

Meadow Lake  
Nutrient TMDL  
Implementation Plan

**D R A F T**

**Wenck File #1240-76**

Prepared for:

**SHINGLE CREEK  
WATERSHED MANAGEMENT  
COMMISSION**

**MINNESOTA  
POLLUTION CONTROL AGENCY**

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## 1.0 Introduction

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The Meadow Lake Nutrient Total Maximum Daily Load (TMDL) Implementation Plan addresses nutrient impairments Meadow Lake (27-0057), which is located in the City of New Hope, Hennepin County, Minnesota, in the Shingle Creek watershed (see Figure 1). Meadow Lake is a small, shallow urban lake with a surface area of about 11 acres and a fully developed watershed of about 103 acres. The lake is impaired by high concentrations of total phosphorus resulting in severe algal blooms, with summer average total phosphorus concentration ranging from approximately 200 µg/L to over 250 µg/L in the years in which measurements were taken. For comparison, the numeric standard for Meadow Lake is 60 µg/L or lower.

The Shingle Creek Watershed Management Commission (SCWMC) has completed a Total Maximum Daily Load (TMDL) analysis for the Minnesota Pollution Control Agency (MPCA) to quantify the phosphorus reductions needed to meet State water quality standards for nutrients in Meadow Lake in accordance with Section 303(d) of the Clean Water Act. The TMDL and Implementation Plan were prepared in cooperation with the City of New Hope.

The final step in the TMDL process is the development of an Implementation Plan that sets forth the activities that will be undertaken to reduce phosphorus loading to the lake. This Implementation Plan provides a brief overview of the TMDL findings; describes the principles guiding this Implementation Plan; discusses sequencing, timing, lead agencies and organizations, and other implementation general strategies; and describes the proposed implementation activities.

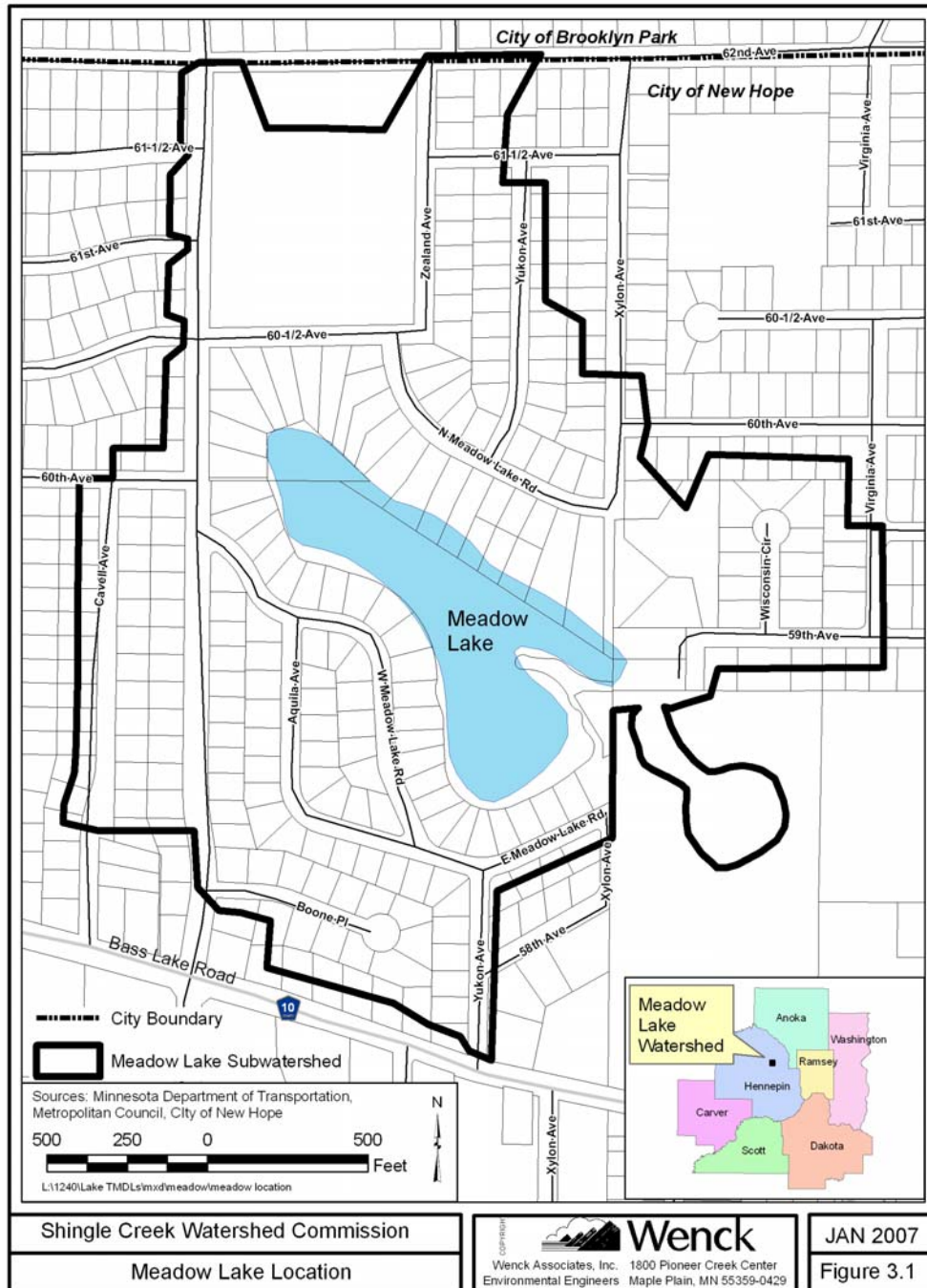


Figure 1. Meadow Lake location.

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## 2.0 Meadow Lake TMDL Summary

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A key aspect of a TMDL is the development of an analytical link between loading sources and receiving water quality. To establish the link between phosphorus loading to the quality of water in the lakes, monitoring data extending back to 1990 was reviewed to better understand conditions and trends.

### 2.1 CURRENT WATER QUALITY

Historic water quality is presented in Figures 2, 3, and 4. Meadow Lake does not meet state standards for total phosphorus concentration, nor for chlorophyll-a or clarity as measured by Secchi depth. There is limited data available. Summer average total phosphorus concentration in Meadow Lake ranges from approximately 200  $\mu\text{g/L}$  to over 250  $\mu\text{g/L}$  in the years in which measurements were taken (Figure 2). For comparison, the numeric standard for Meadow Lake is 60  $\mu\text{g/L}$  or lower.

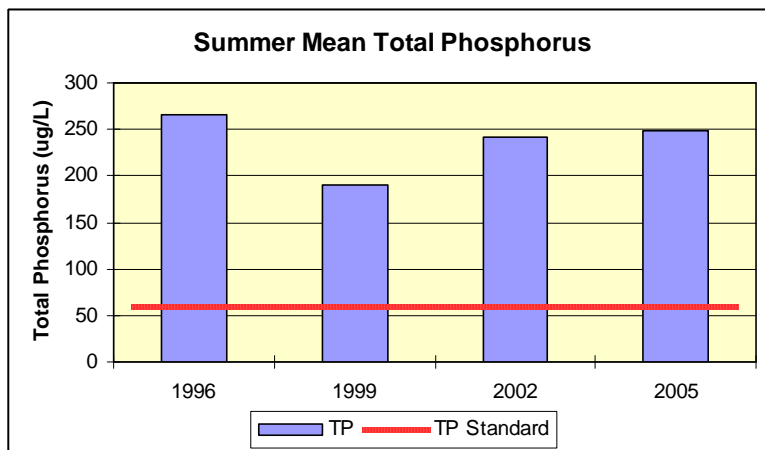


Figure 2. Summer (June 1 –September 30) mean total phosphorus concentrations for Meadow Lake.

More variability is observed in chlorophyll-a concentration than total phosphorus concentration. Chlorophyll-a concentration ranges from approximately 100  $\mu\text{g/L}$  to nearly 200  $\mu\text{g/L}$  with the highest concentration occurring in 2002 (Figure 3). In 2005, the chlorophyll-a concentration was approximately 68  $\mu\text{g/L}$ . The numeric standard for Meadow Lake is 20  $\mu\text{g/L}$  or lower for chlorophyll-a.

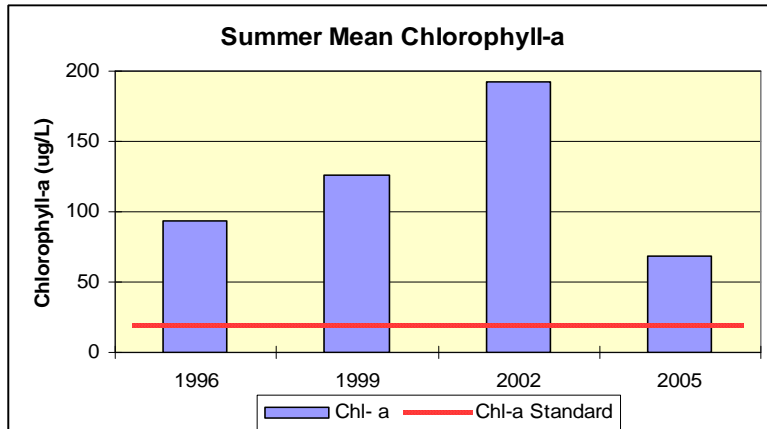


Figure 3. Summer (June 1 –September 30) mean chlorophyll-a concentrations for Meadow Lake.

Water clarity, as measured by Secchi depth, ranges from approximately 0.3 meters to 0.45 meters (Figure 4). The worst clarity occurred in 2002 which coincides with the high chlorophyll-a concentration observed in that year. In 2005, the water clarity was the best of the years in which measurements were taken at nearly 0.45 meters. The numeric standard for Meadow Lake is 1.0 meter of clarity or more as measured by Secchi depth.

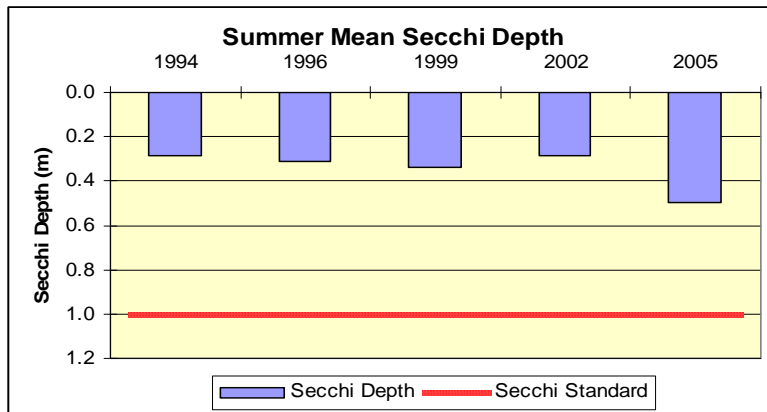


Figure 4. Summer (June 1 –September 30) mean Secchi depth (meters) for Meadow Lake.

## 2.2 MEETING STATE STANDARDS

Meadow Lake was listed as an Impaired Water because it consistently exhibits excess levels of nutrients that could lead to severe nuisance blooms of algae. Nutrient loads in this TMDL and Implementation Plan are set for phosphorus, since this is typically the limiting nutrient for

nuisance aquatic plants. However, it is a goal of this TMDL and Implementation Plan to achieve state standards for chlorophyll-a and Secchi depth as well.

### 2.3 REQUIRED PHOSPHORUS LOAD REDUCTIONS

Wasteload and load allocations to meet State standards indicate a phosphorus load reduction of about 82% would be required to consistently achieve a total phosphorus concentration of 60 µg/L, which would meet the state standard. This Implementation Plan details the activities the stakeholders in the lake’s watershed plan to undertake to attain that reduction.

#### 2.3.1 Allocations

The Wasteload Allocation (WLA) includes permitted discharges such as industrial point and regulated stormwater discharges. The Load Allocation (LA) includes phosphorus load from non-permitted sources, such as internal loading or atmospheric deposition. Stormwater discharges are regulated under the State of Minnesota’s National Pollutant Discharge Elimination System (NPDES) General Permit, and are considered wasteloads that must be divided among permit holders. The City of New Hope is the only permit holder discharging to Meadow Lake. The unique NPDES permit number assigned to New Hope is MS400039. The City of New Hope has committed to implement Best Management Practices (BMPs) to reduce nutrient loading in Meadow Lake. The City cooperated in developing the TMDL and Implementation Plan and will continue to work with the ongoing Commission Technical Advisory Committee (TAC) to identify and implement BMPs.

The pollutant load from construction stormwater is considered to be less than 1 percent of the TMDL and difficult to quantify. Consequently, the WLA includes pollutant loading from construction stormwater sources. There are no known municipal or industrial wastewater dischargers in the watershed.

Construction stormwater activities are considered in compliance with provisions of the TMDL if they obtain a Construction General Permit under the NPDES program and properly select, install, and maintain all BMPs required under the permit, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit.

#### 2.3.2 Implementation Focus

The focus in implementation will be on reducing the annual phosphorus loads to Meadow Lake through structural and nonstructural BMPs. The load and wasteload allocations are shown in Table 1.

