Spring Lake – Upper Prior Lake Nutrient TMDL

Prepared for

Prior Lake-Spring Lake Watershed District

Minnesota Pollution Control Agency

May 2011

Wenck

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Spring Lake – Upper Prior Lake Nutrient TMDL

Wenck File #1242-53

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And

PRIOR LAKE-SPRING LAKE WATERSHED DISTRICT

May 2011
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Load Allocation	**Source**	**LA**	
	Atmospheric Load, Watershed Load (not regulated under an MS4 permit), Septic Systems, Internal Load, and Upstream Lake Load	See Table 5.3 and 5.4	5-6
Margin of Safety	The margin of safety is implicit in each TMDL due to the conservative assumptions of the model.		5-7
Seasonal Variation	Seasonal variation is accounted for by developing targets for the summer critical period where the frequency and severity of nuisance algal growth is greatest. Although the critical period is the summer, lakes are not sensitive to short-term changes but rather respond to long term changes in annual load.		5-7
Reasonable Assurance	Some of the contributing area to these lakes is regulated under the NPDES program, and Minnesota's General Permit requires MS4s to review the adequacy of and, if necessary, amend their NPDES permits Storm Water Pollution Prevention Plan within 18 months after adoption of a TMDL to set forth a plan to meet the TMDL wasteload allocation. The remaining contributing area is managed by the Prior Lake-Spring Lake Watershed District.		8-1
Monitoring	Monitoring has been set forth in the implementation section of this report.		7-1
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.		7-1
Public Participation	Public Comment period: August 2, 2010 through September 1, 2010 Comment received: Yes		6-1

Executive Summary

This Total Maximum Daily Load (TMDL) study addresses a nutrient impairment for Spring and Upper Prior Lakes. The goal of this TMDL is to quantify the pollutant reductions needed to meet State water quality standards for nutrients in Spring Lake (70-0054) and Upper Prior Lake (70-0072). In 2002, Upper Prior Lake and Spring Lake were listed on Minnesota's 303(d) List of Impaired Waters for aquatic recreation due to excessive nutrients.

This TMDL also provides Waste Load Allocations (WLA) and Load Allocations (LA) for the two impaired lakes. A numeric target of 40 µg/L total phosphorus concentration for Spring Lake, a deep lake and a numeric target of 60 µg/L total phosphorus concentration for Upper Prior Lake, a shallow lake were established.

Spring Lake is centrally located within the Prior Lake-Spring Lake Watershed District. Spring Lake has a surface area of 642 acres and an average depth of 16 feet. The lake is a deep lake with a maximum depth of 35 feet and 47% littoral. 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. Spring Lake receives stormwater runoff from a 12,670 acre, mostly agricultural watershed. Approximately 721 acres of the Spring Lake watershed drain to Fish Lake upstream of Spring Lake which accounts for approximately 10% of the Spring Lake inflow volume. Stormwater is conveyed mostly through surface channels, storm sewers, ponds, overland flow and small lakes. Spring Lake outlets to Upper Prior Lake through a channel.

Upper Prior Lake has a surface area of 337 acres. Upper Prior Lake is a shallow lake with an average depth of 11 feet, a maximum depth of 45 feet, and 81% of the lake is littoral. The lake receives stormwater runoff from a 16,115-acre developing watershed which includes Rice Lake, Crystal Lake, and Crystal Bay (Arctic Lake). Approximately 1,202 acres of the watershed drains to Crystal Lake and the direct contributing area to Upper Prior Lake is 2,243 acres. Stormwater is conveyed primarily through storm sewers, ponds, wetlands, and overland flow. Upper Prior Lake outlets to Lower Prior Lake through a channel which is constricted by fill added to the lake to support a railroad bridge.

To obtain the wasteload and load allocations, lake response models were used to assess necessary load reductions to meet the water quality standards. In the case of Spring Lake, the internal load rate was reduced to 2 $mg/m^2/day$ (typical for mesotrophic lakes) and then the watershed load was reduced until the standard was met. For Upper Prior Lake, the standard can be met with reductions from Spring Lake once Spring Lake meets its TMDL requirements, and small reductions in internal loading. So the watershed load was held at current conditions and the internal release rate was lowered until Spring Lake met the standard. Loads from upstream lakes were calculated based on each lake meeting the state standard. Load and wasteload allocations for the upstream lakes will need to be developed in a separate future TMDL.

The following TMDLs have been established for Spring and Upper Prior Lakes (lbs/day of phosphorus):

Lake	LA	WLA	MOS	TMDL
Spring Lake	3.7	1.3	Implicit	5.0
Upper Prior Lake	7.24	1.1	Implicit	8.34

1.0 Introduction

1.1 PURPOSE

This Total Maximum Daily Load (TMDL) study addresses a nutrient impairment for Spring and Upper Prior Lakes. The goal of this TMDL is to quantify the pollutant reductions needed to meet the water quality standards for nutrients in the North Central Hardwoods Forest (NCHF) ecoregion. The Spring and Upper Prior Lakes TMDL for nutrients is being established in accordance with section 303(d) of the Clean Water Act because the State of Minnesota has determined waters in Spring and Upper Prior Lakes exceed the State established standards for nutrients. This TMDL also identifies pollutant reductions for those lakes.

This TMDL provides waste load allocations (WLAs) and load allocations (LAs) for the two impaired lakes. Based on the State standard for nutrients for deep and shallow lakes, the TMDL establishes a numeric target of 40 μg/L total phosphorus concentration for Spring Lake (a deep lake) and a numeric target of 60 μg/L total phosphorus concentration for Upper Prior Lake (a shallow lake).

1.2 PROBLEM IDENTIFICATION

The Prior Lake-Spring Lake Watershed (PLSLWD), located in Scott County, is a subwatershed of the Minnesota River Watershed. In 2002, Upper Prior Lake and Spring Lake were listed on Minnesota's 303(d) List of Impaired Waters for aquatic recreation due to excessive nutrients.

2.0 Target Identification and Determination of Endpoints

2.1 IMPAIRED WATERS

The MPCA included Spring and Upper Prior Lakes on the 303(d) impaired waters list for Minnesota in 2002 (see Table 2.1). The lakes are impaired by excess nutrient concentrations which inhibit aquatic recreation. The MPCA's projected schedule for TMDL completions, as indicated on the 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL. The project was scheduled to be completed in 2010. Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the waterbody; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

Table 2.1. Impaired waters addressed in this TMDL.

Lake	DNR Lake #	Listing Year	Affected use	Pollutant or Stressor	Target TMDL Start	Target TMDL Completion
Spring	70-0054-00	2002	Aquatic recreation	Excess nutrients	2004	2010
Upper Prior	70-0072-00	2002	Aquatic recreation	Excess nutrients	2004	2010

Source: MPCA.

2.2 MINNESOTA WATER QUALITY STANDARDS AND ENDPOINTS

Water quality standards are established to protect the beneficial uses of the state's waters. Minnesota Rule 7050 includes eutrophication standards for lakes to provide for the beneficial use of aquatic recreation. Eutrophication standards vary and are based on geographic location in the state (ecoregion) and lake morphometry (depth). Upper Prior and Spring Lake are in the North Central Hardwood Forest (NCHF) ecoregion. According to the MPCA definition of shallow lakes, a lake is considered shallow if its maximum depth is less than 15 ft, or if the littoral zone (area where depth is less than 15 ft and, therefore, able to support emergent and submerged rooted aquatic plants) covers at least 80% of the lake's surface area. Upper Prior Lake is shallow according to this definition and Spring Lake is not. Standards are less stringent for shallow lakes, due to higher rates of internal loading in shallow lakes and different ecological characteristics. The corresponding water quality standards and endpoints for this TMDL for Upper Prior Lake are 60 μg/L total phosphorus, 20 μg/L chlorophyll-a and 1 m Secchi disk transparency. For Spring Lake the standards and endpoints are 40 μg/L total phosphorus, 14 μg/L chlorophyll-a and 1.4 m Secchi disk transparency.

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 for the ecoregion are presented in Table 2.2.

Table 2.2. Pre-settlement total phosphorus concentrations based on water quality reconstructions from fossil diatoms.

Parameter	North Central Hardwood Forest Ecoregion	
	Shallow	Deep
Phosphorus Concentration (ug/L)	47	26

Source: MPCA 2002.

Note: All concentrations are at the 75th percentile.

Another benchmark that may be useful in determining goals and load reductions are expected stream concentrations under natural or undisturbed conditions. Table 2.3 provides data from minimally impacted streams in the North Central Hardwood Forest ecoregion.

Table 2.3. 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

Source: McCollor and Heiskary 1993.

3.0 Watershed and Lake Characterization

3.1 LAKE AND WATERSHED DESCRIPTION

Spring and Upper Prior Lakes are located in the southwestern suburban Twin Cities metropolitan area (Figure 3.1). The lakes are located in the City of Prior Lake and Spring Lake Township, while the drainage area (see Figure 3.3) includes portions of Sand Creek Township. The tributary area to Upper Prior Lake is about 16,000 acres, or about sixty percent of the Prior Lake-Spring Lake Watershed District. This is a developing watershed, with a 2000 Census population of about 25,000. Upper Prior Lake discharges to Lower Prior Lake which flows through the Prior Lake Outlet Channel to the Minnesota River.

3.1.1 Spring Lake

Spring Lake is centrally located within the Prior Lake-Spring Lake Watershed District. The watershed for Spring Lake includes wetlands, Sutton, Fish, and Buck Lakes. Spring Lake has a surface area of 642 acres and an average depth of 16 feet (Table 3.1). The lake is a deep lake with a maximum depth of 35 feet and 47% littoral. 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.

Table 3.1. Lake characteristics of Spring and Upper Prior Lakes.

Parameter	Spring Lake	Upper Prior
Surface Area (ac)	642	337
Average Depth (ft)	16	11
Maximum Depth (ft)	35	45
Volume (ac-ft)	10,206	3,621
Residence Time (years)[1]	2.5	0.7
Littoral Area (ac)	301	272
Littoral Percent	47%	81%
Watershed Area (ac) (cumulative)	12,670	3,446 (16,116)

Source: Minnesota DNR and Wenck Associates.
[1] Average residence time from nine years of modeled data.

Spring Lake receives stormwater runoff from a 12,670 acre, mostly agricultural watershed. Approximately 721 acres of the Spring Lake watershed drain to Fish Lake upstream of Spring Lake which accounts for approximately 10% of the Spring Lake inflow volume (Figures 3.2 and 3.3). Stormwater is conveyed mostly through surface channels, storm sewers, ponds, overland flow and small lakes. Spring Lake outlets to Upper Prior Lake through a channel.

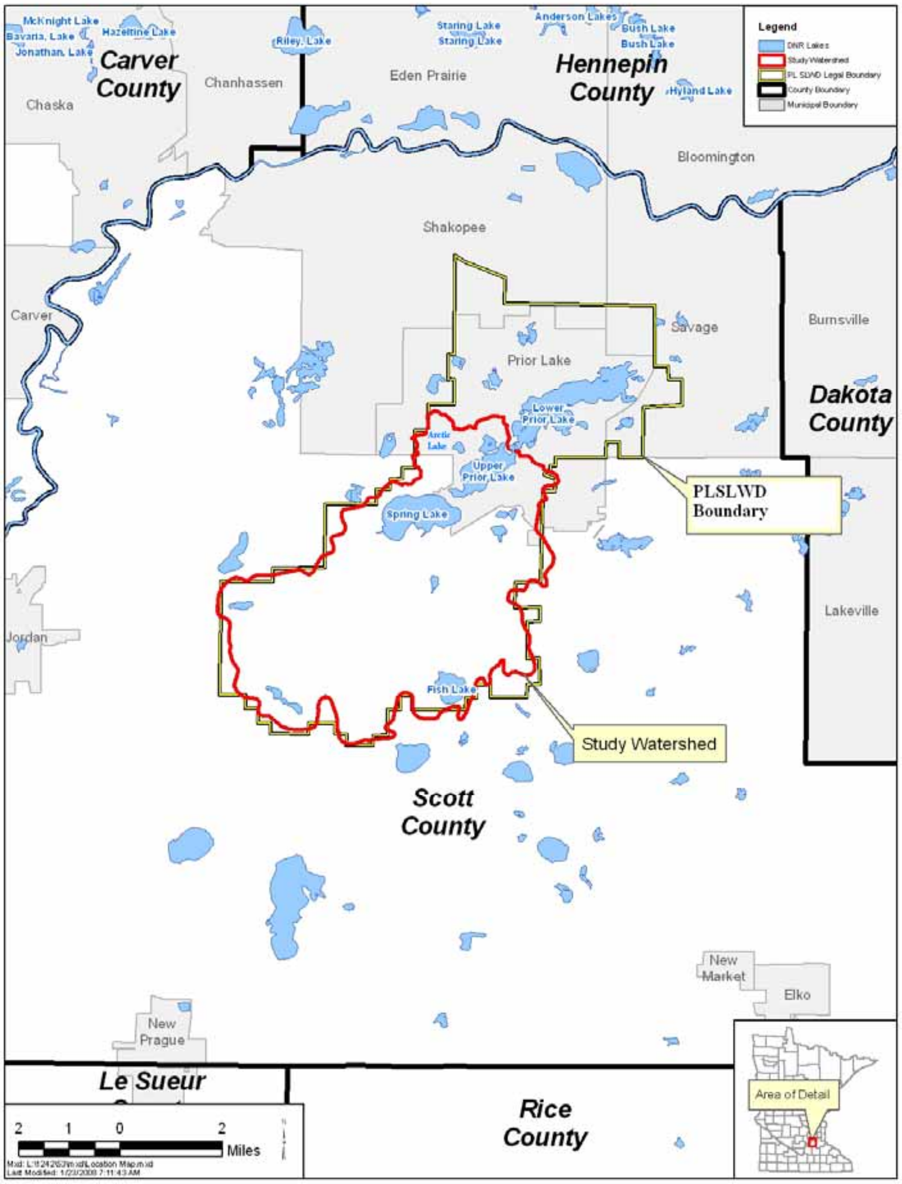


Figure 3.1. Location map.

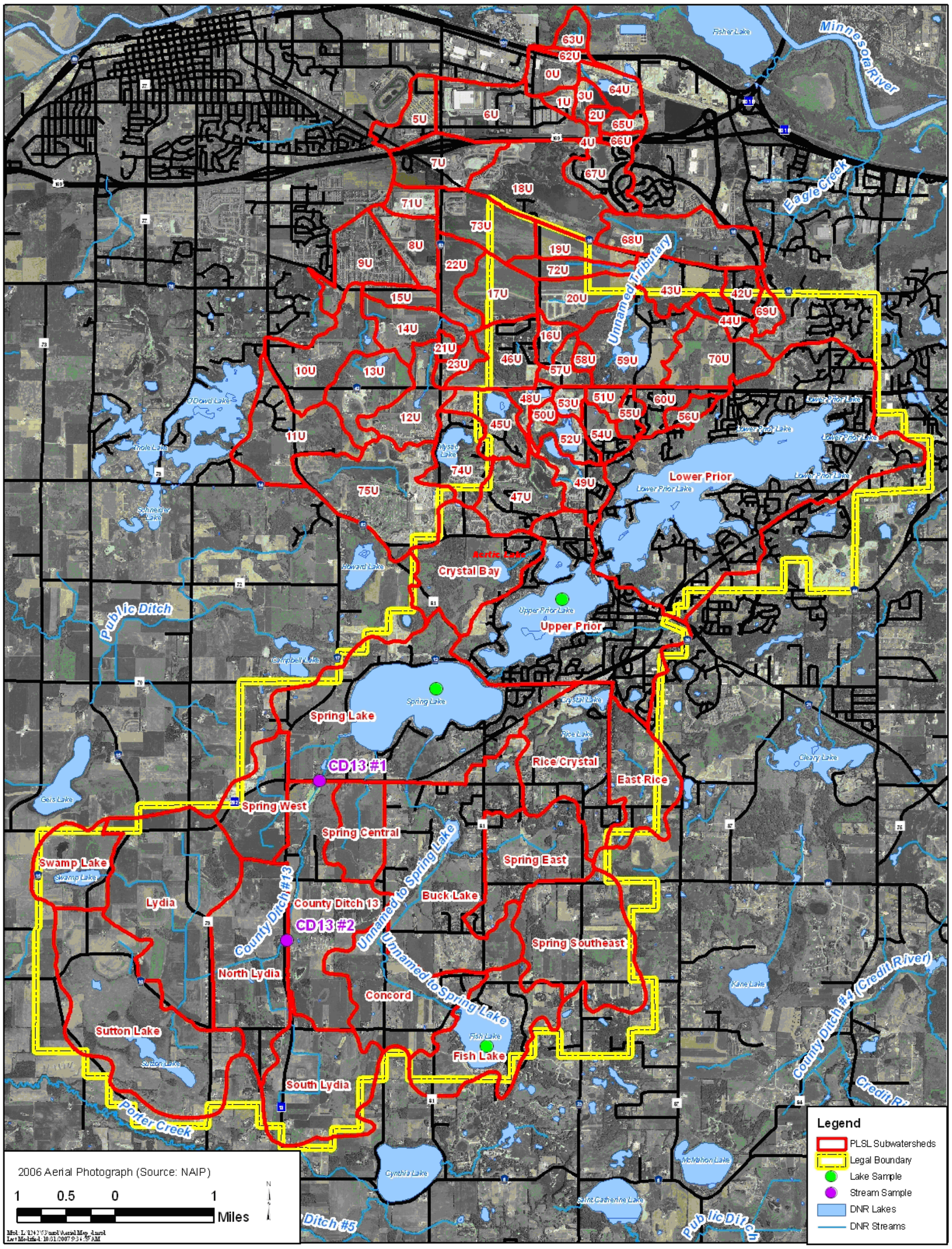


Figure 3.2. Aerial photo and subwatershed map.

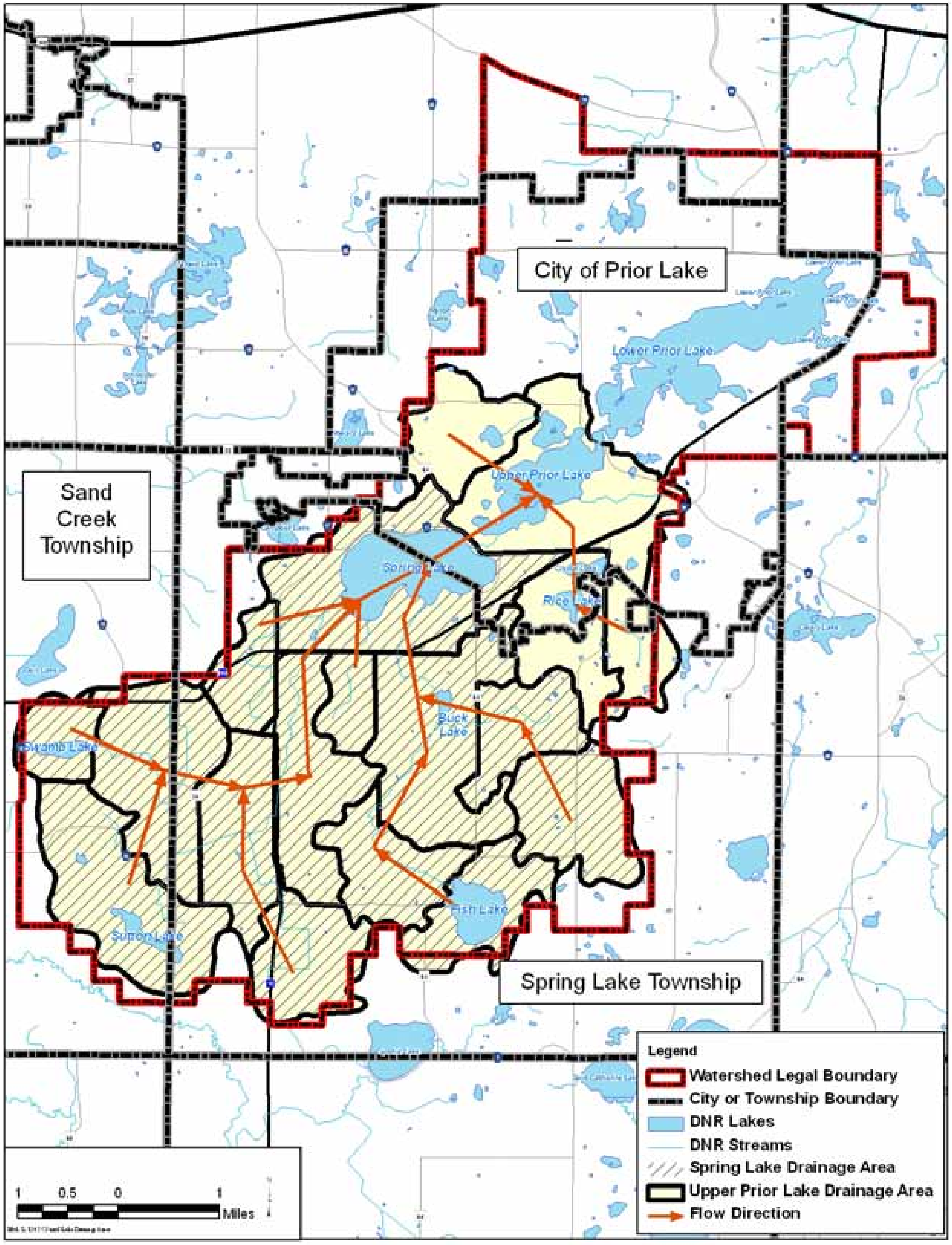


Figure 3.3. Lake drainage areas and direction of flow.

3.1.2 Upper Prior Lake

Upper Prior Lake has a surface area of 337 acres. Upper Prior Lake is a shallow lake with an average depth of 11 feet, a maximum depth of 45 feet, and 81% of the lake is littoral.

The lake receives stormwater runoff from a 16,116-acre developing watershed which includes Rice Lake, Crystal Lake, and Crystal Bay subwatershed. Approximately 1,202 acres of the watershed drains to Crystal Lake while the direct contributing area to Upper Prior Lake is 2,243 acres. Stormwater is conveyed primarily through storm sewers, ponds, wetlands, and overland flow. Upper Prior Lake outlets to Lower Prior Lake through a channel which is constricted by fill added to the lake to support a railroad bridge.

3.2 LAND USE

General land use in the Spring Lake Upper Prior Lake watershed is dominated by NWI Type 3, 4, and 5 wetlands (23%), Corn/Soybean (21%), Single Family Residential (13%), and Undeveloped and Pasture (11% for each) (Table 3.2 and Figure 3.4). Undeveloped land is land that is currently undeveloped and not used for other activities such as agriculture or pasture. Agriculture is land that is classified as agriculture in use, but specific agriculture type could not be identified.

Table 3.2. 2005 land use in the Spring Lake - Upper Prior Lake watershed by Lake. Area in acres.

Sub-Watershed ID	Spring Lake	Upper Prior Lake	**Grand Total**	**Percent of Watershed**
NWI Types 3,4,5	2,708	918	3,626	23%
Corn/Soybean	3,172	142	3,314	21%
Single Family Residential	1,276	844	2,121	13%
Undeveloped	1,327	380	1,708	11%
Pasture	1,519	168	1,687	11%
NWI Types 1,2,6,7,8	1,148	80	1,228	7.6%
Agriculture	909	86	995	6.2%
Park and Recreation	134	253	387	2.4%
Right of Way (Transportation)*	54	261	315	2.0%
Wheat/Rye/Alfalfa	319		319	2.0%
Multi-Family Residential	17	168	185	1.1%
Public/Semi Public	48	54	101	0.6%
Commercial	15	55	71	0.4%
Open Water	20	13	33	0.2%
PL Wetland		20	20	0.1%
Industrial	3	4	7	<0.1%
Woodland		0.2	0.2	<0.1%
Grand Total	12,670	3,446	16,116	100%

Source: Metropolitan Council.

*Transportation right-of-way areas in this table include railroads, local streets, county roads, and state highways under the jurisdiction of Mn/DOT, both inside and outside the 2000 Census-designated urbanized area.

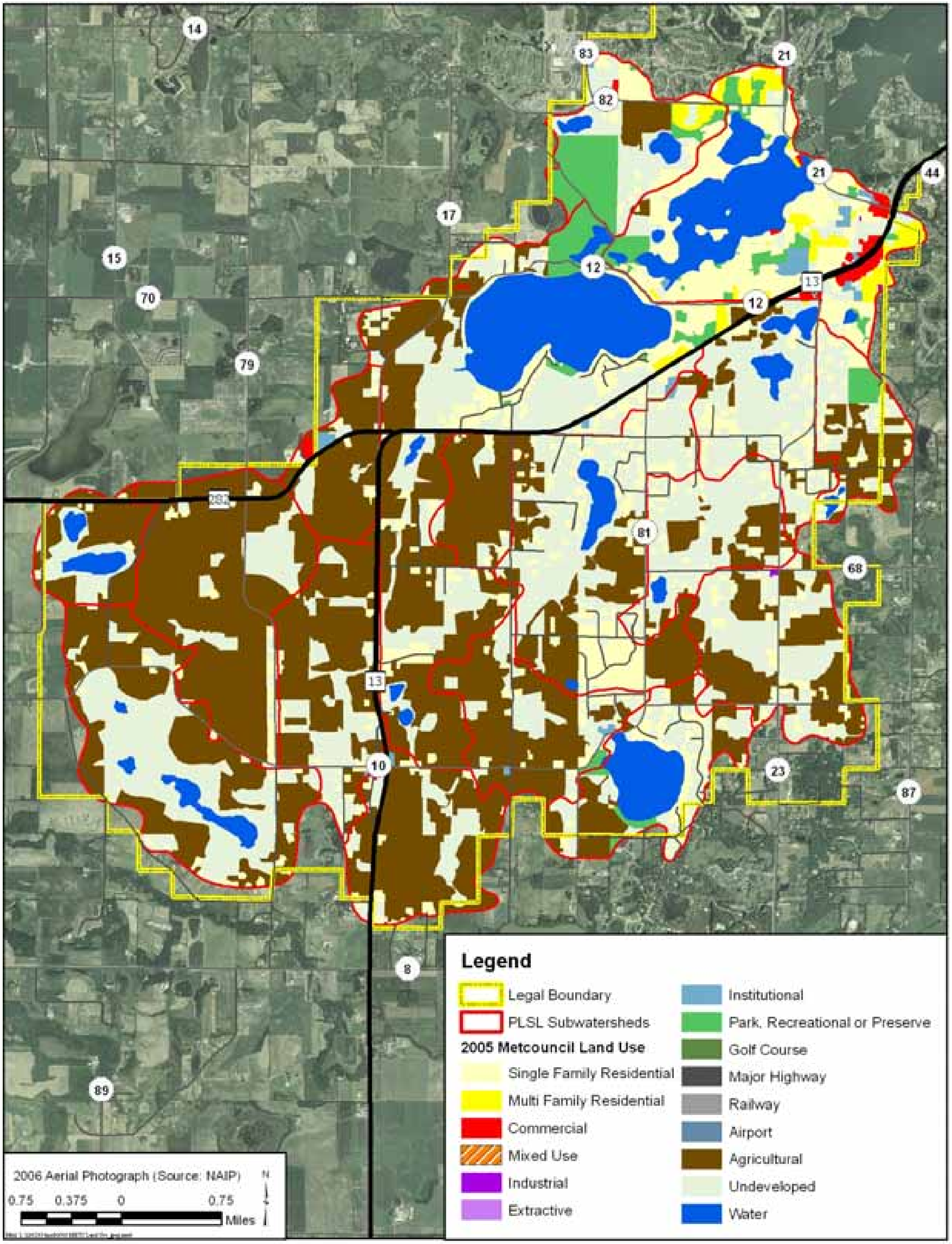


Figure 3.4. 2005 Met Council land use in the Spring and Upper Prior Lakes watersheds.

3.3 RECREATIONAL USES

Spring and Upper Prior Lakes are highly used recreational water bodies with public boat ramps on both. Open water activities include fishing, boating, water skiing, jet skiing, sailing and swimming.

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. Higher 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 Monitoring in Spring Lake and Prior Lake

3.4.2.1 Citizen Assisted Monitoring Program (CAMP)

Spring and Prior Lakes have been periodically monitored by volunteers through the Citizen Assisted Monitoring Program. The CAMP program is operated by Metropolitan Council Environmental Services, which provides coordination and data analysis for the almost 200 lakes monitored annually in the Metro area. Citizen volunteers collect Secchi data and surface samples which are tested for TP and chlorophyll-a biweekly. Met Council staff has periodically conducted quality control and found that these volunteer-collected data are generally accurate and provide acceptable surface water quality data. Data collected will be submitted to the MPCA for storage in the USEPA STORET database.

3.4.2.2 Other Monitoring

The Metropolitan Council and Three Rivers Park District have both conducted monitoring on Spring and Upper Prior Lakes.

3.4.3 Monitoring Parameters

3.4.3.1 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.

Spring Lake and Upper Prior Lake are both dimictic, based on June-September temperature and dissolved oxygen profiles for each lake that span the last two decades. The hypolimnia of both lakes exhibit anoxic conditions throughout the summer. These observations are consistent with significant internal loading in Spring and Upper Prior lakes.

3.4.3.2 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 can lead to nitrogen limiting conditions. Phosphorus and nitrogen are measured to determine the availability of the nutrients for algal production. Dissolved and orthophosphorus are the most readily available forms of phosphorus while total phosphorus is a measure of all the phosphorus, bound and unbound. Nitrate is the most readily available form of nitrogen for algal production and Total Kjeldahl nitrogen is a measure of organic nitrogen plus ammonia in the water column.

3.4.3.3 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 reasonable estimator of algal biomass and is inexpensive and easy to analyze.

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

3.4.4 Lake Monitoring Results

Following is a discussion of the lake monitoring results for Spring Lake and Upper Prior Lake.

3.4.4.1 Spring Lake

3.4.4.1.1 Historic Data

Historic summer average (June 1-September 30) chlorophyll-a, total phosphorus, and Secchi depth data are presented in Table 3.3

Table 3.3. Historic summer average (June 1-Septmber 30) data for Spring Lake.

	Total Phosphorus [µg/L]		Chlorophyll-a [µg/L]		Secchi Depth [m]	
Year	Number	Average	Number	Average	Number	Average
1980						
1981						
1982	11	170.6			17	1.89
1983					5	1.40
1984	4	112.5			9	0.90
1985					5	0.70
1986					5	1.00
1987					5	0.70
1988					5	0.79
1989					3	1.37
1990	8	116.9			19	1.37
1991					8	0.97
1992					13	1.99
1993					14	1.91
1994					9	1.73
1995					14	1.73
1996	8	73.8			12	1.16
1997	9	81.1			9	1.33
1998	7	148.6	7	62.6		
1999	6	123.5	6	47.2		
2000	4	192.5			4	1.40
2001	8	96.3	7	68.3	8	0.64
2002	11	126.5	10	85.1	11	0.58
2003	9	99.1	8	44.5	9	1.33
2004	17	132.2	18	50.6	19	1.02
2005	15	95.1	15	60.6	15	0.99
2006	15	83.3	15	46.8	15	0.94

Source: STORET.

3.4.4.1.2 Total Phosphorus

Spring Lake demonstrates high total phosphorus concentrations compared to the State standard for deep lakes of 40 µg/L total phosphorus. Between 1996 and 2006, the lowest summer average concentration was nearly twice the state standard (Figure 3.5).

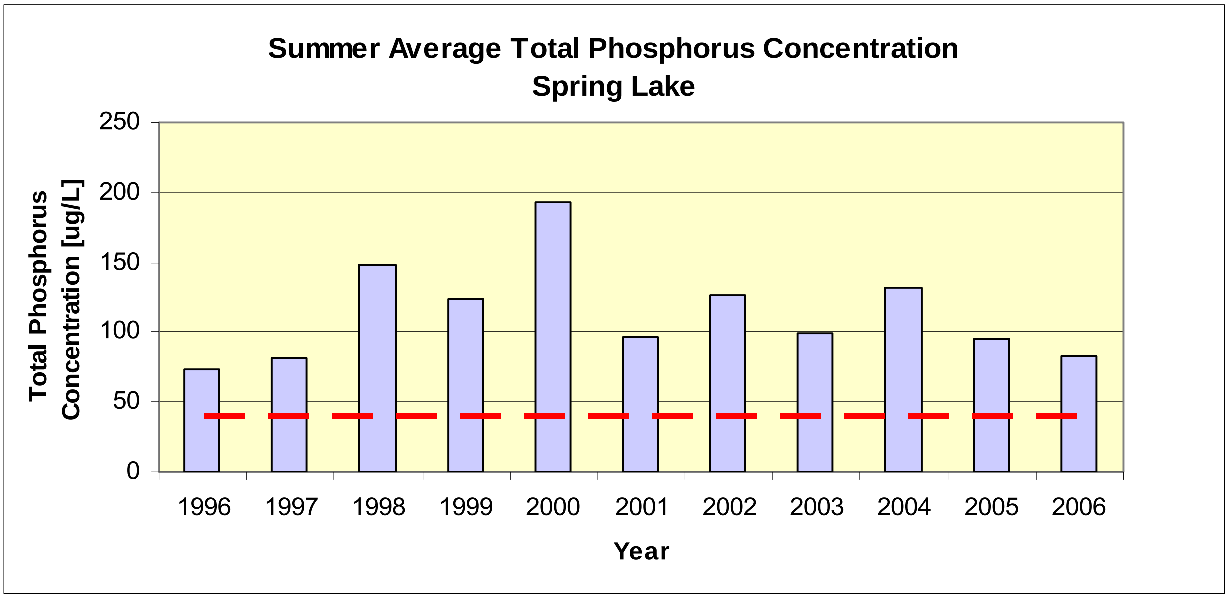


Figure 3.5. Summer average (June 1-September 30) total phosphorus concentrations for Spring Lake compared to the state average (dashed line).

3.4.4.1.3 Chlorophyll-a

Chlorophyll-a concentrations generally track with TP concentrations, although that relationship is not evident in every year. In deep lakes, the state standard for chlorophyll-a is 14 µg/L or less. Spring Lake exceeded that standard every year between 1996 and 2006 in which chlorophyll-a was measured (Figure 3.6).

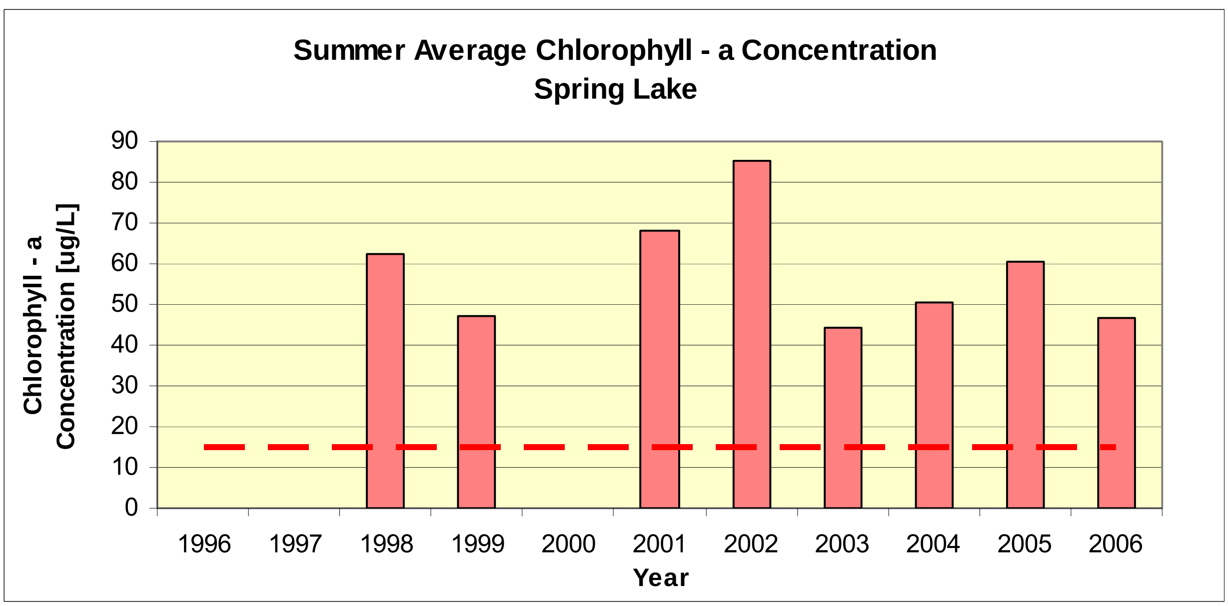


Figure 3.6. Summer average (June 1-September 30) chlorophyll-a concentrations for Spring Lake compared to the state average (dashed line).

3.4.4.1.4 Secchi Depth

Secchi depth is a measure of water clarity. In deep lakes, the NCHF state standard for clarity is a Secchi depth of 1.4 meters or greater. Spring Lake met the standard in only one year, 2000, of the measured years between 1996 and 2006.

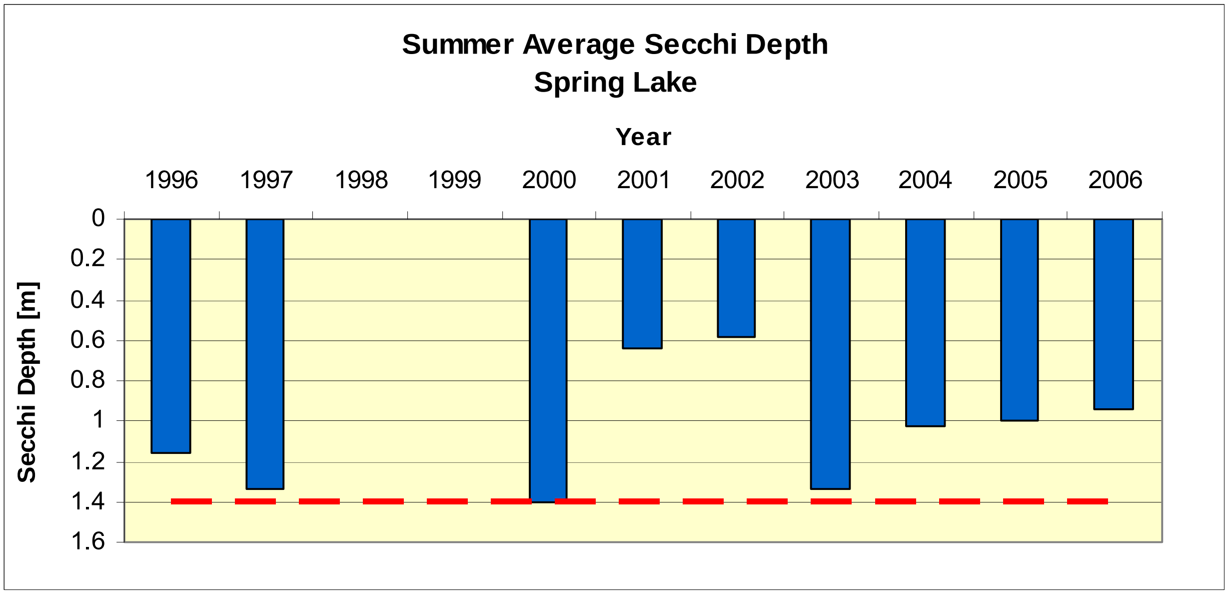


Figure 3.7. Summer average (June 1-September 30) Secchi depth in meters of Spring Lake compared to NCHF deep lake standard (dashed line).

3.4.4.2 Upper Prior Lake

3.4.4.2.1 Historic Data

Historic chlorophyll-a, total phosphorus, and Secchi depth data are presented in Table 3.4.

Table 3.4. Historic summer average (June 1-September 30) data for Upper Prior Lake.

	Total Phosphorus [µg/L]		Chlorophyll-a [µg/L]		Secchi Depth [m]	
Year	Number	Average	Number	Average	Number	Average
1948					1	0.91
1968	1	160				
1972					1	0.69
1979	2	40				
1980	5	64			4	1.00
1981	4	64			17	0.57
1982					12	0.80
1983					16	0.60
1984	4	88			18	0.80
1985					10	0.88
1986					8	1.10

	Total Phosphorus [µg/L]		Chlorophyll-a [µg/L]		Secchi Depth [m]	
Year	Number	Average	Number	Average	Number	Average
1987					10	0.53
1988					12	0.62
1989	7	87			16	0.99
1990	8	43			15	0.80
1991					9	0.73
1992					7	1.11
1993					4	0.99
1994					8	0.84
1995					26	1.25
1996	8	49			29	1.41
1997	9	58			32	1.19
1998	8	59			31	0.86
1999	8	83			29	0.78
2000	6	87			23	1.02
2001	11	88	10	79	32	0.92
2002	9	106	9	69	33	0.73
2003	8	74	8	65	31	0.99
2004	9	77	9	52	31	1.07
2005	14	80	15	44	45	1.33
2006	15	83	15	69	40	0.87

Source: STORET.

3.4.4.2.2 Phosphorus

Upper Prior Lake demonstrates high total phosphorus concentrations. In past years' monitoring, the summer average concentration has been higher than the NCHF shallow lake standard of 60 µg/L in every year since 1998 (Figure 3.8).

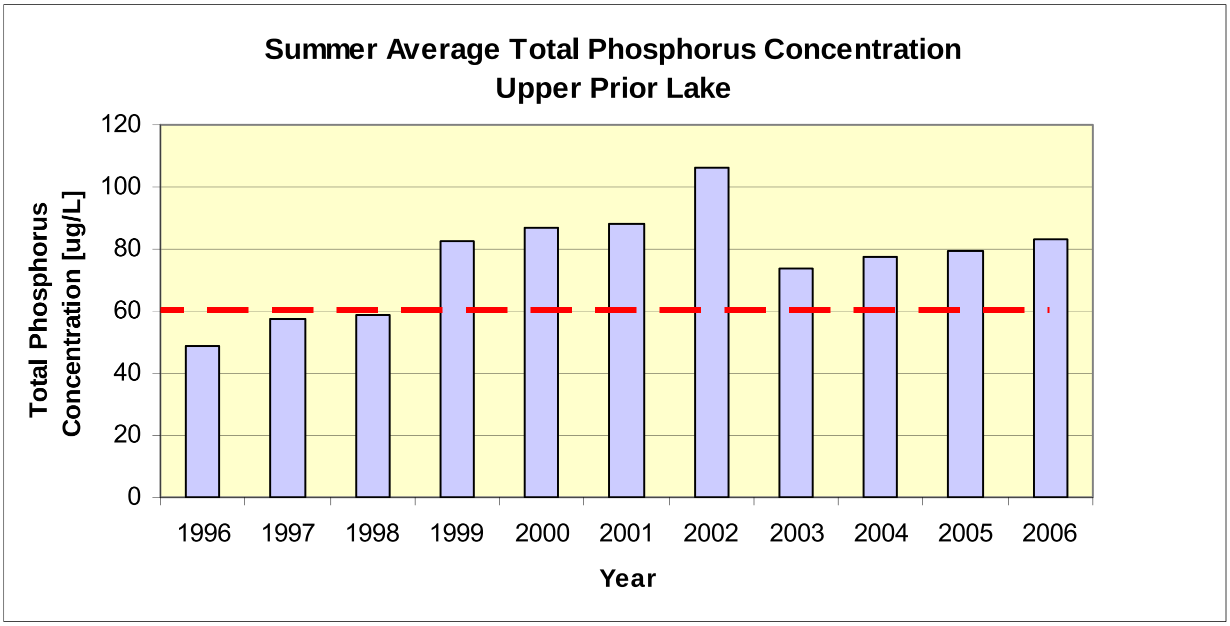


Figure 3.8. Summer average (June 1-September 30) total phosphorus concentrations for Upper Prior Lake compared to NCHF shallow lake standard (dashed line).

3.4.4.2.3 Chlorophyll-a

Chlorophyll-a concentrations generally track with TP concentrations, although that relationship is not evident in every year. In shallow lakes, the NCHF state standard for chlorophyll-a is 20 µg/L or less. Upper Prior Lake exceeded that standard by a factor of two, or greater, in every year in which chlorophyll-a data were collected between 2001 and 2006 (Figure 3.9).

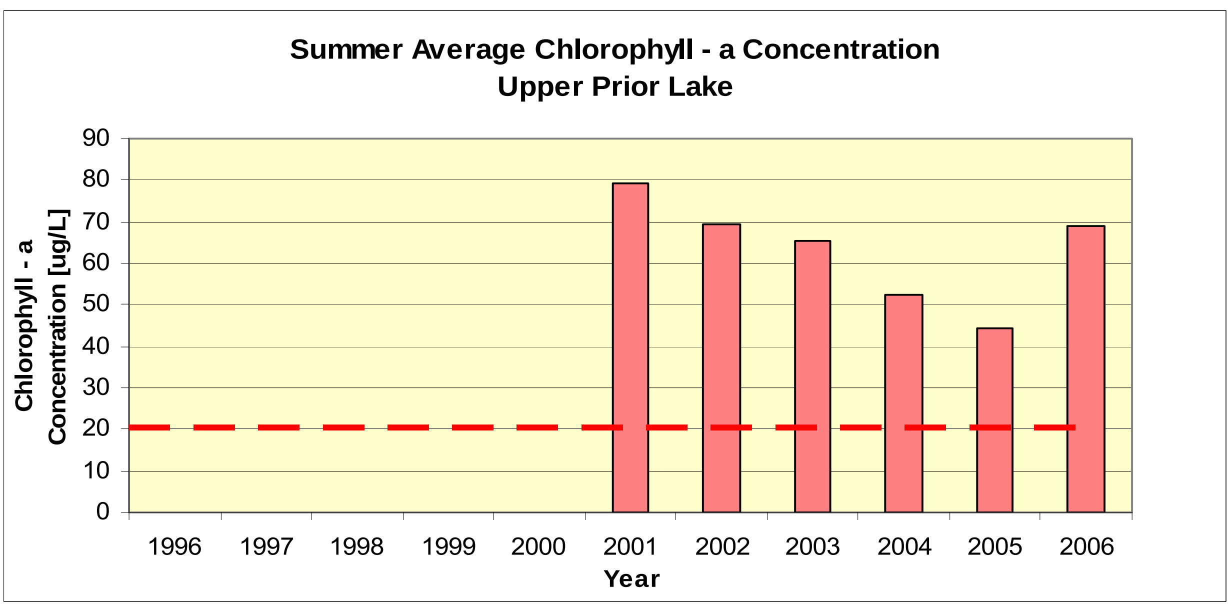


Figure 3.9. Summer average (June 1-September 30) chlorophyll-a concentrations in Upper Prior Lake compared to the NCHF shallow lake standard (dashed line).

