sized to infiltrate one inch of runoff from all (existing and new) impervious surfaces, which results in a significant reduction in TP loads from all of these corresponding areas.

Table 5 Kohlman Lake Growing Season External (Watershed) Phosphorus Budget and Wasteload Allocations by Drainage District

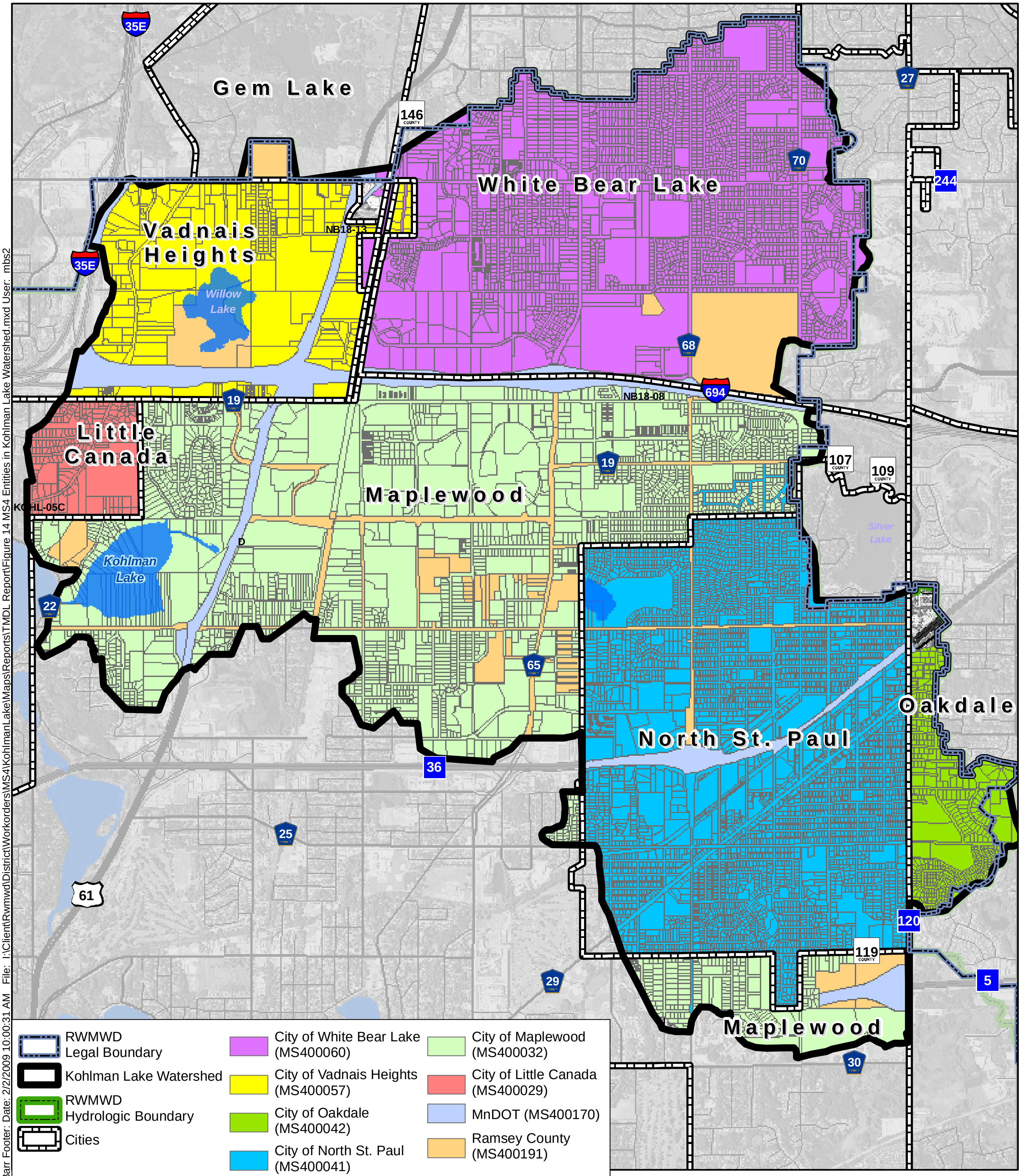
Watershed TP Sources (By Drainage District)	Existing TP Load (Pounds)	TMDL Wasteload Allocation (WLA) (Pounds)	Percent Reduction of Existing TP Load (Percent)
Main	836	627	25
Direct	66	66	0
South	5	5	0
North (SPLIT)	36	36	0
Total Wasteload Sources	**943**	**734**	**22**

Note: Wasteloads are based on average year precipitation model, summed over the growing season (June through September).