**Table 1. Meadow Lake TMDL total phosphorus allocations expressed as daily and annual loads.**

Wasteload TP Allocation		Load TP Allocation		Margin of Safety	Total Phosphorus TMDL	
(kg/day)	(kg/yr)	(kg/day)	(kg/yr)		(kg/day)	(kg/yr)
0.025	9.0	0.019	6.8	Implicit	0.044	15.8

Load allocations by source are provided in Table 2. No reduction in atmospheric loading is targeted because this source is impossible to control on a local basis.

**Table 2. Meadow Lake TMDL total phosphorus daily and annual loads partitioned among the major sources.**

	Source	Total Maximum Daily TP Load (kg/day)	Total Maximum Daily TP Load (kg/day)	Current Load (1999-2003 Average) (kg/yr)	Load Reduction (kg/year)
Wasteload Load	Watershed Load	0.025	9.0	52.6	43.6
	Atmospheric Load	0.003	1.1	1.1	-
	Internal Load	0.016	5.7	33.9	28.2
<b>TOTAL LOAD</b>		0.044	15.8	87.6	71.8
<b>82% Load Reduction</b>					

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## 3.0 Implementation Plan

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### 3.1 TMDL AND IMPLEMENTATION PLAN PROCESS

The activities and Best Management Practices (BMPs) identified in this Implementation Plan are the result of a series of Technical Advisory Committee (TAC) and stakeholder meetings led by the Shingle Creek Watershed Management Commission (SCWMC). The TAC included stakeholder representatives from local cities, Minnesota Department of Natural Resources (DNR), the Metropolitan Council, the United States Geological Survey (USGS) and the Minnesota Pollution Control Agency. All meetings were open to interested individuals and organizations. Technical Advisory Committee meetings to review this and other lake TMDLs in the watershed were held on December 8, 2005, February 10, 2006, March 9, 2006, and June 27, 2007.

The general TMDL approach and general results of TMDLs were presented to seven City Councils in May and July 2006. A public meeting was held March 5, 2009 to review the findings of the TMDL with lakeshore property owners and to take public input in the development of this Implementation Plan.

This implementation plan was distributed to the cities and Mn/DOT for review and posted on the SCWMC website [www.shinglecreek.org](http://www.shinglecreek.org) for public review and comment. On xxxxxxxx xx, 2009 the Shingle Creek Watershed Management Commission reviewed the draft Implementation Plan and all comments received and approved this Plan.

### 3.2 IMPLEMENTATION PLAN PRINCIPLES

Through the discussion of policies and practices, current activities, and ongoing research, the stakeholders developed principles to guide development and implementation of the load reduction plan. These principles, in no order, include:

#### 1. Restore Biological Integrity

The Commission, City of New Hope, and residents recognize the importance of a healthy biological community in the lake to provide internal controls on water clarity. To that end, the stakeholders agreed to work cooperatively to restore the biological community in this lake, including fish, plants, and zooplankton.

#### 2. Control Internal Load

It is recognized that a significant portion of the phosphorus load in Meadow Lake is a result of internal loading and that the internal load must be addressed to successfully improve water quality. Consequently, the stakeholders agreed to work cooperatively to reduce internal phosphorus loading in the lake.

3. Retrofit BMPs in the Watershed As Opportunities Arise

New Hope as the sole MS4 in the watershed discharging to Meadow Lake understands that nutrient loading must be reduced, but that options for retrofitting BMPs are limited. Nutrient-reduction BMPs have already been incorporated into street projects in this neighborhood, and the city will evaluate opportunities such as other street projects or redevelopment to add or upsize BMPs.

4. Foster Stewardship

City staff, especially maintenance staff, will be provided opportunities for education and training to better understand how their areas of responsibility relate to the protection and improvement of water quality in the lake.

5. Communicate with the Public

Public education should take a variety of forms, and should include both general and specialized information, targeted but not limited to:

- General public
- Elected and appointed officials
- Lakeshore residents
- Lake users
- Property owners and managers

### **3.3 IMPLEMENTATION PLAN**

Implementation will be a joint effort, with the SCWMC taking responsibility for ongoing coordination, general education and monitoring activities and the City of New Hope taking responsibility for BMP implementation. New Hope will incorporate these BMPs into its Storm Water Pollution Prevention Program (SWPPP) and NPDES Minimum Measures, and will work with the SCWMC to periodically assess progress toward advancing the implementation principles detailed above. New Hope will report its annual TMDL Implementation Plan activities to the SCWMC, and the Commission will summarize those activities into its own Water Quality Monitoring Annual Report. This framework is illustrated in Figure 5 below.

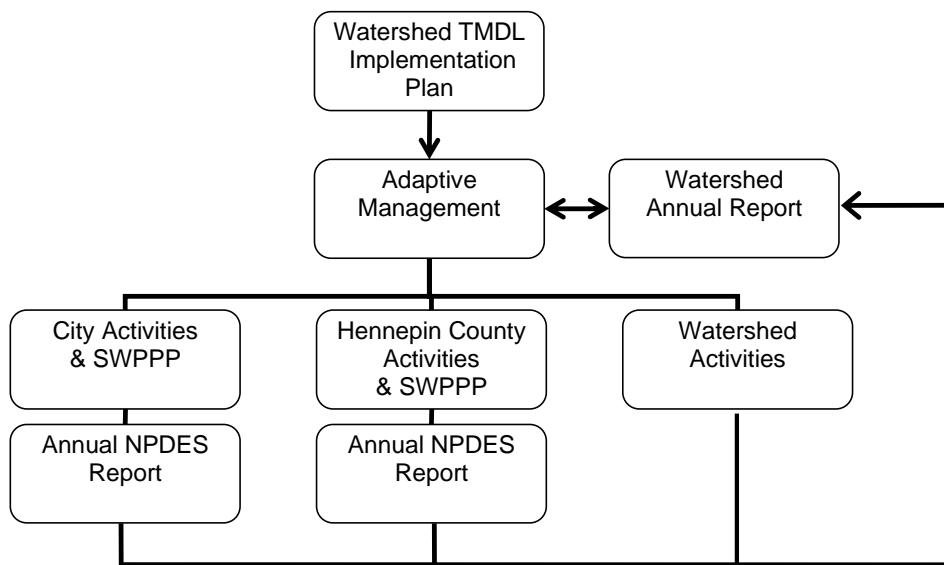


Figure 5. Implementation framework.

### 3.3.1 Implementation Approach

The impairment to Meadow Lake developed over time as the watershed draining to the lake urbanized. As the watershed developed, the native prairie and savanna was cleared to support farming. Over the past century the farms and remaining undeveloped land were converted to urban and suburban uses, increasing the volume of runoff and the amount of pollutants conveyed to the lake. As a result of this land use and land cover change, the lake slowly degraded. Just as this degradation took many years, improvement will take many years through ongoing retrofit of the watershed with BMPs as well as eventual redevelopment of existing land uses with lower-impact development and stormwater treatment. However, it is likely that it will take several decades to see any significant redevelopment in this subwatershed.

The TMDL study and this Implementation Plan identified general improvements to reduce external and internal phosphorus loading. These are “short term” projects that could be accomplished in the next 10-20 years. However, these projects alone will not be sufficient to achieve water quality goals for this lake. An essential “long-term” component of this Implementation Plan is to routinely retrofit BMPs in this fully developed watershed as redevelopment or construction activities provide opportunities.

As the City cycles through its street reconstruction program, it is now routine to include treatment BMPs such as stormwater detention ponds and underground treatment devices where possible. These incremental reductions will over time add up to a significant external load reduction.

Another long-term type of external load reduction is redevelopment. Much of the watershed draining to the lake developed prior to the development of Shingle Creek Watershed rules and standards and subsequently there is currently little or no treatment of stormwater. As this area redevelops over time, the redevelopment will be required to abstract some stormwater and treat the balance of the runoff before discharging it to the lake. Depending on the nature of the development or redevelopment, it may be possible to provide even more load reduction by “upsizing” treatment above and beyond the minimum required by the rules or to create new regional treatment opportunities.

### **3.3.2 Implementation Strategies**

The emphasis of implementation will be on controlling both external and internal loading. Some significant external load reduction activities have recently been undertaken by New Hope. Because internal load is an important factor in this lake some internal load management activities could be initiated early in the Implementation Program. An important part of the internal load strategy is restoring and maintaining biological integrity and associated impacts to water quality through management of the aquatic plant community, fishery, and macroinvertebrate and zooplankton assemblages. However, biological manipulation may not provide all the internal load reduction that would be required. Additional feasibility work must be completed to evaluate whether other means of reducing internal loading such as a whole-lake drawdown are feasible.

The following sections discuss the general BMP strategies that were identified in the TMDL process to reduce phosphorus load, restore ecological integrity, and meet state water quality goals for these lakes; the general sequence of implementation activities; and the stakeholders who would take the lead in implementing each activity. BMP strategies are listed below and described in more detail in Sections 4 and 5 of this Plan.

#### External Load Best Management Practice (BMP) Strategies

- Add BMPs as opportunities arise to decrease runoff from the watershed and increase stormwater treatment
- Increase infiltration and abstraction in the watershed
- Increase frequency of street sweeping in sensitive areas
- Encourage shoreline restoration to improve runoff filtration

#### Internal Load Best Management Practice (BMP) Strategies

- Conduct aquatic plant, fish, zooplankton, and phytoplankton surveys
- Prepare and implement an aquatic vegetation management plan
- Restore a balanced fishery
- Evaluate other potential internal load management projects

### **3.3.3 Sequencing**

Some of the above activities may be undertaken immediately, while others would be implemented as opportunities arise. In general implementation will proceed according to the following sequence of activities:

### First Five Years

- Continue monitoring the lake
- Continuously update the watershed SWMM and P8 models
- Evaluate ways to refine street sweeping practices to maximize pollutant removal
- Conduct or update aquatic vegetation, fish, phytoplankton, and zooplankton surveys
- Develop and implement an aquatic vegetation management plan
- Encourage lakeshore property owners to plant or widen native buffers on their shoreline
- Implement BMP retrofits as opportunities such as street and utility reconstruction arise
- Implement BMP and restoration demonstration projects as opportunities arise
- Evaluate options for internal load control, such as a whole-lake drawdown
- Implement an internal load control project

### Second Five Years and Subsequent Permit Cycles

- Continue monitoring the lake
- Evaluate progress towards goals including what BMPs and activities were implemented and subsequent water quality improvement.
- Amend the Implementation Plan as necessary based on progress
- Implement BMP retrofits as opportunities arise to continue to reduce external loading
- Work with the DNR to restore a balanced fishery

#### **3.3.4 Stakeholder Responsibilities**

The primary stakeholders in this Plan are the Shingle Creek Watershed Management Commission (SCWMC) and the City of New Hope. In addition, property owners in the watershed and the Meadow Lake Association have a role to play in implementing BMPs on their private properties. The SCWMC Education program will provide both residential and non-residential property owners and managers with information on BMPs that would have the most impact on improving water quality.

Table 3 shows which stakeholders will take the lead in implementing the various activities identified in this Plan.

**Table 3. Implementation activity by stakeholder.**

<b>Actor</b>	<b>Stormwater</b>	<b>Internal Load</b>	<b>Aquatic Vegetation</b>	<b>Aquatic Life</b>	<b>Monitoring/ Reporting</b>
<b>SCWMC</b>	<ul style="list-style-type: none"> <li>• Provide focused education and outreach</li> <li>• Solicit and fund Demonstration Projects</li> <li>• Prepare grant applications</li> <li>• Evaluate ways to refine street sweeping practices</li> </ul>	<ul style="list-style-type: none"> <li>• Measure internal loads</li> <li>• Prepare feasibility reports and make recommendations on internal load strategies in partnership with the City of New Hope</li> </ul>	<ul style="list-style-type: none"> <li>• Evaluate and make recommendations for aquatic vegetation management</li> <li>• Identify potential shoreline restoration projects</li> </ul>	<ul style="list-style-type: none"> <li>• Work in partnership with the DNR to manage the fishery to maintain a beneficial community</li> </ul>	<ul style="list-style-type: none"> <li>• Continue CAMP citizen water quality monitoring</li> <li>• Conduct periodic in-depth lake monitoring</li> <li>• Monitor aquatic vegetation, zooplankton, and phytoplankton every five years or as necessary</li> <li>• Collect implementation data from stakeholders annually</li> <li>• Prepare annual report on monitoring and activities</li> </ul>
<b>City of New Hope</b>	<ul style="list-style-type: none"> <li>• Provide focused education and outreach</li> <li>• Implement BMPs to reduce loads as opportunities arise</li> <li>• Conduct routine pond inspections for maintenance</li> <li>• Perform pond maintenance as necessary per inspection results</li> <li>• Sweep streets at least twice annually</li> </ul>	<ul style="list-style-type: none"> <li>• Consider and implement internal load reduction strategies</li> </ul>	<ul style="list-style-type: none"> <li>• Consider aquatic vegetation management</li> <li>• Consider shoreline restoration projects</li> </ul>	<ul style="list-style-type: none"> <li>• Work in partnership with the DNR to manage the fishery to maintain a beneficial community</li> </ul>	<ul style="list-style-type: none"> <li>• Report implementation activities to SCWMC annually</li> </ul>
<b>Property Owners</b>	<ul style="list-style-type: none"> <li>• Implement volume reduction practices</li> </ul>		<ul style="list-style-type: none"> <li>• Implement aquatic vegetation management</li> <li>• Implement shoreline restoration projects</li> </ul>		<ul style="list-style-type: none"> <li>• Participate in volunteer monitoring</li> </ul>

### 3.4 ADAPTIVE MANAGEMENT

The load allocations in the TMDL represent aggressive goals for nutrient reduction. Consequently, implementation will be conducted using adaptive management principles. Adaptive management is an iterative approach of implementation, evaluation, and course correction (see Figure 6). It is appropriate here because it is difficult to predict the lake response to load reductions. Future conditions and technological advances may alter the specific course of actions detailed in this Plan. Continued lake water quality monitoring and course corrections responding to monitoring results offer the best opportunity for meeting the water quality goals established in this TMDL and Implementation Plan.