3.4.4.2.4 Secchi Depth

Secchi depth is a measurement of clarity. In shallow lakes, the state standard for clarity in the NCHF ecoregion is a Secchi depth of 1.0 meter or greater. Between 1996 and 2006, Upper Prior Lake met the standard of 1.0 meters in 1996, 1997, 2000, 2004, and 2005 (Figure 3.10).

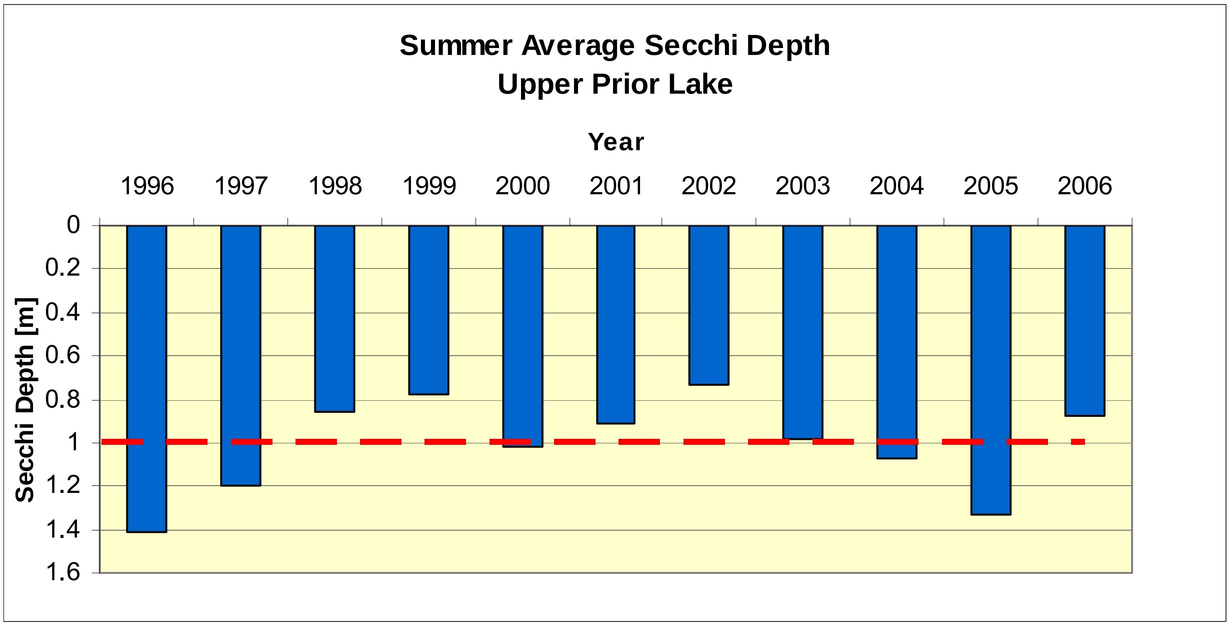


Figure 3.10. Summer average (June 1-September 30) Secchi depth in meters in Upper Prior Lake compared to the state standard in the NCHF ecoregion (dashed line).

3.4.5 Conclusions

Monitoring data in the Prior Lake-Spring Lake watershed suggest that Spring and Upper Prior Lakes are productive systems with the poorest water quality occurring in Spring Lake. Spring Lake meets the characteristics of a deep lake and does not meet standards for deep lakes in most years for total phosphorus, chlorophyll-a, and Secchi depth. Upper Prior Lake meets the characteristics of a shallow lake and does not meet the shallow lake standards for most years for total phosphorus, chlorophyll-a, and Secchi depth.

3.5 FISH POPULATIONS AND FISH HEALTH

3.5.1 Fish Populations

A review of the lake management file at the DNR office in St. Paul revealed that a variety of historical fish survey data are available for Spring Lake (Figures 3.11 and 3.12) and Upper Prior Lake (Figures 3.13 and 3.14). Standard survey methods used by the DNR include gill net and trap nets. These sampling methods do have some sampling bias, including focusing on game management species (i.e., northern pike and walleye), under representing small minnow and darter species presence/abundance and under representing management species such as

Largemouth bass. The lake management plan developed by the Fisheries Division of the DNR identifies walleye and largemouth bass as primary management species and northern pike and bluegill as secondary management species for the lakes.

Fish community data were summarized by trophic groups. Species within a trophic group serve the same ecological process in the lake (i.e., panfish species feed on zooplankton and invertebrates; may serve as prey for predators). Analyzing all the species as a group is often a more accurate summary of the fish community.

The following conclusions can be drawn from Spring Lake fish surveys:

- Walleye and largemouth bass are primary DNR management species with northern pike and bluegill as secondary species.
- Panfish species, including black crappie and bluegill, are the most abundant group during most DNR surveys.
- Top predators species are present in sufficient numbers to provide top-down control on panfish population. Walleye and northern pike collected in recent surveys are large and experience good growth.
- Fluctuations in rough fish populations are mainly due to black bullhead year class success. Carp and yellow bullhead populations are more stable.
- Carp population is likely underestimated by DNR collections.
- Carp collected in DNR surveys are large adults, averaging between 6 and 12 pounds during the last eight surveys.
- Adult carp stir up mucky, unconsolidated sediments and are likely reducing water clarity, increasing internal nutrient loads and reducing vegetation growth.

The following conclusions can be drawn from the Upper Prior Lake fish surveys:

- Walleye and largemouth bass are primary DNR management species with northern pike and bluegill as secondary species.
- Panfish species, including black crappie and bluegill, dominate the DNR collections in terms of abundance and biomass during most surveys.
- Walleye numbers are down in the most recent survey. Growth has been below average and it appears walleye natural reproduction is not occurring.
- Upper Prior Lake is known to have a strong largemouth bass population with large adult fish, even though bass are not easily sampled.
- Rough fish populations have been fairly stable in DNR surveys over the last 20 years in terms of abundance and biomass.
- Carp collected in DNR surveys are large adults, averaging between 4 and 12 pounds during last five surveys.

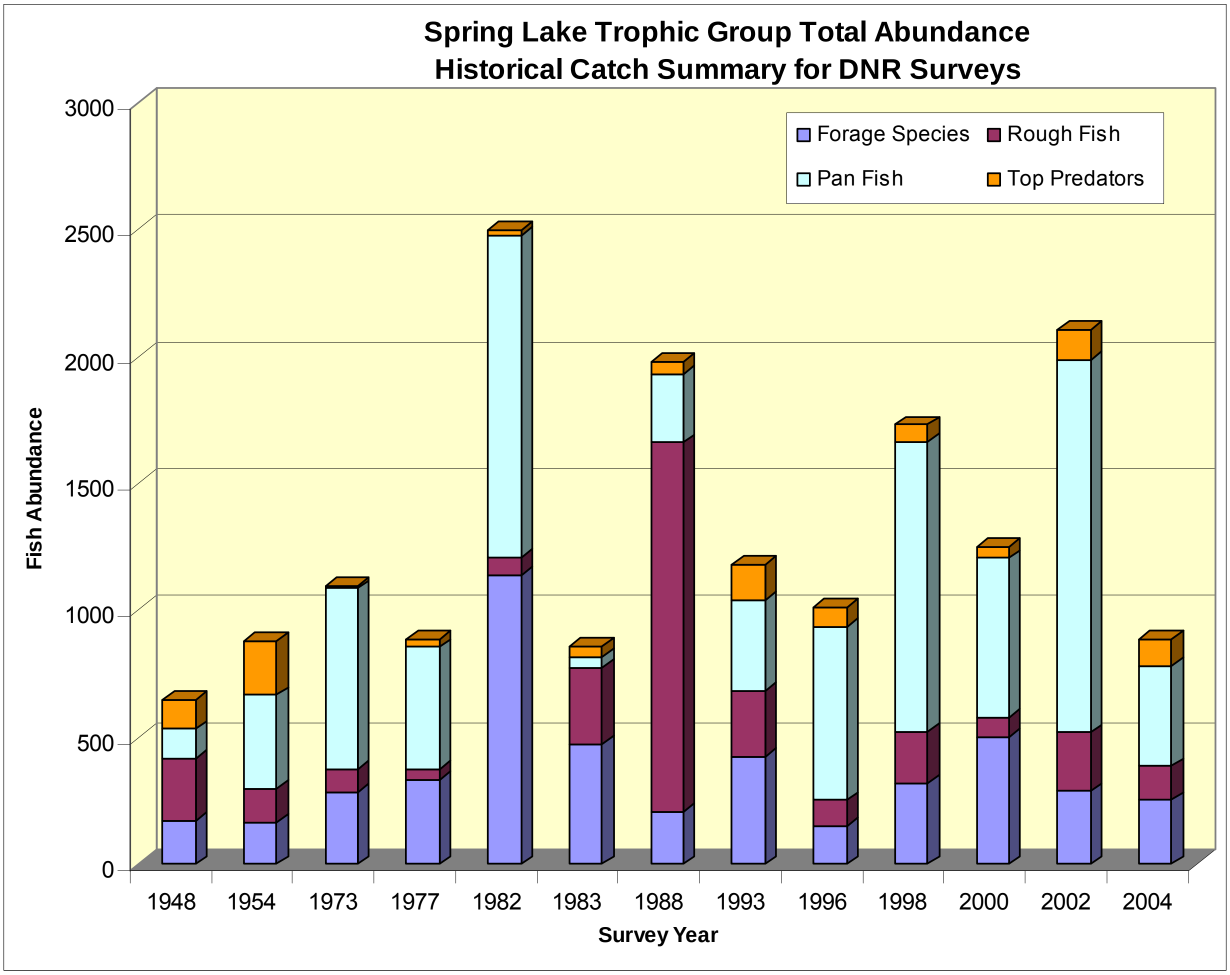


Figure 3.11 Fish abundance for Spring Lake DNR fish surveys.

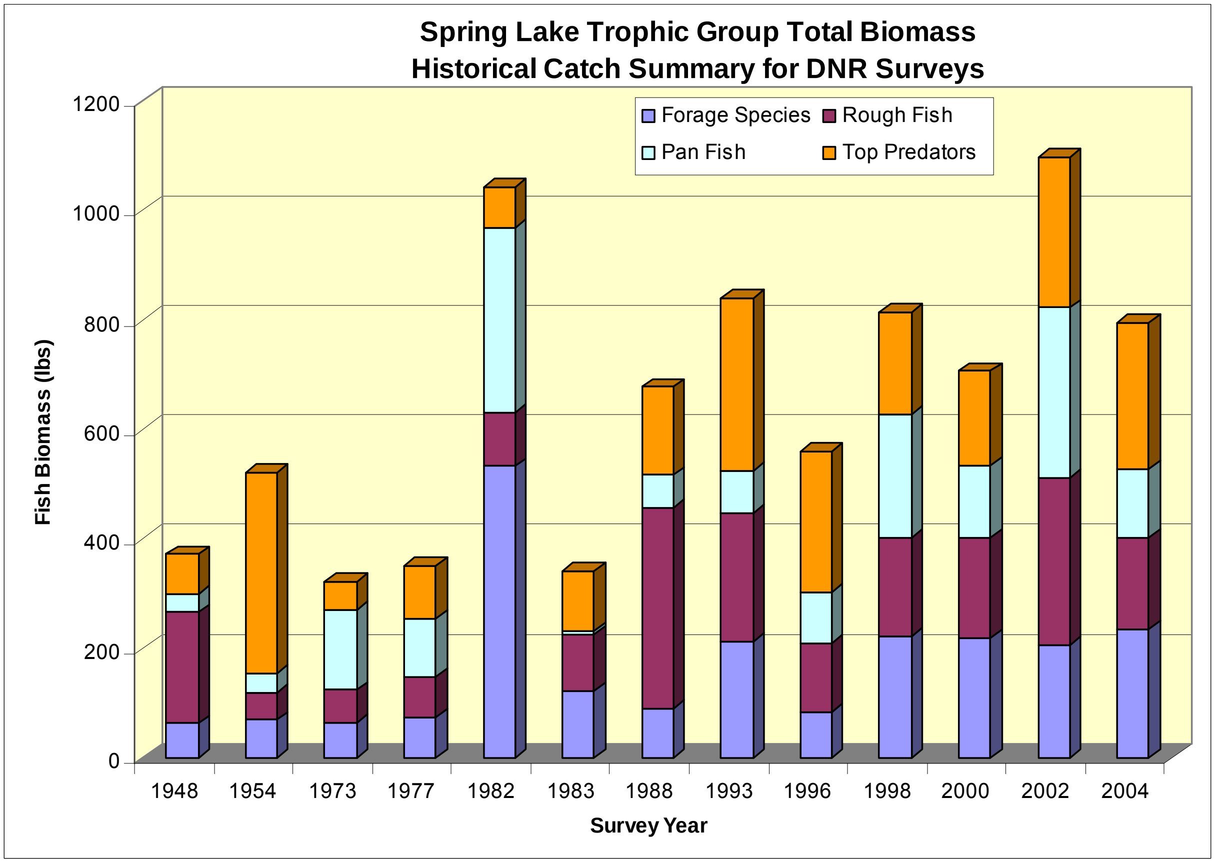


Figure 3.12. Fish biomass for Spring Lake DNR fish surveys.

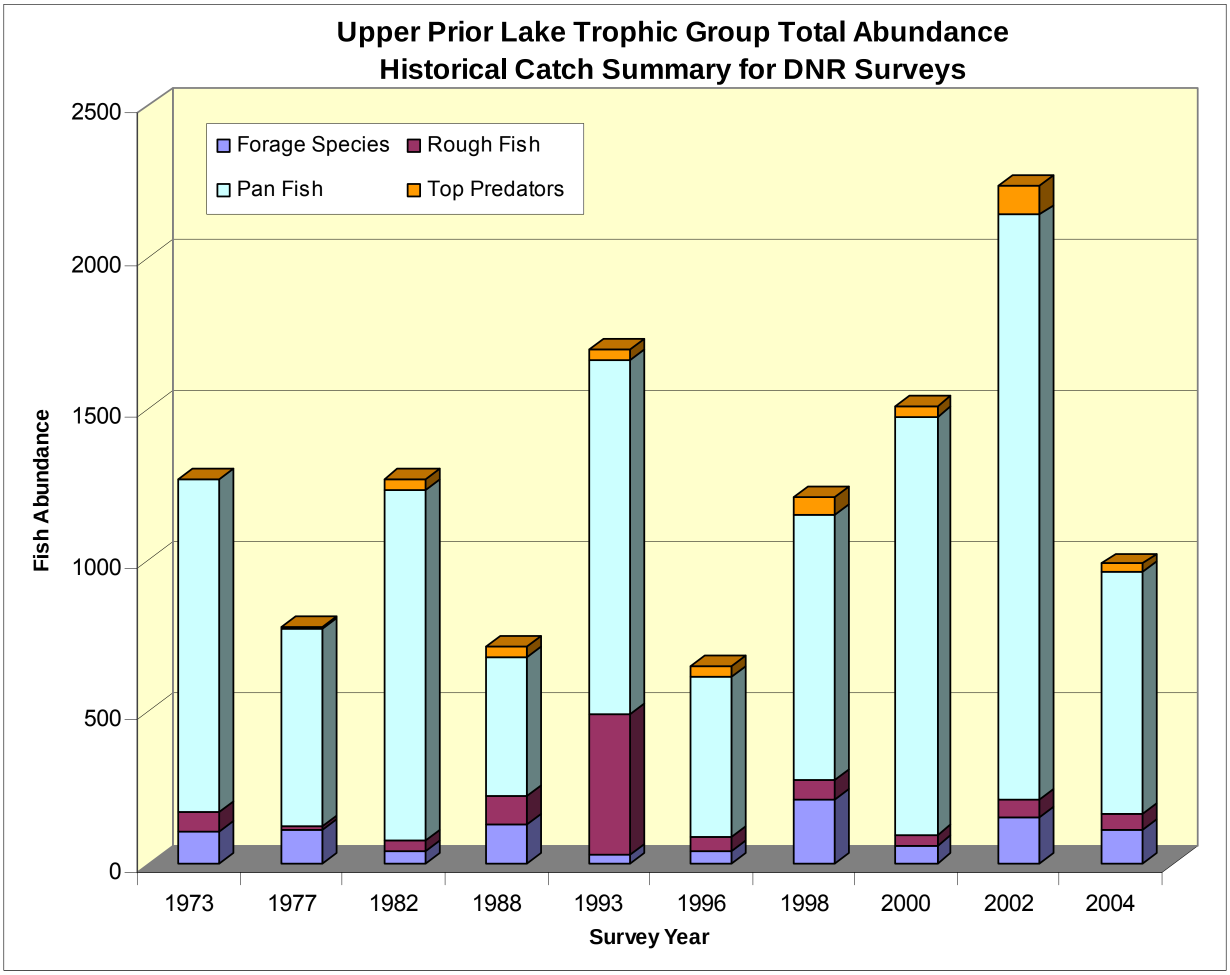


Figure 3.13. Fish abundance for Upper Prior Lake DNR fish surveys.

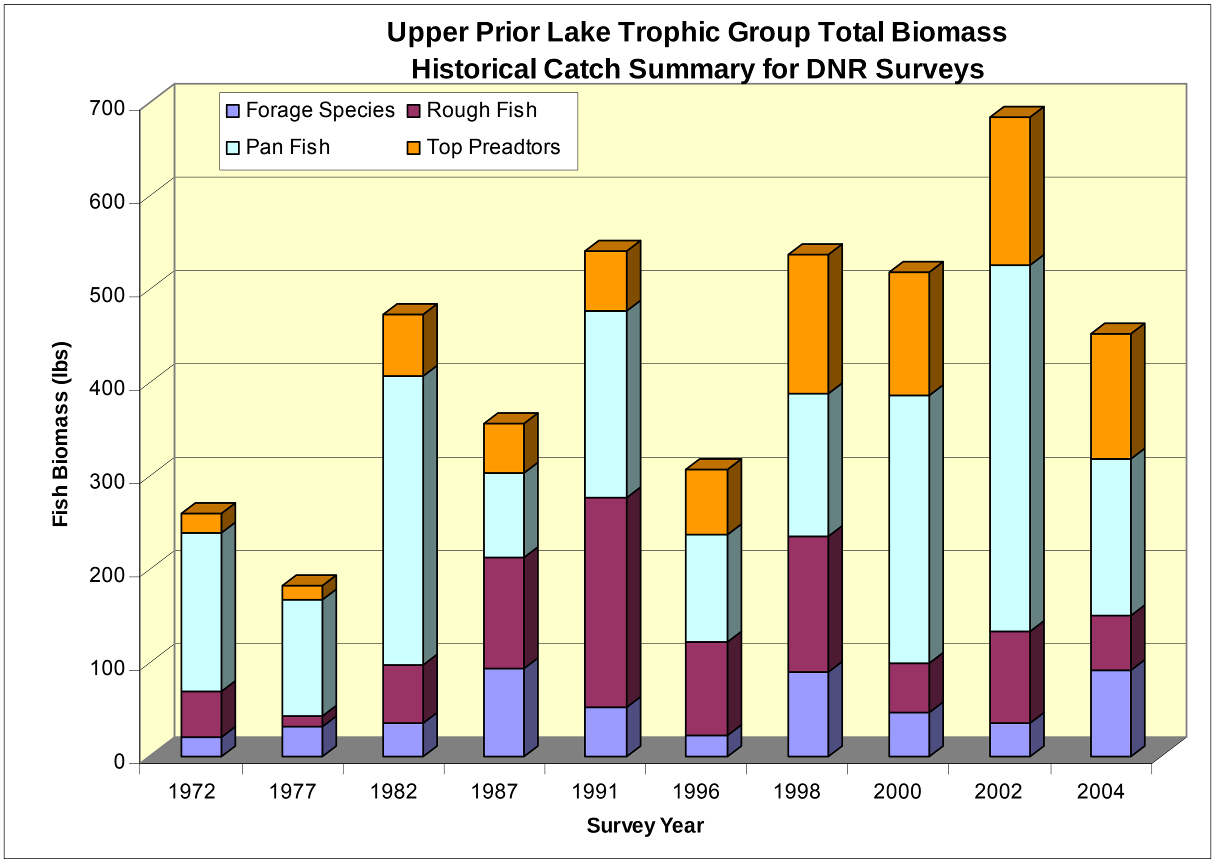


Figure 3.14. Fish biomass for Upper Prior Lake DNR fish surveys.

3.5.2 Rough Fish

Common carp, black bullheads, and other rough fish have both direct and indirect effects on aquatic environments. Rough fish are bottom-feeders and uproot aquatic macrophytes during feeding and spawning, re-suspending bottom sediments and nutrients. These activities can lead to increased nutrients in the water column, ultimately resulting in increased nuisance algal blooms. Especially in a shallow lake such as Upper Prior Lake, a lake with a relatively large littoral area, this can be a significant source of phosphorus and is part of the internal load. Rough fish management will be a key factor in managing nutrient levels in the lakes.

Common carp are abundant in both Spring and Upper Prior Lakes. Rough fish populations peaked in 1988 and have subsequently declined since then, likely as a result of management activities by the Prior Lake-Spring Lake Watershed District. Continuing these efforts will be critical in successfully achieving this TMDL.

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 as well as aesthetic appreciation. Excess nutrients in lakes can lead to exotics 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 crowds the other plants out. Ultimately, this can lead to a shift in the fish community because these high densities favor panfish over larger game fish. Species such as curlyleaf pondweed can cause very specific problems by changing the dynamics of internal phosphorus loading. All things considered, 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). Upper Prior Lake has a large littoral area (81%) and is a classic shallow lake. Spring Lake is much deeper, but still has a relatively large littoral area (47%). Since both of these lakes have relatively large littoral areas, the biological health of both of these systems will play critical roles in achieving the TMDLs.

3.6.3 Aquatic Vegetation

3.6.3.1 Spring Lake

Vegetation surveys were first conducted in Spring Lake in 1948. The DNR conducted four additional vegetation surveys between 1973 and 1988. The District conducted their first independent vegetation survey in Spring Lake in 2000, with follow up surveys in 2002 through 2007. The native vegetation base of Spring Lake exhibits moderate diversity across all vegetation surveys, with the total number of submerged species typically ranging from 5 to 8 species. The results of all vegetation surveys conducted on Spring Lake through 2005 are presented in Table 3.5.

Table 3.5. List of aquatic plants found in past surveys.
Surveys from 1948 to 1988 were conducted by MN DNR. Surveys in 2000, 2002, 2003, 2004, and 2005 were conducted by Blue Water Science. Numbers for plant species in 2000, 2002, 2003, 2004, and 2005 represent percent occurrence (provided by Blue Water Science).

Year		1948	1973	1982	1986	1988	2000		2002		2003	2004			2005		
Date (month.day)		9.18	7.9	8.16	7.2	8.15	6.3	9.3	6.7	9.3	5.15	5.2	6.14	8.27	4.20	6.1	8.18
Secchi disc (ft)		2.6	3.0	3.3	--	2.5	7.0					7.1	7.2	3.5	16.7	6.9	2.0
Coontail	Ceratophyllum demersum	R	O	A	X	O		29	4	22		13	28	40	8	14	58
Chara	Chara sp							4		2			4				
Elodea	Elodea canadensis			O		O		25	8	18	6	25	48	68	22	54	76
Berchtold's pondweed	Potamogeton berchtoldi	R	O														
Curlyleaf pondweed	P. crispus			R	X		98	40	86	4	72	78	6	10	58	72	12
Variable pondweed	P. gramineus	R	C	O													
Floatingleaf	P. natans	R	C			P											
Stringy pondweed	P. pusillus							2	6	8	2			4		6	8
Claspingleaf	P. richardsonii	R	C			O				10				6		2	4
Narrowleaf pondweed	Potamogeton sp.			O	X												
Sago	Stuckenia pectinata*	R	C			C	40	15		36	2		24	6		6	14
Lesser duckweed	Lemna minor				X	R											
Greater duckweed	Spirodela polyrhiza				X									2			
Star duckweed	Lemna trisulca		C														
Duckweed	Lemna sp			O													6
Wild celery	Vallisneria americana			O		P		6		16			2	22		2	32
Mud plantain*	Zosterella dubia*	R	R	C		C		17		22				24			30
Number of submerged species		7	8	8	5	8	2	8	4	9	4	3	6	9	3	7	9
Reed-meadow grass	Glyceria grandis		C														
Water smartweed	Polygonum amphibium		O														
Softstem bulrush	Scirpus validus		O	O													
Narrowleaf cattail	Typha augustifolia					O											
Common cattail	Typha latifolia		O	A	X	P					P						

* Stuckenia pectinata = Potamogeton pectinatus
Mud plantain = water stargrass
Zosterella dubia = Heteranthera dubia

The plant community in Spring Lake is relatively diverse; however the community is facing pressure from the presence of curlyleaf pondweed and nutrient enrichment. Past efforts in controlling curlyleaf pondweed have shown some success providing for native plants to stay competitive (see Section 3.6.4). Continued efforts to manage the vegetation population in Spring Lake will be critical in restoring a clear water state in the lake.

3.6.3.2 Upper Prior Lake

There have been a limited number of plant surveys conducted by the District on Upper Prior Lake, including surveys in 2000, 2005, 2006, and 2007. The surveys reveal that the diversity of submerged aquatic plants is low in the Upper Prior basin. A total of only five submerged species have been observed between the two surveys, with two of these species being the exotics Eurasian watermilfoil and curlyleaf pondweed. Overall the exotic species dominated the surveys in the lake with Eurasian watermilfoil and curlyleaf pondweed occurring at 75 and 95 percent of the survey points, respectively in 2005. The three native plant species that were observed in Upper Prior Lake include coontail, sago pondweed and stringy pondweed; however these species were found at a very limited number of sample stations. Water clarity is likely limiting submerged vegetation growth in Upper Prior Lake as many observed plant beds exhibit patchy growth and the plants are observed growing out to a depth of only four to six feet.

In general, plant communities in Upper Prior Lake were dominated by invasive species (curlyleaf pondweed and Eurasian watermilfoil). Little diversity is left in the lakes with only five total species identified in the surveys. A healthy, diverse aquatic vegetation population is critical in maintaining a clear water state in these lakes. Consequently, vegetation management will be a critical part of restoring Upper Prior Lake.

3.6.4 Curlyleaf Pondweed

Curlyleaf pondweed is present in these lakes at nuisance to dominant levels. It is an exotic species similar to Eurasian watermilfoil in that it can easily take over a lake's aquatic macrophyte community. Curlyleaf pondweed provides a unique problem in that it is believed to significantly affect the in-lake production of phosphorus, contributing to the eutrophication problem. Curlyleaf pondweed grows under the ice, but dies back relatively early, releasing nutrients to the water column in summer possibly leading to algal blooms. Curlyleaf pondweed can also out-compete more desirable native plant species.

The exotic species curlyleaf pondweed was detected in Spring Lake as early as 1982. By the 2000 vegetation survey, curlyleaf pondweed was observed at 98 percent of the sample points and had reached nuisance level densities at many locations. In 2002 the District began herbicide treatments to control curlyleaf pondweed in Spring Lake. Figure 3.15 presents the stem densities of curlyleaf pondweed from survey transects during pre-treatment conditions in Spring Lake. The results indicate that the treatments have been effective in reducing the densities of curlyleaf pondweed in Spring Lake.

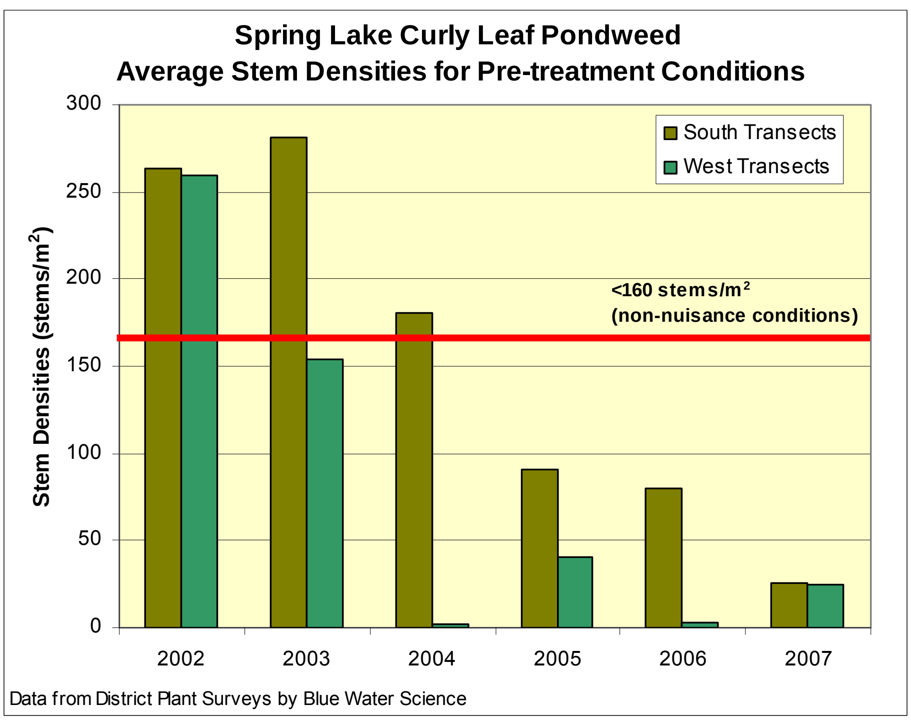


Figure 3.15. Spring Lake curlyleaf pondweed densities before and after herbicide treatments. Herbicide treatments began in 2002.

3.6.5 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. Natural shorelines provide water quality treatment, wildlife habitat, and increased biodiversity of plants and aquatic organisms. Natural shoreline areas also provide important habitat to fisheries including spawning areas and refuge as well as aesthetic values.

No shoreline surveys have been conducted for either Spring or Upper Prior Lake.

4.0 Linking Water Quality Targets and Sources

4.1 INTRODUCTION

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

4.2 SELECTION OF MODELS AND TOOLS

Modeling was completed using three independent platforms: SWMM, the ArcSWAT GIS interface, and model equations extracted from BATHTUB. SWMM was used to develop watershed hydraulics and runoff volumes through calibration to collected data. The ArcSWAT interface was used to model watershed phosphorus loads for each of the subwatersheds. Runoff volumes and watershed loads, along with atmospheric and internal loads estimated independently from the models, were input into the BATHTUB model equations in a spreadsheet to predict lake response. The watershed modeling methods are summarized below. The lake response modeling is described in subsection 4.4.

4.2.1 SWMM Modeling

Hydrologic and hydraulic modeling was completed using an existing XP-SWMM model developed for the Prior Lake-Spring Lake Watershed District. The XP-SWMM model was calibrated to measured lake level data and measured evaporation data. Local rainfall data were used as an input into the model. That model was used to simulate annual water budgets for the period of January 1, 1998 to December 31, 2006.

4.2.2 SWAT Modeling

The SWAT model interface was used to develop robust Unit Area Loads (UALs) for the Spring and Upper Prior Lakes watersheds. The SWAT model interface combined soil types from the County soil survey (STATSGO), slope, and land use into Hydrologic Response Units (HRUs).

Land use was developed from three data sources including Metropolitan Council, City of Prior Lake and the NRCS. Land use provided by the City of Prior Lake was maintained within the City limits. Outside of the City limits, Metropolitan Council data were combined with NASS crop cover data and NWI wetland data to develop a more robust land use including crop rotations (Figure 4.1).

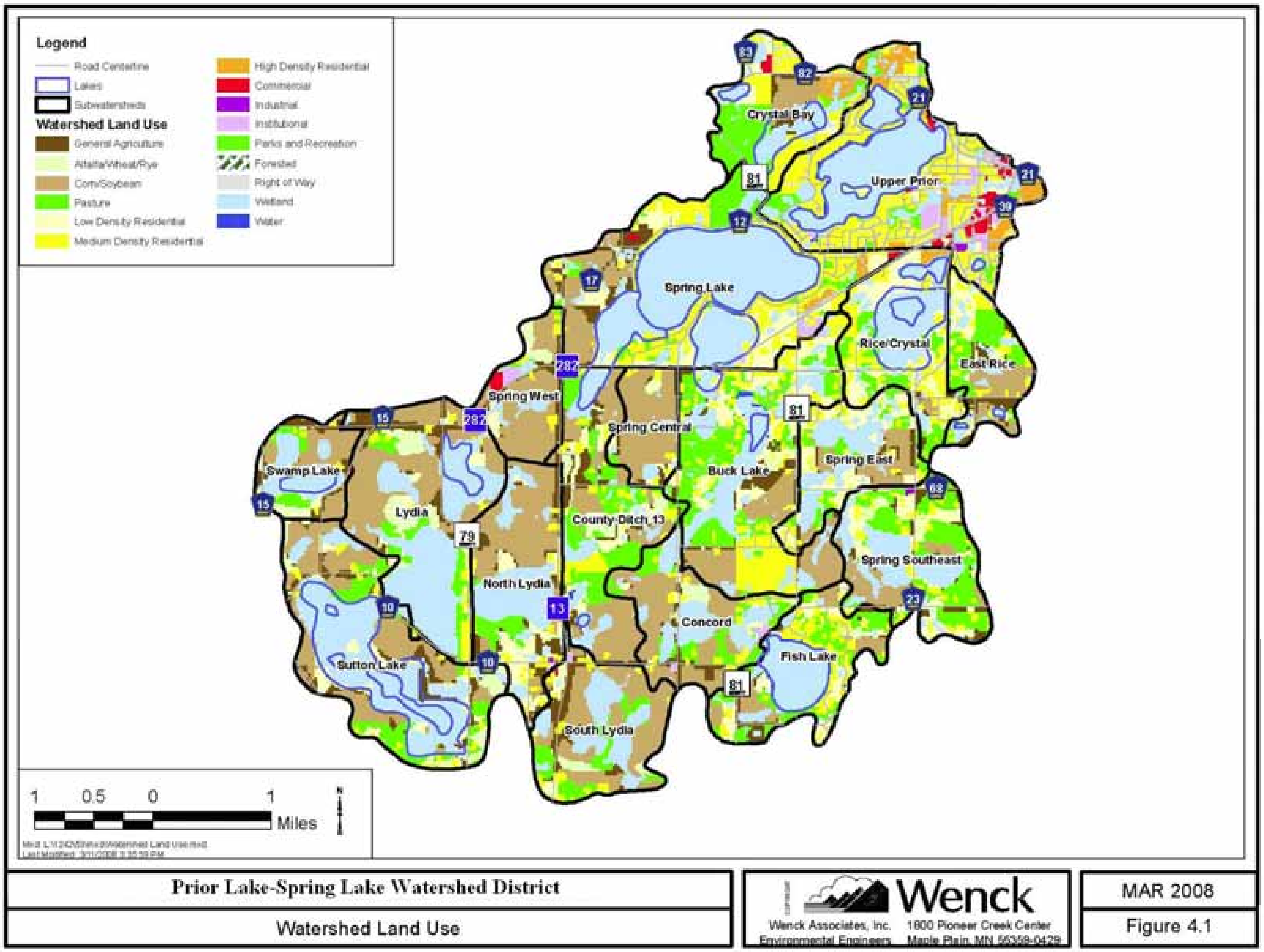


Figure 4.1. Watershed Land Use. Data sources include Met Council, City of Prior Lake, and NRCS.

Soil erodibility and saturated infiltration were used to develop a soil delivery potential (Figures 4.2 and 4.3). Land slope was calculated from 30 meter resolution Digital Elevation Models (DEM; Figure 4.4). A range of loading rates was selected to represent loading from each of the HRUs (Table 4.1). Data were selected based on literature review for land uses in Minnesota (Reckhow et al. 1980).

Table 4.1. Selected P loading rates for each HRU

Loading Class	Slope (%)	Delivery Potential	P Loading Factor (lbs/ac/yr)
General Agriculture	<8	Low	0.5
	<4	Moderate -High	1.1
	>8	Low	1.1
	>4	Moderate - High	1.6
Non-row Crops	<8	Low	0.5
	<4	Moderate -High	0.6
	>8	Low	0.6
	>4	Moderate - High	1.0
Parks	NA	NA	0.1
Corn-Soybean	<4	Low	0.9
	<4	Moderate -High	2.2
	>4	Low	2.2
	>4	Moderate - High	3.1
	>8	Low	3.1
Forested	NA	NA	0.1
Pasture	<4	Low-Moderate	0.1
	<4	High	0.2
	>4	Low-Moderate	0.2
	>4	High	0.9
	>8	Low-Moderate	0.9
Commercial	NA	NA	0.9
Industrial	NA	NA	0.9
Institutional	NA	NA	0.7
High Density Urban	NA	NA	0.9
Low Density Urban/Undeveloped	NA	NA	0.1
Medium Density Urban	NA	NA	0.7
Transportation	NA	NA	0.9
Water	NA	NA	0.0
Wetland	NA	NA	0.0

The loading rates were then adjusted to match monitored water quality data at the CD13 #2 monitoring locations (Figure 4.5). The only loading rate adjustment that occurred was for the corn-soybean rotations. Initial values had high loading at 3.9 lbs/ac/yr and moderate at 3 lbs/ac/yr. Since these were the highest rates and had a large range in the literature, they were adjusted to the current values. The loading rates were assumed to be reasonable for characterizing watershed sources of phosphorus. The loading rates were subsequently applied to the remaining, unmonitored portion of the watershed.

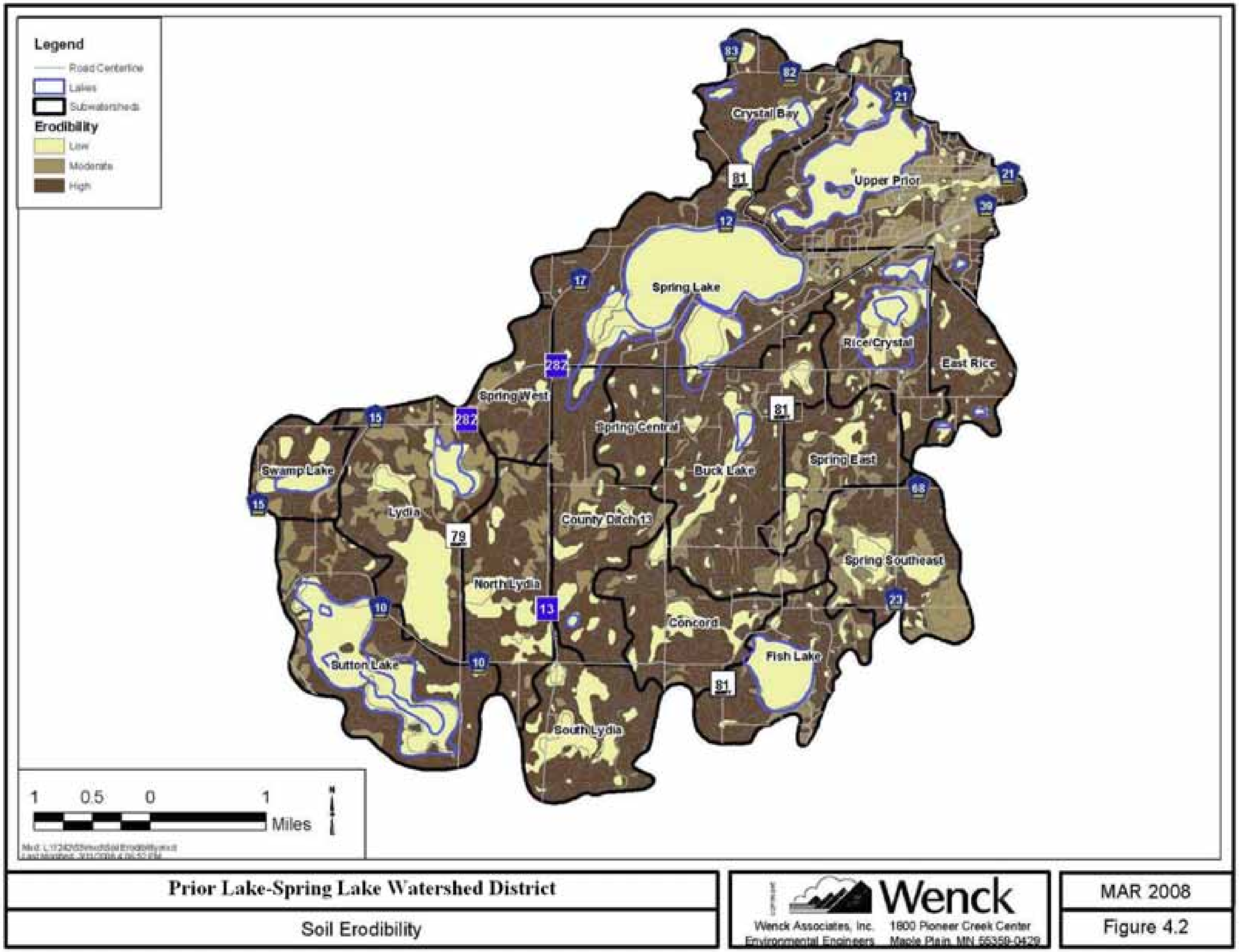


Figure 4.2. Soil Erodibility.

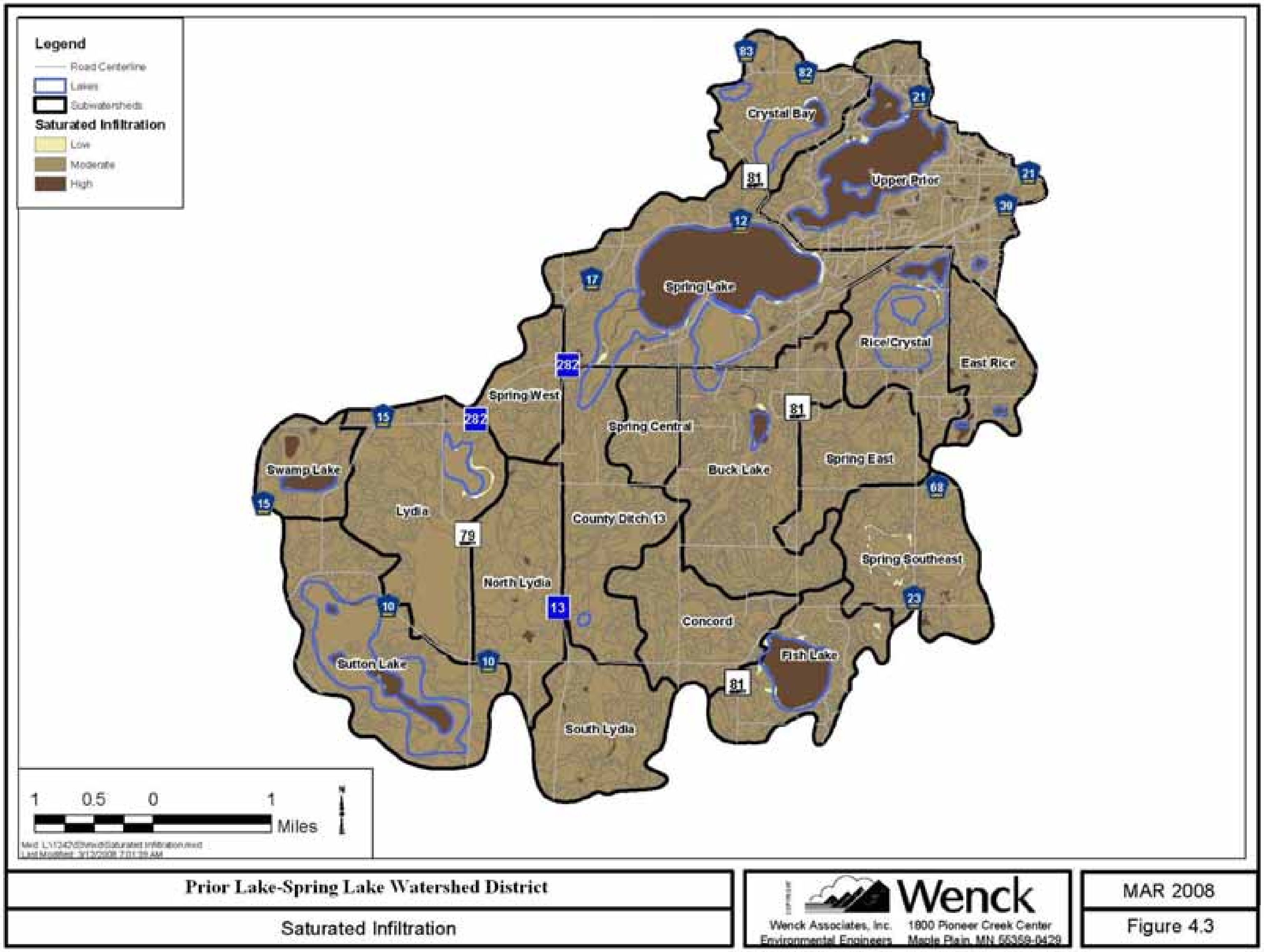


Figure 4.3. Saturated Infiltration.