Table 6 Kohlman Lake Growing Season Total Phosphorus Budget with Wasteload Allocations by MS4 and Load Allocations

Watershed TP Sources (By MS4)	Existing TP Load (Pounds)	TMDL Wasteload Allocation (WLA) (Pounds)	Daily TMDL Wasteload Allocation (WLA) (lbs/day) (Growing Season Pounds/122 days)	Percent Reduction of Existing TP Load (Percent)
Little Canada	14	14	0.12	0
Maplewood	98	88	0.72	10
North Saint Paul	407	306	2.51	25
Oakdale	54	41	0.33	24
Vadnais Heights	121	94	0.77	22
White Bear Lake	171	129	1.05	25
Ramsey County	6	5	0.04	17
MNDOT	72	58	0.47	21
Total Wasteload Sources	**943**	**734**	**6.02**	**22**
Internal and Atmospheric Sources	**Existing TP Load (Pounds)**	**TMDL Load Allocation (LA) (Pounds)**	**TMDL Load Allocation (LA) (lbs/day) (Growing Season Pounds/122 Days)**	**Percent Reduction of Existing TP Load (Percent)**
Kohlman Lake Internal Sources (from sediment release and curlyleaf pondweed)	283	28	0.23	90
Atmospheric Sources:	7	7	0.06	0
Total Load Sources	**290**	**35**	**0.29**	**88**
Overall Source Total	**1233**	**769**	**6.31**	**38**

Note: Wasteload and load allocations are based on the loads estimated by the average year precipitation model. During that growing season, the watershed phosphorus load and the lake's internal load of phosphorus combined to produce higher concentrations than in the other growing seasons modeled for this study. Both allocations were summed over the growing season (June through September). The margin of safety is implicitly included in the way that modeling was conducted for Kohlman Lake and the selection of its management scenario recommendations.



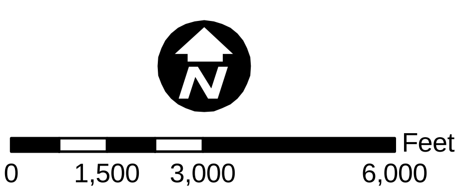


Figure 14
MS4 ENTITIES IN KOHLMAN LAKE WATERSHED
Kohlman Lake
Total Maximum Daily Load Report

5.5 Seasonal Variation

TP concentrations in the lake vary significantly during the growing season, generally peaking in August. The TMDL guideline for TP is defined as the growing season (June through September) mean concentration (MPCA, 2004). Accordingly, existing and future water quality scenarios (under different management options) were evaluated in terms of the mean growing season TP.

5.6 Reasonable Assurances

The overall implementation plan (Section 7.0) is multifaceted, with various projects put into place over the course of many years, allowing for monitoring and reflection on project successes and the chance to change course if progress is exceeding expectations or is unsatisfactory. Some of the projects that will help achieve the WLA reductions described in Section 4.0 have already been constructed in the Kohlman Lake watershed, namely:

- Enhanced Sand Filter north of Beam Avenue and east of Hwy 61 (2007)
- Permeable Reactive Limestone Barriers in Kohlman Basin (2007)

These projects are described in detail in the Kohlman Basin Area Water Quality Enhancements Study, and are estimated to achieve a 6% reduction in the phosphorus that would have otherwise traveled from Kohlman Basin into Kohlman Lake. If these projects are successful in achieving this reduction, all of the cities and other entities with MS4s listed in Table 5 will be able to take a credit toward achieving their WLA.

The volume reduction rule, only one year after its inception, has proved effective in creating projects that capture and infiltrate runoff from impervious surfaces in the Kohlman Lake watershed, providing 3.7 Acre-Feet (AF) of new depression storage, such as rainwater gardens or infiltration basins as of December, 2007. The District's annual volume reduction goal, as defined in the Kohlman Creek Watershed Infiltration Study (December, 2007), is 3.2 AF. This goal is defined as the annual runoff volume reduction that must be achieved each year in order to keep on track with the 10-year and 20-year water quality goals for the lake.