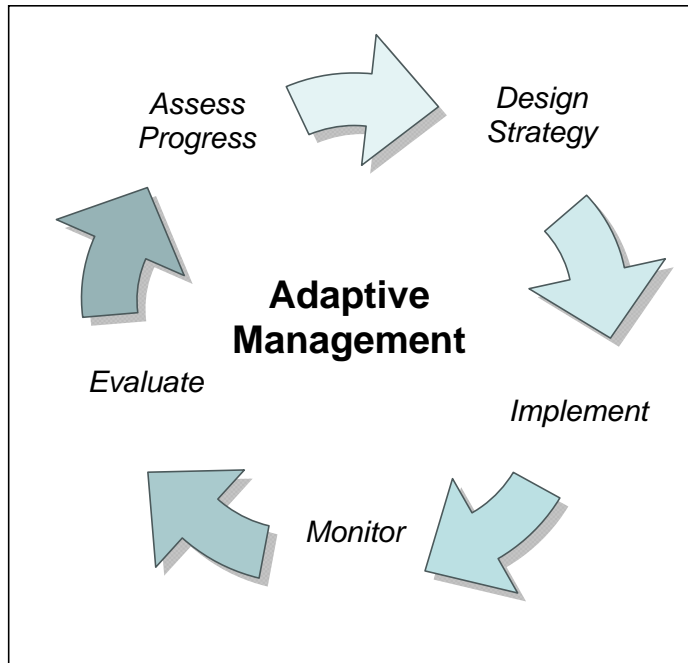


Figure 6. Adaptive management.

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## 4.0 Watershed Commission Activities

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The SCWMC has agreed to take the lead on general coordination, education, and ongoing monitoring. The Commission will also collect annual NPDES reports and other information from the stakeholders and compile BMP activities undertaken by all parties. This information will be incorporated into the Commission's annual Water Quality Report. The following activities will be conducted by the SCWMC.

**Comment [S1]:** Is this a reference to the MS4 annual reports?

### 4.1 GENERAL COORDINATION

#### 4.1.1 Coordination

One of the primary Commission roles in managing the watershed is serving as a coordinator of water resource policies and activities. The Commission will continue in that role in the implementation of this TMDL. General activities now undertaken by the Commission will be continued or expanded as the Commission moves from management planning to implementation coordination. These are activities that are included as part of the Commission's general administrative budget and no additional cost is expected from their implementation:

- Provide advice and assistance to member cities on their implementation activities;
- Research and disseminate information on changing BMP technology and practices;
- Collect annual implementation activity data;
- Recommend activities such as vegetation or fishery management, partnering with the DNR;
- Periodically update the Commission's Capital Improvement Program (CIP);
- Maintain the watershed SWMM and P8 models;
- Conduct public hearings on proposed projects; and
- Share the cost of qualifying improvement projects.

*Estimated Cost:* Ongoing activity

*Funding Source:* General operating budget, county levy for project share

#### 4.1.2 Annual Report on Monitoring and Activities

An annual report on phosphorus load reduction activities is necessary under the adaptive management approach established in the TMDL. Each year the Commission will collect from the permittees in the watershed a listing of the activities undertaken in the previous year. This report will summarize those activities and provide the permittees assigned a categorical wasteload allocation the necessary information for their annual NPDES reports. The report will detail BMP implementation, associated load and volume reductions, and current monitoring data to evaluate activity effectiveness. At the end of each five year period this report will include an assessment of progress and identification of any revisions to the implementation plan. This report will be a part of the Commission's annual Water Quality Monitoring Report. The format and content of the Water Quality Monitoring Report is being revised to include reporting on the three stream TMDLs and 13 lake TMDLs in the watershed.

**Estimated Cost:** \$10,000-12,000

**Funding Source:** General operating budget (currently budgeted at about \$5,000)

#### **4.1.3 Rules and Standards**

In early 2008 the Commission directed its Technical Advisory Committee (TAC) to review and if necessary recommend revisions to the current rules to address the effectiveness of the regulatory program in meeting the TMDL requirements. The TAC reviewed the current pollutant removal performance standard and current infiltration requirement to determine if a more stringent rule was necessary. The TAC concluded that the current pollutant removal standards of 85% total suspended solids (TSS) and 60% phosphorus removal combined with the infiltration standard were sufficiently stringent without being overly burdensome. The TAC did recommend revising the infiltration standard into a more broad volume management rule to provide flexibility in implementation. The revised rules and standards were adopted October 9, 2008, and are effective January 1, 2009.

**Estimated Cost:** \$2,000

**Funding Source:** General operating budget for Management Plan activities (current budget is \$3,000)

#### **4.1.4 Establish Performance Standards**

As a part of this and other TMDL Implementation Plans the City of New Hope will be implementing various BMPs to reduce phosphorus load and stormwater volume. Stakeholders will report load reductions made by each BMP to the Commission, which will track progress toward meeting load reductions throughout the watershed.

Stakeholders will have varying levels of information and data about these BMPs. In some cases estimating the load reduction will be part of the BMP design process. For example, load reductions for a new or enhanced pond can be calculated using standard modeling techniques. However, many other types of BMPs such as rain gardens, reforestation, reductions in impervious pavement, etc. have an impact that is more difficult and time-consuming to calculate. The Commission has directed its Technical Advisory Committee (TAC) to review literature and other data and establish standardized performance values for various BMPs. For example, a typical residential rain garden might be credited with reducing phosphorus by X kilograms per unit area annually. Or, an underground treatment device of Brand X would be assigned specific removal efficiencies. The MPCA is exploring establishing such standards, as are other watershed management organizations. The TAC will work in partnership with the MPCA to establish or agree upon such standards for Shingle Creek.

**Estimated Cost:** \$3,000

**Funding Source:** General operating budget for Engineering Administration activities (current budget is \$41,000)

## 4.2 EDUCATION

### 4.2.1 Public Education and Outreach

The Commission operates an ongoing education and outreach program that is managed by the standing Education and Public Outreach Committee (EPOC). The EPOC is a group comprised of city staff, Commissioners, and watershed resident volunteers that develops and implements educational materials and programming.

The Commission in fall 2007 undertook a professional opinion survey to better understand what people know and how public education and outreach can most effectively communicate how individual property owners can impact water quality through the implementation of individual Best Management Practices in the watershed. The EPOC is preparing recommendations for the Commission for implementation in 2009 and beyond.

The Minnesota and Wisconsin Departments of Natural Resources, the University of Minnesota Extension Service, and University of Wisconsin Extension have prepared numerous fliers and brochures on various topics relating to lake management that can be made available to target audiences at city meetings, block club and National Night Out gatherings, and other opportunities, and links posted on the Commission's and cities' web sites. The EPOC has also developed specialty brochures focused on groups such as apartment and small commercial building managers.

*Estimated Cost:* Ongoing activity

*Funding Source:* General operating budget for Education activities (current budget is \$28,700)

### 4.2.2 Encourage Public Official and Staff Education

There is a need for city, county and state officials and staff to understand the TMDL process and the proposed implementation activities so that they can effectively make regulatory, budget and programming decisions and conduct daily business. Resources such as self-study lake management background information from Water on the Web ("Understanding Lake Ecology"), Project NEMO (Nonpoint Education for Municipal Officials), UW Extension ("Understanding Lake Data") and other sources would provide basic information about lake ecology to help staff, Councils and Commissions make informed decisions about lake management.

*Estimated Cost:* \$500

*Funding Source:* General operating budget for Education activities (current budget is \$28,700)

### 4.2.3 Presentations at Meetings

Awareness of lake management can be raised through periodic presentations at meetings of lake associations, homeownership associations, block clubs, garden clubs, service organizations, senior associations, advisory commissions, City Councils, or other groups as well as displays at events such as remodeling fairs and yard and garden events. "Discussion kits" including more detailed information about topics and questions and points for topic discussion could be made available to interested parties. The Commission's annual education budget assumes staff attendance at three presentations or events per year such as staffing booths at events.

**Estimated Cost:** \$1,000

**Funding Source:** General operating budget for Education activities (current budget is \$28,700)

#### **4.2.4 Demonstration Projects**

Property owners may be reluctant to adopt good lake management practices without examples they can evaluate and emulate. A few demonstration projects have been completed in the watershed through outside grants or from the Commission's Education and Implementation Grant program, including a shoreline restoration project in a park on Middle Twin Lake in Brooklyn Center and a shoreline restoration and a rain garden in a park on Ryan Lake in Minneapolis. The Commission will encourage demonstration projects so property owners can see how a project or practice is implemented and how it looks. Examples might include planting native plants; planting a rain garden; restoring a shoreline; managing turf using low-impact practices such as phosphorus-free fertilizer, reduced herbicides and pesticides, and proper mowing and watering techniques; and improving drainage practices with redirected downspouts and rain barrels. The estimated cost of this activity is highly variable. The Commission annually budgets \$20,000 for grant matching and small projects. The Commission will evaluate appropriate activities and develop guidelines for funding demonstration projects from this budget.

**Estimated Cost:** Varies based on the type of activity

**Funding Source:** General operating budget for grant match/demonstration projects (current budget is \$20,000)

### **4.3 ONGOING MONITORING**

#### **4.3.1 Water Quality Monitoring**

The SCWMC will lead monitoring and tracking of the effectiveness of activities implemented to reduce nutrient loading in the watershed. The Commission will continue to participate in the Metropolitan Council's Citizen Assisted Lake Monitoring Program (CAMP). Through this program, citizen volunteers monitor surface water quality and aesthetic conditions biweekly. Each year four to six lakes in the Shingle Creek watershed are monitored in this manner. This program is also a useful outreach tool for increasing awareness of water quality issues. The estimated cost of this monitoring is \$6,500 annually, and is included in the Commission's existing Monitoring budget.

**Estimated Cost:** \$6,500 annually

**Funding Source:** Monitoring budget for CAMP monitoring (current budget is \$6,500)

The Commission will also periodically (every 4-5 years) conduct a more detailed analysis of water quality, collecting biweekly data on lake surface, water column, and bottom conditions. This data will provide a more detailed picture of lake response to BMP activities and will help determine necessary "course corrections" as part of the Adaptive Management philosophy guiding this Implementation Plan.

As described above, the Commission annually publishes a Water Quality Monitoring Report that compiles and interprets monitoring data from the lakes, streams, and wetlands in the watershed. The monitoring data collected by the Commission and other agencies will be analyzed to determine the linkage between BMP implementation and water quality and biotic integrity in Meadow Lake, and to assess progress toward meeting the Total Maximum Daily Load and in-lake phosphorus concentration goals. This detailed monitoring is not part of the Commission's existing Monitoring budget. As the Commission completes its current cycle of management planning in 2010 with the Wetland Management Plan, that annual budget (\$15,000) will be reallocated to more extensive lake monitoring.

**Estimated Cost:** \$7,000 – 10,000

**Funding Source:** Reallocated operating budget for management plans (current budget is \$15,000)

#### **4.3.2 Other Monitoring**

A baseline aquatic vegetation survey has been completed and should be updated every 4-5 years as part of the more detailed water quality assessment described above. Zooplankton sampling has not been conducted. Research being conducted by the University of St. Thomas and the DNR on various shallow lakes in the Metro area may include a baseline assessment for Meadow Lake. The estimated cost of this monitoring is \$2,000-3,000 per lake. Neither type of monitoring is routinely part of the Commission's existing Monitoring budget. As the Commission completes its current cycle of management planning in 2010 with the Wetland Management Plan, that annual budget (\$15,000) will be reallocated to more extensive lake monitoring.

**Estimated Cost:** \$2,000-3,000

**Funding Source:** Reallocated operating budget for management plans (current budget is \$15,000)

The Commission will work together with the DNR to determine the optimum strategy for monitoring the fish community.

**Estimated Cost:** To be determined

**Funding Source:** To be determined

The Commission will explore funding opportunities to research or pilot monitoring of BMP effectiveness.