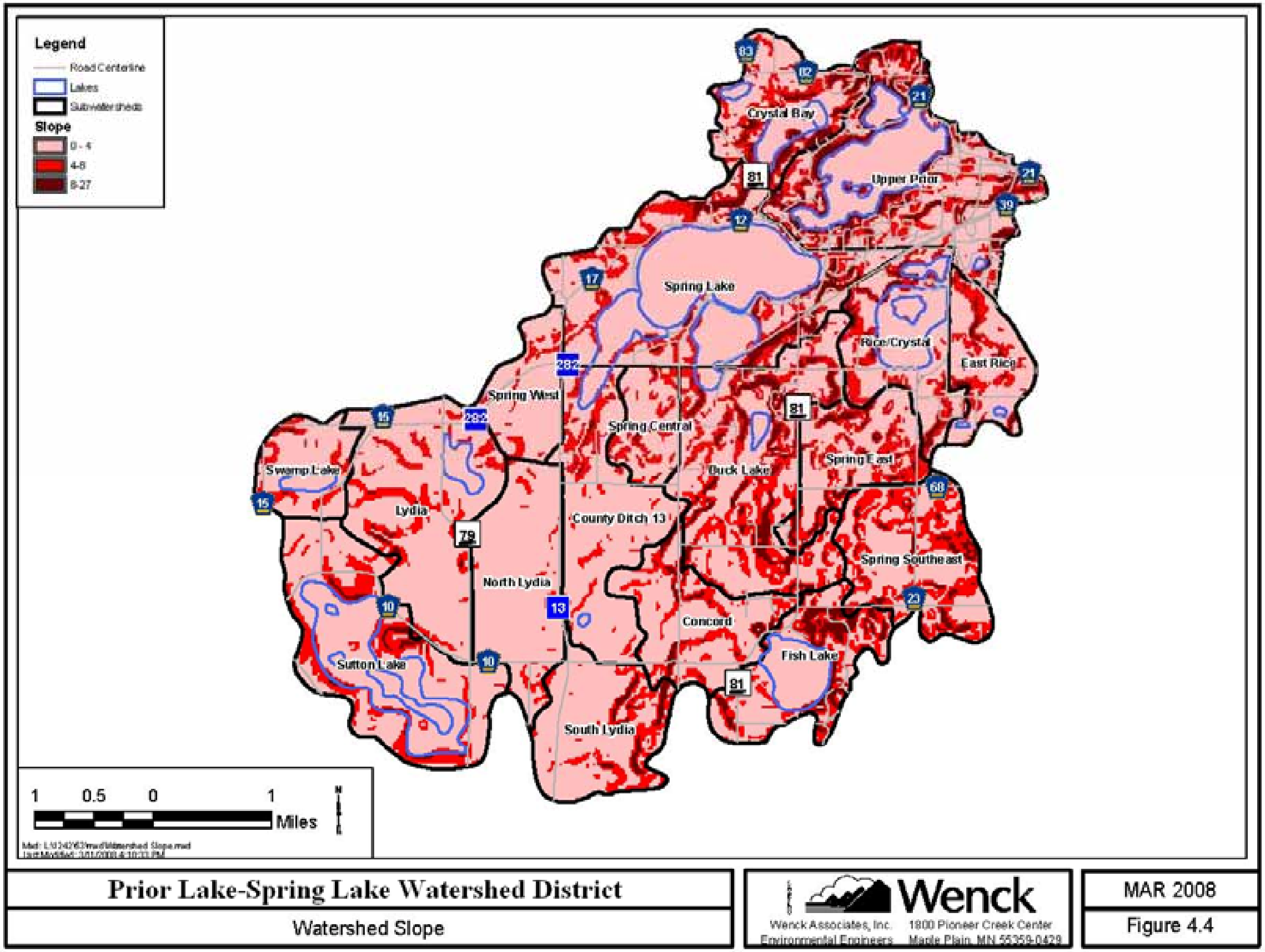


Figure 4.4. Watershed Slope.

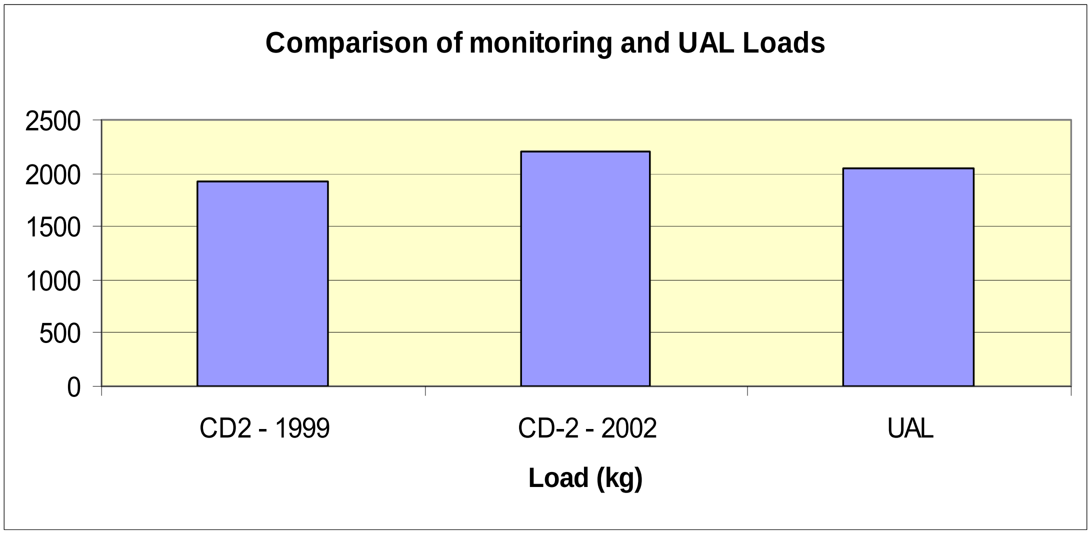


Figure 4.5. Comparison of monitored phosphorus loads from 1999 and 2002 to results of the UAL model loads.

Since both 1999 and 2002 were relatively wet years, a correction factor was developed based on volumetric ratios between the monitored years and other precipitation years. The correction factor was determined by the ratio between modeled runoff in the modeled years (1999 and 2002) and the analysis year. It is important to note that the correction factor is based off volumes for the entire watershed while runoff volumes for each year are from the calibrated SWMM model. In other words, the loads and volumes are calculated independently, providing for a range of concentrations across the years. This is consistent with monitoring data for tributaries in the watershed.

4.3 CURRENT PHOSPHORUS BUDGET COMPONENTS

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

4.3.1 Point Sources

The National Pollutant Discharge Elimination System (NPDES) regulates point sources of pollution throughout the United States. NPDES Phase II permits for small municipal separate storm sewer systems (MS4) have been issued to the City of Prior Lake, Scott County, Spring Lake Township, and the Minnesota Department of Transportation (Mn/DOT). 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.

The four MS4s are covered under the Phase II General NPDES Stormwater Permit – MNR040000. The unique identification numbers assigned to the MS4s that drain to Spring and Upper Prior Lakes, are as follows:

- City of Prior Lake - MS400113
- Scott County - MS400154
- Spring Lake Township - MS400156
- Mn/DOT Metro District - MS400170

Only those portions of Mn/DOT and Scott County that occur within the Twin Cities Urban Area, as defined by the U.S. Census Bureau, are regulated under a NPDES permit. In the case of Scott County it is only the land area occupied by stormwater conveyances (e.g., any county roads or ditches) that is regulated. The regulated area for Spring Lake Township is not limited by the boundary of the Twin Cities Urban Area, but only those stormwater conveyances owned by the township are regulated. Sand Creek Township is not a regulated MS4 and will not be in the near future. The Prior Lake-Spring Lake Watershed District does not own any stormwater conveyances in the project watershed, but owns and operates a ferric chloride treatment plant that has an NPDES permit; however, this facility is not a phosphorus source for these lakes.

4.3.2 Watershed Load and Septic System Load

The term "Watershed Load" in this study refers to stormwater discharge that is not regulated under an NPDES permit and includes runoff from nonregulated urban, agricultural and natural areas within the direct watershed.

The Watershed Loads were developed using the SWAT interface and a Unit Area Load model as described in section 4.2.2. However, one large tributary (County Ditch 13) is treated by the PLSLWD using a ferric chloride injection system. The phosphorus removal efficiency of the ferric chloride system located southwest of Spring Lake was assumed to be 30% based on monitoring conducted by the Watershed District (Barr Engineering 2003). Additionally, several of the drainages flow through lake systems prior to discharging to either Spring or Upper Prior Lake. Where data were available for the lakes (Fish, Arctic and Crystal Lakes), summer average concentrations were used to determine loads from those lakes into Spring and Upper Prior Lakes.

Apart from the Watershed Loads, Septic System Loads were calculated for the lakes based on a loading of 4.2 lb/yr per system, and an assumed 10% system failure rate. There are 626 septic systems draining to Spring Lake, and nine systems draining to Upper Prior Lake. Accordingly, the septic system loads are 263 lb/yr for Spring Lake and 3.8 lb/yr for Upper Prior Lake. All of the systems drain to the lakes via groundwater flow – i.e., there are no "straight pipes" – so they are not considered a point source.

4.3.3 Advective or Upstream Load

Lakes or bays can exchange nutrients through either advective exchange (water moving through) or diffusive exchange (molecules moving along a gradient). Diffusive exchange was assumed to be negligible between Spring Lake and Upper Prior Lake (connected by a shallow channel) and between Upper and Lower Prior Lakes (connected by a constricted channel). Thus, all exchange of phosphorus is assumed to occur through advection. Furthermore, no backwater affects are assumed in the exchange process. The watershed is small enough that it is unlikely that there are significant geographic differences in rainfall intensity and amounts across the watershed. The results from lake response modeling of Fish Lake are used as tributary contributions to Spring Lake, Spring Lake as tributary contributions to Upper Prior Lake, and Crystal Lake as tributary contributions to Upper Prior Lake.

4.3.4 Atmospheric Load

Precipitation contains phosphorus that can ultimately end up in the lakes as a result of direct input on the lake surface. Although atmospheric inputs must be accounted for in development of a nutrient budget, these inputs cannot be controlled.

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 watershed is small enough that it is unlikely that there are significant geographic differences in rainfall intensity and amounts across the watershed.

4.3.5 Internal Load

Internal phosphorus loading from lakes has been demonstrated to be an important aspect of the phosphorus budgets of lakes. However, measuring or estimating internal loads can be difficult, especially in shallow lakes that may mix many times throughout the year.

Internal loading was estimated using measured anoxic sediment P release rates with the method of Nürnberg (2005), which entails calculating an anoxic factor for each lake from lake morphometry and dissolved oxygen data. The average anoxic factors calculated for the lakes were 53 days for Spring Lake and 24 days for Upper Prior Lake. Estimates of sediment phosphorus release rates were available for Spring (17 mg/m^2-day) and Upper Prior (36 mg/m^2-day) Lakes (Barr Engineering 1999; Figures 4.6 and 4.7). Internal load is estimated as the product of (anoxic factor) x (sediment phosphorus release rate) x (lake area).

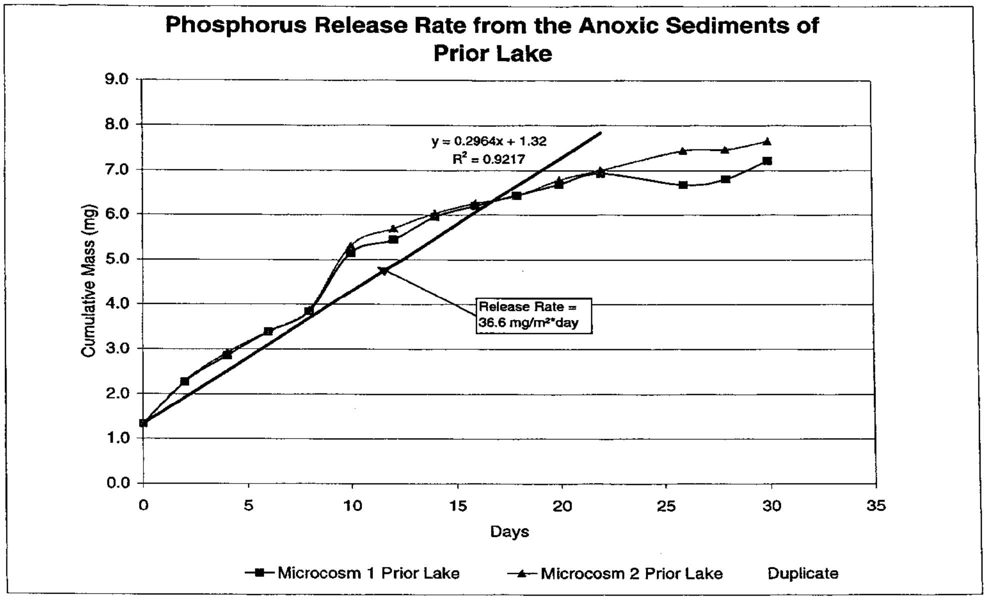


Figure 4.6. Measured anoxic phosphorus release rate from Upper Prior Lake (Barr Engineering 1999).

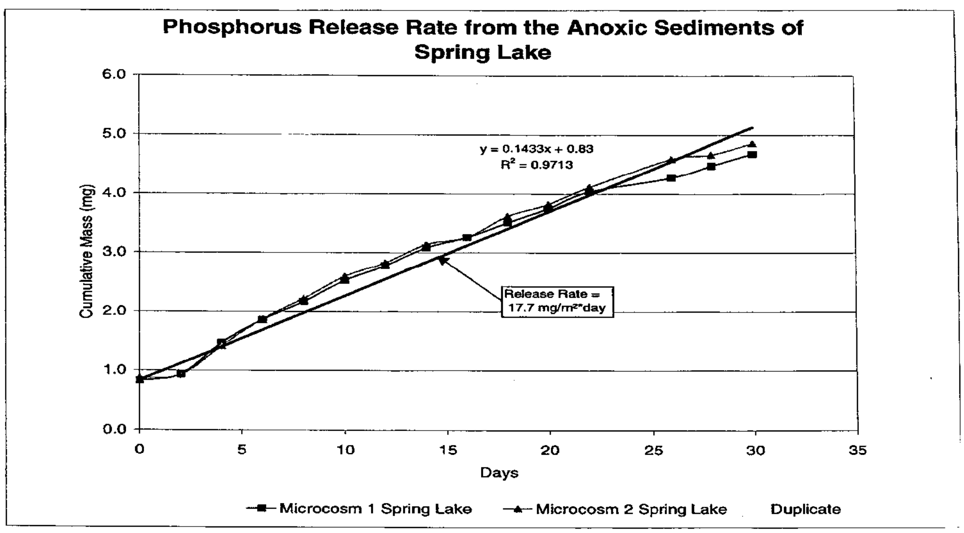


Figure 4.7. Measured anoxic phosphorus release rate from Spring Lake (Barr Engineering 1999).

Alternative values of the anoxic sediment P release rates were also calculated by a hypolimnetic mass balance approach. The total mass of phosphorus in the hypolimnion at its peak concentration (see, for example, Spring Lake data in Figure 4.8) was divided by the hypolimnetic area to estimate the release rate. This method resulted in estimated average release rates of 25 mg/m^2-day for Spring Lake and 8 mg/m^2-day for Upper Prior Lake. The Spring Lake result roughly corroborates the earlier study. The Upper Prior Lake result, however, differs markedly from the earlier study's results. The reason for the difference is unknown, but in light of the controlled conditions in the earlier study, that study's result was adopted here.

Accordingly, internal loading was calculated using an anoxic factor of 53 days and a release rate of 17 mg/m^2-day for Spring Lake, and an anoxic factor of 24 days and a release rate of 36 mg/m^2-day for Upper Prior Lake.

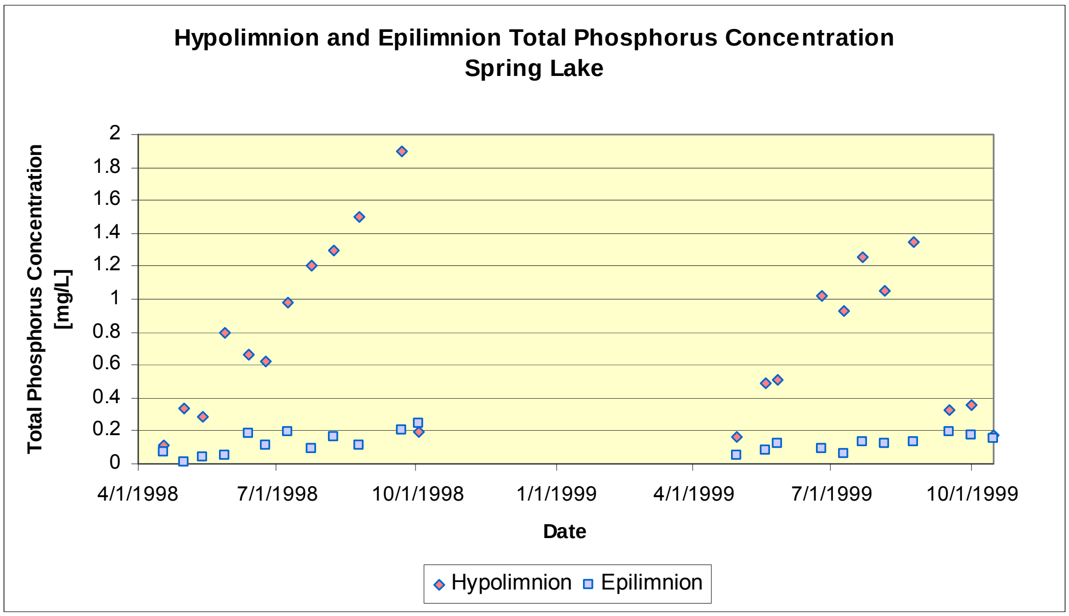


Figure 4.8. Total phosphorus concentrations in the hypolimnion and epilimnion of Spring Lake in 1998 and 1999.

4.3.6 Total Phosphorus Budget

Table 4.2 sets forth the current total phosphorus budget for Spring Lake and Upper Prior Lake. Several years' data were examined, and an average of the model predicted total annual load for 1998-2006 were used for the phosphorus budget presented in Table 4.2. 2. The upstream load is the load discharged from an upstream lake. The watershed load is the load from the watershed that is not regulated under an MS4 permit. Results of the Lake Response Model, which were used to develop the phosphorus budget for individual years, may be found in Appendix A.

Table 4.2. Current total phosphorus budget for Spring and Upper Prior Lakes based on the average from 1998-2006.

Lake		Source	Average Annual TP Load (lb)	Average Daily TP Load (lb)
Spring Lake	Wasteload	Stormwater[1]	1,352	3.7
	Load	Septic Systems	263	0.7
		Upstream Load	63	0.2
		Watershed Load	3,595	9.8
		Atmospheric Load	30	0.1
		Internal Load	5,161	14.1
		TOTAL LOAD	*10,464*	*28.6*
Upper Prior Lake	Wasteload	Stormwater[1]	419	1.1
	Load	Septic Systems	4	0.01
		Upstream Load	2,179	6.0
		Atmospheric Load	16	0.04
		Internal Load	2,598	7.1
		TOTAL LOAD	*5,216*	*14.25*

[1]Stormwater load is the load regulated under MS4 permits.

4.4 LAKE RESPONSE MODELING

Several equations used within the BATHTUB (Walker 1996) model were incorporated into a spreadsheet model and used to estimate the phosphorus, chlorophyll-a, and Secchi depth response in Spring and Upper Prior Lakes. Calibration factors were not used to adjust the model equations. Detailed results of the lake response modeling can be found in Appendix B. To validate the model, model results were compared to available phosphorus, chlorophyll-a, and Secchi depth data collected from 1998 through 2006.

Spring Lake was modeled using the Canfield-Bachmann natural lakes model. The model adequately predicted monitored phosphorus concentrations for most years (Figure 4.9). Consequently, the model was considered reasonable for Spring Lake.

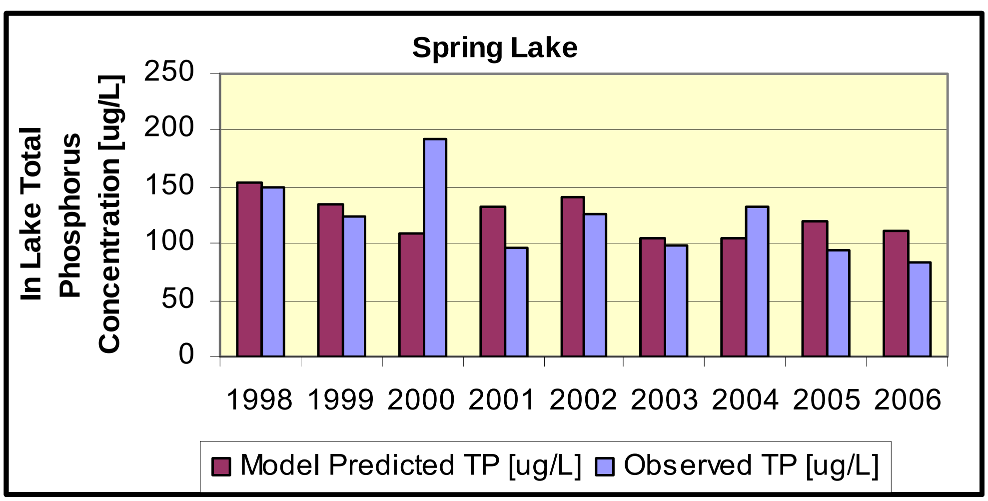


Figure 4.9. Observed and modeled TP concentrations for Spring Lake for 1998 to 2006.

The Canfield-Bachmann model was applied to Upper Prior Lake; however the model performed poorly for most years (Figure 4.10). To improve model performance, a second order decay model was selected for Upper Prior Lake, which resulted in much better water quality predictions. The water quality response model is considered reasonable for Upper Prior Lake.

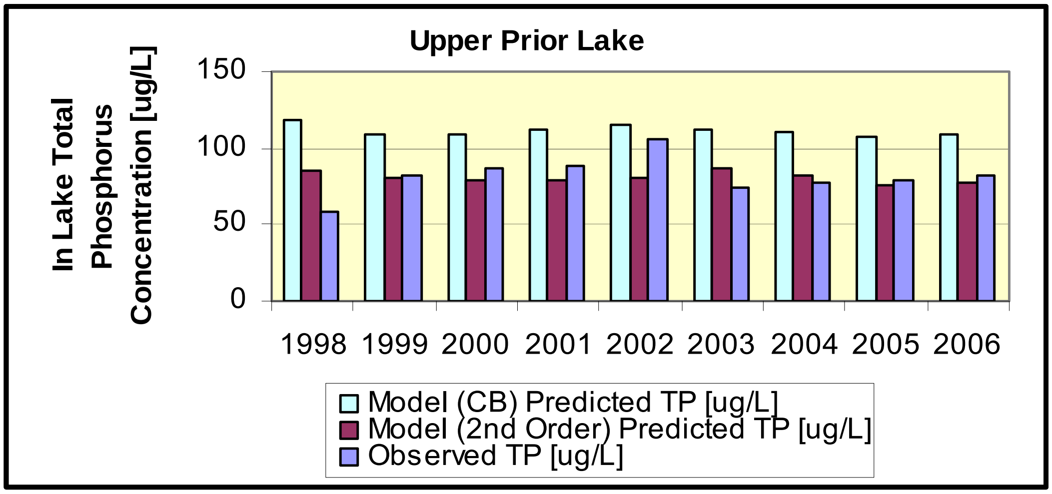


Figure 4.10. Observed and modeled total phosphorus concentrations for Upper Prior Lake for 1998 to 2006.

4.5 CONCLUSIONS

Spring Lake

- Internal phosphorus load was estimated at approximately 49% of the total load,
- Approximately 47% of the total load comes from the watershed.
- The remaining 4% represents atmospheric load and septic systems.

Upper Prior Lake

- Internal phosphorus load was estimated at approximately 50% of the total load,
- Approximately 42% of the total load comes from upstream lakes, 38% from Spring Lake alone.
- The remaining 8% represents the direct watershed load, atmospheric load and septic systems.

5.0 TMDL Allocation

5.1 LOAD AND WASTELOAD ALLOCATIONS

Nutrient loads in this TMDL are set for phosphorus. Upper Prior Lake is a shallow lake and is subject to the numeric target of 60 µg/L for total phosphorus. Spring Lake is a deep lake and therefore the numeric standard of 40 µg/L applies. This TMDL presents load and wasteload allocations for each of these lakes.

5.1.1 Allocation Approach

Nutrient loads from stormwater discharges regulated under NPDES are subject to Wasteload Allocations (WLAs) that divide the allowable load among the permit holders. Given that the Prior Lake-Spring Lake Watershed District provides strong water management oversight, the stormwater WLAs are generally combined in this TMDL as categorical, applying to the MS4s as a group (see Table 5.1). The Minnesota Department of Transportation (Mn/DOT) is the exception, as Mn/DOT requested an individual WLA. Each permittee in the categorical group is required 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.

Table 5.1. NPDES permitted facilities for each lake.

NPDES Permittee and Number	Spring Lake	Upper Prior Lake
City of Prior Lake MS400113	Categorical WLA*	Categorical WLA
MnDOT MS400170	Individual WLA	Individual WLA
Scott County MS400154	Categorical WLA	Categorical WLA
Construction Stormwater	Categorical WLA	Categorical WLA
Industrial Stormwater	Categorical WLA	Categorical WLA

*The City of Prior Lake's portion of the WLA for this lake includes area currently within Spring Lake Township (MS400156) that will ultimately be annexed by the city (see text). Until that occurs Spring Lake Township is responsible for that portion of the WLA.

In addition to the WLAs, Load Allocations (LAs) are determined for watershed areas not under an MS4 permit, atmospheric deposition, upstream lake discharges, and internal loading.

The watershed load was divided between the load allocation and wasteload allocation based on an annexation plan from the City of Prior Lake and input from the local stakeholders (Figure 5.1). Areas expected to be annexed by the City of Prior Lake were included in the categorical wasteload allocation at phosphorus export rates based on future land use after annexation. The urban expansion line in Figure 5.1 follows the 2030 annexation plan lines. Any areas not

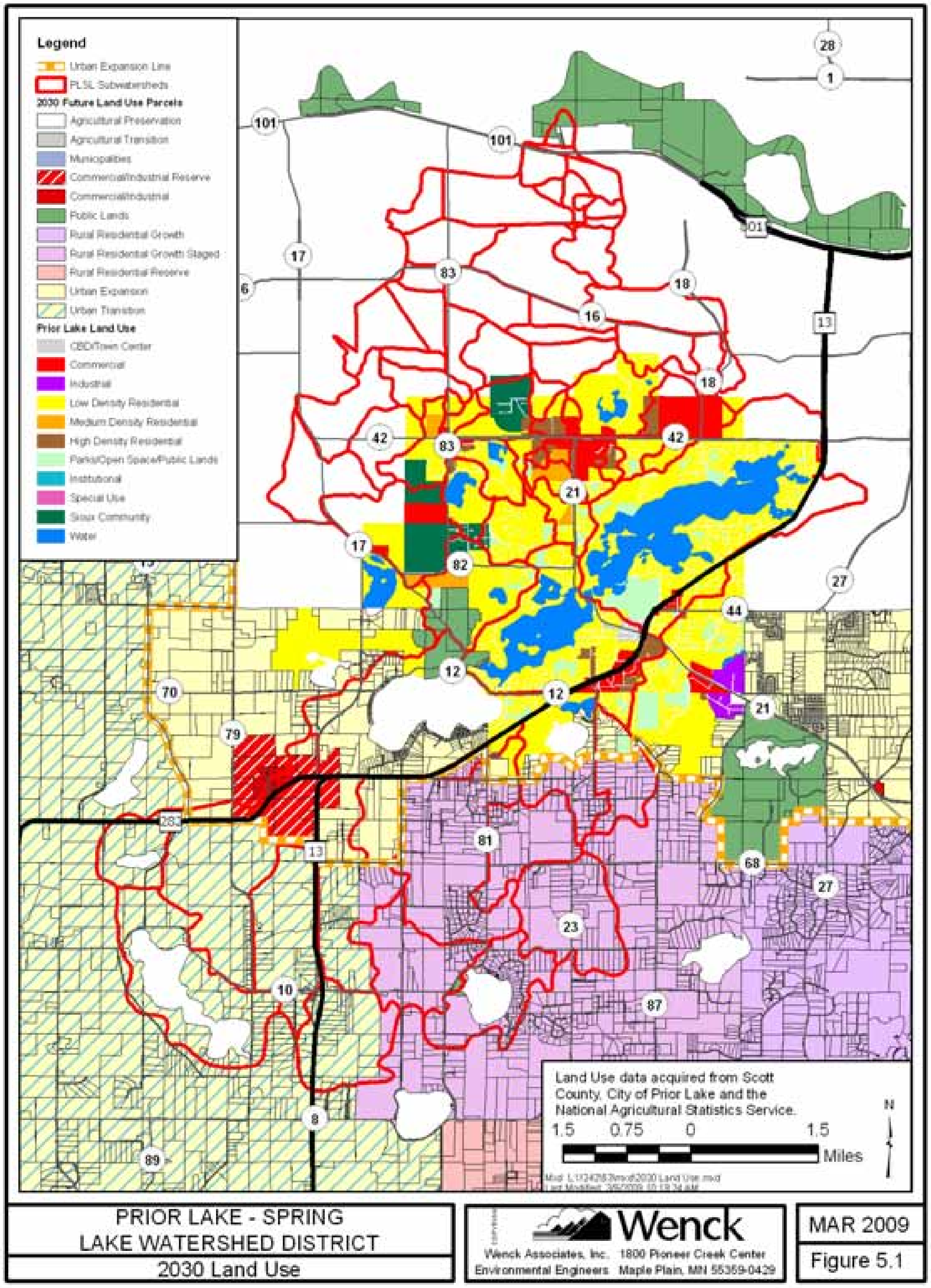


Figure 5.1. 2030 Land use plan used to set the wasteload allocation.

included in the annexation plan or within the City of Prior Lake's municipal boundaries are included in the load allocation (Table 5.2).

Table 5.2. Land areas for MS4s

MS4	Area (acres)		
	Spring Lake DA	**Upper Prior DA**	**Total DA**
Regulated MS4 Areas			
City of Prior Lake*	3,075	3,405	6,479
Mn/DOT	49	40	89
Total regulated MS4 area	**3,123**	**3,445**	**6,568**
Nonregulated Areas			
Sand Creek Township	2,238	0	2,238
Spring Lake Township†	7,309	0	7,309
Total nonregulated area	**9,547**	**0**	**9,547**
Total area	**12,670**	**3,445**	**16,115**

* City of Prior Lake areas include (1) Spring Lake Township portions inside the Urban Expansion Line, which are planned for annexation by the City, and (2) Scott County's regulated MS4 areas, which consist of transportation corridors within the Urban Expansion Line.

† Spring Lake Township portions inside the Urban Expansion Line are planned for annexation by City of Prior Lake and are included in the City's area.

5.1.2 Critical Condition

The TMDL equations represent loads for the critical conditions in the lakes. Minnesota lakes typically demonstrate impacts from excessive nutrients during the summer growing season (June 1 through September 30) including excessive algal blooms and fish kills. Consequently, the critical condition for these lakes is the summer growing season. 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.

5.1.3 Determination of Loading Capacity

The phosphorus loading capacity – that is, the maximum annual load under which a lake can achieve its water quality standards – was determined using the lake response models as described below. The TMDL is the same as the loading capacity, but expressed on an average daily basis.

The water quality models were applied to in-lake total phosphorus (TP) data (summer surface averages) for the nine-year period from 1998 through 2006 and were first used to simulate the observed conditions for each year (Section 4.4). The lakes' overall water and phosphorus budgets for each year were estimated as part of the simulations. Without changing the water budgets, the models were then applied with the overall phosphorus load reduced by 5%

increments over a range of 0% to 95% reductions. The allowable load for each lake and year can then be interpolated from the tabulated results (Appendix B). Figures 5.2 and 5.3 show the

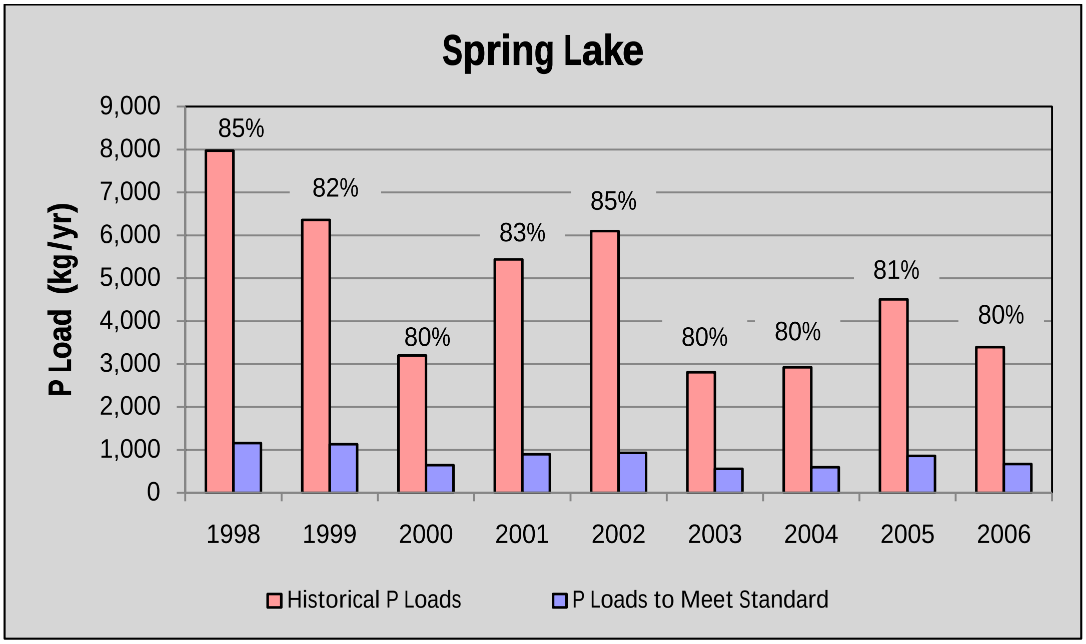


Figure 5.2. Modeled annual load and load at the standard for Spring Lake
The percentages represent the reduction needed to meet the standard.

historical and allowable loadings. The required load reductions are indicated in the figures as percentages. For the period 1998 – 2006, Spring Lake would have required load reductions of 80 to 85 percent to meet the 40-µg/L TP water quality standard for a deep lake (Figure 5.2). Upper Prior Lake would have required reductions of 33 to 48 percent to meet the 60-µg/L TP water quality standard for a shallow lake (Figure 5.3).

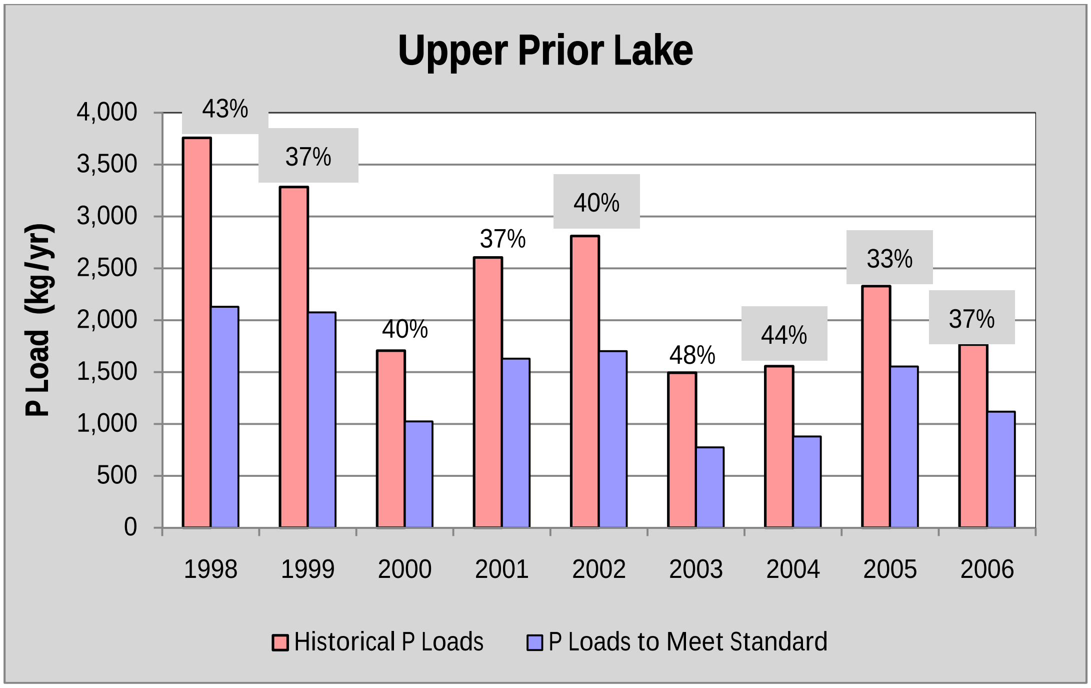


Figure 5.3. Modeled annual load and load at the standard for Upper Prior Lake.
The percentages represent the reduction needed to meet the standard.

The loading capacity for each lake was determined as the average of the annual allowable loadings for the nine-year period. For Spring Lake, the loading capacity is 1,824 lb/yr; for Upper Prior Lake, it is 3,073 lb/yr. In other words, the TMDLs (annual load capacities divided by 365.25 days per year on average) are 5.0 lb/day for Spring Lake, and 8.34 lb/day for Upper Prior Lake.

Spring Lake's TMDL produces a summer average TP of 40 µg/L, equal to the deep lake water quality standard and Upper Prior Lake's TMDL produces a summer average TP of 60 µg/L, equal to the shallow lake water quality standard. In developing the lake nutrient standards for Minnesota lakes (Minn. Rule 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (Heiskary and Wilson, 2005). Clear relationships were established between the causal factor total phosphorus and the response variables chlorophyll-a and Secchi disk. Based on these relationships it is expected that by meeting the phosphorus targets for Spring and Upper Prior Lakes the chlorophyll-a standards (14 µg/L and 20 µg/L, respectively) and Secchi standards (1.4 m and 1.0 m, respectively) will likewise be met.

5.1.4 TMDL Allocations

Tables 5.3 and 5.4 show the lakes' allocated TMDLs along with their existing loads. To achieve the TMDL in Spring Lake, the internal loading rate was reduced to a rate typical for mesotrophic lakes, 2 mg/m^2/day, and then the watershed load was reduced until the standard was met. For Upper Prior Lake, the standard can be met with reductions from Spring Lake once Spring Lake meets its TMDL requirements, plus small reductions in internal loading. So, the watershed load was held at current conditions and the internal release rate was lowered until the lake met the standard. Loads from upstream lakes were calculated based on those lakes meeting their respective state standard. Separate TMDL studies may be required for some upstream lakes.

The WLAs for MS4s in both lakes' watersheds are lumped together as categorical WLAs, except for the Minnesota Department of Transportation (Mn/DOT). The individual WLAs for Mn/DOT's right-of-way (ROW) areas were calculated using the same percentage reductions as the average for the other MS4s within each watershed. These percentage reductions are 64% for Spring Lake and 0% for Upper Prior Lake (when Spring Lake meets its water quality standards, the reduction in its outflow load will be sufficient to bring Upper Prior Lake into compliance with its standards as well). For current conditions, Mn/DOT's loads were calculated using the areal export rate of 0.9 lb/ac-yr from Table 4.1. Under the TMDL, Mn/DOT's WLA for Spring Lake corresponds to an areal export rate of 0.327 lb/ac-yr. Mn/DOT's ROW areas are 48.70 acres in Spring Lake's watershed, and 40.46 acres in Upper Prior Lake's watershed. Although parts of these areas are not yet in the Census Bureau-defined Urban Area, the total ROW areas were included in the WLAs in anticipation of the Urban Area expansion.

The WLAs are expected to reduce the amount of phosphorus export associated with development of high loading land uses under current stormwater rules. The remaining reductions required to meet the standards are expected to come from BMP implementation in the nonpermitted areas.

In the future it may be necessary to account for additional regulated discharges. For example, as development occurs within the watershed, the Census Bureau-defined Urban Area may expand or new regulated conveyances not considered in this TMDL may be established. To account for additional regulated discharges, it may be necessary to transfer load, either from the LA to the WLA or from one MS4 to another. In the event that additional stormwater discharges come under permit coverage within the watershed, load will be transferred based on the process used to set wasteload allocations in the TMDL. MS4s will be notified and will have an opportunity to comment on the reallocation.

Table 5.3. TMDL total phosphorus allocations expressed as annual and daily loads for Spring Lake.

Allocation	Source	Existing TP Load [1, 2]		TP Allocations [2]		Reduction
		lbs/year	lbs/day	lbs/year	lbs/day	lbs/year
Wasteload Allocation	MS4 - Mn/DOT	43.8	0.12	15.9	0.04	28
	MS4 - Other Municipal; see Table 5.1	1308.2	3.6	472.1	1.3	836
	Construction Stormwater					
	Industrial Stormwater					
Load Allocation	Upstream Lake	63	0.2	63	0.2	0
	Watershed Load[3]	3,595	9.8	636	1.7	2,959
	Septic	263	0.7	0	0	263
	Atmospheric	30	0.1	30	0.10	0
	Internal	5,161	14.1	607	1.7	4,554
	TOTAL LOAD	**10,464**	**28.62**	**1,824**	**5.04**	**8,640**

[1] Existing load is based on calibrated areal unit loads; water budget is the average for the years 1998-2006.
[2] Annual loads converted to daily by dividing by 365.25 days per year accounting for leap years
[3] The watershed load is the load from the watershed that is not regulated under an MS4 permit.

Table 5.4. TMDL total phosphorus allocations expressed as annual and daily loads for Upper Prior Lake.

Allocation	Source	Existing TP Load [1, 2]		TP Allocations [2]		Reduction
		lbs/year	lbs/day	lbs/year	lbs/day	lbs/year
Wasteload Allocation	MS4 - Mn/DOT	36.4	0.10	36.4	0.10	0
	MS4 - Other Municipal; see Table 5.1	382.6	1.0	382.6	1.0	0
	Construction Stormwater					
	Industrial Stormwater					
Load Allocation	Upstream Lakes	2,179	6.0	611	1.7	1,568
	Septic	4	0.01	0	0	4
	Atmospheric	16	0.04	16	0.04	0
	Internal	2,598	7.1	2,027	5.5	571
	TOTAL LOAD	**5,216**	**14.25**	**3,073**	**8.34**	**2,143**

[1] Existing load is based on calibrated areal unit loads; water budget is the average for the years 1998-2006.
[2] Annual loads converted to daily by dividing by 365.25 days per year accounting for leap year

5.2 ANNUAL AND SEASONAL 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 nine 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 though 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; but 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 where 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.

5.3 MARGIN OF SAFETY

TMDLs incorporate a margin of safety (MOS) because of scientific uncertainties that are inherent in all real-world studies. Some aspects of this TMDL study serve to reduce those scientific uncertainties. First and foremost of those aspects are the data records for the lakes, which are long term and of high quality. The data records consist of nine consecutive and recent years of in-lake data and several additional years of data extending back over two decades. Second, the in-lake modeling work made good use of these excellent data records in that all nine years of the recent record were modeled, making the in-lake water quality model a well tested, robust tool for determining the lakes' loading capacities. Thirdly, this TMDL study's estimates of the phosphorus and water loadings from the lakes' watersheds had the benefit of substantial previous watershed modeling work conducted by the watershed district. All three of these aspects of the Spring Lake – Upper Prior Lake TMDL study have minimized scientific uncertainties to a great extent.

An implicit MOS has also been incorporated into this TMDL by using a conservative modeling approach. The lake response model for total phosphorus used for this TMDL uses the rate of lake sedimentation, or the loss of phosphorus from the water column as a result of settling, to predict total phosphorus concentration. Sedimentation can occur as algae die and settle, as organic material settles, or as algae are grazed by zooplankton. Sedimentation rates in shallow lakes such as Upper Prior Lake can be higher than rates for deep lakes. Shallow lakes also differ from deep lakes in that they tend to exist in one of two stable states: turbid water and clear water.

Lake response models assume that even when the total phosphorus concentration in a lake is at or better than the state water quality standard the lake will continue to be in the turbid state. As nutrient load is reduced and other internal load management activities, such as fish community management, occur to provide a more balanced lake system, shallow lakes will tend to “flip” to a clear water condition. In that balanced, clear water condition, light penetration allows rooted aquatic vegetation to grow and stabilize the sediments thus allowing zooplankton to thrive and graze on algae at a much higher rate than is experienced in turbid waters. Hence, in a clear water state more phosphorus will be removed from the water column through settling than the model would predict.

In effect the TMDL is set to achieve water quality standards while still in a turbid water state. To achieve the beneficial use, the lake must flip to a clear water state which can support the response variables at higher total phosphorus concentrations due to increased zooplankton grazing and reduced sediment resuspension. Therefore, this TMDL is inherently conservative by setting allocations for the turbid water state.

Spring Lake is classified as a deep lake; however, its littoral area represents 47% of its total area. For this reason it shares some shallow-lake characteristics with Upper Prior Lake. The implicit MOS discussion above thus applies by and large to both lakes.

5.4 RESERVE CAPACITY/FUTURE GROWTH

Wasteload allocations were set based on orderly annexation plans for the City of Prior Lake (See Section 5.1.3). A WLA based on these annexation plans account for future growth in the watershed. Therefore, no reserve capacity is included in this TMDL.

6.0 Public Participation

6.1 INTRODUCTION

A stakeholder process was conducted for this TMDL so that interested stakeholders were involved in key decisions for the TMDL.