Lastly, the District will be closely monitoring not only the water quality in the lake itself, but also the runoff from Kohlman Basin. A permanent continuous flow monitoring and water quality sampling station has been established at Kohlman Basin's outflow point at Hwy 61 in order to track progress toward the 25% TP reduction goal. As additional data becomes available after USEPA approval of the TMDL, WLAs for individual permitted sources may be modified, provided overall WLA does not change. Any modifications in individual WLAs will be public-noticed.

6.0 Monitoring Plan to Track TMDL Effectiveness

The water quality in Kohlman Lake has been monitored for over 50 years, and will continue to be monitored for the foreseeable future. The RWMWD, with assistance from Ramsey County, will continue to monitor the water quality in the lake annually. The typical Ramsey County lake sampling protocol is to visit the lakes 6 to 8 times between May and September (about every 3 weeks.) The following water quality parameters are measured at each visit. All parameters except Secchi disc and chlorophyll *a* are measured at various depths in the water column (every 1 to 2 meters.)

- Secchi disc
- Dissolved Oxygen
- Temperature
- Total Phosphorus
- Soluble Reactive Phosphorus
- Chlorophyll *a*
- Total Particulate Matter
- Organic Particulate Matter
- pH
- Turbidity
- Chlorides
- Total Alkalinity
- Total Hardness
- Specific Conductivity

Also, it will be important to monitor the long-term effectiveness of all of the different projects being constructed in the Kohlman Lake Watershed. A new permanent continuous flow monitoring and water quality sampling station has recently been installed at the outflow point of Kohlman Basin, just upstream of the culvert that carries Kohlman Basin outflows under Hwy 61 to Kohlman Lake. Now that a specific phosphorus reduction goal has been set for Kohlman Basin outflows (25 percent), this monitoring station and the P8 models created for the area as a part of the Phalen Chain of Lakes SLMP can be used to determine whether or not the reduction goal has been met in any given time period.

The comparison between future monitoring data and P8 results can be conducted as follows:

1. Using monitoring results (continuous flow and water quality sampling data), calculate the annual load (or the load over some other time period) of phosphorus leaving Kohlman Basin.
2. Run the P8 model of Kohlman Basin for same time period and calculate the load that the model predicts for pre-project conditions.
3. Compare the two loads, and calculate the percent reduction that was achieved over the time period of interest.

7.0 Kohlman Lake TMDL Implementation Plan (Summary)

7.1 Annual Load Reductions

The TMDL implementation plan focuses on reducing both external, watershed sources of phosphorus and internal, in-lake sources of phosphorus. Growing season reductions of 209 pounds (22%) from external loading and 255 pounds (88%) from internal loading sources are required to achieve the required TMDL threshold of 60 µg/L for shallow lakes. Total phosphorus load reduction (both external and internal) to Kohlman Lake will decrease overall loading by 464 pounds, or 38% over the growing season (Table 6) in order to achieve the overall TMDL load allocation of 769 lbs. The projects will be implemented in a stepwise manner, with some implementation of projects already having occurred prior to this report. It is anticipated that it will take 20 years to implement all of the projects required to achieve these annual load reductions.

7.1.1 External (Watershed) Sources-Reduction Goal of 209 Pounds of Phosphorus over the Growing Season

Under the District's volume reduction rules, permit applicants are expected to achieve infiltration of 63.7 acre-ft of stormwater runoff through various BMPs installed over a 20-year period (3.2 acre-ft per year). Those BMPs will include: impervious surface reduction, infiltration basis, biofiltration basins, permeable pavement and boulevard bump-outs with infiltration. In 2007, projects designed to infiltrate 3.7 acre-ft of stormwater runoff were permitted throughout the watershed. Where the permitting program falls short of the 3.2 acre-ft per year goal, the District will make up the difference (to the maximum extent practicable) with retro-fit volume reduction projects. In addition, other BMPs for phosphorus removal from stormwater will also be implemented. These include the already constructed Enhanced Sand Filter and Permeable Limestone Barriers.