**Estimated Cost:** To be determined

**Funding Source:** To be determined

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## 5.0 Stakeholder Activities

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While the SCWMC will coordinate implementation of the Meadow Lake TMDL, the City of New Hope and other stakeholders ultimately will implement the identified BMPs. Table 3 in Section 3 of this report shows the lead agencies for each of the stakeholder activities. Not all stakeholders will undertake all these activities. Those activities for which the City will take the lead will be incorporated into its NPDES Stormwater Pollution Prevention Program (SWPPP), and implementation actions will be reported annually.

Each stakeholder is in a unique position to implement BMPs. For example, street and highway reconstruction can provide opportunities to retrofit or enhance treatment, but some streets and highways may not require reconstruction for years or even decades. BMPs requiring new equipment or accessories are dependent upon the individual stakeholder's ongoing equipment replacement schedule. Other activities must be integrated into ongoing maintenance responsibilities as the budget allows.

The following are the general BMP implementation activities that will be most effective in restoring water quality in the lakes to state standards and an estimate of their cost. Refer to Section 3 of this report for information regarding sequencing and lead agencies.

### 5.1 REDUCE EXTERNAL LOAD

#### 5.1.1 Retrofit BMPs to Add Stormwater Treatment in the Watershed

Much of the Meadow Lake watershed developed prior to the implementation of watershed rules and standards requiring treatment of stormwater runoff. Some treatment has been added as redevelopment or street projects provide opportunities. For example, in 2006, New Hope installed grit chambers and a large curb cut rain garden to treat runoff as part of a project to reconstruct streets in the neighborhood adjacent to the lake. Additional treatment Best Management Practices (BMPs) will be sought across the watershed as those opportunities continue to arise. Treatment options include but are not limited to:

- New or enhanced stormwater ponding;
- Infiltration basins and devices and other types of abstraction such as native vegetation or reforestation;
- In-line or off-line treatment manufactured devices; and
- Rain gardens and biofiltration.

Other projects would be implemented as opportunities arise, such as through street reconstruction projects and redevelopment. Examples of potential BMPs include detention ponds, native plantings, swirl separators, and trash collectors. These small practices are effective in removing debris, leaf litter, and other potential pollutants. Depending on the type of BMP, location, easement requirements, and other factors, costs can range from \$5,000 for a trash collector to \$250,000 or more for a detention pond. The number of BMPs necessary to achieve

the required phosphorus load reduction is unknown and is dependent on the types of opportunities that arise.

*Estimated Cost:* Varies by specific project

*Funding Source:* City, SCWMC through county levy, grant funds

### **5.1.2 Increase Infiltration in Watershed**

Cities will work with developers to incorporate Low Impact Development principles into redevelopment as appropriate. Cities will incorporate infiltration and other abstraction strategies into city improvement projects where possible as opportunities arise. The cost of this strategy varies depending on the BMP, and may range from a single property owner installing an individual rain garden to retrofitting parks and open space with native vegetation rather than mowed turf. The Commission's Education and Outreach Committee regularly provides education and outreach information to member cities on these topics for publication in city newsletters, neighborhood and block club fliers, and the city's website.

*Estimated Cost:* Varies by specific project

*Funding Source:* City, Commission's education program

### **5.1.3 Shoreline Management and Restoration**

Restore shoreline areas with native vegetation and lakescaping where opportunities present themselves. Shoreline restoration can cost \$30-50 per linear foot, depending on the width of the buffer installed. Meadow Lake contains about 3,500 linear feet of residential shoreline. Ideally about 75 percent of the residential and park shoreline would be native vegetation, with about 25 percent available for lake access. Many residents have at least some shoreline buffer, usually simply an unmowed area but in some cases a planted natural buffer. Accomplishing this goal would require planting buffers or enhancing existing buffers for about 2,625 feet of shoreline at a cost of about \$78,750 to \$131,250.

*Estimated Cost:* \$130,500 – \$217,500

*Funding Source:* Private property owners, cities, grant funds

### **5.1.4 Street Sweeping**

Newer street sweeping technologies are available that use high pressure to remove a greater percent of the small particles that can carry phosphorus to the lakes. Using these newer technologies can help improve water quality. Studies conducted in the Lakes Nokomis and Hiawatha lakesheds in Minneapolis (Wenck Associates 1998) suggest that improved street sweeping technologies and increased street sweeping frequency could reduce phosphorus loads by 7 percent. The City will consider how to increase the efficiency and effectiveness of street sweeping within the context of its overall sweeping program.

*Estimated Cost:* \$100,000 to 200,000 per new sweeper

*Funding Source:* City

Increased and targeted street sweeping may be most effective where there is minimal treatment opportunity in the catchment area. The City's existing sweeping policies and practices should be reviewed to determine how existing practices could be refined to improve efficiency and effectiveness as well as to identify where additional sweeping would provide the most water quality benefit.

*Estimated Cost:* \$65-85 per mile of additional sweeping

*Funding Source:* City

## **5.2 REDUCE INTERNAL LOAD**

### **5.2.1 Internal Load Reduction Project**

Meadow Lake may be a good candidate for a water level drawdown. A drawdown would expose the lake sediments and provide an opportunity for the native seed bank to reestablish a more beneficial aquatic vegetation community. Some additional chemical treatment may be necessary if the entire lake cannot be entirely drained. A partial drawdown was completed in winter 200x to allow for dredging of excess material at the outfalls into the lake. The following year residents reported reduced levels of invasive aquatic vegetation and improved water clarity. The estimated cost of this option is \$50,000.

*Estimated Cost:* \$50,000

*Funding Source:* City

## **5.3 BIOLOGIC INTEGRITY MANAGEMENT**

### **5.3.1 Aquatic Plant Management**

The SCWMC recognizes the importance of a healthy biological community in meeting water clarity goals, especially in shallow lakes. Aquatic plant management is a key aspect in maintaining a healthy shallow lake. To establish and maintain a healthy lake system, an aquatic plant management plan should be developed, including an action plan for treatment and management of invasive aquatic vegetation, most notably curly-leaf pondweed.

*Estimated Cost:* \$10,000 for an aquatic plant survey and management plan and \$5,000-10,000 per year for treatment

*Funding Source:* City, lake association

### **5.3.2 Fish Population Management**

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

*Estimated Cost:* varies depending on the necessary strategy(ies)

*Funding Source:* City, lake association, grant funds, DNR

#### **5.4 TRACKING AND REPORTING**

The City of New Hope will integrate BMPs into its SWPPP required by its NPDES General Permits for stormwater discharges. Activities will be tracked and reported in their annual NPDES report. Each stakeholder will make a copy of the annual report available to the Commission, which will then incorporate that information into the Commission's annual Water Quality Monitoring Report. Additional city staff time will be necessary to track and report on activities specific to this TMDL and Implementation Plan, however, it is difficult to estimate the magnitude of the additional level of effort.

*Estimated Cost:* Staff level of effort to be determined

*Funding Source:* City

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## Literature Cited

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Wenck Associates Inc. 1998. Lakes Nokomis and Hiawatha Diagnostic Feasibility Study – Internal Phosphorus Load Estimates. Internal Technical Memorandum.

Wenck Associates Inc. 2009. Meadow Lake Nutrient TMDL. Wenck Project 1240-22.

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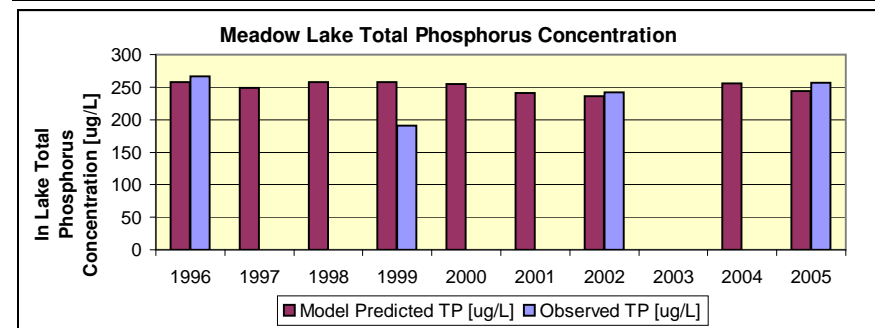
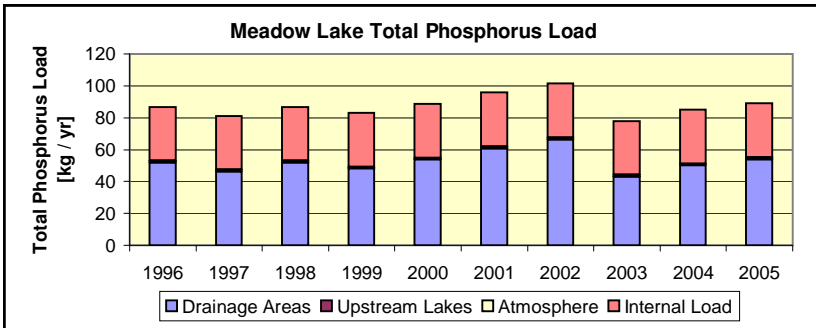
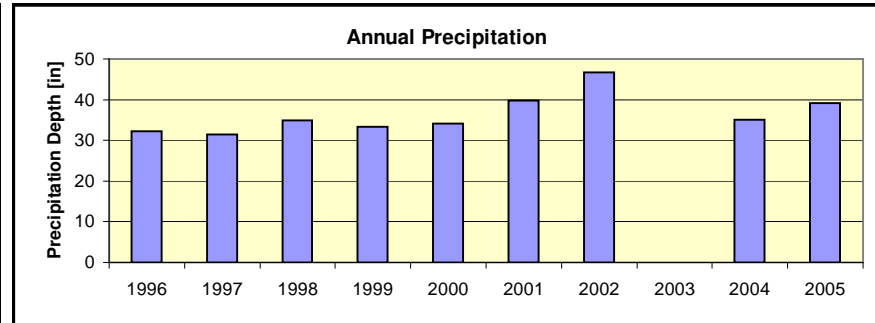
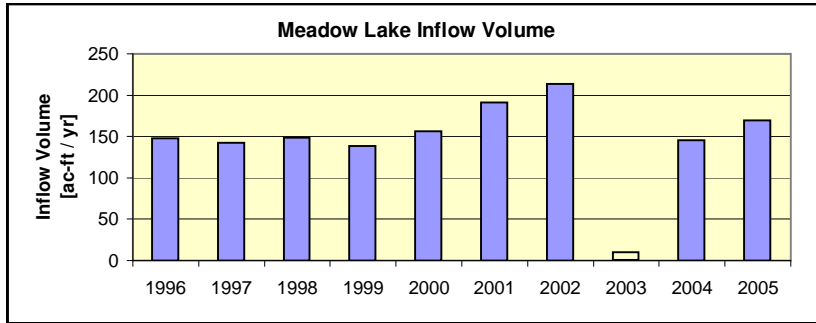
## **Appendix A**

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### **Lake Response Modeling Summary**

**Table 1: Meadow Lake Response Modeling Summary: Current Conditions**

Meadow Lake	Source	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Average 1996-2005	
Precipitation Depth [in]		32.3	31.5	34.9	33.3	34.1	39.8	46.7	0.0	35.1	39.2	Annual	Daily
Inflow Volume [ac-ft / yr]	Residence Time [yr]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		
	Drainage Areas	148	143	148	139	156	191	213	Summati	146	170		
	Upstream Lakes	0	0	0	0	0	0	0	Summati	0	0		
	Atmosphere	0	0	0	0	0	0	0	10	0	0		
	<b>TOTAL =</b>	<b>148</b>	<b>143</b>	<b>148</b>	<b>139</b>	<b>156</b>	<b>191</b>	<b>213</b>	<b>10</b>	<b>146</b>	<b>170</b>		
Total Phosphorus Load [kg / yr]	Drainage Areas	51.7	46.1	51.8	48.0	53.7	60.6	66.4	43.0	50.0	53.9	52.6	0.144
	Upstream Lakes	0	0	0	0	0	0	0	0	0	0	-	-
	Atmosphere	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.1	1.1	1.2	1.1	0.003
	Internal Load	33.9	33.9	33.9	33.9	33.9	33.9	33.9	33.9	33.9	33.9	33.9	0.093
	<b>TOTAL =</b>	<b>86.7</b>	<b>81.1</b>	<b>86.8</b>	<b>83.0</b>	<b>88.7</b>	<b>95.7</b>	<b>101.5</b>	<b>78.0</b>	<b>85.0</b>	<b>89.0</b>	<b>87.6</b>	<b>0.240</b>
Model Results	Model Predicted TP [ug/L]	257	249	257	258	254	241	237	0	255	244	252	
	Observed TP [ug/L]	266	-	-	191	-	-	242	0	-	257	-	
	Phosphorus Sedimentation [lb]	88	82	88	86	88	86	87	0	86	84		
	<b>TOTAL OUTFLOW [lb] =</b>	<b>104</b>	<b>97</b>	<b>104</b>	<b>97</b>	<b>108</b>	<b>125</b>	<b>137</b>	<b>0</b>	<b>101</b>	<b>112</b>		
Internal Load Factors:	Release Rate [mg/m <sup>2</sup> -day]	12	12	12	12	12	12	12	12	12	12		
	Anoxic factor [day]	70	70	70	70	70	70	70	70	70	70		