6.2 TECHNICAL ADVISORY COMMITTEE

A technical advisory committee was established so that interested stakeholders were involved in key decisions during developing the TMDL. Stakeholders invited to the Technical Advisory Committee include local cities and counties, Minnesota DNR, the Metropolitan Council, the 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 October 11, 2007, and January 11, 2008. Additionally, interested parties were asked to comment on the draft TMDL.

6.3 STAKEHOLDER MEETINGS AND PUBLIC COMMENT PERIOD

Stakeholder meetings were held on November 20, 2007, December 15, 2008, and March 4, 2009. During these meetings, issues were discussed including the staging for TMDL development, the use of modeling, impact of other impaired water bodies on this TMDL, the division between WLA / LA and the amount of reductions that may be expected from the different municipalities. The draft TMDL was made available for a 30-day public comment period from August 2, 2010, through September 1, 2010.

7.0 Implementation

7.1 IMPLEMENTATION FRAMEWORK

This section provides general information for overall strategy and considerations for implementation. Following approval of this TMDL an Implementation Plan will be drafted that will provide more details, with attention on cost-effectiveness for phosphorus reductions. The Prior Lake-Spring Lake Watershed District will take the lead on development of this plan.

In addition, given that the lake model in this study was calibrated to monitoring data which reflect land use and BMPs in place during the monitored period from 1998-2006, 2006 will be used as the baseline year/condition from which to gauge phosphorus reductions for determining progress toward the TMDL. Given the likely lag in lake response to decreased loading from some BMP projects the MPCA will consider crediting BMPs installed later in the monitoring period (e.g., 2004 through 2006) on a case-by-case basis.

7.1.1 Watershed and Local Plans

The Prior Lake-Spring Lake Watershed District (PLSLWD) was formed in 1970 at the request of local citizens. The District is over 42 square miles in size, and contains parts of five municipalities and townships in Scott County, Minnesota. The District's mission is "To manage and preserve the water resources of the Prior Lake-Spring Lake Watershed District to the best of our ability using input from our communities, sound engineering practices, and our ability to efficiently fund beneficial projects which transcend political jurisdictions." To accomplish this mission, the District has developed and implemented a series of watershed management plans. The first water resources management plan was prepared and adopted in 1971, in accordance with the Minnesota Statute governing watershed districts (Minn. Stat. 103D). The plan was subsequently revised and adopted in 1999 in accordance with the Metropolitan Surface Water Management Act of 1982 (Minn. Stat. 103B), and has undergone revision and has been adopted in 2010.

7.2 REDUCTION STRATEGIES

7.2.1 Annual Load Reductions

The focus in implementation will be on reducing the annual phosphorus loads to the lakes by reducing both the external water loads from the watershed and internal loads through rough fish management and curlyleaf pondweed control as well as controlling the chemical release of phosphorus.

7.2.2 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 each lake.

Following is a description of potential actions for controlling nutrients in Spring Lake and Upper Prior Lake and their respective watersheds that will be further developed in the Implementation Plan. Costs to implement these activities will range from $500,000 to $5,000,000.

7.2.2.1 Watershed Load Reductions

Nutrients from Spring Lake are the most significant source of watershed load to Upper Prior Lake. Therefore, reducing the total phosphorus load exported from Spring Lake is the key external load reduction activity for Upper Prior Lake.

Construction stormwater activities are considered in compliance with provisions of the TMDL if they obtain a Construction General Permit under the NPDES program and properly select, install, and maintain all BMPs required under the permit, including any applicable additional BMPs required in Appendix A of the Construction General Permit for discharges to impaired waters, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit.

Industrial stormwater activities are also considered in compliance with provisions of the TMDL if they obtain an Industrial Stormwater General Permit or General Sand and Gravel general permit (MNG49) under the NPDES program and properly select, install, and maintain all BMPs required under the permit, or meet local industrial stormwater requirements if they are more restrictive than requirements of the State General Permit.

The Prior Lake-Spring Lake Watershed District has recently undertaken a revision of its Water Resources Management Plan (WRMP) to incorporate information from recent studies. The updated document better reflects the current understanding on the watershed and the reiterate the District's focus to improve the water resources in the watershed.

Watershed load reductions will be implemented on an opportunistic basis, including the following:

Evaluate the need to amend rules regulating development and redevelopment; amend as necessary. The Prior Lake-Spring Lake Watershed District should consider a revision to its rules and standards that will adopt more stringent stormwater management rules. Evaluation of current rules will be done as a first step. The rules revision would consider requiring new development to incorporate site design that better reflects our current understanding of stormwater into site plans, and to retain water on site through infiltration or other volume management of the runoff from smaller rain events. Small events convey the majority of the annual phosphorus and sediment load (Pitt 1999) to downstream receiving waters. Requiring that redevelopment provide volume management will also be evaluated. Adoption of this volume management rule will limit new phosphorus and sediment loading to the lakes. Any amendments would be carried out in accordance with the process in Minnesota Statutes 103D for developing rules.

Mitigate load from development and redevelopment. As redevelopment occurs, areas with little or no treatment will be required to meet permit requirements or local rules. It may be possible to "upsize" water quality treatment BMPs for both development and redevelopment projects to increase treatment efficiency beyond the minimum required by the rules. This could be done through an incentive program, pollution credits or treatment in excess of the minimum standard funded by the District. An important goal will be to prioritize and size infrastructure based on cost efficiency.

Protect high-value wetlands to prevent phosphorus export. Numerous high-value wetlands are present in the watershed. As development or redevelopment occurs, there is the potential to discharge additional nutrients and sediment to them, altering the hydroperiod and natural assimilative characteristics and converting the wetlands from nutrient sinks to nutrient sources. The District should consider a rules revision that includes standards limiting impacts to wetland hydroperiod based on wetland classification as well as requiring pretreatment of discharges to wetlands.

The District should consider working with the Local Government Units (LGUs) responsible for administration of the Wetland Conservation Act (WCA) to prepare wetland management plans to determine if additional preventive or mitigation activities are necessary to maintain or improve the wetlands.

In an effort to better understand the current state of the wetlands within the District and to prioritize conservation efforts, the District has begun preparing a Comprehensive Wetland Protection and Management Plan (CWPMP). The CWPMP will help provide a better understanding of the wetlands within the jurisdictional boundaries of the District and will provide a priority listing for wetland restoration and protection.

Furthermore, the District has received funding from the USDA-NRCS Wetlands Reserve Enhancement Program (WREP) to fund projects that enhance and protect water resources in the District. This is a joint grant available to both the PLSLWD and the Scott WMO and has a funding level of $2.5 million to purchase permanent easements and construct restorations as needed.

Increase infiltration and filtration in the watershed. As described above, the District will consider a rules revision requiring site designs to minimize new impervious surface and management of new runoff volumes on new development and redevelopment. On existing development, the use of rain gardens, native plantings, soil amendments, and reforestation should be encouraged as a means to increase infiltration, evapotranspiration, and filtration of runoff conveying pollutant loads to the lakes. Priority will be given to measures that address infiltration and filtration in a cost effective manner.

Target street sweeping. Identify key areas and target those areas for more frequent street sweeping. The first step is to identify roads that drain to Spring and Upper Prior Lakes without any stormwater treatment.

Retrofit BMPs. Street or highway reconstruction projects, park improvements, and other projects may provide opportunities to incorporate BMPs to add or increase treatment in the watershed. The District should work cooperatively with Scott County, Spring Lake Township, and the City of Prior Lake to identify opportunities to add treatment to subwatersheds where currently there is none and to develop BMPs for street and highway projects.

Encourage shoreline restoration. The District plans to continue to encourage natural shorelines through education, demonstrations and potentially grants. The district has conducted workshops and aquascaping promotion programs in the past and plans to work with LGUs to gain a wider audience and greater effectiveness.

Conduct education and outreach awareness programs. Educate property owners in the subwatershed about proper fertilizer use, low-impact lawn care practices, and other topics to increase awareness of sources of pollutant loadings to the lakes and encourage the adoption of good individual property management practices. Lakeshore property owners should be educated about aquatic vegetation management practices and how they relate to beneficial biological communities and water quality.

Encourage agricultural conservation practice. Conservation practices in the agricultural portions of the watershed will be encouraged and include conservation tillage, buffers, and other best management practices. The District purchased a no-till drill in the past; however the drill has been moved to the Scott County SWCD where it could get wider use over the County. The District has joined forces with the Scott SWCD to promote filter strips and the Conservation Reserve Enhancement Program (CREP). The past filter strip program provided a supplemental payment for participants in the Conservation Reserve Program (CRP).

The District will continue to promote new farming techniques to help reduce the amount of input from surface runoff and tile lines. The District also intends to partner with the SWCD to conduct targeted conservation on high priority areas as well as specific projects. Of particular interest will be the promotion of wetland restoration efforts through the Wetland Reserve Enhancement Project. The District is also committed to work with the University of Minnesota to establish a "Discovery Farm" water quality monitoring site within the upper watershed to evaluate a field by field evaluation of loading from agriculture. This is in addition to the targeted runoff monitoring in 2009 and 2010 of the larger upper watershed area to evaluate loading inputs.

Finally, the District has been an educational effort to have lake residents meet and visit farmers in the area on their farms, and for farmers to meet lake residents for pontoon rides on the lakes to see the water quality issues first hand. It is hoped that this dialogue will motivate both parties to do more to address the impacts coming from their respective properties.

7.2.2.2 Internal Loads

Two options are available for controlling internal loading in Spring and Upper Prior Lakes, both of which will need to be addressed to be effective. The primary option for the control of internal loading is likely to be chemical binding of sediment phosphorus using alum or iron additions. The secondary approach will be biological manipulation. This will include integrated plans for each lake to manage the aquatic vegetation, fish, and zooplankton communities to reduce nutrient loads and maintain a level of water clarity that is desirable both aesthetically and for maintenance of a fishery.

Sediment phosphorus inactivation. One of the most effective ways to reduce internal loading is to bind sediment phosphorus with a chemical agent such as alum or iron. Alum provides a long term stable bond with phosphorus and can be quite effective in controlling internal loading. Alum was identified in the past as the preferred method for controlling internal loading in Spring Lake by the District. The District estimated alum dosing at $160,000 but has not done the project.

Vegetation management. Curlyleaf pondweed is present in both Spring and Upper Prior Lakes and is at nuisance levels in some areas. Senescence of the curlyleaf pondweed in summer is a significant source of internal phosphorus loading that often results in a late summer nuisance algal bloom. Vegetation management such as several successive years of chemical treatment will be required to keep this exotic invasive species at non-nuisance levels.

The District has prepared whole lake macrophyte management plans for both Spring Lake and Upper Prior Lake.

As BMPs are implemented and water clarity improves, the aquatic vegetation community will change. Surveys should be updated periodically and vegetation management plans amended to take into account appropriate management activities for the changing community.

Manage fish populations. Partner with the DNR to monitor and manage the fish population to maintain a beneficial community. As the aquatic vegetation changes to a more desirable mix of species, it may be possible to restore a more balanced fish community that includes both panfish and top predators. Options to reduce rough fish populations should be evaluated, and the possibility of fish barriers explored to reduce rough fish access to spawning areas and to minimize rough fish migration between lakes.

7.2.3 Studies

Better carp management. The District has worked on Carp reduction over the years, however with limited success in affecting water quality. One approach will be to invest in a better understanding of the carp population in Spring and Upper Prior Lakes including utilized habitat, migration, and population size. The District is considering developing a carp management plan to evaluate and address carp in the Spring and Prior Lake system to reduce their effects on water quality.

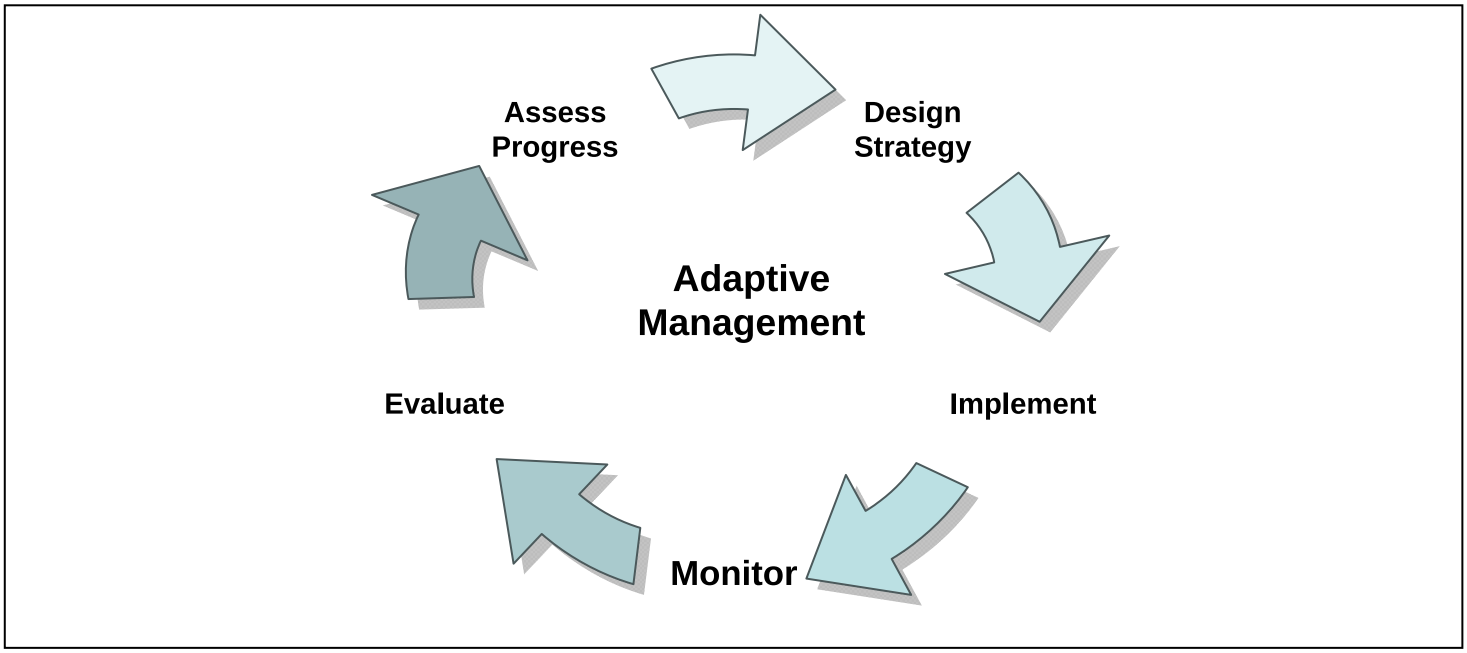
Monitoring. The District is developing a monitoring plan that focuses on the adaptive management approach outlined in this TMDL. The monitoring plan will focus on collecting data to reduce the uncertainty in the modeling approach as well as track improvements in water quality associated with District activities.

7.3 IMPLEMENTATION STRATEGY

The load allocations in the TMDL represent aggressive goals for nutrient reductions and are highly dependent on the achievement of reductions in an upstream watershed. Consequently, implementation will be conducted using adaptive management principles (Figure 7.1). Adaptive management is appropriate because it is difficult to predict the lake response that will occur from implementing strategies with the paucity of information available to demonstrate expected reductions. Future technological advances may alter the course of actions detailed here. Continued monitoring and "course corrections" responding to monitoring results are the most appropriate strategies for attaining the water quality goals established in this TMDL.

Based on the understanding of the appropriate standards for lakes, this TMDL has been established with the intent to implement all reasonably appropriate activities. If all of the appropriate BMPs and activities have been implemented and any of the lakes still do not meet the current water quality standards, the TMDL will be reevaluated and the Prior Lake-Spring Lake Watershed District 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 7.1. Adaptive Management



8.0 Reasonable Assurance

8.1 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 the lakes. In fact there are few, if any, examples where these levels of reductions have been achieved where the sources were primarily nonpoint source in nature.

The TMDL will be implemented on an iterative basis so that course corrections based on periodic monitoring and reevaluation can be made. 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 other lake problems not directly linked to phosphorus loading such as invasive plant species (curlyleaf pondweed) and invasive fish (carp). These practices go beyond the traditional nutrient controls and provide additional protection for lake water quality.

8.2 PRIOR LAKE-SPRING LAKE WATERSHED DISTRICT

The District was formed in 1970. The first management plan was prepared in 1971 with an update in 1999. The update was done according to the state requirements set forth in Minnesota statutes.

The Metropolitan Surface Water Management Act (Chapter 509, Laws of 1982, Minnesota Statute Section 473.875 to 473.883 as amended) establishes requirements for watershed management plans within the Twin Cities Metropolitan Area. The law requires plans to focus on preserving and using natural water storage and retention systems to:

- Improve water quality
- Prevent flooding and erosion from surface flows
- Promote groundwater recharge
- Protect and enhance fish and wildlife habitat and water recreation facilities
- Reduce, to the greatest practical extent, the public capital expenditures necessary to control excessive volumes and rate of runoff and to improve water quality
- Secure other benefits associated with proper management of surface water

Minnesota Rules Chapter 8410 requires watershed management plans to address eight management areas and to include specific goals and policies for each to serve as a management framework. To implement its approved watershed management plan, the PLSLWD has undertaken a number of activities, including administering rules and standards regulating stormwater runoff quantity and quality from development and redevelopment in the district; operating a lake and ditch monitoring program; constructing improvements to the Prior Lake outlet system; managing nuisance aquatic vegetation in Spring and Prior Lakes through chemical treatment; and constructing improvements to improve water quality, including construction and ongoing operations of the Highway 13 wetland ferric chloride treatment system at the southwest corner of Spring Lake.

The District has prepared its "Third Generation" watershed management plan. This plan focuses on stormwater volume management and water quality improvement, and includes a revised Capital Improvement Program and Implementation Plan. Amended rules will incorporate more stringent stormwater volume management requirements for new development. Following completion and adoption of that Third Generation Plan, each of the local governments with land in the watershed must within two years revise their Local Water Management Plans to be consistent with the revised PLSLWD plan.

The District has been and will continue to work with the City of Prior Lake and Scott County Soil and Water Conservation District to incorporate new, innovative and established BMPs to treat stormwater before it carries nutrients into the lakes. Through cooperation with these different agencies, a number of different BMPs have been installed, treating runoff from areas that have not had treatment in the past.

As a means to address internal loading in Spring and Upper Prior Lakes, the District has worked to address issues with both carp and curlyleaf pondweed. The District has partnered with a contractor to conduct carp seining in Spring Lake and is willing to conduct additional efforts in the future when opportunities arise. The District has also conducted both mechanical and chemical treatments for curlyleaf pondweed in the past and has seen some success; curlyleaf pondweed numbers had decreased and native species began to repopulate the lake bottom. The District remains willing to conduct additional efforts in the future if surveys indicate a need. With the treatment of curlyleaf pondweed, there is a concern that a decline in curlyleaf pondweed numbers could allow for an increase in Eurasian water milfoil. The District will continue to monitor submerged macrophyte populations and will adjust its management strategies when warranted.

8.3 NPDES MS4 STORMWATER PERMITS

NPDES Phase II stormwater permits are in place for the City of Prior Lake, Scott County and Mn/DOT which discharge to Spring Lake and Upper Prior Lake. Sand Creek Township is not a mandatory MS4 and hence does not require a stormwater permit. The City of Savage has land in the watershed, but it discharges stormwater downstream of Spring Lake and Upper Prior Lake. The PLSLWD is a permit holder for the Outlet Channel that flows out of Lower Prior Lake to the Minnesota River. Under the NPDES stormwater program, permit holders are required to develop and implement a Stormwater Pollution Prevention Program (SWPPP). The SWPPP must cover six minimum control measures:

- Public education and outreach
- Public participation/involvement
- Illicit discharge, detection and elimination
- Construction site runoff control
- Post-construction site runoff control
- Pollution prevention/good housekeeping.

The permit holder must identify BMPs and measurable goals associated with each minimum control measure.

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 the lakes will comply with this requirement during the implementation planning period of the TMDL. The implementation plan will identify specific BMP opportunities sufficient to achieve their load reduction and the individual SWPPPs will be modified accordingly as a product of this plan.

MS4s contributing stormwater to Spring Lake and Upper Prior Lake are covered under the Phase II General NPDES Stormwater Permit – MNR040000. The unique NPDES Phase II identification numbers assigned to the small municipal separate storm sewer systems (MS4) that contribute drainage to Spring and Upper Prior Lakes are as follows:

- City of Prior Lake - MS400113
- Scott County - MS400154
- Mn/DOT Metro District - MS400170

8.4 MONITORING

8.4.1 Monitoring Implementation of Policies and BMPs

The PLSLWD will evaluate progress toward meeting the goals and policies outlined in the Implementation Plan in its Annual Report. Success will be measured by completion of policies and strategies, or progress toward completion of policies and strategies. The findings of the Annual Report and the comments received from the member cities and the public will then be used to formulate the work plan, budget, Capital Improvement Plan 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.

8.4.2 Follow-up Monitoring

The PLSLWD monitors water quality in these lakes through the funding of special studies and citizen volunteer efforts. Results of all monitoring are included in the Annual Report. Spring and Upper Prior Lakes will be periodically monitored through the CAMP program. The CAMP program is operated by the Metropolitan Council Environmental Services and is a volunteer monitoring program. Citizen volunteers collect data and samples biweekly throughout the monitoring season.

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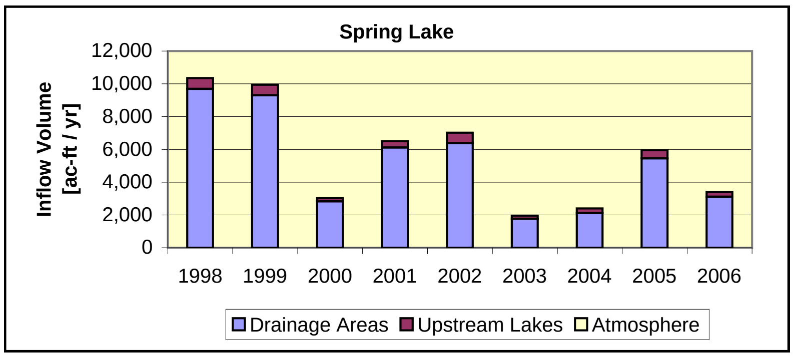
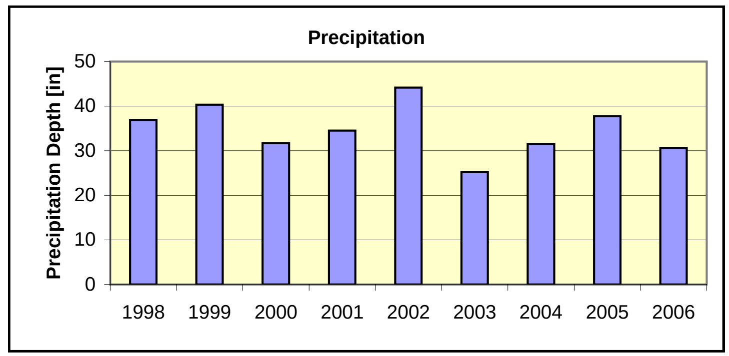
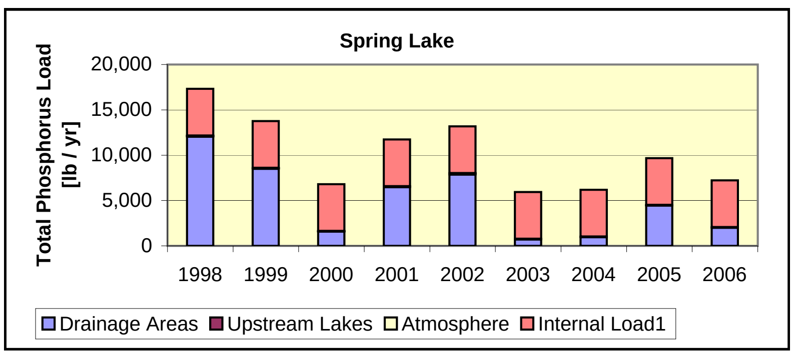
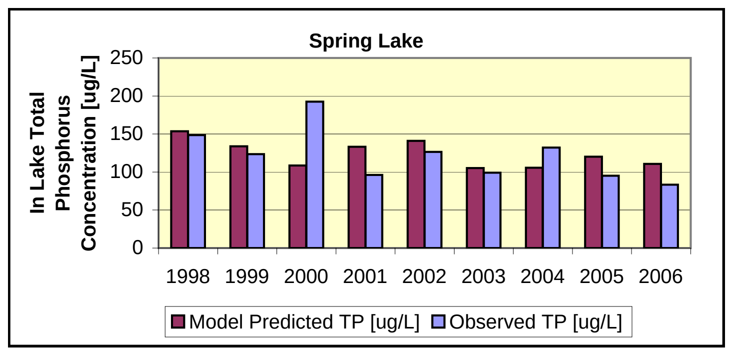
Spring Lake	**Source**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Precipitation Depth [in]		36.9	40.3	31.7	34.5	44.2	25.2	31.5	37.8	30.6
	Residence Time [yr]	1.0	1.0	3.4	1.6	1.5	5.2	4.3	1.7	3.0
Inflow Volume [ac-ft / yr]	Drainage Areas	9690	9298	2823	6109	6390	1766	2113	5445	3107
	Upstream Lakes	659	645	204	394	628	188	288	514	296
	Atmosphere	0	0	0	0	0	0	0	0	0
	TOTAL =	**10349**	**9943**	**3027**	**6503**	**7017**	**1955**	**2400**	**5959**	**3403**
Total Phosphorus Load [lb / yr]	Drainage Areas	12038	8489	1576	6474	7856	713	950	4436	1992
	Septic Systems	263	263	263	263	263	263	263	263	263
	Upstream Lakes	90	79	30	71	130	29	45	55	36
	Atmosphere	29	34	29	29	34	29	29	29	29
	Internal Load[1]	5161	5161	5161	5161	5161	5161	5161	5161	5161
	TOTAL =	**17580**	**14025**	**7058**	**11997**	**13444**	**6195**	**6448**	**9943**	**7481**
Model Results	Model Predicted TP [ug/L]	154	134	109	133	141	105	106	120	111
	Observed TP [ug/L]	149	124	193	96	126	99	132	95	83
	Phosphorus Sedimentation [lb]	13257	10408	6165	9643	10755	5635	5758	7995	6457
	TOTAL OUTFLOW [lb] =	***4323***	***3616***	***893***	***2354***	***2689***	***560***	***690***	***1949***	***1024***
[1] Internal Load Factors:	*Release Rate [mg/m2-day]*	*17*	*17*	*17*	*17*	*17*	*17*	*17*	*17*	*17*
	Anoxic factor [day]	*53*	*53*	*53*	*53*	*53*	*53*	*53*	*53*	*53*

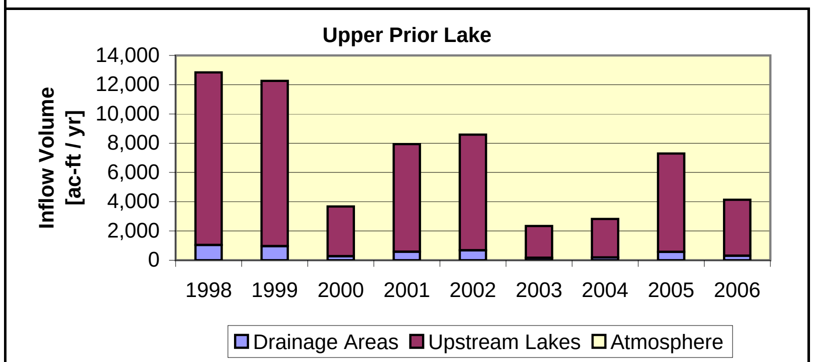


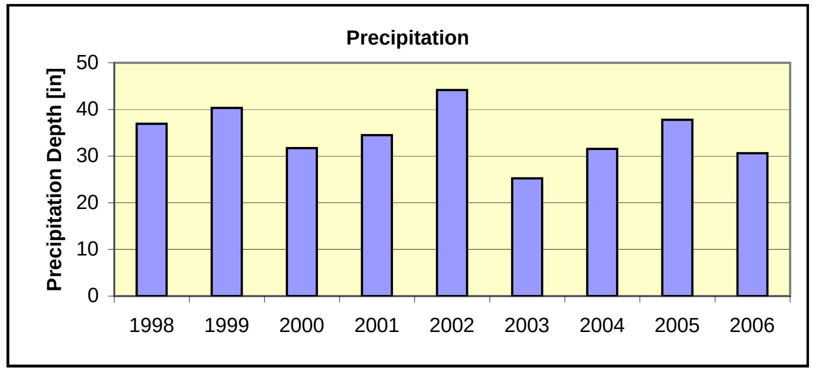


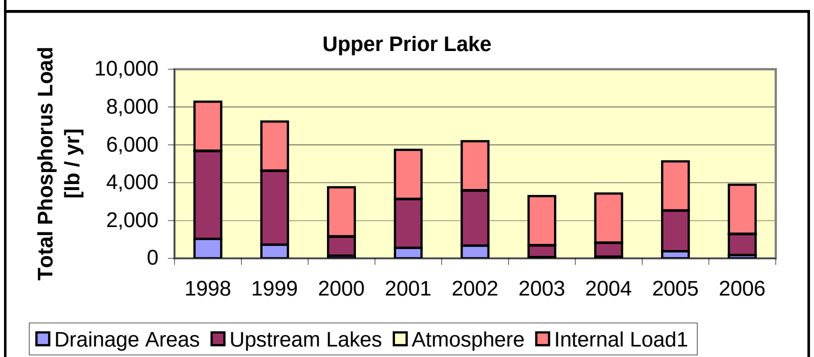


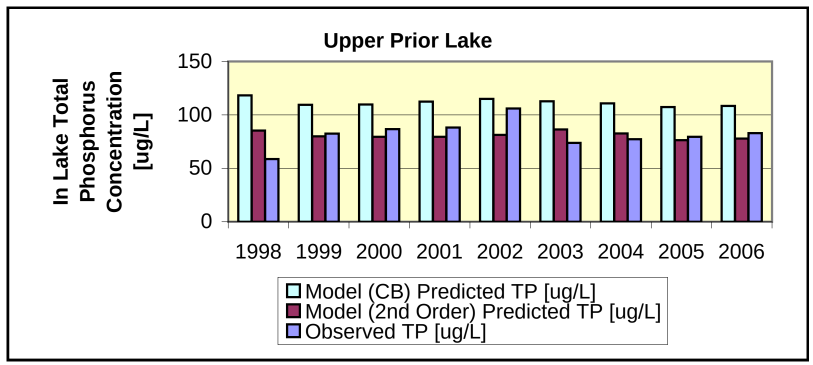


Upper Prior Lake	Source	1998	1999	2000	2001	2002	2003	2004	2005	2006
Precipitation Depth [in]		36.9	40.3	31.7	34.5	44.2	25.2	31.5	37.8	30.6
	Residence Time [yr]	0.3	0.3	1.0	0.5	0.4	1.5	1.3	0.5	0.9
Inflow Volume [ac-ft / yr]	Drainage Areas	1,035	960	270	585	676	167	188	571	310
	Upstream Lakes	11,807	11,302	3,405	7,360	7,911	2,172	2,639	6,727	3,828
	Atmosphere	0	0	0	0	0	0	0	0	0
	TOTAL =	**12,842**	**12,262**	**3,675**	**7,945**	**8,587**	**2,339**	**2,827**	**7,298**	**4,138**
Total Phosphorus Load [lb / yr]	Drainage Areas	1,020	719	134	548	666	60	80	376	169
	Septic Systems	4	4	4	4	4	4	4	4	4
	Upstream Lakes	4,649	3,899	1,012	2,578	2,914	617	735	2,141	1,107
	Atmosphere	15	18	15	15	18	15	15	15	15
	Internal Load[1]	2,598	2,598	2,598	2,598	2,598	2,598	2,598	2,598	2,598
	TOTAL =	**8,285**	**7,238**	**3,762**	**5,743**	**6,199**	**3,294**	**3,432**	**5,133**	**3,892**
Model Results	Model (2nd Order) Predicted TP [ug/L]	85	80	79	79	81	86	83	76	78
	Observed TP [ug/L]	59	83	87	88	106	74	77	80	83
[1] Internal Load Factors:	*Release Rate [mg/m2-day]*	*36*	*36*	*36*	*36*	*36*	*36*	*36*	*36*	*36*
	Anoxic factor [day]	*24*	*24*	*24*	*24*	*24*	*24*	*24*	*24*	*24*



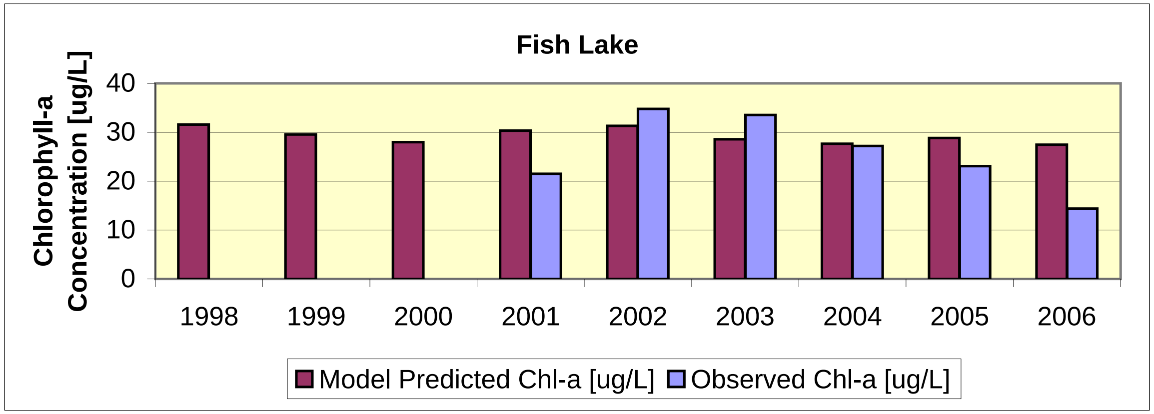


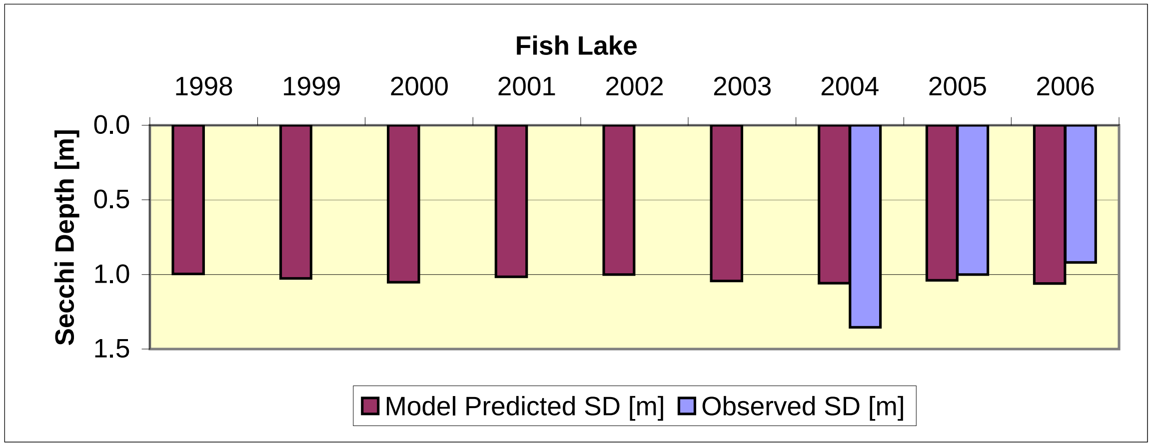




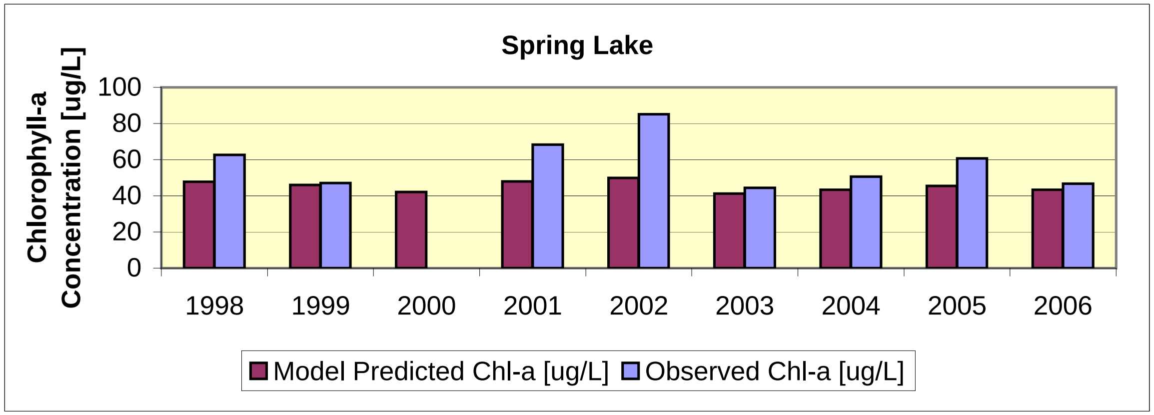
Water Quality Response Data

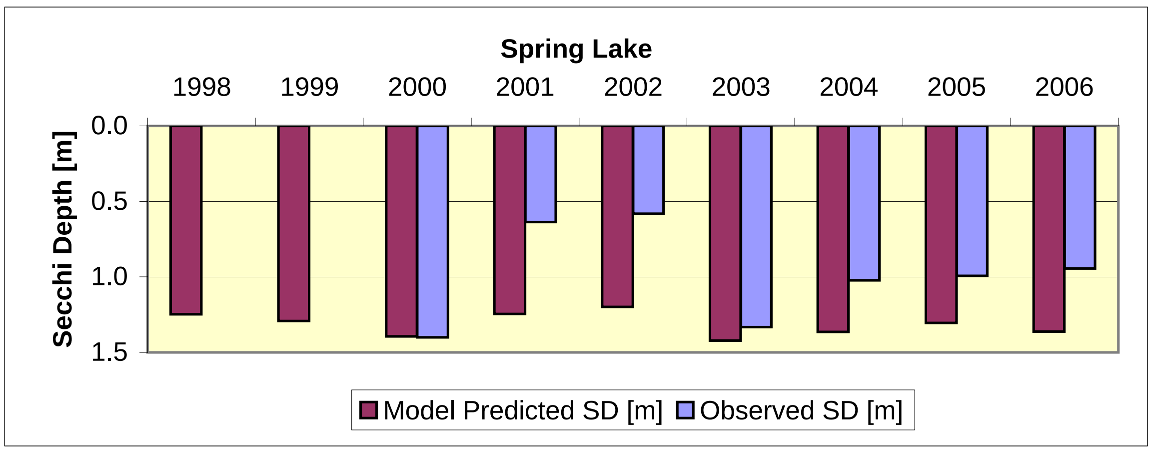
Fish Lake	Model Results								
	1998	***1999***	***2000***	***2001***	***2002***	***2003***	***2004***	***2005***	***2006***
Model Predicted Chl-a [ug/L]	32	30	28	30	31	29	28	29	27
Observed Chl-a [ug/L]				22	35	34	27	23	14
Model Predicted SD [m]	1.0	1.0	1.1	1.0	1.0	1.0	1.1	1.0	1.1
Observed SD [m]							1.4	1.0	0.9



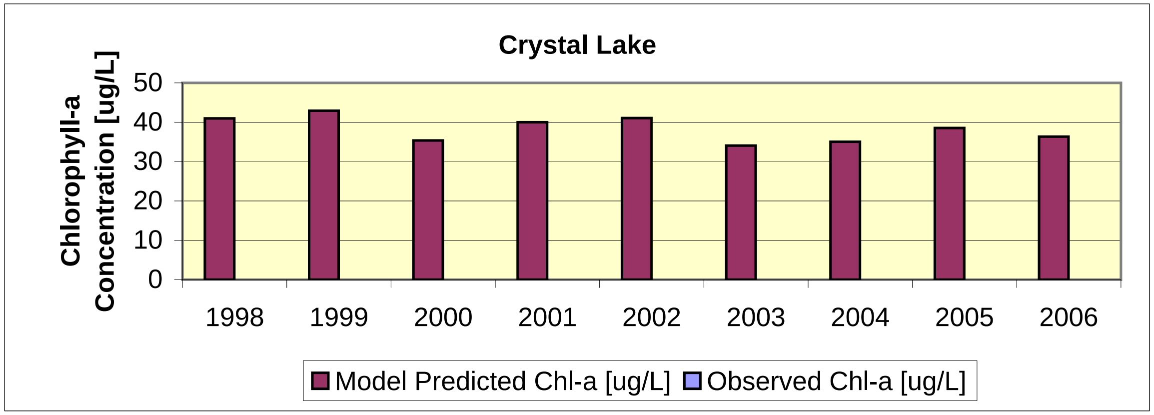


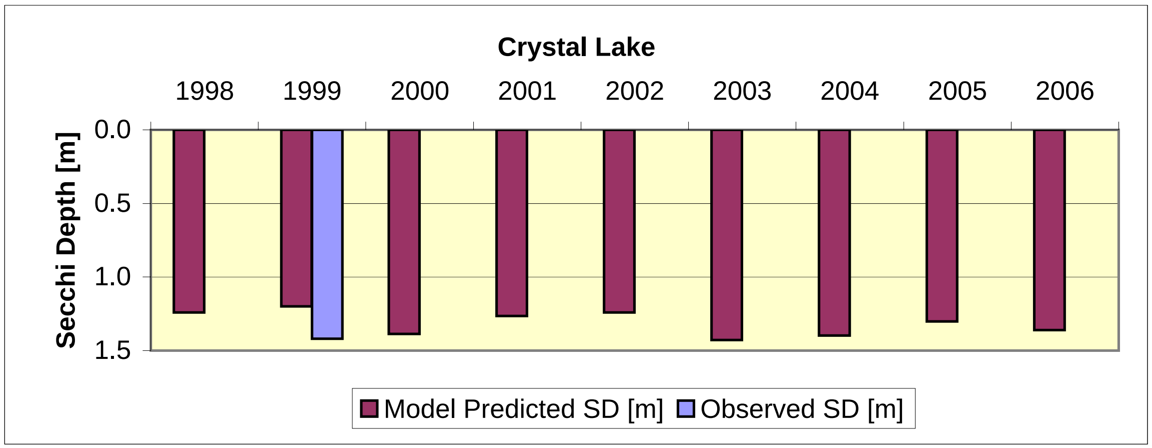
Spring Lake	***Model Results***								
	1998	***1999***	***2000***	***2001***	***2002***	***2003***	***2004***	***2005***	***2006***
Model Predicted Chl-a [ug/L]	48	46	42	48	50	41	43	46	43
Observed Chl-a [ug/L]	63	47		68	85	44	51	61	47
Model Predicted SD [m]	1.2	1.3	1.4	1.2	1.2	1.4	1.4	1.3	1.4
Observed SD [m]			1.4	0.6	0.6	1.3	1.0	1.0	0.9



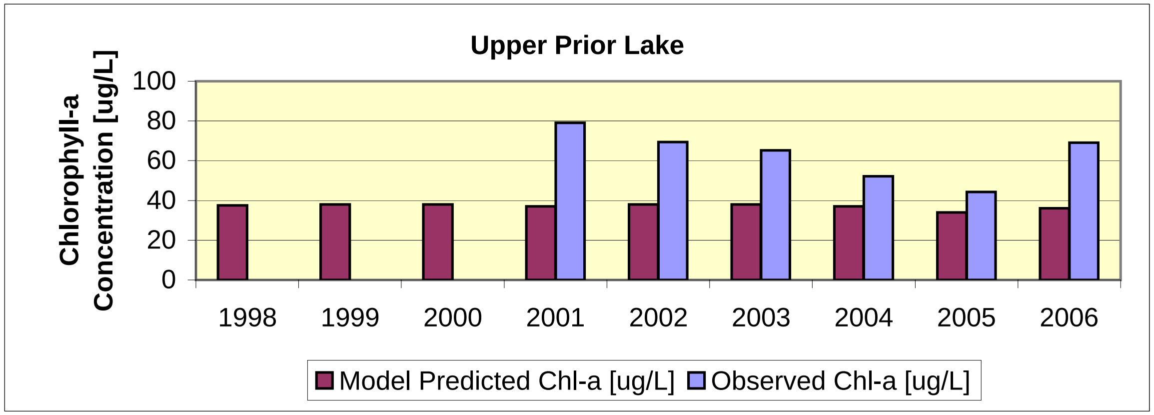


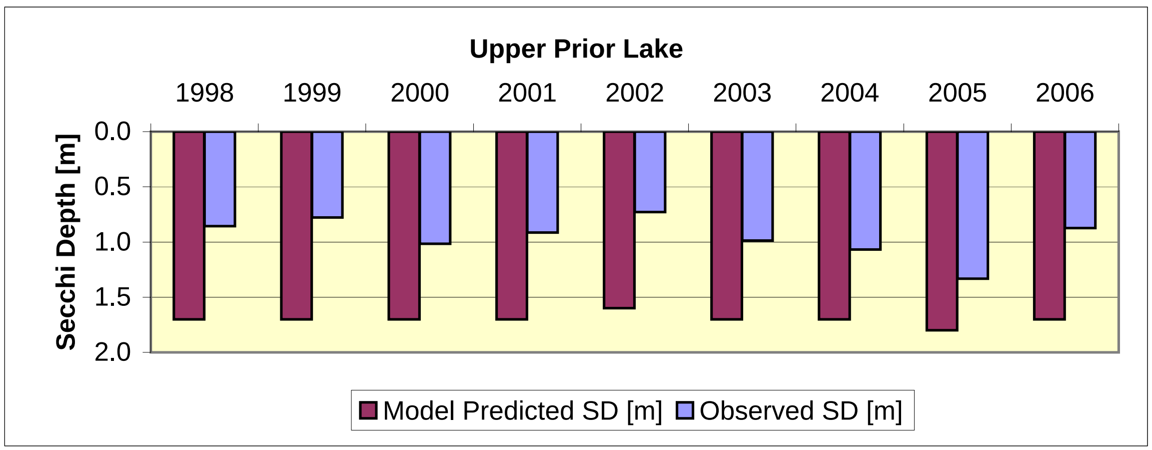
Crystal Lake	Model Results								
	1998	1999	2000	2001	2002	2003	2004	2005	2006
Model Predicted Chl-a [ug/L]	41	43	35	40	41	34	35	39	36
Observed Chl-a [ug/L]									
Model Predicted SD [m]	1.2	1.2	1.4	1.3	1.2	1.4	1.4	1.3	1.4
Observed SD [m]		1.4							