Load reductions for construction storm water activities are not specifically targeted in this TMDL. It should be noted that construction storm water activities are considered in compliance with provisions of this TMDL if they obtain a Construction General Permit under the NPDES program and properly select, install and maintain all BMPs required under the permit, including any applicable additional BMPs required in Appendix A of the Construction General Permit for discharges to impaired waters, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit.

Task 1. Identify Areas and BMPs for Potential Phosphorus Reduction in Flows through Kohlman Basin

Use existing information to identify specific BMPs to reduce phosphorus entering and flowing through Kohlman Basin.

1.	Responsible Parties	RWMWD
2.	Timeline	Completed 2006
3.	Cost	$30,000

Task 2. Kohlman Creek Subwatershed Infiltration Study

Identify an annual reduction goal, potential infiltration opportunities, and specific infiltration BMPs to reduce external loading of phosphorus to Kohlman Lake.

1.	Responsible Parties	RWMWD
2.	Timeline	Completed 2007
3.	Cost	$35,000

Task 3. Implement and Enforce the District's Infiltration Rules Within the Kohlman Lake Watershed

Through the District's permitting program, implementation projects by applicants are estimated to cumulatively infiltrate 63.7 acre-ft of stormwater runoff (3.2 acre-feet annually), over 20 year period. Shortfalls, should they occur, will be made up through implementation of District-sponsored projects (to the maximum extent practicable) as identified in the study completed under Task 2.

1.	Responsible Parties	RWMWD
2.	Timeline	2007-2027
3.	Estimated Capital Cost	$55,000 annually
4.	Phosphorus Reduction	50 Pounds/Growing Season (expected minimum)

Task 4a. Design and Implement Stormwater Best Management Practices

Enhanced Sand Filter and Permeable Reactive Limestone Barriers design and construction (does not include maintenance).

1.	Responsible Parties	RWMWD
2.	Timeline	Completed 2008
3.	Estimated Capital Cost	$395,000
4.	Phosphorus Reduction	50 Pounds/Growing Season

Task 4b. Improvements to Hazelwood Park Pond to Reduce Phosphorus if Monitoring Indicates Additional Efforts are Needed

1.	Responsible Parties	RWMWD
2.	Timeline	2015-2017
3.	Estimated Capital Cost	$914,000
4.	Phosphorus Reduction	50 Pounds/Growing Season

Task 5. Implementation of Projects Defined in the Kohlman Creek Subwatershed Infiltration Study under Task 2.

1.	Responsible Parties	RWMWD
2.	Timeline	2007-2027
3.	Estimated Capital Cost	$605,000
4.	Phosphorus Reduction	59 Pounds/Growing Season

Total cost for all external source phosphorus reduction tasks: $3,079,000.

Total already spent on external source phosphorus reduction tasks by the end of 2008: $30,000 (Task 1) + $35,000 (Task 2), + $395,000 (Task 4a) + $28,000 (Task 5) = $488,000.

7.1.2 Internal Sources—Reduction Goal of 255 Pounds of Phosphorus over the Growing Season

The reduction of internal sources of phosphorus requires a two step approach. Initially, macrophyte management of the invasive, nuisance species curlyleaf pondweed and Eurasian water milfoil will be conducted (Task 2). The reduction of curlyleaf pondweed will reduce internal phosphorus loading caused by this macrophyte. The reduction of Eurasian water milfoil and curlyleaf pondweed together is needed for the successful application of aluminum sulfate (Task 3).

Task 1. Internal Phosphorus Loading Study

Determine the sources and potential remediation measures for internal phosphorus loading to Kohlman Lake (does not include macrophyte monitoring).

1. Responsible Parties	RWMWD
2. Timeline	Completed 2005
3. Cost	$20,000

Task 2. Macrophyte Management to Control Curlyleaf Pondweed and Eurasian Water Milfoil

Treat Kohlman Lake with herbicide to limit the growth of curlyleaf pondweed and Eurasian water milfoil, to limit internal phosphorus loading from curlyleaf pondweed, and to prepare the lake for Task 3 – Inactivation of sediment phosphorus.

1. Responsible Parties	RWMWD
2. Timeline	2008-2010 (whole lake treatment)
	2010-2011 (spot treatment)
3. Estimated Capital Cost	$300,000
4. Phosphorus Reduction	78 Pounds/Growing Season

Task 3. Inactivation of Sediment Phosphorus

Based on current sediment phosphorus data for Kohlman Lake, design and apply an aluminum application to inactivate phosphorus in the sediment and reduce internal phosphorus loading.