<b>1996 Loading Summary for: Meadow Lake</b>							
<b>Water Budgets</b>				<b>Phosphorus Loading</b>			
<b>Inflow from Drainage Areas</b>							
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF) <sup>1</sup>	Load	
Name	[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
1 Watershed	0.42	0.44	0.182	283.6	1.0	51.7	
2					1.0		
3					1.0		
4					1.0		
5					1.0		
6					1.0		
7					1.0		
8					1.0		
9					1.0		
10					1.0		
11					1.0		
12					1.0		
13					1.0		
<i>Summation</i>	<i>0.42</i>	<i>0.44</i>	<i>0.18</i>	<i>283.6</i>		<i>51.7</i>	
<b>Inflow from Upstream Lakes</b>							
			Discharge	Estimated P Concentration	Calibration Factor	Load	
Name			[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
1				-	1.0		
2				-	1.0		
3				-	1.0		
<i>Summation</i>			<i>0.00</i>	<i>-</i>		<i>-</i>	
<b>Atmosphere</b>							
	Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
	[km <sup>2</sup> ]	[m/yr]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[kg/km <sup>2</sup> -yr]	[--]	[kg/yr]
	0.04	0.82	0.82	0.00	26.80	1.0	1.1
Dry-year total P deposition =					24.9		
Average-year total P deposition =					26.8		
Wet-year total P deposition =					29.0		
(Barr Engineering 2004)							
<b>Groundwater</b>							
	Lake Area	Groundwater Flux	Net Inflow	Phosphorus Concentration	Calibration Factor	Load	
	[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
	0.04	0.0	0.00	0	1.0	-	
<b>Internal</b>							
	Lake Area	Anoxic Factor		Release Rate	Calibration Factor	Load	
	[km <sup>2</sup> ]	[days]		[mg/m <sup>2</sup> -day]	[--]	[kg/yr]	
	0.04	70.0		12.0	1.0	33.9	
<b>Net Discharge [10<sup>6</sup> m<sup>3</sup>/yr] =</b>			<b>0.18</b>	<b>Net Load [kg/yr] =</b>		<b>86.7</b>	

**NOTES**

<sup>1</sup> 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.



<b>1999 Loading Summary for: Meadow Lake</b>							
<b>Water Budgets</b>				<b>Phosphorus Loading</b>			
<b>Inflow from Drainage Areas</b>							
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF) <sup>1</sup>	Load	
Name	[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
1 Watershed	0.42	0.41	0.171	280.7	1.0	48.0	
2					1.0		
3					1.0		
4					1.0		
5					1.0		
6					1.0		
7					1.0		
8					1.0		
9					1.0		
10					1.0		
11					1.0		
12					1.0		
13					1.0		
<i>Summation</i>	<i>0.42</i>	<i>0.41</i>	<i>0.17</i>	<i>280.7</i>		<i>48.0</i>	
<b>Inflow from Upstream Lakes</b>							
			Discharge	Estimated P Concentration	Calibration Factor	Load	
Name			[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
1				-	1.0		
2				-	1.0		
3				-	1.0		
<i>Summation</i>			<i>0.00</i>	<i>-</i>		<i>-</i>	
<b>Atmosphere</b>							
	Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
	[km <sup>2</sup> ]	[m/yr]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[kg/km <sup>2</sup> -yr]	[--]	[kg/yr]
	0.04	0.85	0.85	0.00	26.80	1.0	1.1
				Dry-year total P deposition =	24.9		
				Average-year total P deposition =	26.8		
				Wet-year total P deposition =	29.0		
				(Barr Engineering 2004)			
<b>Groundwater</b>							
	Lake Area	Groundwater Flux	Net Inflow	Phosphorus Concentration	Calibration Factor	Load	
	[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
	0.04	0.0	0.00	0	1.0	-	
<b>Internal</b>							
	Lake Area	Anoxic Factor		Release Rate	Calibration Factor	Load	
	[km <sup>2</sup> ]	[days]		[mg/m <sup>2</sup> -day]	[--]	[kg/yr]	
	0.04	70.0		12.0	1.0	33.9	
			<b>Net Discharge [10<sup>6</sup> m<sup>3</sup>/yr] =</b>	<b>0.17</b>		<b>Net Load [kg/yr] =</b>	<b>83.0</b>

**NOTES**

<sup>1</sup> 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: Meadow Lake

Modeled Parameter	Equation	Parameters	Value [Units]
<b>TOTAL IN-LAKE PHOSPHORUS CONCENTRATION</b>			
	$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$	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.) =	83 [kg/yr]
		$Q$ (lake outflow) =	0.2 [ $10^6$ m <sup>3</sup> /yr]
		$V$ (modeled lake volume) =	0.0211 [ $10^6$ m <sup>3</sup> ]
		$T = V/Q =$	0.12 [yr]
		$P_i = W/Q =$	486 [ug/l]
<b>Model Predicted In-Lake [TP]</b>			<b>257.5 [ug/l]</b>
<b>Observed In-Lake [TP]</b>			<b>191.3 [ug/l]</b>
<b>CHLOROPHYLL-A CONCENTRATION</b>			
	$[Chla] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		$CB$ (Calibration factor) =	1.00 [--]
<b>Model Predicted In-Lake [Chl-a]</b>			<b>72.1 [ug/l]</b>
	$[Chla] = \frac{CB \times B_x}{\left[(1 + 0.025 \times B_x \times G)(1 + G \times a)\right]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		$CB$ (Calibration factor) =	1.00
		$P$ (Total Phosphorus) =	258 [ug/l]
		$N$ (Total Nitrogen) =	2,950 [ug/l]
		$B_x$ (Nutrient-Potential Chl-a conc.) =	219.7 [ug/l]
		$X_{pn}$ (Composite nutrient conc.) =	172.9 [ug/l]
		$G$ (Kinematic factor) =	0.19 [--]
		$F_s$ (Flushing Rate) =	8.10 [year <sup>-1</sup> ]
		$Z_{mix}$ (Mixing Depth) =	1.09 [m]
		$a$ (Non algal turbidity) =	0.10 [m <sup>-1</sup> ]
		$S$ (Secchi Depth) =	0.36 [m]
		Maximum lake depth =	1.09 [m]
	$B_x = \frac{X_{pn}^{1.33}}{4.31}$		
	$X_{pn} = \left[ P^{-2} + \left( \frac{N - 150}{12} \right)^{-2} \right]^{-0.5}$		
	$G = Z_{mix} (0.14 + 0.0039 F_s)$		
	$F_s = \frac{Q}{V} \quad a = \frac{1}{SD} - 0.025 \times [Chla]$		
<b>Model Predicted In-Lake [Chl-a]</b>			<b>106.3 [ug/l]</b>
<b>Observed In-Lake [Chl-a]</b>			<b>125.6 [ug/l]</b>
<b>SECCHI DEPTH</b>			
	$SD = \frac{CS}{(a + 0.025 \times [Chla])}$	as f(Chla), Walker (1999)	
		$CS$ (Calibration factor) =	1.00 [--]
		$a$ (Non algal turbidity) =	0.10 [m <sup>-1</sup> ]
<b>Model Predicted In-Lake SD</b>			<b>0.36 [m]</b>
<b>Observed In-Lake SD</b>			<b>0.34 [m]</b>
<b>PHOSPHORUS SEDIMENTATION RATE</b>			
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$		
<b>P<sub>sed</sub> (phosphorus sedimentation) =</b>			<b>39 [kg/yr]</b>
<b>PHOSPHORUS OUTFLOW LOAD</b>			
<b>W-P<sub>sed</sub> =</b>			<b>44 [kg/yr]</b>

<b>2002 Loading Summary for: Meadow Lake</b>							
<b>Water Budgets</b>				<b>Phosphorus Loading</b>			
<b>Inflow from Drainage Areas</b>							
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF) <sup>1</sup>	Load	
Name	[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
1 Watershed	0.42	0.63	0.263	252.3	1.0	66.4	
2					1.0		
3					1.0		
4					1.0		
5					1.0		
6					1.0		
7					1.0		
8					1.0		
9					1.0		
10					1.0		
11					1.0		
12					1.0		
13					1.0		
<i>Summation</i>	<i>0.42</i>	<i>0.63</i>	<i>0.26</i>	<i>252.3</i>		<i>66.4</i>	
<b>Inflow from Upstream Lakes</b>							
			Discharge	Estimated P Concentration	Calibration Factor	Load	
Name			[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
1				-	1.0		
2				-	1.0		
3				-	1.0		
<i>Summation</i>			<i>0.00</i>	<i>-</i>		<i>-</i>	
<b>Atmosphere</b>							
	Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
	[km <sup>2</sup> ]	[m/yr]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[kg/km <sup>2</sup> -yr]	[--]	[kg/yr]
	0.04	1.19	1.19	0.00	29.00	1.0	1.2
Dry-year total P deposition =					24.9		
Average-year total P deposition =					26.8		
Wet-year total P deposition =					29.0		
(Barr Engineering 2004)							
<b>Groundwater</b>							
	Lake Area	Groundwater Flux	Net Inflow	Phosphorus Concentration	Calibration Factor	Load	
	[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
	0.04	0.0	0.00	0	1.0	-	
<b>Internal</b>							
	Lake Area	Anoxic Factor		Release Rate	Calibration Factor	Load	
	[km <sup>2</sup> ]	[days]		[mg/m <sup>2</sup> -day]	[--]	[kg/yr]	
	0.04	70.0		12.0	1.0	33.9	
<b>Net Discharge [10<sup>6</sup> m<sup>3</sup>/yr] =</b>			<b>0.26</b>	<b>Net Load [kg/yr] =</b>		<b>101.5</b>	

**NOTES**

<sup>1</sup> 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: Meadow Lake

Modeled Parameter	Equation	Parameters	Value [Units]
<b>TOTAL IN-LAKE PHOSPHORUS CONCENTRATION</b>			
	$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$	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.) =	102 [kg/yr]
		$Q$ (lake outflow) =	0.3 [ $10^6$ m <sup>3</sup> /yr]
		$V$ (modeled lake volume) =	0.0211 [ $10^6$ m <sup>3</sup> ]
		$T = V/Q =$	0.08 [yr]
		$P_i = W/Q =$	386 [ug/l]
<b>Model Predicted In-Lake [TP]</b>			<b>236.5 [ug/l]</b>
<b>Observed In-Lake [TP]</b>			<b>242.0 [ug/l]</b>
<b>CHLOROPHYLL-A CONCENTRATION</b>			
	$[Chla] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		$CB$ (Calibration factor) =	1.00 [--]
<b>Model Predicted In-Lake [Chl-a]</b>			<b>66.2 [ug/l]</b>
	$[Chla] = \frac{CB \times B_x}{\left[(1 + 0.025 \times B_x \times G)(1 + G \times a)\right]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		$CB$ (Calibration factor) =	1.00
		$P$ (Total Phosphorus) =	237 [ug/l]
		$N$ (Total Nitrogen) =	4,100 [ug/l]
		$B_x$ (Nutrient-Potential Chl-a conc.) =	252.7 [ug/l]
		$X_{pn}$ (Composite nutrient conc.) =	192.1 [ug/l]
		$G$ (Kinematic factor) =	0.21 [--]
		$F_s$ (Flushing Rate) =	12.48 [year <sup>-1</sup> ]
		$Z_{mix}$ (Mixing Depth) =	1.09 [m]
		$a$ (Non algal turbidity) =	0.10 [m <sup>-1</sup> ]
		$S$ (Secchi Depth) =	0.36 [m]
		Maximum lake depth =	1.09 [m]
	$B_x = \frac{X_{pn}^{1.33}}{4.31}$		
	$X_{pn} = \left[ P^{-2} + \left( \frac{N - 150}{12} \right)^{-2} \right]^{-0.5}$		
	$G = Z_{mix} (0.14 + 0.0039 F_s)$		
	$F_s = \frac{Q}{V} \quad a = \frac{1}{SD} - 0.025 \times [Chla]$		
<b>Model Predicted In-Lake [Chl-a]</b>			<b>107.6 [ug/l]</b>
<b>Observed In-Lake [Chl-a]</b>			<b>192.0 [ug/l]</b>
<b>SECCHI DEPTH</b>			
	$SD = \frac{CS}{(a + 0.025 \times [Chla])}$	as f(Chla), Walker (1999)	
		$CS$ (Calibration factor) =	1.00 [--]
		$a$ (Non algal turbidity) =	0.10 [m <sup>-1</sup> ]
<b>Model Predicted In-Lake SD</b>			<b>0.36 [m]</b>
<b>Observed In-Lake SD</b>			<b>0.28 [m]</b>
<b>PHOSPHORUS SEDIMENTATION RATE</b>			
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$		
<b>P<sub>sed</sub> (phosphorus sedimentation) =</b>			<b>39 [kg/yr]</b>
<b>PHOSPHORUS OUTFLOW LOAD</b>			
<b>W-P<sub>sed</sub> =</b>			<b>62 [kg/yr]</b>