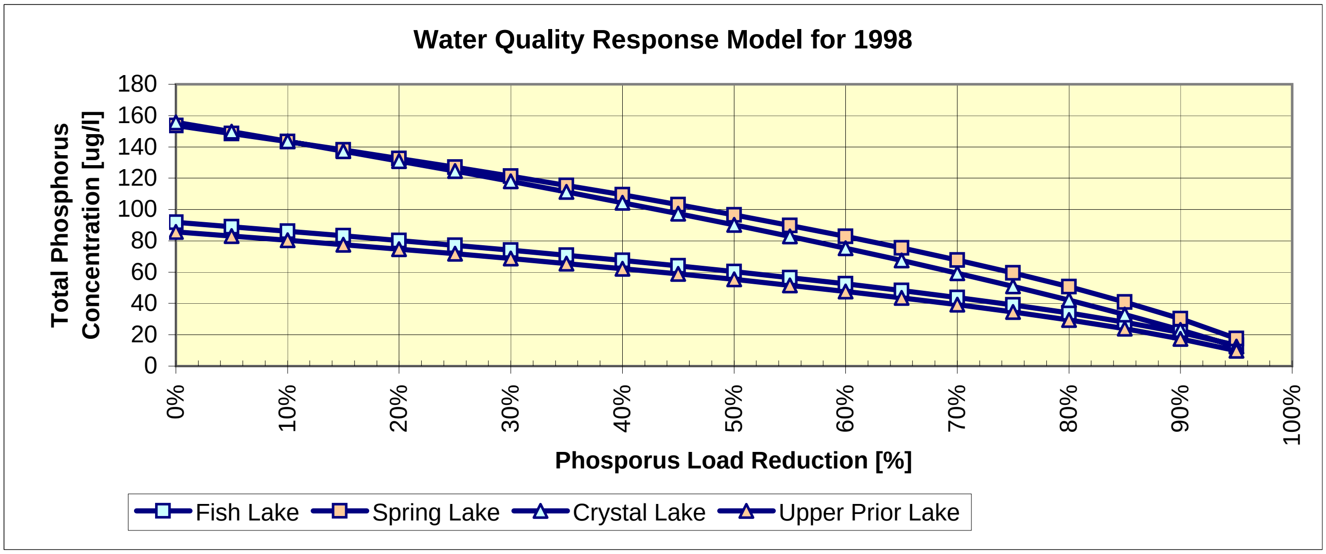


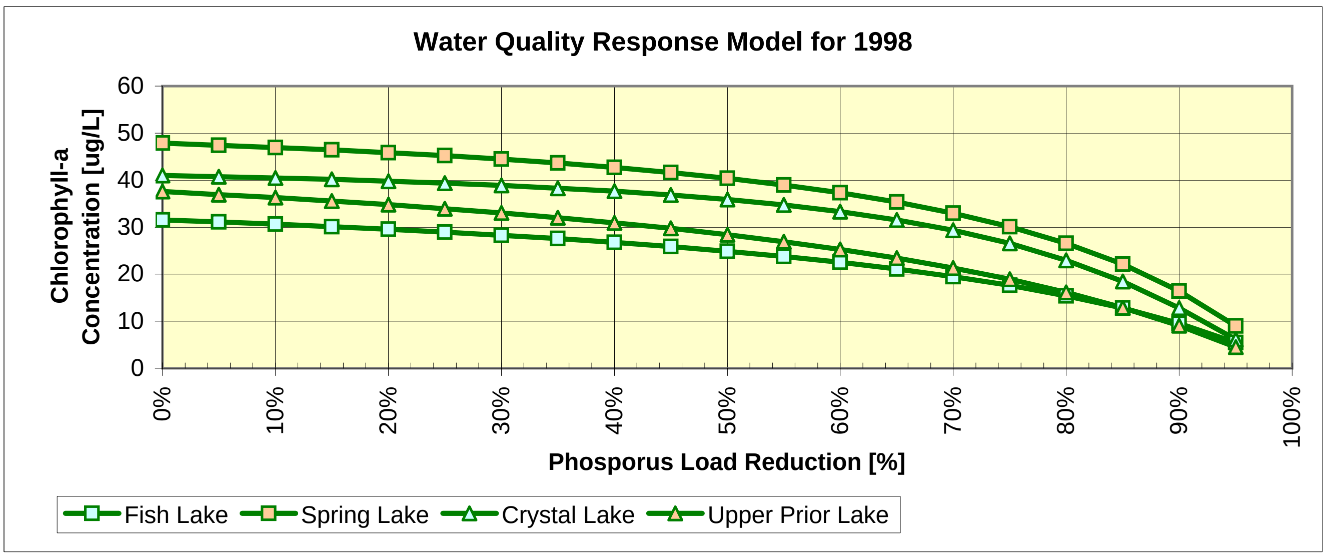


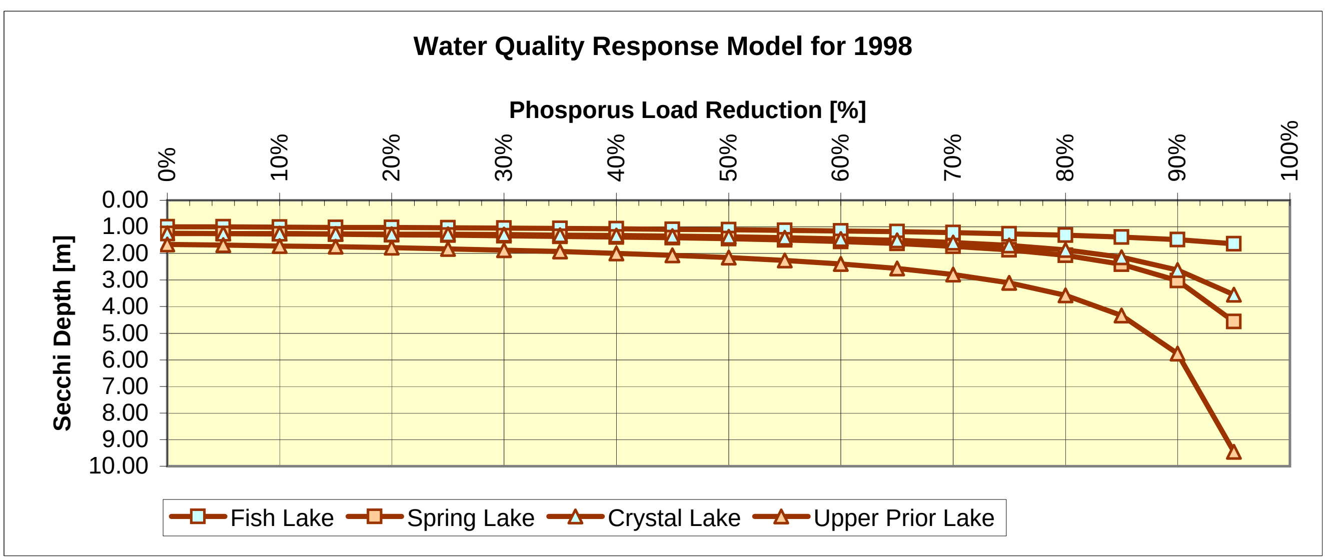
Upper Prior Lake	Model Results								
	1998	1999	2000	2001	2002	2003	2004	2005	2006
Model Predicted Chl-a [ug/L]	38	38	38	37	38	38	37	34	36
Observed Chl-a [ug/L]				79	69	65	52	44	69
Model Predicted SD [m]	1.7	1.7	1.7	1.7	1.6	1.7	1.7	1.8	1.7
Observed SD [m]	0.9	0.8	1.0	0.9	0.7	1.0	1.1	1.3	0.9

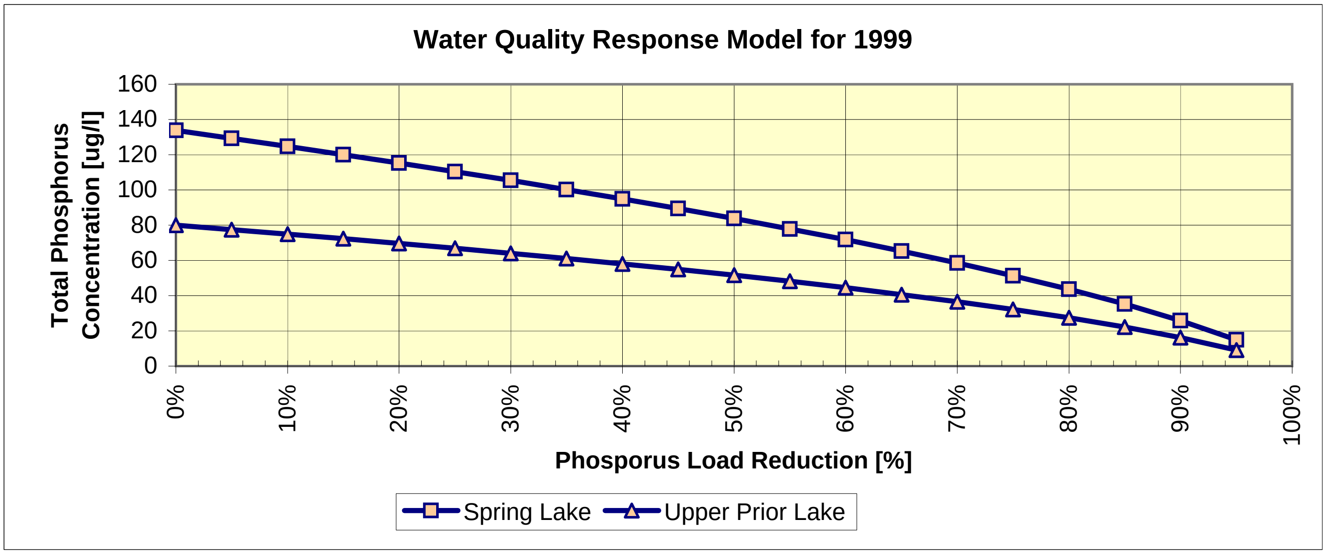


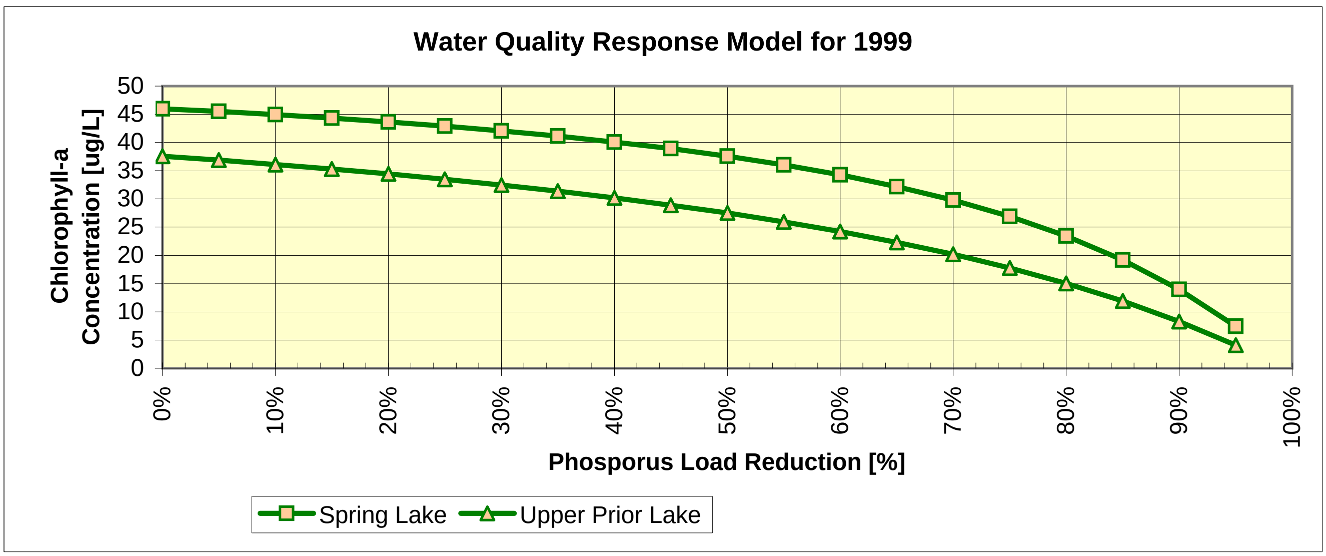


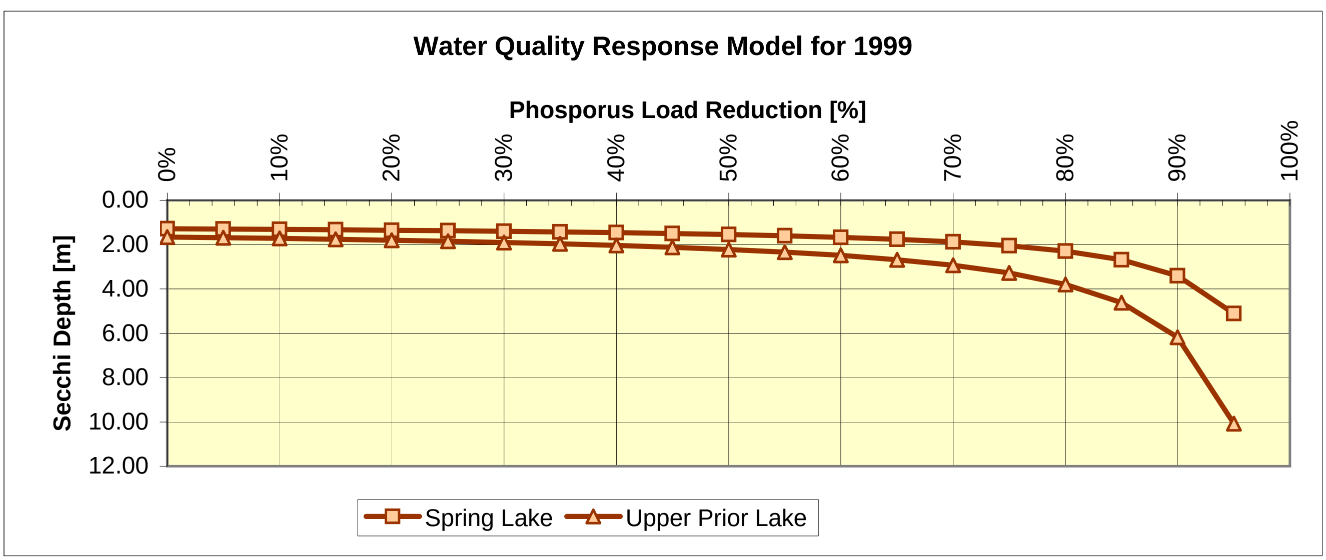

Water Quality Response Model for 1998
Total Phosphorus Concentration [ug/l]
180
160
140
120
100
80
60
40
20
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Phosporus Load Reduction [%]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake

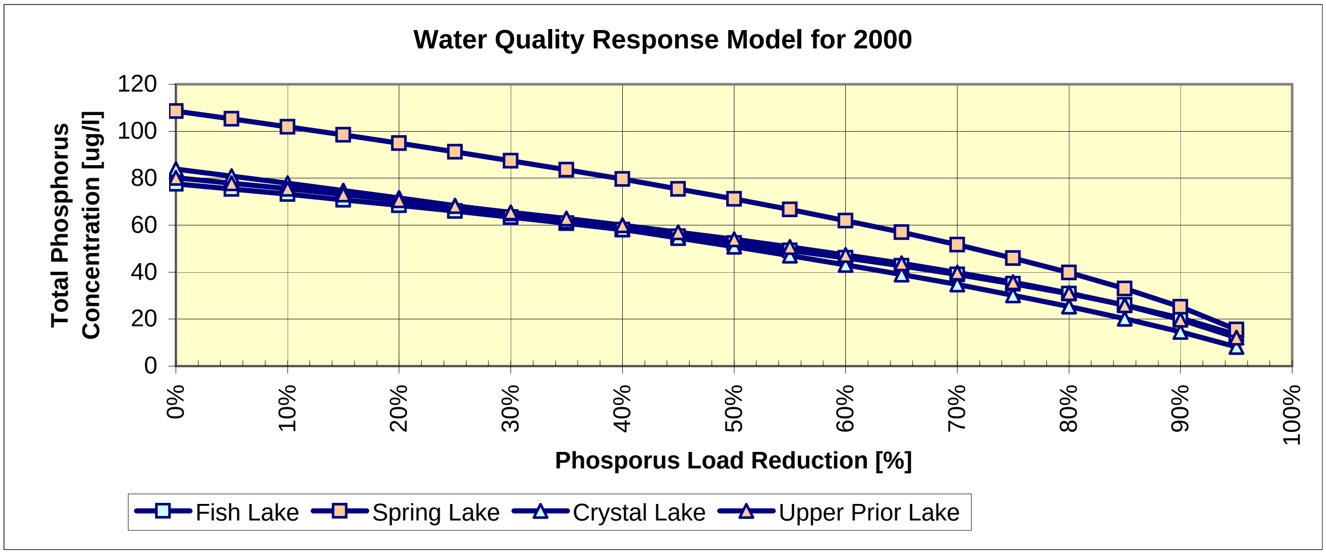

Water Quality Response Model for 1998
Chlorophyll-a Concentration [ug/L]
60
50
40
30
20
10
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Phosporus Load Reduction [%]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake

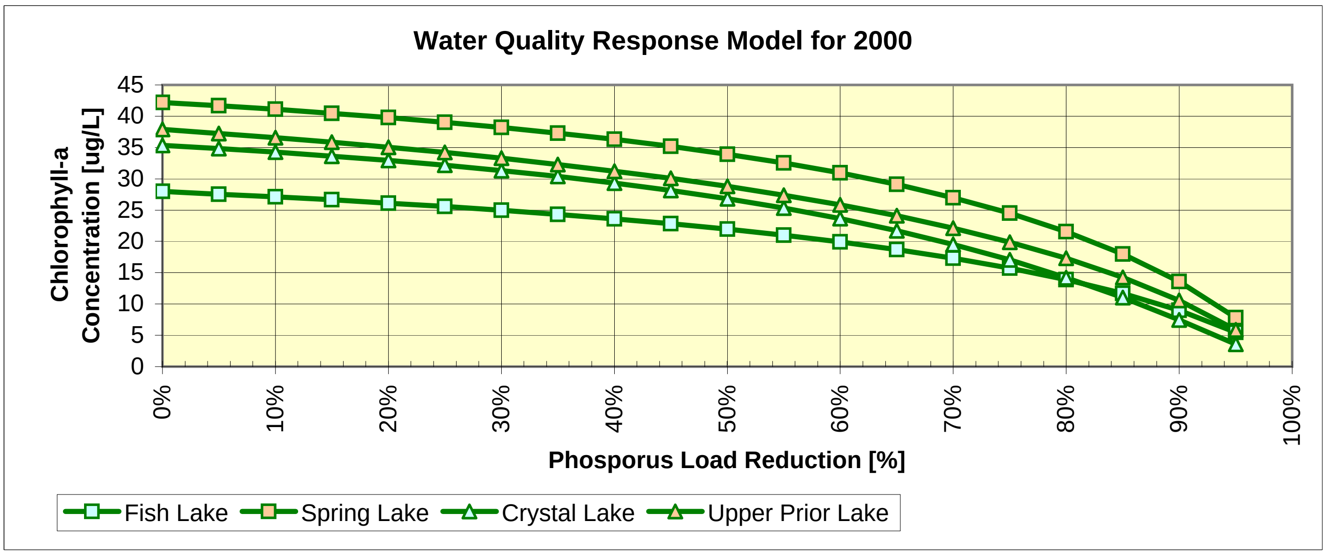

Water Quality Response Model for 1998
Phosporus Load Reduction [%]
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Secchi Depth [m]
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake

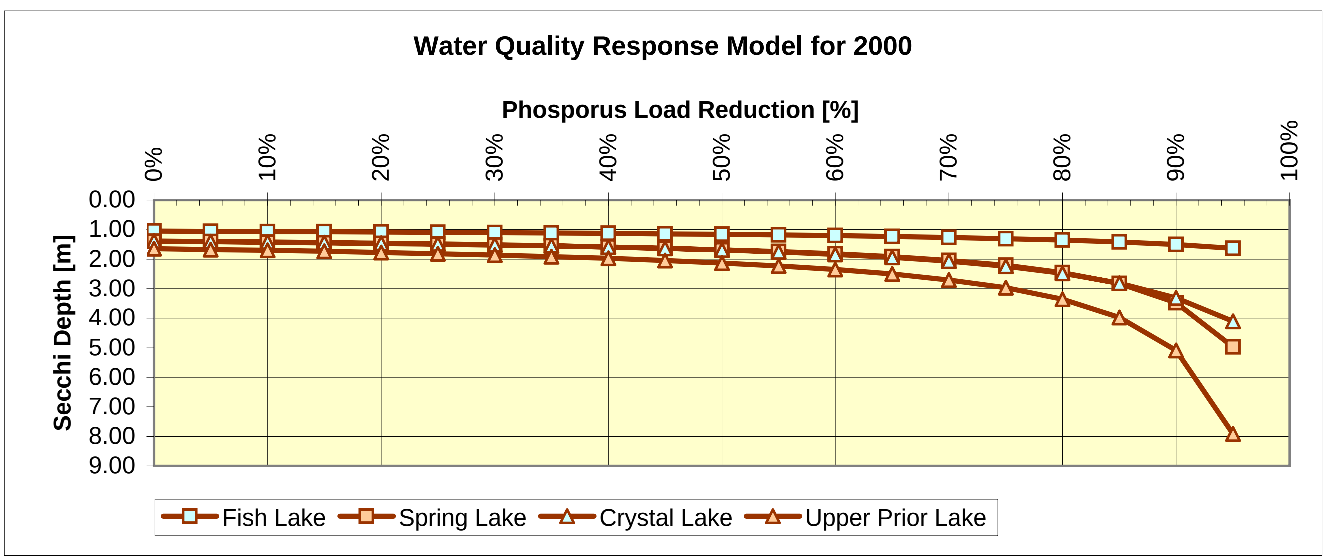

Water Quality Response Model for 1999
Total Phosphorus Concentration [ug/l]
160
140
120
100
80
60
40
20
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Phosporus Load Reduction [%]
Spring Lake
Upper Prior Lake

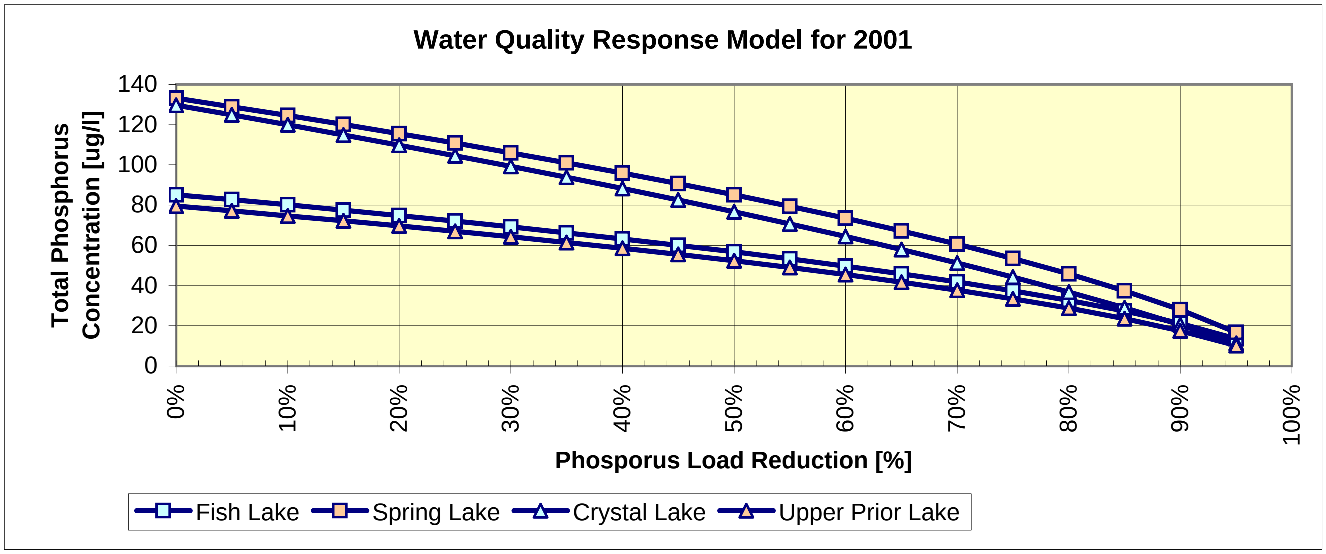

Water Quality Response Model for 1999
Chlorophyll-a Concentration [ug/L]
50
45
40
35
30
25
20
15
10
5
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Phosporus Load Reduction [%]
Spring Lake
Upper Prior Lake

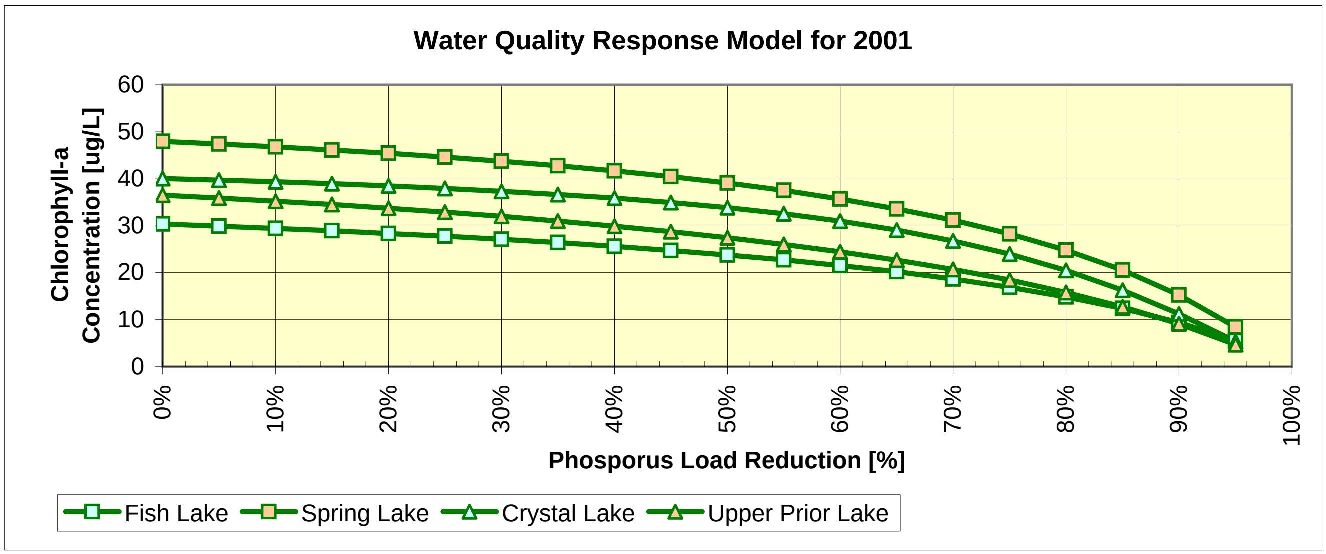

Water Quality Response Model for 1999
Phosporus Load Reduction [%]
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Secchi Depth [m]
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Spring Lake
Upper Prior Lake

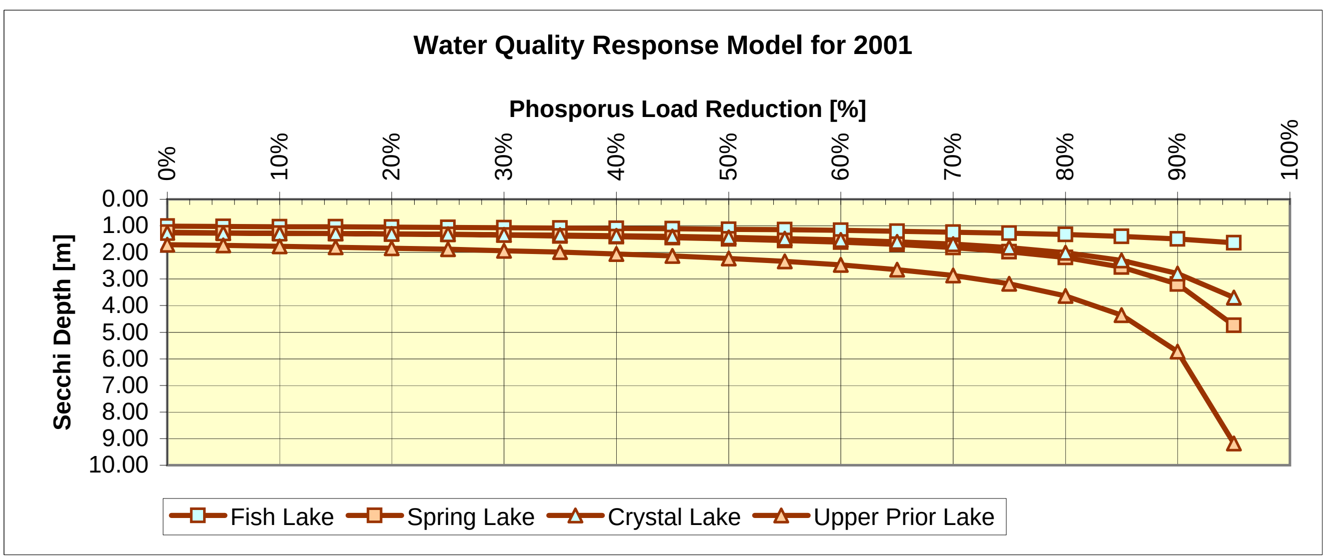

Water Quality Response Model for 2000
Total Phosphorus Concentration [ug/l]
Phosporus Load Reduction [%]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake

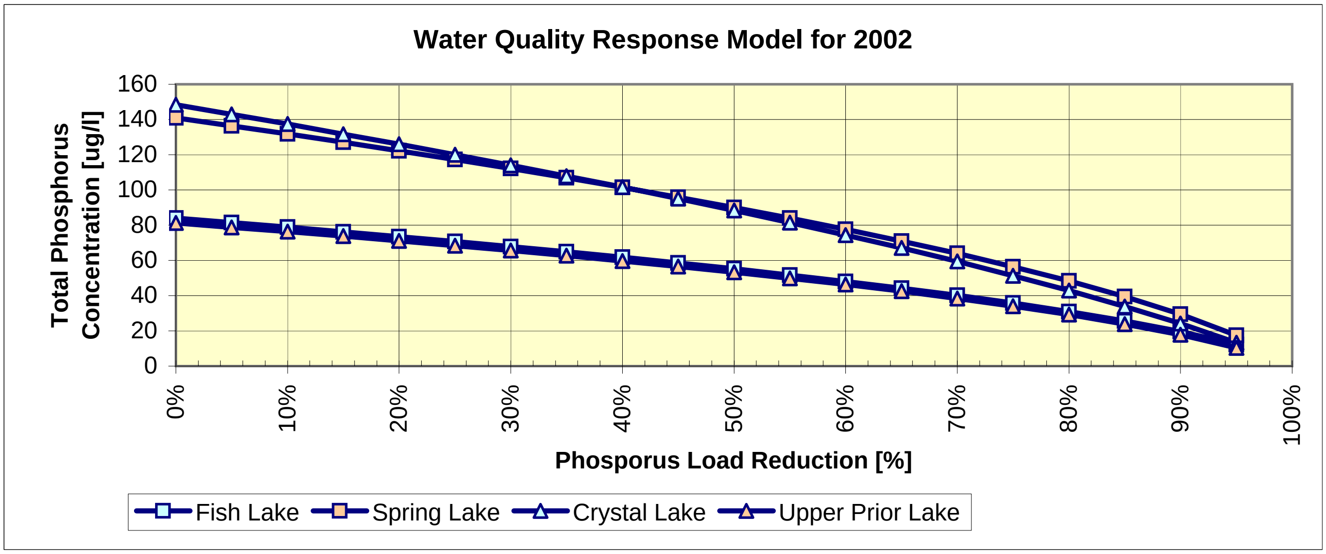

Water Quality Response Model for 2000
Chlorophyll-a Concentration [ug/L]
Phosporus Load Reduction [%]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake

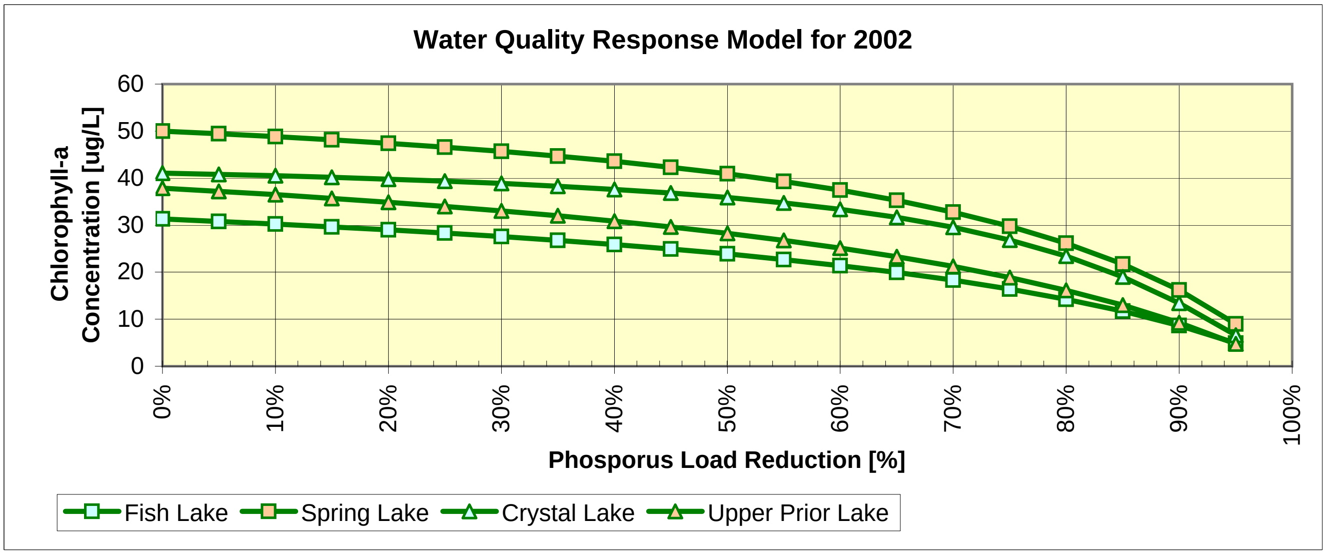

Water Quality Response Model for 2000
Phosporus Load Reduction [%]
Secchi Depth [m]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake

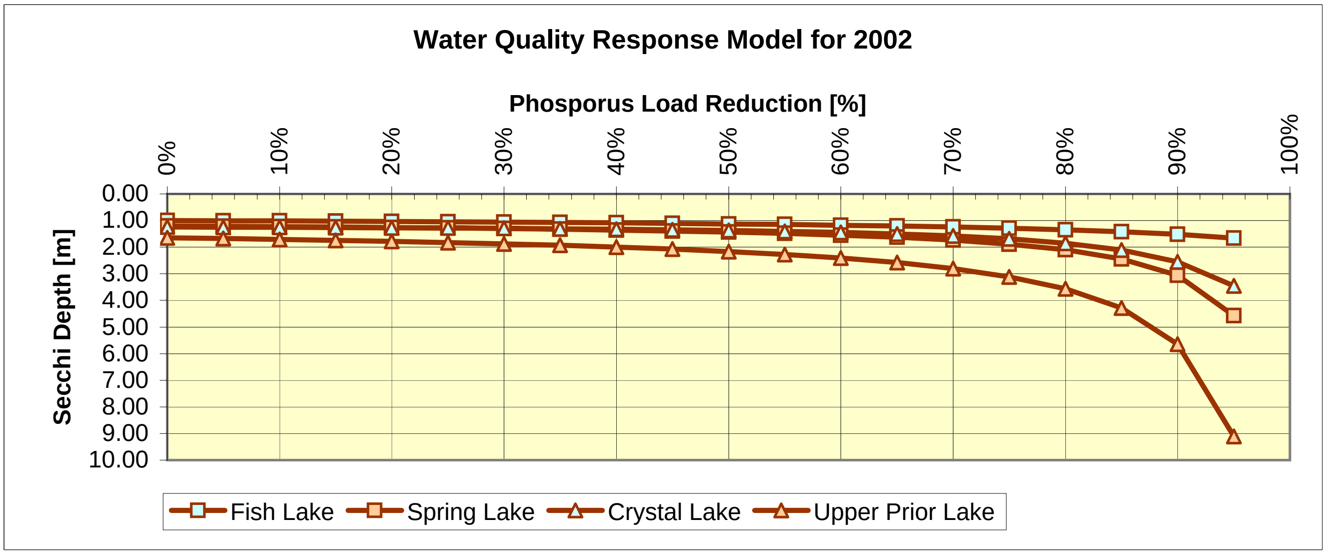

Water Quality Response Model for 2001
Total Phosphorus Concentration [ug/l]
140
120
100
80
60
40
20
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Phosporus Load Reduction [%]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake

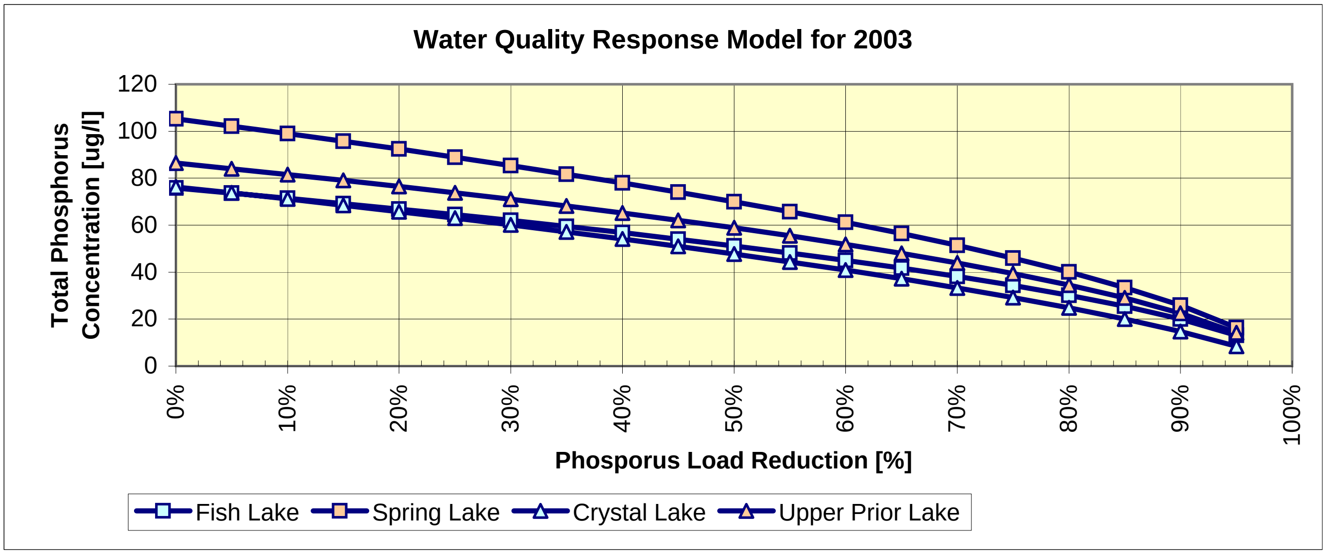

Water Quality Response Model for 2001
Chlorophyll-a Concentration [ug/L]
60
50
40
30
20
10
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Phosporus Load Reduction [%]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake


Water Quality Response Model for 2001
Phosporus Load Reduction [%]
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Secchi Depth [m]
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake

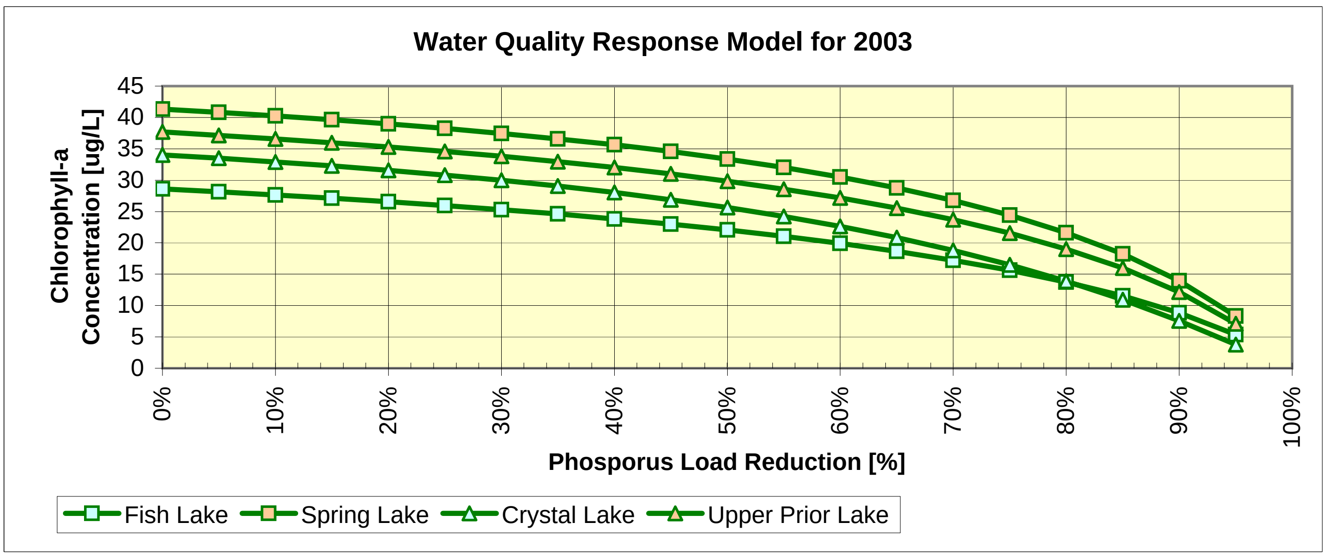

Water Quality Response Model for 2002
Total Phosphorus Concentration [ug/l]
160
140
120
100
80
60
40
20
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Phosporus Load Reduction [%]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake


Water Quality Response Model for 2002
Chlorophyll-a Concentration [ug/L]
60
50
40
30
20
10
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Phosporus Load Reduction [%]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake

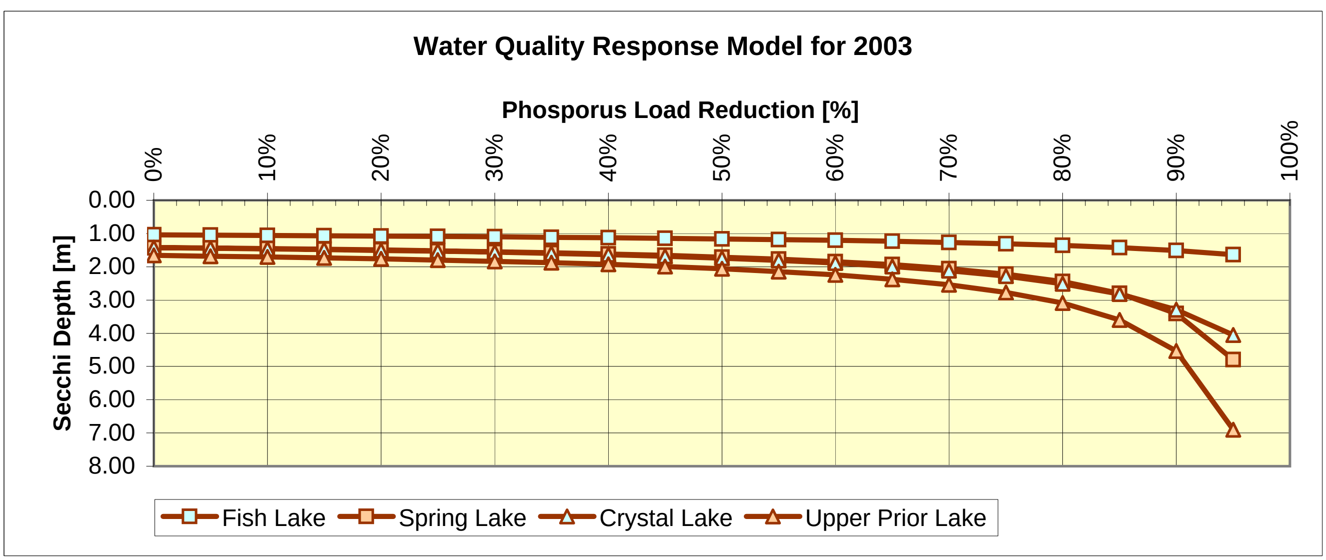

Water Quality Response Model for 2002
Phosporus Load Reduction [%]
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Secchi Depth [m]
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake



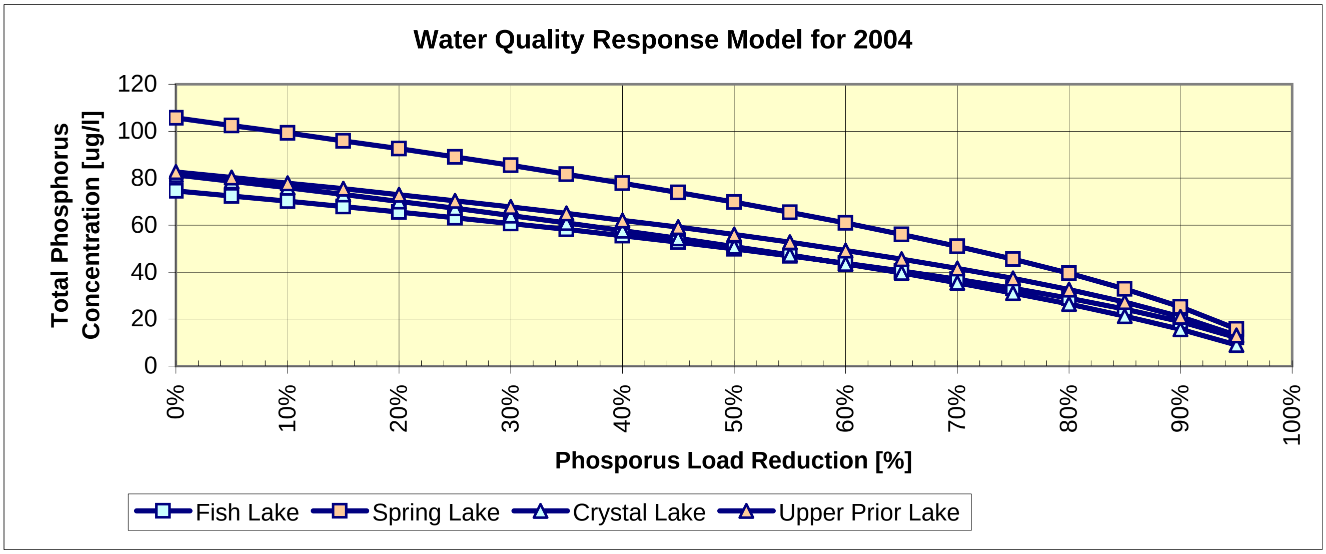
Water Quality Response Model for 2003
Total Phosphorus Concentration [ug/l]
120
100
80
60
40
20
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Phosporus Load Reduction [%]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake

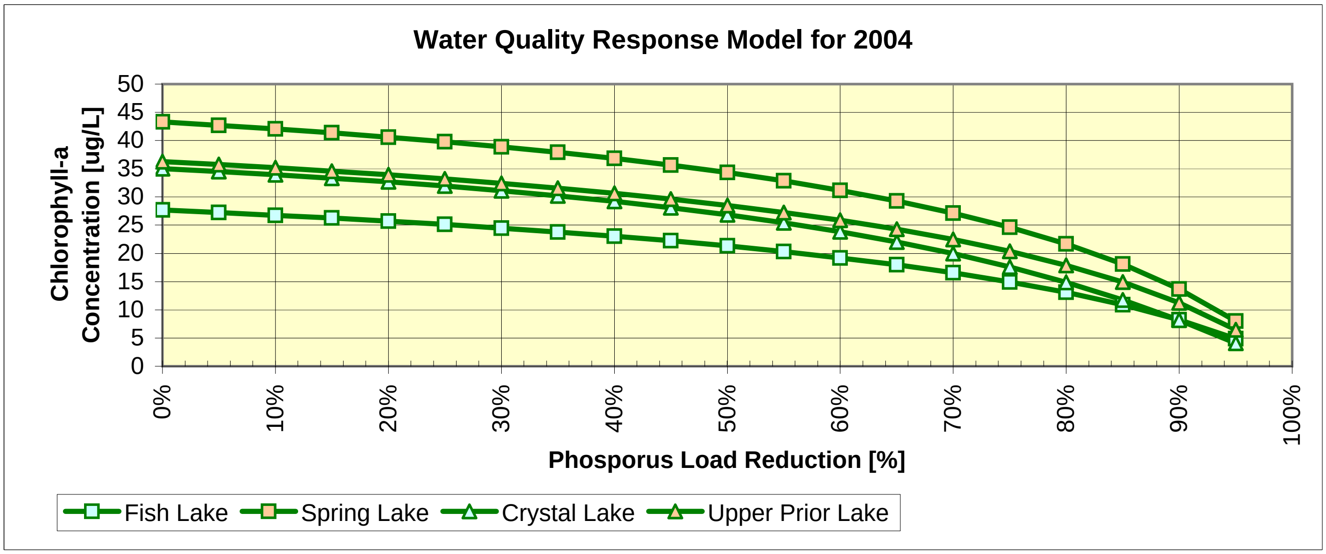


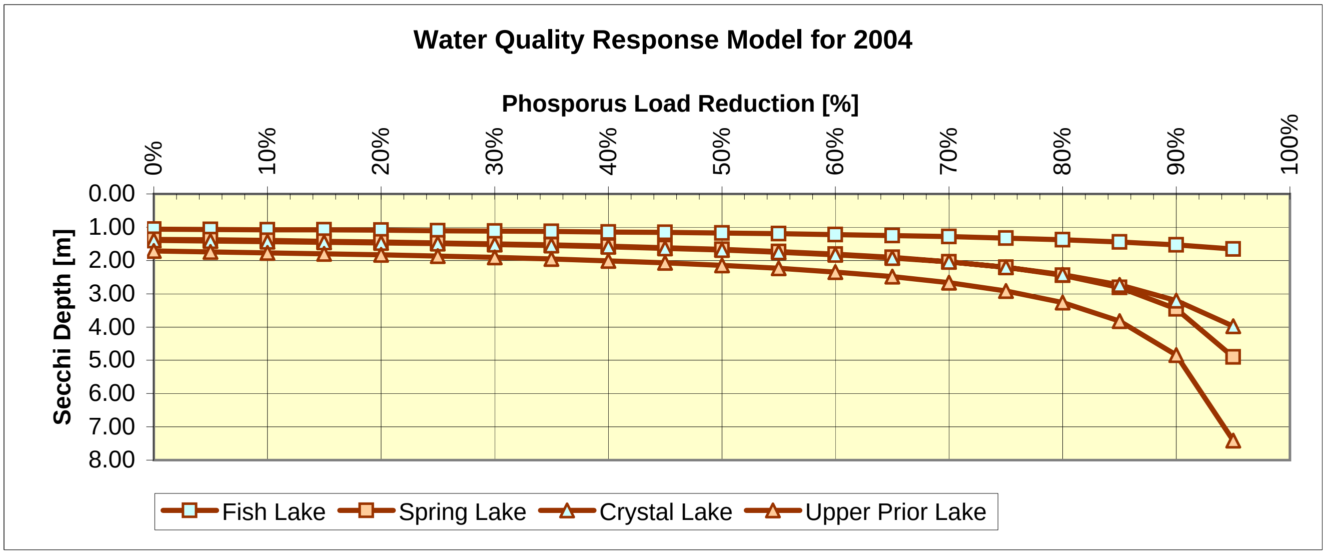
Water Quality Response Model for 2003
Chlorophyll-a Concentration [ug/L]
45
40
35
30
25
20
15
10
5
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Phosporus Load Reduction [%]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake

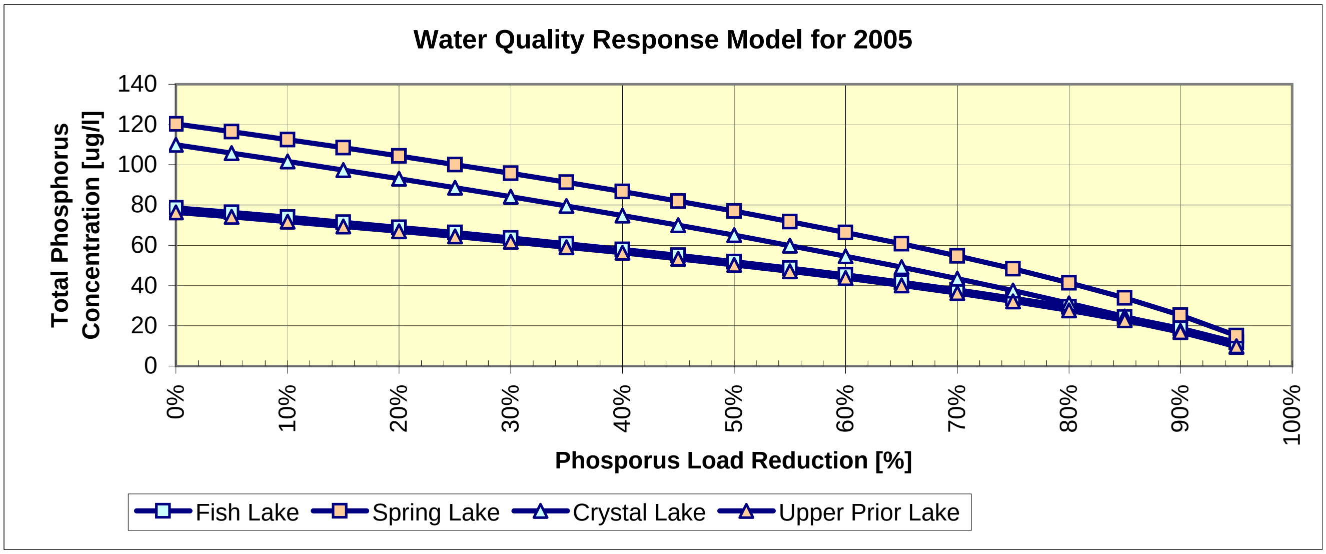


Water Quality Response Model for 2003
Phosporus Load Reduction [%]
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Secchi Depth [m]
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake

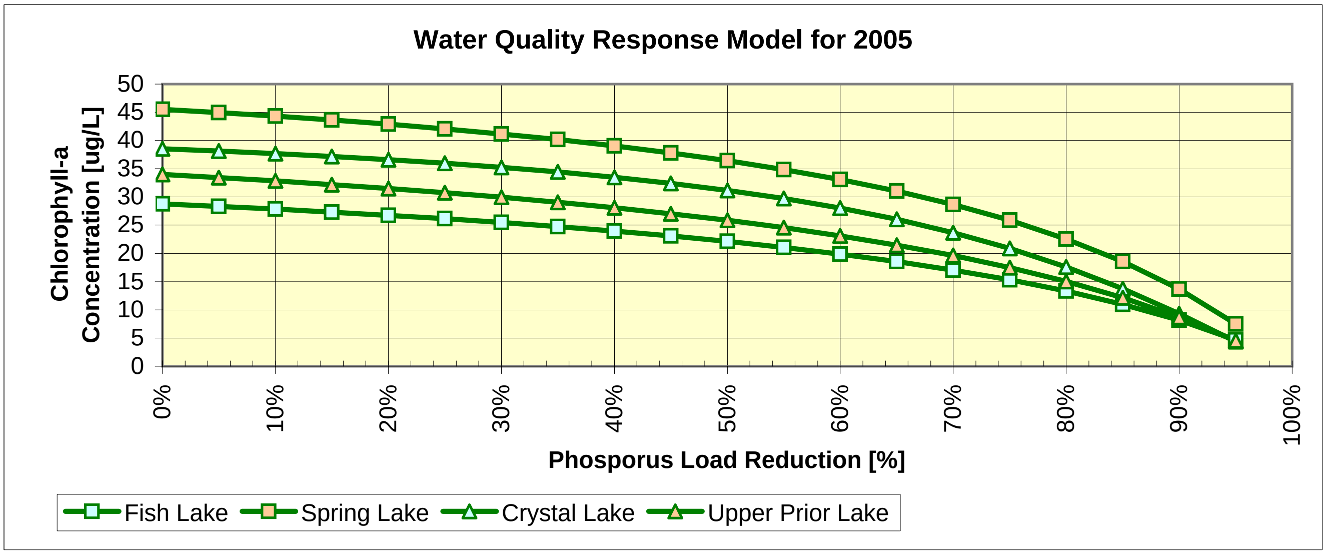

Water Quality Response Model for 2004
Total Phosphorus Concentration [ug/l]
Phosporus Load Reduction [%]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake


Water Quality Response Model for 2004
Chlorophyll-a Concentration [ug/L]
Phosporus Load Reduction [%]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake

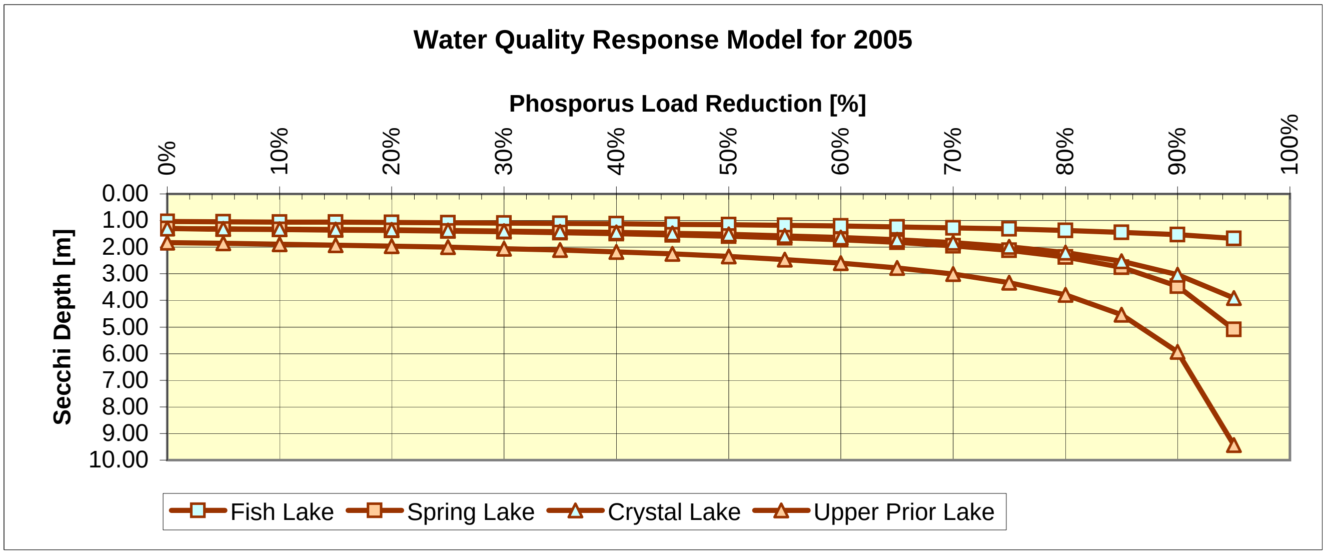

Water Quality Response Model for 2004
Phosporus Load Reduction [%]
Secchi Depth [m]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake



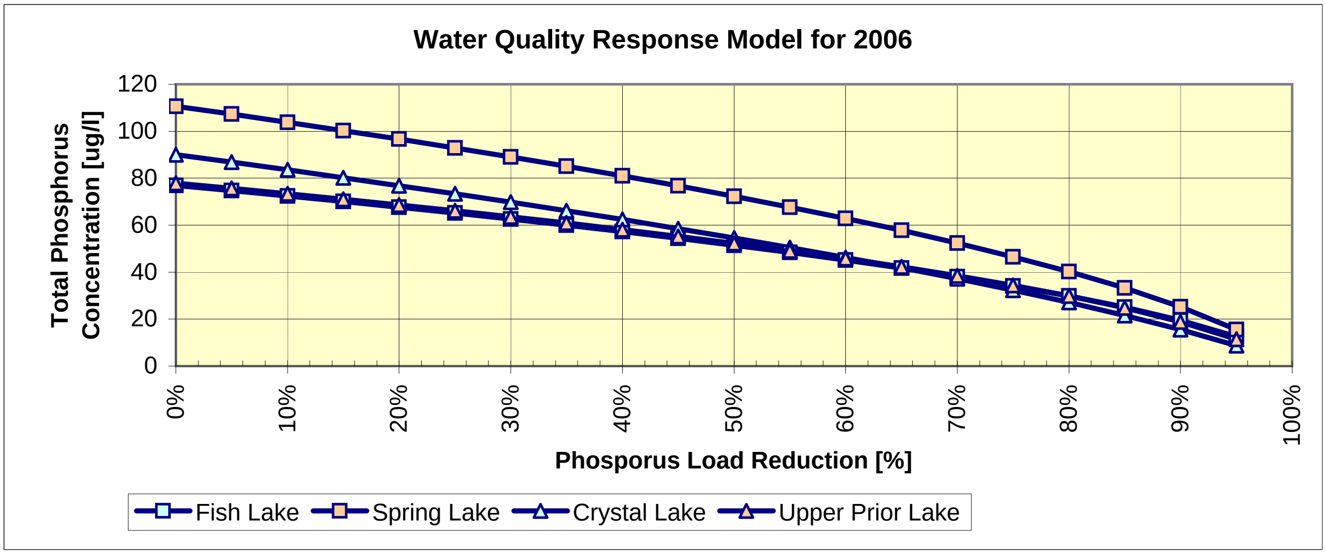
Water Quality Response Model for 2005
Total Phosphorus Concentration [ug/l]
Phosporus Load Reduction [%]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake



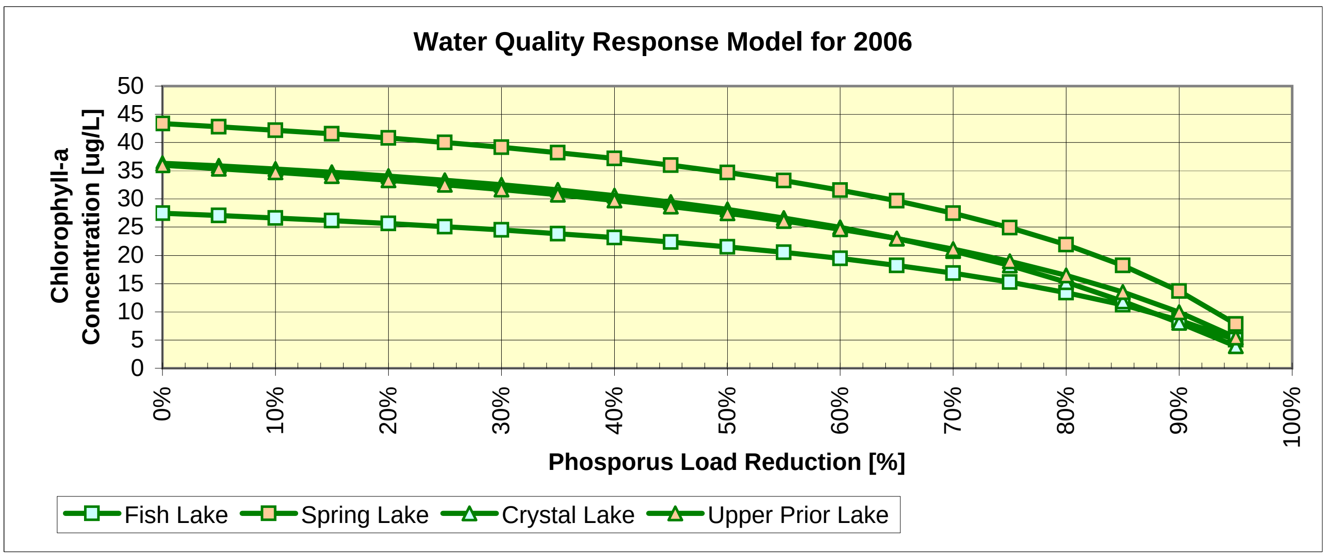
Water Quality Response Model for 2005
Chlorophyll-a Concentration [ug/L]
Phosporus Load Reduction [%]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake



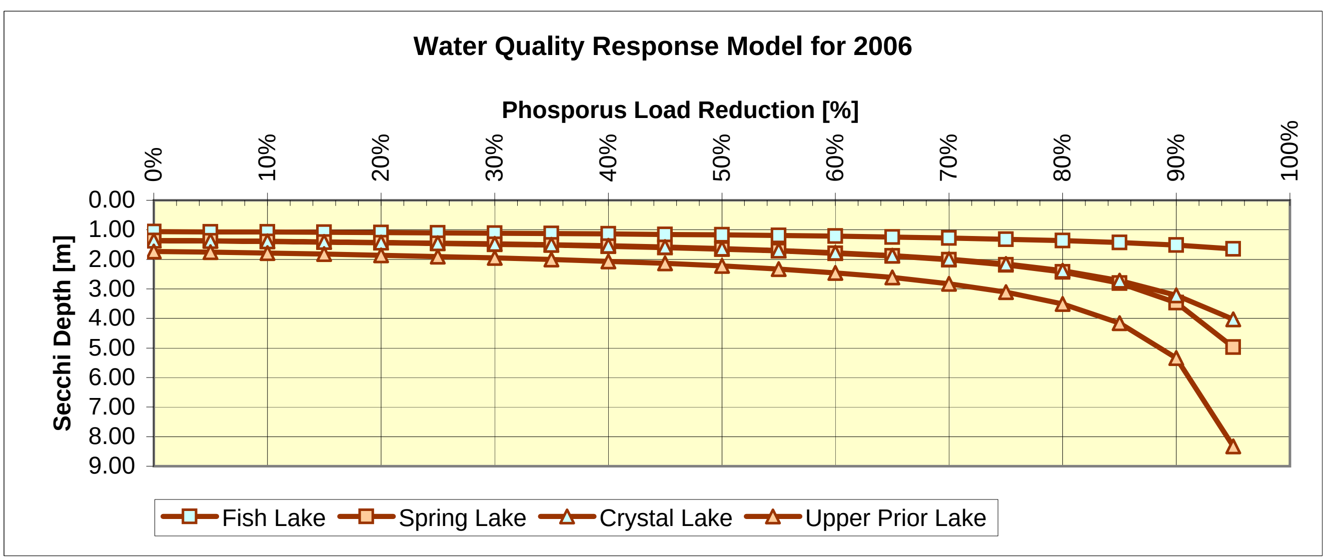
Water Quality Response Model for 2005
Phosporus Load Reduction [%]
Secchi Depth [m]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake



Water Quality Response Model for 2006
Total Phosphorus Concentration [ug/l]
0
20
40
60
80
100
120
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Phosporus Load Reduction [%]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake



Water Quality Response Model for 2006
Chlorophyll-a Concentration [ug/L]
0
5
10
15
20
25
30
35
40
45
50
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Phosporus Load Reduction [%]
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake



Water Quality Response Model for 2006
Phosporus Load Reduction [%]
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Secchi Depth [m]
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
Fish Lake
Spring Lake
Crystal Lake
Upper Prior Lake

1998 Loading Summary for: Spring Lake

Water Budgets				**Phosphorus Loading**			
Inflow from Drainage Areas							
		Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF)[1]	Load
	Name	[acre]	[in/yr]	[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1	Route 14 (W. Spr)	415.2	16.2	561.9	590.1	1.0	901.8
2	Route 7 (CD 13)	5636.5	9.5	4,444.7	445.1	0.7	5,380.3
3	Route 13 (C. Spr)	316.0	8.8	232.6	1401.4	1.0	886.4
4	Route 12 (Buck)	3659.3	11.0	3,367.4	402.7	1.0	3,687.6
5	Spring Direct	1922.4	6.8	1,083.1	401.2	1.0	1,181.7
	Summation	*11,949*	*52*	*9,690*	*648.1*		*12,037.8*
Failing Septic Systems							
	Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1	Route 14 (W. Spr)	415	10	10%	4.2	0.0	4.2
2	Route 7 (CD 13)	5,636	180	10%	4.2	0.0	75.6
3	Route 13 (C. Spr)	316	5	10%	4.2	0.0	2.1
4	Route 12 (Buck)	3,659	302	10%	4.2	0.0	126.8
5	Spring Direct	1,922	129	10%	4.2	0.0	54.2
	Summation	*11,949*	*626*	*10%*		*0.0*	*262.9*
Inflow from Upstream Lakes							
				Discharge	Estimated P Concentration	Calibration Factor	Load
	Name			[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1	Fish			658.9	50.0	1.0	90
2					-	1.0	
3					-	1.0	
	Summation			*659*	*50.0*		*90*
Atmosphere							
	Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
	[acre]	[in/yr]	[in/yr]	[ac-ft/yr]	[lb/ac-yr]	[--]	[lb/yr]
	642	36.9	36.9	0.00	0.13	1.0	28.5
				Dry-year total P deposition =	0.109		
				Average-year total P deposition =	0.133		
				Wet-year total P deposition =	0.158		
				(Barr Engineering 2004)			
Groundwater							
	Lake Area	Groundwater Flux		Net Inflow	Phosphorus Concentration	Calibration Factor	Load
	[acre]	[m/yr]		[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
	642	0.0		0.00	0	1.0	0
Internal							
	Lake Area	Anoxic Factor			Release Rate	Calibration Factor	Load
	[acre]	[days]			[mg/m^2-day]	[--]	[lb/yr]
	642	53.0			17.00	1.0	5,161
				Net Discharge [ac-ft/yr] = 10,349			**Net Load [lb/yr] = 17,580**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

1998 Lake Response Modeling for: Spring Lake

Modeled Parameter	Equation	Parameters	Value [Units]

TOTAL IN-LAKE PHOSPHORUS CONCENTRATION

$$\boxed{P = P_i \Big/ \left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$

as f(W,Q,V) from Canfield & Bachmann (1981)		
C_P =	1.00	[--]
C_{CB} =	0.162	[--]
b =	0.458	[--]
W (total P load = inflow + atm.) =	17,580	[lb/yr]
Q (lake outflow) =	10,349	[ac-ft/yr]
V (modeled lake volume) =	10,206	[ac-ft]
T = V/Q =	0.99	[yr]
P_i = W/Q =	625	[ug/l]
Model Predicted In-Lake [TP]	**153.6**	**[ug/l]**
Observed In-Lake [TP]	**148.6**	**[ug/l]**

CHLOROPHYLL-A CONCENTRATION

$$\boxed{[\mathrm{Chl}a] = CB \times 0.28 \times [TP]}$$

as f(TP), Walker 1999, Model 4		
CB (Calibration factor) =	1.00	[--]
Model Predicted In-Lake [Chl-a]	**43.0**	**[ug/l]**

$$\boxed{[\mathrm{Chl}a] = \frac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \mathrm{a})]}}$$

$$\boxed{B_x = \frac{X_{pn}^{1.33}}{4.31}}$$

$$\boxed{X_{pn} = \left[P^{-2} + \left(\frac{N - 150}{12}\right)^{-2}\right]^{-0.5}}$$

$$\boxed{G = Z_{mix}(0.14 + 0.0039 F_s)}$$

$$\boxed{F_s = \frac{Q}{V}} \quad \boxed{a = \frac{1}{SD} - 0.015 \times [\mathrm{Chl}a]}$$

as f(TP, N, Flushing), Walker 1999, Model 1		
CB (Calibration factor) =	1.00	
P (Total Phosphorus) =	154	[ug/l]
N (Total Nitrogen) =	1746	[ug/l]
B_x (Nutrient-Potential Chl-a conc.) =	106.8	[ug/l]
X_{pn} (Composite nutrient conc.)=	100.5	[ug/l]
G (Kinematic factor) =	0.43	[--]
F_s (Flushing Rate) =	1.01	[year^{-1}]
Z_{mix} (Mixing Depth) =	9.84	[ft]
a (Non algal turbidity) =	0.08	[m^{-1}]
S (Secchi Depth) =	4.09	[ft]
Maximum lake depth =	35.00	[ft]
Model Predicted In-Lake [Chl-a]	**47.9**	**[ug/l]**
Observed In-Lake [Chl-a]	**62.6**	**[ug/l]**

SECCHI DEPTH

$$\boxed{SD = \frac{CS}{(\mathrm{a} + 0.015 \times [\mathrm{Chl}a])}}$$

as f(Chla), Walker (1999)		
CS (Calibration factor) =	1.00	[--]
a (Non algal turbidity) =	0.08	[m^{-1}]
Model Predicted In-Lake SD	**1.25**	**[m]**
Observed In-Lake SD		**[m]**

PHOSPHORUS SEDIMENTATION RATE

$$\boxed{P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V}$$

P_{sed} (phosphorus sedimentation) =	**13,257**	**[lb/yr]**

PHOSPHORUS OUTFLOW LOAD

W-P_{sed} =	**4,323**	**[lb/yr]**

1998 Load Reduction Table for: Spring Lake

LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**					**TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS**			
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**[Chla] [ug/L]**	**SD [ft]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**	**TSI [Chla] [--]**	**TSI SD [--]**	**TSI Avg. [--]**
0%	**17,580**	154	48	4.09	13257	**4323**	76.7	68.5	56.8	**67.4**
5%	**16,701**	149	47	4.12	12521	**4180**	76.3	68.5	56.7	**67.1**
10%	**15,822**	143	47	4.16	11788	**4034**	75.7	68.4	56.6	**66.9**
15%	**14,943**	138	46	4.20	11058	**3885**	75.2	68.2	56.4	**66.6**
20%	**14,064**	133	46	4.25	10332	**3732**	74.6	68.1	56.3	**66.3**
25%	**13,185**	127	45	4.31	9610	**3575**	74.0	68.0	56.1	**66.0**
30%	**12,306**	121	44	4.37	8892	**3414**	73.3	67.8	55.9	**65.7**
35%	**11,427**	115	44	4.44	8178	**3248**	72.6	67.6	55.6	**65.3**
40%	**10,548**	109	43	4.53	7470	**3078**	71.8	67.4	55.4	**64.9**
45%	**9,669**	103	42	4.63	6767	**2902**	71.0	67.2	55.0	**64.4**
50%	**8,790**	97	40	4.75	6071	**2719**	70.1	66.9	54.7	**63.9**
55%	**7,911**	90	39	4.91	5381	**2530**	69.0	66.5	54.2	**63.3**
60%	**7,032**	83	37	5.10	4700	**2332**	67.8	66.1	53.7	**62.5**
65%	**6,153**	75	35	5.34	4028	**2125**	66.5	65.6	53.0	**61.7**
70%	**5,274**	68	33	5.67	3368	**1906**	64.9	64.9	52.1	**60.7**
75%	**4,395**	59	30	6.12	2721	**1674**	63.1	64.0	51.0	**59.4**
80%	**3,516**	51	27	6.80	2091	**1425**	60.7	62.8	49.5	**57.7**
85%	**2,637**	41	22	7.89	1484	**1153**	57.7	61.0	47.4	**55.3**
90%	**1,758**	30	16	9.93	908	**850**	53.3	58.1	44.0	**51.8**
95%	**879**	18	9	14.98	385	**494**	45.5	52.2	38.1	**45.3**

1998 Loading Summary for: Upper Prior Lake

	Water Budgets			Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Upper Prior Direct	1588.6	7.8	1,034.9	362.4	1.0	1,019.8
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*1,589*	*8*	*1,035*	*362.4*		*1,019.8*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Upper Prior Direct	1,589	9	10%	4.2	0.0	3.8
2		37				
3						
4						
5						
Summation	*1,589*	*46*	*10%*		*0.0*	*3.8*
Inflow from Upstream Lakes						
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Spring Lake			10,348.6	153.6	1.0	4323
2 Crystal Lake			896.1	47.0	1.0	115
3 Arctic Lake			562.2	138.4	1.0	212
Summation			*11,807*	*113.0*		*4,649*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
337	36.9	36.9	0.00	0.13	1.0	15.0
			Dry-year total P deposition =	0.109		
			Average-year total P deposition =	0.133		
			Wet-year total P deposition =	0.158		
			(Barr Engineering 2004)			
Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
337	0.0		0.00	0	1.0	0
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
337	24.0			36.00	1.0	2,598
			Net Discharge [ac-ft/yr] = 12,842			**Net Load [lb/yr] = 8,285**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

1998 Lake Response Modeling for: Upper Prior Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
		as f(W,Q,V,Fot) from BATHTUB 2nd Order Decay	
	$P = \left[-1+\left(1+4KA1P_iT\right)^{0.5}\right] \Big/ \left(2KA1T\right)$	C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
	$A1 = 0.056 Fot^{-1} Qs \Big/ \left(Qs+13.3\right)$	W (total P load = inflow + atm.) =	8,285 [lb/yr]
		Q (lake outflow) =	12,842 [ac-ft/yr]
		V (modeled lake volume) =	3,621 [ac-ft]
	$Qs = Max(Z/T, 4)$	Fot=	0.6 [--]
		Qs=	48.6 [m/yr]
		T = V/Q =	0.28 [yr]
		P_i = W/Q =	237 [ug/l]
Model Predicted In-Lake [TP]			**85.6 [ug/l]**
Observed In-Lake [TP]			**58.8 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**24.0 [ug/l]**
	$[\mathrm{Chl}a] = \dfrac{CB \times B_x}{\left[\left(1+0.025 \times B_x \times G\right)\left(1+G \times \mathrm{a}\right)\right]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \dfrac{X_{pn}^{\ 1.33}}{4.31}$	P (Total Phosphorus) =	86 [ug/l]
		N (Total Nitrogen) =	1738 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	68.4 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\dfrac{N-150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	71.9 [ug/l]
		G (Kinematic factor) =	0.46 [--]
		F_s (Flushing Rate) =	3.55 [year^{-1}]
	$G = Z_{mix}\left(0.14 + 0.0039 F_s\right)$	Z_{mix} (Mixing Depth) =	9.84 [ft]
	$F_s = \dfrac{Q}{V}$; $a = \dfrac{1}{SD} - 0.015 \times [\mathrm{Chl}a]$	a (Non algal turbidity) =	0.04 [m^{-1}]
		S (Secchi Depth) =	5.45 [ft]
		Maximum lake depth =	45.00 [ft]
Model Predicted In-Lake [Chl-a]			**37.6 [ug/l]**
Observed In-Lake [Chl-a]			**[ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{\left(\mathrm{a} + 0.015 \times [\mathrm{Chl}a]\right)}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.04 [m^{-1}]
Model Predicted In-Lake SD			**1.66 [m]**
Observed In-Lake SD			**0.86 [m]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**2,991 [lb/yr]**

1998 Load Reduction Table for: Upper Prior Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS					TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS			
REDUC-TION [%]	NET LOAD [lb]	[TP] [ug/L]	[Chla] [ug/L]	SD [ft]	P SEDIMEN-TATION [lb]	TP OUT-FLOW [lb]	TSI [TP] [--]	TSI [Chla] [--]	TSI SD [--]	TSI Avg. [--]
0%	**8,285**	85.6	38	5.45	2987	**5298**	68.3	66.2	52.7	**62.4**
5%	**7,871**	83.0	37	5.54	2827	**5044**	67.9	66.0	52.4	**62.1**
10%	**7,457**	80.3	36	5.64	2668	**4789**	67.4	65.8	52.2	**61.8**
15%	**7,042**	77.5	36	5.74	2509	**4533**	66.9	65.6	51.9	**61.5**
20%	**6,628**	74.6	35	5.86	2350	**4278**	66.3	65.4	51.6	**61.1**
25%	**6,214**	71.7	34	6.00	2192	**4022**	65.8	65.2	51.3	**60.7**
30%	**5,800**	68.7	33	6.15	2033	**3766**	65.1	64.9	50.9	**60.3**
35%	**5,385**	65.5	32	6.33	1876	**3510**	64.5	64.6	50.5	**59.9**
40%	**4,971**	62.3	31	6.54	1718	**3253**	63.7	64.3	50.1	**59.4**
45%	**4,557**	58.9	30	6.78	1561	**2996**	62.9	63.9	49.5	**58.8**
50%	**4,143**	55.3	28	7.07	1405	**2738**	62.0	63.4	48.9	**58.1**
55%	**3,728**	51.6	27	7.42	1249	**2479**	61.0	62.9	48.2	**57.4**
60%	**3,314**	47.8	25	7.86	1095	**2219**	59.9	62.3	47.4	**56.5**
65%	**2,900**	43.7	23	8.43	941	**1959**	58.6	61.5	46.4	**55.5**
70%	**2,486**	39.3	21	9.17	789	**1696**	57.1	60.6	45.2	**54.3**
75%	**2,071**	34.6	19	10.20	639	**1432**	55.2	59.4	43.7	**52.8**
80%	**1,657**	29.5	16	11.72	492	**1165**	52.9	57.9	41.6	**50.8**
85%	**1,243**	23.8	13	14.20	349	**894**	49.9	55.7	38.9	**48.1**
90%	**829**	17.4	9	18.92	212	**617**	45.4	52.2	34.8	**44.1**
95%	**414**	9.9	5	31.05	87	**327**	37.1	45.4	27.6	**36.7**

1999 Loading Summary for: Spring Lake

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Route 14 (W. Spr)	415.2	15.2	525.0	445.4	1.0	635.9
2 Route 7 (CD 13)	5636.5	9.3	4,353.7	320.5	0.7	3,794.0
3 Route 13 (C. Spr)	316.0	8.3	219.6	1046.7	1.0	625.1
4 Route 12 (Buck)	3659.3	10.5	3,192.8	299.5	1.0	2,600.3
5 Spring Direct	1922.4	6.3	1,006.8	304.4	1.0	833.3
Summation	*11,949*	*50*	*9,298*	*483.3*		*8,488.5*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Route 14 (W. Spr)	415	10	10%	4.2	0.0	4.2
2 Route 7 (CD 13)	5,636	180	10%	4.2	0.0	75.6
3 Route 13 (C. Spr)	316	5	10%	4.2	0.0	2.1
4 Route 12 (Buck)	3,659	302	10%	4.2	0.0	126.8
5 Spring Direct	1,922	129	10%	4.2	0.0	54.2
Summation	*11,949*	*626*	*10%*		*0.0*	*262.9*

Inflow from Upstream Lakes

Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Fish	645.1	45.0	1.0	79
2		-	1.0	
3		-	1.0	
Summation	*645*	*45.0*		*79*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
642	40.3	40.3	0.00	0.16	1.0	33.8
			Dry-year total P deposition =	0.109		
			Average-year total P deposition =	0.133		
			Wet-year total P deposition =	0.158		
			(Barr Engineering 2004)			

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
642	0.0	0.00	0	1.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m²-day]	Calibration Factor [--]	Load [lb/yr]
642	53.0	17.00	1.0	5,161

Net Discharge [ac-ft/yr] =	**9,943**		**Net Load [lb/yr] =**	**14,025**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

1999 Lake Response Modeling for: Spring Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	14,025 [lb/yr]
		Q (lake outflow) =	9,943 [ac-ft/yr]
		V (modeled lake volume) =	10,206 [ac-ft]
		T = V/Q =	1.03 [yr]
		P_i = W/Q =	519 [ug/l]
Model Predicted In-Lake [TP]			**133.8 [ug/l]**
Observed In-Lake [TP]			**123.5 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**37.5 [ug/l]**
	$[\mathrm{Chl}a] = \dfrac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \mathrm{a})]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \dfrac{X_{pn}^{1.33}}{4.31}$	P (Total Phosphorus) =	134 [ug/l]
		N (Total Nitrogen) =	1746 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	98.1 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\dfrac{N - 150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	94.3 [ug/l]
		G (Kinematic factor) =	0.43 [--]
		F_s (Flushing Rate) =	0.97 [year^{-1}]
	$G = Z_{mix}(0.14 + 0.0039F_s)$	Z_{mix} (Mixing Depth) =	9.84 [ft]
	$F_s = \dfrac{Q}{V}$; $a = \dfrac{1}{SD} - 0.015 \times [\mathrm{Chl}a]$	a (Non algal turbidity) =	0.08 [m^{-1}]
		S (Secchi Depth) =	4.24 [ft]
		Maximum lake depth =	35.00 [ft]
Model Predicted In-Lake [Chl-a]			**46.0 [ug/l]**
Observed In-Lake [Chl-a]			**47.2 [ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{(\mathrm{a} + 0.015 \times [\mathrm{Chl}a])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.08 [m^{-1}]
Model Predicted In-Lake SD			**1.29 [m]**
Observed In-Lake SD			**[m]**
PHOSPHORUS SEDIMENTATION RATE			
	$P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$		
		P_{sed} (phosphorus sedimentation) =	**10,408 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**3,616 [lb/yr]**

1999 Load Reduction Table for: Spring Lake										
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**					**TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS**			
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**[Chla] [ug/L]**	**SD [ft]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**	**TSI [Chla] [--]**	**TSI SD [--]**	**TSI Avg. [--]**
0%	**14,025**	134	46	4.24	10408	**3616**	74.8	68.2	56.3	**66.4**
5%	**13,324**	129	45	4.28	9828	**3496**	74.3	68.0	56.2	**66.2**
10%	**12,622**	125	45	4.33	9250	**3373**	73.7	67.9	56.0	**65.9**
15%	**11,921**	120	44	4.38	8674	**3247**	73.2	67.8	55.8	**65.6**
20%	**11,220**	115	44	4.44	8102	**3118**	72.6	67.6	55.6	**65.3**
25%	**10,519**	110	43	4.51	7533	**2986**	72.0	67.5	55.4	**65.0**
30%	**9,817**	105	42	4.59	6967	**2850**	71.3	67.3	55.2	**64.6**
35%	**9,116**	100	41	4.68	6405	**2711**	70.6	67.1	54.9	**64.2**
40%	**8,415**	95	40	4.79	5848	**2567**	69.8	66.8	54.6	**63.7**
45%	**7,714**	89	39	4.91	5295	**2419**	69.0	66.5	54.2	**63.2**
50%	**7,012**	84	38	5.07	4747	**2266**	68.0	66.2	53.7	**62.6**
55%	**6,311**	78	36	5.25	4205	**2106**	67.0	65.8	53.2	**62.0**
60%	**5,610**	72	34	5.49	3670	**1940**	65.8	65.3	52.6	**61.2**
65%	**4,909**	65	32	5.79	3143	**1766**	64.4	64.7	51.8	**60.3**
70%	**4,207**	59	30	6.18	2625	**1583**	62.8	63.9	50.9	**59.2**
75%	**3,506**	51	27	6.73	2118	**1388**	60.9	62.9	49.6	**57.8**
80%	**2,805**	44	23	7.53	1625	**1180**	58.6	61.5	48.0	**56.1**
85%	**2,104**	35	19	8.82	1151	**953**	55.5	59.6	45.8	**53.6**
90%	**1,402**	26	14	11.17	702	**700**	51.1	56.5	42.3	**50.0**
95%	**701**	15	7	16.75	296	**405**	43.2	50.3	36.5	**43.3**

1999 Loading Summary for: Upper Prior Lake						
Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Upper Prior Direct	1588.6	7.3	959.8	275.5	1.0	719.1
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*1,589*	*7*	*960*	*275.5*		*719.1*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Upper Prior Direct	1,589	9	10%	4.2	0.0	3.8
2		37				
3						
4						
5						
Summation	*1,589*	*46*	*10%*		*0.0*	*3.8*
Inflow from Upstream Lakes						
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Spring Lake			9,942.9	133.8	1.0	3616
2 Crystal Lake			838.1	38.0	1.0	87
3 Arctic Lake			521.0	138.4	1.0	196
Summation			*11,302*	*103.4*		*3,899*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
337	40.3	40.3	0.00	0.16	1.0	17.8
			Dry-year total P deposition =	0.109		
			Average-year total P deposition =	0.133		
			Wet-year total P deposition =	0.158		
			(Barr Engineering 2004)			
Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
337	0.0		0.00	0	1.0	0
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
337	24.0			36.00	1.0	2,598
			Net Discharge [ac-ft/yr] = 12,262			**Net Load [lb/yr] = 7,238**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

1999 Lake Response Modeling for: Upper Prior Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = \left[-1+\left(1+4KA1P_iT\right)^{0.5}\right] \Big/ \left(2KA1T\right)$	as f(W,Q,V,Fot) from BATHTUB 2nd Order Decay	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
	$A1 = 0.056 Fot^{-1} Qs \Big/ \left(Qs+13.3\right)$	W (total P load = inflow + atm.) =	7,238 [lb/yr]
		Q (lake outflow) =	12,262 [ac-ft/yr]
		V (modeled lake volume) =	3,621 [ac-ft]
	$Qs = Max(Z/T, 4)$	Fot=	0.6 [--]
		Qs=	46.4 [m/yr]
		T = V/Q =	0.30 [yr]
		P_i = W/Q =	217 [ug/l]
Model Predicted In-Lake [TP]			**80.0 [ug/l]**
Observed In-Lake [TP]			**82.5 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**22.4 [ug/l]**
	$[\mathrm{Chl}a] = \dfrac{CB \times B_x}{\left[\left(1+0.025\times B_x \times G\right)\left(1+G\times \mathrm{a}\right)\right]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \dfrac{X_{pn}^{\;1.33}}{4.31}$	P (Total Phosphorus) =	80 [ug/l]
		N (Total Nitrogen) =	2104 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	68.2 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\dfrac{N-150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	71.8 [ug/l]
		G (Kinematic factor) =	0.46 [--]
		F_s (Flushing Rate) =	3.39 [year^{-1}]
	$G = Z_{mix}\left(0.14 + 0.0039 F_s\right)$	Z_{mix} (Mixing Depth) =	9.84 [ft]
	$F_s = \dfrac{Q}{V}$; $a = \dfrac{1}{SD} - 0.015\times[\mathrm{Chl}a]$	a (Non algal turbidity) =	0.04 [m^{-1}]
		S (Secchi Depth) =	5.45 [ft]
		Maximum lake depth =	45.00 [ft]
Model Predicted In-Lake [Chl-a]			**37.6 [ug/l]**
Observed In-Lake [Chl-a]			**[ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{\left(\mathrm{a} + 0.015\times[\mathrm{Chl}a]\right)}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.04 [m^{-1}]
Model Predicted In-Lake SD			**1.66 [m]**
Observed In-Lake SD			**0.78 [m]**
PHOSPHORUS OUTFLOW LOAD			
	$W-P_{sed}$ =		**2,667 [lb/yr]**