1. Responsible Parties	RWMWD
2. Timeline	2009 and 2013
3. Estimated Capital Cost	$266,000
4. Phosphorus Reduction	177 Pounds/Growing Season

Task 4. Identify the Potential for Fisheries Management and Carp Control

Implement ongoing research, in cooperation with the University of MN, on carp populations in Kohlman Lake and the potential effects on in-lake phosphorus dynamics. Provide information to the public on the status of the fishery, and in particular carp, in Kohlman Lake. Results will be used to evaluate the need and methods for carp population reduction and the water quality and fisheries management benefits.

1. Responsible Parties	RWMWD
2. Timeline	2009-2010
3. Estimated Cost	$350,000

Total cost for all internal source phosphorus reduction tasks: $936,000
Total already spent on external source phosphorus reduction tasks by the end of 2008: $20,000 (Task 1) + $50,000 (Task 2) = $70,000.

7.1.3 Overall Cost Estimate for Implementation

The grand total cost estimate for implementing the recommendations in this TMDL, including tasks that address both external and internal source phosphorus reductions is $4,015,000. By the end of 2008, $558,000 of this total had already been spent.

7.2 MS4 Responsibilities

The District will initially take the lead role in implementing projects to achieve the WLA defined in this TMDL. However, cities and other MS4s in the Kohlman Lake Watershed are expected to fulfill their existing responsibilities in storm water management to help meet the goals of this TMDL. Specifically, cities and other MS4s in the Kohlman Lake Watershed will:

- Continue to implement volume reduction BMPs on all City projects to comply with District rules.
- Look for opportunities to implement voluntary projects to reduce runoff wherever possible, taking advantage of the District's cost-share program for water quality improvements.

- Continue to implement their Storm Water Pollution Prevention Plans (SWPPPs) and to improve their public works maintenance practices wherever possible. This work is facilitated through the District Public Works Forum and District sponsored and co-sponsored training and education programs.

7.3 Long Term Planning

After the first 10 years, a comprehensive analysis of the program will be conducted to determine if the projects implemented are achieving the required reductions in phosphorus to Kohlman Lake. If the goals laid out in this report are not reached within the required time frame, the District will meet with city and county governmental units to determine future direction and if additional participation by these groups is needed.

8.0 Public Participation

RWMWD staff and the RWMWD Board of Managers were intimately involved in the creation of the SLMP and its management recommendations for Kohlman Lake. The RWMWD's Natural Resources Board was also kept abreast of the contents of the SLMP during its development.

On November 7, 2007 a TMDL stakeholders meeting was conducted between District staff and representatives from the various MS4 permittees that are responsible for loads within the Kohlman Lake watershed. Specifically, members from the following entities were in attendance:

- Ramsey Washington Metro Watershed District
- Minnesota Pollution Control Agency
- Minnesota Department of Transportation
- City of White Bear Lake
- City of Maplewood
- City of Vadnais Heights
- City of North St. Paul
- City of Oakdale
- Ramsey County

At the meeting, the District's planned activities for meeting the TMDL criteria for Kohlman Lake were discussed. District staff explained that the District was willing to take on the task of implementing the various projects needed to meet the water quality goals for the lake, if the cities and other MS4s in the lake's watershed are willing to:

- Meet the requirements that are already set forth in SWPPP plans
- Help the District in finding good opportunities for implementation of retro-fit infiltration projects and provide support for projects within their right-of-ways

In addition to the public participation above, an opportunity for public comment on the TMDL report was provided via a 30-day comment period from August 31 to September 30, 2009. A public notice of this comment period was provided in the State Register.

The District, through implementation of the projects outlined in the Implementation Plan submitted to the MPCA, assumes the TMDL requirements will be met. If, after these projects are implemented, the water quality goals for the lake are still not met, further definition of specific load reductions assigned to each individual MS4 may be necessary.

9.0 Submittal Letter

The submittal letter will explicitly state that the submittal is the final TMDL under 303 (d) of the Clean Water Act for EPA review and approval when this TMDL has been accepted by the MPCA.

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Appendices

Appendix A

Phalen Chain of Lakes Strategic Lake Management Plan: Improvement Options and Recommendations