<b>2005 Loading Summary for: Meadow Lake</b>							
<b>Water Budgets</b>				<b>Phosphorus Loading</b>			
<b>Inflow from Drainage Areas</b>							
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF) <sup>1</sup>	Load	
Name	[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
1 Watershed	0.42	0.50	0.209	257.7	1.0	53.9	
2					1.0		
3					1.0		
4					1.0		
5					1.0		
6					1.0		
7					1.0		
8					1.0		
9					1.0		
10					1.0		
11					1.0		
12					1.0		
13					1.0		
<i>Summation</i>	<i>0.42</i>	<i>0.50</i>	<i>0.21</i>	<i>257.7</i>		<i>53.9</i>	
<b>Inflow from Upstream Lakes</b>							
			Discharge	Estimated P Concentration	Calibration Factor	Load	
Name			[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
1				-	1.0		
2				-	1.0		
3				-	1.0		
<i>Summation</i>			<i>0.00</i>	<i>-</i>		<i>-</i>	
<b>Atmosphere</b>							
	Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
	[km <sup>2</sup> ]	[m/yr]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[kg/km <sup>2</sup> -yr]	[--]	[kg/yr]
	0.04	0.99	0.99	0.00	29.00	1.0	1.2
				Dry-year total P deposition =	24.9		
				Average-year total P deposition =	26.8		
				Wet-year total P deposition =	29.0		
				(Barr Engineering 2004)			
<b>Groundwater</b>							
	Lake Area	Groundwater Flux	Net Inflow	Phosphorus Concentration	Calibration Factor	Load	
	[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
	0.04	0.0	0.00	0	1.0	-	
<b>Internal</b>							
	Lake Area	Anoxic Factor		Release Rate	Calibration Factor	Load	
	[km <sup>2</sup> ]	[days]		[mg/m <sup>2</sup> -day]	[--]	[kg/yr]	
	0.04	70.0		12.0	1.0	33.9	
			<b>Net Discharge [10<sup>6</sup> m<sup>3</sup>/yr] =</b>	<b>0.21</b>		<b>Net Load [kg/yr] =</b>	<b>89.0</b>

**NOTES**

<sup>1</sup> 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: Meadow Lake

Modeled Parameter	Equation	Parameters	Value [Units]
<b>TOTAL IN-LAKE PHOSPHORUS CONCENTRATION</b>			
	$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$	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.) =	89 [kg/yr]
		$Q$ (lake outflow) =	0.2 [ $10^6$ m <sup>3</sup> /yr]
		$V$ (modeled lake volume) =	0.0211 [ $10^6$ m <sup>3</sup> ]
		$T = V/Q =$	0.10 [yr]
		$P_i = W/Q =$	425 [ug/l]
<b>Model Predicted In-Lake [TP]</b>			<b>243.5 [ug/l]</b>
<b>Observed In-Lake [TP]</b>			<b>256.8 [ug/l]</b>
<b>CHLOROPHYLL-A CONCENTRATION</b>			
	$[Chla] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		$CB$ (Calibration factor) =	1.00 [--]
<b>Model Predicted In-Lake [Chl-a]</b>			<b>68.2 [ug/l]</b>
	$[Chla] = \frac{CB \times B_x}{\left[(1 + 0.025 \times B_x \times G)(1 + G \times a)\right]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		$CB$ (Calibration factor) =	1.00
		$P$ (Total Phosphorus) =	244 [ug/l]
		$N$ (Total Nitrogen) =	3,233 [ug/l]
		$B_x$ (Nutrient-Potential Chl-a conc.) =	226.2 [ug/l]
		$X_{pn}$ (Composite nutrient conc.) =	176.8 [ug/l]
		$G$ (Kinematic factor) =	0.19 [--]
		$F_s$ (Flushing Rate) =	9.92 [year <sup>-1</sup> ]
		$Z_{mix}$ (Mixing Depth) =	1.09 [m]
		$a$ (Non algal turbidity) =	0.10 [m <sup>-1</sup> ]
		$S$ (Secchi Depth) =	0.37 [m]
		Maximum lake depth =	1.09 [m]
	$B_x = \frac{X_{pn}^{1.33}}{4.31}$		
	$X_{pn} = \left[ P^{-2} + \left( \frac{N - 150}{12} \right)^{-2} \right]^{-0.5}$		
	$G = Z_{mix} (0.14 + 0.0039 F_s)$		
	$F_s = \frac{Q}{V} \quad a = \frac{1}{SD} - 0.025 \times [Chla]$		
<b>Model Predicted In-Lake [Chl-a]</b>			<b>105.5 [ug/l]</b>
<b>Observed In-Lake [Chl-a]</b>			<b>90.7 [ug/l]</b>
<b>SECCHI DEPTH</b>			
	$SD = \frac{CS}{(a + 0.025 \times [Chla])}$	as f(Chla), Walker (1999)	
		$CS$ (Calibration factor) =	1.00 [--]
		$a$ (Non algal turbidity) =	0.10 [m <sup>-1</sup> ]
<b>Model Predicted In-Lake SD</b>			<b>0.37 [m]</b>
<b>Observed In-Lake SD</b>			<b>0.44 [m]</b>
<b>PHOSPHORUS SEDIMENTATION RATE</b>			
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$		
<b><math>P_{sed}</math> (phosphorus sedimentation) =</b>			<b>38 [kg/yr]</b>
<b>PHOSPHORUS OUTFLOW LOAD</b>			
<b><math>W - P_{sed} =</math></b>			<b>51 [kg/yr]</b>

## TP Budget Loading Summary for: Meadow Lake

Water Budgets				Phosphorus Loading			
<b>Inflow from Drainage Areas</b>							
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF) <sup>1</sup>	Load	
Name	[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
1 Watershed	0.42	0.46	0.192	273.4	1.0	52.6	
2					1.0		
3					1.0		
4					1.0		
5					1.0		
6					1.0		
7					1.0		
8					1.0		
9					1.0		
10					1.0		
11					1.0		
12					1.0		
13					1.0		
<i>Summation</i>	0.42	0.46	0.19	273.4		52.6	
<b>Inflow from Upstream Lakes</b>							
			Discharge	Estimated P Concentration	Calibration Factor	Load	
Name			[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
1				-	1.0		
2				-	1.0		
3				-	1.0		
<i>Summation</i>			0.00	-		-	
<b>Atmosphere</b>							
	Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
	[km <sup>2</sup> ]	[m/yr]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[kg/km <sup>2</sup> -yr]	[--]	[kg/yr]
	0.04	0.87	0.87	0.00	26.80	1.0	1.1
					Dry-year total P deposition = 24.9		
					Average-year total P deposition = 26.8		
					Wet-year total P deposition = 29.0		
					(Barr Engineering 2004)		
<b>Groundwater</b>							
	Lake Area	Groundwater Flux		Net Inflow	Phosphorus Concentration	Calibration Factor	Load
	[km <sup>2</sup> ]	[m/yr]		[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]
	0.04	0.0		0.00	0	1.0	-
<b>Internal</b>							
	Lake Area	Anoxic Factor			Release Rate	Calibration Factor	Load
	[km <sup>2</sup> ]	[days]			[mg/m <sup>2</sup> -day]	[--]	[kg/yr]
	0.04	70.0			12.0	1.0	33.9
				<b>Net Discharge [10<sup>6</sup> m<sup>3</sup>/yr] =</b>	<b>0.19</b>	<b>Net Load [kg/yr] =</b>	<b>87.6</b>

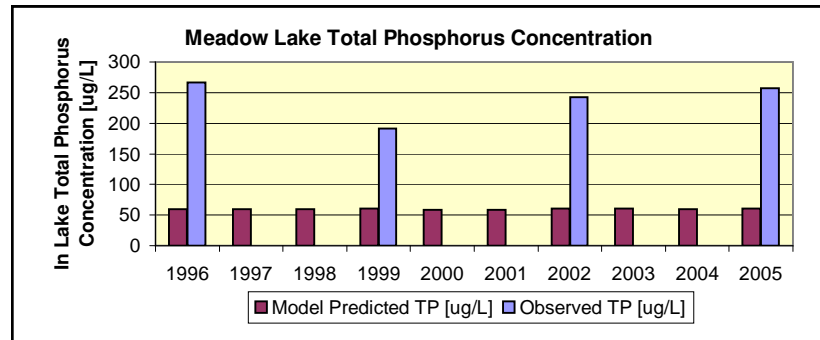
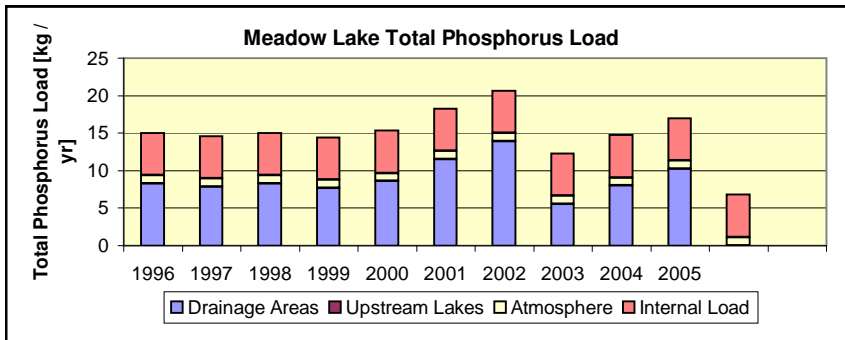
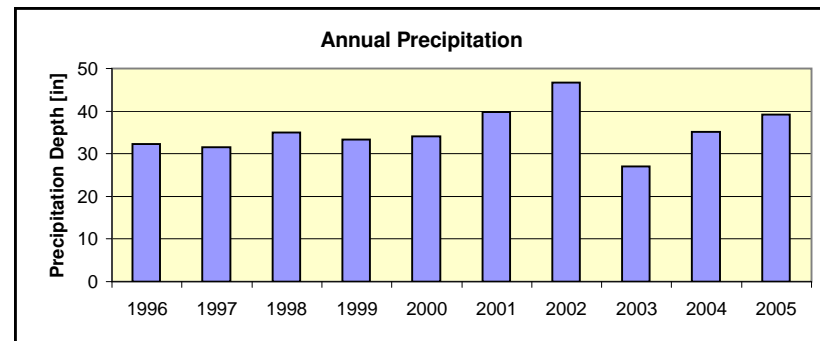
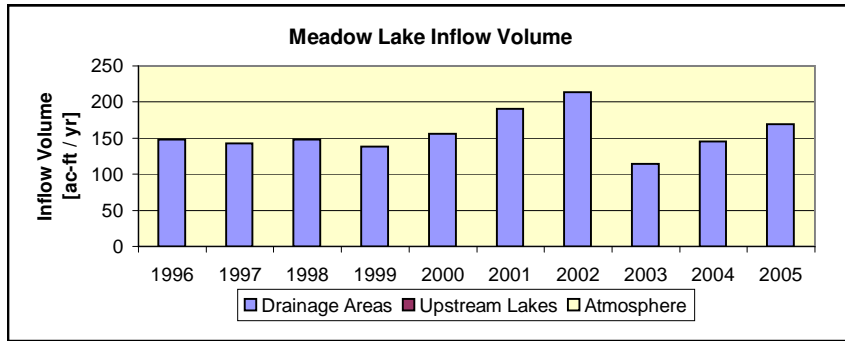
**NOTES**

<sup>1</sup> 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.