1999 Load Reduction Table for: Upper Prior Lake											
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**					**TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS**				
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**[Chla] [ug/L]**	**SD [ft]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**	**TSI [Chla] [--]**	**TSI SD [--]**	**TSI Avg. [--]**
0%	**7,238**	**80.0**	38	5.45	2622	**4616**	67.3	66.2	52.7	**62.1**
5%	**6,876**	**77.5**	37	5.55	2481	**4394**	66.9	66.0	52.4	**61.8**
10%	**6,514**	**75.0**	36	5.66	2341	**4173**	66.4	65.8	52.1	**61.4**
15%	**6,152**	**72.3**	35	5.78	2201	**3951**	65.9	65.6	51.8	**61.1**
20%	**5,790**	**69.7**	34	5.92	2062	**3728**	65.3	65.3	51.5	**60.7**
25%	**5,428**	**66.9**	33	6.07	1922	**3506**	64.8	65.0	51.1	**60.3**
30%	**5,066**	**64.0**	32	6.25	1783	**3283**	64.1	64.7	50.7	**59.9**
35%	**4,704**	**61.1**	31	6.45	1644	**3060**	63.5	64.4	50.3	**59.4**
40%	**4,343**	**58.0**	30	6.68	1506	**2837**	62.7	64.0	49.8	**58.8**
45%	**3,981**	**54.9**	29	6.96	1368	**2613**	61.9	63.6	49.2	**58.2**
50%	**3,619**	**51.6**	27	7.28	1230	**2388**	61.0	63.1	48.5	**57.5**
55%	**3,257**	**48.1**	26	7.68	1094	**2163**	60.0	62.5	47.7	**56.8**
60%	**2,895**	**44.5**	24	8.17	958	**1937**	58.9	61.9	46.8	**55.9**
65%	**2,533**	**40.6**	22	8.80	823	**1710**	57.6	61.1	45.8	**54.8**
70%	**2,171**	**36.5**	20	9.63	690	**1481**	56.0	60.1	44.5	**53.5**
75%	**1,809**	**32.1**	18	10.77	558	**1251**	54.2	58.8	42.9	**52.0**
80%	**1,448**	**27.4**	15	12.44	429	**1018**	51.9	57.2	40.8	**50.0**
85%	**1,086**	**22.1**	12	15.15	304	**782**	48.8	54.9	38.0	**47.2**
90%	**724**	**16.1**	8	20.26	184	**540**	44.2	51.3	33.8	**43.1**
95%	**362**	**9.1**	4	33.08	76	**286**	36.0	44.4	26.7	**35.7**

2000 Loading Summary for: Spring Lake

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Route 14 (W. Spr)	415.2	5.8	201.9	215.0	1.0	118.1
2 Route 7 (CD 13)	5636.5	2.9	1,369.1	189.2	0.7	704.5
3 Route 13 (C. Spr)	316.0	2.3	60.5	705.7	1.0	116.1
4 Route 12 (Buck)	3659.3	3.0	914.2	194.2	1.0	482.9
5 Spring Direct	1922.4	1.7	277.4	205.1	1.0	154.7
Summation	*11,949*	*16*	*2,823*	*301.9*		*1,576.3*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Route 14 (W. Spr)	415	10	10%	4.2	0.0	4.2
2 Route 7 (CD 13)	5,636	180	10%	4.2	0.0	75.6
3 Route 13 (C. Spr)	316	5	10%	4.2	0.0	2.1
4 Route 12 (Buck)	3,659	302	10%	4.2	0.0	126.8
5 Spring Direct	1,922	129	10%	4.2	0.0	54.2
Summation	*11,949*	*626*	*10%*		*0.0*	*262.9*

Inflow from Upstream Lakes

Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Fish	203.5	53.3	1.0	30
2		-	1.0	
3		-	1.0	
Summation	*204*	*53.3*		*30*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
642	31.7	31.7	0.00	0.13	1.0	28.5
			Dry-year total P deposition =	0.109		
			Average-year total P deposition =	0.133		
			Wet-year total P deposition =	0.158		
			(Barr Engineering 2004)			

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
642	0.0	0.00	0	1.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
642	53.0	17.00	1.0	5,161

Net Discharge [ac-ft/yr] =	**3,027**	**Net Load [lb/yr] =**	**7,058**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

2000 Lake Response Modeling for: Spring Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	7,058 [lb/yr]
		Q (lake outflow) =	3,027 [ac-ft/yr]
		V (modeled lake volume) =	10,206 [ac-ft]
		T = V/Q =	3.37 [yr]
		P_i = W/Q =	858 [ug/l]
Model Predicted In-Lake [TP]			**108.5 [ug/l]**
Observed In-Lake [TP]			**192.5 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\text{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**30.4 [ug/l]**
	$[\text{Chl}a] = \dfrac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \text{a})]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \dfrac{X_{pn}^{1.33}}{4.31}$	P (Total Phosphorus) =	109 [ug/l]
		N (Total Nitrogen) =	1650 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	81.4 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\dfrac{N - 150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	81.9 [ug/l]
		G (Kinematic factor) =	0.42 [--]
		F_s (Flushing Rate) =	0.30 [year^{-1}]
	$G = Z_{mix}(0.14 + 0.0039 F_s)$	Z_{mix} (Mixing Depth) =	9.84 [ft]
	$F_s = \dfrac{Q}{V}$; $a = \dfrac{1}{SD} - 0.015 \times [\text{Chl}a]$	a (Non algal turbidity) =	0.08 [m^{-1}]
		S (Secchi Depth) =	4.57 [ft]
		Maximum lake depth =	35.00 [ft]
Model Predicted In-Lake [Chl-a]			**42.2 [ug/l]**
Observed In-Lake [Chl-a]			**[ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{(\text{a} + 0.015 \times [\text{Chl}a])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.08 [m^{-1}]
Model Predicted In-Lake SD			**1.39 [m]**
Observed In-Lake SD			**1.40 [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$		
		P_{sed} (phosphorus sedimentation) =	**6,165 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**893 [lb/yr]**

2000 Load Reduction Table for: Spring Lake										
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**					**TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS**			
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**[Chla] [ug/L]**	**SD [ft]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**	**TSI [Chla] [--]**	**TSI SD [--]**	**TSI Avg. [--]**
0%	**7,058**	109	42	4.57	6165	**893**	71.7	67.3	55.2	**64.8**
5%	**6,705**	105	42	4.63	5839	**866**	71.3	67.2	55.0	**64.5**
10%	**6,352**	102	41	4.68	5514	**838**	70.8	67.1	54.9	**64.2**
15%	**5,999**	98	40	4.75	5189	**810**	70.3	66.9	54.7	**64.0**
20%	**5,646**	95	40	4.82	4866	**781**	69.8	66.7	54.5	**63.7**
25%	**5,293**	91	39	4.90	4543	**751**	69.2	66.5	54.2	**63.3**
30%	**4,941**	87	38	4.99	4221	**720**	68.6	66.3	53.9	**63.0**
35%	**4,588**	84	37	5.10	3900	**688**	68.0	66.1	53.6	**62.6**
40%	**4,235**	80	36	5.22	3580	**655**	67.3	65.8	53.3	**62.1**
45%	**3,882**	75	35	5.36	3261	**621**	66.5	65.5	52.9	**61.6**
50%	**3,529**	71	34	5.53	2943	**586**	65.6	65.2	52.5	**61.1**
55%	**3,176**	67	33	5.74	2627	**549**	64.7	64.8	51.9	**60.5**
60%	**2,823**	62	31	5.99	2313	**510**	63.7	64.3	51.3	**59.7**
65%	**2,470**	57	29	6.30	2001	**469**	62.4	63.7	50.6	**58.9**
70%	**2,117**	52	27	6.71	1692	**425**	61.0	62.9	49.7	**57.9**
75%	**1,764**	46	25	7.26	1386	**379**	59.4	62.0	48.5	**56.6**
80%	**1,412**	40	22	8.05	1084	**328**	57.3	60.7	47.1	**55.0**
85%	**1,059**	33	18	9.27	787	**272**	54.6	59.0	45.0	**52.9**
90%	**706**	25	14	11.41	498	**207**	50.7	56.2	42.0	**49.6**
95%	**353**	16	8	16.30	225	**128**	43.8	50.8	36.9	**43.8**

2000 Loading Summary for: Upper Prior Lake

	Water Budgets			Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Upper Prior Direct	1588.6	2.0	269.5	182.2	1.0	133.5
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*1,589*	*2*	*270*	*182.2*		*133.5*

Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Upper Prior Direct	1,589	9	10%	4.2	0.0	3.8
2		37				
3						
4						
5						
Summation	*1,589*	*46*	*10%*		*0.0*	*3.8*

Inflow from Upstream Lakes				
Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Spring Lake	3,026.7	108.5	1.0	893
2 Crystal Lake	231.0	47.0	1.0	30
3 Arctic Lake	147.6	222.3	1.0	89
Summation	*3,405*	*125.9*		*1,012*

Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
337	31.7	31.7	0.00	0.13	1.0	15.0
			Dry-year total P deposition =	0.109		
			Average-year total P deposition =	0.133		
			Wet-year total P deposition =	0.158		
			(Barr Engineering 2004)			

Groundwater					
Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
337	0.0	0.00	0	1.0	0

Internal				
Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
337	24.0	36.00	1.0	2,598

Net Discharge [ac-ft/yr] =	**3,675**	**Net Load [lb/yr] =**	**3,762**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

2000 Lake Response Modeling for: Upper Prior Lake

Modeled Parameter	Equation	Parameters	Value [Units]

TOTAL IN-LAKE PHOSPHORUS CONCENTRATION

$$P=\left[-1+\left(1+4KA1P_iT\right)^{0.5}\right]\Big/\left(2KA1T\right)$$

$$A1=0.056Fot^{-1}Qs\Big/\left(Qs+13.3\right)$$

$$Qs=Max(Z/T,4)$$

as f(W,Q,V,Fot) from BATHTUB 2nd Order Decay

Parameters	Value	[Units]
C_P =	1.00	[--]
C_{CB} =	0.162	[--]
b =	0.458	[--]
W (total P load = inflow + atm.) =	3,762	[lb/yr]
Q (lake outflow) =	3,675	[ac-ft/yr]
V (modeled lake volume) =	3,621	[ac-ft]
Fot=	0.6	[--]
Qs=	13.9	[m/yr]
T = V/Q =	0.99	[yr]
P_i = W/Q =	376	[ug/l]
Model Predicted In-Lake [TP]	**79.5**	**[ug/l]**
Observed In-Lake [TP]	**86.7**	**[ug/l]**

CHLOROPHYLL-A CONCENTRATION

$$[\mathrm{Chl}a]=CB\times0.28\times[TP]$$

as f(TP), Walker 1999, Model 4

Parameters	Value	[Units]
CB (Calibration factor) =	1.00	[--]
Model Predicted In-Lake [Chl-a]	**22.2**	**[ug/l]**

$$[\mathrm{Chl}a]=\frac{CB\times B_x}{\left[\left(1+0.025\times B_x\times G\right)\left(1+G\times \mathrm{a}\right)\right]}$$

$$B_x=\frac{X_{pn}^{\ 1.33}}{4.31}$$

$$X_{pn}=\left[P^{-2}+\left(\frac{N-150}{12}\right)^{-2}\right]^{-0.5}$$

$$G=Z_{mix}\left(0.14+0.0039F_s\right)$$

$$F_s=\frac{Q}{V}$$

$$a=\frac{1}{SD}-0.015\times[\mathrm{Chl}a]$$

as f(TP, N, Flushing), Walker 1999, Model 1

Parameters	Value	[Units]
CB (Calibration factor) =	1.00	
P (Total Phosphorus) =	79	[ug/l]
N (Total Nitrogen) =	1875	[ug/l]
B_x (Nutrient-Potential Chl-a conc.) =	65.4	[ug/l]
X_{pn} (Composite nutrient conc.)=	69.5	[ug/l]
G (Kinematic factor) =	0.43	[--]
F_s (Flushing Rate) =	1.01	[$year^{-1}$]
Z_{mix} (Mixing Depth) =	9.84	[ft]
a (Non algal turbidity) =	0.04	[m^{-1}]
S (Secchi Depth) =	5.43	[ft]
Maximum lake depth =	45.00	[ft]
Model Predicted In-Lake [Chl-a]	**37.7**	**[ug/l]**
Observed In-Lake [Chl-a]		**[ug/l]**

SECCHI DEPTH

$$SD=\frac{CS}{\left(\mathrm{a}+0.015\times[\mathrm{Chl}a]\right)}$$

as f(Chla), Walker (1999)

Parameters	Value	[Units]
CS (Calibration factor) =	1.00	[--]
a (Non algal turbidity) =	0.04	[m^{-1}]
Model Predicted In-Lake SD	**1.66**	**[m]**
Observed In-Lake SD	**1.02**	**[m]**

PHOSPHORUS OUTFLOW LOAD

Parameters	Value	[Units]
W-P_{sed} =	**794**	**[lb/yr]**

2000 Load Reduction Table for: Upper Prior Lake										
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**					**TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS**			
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**[Chla] [ug/L]**	**SD [ft]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**	**TSI [Chla] [--]**	**TSI SD [--]**	**TSI Avg. [--]**
0%	**3,762**	80.1	38	5.41	1946	**1816**	67.4	66.3	52.8	**62.1**
5%	**3,574**	77.8	37	5.50	1847	**1727**	66.9	66.1	52.6	**61.9**
10%	**3,386**	75.5	37	5.59	1748	**1638**	66.5	65.9	52.3	**61.6**
15%	**3,198**	73.1	36	5.70	1649	**1549**	66.0	65.7	52.0	**61.3**
20%	**3,009**	70.7	35	5.82	1550	**1460**	65.6	65.5	51.7	**60.9**
25%	**2,821**	68.1	34	5.95	1451	**1371**	65.0	65.3	51.4	**60.6**
30%	**2,633**	65.5	33	6.11	1352	**1282**	64.5	65.0	51.0	**60.2**
35%	**2,445**	62.8	32	6.28	1252	**1193**	63.8	64.7	50.6	**59.7**
40%	**2,257**	60.0	31	6.48	1153	**1104**	63.2	64.4	50.2	**59.2**
45%	**2,069**	57.0	30	6.71	1054	**1015**	62.5	64.0	49.7	**58.7**
50%	**1,881**	54.0	29	6.98	954	**926**	61.7	63.6	49.1	**58.1**
55%	**1,693**	50.8	27	7.31	855	**838**	60.8	63.1	48.5	**57.4**
60%	**1,505**	47.3	26	7.71	756	**749**	59.8	62.5	47.7	**56.7**
65%	**1,317**	43.7	24	8.22	657	**660**	58.6	61.8	46.8	**55.7**
70%	**1,129**	39.9	22	8.87	558	**571**	57.3	61.0	45.7	**54.6**
75%	**940**	35.7	20	9.75	459	**481**	55.7	59.9	44.3	**53.3**
80%	**752**	31.1	17	11.02	361	**391**	53.7	58.6	42.5	**51.6**
85%	**564**	25.9	14	13.03	263	**301**	51.1	56.7	40.1	**49.3**
90%	**376**	19.8	11	16.70	167	**209**	47.2	53.7	36.5	**45.8**
95%	**188**	12.2	6	25.97	75	**113**	40.2	48.0	30.2	**39.4**

2001 Loading Summary for: Spring Lake

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Route 14 (W. Spr)	415.2	11.4	395.5	450.9	1.0	485.0
2 Route 7 (CD 13)	5636.5	6.1	2,879.9	369.5	0.7	2,893.5
3 Route 13 (C. Spr)	316.0	5.7	149.2	1174.9	1.0	476.7
4 Route 12 (Buck)	3659.3	6.8	2,063.8	353.4	1.0	1,983.2
5 Spring Direct	1922.4	3.9	620.2	376.8	1.0	635.5
Summation	*11,949*	*34*	*6,109*	*545.1*		*6,474.0*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Route 14 (W. Spr)	415	10	10%	4.2	0.0	4.2
2 Route 7 (CD 13)	5,636	180	10%	4.2	0.0	75.6
3 Route 13 (C. Spr)	316	5	10%	4.2	0.0	2.1
4 Route 12 (Buck)	3,659	302	10%	4.2	0.0	126.8
5 Spring Direct	1,922	129	10%	4.2	0.0	54.2
Summation	*11,949*	*626*	*10%*		*0.0*	*262.9*
Inflow from Upstream Lakes						
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Fish			393.8	66.3	1.0	71
2				-	1.0	
3				-	1.0	
Summation			*394*	*66.3*		*71*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
642	34.5	34.5	0.00	0.13	1.0	28.5
			Dry-year total P deposition =	0.109		
			Average-year total P deposition =	0.133		
			Wet-year total P deposition =	0.158		
			(Barr Engineering 2004)			
Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
642	0.0		0.00	0	1.0	0
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
642	53.0			17.00	1.0	5,161
			Net Discharge [ac-ft/yr] = **6,503**		**Net Load [lb/yr] =**	**11,997**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

2001 Lake Response Modeling for: Spring Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = P_i \Big/ \left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	11,997 [lb/yr]
		Q (lake outflow) =	6,503 [ac-ft/yr]
		V (modeled lake volume) =	10,206 [ac-ft]
		T = V/Q =	1.57 [yr]
		P_i = W/Q =	678 [ug/l]
Model Predicted In-Lake [TP]			**133.1 [ug/l]**
Observed In-Lake [TP]			**96.3 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**37.3 [ug/l]**
	$[\mathrm{Chl}a] = \frac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \mathrm{a})]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \frac{X_{pn}^{1.33}}{4.31}$	P (Total Phosphorus) =	133 [ug/l]
		N (Total Nitrogen) =	1963 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	105.9 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\frac{N-150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	99.9 [ug/l]
		G (Kinematic factor) =	0.43 [--]
		F_s (Flushing Rate) =	0.64 [year^{-1}]
	$G = Z_{mix}(0.14 + 0.0039 F_s)$	Z_{mix} (Mixing Depth) =	9.84 [ft]
	$F_s = \frac{Q}{V}$; $a = \frac{1}{SD} - 0.015 \times [\mathrm{Chl}a]$	a (Non algal turbidity) =	0.08 [m^{-1}]
		S (Secchi Depth) =	4.08 [ft]
		Maximum lake depth =	35.00 [ft]
Model Predicted In-Lake [Chl-a]			**47.9 [ug/l]**
Observed In-Lake [Chl-a]			**68.3 [ug/l]**
SECCHI DEPTH			
	$SD = \frac{CS}{(\mathrm{a} + 0.015 \times [\mathrm{Chl}a])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.08 [m^{-1}]
Model Predicted In-Lake SD			**1.24 [m]**
Observed In-Lake SD			**0.64 [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$		
		P_{sed} (phosphorus sedimentation) =	**9,643 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**2,354 [lb/yr]**

2001 Load Reduction Table for: Spring Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS					TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS			
REDUC-TION [%]	NET LOAD [lb]	[TP] [ug/L]	[Chla] [ug/L]	SD [ft]	P SEDIMEN-TATION [lb]	TP OUT-FLOW [lb]	TSI [TP] [--]	TSI [Chla] [--]	TSI SD [--]	TSI Avg. [--]
0%	**11,997**	133	48	4.08	9643	**2354**	74.7	68.6	56.8	**66.7**
5%	**11,397**	129	47	4.13	9119	**2279**	74.2	68.5	56.7	**66.5**
10%	**10,797**	125	47	4.17	8596	**2202**	73.7	68.3	56.5	**66.2**
15%	**10,198**	120	46	4.23	8074	**2123**	73.2	68.2	56.3	**65.9**
20%	**9,598**	116	45	4.29	7555	**2042**	72.6	68.0	56.1	**65.6**
25%	**8,998**	111	45	4.36	7038	**1960**	72.0	67.9	55.9	**65.3**
30%	**8,398**	106	44	4.43	6523	**1875**	71.4	67.7	55.7	**64.9**
35%	**7,798**	101	43	4.52	6011	**1787**	70.7	67.4	55.4	**64.5**
40%	**7,198**	96	42	4.63	5502	**1697**	70.0	67.2	55.0	**64.1**
45%	**6,598**	91	40	4.75	4995	**1603**	69.1	66.9	54.7	**63.6**
50%	**5,999**	85	39	4.90	4492	**1506**	68.2	66.6	54.2	**63.0**
55%	**5,399**	79	37	5.08	3994	**1405**	67.2	66.2	53.7	**62.4**
60%	**4,799**	73	36	5.30	3499	**1299**	66.1	65.7	53.1	**61.6**
65%	**4,199**	67	34	5.58	3011	**1188**	64.8	65.1	52.4	**60.8**
70%	**3,599**	61	31	5.95	2528	**1071**	63.3	64.3	51.4	**59.7**
75%	**2,999**	53	28	6.46	2054	**946**	61.5	63.4	50.2	**58.4**
80%	**2,399**	46	25	7.19	1589	**811**	59.3	62.1	48.7	**56.7**
85%	**1,800**	37	21	8.36	1138	**662**	56.4	60.3	46.5	**54.4**
90%	**1,200**	28	15	10.48	705	**494**	52.2	57.3	43.3	**50.9**
95%	**600**	17	8	15.54	306	**294**	44.7	51.6	37.6	**44.6**

2001 Loading Summary for: Upper Prior Lake

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF)[1]	Load
Name	[acre]	[in/yr]	[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1 Upper Prior Direct	1588.6	4.4	585.1	344.7	1.0	548.5
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*1,589*	*4*	*585*	*344.7*		*548.5*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Upper Prior Direct	1,589	9	10%	4.2	0.0	3.8
2		37				
3						
4						
5						
Summation	*1,589*	*46*	*10%*		*0.0*	*3.8*
Inflow from Upstream Lakes						
			Discharge	Estimated P Concentration	Calibration Factor	Load
Name			[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1 Spring Lake			6,502.5	133.1	1.0	2354
2 Crystal Lake			538.4	47.0	1.0	69
3 Arctic Lake			319.3	178.8	1.0	155
Summation			*7,360*	*119.6*		*2,578*
Atmosphere						
Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
[acre]	[in/yr]	[in/yr]	[ac-ft/yr]	[lb/ac-yr]	[--]	[lb/yr]
337	34.5	34.5	0.00	0.13	1.0	15.0
			Dry-year total P deposition =	0.109		
			Average-year total P deposition =	0.133		
			Wet-year total P deposition =	0.158		
			(Barr Engineering 2004)			
Groundwater						
Lake Area	Groundwater Flux		Net Inflow	Phosphorus Concentration	Calibration Factor	Load
[acre]	[m/yr]		[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
337	0.0		0.00	0	1.0	0
Internal						
Lake Area	Anoxic Factor			Release Rate	Calibration Factor	Load
[acre]	[days]			[mg/m^2-day]	[--]	[lb/yr]
337	24.0			36.00	1.0	2,598
		Net Discharge [ac-ft/yr] =	**7,945**		**Net Load [lb/yr] =**	**5,743**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

2001 Lake Response Modeling for: Upper Prior Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = \left[-1+\left(1+4KA1P_iT\right)^{0.5}\right] / \left(2KA1T\right)$	as f(W,Q,V,Fot) from BATHTUB 2nd Order Decay	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
	$A1 = 0.056 Fot^{-1} Qs / \left(Qs+13.3\right)$	b =	0.458 [--]
		W (total P load = inflow + atm.) =	5,743 [lb/yr]
		Q (lake outflow) =	7,945 [ac-ft/yr]
	$Qs = Max(Z/T,4)$	V (modeled lake volume) =	3,621 [ac-ft]
		Fot=	0.6 [--]
		Qs=	30.1 [m/yr]
		T = V/Q =	0.46 [yr]
		P_i = W/Q =	266 [ug/l]
Model Predicted In-Lake [TP]			**79.5 [ug/l]**
Observed In-Lake [TP]			**88.2 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**22.3 [ug/l]**
	$[\mathrm{Chl}a] = \dfrac{CB \times B_x}{\left[\left(1+0.025 \times B_x \times G\right)\left(1+G \times \mathrm{a}\right)\right]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \dfrac{X_{pn}^{1.33}}{4.31}$	P (Total Phosphorus) =	79 [ug/l]
		N (Total Nitrogen) =	1719 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	63.4 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\dfrac{N-150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	67.9 [ug/l]
		G (Kinematic factor) =	0.45 [--]
		F_s (Flushing Rate) =	2.19 [year^{-1}]
	$G = Z_{mix}\left(0.14 + 0.0039 F_s\right)$	Z_{mix} (Mixing Depth) =	9.84 [ft]
	$F_s = \dfrac{Q}{V}$; $a = \dfrac{1}{SD} - 0.015 \times [\mathrm{Chl}a]$	a (Non algal turbidity) =	0.04 [m^{-1}]
		S (Secchi Depth) =	5.60 [ft]
		Maximum lake depth =	45.00 [ft]
Model Predicted In-Lake [Chl-a]			**36.5 [ug/l]**
Observed In-Lake [Chl-a]			**79.1 [ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{\left(\mathrm{a} + 0.015 \times [\mathrm{Chl}a]\right)}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.04 [m^{-1}]
Model Predicted In-Lake SD			**1.71 [m]**
Observed In-Lake SD			**0.92 [m]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**1,717 [lb/yr]**

2001 Load Reduction Table for: Upper Prior Lake

LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**					**TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS**			
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**[Chla] [ug/L]**	**SD [ft]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**	**TSI [Chla] [--]**	**TSI SD [--]**	**TSI Avg. [--]**
0%	**5,743**	79.5	37	5.60	2343	**3400**	67.2	65.9	52.3	**61.8**
5%	**5,456**	77.1	36	5.69	2221	**3235**	66.8	65.7	52.1	**61.5**
10%	**5,168**	74.7	35	5.79	2098	**3070**	66.3	65.5	51.8	**61.2**
15%	**4,881**	72.2	35	5.91	1976	**2906**	65.9	65.3	51.5	**60.9**
20%	**4,594**	69.6	34	6.03	1853	**2741**	65.3	65.1	51.2	**60.6**
25%	**4,307**	67.0	33	6.18	1731	**2576**	64.8	64.9	50.9	**60.2**
30%	**4,020**	64.3	32	6.34	1609	**2411**	64.2	64.6	50.5	**59.8**
35%	**3,733**	61.4	31	6.52	1487	**2246**	63.5	64.3	50.1	**59.3**
40%	**3,446**	58.5	30	6.74	1365	**2081**	62.8	63.9	49.6	**58.8**
45%	**3,159**	55.5	29	6.99	1243	**1915**	62.1	63.5	49.1	**58.2**
50%	**2,871**	52.3	27	7.29	1122	**1749**	61.2	63.1	48.5	**57.6**
55%	**2,584**	48.9	26	7.65	1001	**1583**	60.3	62.6	47.8	**56.9**
60%	**2,297**	45.4	24	8.10	880	**1417**	59.2	62.0	47.0	**56.0**
65%	**2,010**	41.7	23	8.67	760	**1250**	57.9	61.2	46.0	**55.1**
70%	**1,723**	37.7	21	9.41	641	**1082**	56.5	60.3	44.8	**53.9**
75%	**1,436**	33.4	18	10.43	523	**913**	54.8	59.2	43.3	**52.4**
80%	**1,149**	28.8	16	11.92	406	**743**	52.6	57.7	41.4	**50.6**
85%	**861**	23.5	13	14.31	291	**570**	49.7	55.6	38.8	**48.0**
90%	**574**	17.5	9	18.78	180	**394**	45.4	52.3	34.9	**44.2**
95%	**287**	10.2	5	30.12	76	**211**	37.7	45.8	28.1	**37.2**

2002 Loading Summary for: Spring Lake

	Water Budgets			Phosphorus Loading		
Inflow from Drainage Areas						
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF)[1]	Load
Name	[acre]	[in/yr]	[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1 Route 14 (W. Spr)	415.2	13.5	466.7	463.7	1.0	588.5
2 Route 7 (CD 13)	5636.5	6.2	2,926.5	441.2	0.7	3,511.1
3 Route 13 (C. Spr)	316.0	4.9	129.7	1640.2	1.0	578.5
4 Route 12 (Buck)	3659.3	7.2	2,202.0	401.9	1.0	2,406.5
5 Spring Direct	1922.4	4.2	665.0	426.4	1.0	771.2
Summation	*11,949*	*36*	*6,390*	*674.7*		*7,855.8*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Route 14 (W. Spr)	415	10	10%	4.2	0.0	4.2
2 Route 7 (CD 13)	5,636	180	10%	4.2	0.0	75.6
3 Route 13 (C. Spr)	316	5	10%	4.2	0.0	2.1
4 Route 12 (Buck)	3,659	302	10%	4.2	0.0	126.8
5 Spring Direct	1,922	129	10%	4.2	0.0	54.2
Summation	*11,949*	*626*	*10%*		*0.0*	*262.9*
Inflow from Upstream Lakes						
			Discharge	Estimated P Concentration	Calibration Factor	Load
Name			[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1 Fish			627.7	76.4	1.0	130
2				-	1.0	
3				-	1.0	
Summation			*628*	*76.4*		*130*
Atmosphere						
Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
[acre]	[in/yr]	[in/yr]	[ac-ft/yr]	[lb/ac-yr]	[--]	[lb/yr]
642	44.2	44.2	0.00	0.16	1.0	33.8
			Dry-year total P deposition =	0.109		
			Average-year total P deposition =	0.133		
			Wet-year total P deposition =	0.158		
			(Barr Engineering 2004)			
Groundwater						
Lake Area	Groundwater Flux		Net Inflow	Phosphorus Concentration	Calibration Factor	Load
[acre]	[m/yr]		[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
642	0.0		0.00	0	1.0	0
Internal						
Lake Area	Anoxic Factor			Release Rate	Calibration Factor	Load
[acre]	[days]			[mg/m^2-day]	[--]	[lb/yr]
642	53.0			17.00	1.0	5,161
		Net Discharge [ac-ft/yr] =	**7,017**		**Net Load [lb/yr] =**	**13,444**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

2002 Lake Response Modeling for: Spring Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	13,444 [lb/yr]
		Q (lake outflow) =	7,017 [ac-ft/yr]
		V (modeled lake volume) =	10,206 [ac-ft]
		T = V/Q =	1.45 [yr]
		P_i = W/Q =	704 [ug/l]
Model Predicted In-Lake [TP]			**140.9 [ug/l]**
Observed In-Lake [TP]			**126.5 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**39.5 [ug/l]**
	$$[\mathrm{Chl}a] = \frac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \mathrm{a})]}$$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$$B_x = \frac{X_{pn}^{1.33}}{4.31}$$	P (Total Phosphorus) =	141 [ug/l]
		N (Total Nitrogen) =	2127 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	116.2 [ug/l]
	$$X_{pn} = \left[P^{-2} + \left(\frac{N-150}{12}\right)^{-2}\right]^{-0.5}$$	X_{pn} (Composite nutrient conc.)=	107.1 [ug/l]
		G (Kinematic factor) =	0.43 [--]
		F_s (Flushing Rate) =	0.69 [year^{-1}]
	$G = Z_{mix}(0.14 + 0.0039 F_s)$	Z_{mix} (Mixing Depth) =	9.84 [ft]
	$F_s = \frac{Q}{V}$; $a = \frac{1}{SD} - 0.015 \times [\mathrm{Chl}a]$	a (Non algal turbidity) =	0.08 [m^{-1}]
		S (Secchi Depth) =	3.93 [ft]
		Maximum lake depth =	35.00 [ft]
Model Predicted In-Lake [Chl-a]			**50.0 [ug/l]**
Observed In-Lake [Chl-a]			**85.1 [ug/l]**
SECCHI DEPTH			
	$$SD = \frac{CS}{(\mathrm{a} + 0.015 \times [\mathrm{Chl}a])}$$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.08 [m^{-1}]
Model Predicted In-Lake SD			**1.20 [m]**
Observed In-Lake SD			**0.58 [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$		
		P_{sed} (phosphorus sedimentation) =	**10,755 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**2,689 [lb/yr]**

2002 Load Reduction Table for: Spring Lake

LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**					**TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS**			
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**[Chla] [ug/L]**	**SD [ft]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**	**TSI [Chla] [--]**	**TSI SD [--]**	**TSI Avg. [--]**
0%	**13,444**	141	50	3.93	10755	**2689**	75.5	69.0	57.4	**67.3**
5%	**12,771**	136	49	3.97	10169	**2603**	75.0	68.9	57.2	**67.0**
10%	**12,099**	132	49	4.02	9584	**2515**	74.5	68.7	57.1	**66.8**
15%	**11,427**	127	48	4.07	9002	**2425**	74.0	68.6	56.9	**66.5**
20%	**10,755**	122	47	4.13	8422	**2332**	73.5	68.5	56.7	**66.2**
25%	**10,083**	117	47	4.19	7845	**2238**	72.9	68.3	56.5	**65.9**
30%	**9,411**	112	46	4.26	7270	**2140**	72.2	68.1	56.2	**65.5**
35%	**8,738**	107	45	4.35	6698	**2040**	71.5	67.9	55.9	**65.1**
40%	**8,066**	101	44	4.45	6130	**1937**	70.8	67.6	55.6	**64.7**
45%	**7,394**	96	42	4.56	5565	**1829**	69.9	67.3	55.2	**64.2**
50%	**6,722**	90	41	4.70	5003	**1718**	69.0	67.0	54.8	**63.6**
55%	**6,050**	84	39	4.87	4447	**1603**	68.0	66.6	54.3	**63.0**
60%	**5,377**	78	37	5.08	3896	**1482**	66.9	66.1	53.7	**62.2**
65%	**4,705**	71	35	5.35	3350	**1355**	65.6	65.6	53.0	**61.4**
70%	**4,033**	64	33	5.70	2813	**1221**	64.1	64.8	52.0	**60.3**
75%	**3,361**	56	30	6.18	2284	**1077**	62.3	63.9	50.9	**59.0**
80%	**2,689**	48	26	6.88	1766	**923**	60.1	62.6	49.3	**57.3**
85%	**2,017**	39	22	8.00	1263	**753**	57.2	60.8	47.2	**55.0**
90%	**1,344**	29	16	10.04	783	**562**	52.9	57.9	43.9	**51.6**
95%	**672**	17	9	14.98	338	**334**	45.4	52.2	38.1	**45.2**

2002 Loading Summary for: Upper Prior Lake

	Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas							
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]		Load [lb/yr]
1 Upper Prior Direct	1588.6	5.1	676.2	361.9	1.0		665.5
2					1.0		
3					1.0		
4					1.0		
5					1.0		
Summation	*1,589*	*5*	*676*	*361.9*			*665.5*
Failing Septic Systems							
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]		[lb/yr]
1 Upper Prior Direct	1,589	9	10%	4.2	0.0		3.8
2		37					
3							
4							
5							
Summation	*1,589*	*46*	*10%*		*0.0*		*3.8*
Inflow from Upstream Lakes							
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]		Load [lb/yr]
1 Spring Lake			7,017.5	140.9	1.0		2689
2 Crystal Lake			526.4	47.0	1.0		67
3 Arctic Lake			366.7	158.5	1.0		158
Summation			*7,911*	*115.5*			*2,914*
Atmosphere							
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]		Load [lb/yr]
337	44.2	44.2	0.00	0.16	1.0		17.8
			Dry-year total P deposition =	0.109			
			Average-year total P deposition =	0.133			
			Wet-year total P deposition =	0.158			
			(Barr Engineering 2004)				
Groundwater							
Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]		Load [lb/yr]
337	0.0		0.00	0	1.0		0
Internal							
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]		Load [lb/yr]
337	24.0			36.00	1.0		2,598
		Net Discharge [ac-ft/yr] =	**8,587**			**Net Load [lb/yr] =**	**6,199**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

2002 Lake Response Modeling for: Upper Prior Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = \left[-1 + \left(1 + 4KA1P_iT\right)^{0.5}\right] \big/ \left(2KA1T\right)$	as f(W,Q,V,Fot) from BATHTUB 2nd Order Decay	
		C_P =	1.00 [--]
	$A1 = 0.056 Fot^{-1} Qs \big/ \left(Qs + 13.3\right)$	C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	6,199 [lb/yr]
	$Qs = Max(Z/T, 4)$	Q (lake outflow) =	8,587 [ac-ft/yr]
		V (modeled lake volume) =	3,621 [ac-ft]
		Fot=	0.6 [--]
		Qs=	32.5 [m/yr]
		T = V/Q =	0.42 [yr]
		P_i = W/Q =	265 [ug/l]
Model Predicted In-Lake [TP]			**81.2 [ug/l]**
Observed In-Lake [TP]			**106.0 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**22.7 [ug/l]**
	$[\mathrm{Chl}a] = \dfrac{CB \times B_x}{\left[\left(1 + 0.025 \times B_x \times G\right)\left(1 + G \times \mathrm{a}\right)\right]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \dfrac{X_{pn}^{\ 1.33}}{4.31}$	P (Total Phosphorus) =	81 [ug/l]
		N (Total Nitrogen) =	1944 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	67.7 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\dfrac{N - 150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	71.4 [ug/l]
		G (Kinematic factor) =	0.45 [--]
		F_s (Flushing Rate) =	2.37 [$year^{-1}$]
	$G = Z_{mix}\left(0.14 + 0.0039F_s\right)$	Z_{mix} (Mixing Depth) =	9.84 [ft]
	$F_s = \dfrac{Q}{V}$; $a = \dfrac{1}{SD} - 0.015 \times [\mathrm{Chl}a]$	a (Non algal turbidity) =	0.04 [m^{-1}]
		S (Secchi Depth) =	5.41 [ft]
		Maximum lake depth =	45.00 [ft]
Model Predicted In-Lake [Chl-a]			**37.9 [ug/l]**
Observed In-Lake [Chl-a]			**69.3 [ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{\left(\mathrm{a} + 0.015 \times [\mathrm{Chl}a]\right)}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.04 [m^{-1}]
Model Predicted In-Lake SD			**1.65 [m]**
Observed In-Lake SD			**0.73 [m]**
PHOSPHORUS OUTFLOW LOAD			
	$W\text{-}P_{sed}$ =		**1,896 [lb/yr]**

2002 Load Reduction Table for: Upper Prior Lake											
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**					**TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS**				
REDUC-TION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**[Chla] [ug/L]**	**SD [ft]**	**P SEDIMEN-TATION [lb]**	**TP OUT-FLOW [lb]**	**TSI [TP] [--]**	**TSI [Chla] [--]**	**TSI SD [--]**	**TSI Avg. [--]**
0%	**6,199**	81.2	38	5.41	2480	**3719**	67.6	66.3	52.8	**62.2**
5%	**5,889**	78.8	37	5.50	2350	**3539**	67.1	66.1	52.5	**61.9**
10%	**5,579**	76.3	36	5.61	2220	**3359**	66.7	65.9	52.3	**61.6**
15%	**5,269**	73.7	36	5.72	2090	**3179**	66.2	65.7	52.0	**61.3**
20%	**4,959**	71.1	35	5.85	1960	**2999**	65.6	65.4	51.7	**60.9**
25%	**4,649**	68.4	34	5.99	1831	**2819**	65.1	65.2	51.3	**60.5**
30%	**4,339**	65.6	33	6.15	1701	**2638**	64.5	64.9	50.9	**60.1**
35%	**4,029**	62.7	32	6.33	1572	**2457**	63.8	64.6	50.5	**59.6**
40%	**3,719**	59.7	31	6.55	1443	**2277**	63.1	64.2	50.0	**59.1**
45%	**3,409**	56.6	30	6.80	1314	**2096**	62.3	63.8	49.5	**58.6**
50%	**3,100**	53.3	28	7.10	1185	**1914**	61.5	63.4	48.9	**57.9**
55%	**2,790**	49.9	27	7.46	1057	**1733**	60.5	62.9	48.2	**57.2**
60%	**2,480**	46.3	25	7.90	929	**1550**	59.5	62.2	47.3	**56.3**
65%	**2,170**	42.5	23	8.46	802	**1368**	58.2	61.5	46.3	**55.3**
70%	**1,860**	38.4	21	9.20	676	**1184**	56.8	60.6	45.1	**54.2**
75%	**1,550**	34.0	19	10.22	551	**999**	55.0	59.4	43.6	**52.7**
80%	**1,240**	29.2	16	11.70	427	**813**	52.8	57.9	41.7	**50.8**
85%	**930**	23.9	13	14.07	306	**624**	49.9	55.8	39.0	**48.2**
90%	**620**	17.7	9	18.53	189	**431**	45.6	52.4	35.1	**44.4**
95%	**310**	10.3	5	29.88	80	**230**	37.8	46.0	28.2	**37.3**

2003 Loading Summary for: Spring Lake

Water Budgets				**Phosphorus Loading**			
Inflow from Drainage Areas							
	Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1	Route 14 (W. Spr)	415.2	4.6	158.5	124.0	1.0	53.4
2	Route 7 (CD 13)	5636.5	1.8	854.4	137.2	0.7	318.8
3	Route 13 (C. Spr)	316.0	1.2	31.0	622.2	1.0	52.5
4	Route 12 (Buck)	3659.3	1.8	562.6	142.8	1.0	218.5
5	Spring Direct	1922.4	1.0	160.0	160.9	1.0	70.0
	Summation	*11,949*	*10*	*1,766*	*237.4*		*713.3*
Failing Septic Systems							
	Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1	Route 14 (W. Spr)	415	10	10%	4.2	0.0	4.2
2	Route 7 (CD 13)	5,636	180	10%	4.2	0.0	75.6
3	Route 13 (C. Spr)	316	5	10%	4.2	0.0	2.1
4	Route 12 (Buck)	3,659	302	10%	4.2	0.0	126.8
5	Spring Direct	1,922	129	10%	4.2	0.0	54.2
	Summation	*11,949*	*626*	*10%*		*0.0*	*262.9*
Inflow from Upstream Lakes							
	Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1	Fish			188.3	57.4	1.0	29
2					-	1.0	
3					-	1.0	
	Summation			*188*	*57.4*		*29*
Atmosphere							
	Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
	642	25.2	25.2	0.00	0.13	1.0	28.5
			Dry-year total P deposition =		0.109		
			Average-year total P deposition =		0.133		
			Wet-year total P deposition =		0.158		
			(Barr Engineering 2004)				
Groundwater							
	Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
	642	0.0		0.00	0	1.0	0
Internal							
	Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m²-day]	Calibration Factor [--]	Load [lb/yr]
	642	53.0			17.00	1.0	5,161
			Net Discharge [ac-ft/yr] =	**1,955**		**Net Load [lb/yr] =**	**6,195**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

2003 Lake Response Modeling for: Spring Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	6,195 [lb/yr]
		Q (lake outflow) =	1,955 [ac-ft/yr]
		V (modeled lake volume) =	10,206 [ac-ft]
		T = V/Q =	5.22 [yr]
		P_i = W/Q =	1165 [ug/l]
Model Predicted In-Lake [TP]			**105.3 [ug/l]**
Observed In-Lake [TP]			**99.1 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**29.5 [ug/l]**
	$[\mathrm{Chl}a] = \dfrac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \mathrm{a})]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \dfrac{X_{pn}^{1.33}}{4.31}$	P (Total Phosphorus) =	105 [ug/l]
		N (Total Nitrogen) =	1600 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	78.0 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\frac{N - 150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	79.4 [ug/l]
		G (Kinematic factor) =	0.42 [--]
		F_s (Flushing Rate) =	0.19 [year^{-1}]
	$G = Z_{mix}(0.14 + 0.0039 F_s)$	Z_{mix} (Mixing Depth) =	9.84 [ft]
	$F_s = \dfrac{Q}{V}$ $a = \dfrac{1}{SD} - 0.015 \times [\mathrm{Chl}a]$	a (Non algal turbidity) =	0.08 [m^{-1}]
		S (Secchi Depth) =	4.66 [ft]
		Maximum lake depth =	35.00 [ft]
Model Predicted In-Lake [Chl-a]			**41.3 [ug/l]**
Observed In-Lake [Chl-a]			**44.5 [ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{(\mathrm{a} + 0.015 \times [\mathrm{Chl}a])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.08 [m^{-1}]
Model Predicted In-Lake SD			**1.42 [m]**
Observed In-Lake SD			**1.33 [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$		
		P_{sed} (phosphorus sedimentation) =	**5,635 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**560 [lb/yr]**

2003 Load Reduction Table for: Spring Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS					TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS			
REDUCTION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**[Chla] [ug/L]**	**SD [ft]**	**P SEDIMENTATION [lb]**	**TP OUTFLOW [lb]**	**TSI [TP] [--]**	**TSI [Chla] [--]**	**TSI SD [--]**	**TSI Avg. [--]**
0%	**6,195**	105	41	4.66	5635	**560**	71.3	67.1	54.9	**64.4**
5%	**5,885**	102	41	4.71	5342	**543**	70.9	67.0	54.8	**64.2**
10%	**5,575**	99	40	4.77	5049	**526**	70.4	66.8	54.6	**64.0**
15%	**5,266**	96	40	4.84	4757	**509**	69.9	66.7	54.4	**63.7**
20%	**4,956**	92	39	4.91	4465	**491**	69.4	66.5	54.2	**63.4**
25%	**4,646**	89	38	4.99	4173	**473**	68.9	66.3	54.0	**63.1**
30%	**4,336**	85	37	5.08	3882	**454**	68.3	66.1	53.7	**62.7**
35%	**4,027**	82	37	5.18	3592	**435**	67.7	65.9	53.4	**62.3**
40%	**3,717**	78	36	5.30	3302	**414**	67.0	65.7	53.1	**61.9**
45%	**3,407**	74	35	5.45	3014	**394**	66.2	65.4	52.7	**61.4**
50%	**3,097**	70	33	5.61	2726	**372**	65.4	65.0	52.3	**60.9**
55%	**2,788**	66	32	5.81	2439	**349**	64.5	64.6	51.8	**60.3**
60%	**2,478**	61	31	6.06	2153	**325**	63.5	64.1	51.2	**59.6**
65%	**2,168**	56	29	6.36	1868	**300**	62.3	63.6	50.5	**58.8**
70%	**1,858**	51	27	6.76	1585	**273**	61.0	62.8	49.6	**57.8**
75%	**1,549**	46	24	7.29	1304	**244**	59.4	61.9	48.5	**56.6**
80%	**1,239**	40	22	8.04	1026	**213**	57.4	60.8	47.1	**55.1**
85%	**929**	33	18	9.18	751	**178**	54.8	59.1	45.2	**53.0**
90%	**619**	26	14	11.19	482	**137**	51.1	56.4	42.3	**49.9**
95%	**310**	16	8	15.73	223	**87**	44.5	51.4	37.4	**44.4**