**Table 2: Meadow Lake Response Modeling Summary: At Goal (60 ug/L TP)**

Meadow Lake	Source	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Average 1996-2005	
Precipitation Depth [in]		32.3	31.5	34.9	33.3	34.1	39.8	46.7	27.1	35.1	39.2	Annual	Daily
Inflow Volume [ac-ft / yr]	Residence Time [yr]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		
	Drainage Areas	148	143	148	139	156	191	213	114	146	170		
	Upstream Lakes	0	0	0	0	0	0	0	0	0	0		
	Atmosphere	0	0	0	0	0	0	0	0	0	0		
	<b>TOTAL =</b>	<b>148</b>	<b>143</b>	<b>148</b>	<b>139</b>	<b>156</b>	<b>191</b>	<b>213</b>	<b>114</b>	<b>146</b>	<b>170</b>	<b>157</b>	
Total Phosphorus Load [kg / yr]	Drainage Areas	8.3	7.8	8.3	7.7	8.6	11.5	13.9	5.6	8.0	10.2	9.0	0.025
	Upstream Lakes	-	-	-	-	-	-	-	-	-	-	-	-
	Atmosphere	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	0.003
	Internal Load	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	0.016
	<b>TOTAL =</b>	<b>15.0</b>	<b>14.6</b>	<b>15.0</b>	<b>14.4</b>	<b>15.3</b>	<b>18.3</b>	<b>20.7</b>	<b>12.3</b>	<b>14.7</b>	<b>17.0</b>	<b>15.8</b>	<b>0.044</b>
Model Results	Model Predicted TP [ug/L]	60	60	60	60	58	59	60	60	59	60	60	
	Observed TP [ug/L]	266	-	-	191	-	-	242	-	-	257		
	Phosphorus Sedimentation [lb]	9	9	9	9	9	10	11	8	9	10		
	<b>TOTAL OUTFLOW [lb] =</b>	<b>24</b>	<b>23</b>	<b>24</b>	<b>23</b>	<b>25</b>	<b>30</b>	<b>35</b>	<b>19</b>	<b>24</b>	<b>28</b>		
Internal Load Factors:	Release Rate [mg/m <sup>2</sup> -day]	2	2	2	2	2	2	2	2	2	2	2	2
	Anoxic factor [day]	70	70	70	70	70	70	70	70	70	70	70	70



<b>1996 Loading Summary for: Meadow Lake at Goal</b>						
<b>Water Budgets</b>				<b>Phosphorus Loading</b>		
<b>Inflow from Drainage Areas</b>						
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF) <sup>1</sup>	Load
Name	[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]
1 Watershed	0.42	0.44	0.182	45.4	0.16	8.3
2					1.0	
3					1.0	
4					1.0	
5					1.0	
6					1.0	
7					1.0	
8					1.0	
9					1.0	
10					1.0	
11					1.0	
12					1.0	
13					1.0	
<i>Summation</i>	<i>0.42</i>	<i>0.44</i>	<i>0.18</i>	<i>45.4</i>		<i>8.3</i>
<b>Inflow from Upstream Lakes</b>						
Name		Discharge	Estimated P Concentration	Calibration Factor	Load	
		[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
1			-	1.0		
2			-	1.0		
3			-	1.0		
<i>Summation</i>		<i>0.00</i>	<i>-</i>			<i>-</i>
<b>Atmosphere</b>						
Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
[km <sup>2</sup> ]	[m/yr]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[kg/km <sup>2</sup> -yr]	[--]	[kg/yr]
0.04	0.82	0.82	0.00	26.80	1.0	1.1
Dry-year total P deposition =				24.9		
Average-year total P deposition =				26.8		
Wet-year total P deposition =				29.0		
(Barr Engineering 2004)						
<b>Groundwater</b>						
Lake Area	Groundwater Flux	Net Inflow	Phosphorus Concentration	Calibration Factor	Load	
[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
0.04	0.0	0.00	0	1.0	-	
<b>Internal</b>						
Lake Area	Anoxic Factor	Release Rate	Calibration Factor	Load		
[km <sup>2</sup> ]	[days]	[mg/m <sup>2</sup> -day]	[--]	[kg/yr]		
0.04	70.0	2.0	1.0	5.7		
<b>Net Discharge [10<sup>6</sup> m<sup>3</sup>/yr] =</b>			<b>0.18</b>	<b>Net Load [kg/yr] =</b>		<b>15.0</b>

**NOTES**

<sup>1</sup> 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.

## 1996 Lake Response Modeling for: Meadow Lake at Goal

Modeled Parameter	Equation	Parameters	Value [Units]
<b>TOTAL IN-LAKE PHOSPHORUS CONCENTRATION</b>			
	$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C <sub>P</sub> =	1.00 [--]
		C <sub>CB</sub> =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	15 [kg/yr] [106]
		Q (lake outflow) =	0.2 m3/yr
		V (modeled lake volume) =	0.0211 [106 m3]
		T = V/Q =	0.12 [yr]
		P <sub>i</sub> = W/Q =	82 [ug/l]
<b>Model Predicted In-Lake [TP]</b>			<b>59.7 [ug/l]</b>
<b>Observed In-Lake [TP]</b>			<b>266.3 [ug/l]</b>
<b>CHLOROPHYLL-A CONCENTRATION</b>			
	$[Chla] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
<b>Model Predicted In-Lake [Chl-a]</b>			<b>16.7 [ug/l]</b>
	$[Chla] = \frac{CB \times B_x}{\left[(1 + 0.025 \times B_x \times G)(1 + G \times a)\right]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
		P (Total Phosphorus) =	60 [ug/l]
		N (Total Nitrogen) =	3,313 [ug/l]
		B <sub>x</sub> (Nutrient-Potential Chl-a conc.) =	51.6 [ug/l]
		X <sub>pn</sub> (Composite nutrient conc.) =	58.2 [ug/l]
		G (Kinematic factor) =	0.19 [--]
		F <sub>s</sub> (Flushing Rate) =	8.65 [year-1]
		Z <sub>mix</sub> (Mixing Depth) =	1.09 [m]
		a (Non algal turbidity) =	0.10 [m-1]
		S (Secchi Depth) =	0.89 [m]
		Maximum lake depth =	1.09 [m]
<b>Model Predicted In-Lake [Chl-a]</b>			<b>40.7 [ug/l]</b>
<b>Observed In-Lake [Chl-a]</b>			<b>93.2 [ug/l]</b>
<b>SECCHI DEPTH</b>			
	$SD = \frac{CS}{(a + 0.025 \times [Chla])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.10 [m-1]
<b>Model Predicted In-Lake SD</b>			<b>0.89 [m]</b>
<b>Observed In-Lake SD</b>			<b>0.31 [m]</b>
<b>PHOSPHORUS SEDIMENTATION RATE</b>			
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$		
		<b>P<sub>sed</sub> (phosphorus sedimentation) =</b>	<b>4 [kg/yr]</b>
<b>PHOSPHORUS OUTFLOW LOAD</b>			
		<b>W-P<sub>sed</sub> =</b>	<b>11 [kg/yr]</b>

<b>1999 Loading Summary for: Meadow Lake at Goal</b>						
<b>Water Budgets</b>				<b>Phosphorus Loading</b>		
<b>Inflow from Drainage Areas</b>						
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF) <sup>1</sup>	Load
Name	[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]
1 Watershed	0.42	0.41	0.171	44.9	0.16	7.7
2					1.0	
3					1.0	
4					1.0	
5					1.0	
6					1.0	
7					1.0	
8					1.0	
9					1.0	
10					1.0	
11					1.0	
12					1.0	
13					1.0	
<i>Summation</i>	<i>0.42</i>	<i>0.41</i>	<i>0.17</i>	<i>44.9</i>		<i>7.7</i>
<b>Inflow from Upstream Lakes</b>						
Name		Discharge	Estimated P Concentration	Calibration Factor	Load	
		[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
1			-	1.0		
2			-	1.0		
3			-	1.0		
<i>Summation</i>		<i>0.00</i>	<i>-</i>			<i>-</i>
<b>Atmosphere</b>						
Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
[km <sup>2</sup> ]	[m/yr]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[kg/km <sup>2</sup> -yr]	[--]	[kg/yr]
0.04	0.85	0.85	0.00	26.80	1.0	1.1
Dry-year total P deposition =				24.9		
Average-year total P deposition =				26.8		
Wet-year total P deposition =				29.0		
(Barr Engineering 2004)						
<b>Groundwater</b>						
Lake Area	Groundwater Flux	Net Inflow	Phosphorus Concentration	Calibration Factor	Load	
[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
0.04	0.0	0.00	0	1.0	-	
<b>Internal</b>						
Lake Area	Anoxic Factor	Release Rate	Calibration Factor	Load		
[km <sup>2</sup> ]	[days]	[mg/m <sup>2</sup> -day]	[--]	[kg/yr]		
0.04	70.0	2.0	1.0	5.7		
<b>Net Discharge [10<sup>6</sup> m<sup>3</sup>/yr] =</b>			<b>0.17</b>	<b>Net Load [kg/yr] =</b>		<b>14.4</b>

**NOTES**

<sup>1</sup> 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: Meadow Lake at Goal

Modeled Parameter	Equation	Parameters	Value [Units]
<b>TOTAL IN-LAKE PHOSPHORUS CONCENTRATION</b>			
	$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$	as f(W,Q,V) from Canfield & Bachmann (1981)	
		C <sub>P</sub> =	1.00 [--]
		C <sub>CB</sub> =	0.162 [--]
		b =	0.458 [--]
		W (total P load = inflow + atm.) =	14 [kg/yr] [106]
		Q (lake outflow) =	0.2 m3/yr
		V (modeled lake volume) =	0.0211 [106 m3]
		T = V/Q =	0.12 [yr]
		P <sub>i</sub> = W/Q =	84 [ug/l]
<b>Model Predicted In-Lake [TP]</b>			<b>60.4 [ug/l]</b>
<b>Observed In-Lake [TP]</b>			<b>191.3 [ug/l]</b>
<b>CHLOROPHYLL-A CONCENTRATION</b>			
	$[Chla] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
<b>Model Predicted In-Lake [Chl-a]</b>			<b>16.9 [ug/l]</b>
	$[Chla] = \frac{CB \times B_x}{\left[(1 + 0.025 \times B_x \times G)(1 + G \times a)\right]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	1.00
		P (Total Phosphorus) =	60 [ug/l]
		N (Total Nitrogen) =	2,950 [ug/l]
		B <sub>x</sub> (Nutrient-Potential Chl-a conc.) =	51.9 [ug/l]
		X <sub>pn</sub> (Composite nutrient conc.) =	58.4 [ug/l]
		G (Kinematic factor) =	0.19 [--]
		F <sub>s</sub> (Flushing Rate) =	8.10 [year-1]
		Z <sub>mix</sub> (Mixing Depth) =	1.09 [m]
		a (Non algal turbidity) =	0.10 [m-1]
		S (Secchi Depth) =	0.89 [m]
		Maximum lake depth =	1.09 [m]
<b>Model Predicted In-Lake [Chl-a]</b>			<b>41.0 [ug/l]</b>
<b>Observed In-Lake [Chl-a]</b>			<b>125.6 [ug/l]</b>
<b>SECCHI DEPTH</b>			
	$SD = \frac{CS}{(a + 0.025 \times [Chla])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.10 [m-1]
<b>Model Predicted In-Lake SD</b>			<b>0.89 [m]</b>
<b>Observed In-Lake SD</b>			<b>0.34 [m]</b>
<b>PHOSPHORUS SEDIMENTATION RATE</b>			
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$		
		P <sub>sed</sub> (phosphorus sedimentation) =	4 [kg/yr]
<b>PHOSPHORUS OUTFLOW LOAD</b>			
		W-P <sub>sed</sub> =	10 [kg/yr]

<b>2002 Loading Summary for: Meadow Lake at Goal</b>						
<b>Water Budgets</b>				<b>Phosphorus Loading</b>		
<b>Inflow from Drainage Areas</b>						
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF) <sup>1</sup>	Load
Name	[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]
1 Watershed	0.42	0.63	0.263	53.0	0.21	13.9
2					1.0	
3					1.0	
4					1.0	
5					1.0	
6					1.0	
7					1.0	
8					1.0	
9					1.0	
10					1.0	
11					1.0	
12					1.0	
13					1.0	
<i>Summation</i>	<i>0.42</i>	<i>0.63</i>	<i>0.26</i>	<i>53.0</i>		<i>13.9</i>
<b>Inflow from Upstream Lakes</b>						
Name		Discharge	Estimated P Concentration	Calibration Factor	Load	
		[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
1			-	1.0		
2			-	1.0		
3			-	1.0		
<i>Summation</i>		<i>0.00</i>	<i>-</i>			<i>0.0</i>
<b>Atmosphere</b>						
Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
[km <sup>2</sup> ]	[m/yr]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[kg/km <sup>2</sup> -yr]	[--]	[kg/yr]
0.04	1.19	1.19	0.00	26.80	1.0	1.1
Dry-year total P deposition =				24.9		
Average-year total P deposition =				26.8		
Wet-year total P deposition =				29.0		
(Barr Engineering 2004)						
<b>Groundwater</b>						
Lake Area	Groundwater Flux	Net Inflow	Phosphorus Concentration	Calibration Factor	Load	
[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
0.04	0.0	0.00	0	1.0	0.0	
<b>Internal</b>						
Lake Area	Anoxic Factor	Release Rate	Calibration Factor	Load		
[km <sup>2</sup> ]	[days]	[mg/m <sup>2</sup> -day]	[--]	[kg/yr]		
0.04	70.0	2.0	1.0	5.7		
<b>Net Discharge [10<sup>6</sup> m<sup>3</sup>/yr] =</b>			<b>0.26</b>	<b>Net Load [kg/yr] =</b>		<b>20.7</b>

**NOTES**

<sup>1</sup> 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.