2003 Loading Summary for: Upper Prior Lake

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Upper Prior Direct	1588.6	1.3	166.8	133.2	1.0	60.4
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*1,589*	*1*	*167*	*133.2*		*60.4*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Upper Prior Direct	1,589	9	10%	4.2	0.0	3.8
2		37				
3						
4						
5						
Summation	*1,589*	*46*	*10%*		*0.0*	*3.8*

Inflow from Upstream Lakes

Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Spring Lake	1,954.8	105.3	1.0	560
2 Crystal Lake	126.1	47.0	1.0	16
3 Arctic Lake	91.3	167.0	1.0	41
Summation	*2,172*	*106.4*		*617*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
337	25.2	25.2	0.00	0.13	1.0	15.0
			Dry-year total P deposition =	0.109		
			Average-year total P deposition =	0.133		
			Wet-year total P deposition =	0.158		
			(Barr Engineering 2004)			

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
337	0.0	0.00	0	1.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
337	24.0	36.00	1.0	2,598

Net Discharge [ac-ft/yr] =	**2,339**	**Net Load [lb/yr] =**	**3,294**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

2003 Lake Response Modeling for: Upper Prior Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
$P=\left[-1+\left(1+4KA1P_iT\right)^{0.5}\right]\Big/\left(2KA1T\right)$		as f(W,Q,V,Fot) from BATHTUB 2nd Order Decay	
		C_P =	1.00 [--]
$A1=0.056Fot^{-1}Qs\Big/\left(Qs+13.3\right)$		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	3,294 [lb/yr]
$Qs=Max(Z/T,4)$		Q (lake outflow) =	2,339 [ac-ft/yr]
		V (modeled lake volume) =	3,621 [ac-ft]
		Fot=	0.6 [--]
		Qs=	8.9 [m/yr]
		T = V/Q =	1.55 [yr]
		P_i = W/Q =	518 [ug/l]
Model Predicted In-Lake [TP]			**86.4 [ug/l]**
Observed In-Lake [TP]			**73.9 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a]=CB\times0.28\times[TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**24.2 [ug/l]**
	$[\mathrm{Chl}a]=\dfrac{CB\times B_x}{\left[\left(1+0.025\times B_x\times G\right)\left(1+G\times a\right)\right]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
$B_x=\dfrac{X_{pn}^{\ 1.33}}{4.31}$		P (Total Phosphorus) =	86 [ug/l]
		N (Total Nitrogen) =	1529 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	64.8 [ug/l]
$X_{pn}=\left[P^{-2}+\left(\dfrac{N-150}{12}\right)^{-2}\right]^{-0.5}$		X_{pn} (Composite nutrient conc.)=	69.1 [ug/l]
		G (Kinematic factor) =	0.43 [--]
		F_s (Flushing Rate) =	0.65 [year^{-1}]
$G=Z_{mix}\left(0.14+0.0039F_s\right)$		Z_{mix} (Mixing Depth) =	9.84 [ft]
$F_s=\dfrac{Q}{V}$	$a=\dfrac{1}{SD}-0.015\times[\mathrm{Chl}a]$	a (Non algal turbidity) =	0.04 [m^{-1}]
		S (Secchi Depth) =	5.44 [ft]
		Maximum lake depth =	45.00 [ft]
Model Predicted In-Lake [Chl-a]			**37.7 [ug/l]**
Observed In-Lake [Chl-a]			**65.2 [ug/l]**
SECCHI DEPTH			
	$SD=\dfrac{CS}{\left(a+0.015\times[\mathrm{Chl}a]\right)}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.04 [m^{-1}]
Model Predicted In-Lake SD			**1.66 [m]**
Observed In-Lake SD			**0.99 [m]**
PHOSPHORUS OUTFLOW LOAD			
	$W-P_{sed}$ =		**550 [lb/yr]**

2003 Load Reduction Table for: Upper Prior Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS					TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS			
REDUCTION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**[Chla] [ug/L]**	**SD [ft]**	**P SEDIMENTATION [lb]**	**TP OUTFLOW [lb]**	**TSI [TP] [--]**	**TSI [Chla] [--]**	**TSI SD [--]**	**TSI Avg. [--]**
0%	**3,294**	86.4	38	5.44	1975	**1319**	68.5	66.2	52.7	**62.5**
5%	**3,129**	84.0	37	5.51	1876	**1253**	68.0	66.1	52.5	**62.2**
10%	**2,965**	81.6	37	5.59	1777	**1188**	67.6	65.9	52.3	**61.9**
15%	**2,800**	79.1	36	5.68	1678	**1122**	67.2	65.7	52.1	**61.7**
20%	**2,635**	76.5	35	5.78	1578	**1057**	66.7	65.6	51.8	**61.4**
25%	**2,471**	73.8	35	5.89	1479	**992**	66.2	65.4	51.6	**61.0**
30%	**2,306**	71.0	34	6.02	1379	**927**	65.6	65.1	51.3	**60.7**
35%	**2,141**	68.2	33	6.17	1279	**862**	65.0	64.9	50.9	**60.3**
40%	**1,977**	65.2	32	6.33	1179	**797**	64.4	64.6	50.5	**59.8**
45%	**1,812**	62.1	31	6.53	1079	**732**	63.7	64.3	50.1	**59.4**
50%	**1,647**	58.9	30	6.76	979	**668**	62.9	63.9	49.6	**58.8**
55%	**1,482**	55.4	29	7.03	879	**603**	62.1	63.5	49.0	**58.2**
60%	**1,318**	51.8	27	7.37	779	**539**	61.1	63.0	48.3	**57.5**
65%	**1,153**	48.0	26	7.79	679	**474**	60.0	62.4	47.5	**56.6**
70%	**988**	43.9	24	8.34	578	**410**	58.7	61.7	46.6	**55.6**
75%	**824**	39.5	22	9.08	478	**345**	57.2	60.7	45.3	**54.4**
80%	**659**	34.6	19	10.15	378	**281**	55.2	59.5	43.7	**52.8**
85%	**494**	29.0	16	11.82	278	**216**	52.7	57.8	41.5	**50.7**
90%	**329**	22.5	12	14.89	179	**150**	49.1	55.1	38.2	**47.5**
95%	**165**	14.2	7	22.66	82	**82**	42.4	49.9	32.2	**41.5**

2004 Loading Summary for: Spring Lake

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF)[1]	Load
Name	[acre]	[in/yr]	[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1 Route 14 (W. Spr)	415.2	5.5	189.9	137.8	1.0	71.2
2 Route 7 (CD 13)	5636.5	2.1	989.2	157.8	0.7	424.6
3 Route 13 (C. Spr)	316.0	1.3	33.4	769.2	1.0	70.0
4 Route 12 (Buck)	3659.3	2.4	724.4	147.7	1.0	291.0
5 Spring Direct	1922.4	1.1	176.0	194.8	1.0	93.3
Summation	*11,949*	*12*	*2,113*	*281.5*		*949.9*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Route 14 (W. Spr)	415	10	10%	4.2	0.0	4.2
2 Route 7 (CD 13)	5,636	180	10%	4.2	0.0	75.6
3 Route 13 (C. Spr)	316	5	10%	4.2	0.0	2.1
4 Route 12 (Buck)	3,659	302	10%	4.2	0.0	126.8
5 Spring Direct	1,922	129	10%	4.2	0.0	54.2
Summation	*11,949*	*626*	*10%*		*0.0*	*262.9*
Inflow from Upstream Lakes						
			Discharge	Estimated P Concentration	Calibration Factor	Load
Name			[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
1 Fish			287.5	58.1	1.0	45
2				-	1.0	
3				-	1.0	
Summation			*288*	*58.1*		*45*
Atmosphere						
Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
[acre]	[in/yr]	[in/yr]	[ac-ft/yr]	[lb/ac-yr]	[--]	[lb/yr]
642	31.5	31.5	0.00	0.13	1.0	28.5
			Dry-year total P deposition =	0.109		
			Average-year total P deposition =	0.133		
			Wet-year total P deposition =	0.158		
			(Barr Engineering 2004)			
Groundwater						
Lake Area	Groundwater Flux		Net Inflow	Phosphorus Concentration	Calibration Factor	Load
[acre]	[m/yr]		[ac-ft/yr]	[ug/L]	[--]	[lb/yr]
642	0.0		0.00	0	1.0	0
Internal						
Lake Area	Anoxic Factor			Release Rate	Calibration Factor	Load
[acre]	[days]			[mg/m^2-day]	[--]	[lb/yr]
642	53.0			17.00	1.0	5,161
			Net Discharge [ac-ft/yr] = 2,400		**Net Load [lb/yr] =**	**6,448**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

2004 Lake Response Modeling for: Spring Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	6,448 [lb/yr]
		Q (lake outflow) =	2,400 [ac-ft/yr]
		V (modeled lake volume) =	10,206 [ac-ft]
		T = V/Q =	4.25 [yr]
		P_i = W/Q =	988 [ug/l]
Model Predicted In-Lake [TP]			**105.6 [ug/l]**
Observed In-Lake [TP]			**132.2 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\text{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**29.6 [ug/l]**
	$[\text{Chl}a] = \dfrac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \text{a})]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \dfrac{X_{pn}^{1.33}}{4.31}$	P (Total Phosphorus) =	106 [ug/l]
		N (Total Nitrogen) =	1857 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	85.2 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\dfrac{N - 150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	84.8 [ug/l]
		G (Kinematic factor) =	0.42 [--]
		F_s (Flushing Rate) =	0.24 [year^{-1}]
	$G = Z_{mix}(0.14 + 0.0039 F_s)$	Z_{mix} (Mixing Depth) =	9.84 [ft]
	$F_s = \dfrac{Q}{V}$; $a = \dfrac{1}{SD} - 0.015 \times [\text{Chl}a]$	a (Non algal turbidity) =	0.08 [m^{-1}]
		S (Secchi Depth) =	4.47 [ft]
		Maximum lake depth =	35.00 [ft]
Model Predicted In-Lake [Chl-a]			**43.3 [ug/l]**
Observed In-Lake [Chl-a]			**50.6 [ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{(\text{a} + 0.015 \times [\text{Chl}a])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.08 [m^{-1}]
Model Predicted In-Lake SD			**1.36 [m]**
Observed In-Lake SD			**1.02 [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$		
		P_{sed} (phosphorus sedimentation) =	**5,758 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**690 [lb/yr]**

2004 Load Reduction Table for: Spring Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS					TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS			
REDUCTION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**[Chla] [ug/L]**	**SD [ft]**	**P SEDIMENTATION [lb]**	**TP OUTFLOW [lb]**	**TSI [TP] [--]**	**TSI [Chla] [--]**	**TSI SD [--]**	**TSI Avg. [--]**
0%	**6,448**	106	43	4.47	5758	**689**	71.3	67.6	55.5	**64.8**
5%	**6,125**	102	43	4.53	5456	**669**	70.9	67.4	55.4	**64.6**
10%	**5,803**	99	42	4.59	5155	**648**	70.4	67.3	55.2	**64.3**
15%	**5,480**	96	41	4.66	4854	**626**	70.0	67.1	54.9	**64.0**
20%	**5,158**	93	41	4.73	4554	**604**	69.4	66.9	54.7	**63.7**
25%	**4,836**	89	40	4.82	4254	**581**	68.9	66.7	54.5	**63.4**
30%	**4,513**	85	39	4.92	3956	**558**	68.3	66.5	54.2	**63.0**
35%	**4,191**	82	38	5.03	3657	**533**	67.6	66.3	53.8	**62.6**
40%	**3,869**	78	37	5.15	3360	**508**	67.0	66.0	53.5	**62.1**
45%	**3,546**	74	36	5.30	3064	**482**	66.2	65.7	53.1	**61.6**
50%	**3,224**	70	34	5.48	2768	**455**	65.4	65.3	52.6	**61.1**
55%	**2,901**	65	33	5.69	2474	**427**	64.4	64.9	52.1	**60.5**
60%	**2,579**	61	31	5.95	2182	**397**	63.4	64.3	51.4	**59.7**
65%	**2,257**	56	29	6.27	1891	**366**	62.2	63.7	50.7	**58.9**
70%	**1,934**	51	27	6.68	1601	**333**	60.8	63.0	49.7	**57.9**
75%	**1,612**	46	25	7.24	1315	**297**	59.2	62.0	48.6	**56.6**
80%	**1,290**	40	22	8.03	1031	**258**	57.2	60.8	47.1	**55.0**
85%	**967**	33	18	9.23	752	**215**	54.5	59.0	45.1	**52.9**
90%	**645**	25	14	11.34	480	**165**	50.7	56.3	42.1	**49.7**
95%	**322**	16	8	16.09	219	**103**	44.0	51.0	37.1	**44.0**

2004 Loading Summary for: Upper Prior Lake

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Upper Prior Direct	1588.6	1.4	188.3	157.1	1.0	80.5
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*1,589*	*1*	*188*	*157.1*		*80.5*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Upper Prior Direct	1,589	9	10%	4.2	0.0	3.8
2		37				
3						
4						
5						
Summation	*1,589*	*46*	*10%*		*0.0*	*3.8*
Inflow from Upstream Lakes						
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Spring Lake			2,400.5	105.6	1.0	690
2 Crystal Lake			136.4	47.0	1.0	17
3 Arctic Lake			102.1	101.3	1.0	28
Summation			*2,639*	*84.6*		*735*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
337	31.5	31.5	0.00	0.13	1.0	15.0
			Dry-year total P deposition =	0.109		
			Average-year total P deposition =	0.133		
			Wet-year total P deposition =	0.158		
			(Barr Engineering 2004)			
Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
337	0.0		0.00	0	1.0	0
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
337	24.0			36.00	1.0	2,598
			Net Discharge [ac-ft/yr] = 2,827		**Net Load [lb/yr] =**	**3,432**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

2004 Lake Response Modeling for: Upper Prior Lake

Modeled Parameter	Equation	Parameters	Value [Units]

TOTAL IN-LAKE PHOSPHORUS CONCENTRATION

$$P = \left[-1 + \left(1 + 4KA1P_iT\right)^{0.5}\right] \Big/ \left(2KA1T\right)$$

$$A1 = 0.056\,Fot^{-1}Qs \Big/ \left(Qs + 13.3\right)$$

$$Qs = Max(Z/T, 4)$$

as f(W,Q,V,Fot) from BATHTUB 2nd Order Decay

C_P =	1.00	[--]
C_{CB} =	0.162	[--]
b =	0.458	[--]
W (total P load = inflow + atm.) =	3,432	[lb/yr]
Q (lake outflow) =	2,827	[ac-ft/yr]
V (modeled lake volume) =	3,621	[ac-ft]
Fot=	0.6	[--]
Qs=	10.7	[m/yr]
T = V/Q =	1.28	[yr]
P_i = W/Q =	446	[ug/l]
Model Predicted In-Lake [TP]	**82.6**	**[ug/l]**
Observed In-Lake [TP]	**77.2**	**[ug/l]**

CHLOROPHYLL-A CONCENTRATION

$$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$$

as f(TP), Walker 1999, Model 4

CB (Calibration factor) =	1.00	[--]
Model Predicted In-Lake [Chl-a]	**23.1**	**[ug/l]**

$$[\mathrm{Chl}a] = \frac{CB \times B_x}{\left[\left(1 + 0.025 \times B_x \times G\right)\left(1 + G \times \mathrm{a}\right)\right]}$$

$$B_x = \frac{X_{pn}^{\;1.33}}{4.31}$$

$$X_{pn} = \left[P^{-2} + \left(\frac{N - 150}{12}\right)^{-2}\right]^{-0.5}$$

$$G = Z_{mix}\left(0.14 + 0.0039F_s\right)$$

$$F_s = \frac{Q}{V} \qquad a = \frac{1}{SD} - 0.015 \times [\mathrm{Chl}a]$$

as f(TP, N, Flushing), Walker 1999, Model 1

CB (Calibration factor) =	1.00	
P (Total Phosphorus) =	83	[ug/l]
N (Total Nitrogen) =	1467	[ug/l]
B_x (Nutrient-Potential Chl-a conc.) =	61.0	[ug/l]
X_{pn} (Composite nutrient conc.)=	66.0	[ug/l]
G (Kinematic factor) =	0.43	[--]
F_s (Flushing Rate) =	0.78	[year^{-1}]
Z_{mix} (Mixing Depth) =	9.84	[ft]
a (Non algal turbidity) =	0.04	[m^{-1}]
S (Secchi Depth) =	5.63	[ft]
Maximum lake depth =	45.00	[ft]
Model Predicted In-Lake [Chl-a]	**36.3**	**[ug/l]**
Observed In-Lake [Chl-a]	**52.2**	**[ug/l]**

SECCHI DEPTH

$$SD = \frac{CS}{\left(\mathrm{a} + 0.015 \times [\mathrm{Chl}a]\right)}$$

as f(Chla), Walker (1999)

CS (Calibration factor) =	1.00	[--]
a (Non algal turbidity) =	0.04	[m^{-1}]
Model Predicted In-Lake SD	**1.72**	**[m]**
Observed In-Lake SD	**1.07**	**[m]**

PHOSPHORUS OUTFLOW LOAD

W-P_{sed} =	**635**	**[lb/yr]**

2004 Load Reduction Table for: Upper Prior Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS					TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS			
REDUC-TION [%]	NET LOAD [lb]	[TP] [ug/L]	[Chla] [ug/L]	SD [ft]	P SEDIMEN-TATION [lb]	TP OUT-FLOW [lb]	TSI [TP] [--]	TSI [Chla] [--]	TSI SD [--]	TSI Avg. [--]
0%	**3,432**	82.6	36	5.63	1924	**1508**	67.8	65.8	52.2	**61.9**
5%	**3,260**	80.3	36	5.71	1827	**1434**	67.4	65.7	52.0	**61.7**
10%	**3,089**	77.9	35	5.80	1730	**1359**	67.0	65.5	51.8	**61.4**
15%	**2,917**	75.5	35	5.89	1632	**1285**	66.5	65.4	51.6	**61.1**
20%	**2,746**	73.0	34	6.00	1535	**1211**	66.0	65.2	51.3	**60.8**
25%	**2,574**	70.4	33	6.12	1438	**1136**	65.5	65.0	51.0	**60.5**
30%	**2,402**	67.7	32	6.26	1340	**1062**	64.9	64.7	50.7	**60.1**
35%	**2,231**	65.0	32	6.41	1243	**988**	64.3	64.5	50.3	**59.7**
40%	**2,059**	62.1	31	6.59	1145	**914**	63.7	64.2	49.9	**59.3**
45%	**1,888**	59.1	30	6.80	1047	**840**	63.0	63.8	49.5	**58.8**
50%	**1,716**	56.0	29	7.05	949	**767**	62.2	63.5	49.0	**58.2**
55%	**1,544**	52.7	27	7.34	852	**693**	61.3	63.0	48.4	**57.6**
60%	**1,373**	49.2	26	7.70	754	**619**	60.3	62.5	47.7	**56.8**
65%	**1,201**	45.6	24	8.16	656	**545**	59.2	61.9	46.9	**56.0**
70%	**1,030**	41.6	22	8.75	558	**471**	57.9	61.1	45.9	**55.0**
75%	**858**	37.3	20	9.56	461	**397**	56.3	60.2	44.6	**53.7**
80%	**686**	32.6	18	10.71	363	**323**	54.4	58.9	42.9	**52.1**
85%	**515**	27.3	15	12.53	266	**248**	51.8	57.1	40.7	**49.9**
90%	**343**	21.0	11	15.88	171	**173**	48.1	54.3	37.3	**46.6**
95%	**172**	13.1	6	24.33	78	**94**	41.3	48.9	31.1	**40.4**

2005 Loading Summary for: Spring Lake

Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas						
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Route 14 (W. Spr)	415.2	10.8	374.3	326.5	1.0	332.3
2 Route 7 (CD 13)	5636.5	5.3	2,512.5	290.2	0.7	1,982.7
3 Route 13 (C. Spr)	316.0	4.3	114.4	1049.6	1.0	326.7
4 Route 12 (Buck)	3659.3	6.1	1,872.0	266.9	1.0	1,358.9
5 Spring Direct	1922.4	3.6	572.1	279.9	1.0	435.5
Summation	*11,949*	*30*	*5,445*	*442.6*		*4,436.1*
Failing Septic Systems						
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Route 14 (W. Spr)	415	10	10%	4.2	0.0	4.2
2 Route 7 (CD 13)	5,636	180	10%	4.2	0.0	75.6
3 Route 13 (C. Spr)	316	5	10%	4.2	0.0	2.1
4 Route 12 (Buck)	3,659	302	10%	4.2	0.0	126.8
5 Spring Direct	1,922	129	10%	4.2	0.0	54.2
Summation	*11,949*	*626*	*10%*		*0.0*	*262.9*
Inflow from Upstream Lakes						
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Fish			513.8	39.5	1.0	55
2				-	1.0	
3				-	1.0	
Summation			*514*	*39.5*		*55*
Atmosphere						
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
642	37.8	37.8	0.00	0.13	1.0	28.5
			Dry-year total P deposition =	0.109		
			Average-year total P deposition =	0.133		
			Wet-year total P deposition =	0.158		
			(Barr Engineering 2004)			
Groundwater						
Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
642	0.0		0.00	0	1.0	0
Internal						
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
642	53.0			17.00	1.0	5,161
			Net Discharge [ac-ft/yr] = 5,959			**Net Load [lb/yr] = 9,943**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

2005 Lake Response Modeling for: Spring Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$P = \dfrac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	9,943 [lb/yr]
		Q (lake outflow) =	5,959 [ac-ft/yr]
		V (modeled lake volume) =	10,206 [ac-ft]
		T = V/Q =	1.71 [yr]
		P_i = W/Q =	614 [ug/l]
Model Predicted In-Lake [TP]			**120.3 [ug/l]**
Observed In-Lake [TP]			**95.1 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**33.7 [ug/l]**
	$[\mathrm{Chl}a] = \dfrac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \mathrm{a})]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$B_x = \dfrac{X_{pn}^{1.33}}{4.31}$	P (Total Phosphorus) =	120 [ug/l]
		N (Total Nitrogen) =	1865 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	94.9 [ug/l]
	$X_{pn} = \left[P^{-2} + \left(\dfrac{N-150}{12}\right)^{-2}\right]^{-0.5}$	X_{pn} (Composite nutrient conc.)=	92.0 [ug/l]
		G (Kinematic factor) =	0.43 [--]
		F_s (Flushing Rate) =	0.58 [year^{-1}]
	$G = Z_{mix}(0.14 + 0.0039F_s)$	Z_{mix} (Mixing Depth) =	9.84 [ft]
	$F_s = \dfrac{Q}{V}$ $a = \dfrac{1}{SD} - 0.015 \times [\mathrm{Chl}a]$	a (Non algal turbidity) =	0.08 [m^{-1}]
		S (Secchi Depth) =	4.28 [ft]
		Maximum lake depth =	35.00 [ft]
Model Predicted In-Lake [Chl-a]			**45.5 [ug/l]**
Observed In-Lake [Chl-a]			**60.6 [ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{(\mathrm{a} + 0.015 \times [\mathrm{Chl}a])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.08 [m^{-1}]
Model Predicted In-Lake SD			**1.30 [m]**
Observed In-Lake SD			**0.99 [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$		
		P_{sed} (phosphorus sedimentation) =	**7,995 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**1,949 [lb/yr]**

2005 Load Reduction Table for: Spring Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS					TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS			
REDUCTION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**[Chla] [ug/L]**	**SD [ft]**	**P SEDIMENTATION [lb]**	**TP OUTFLOW [lb]**	**TSI [TP] [--]**	**TSI [Chla] [--]**	**TSI SD [--]**	**TSI Avg. [--]**
0%	**9,943**	120	46	4.28	7995	**1949**	73.2	68.1	56.2	**65.8**
5%	**9,446**	116	45	4.33	7560	**1887**	72.7	67.9	56.0	**65.6**
10%	**8,949**	112	44	4.38	7126	**1823**	72.3	67.8	55.8	**65.3**
15%	**8,452**	108	44	4.44	6694	**1758**	71.7	67.6	55.6	**65.0**
20%	**7,955**	104	43	4.51	6264	**1691**	71.2	67.5	55.4	**64.7**
25%	**7,458**	100	42	4.59	5835	**1623**	70.6	67.3	55.2	**64.3**
30%	**6,960**	96	41	4.68	5408	**1552**	69.9	67.1	54.9	**64.0**
35%	**6,463**	91	40	4.78	4983	**1480**	69.2	66.8	54.6	**63.6**
40%	**5,966**	87	39	4.90	4561	**1405**	68.5	66.6	54.2	**63.1**
45%	**5,469**	82	38	5.04	4141	**1328**	67.7	66.2	53.8	**62.6**
50%	**4,972**	77	36	5.20	3725	**1247**	66.8	65.9	53.4	**62.0**
55%	**4,475**	72	35	5.40	3311	**1164**	65.8	65.4	52.8	**61.3**
60%	**3,977**	66	33	5.65	2901	**1076**	64.7	64.9	52.2	**60.6**
65%	**3,480**	61	31	5.97	2496	**984**	63.4	64.3	51.4	**59.7**
70%	**2,983**	55	29	6.39	2096	**887**	61.9	63.5	50.4	**58.6**
75%	**2,486**	48	26	6.95	1703	**783**	60.1	62.5	49.2	**57.3**
80%	**1,989**	41	23	7.77	1317	**671**	57.8	61.2	47.6	**55.5**
85%	**1,492**	34	19	9.05	943	**548**	54.9	59.3	45.4	**53.2**
90%	**994**	25	14	11.36	585	**409**	50.7	56.2	42.1	**49.7**
95%	**497**	15	8	16.70	253	**244**	43.2	50.4	36.6	**43.4**

2005 Loading Summary for: Upper Prior Lake

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 Upper Prior Direct	1588.6	4.3	571.0	242.0	1.0	375.8
2					1.0	
3					1.0	
4					1.0	
5					1.0	
Summation	*1,589*	*4*	*571*	*242.0*		*375.8*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 Upper Prior Direct	1,589	9	10%	4.2	0.0	3.8
2		37				
3						
4						
5						
Summation	*1,589*	*46*	*10%*		*0.0*	*3.8*

Inflow from Upstream Lakes

Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1 Spring Lake			5,959.3	120.3	1.0	1949
2 Crystal Lake			458.4	47.0	1.0	59
3 Arctic Lake			309.7	158.8	1.0	134
Summation			*6,727*	*108.7*		*2,141*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
337	37.8	37.8	0.00	0.13	1.0	15.0
			Dry-year total P deposition =	0.109		
			Average-year total P deposition =	0.133		
			Wet-year total P deposition =	0.158		
			(Barr Engineering 2004)			

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
337	0.0		0.00	0	1.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m²-day]	Calibration Factor [--]	Load [lb/yr]
337	24.0			36.00	1.0	2,598

		Net Discharge [ac-ft/yr] =	**7,298**		**Net Load [lb/yr] =**	**5,133**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

2005 Lake Response Modeling for: Upper Prior Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
$P = \left[-1 + (1 + 4KA1P_iT)^{0.5}\right] / (2KA1T)$		as f(W,Q,V,Fot) from BATHTUB 2nd Order Decay	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
$A1 = 0.056\,Fot^{-1}Qs / (Qs + 13.3)$		b =	0.458 [--]
		W (total P load = inflow + atm.) =	5,133 [lb/yr]
		Q (lake outflow) =	7,298 [ac-ft/yr]
$Qs = Max(Z/T, 4)$		V (modeled lake volume) =	3,621 [ac-ft]
		Fot=	0.6 [--]
		Qs=	27.6 [m/yr]
		T = V/Q =	0.50 [yr]
		P_i = W/Q =	259 [ug/l]
Model Predicted In-Lake [TP]			**76.4 [ug/l]**
Observed In-Lake [TP]			**79.5 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**21.4 [ug/l]**
$[\mathrm{Chl}a] = \dfrac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times a)]}$		as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
$B_x = \dfrac{X_{pn}^{1.33}}{4.31}$		P (Total Phosphorus) =	76 [ug/l]
		N (Total Nitrogen) =	1419 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	56.0 [ug/l]
$X_{pn} = \left[P^{-2} + \left(\dfrac{N - 150}{12}\right)^{-2}\right]^{-0.5}$		X_{pn} (Composite nutrient conc.)=	61.9 [ug/l]
		G (Kinematic factor) =	0.44 [--]
		F_s (Flushing Rate) =	2.02 [year^{-1}]
$G = Z_{mix}(0.14 + 0.0039F_s)$		Z_{mix} (Mixing Depth) =	9.84 [ft]
$F_s = \dfrac{Q}{V}$	$a = \dfrac{1}{SD} - 0.015 \times [\mathrm{Chl}a]$	a (Non algal turbidity) =	0.04 [m^{-1}]
		S (Secchi Depth) =	5.99 [ft]
		Maximum lake depth =	45.00 [ft]
Model Predicted In-Lake [Chl-a]			**34.0 [ug/l]**
Observed In-Lake [Chl-a]			**44.2 [ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{(a + 0.015 \times [\mathrm{Chl}a])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.04 [m^{-1}]
Model Predicted In-Lake SD			**1.83 [m]**
Observed In-Lake SD			**1.33 [m]**
PHOSPHORUS OUTFLOW LOAD			
	$W-P_{sed}$ =		**1,515 [lb/yr]**

2005 Load Reduction Table for: Upper Prior Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS					TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS			
REDUC-TION [%]	NET LOAD [lb]	[TP] [ug/L]	[Chla] [ug/L]	SD [ft]	P SEDIMEN-TATION [lb]	TP OUT-FLOW [lb]	TSI [TP] [--]	TSI [Chla] [--]	TSI SD [--]	TSI Avg. [--]
0%	**5,133**	76.4	34	5.99	2139	**2995**	66.7	65.2	51.3	**61.1**
5%	**4,877**	74.1	33	6.08	2027	**2850**	66.2	65.0	51.1	**60.8**
10%	**4,620**	71.8	33	6.18	1915	**2705**	65.8	64.9	50.9	**60.5**
15%	**4,363**	69.4	32	6.30	1804	**2560**	65.3	64.7	50.6	**60.2**
20%	**4,107**	66.9	32	6.43	1692	**2415**	64.8	64.4	50.3	**59.8**
25%	**3,850**	64.4	31	6.57	1581	**2269**	64.2	64.2	50.0	**59.5**
30%	**3,593**	61.8	30	6.73	1469	**2124**	63.6	63.9	49.6	**59.1**
35%	**3,337**	59.1	29	6.92	1358	**1979**	63.0	63.7	49.2	**58.6**
40%	**3,080**	56.3	28	7.14	1247	**1833**	62.3	63.3	48.8	**58.1**
45%	**2,823**	53.3	27	7.40	1136	**1688**	61.5	62.9	48.3	**57.6**
50%	**2,567**	50.3	26	7.70	1025	**1542**	60.6	62.5	47.7	**56.9**
55%	**2,310**	47.1	25	8.07	915	**1395**	59.7	62.0	47.0	**56.2**
60%	**2,053**	43.7	23	8.53	805	**1249**	58.6	61.4	46.2	**55.4**
65%	**1,797**	40.1	21	9.11	695	**1102**	57.4	60.7	45.3	**54.5**
70%	**1,540**	36.3	20	9.87	586	**954**	56.0	59.8	44.1	**53.3**
75%	**1,283**	32.2	17	10.92	478	**805**	54.2	58.7	42.7	**51.9**
80%	**1,027**	27.7	15	12.45	371	**655**	52.1	57.2	40.8	**50.0**
85%	**770**	22.7	12	14.89	267	**503**	49.2	55.1	38.2	**47.5**
90%	**513**	16.9	9	19.46	165	**348**	44.9	51.8	34.3	**43.7**
95%	**257**	9.9	5	30.97	70	**186**	37.2	45.4	27.7	**36.7**

2006 Loading Summary for: Spring Lake

	Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas							
Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]		Load [lb/yr]
1 Route 14 (W. Spr)	415.2	7.7	265.6	206.6	1.0		149.3
2 Route 7 (CD 13)	5636.5	3.1	1,456.9	224.8	0.7		890.5
3 Route 13 (C. Spr)	316.0	2.5	65.7	821.2	1.0		146.7
4 Route 12 (Buck)	3659.3	3.3	1,008.8	222.5	1.0		610.4
5 Spring Direct	1922.4	1.9	309.9	232.1	1.0		195.6
Summation	*11,949*	*19*	*3,107*	*341.4*			*1,992.4*
Failing Septic Systems							
Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]		[lb/yr]
1 Route 14 (W. Spr)	415	10	10%	4.2	0.0		4.2
2 Route 7 (CD 13)	5,636	180	10%	4.2	0.0		75.6
3 Route 13 (C. Spr)	316	5	10%	4.2	0.0		2.1
4 Route 12 (Buck)	3,659	302	10%	4.2	0.0		126.8
5 Spring Direct	1,922	129	10%	4.2	0.0		54.2
Summation	*11,949*	*626*	*10%*		*0.0*		*262.9*
Inflow from Upstream Lakes							
Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]		Load [lb/yr]
1 Fish			296.4	45.1	1.0		36
2				-	1.0		
3				-	1.0		
Summation			*296*	*45.1*			*36*
Atmosphere							
Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]		Load [lb/yr]
642	30.6	30.6	0.00	0.13	1.0		28.5
			Dry-year total P deposition =	0.109			
			Average-year total P deposition =	0.133			
			Wet-year total P deposition =	0.158			
			(Barr Engineering 2004)				
Groundwater							
Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]		Load [lb/yr]
642	0.0		0.00	0	1.0		0
Internal							
Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]		Load [lb/yr]
642	53.0			17.00	1.0		5,161
		Net Discharge [ac-ft/yr] =	**3,403**		**Net Load [lb/yr] =**		**7,481**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

2006 Lake Response Modeling for: Spring Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
	$$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	7,481 [lb/yr]
		Q (lake outflow) =	3,403 [ac-ft/yr]
		V (modeled lake volume) =	10,206 [ac-ft]
		T = V/Q =	3.00 [yr]
		P_i = W/Q =	808 [ug/l]
Model Predicted In-Lake [TP]			**110.6 [ug/l]**
Observed In-Lake [TP]			**83.3 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\text{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**31.0 [ug/l]**
	$$[\text{Chl}a] = \frac{CB \times B_x}{[(1 + 0.025 \times B_x \times G)(1 + G \times \text{a})]}$$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
	$$B_x = \frac{X_{pn}^{1.33}}{4.31}$$	P (Total Phosphorus) =	111 [ug/l]
		N (Total Nitrogen) =	1751 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	85.7 [ug/l]
	$$X_{pn} = \left[P^{-2} + \left(\frac{N-150}{12}\right)^{-2}\right]^{-0.5}$$	X_{pn} (Composite nutrient conc.)=	85.2 [ug/l]
		G (Kinematic factor) =	0.42 [--]
		F_s (Flushing Rate) =	0.33 [year^{-1}]
	$$G = Z_{mix}(0.14 + 0.0039 F_s)$$	Z_{mix} (Mixing Depth) =	9.84 [ft]
	$$F_s = \frac{Q}{V}$$ $$a = \frac{1}{SD} - 0.015 \times [\text{Chl}a]$$	a (Non algal turbidity) =	0.08 [m^{-1}]
		S (Secchi Depth) =	4.47 [ft]
		Maximum lake depth =	35.00 [ft]
Model Predicted In-Lake [Chl-a]			**43.4 [ug/l]**
Observed In-Lake [Chl-a]			**46.8 [ug/l]**
SECCHI DEPTH			
	$$SD = \frac{CS}{(\text{a} + 0.015 \times [\text{Chl}a])}$$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.08 [m^{-1}]
Model Predicted In-Lake SD			**1.36 [m]**
Observed In-Lake SD			**0.94 [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$$		
		P_{sed} (phosphorus sedimentation) =	**6,457 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**1,024 [lb/yr]**

2006 Load Reduction Table for: Spring Lake

LOAD		MODELED IN-LAKE WATER QUALITY PARAMETERS					TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS			
REDUC-TION [%]	NET LOAD [lb]	[TP] [ug/L]	[Chla] [ug/L]	SD [ft]	P SEDIMEN-TATION [lb]	TP OUT-FLOW [lb]	TSI [TP] [--]	TSI [Chla] [--]	TSI SD [--]	TSI Avg. [--]
0%	**7,481**	111	43	4.47	6457	**1024**	72.0	67.6	55.6	**65.0**
5%	**7,107**	107	43	4.52	6114	**993**	71.6	67.4	55.4	**64.8**
10%	**6,733**	104	42	4.58	5772	**961**	71.1	67.3	55.2	**64.5**
15%	**6,359**	100	42	4.64	5431	**928**	70.6	67.2	55.0	**64.2**
20%	**5,985**	97	41	4.71	5091	**894**	70.1	67.0	54.8	**63.9**
25%	**5,611**	93	40	4.79	4751	**860**	69.5	66.8	54.5	**63.6**
30%	**5,237**	89	39	4.89	4413	**824**	68.9	66.6	54.3	**63.2**
35%	**4,863**	85	38	4.99	4075	**787**	68.2	66.3	54.0	**62.8**
40%	**4,489**	81	37	5.11	3739	**749**	67.5	66.1	53.6	**62.4**
45%	**4,115**	77	36	5.26	3405	**710**	66.7	65.8	53.2	**61.9**
50%	**3,740**	72	35	5.43	3071	**669**	65.9	65.4	52.7	**61.3**
55%	**3,366**	68	33	5.63	2740	**626**	64.9	65.0	52.2	**60.7**
60%	**2,992**	63	32	5.88	2411	**582**	63.9	64.5	51.6	**60.0**
65%	**2,618**	58	30	6.20	2084	**535**	62.6	63.9	50.8	**59.1**
70%	**2,244**	52	27	6.61	1760	**484**	61.2	63.1	49.9	**58.1**
75%	**1,870**	47	25	7.17	1439	**431**	59.5	62.1	48.7	**56.8**
80%	**1,496**	40	22	7.96	1124	**372**	57.4	60.9	47.2	**55.2**
85%	**1,122**	33	18	9.19	814	**308**	54.7	59.1	45.2	**53.0**
90%	**748**	25	14	11.36	514	**234**	50.7	56.2	42.1	**49.7**
95%	**374**	16	8	16.31	230	**144**	43.7	50.8	36.9	**43.8**

2006 Loading Summary for: Upper Prior Lake

	Water Budgets				Phosphorus Loading		
Inflow from Drainage Areas							
	Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1	Upper Prior Direct	1588.6	2.3	310.0	200.2	1.0	168.8
2						1.0	
3						1.0	
4						1.0	
5						1.0	
	Summation	*1,589*	*2*	*310*	*200.2*		*168.8*
Failing Septic Systems							
	Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1	Upper Prior Direct	1,589	9	10%	4.2	0.0	3.8
2			37				
3							
4							
5							
	Summation	*1,589*	*46*	*10%*		*0.0*	*3.8*
Inflow from Upstream Lakes							
	Name			Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1	Spring Lake			3,403.3	110.6	1.0	1024
2	Crystal Lake			254.1	47.0	1.0	32
3	Arctic Lake			170.8	108.8	1.0	51
	Summation			*3,828*	*88.8*		*1,107*
Atmosphere							
	Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
	337	30.6	30.6	0.00	0.13	1.0	15.0
				Dry-year total P deposition =	0.109		
				Average-year total P deposition =	0.133		
				Wet-year total P deposition =	0.158		
				(Barr Engineering 2004)			
Groundwater							
	Lake Area [acre]	Groundwater Flux [m/yr]		Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
	337	0.0		0.00	0	1.0	0
Internal							
	Lake Area [acre]	Anoxic Factor [days]			Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
	337	24.0			36.00	1.0	2,598
				Net Discharge [ac-ft/yr] = 4,138			**Net Load [lb/yr] = 3,892**

NOTES

[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

2006 Lake Response Modeling for: Upper Prior Lake

Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
$P = \left[-1 + \left(1 + 4 K A1 P_i T\right)^{0.5}\right] \Big/ \left(2 K A1 T\right)$		as f(W,Q,V,Fot) from BATHTUB 2nd Order Decay	
		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
$A1 = 0.056 Fot^{-1} Qs \Big/ \left(Qs + 13.3\right)$		b =	0.458 [--]
		W (total P load = inflow + atm.) =	3,892 [lb/yr]
		Q (lake outflow) =	4,138 [ac-ft/yr]
$Qs = Max(Z/T, 4)$		V (modeled lake volume) =	3,621 [ac-ft]
		Fot=	0.6 [--]
		Qs=	15.7 [m/yr]
		T = V/Q =	0.88 [yr]
		P_i = W/Q =	346 [ug/l]
Model Predicted In-Lake [TP]			**77.9 [ug/l]**
Observed In-Lake [TP]			**82.9 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**21.8 [ug/l]**
	$[\mathrm{Chl}a] = \dfrac{CB \times B_x}{\left[\left(1 + 0.025 \times B_x \times G\right)\left(1 + G \times a\right)\right]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
$B_x = \dfrac{X_{pn}^{1.33}}{4.31}$		P (Total Phosphorus) =	78 [ug/l]
		N (Total Nitrogen) =	1609 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	60.5 [ug/l]
$X_{pn} = \left[P^{-2} + \left(\dfrac{N - 150}{12}\right)^{-2}\right]^{-0.5}$		X_{pn} (Composite nutrient conc.)=	65.6 [ug/l]
		G (Kinematic factor) =	0.43 [--]
		F_s (Flushing Rate) =	1.14 [$year^{-1}$]
$G = Z_{mix}\left(0.14 + 0.0039 F_s\right)$		Z_{mix} (Mixing Depth) =	9.84 [ft]
$F_s = \dfrac{Q}{V}$	$a = \dfrac{1}{SD} - 0.015 \times [\mathrm{Chl}a]$	a (Non algal turbidity) =	0.04 [m^{-1}]
		S (Secchi Depth) =	5.68 [ft]
		Maximum lake depth =	45.00 [ft]
Model Predicted In-Lake [Chl-a]			**36.0 [ug/l]**
Observed In-Lake [Chl-a]			**69.1 [ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{\left(a + 0.015 \times [\mathrm{Chl}a]\right)}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.04 [m^{-1}]
Model Predicted In-Lake SD			**1.73 [m]**
Observed In-Lake SD			**0.87 [m]**
PHOSPHORUS OUTFLOW LOAD			
	$W - P_{sed}$ =		**876 [lb/yr]**

2006 Load Reduction Table for: Upper Prior Lake											
LOAD		**MODELED IN-LAKE WATER QUALITY PARAMETERS**					**TROPHIC STATE INDICES (Carlson, 1980) FOR MODELED PARAMETERS**				
REDUCTION [%]	**NET LOAD [lb]**	**[TP] [ug/L]**	**[Chla] [ug/L]**	**SD [ft]**	**P SEDIMENTATION [lb]**	**TP OUTFLOW [lb]**	**TSI [TP] [--]**	**TSI [Chla] [--]**	**TSI SD [--]**	**TSI Avg. [--]**	
0%	**3,892**	77.9	36	5.68	1922	**1971**	67.0	65.7	52.1	**61.6**	
5%	**3,698**	75.7	35	5.77	1823	**1874**	66.5	65.6	51.9	**61.3**	
10%	**3,503**	73.4	35	5.87	1725	**1778**	66.1	65.4	51.6	**61.0**	
15%	**3,308**	71.0	34	5.98	1627	**1681**	65.6	65.2	51.4	**60.7**	
20%	**3,114**	68.6	33	6.10	1529	**1585**	65.1	65.0	51.1	**60.4**	
25%	**2,919**	66.1	33	6.24	1430	**1489**	64.6	64.8	50.7	**60.0**	
30%	**2,725**	63.6	32	6.39	1332	**1393**	64.0	64.5	50.4	**59.6**	
35%	**2,530**	60.9	31	6.57	1234	**1296**	63.4	64.2	50.0	**59.2**	
40%	**2,335**	58.1	30	6.78	1135	**1200**	62.7	63.9	49.5	**58.7**	
45%	**2,141**	55.3	29	7.01	1037	**1104**	62.0	63.5	49.0	**58.2**	
50%	**1,946**	52.3	27	7.30	939	**1007**	61.2	63.1	48.5	**57.6**	
55%	**1,752**	49.1	26	7.64	840	**911**	60.3	62.6	47.8	**56.9**	
60%	**1,557**	45.8	25	8.05	742	**815**	59.3	62.0	47.1	**56.1**	
65%	**1,362**	42.2	23	8.58	644	**718**	58.1	61.3	46.2	**55.2**	
70%	**1,168**	38.4	21	9.26	547	**621**	56.8	60.5	45.0	**54.1**	
75%	**973**	34.3	19	10.19	449	**524**	55.1	59.5	43.7	**52.8**	
80%	**778**	29.8	16	11.52	352	**426**	53.1	58.1	41.9	**51.0**	
85%	**584**	24.8	14	13.63	256	**328**	50.4	56.1	39.5	**48.7**	
90%	**389**	18.9	10	17.52	162	**227**	46.5	53.1	35.9	**45.2**	
95%	**195**	11.5	5	27.31	72	**123**	39.3	47.3	29.5	**38.7**	