<b>2005 Loading Summary for: Meadow Lake at Goal</b>							
<b>Water Budgets</b>				<b>Phosphorus Loading</b>			
<b>Inflow from Drainage Areas</b>							
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF) <sup>1</sup>	Load	
Name	[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
1 Watershed	0.42	0.50	0.209	49.0	0.19	10.2	
2					1.0		
3					1.0		
4					1.0		
5					1.0		
6					1.0		
7					1.0		
8					1.0		
9					1.0		
10					1.0		
11					1.0		
12					1.0		
13					1.0		
<i>Summation</i>	<i>0.42</i>	<i>0.50</i>	<i>0.21</i>	<i>49.0</i>		<i>10.2</i>	
<b>Inflow from Upstream Lakes</b>							
			Discharge	Estimated P Concentration	Calibration Factor	Load	
Name			[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
1				-	1.0		
2				-	1.0		
3				-	1.0		
<i>Summation</i>			<i>0.00</i>	<i>-</i>		<i>0.0</i>	
<b>Atmosphere</b>							
	Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
	[km <sup>2</sup> ]	[m/yr]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[kg/km <sup>2</sup> -yr]	[--]	[kg/yr]
	0.04	0.99	0.99	0.00	26.80	1.0	1.1
				Dry-year total P deposition =	24.9		
				Average-year total P deposition =	26.8		
				Wet-year total P deposition =	29.0		
				(Barr Engineering 2004)			
<b>Groundwater</b>							
	Lake Area	Groundwater Flux	Net Inflow	Phosphorus Concentration	Calibration Factor	Load	
	[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
	0.04	0.0	0.00	0	1.0	0.0	
<b>Internal</b>							
	Lake Area	Anoxic Factor		Release Rate	Calibration Factor	Load	
	[km <sup>2</sup> ]	[days]		[mg/m <sup>2</sup> -day]	[--]	[kg/yr]	
	0.04	70.0		2.0	1.0	5.7	
			<b>Net Discharge [10<sup>6</sup> m<sup>3</sup>/yr] =</b>	<b>0.21</b>		<b>Net Load [kg/yr] =</b>	<b>17.0</b>

**NOTES**

<sup>1</sup> 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: Meadow Lake at Goal

Modeled Parameter	Equation	Parameters	Value [Units]
<b>TOTAL IN-LAKE PHOSPHORUS CONCENTRATION</b>			
$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$	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.) =	17 [kg/yr]
		$Q$ (lake outflow) =	0.2 [10 <sup>6</sup> m <sup>3</sup> /yr]
		$V$ (modeled lake volume) =	0.0211 [10 <sup>6</sup> m <sup>3</sup> ]
		$T = V/Q =$	0.10 [yr]
		$P_i = W/Q =$	81 [ug/l]
<b>Model Predicted In-Lake [TP]</b>			<b>60.1 [ug/l]</b>
<b>Observed In-Lake [TP]</b>			<b>256.8 [ug/l]</b>
<b>CHLOROPHYLL-A CONCENTRATION</b>			
	$[Chla] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		$CB$ (Calibration factor) =	1.00 [--]
<b>Model Predicted In-Lake [Chl-a]</b>			<b>16.8 [ug/l]</b>
	$[Chla] = \frac{CB \times B_x}{\left[(1 + 0.025 \times B_x \times G)(1 + G \times a)\right]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		$CB$ (Calibration factor) =	1.00
		$P$ (Total Phosphorus) =	60 [ug/l]
		$N$ (Total Nitrogen) =	3,233 [ug/l]
		$B_x$ (Nutrient-Potential Chl-a conc.) =	52.0 [ug/l]
		$X_{pn}$ (Composite nutrient conc.) =	58.5 [ug/l]
		$G$ (Kinematic factor) =	0.19 [--]
		$F_s$ (Flushing Rate) =	9.92 [year <sup>-1</sup> ]
		$Z_{mix}$ (Mixing Depth) =	1.09 [m]
		$a$ (Non algal turbidity) =	0.10 [m <sup>-1</sup> ]
		$S$ (Secchi Depth) =	0.89 [m]
		Maximum lake depth =	1.09 [m]
	$B_x = \frac{X_{pn}^{1.33}}{4.31}$		
	$X_{pn} = \left[ P^{-2} + \left( \frac{N - 150}{12} \right)^{-2} \right]^{-0.5}$		
	$G = Z_{mix} (0.14 + 0.0039 F_s)$		
	$F_s = \frac{Q}{V} \quad a = \frac{1}{SD} - 0.025 \times [Chla]$		
<b>Model Predicted In-Lake [Chl-a]</b>			<b>40.7 [ug/l]</b>
<b>Observed In-Lake [Chl-a]</b>			<b>90.7 [ug/l]</b>
<b>SECCHI DEPTH</b>			
	$SD = \frac{CS}{(a + 0.025 \times [Chla])}$	as f(Chla), Walker (1999)	
		$CS$ (Calibration factor) =	1.00 [--]
		$a$ (Non algal turbidity) =	0.10 [m <sup>-1</sup> ]
<b>Model Predicted In-Lake SD</b>			<b>0.89 [m]</b>
<b>Observed In-Lake SD</b>			<b>0.44 [m]</b>
<b>PHOSPHORUS SEDIMENTATION RATE</b>			
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$		
<b>P<sub>sed</sub> (phosphorus sedimentation) =</b>			<b>4 [kg/yr]</b>
<b>PHOSPHORUS OUTFLOW LOAD</b>			
<b>W-P<sub>sed</sub> =</b>			<b>13 [kg/yr]</b>

<b>TMDL Loading Summary for: Meadow Lake at Goal</b>						
<b>Water Budgets</b>				<b>Phosphorus Loading</b>		
<b>Inflow from Drainage Areas</b>						
	Drainage Area	Runoff Depth	Discharge	Phosphorus Concentration	Loading Calibration Factor (CF) <sup>1</sup>	Load
Name	[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]
1 Watershed	0.42	0.46	0.194	46.5	0.19	9.0
2					1.0	
3					1.0	
4					1.0	
5					1.0	
6					1.0	
7					1.0	
8					1.0	
9					1.0	
10					1.0	
11					1.0	
12					1.0	
13					1.0	
<i>Summation</i>	<i>0.42</i>	<i>0.46</i>	<i>0.19</i>	<i>46.5</i>		<i>9.0</i>
<b>Inflow from Upstream Lakes</b>						
Name		Discharge	Estimated P Concentration	Calibration Factor	Load	
		[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
1			-	1.0		
2			-	1.0		
3			-	1.0		
<i>Summation</i>		<i>0.00</i>	<i>-</i>			<i>0.0</i>
<b>Atmosphere</b>						
Lake Area	Precipitation	Evaporation	Net Inflow	Aerial Loading Rate	Calibration Factor	Load
[km <sup>2</sup> ]	[m/yr]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[kg/km <sup>2</sup> -yr]	[--]	[kg/yr]
0.04	0.87	0.87	0.00	26.80	1.0	1.1
Dry-year total P deposition =				24.9		
Average-year total P deposition =				26.8		
Wet-year total P deposition =				29.0		
(Barr Engineering 2004)						
<b>Groundwater</b>						
Lake Area	Groundwater Flux	Net Inflow	Phosphorus Concentration	Calibration Factor	Load	
[km <sup>2</sup> ]	[m/yr]	[10 <sup>6</sup> m <sup>3</sup> /yr]	[ug/L]	[--]	[kg/yr]	
0.04	0.0	0.00	0	1.0	0.0	
<b>Internal</b>						
Lake Area	Anoxic Factor	Release Rate	Calibration Factor	Load		
[km <sup>2</sup> ]	[days]	[mg/m <sup>2</sup> -day]	[--]	[kg/yr]		
0.04	70.0	2.0	1.0	5.7		
<b>Net Discharge [10<sup>6</sup> m<sup>3</sup>/yr] =</b>			<b>0.19</b>	<b>Net Load [kg/yr] =</b>		<b>15.8</b>

**NOTES**

<sup>1</sup> 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.

## TMDL Lake Response Modeling for: Meadow Lake at Goal

Modeled Parameter	Equation	Parameters	Value [Units]
<b>TOTAL IN-LAKE PHOSPHORUS CONCENTRATION</b>			
	$P = \frac{P_i}{\left(1 + C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times T\right)}$	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.) =	16 [kg/yr]
		$Q$ (lake outflow) =	0.2 [10 <sup>6</sup> m <sup>3</sup> /yr]
		$V$ (modeled lake volume) =	0.0211 [10 <sup>6</sup> m <sup>3</sup> ]
		$T = V/Q =$	0.11 [yr]
		$P_i = W/Q =$	81 [ug/l]
<b>Model Predicted In-Lake [TP]</b>			<b>59.6 [ug/l]</b>
<b>Observed In-Lake [TP]</b>			- [ug/l]
<b>CHLOROPHYLL-A CONCENTRATION</b>			
	$[Chla] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		$CB$ (Calibration factor) =	1.00 [--]
<b>Model Predicted In-Lake [Chl-a]</b>			<b>16.7 [ug/l]</b>
	$[Chla] = \frac{CB \times B_x}{\left[(1 + 0.025 \times B_x \times G)(1 + G \times a)\right]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		$CB$ (Calibration factor) =	1.00
		$P$ (Total Phosphorus) =	60 [ug/l]
		$N$ (Total Nitrogen) =	3,361 [ug/l]
		$B_x$ (Nutrient-Potential Chl-a conc.) =	51.6 [ug/l]
		$X_{pn}$ (Composite nutrient conc.) =	58.2 [ug/l]
		$G$ (Kinematic factor) =	0.19 [--]
		$F_s$ (Flushing Rate) =	9.18 [year <sup>-1</sup> ]
		$Z_{mix}$ (Mixing Depth) =	1.09 [m]
		$a$ (Non algal turbidity) =	0.50 [m <sup>-1</sup> ]
		$S$ (Secchi Depth) =	0.69 [m]
		Maximum lake depth =	1.09 [m]
<b>Model Predicted In-Lake [Chl-a]</b>			<b>37.7 [ug/l]</b>
<b>Observed In-Lake [Chl-a]</b>			- [ug/l]
<b>SECCHI DEPTH</b>			
	$SD = \frac{CS}{(a + 0.025 \times [Chla])}$	as f(Chla), Walker (1999)	
		$CS$ (Calibration factor) =	1.00 [--]
		$a$ (Non algal turbidity) =	0.50 [m <sup>-1</sup> ]
<b>Model Predicted In-Lake SD</b>			<b>0.69 [m]</b>
<b>Observed In-Lake SD</b>			- [m]
<b>PHOSPHORUS SEDIMENTATION RATE</b>			
	$P_{sed} = C_P \times C_{CB} \times \left(\frac{W_P}{V}\right)^b \times [TP] \times V$		
		$P_{sed}$ (phosphorus sedimentation) =	4 [kg/yr]
<b>PHOSPHORUS OUTFLOW LOAD</b>			
	$W - P_{sed} =$		12 [kg/yr]

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## **Appendix B**

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### Water Quality Monitoring

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## **1.0 Water Quality Monitoring**

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Water quality monitoring has been conducted in the Shingle Creek watershed since 1990 as a part of the Citizen Assisted Monitoring Program (CAMP) program. This appendix is focused on characterizing current conditions and diagnosing key problems degrading current water quality.

### **1.1 PREVIOUS STUDIES AND MONITORING ON MEADOW LAKE**

#### **1.1.1 Citizen Assisted Monitoring Program (CAMP)**

Since 1990, the Shingle Creek Watershed Management Commission (SCWMC) has participated in the Citizens Assisted Monitoring Program (CAMP) operated by the Metropolitan Council Environmental Services (MCES). The CAMP program is a volunteer monitoring program where volunteers collect data and samples biweekly including samples for total phosphorus, total Kjeldahl nitrogen, and Secchi depth. Meadow Lake has been monitored through this program every three years since 1995. The SCWMC has no professional lakes monitoring program at this time.

### **1.2 MONITORING PARAMETERS**

#### **1.2.1 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. Shallow lakes such as Meadow Lake often mix periodically throughout the year as a result of wind and wave action. No data is available to determine how often Meadow Lake mixes.

#### **1.2.2 Phosphorus and Nitrogen**

Lake algal production is typically limited by nutrient availability, specifically phosphorus and nitrogen. Minnesota lakes are almost exclusively limited by phosphorus; however excessive phosphorus concentrations can lead to nitrogen limiting conditions. Phosphorus and nitrogen are measured to determine the availability of the nutrients for

algal production. Dissolved and orthophosphorus are the most readily available forms of phosphorus while total phosphorus is a measure of all the phosphorus, bound and unbound. Nitrate is the most readily available form of nitrogen for algal production and total Kjeldahl nitrogen is a measure of all nitrogen in the water column.

### 1.2.3 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 good 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.

## 1.3 LAKE MONITORING RESULTS

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

### 1.3.1 Historical Data

Spring and summer average water quality for Meadow Lake is presented in Table 1.1 and Table 1.2, respectively. Data suggests that severe algal bloom conditions persist year round.

**Table 1.1. Spring average (January 1 through May 31) water quality conditions for Meadow Lake.**

Year	Chlorophyll-a (µg/L)		Total Phosphorus (mg/L)		Secchi Depth (m)		Total Kjeldahl Nitrogen (mg/L)	
	N	Mean	N	Mean	N	Mean	N	Mean
1994								
1996	2	11.4	2	0.085	2	0.7	2	1.2
1999	4	49.5	4	0.122	4	0.5	4	2.2
2002	2	53.0	2	0.164	2	0.5	2	2.2
2005	2	3.2	2	0.225	2	0.6	2	5.1

**Table 1.2. Summer average (June 1 through September 30) water quality conditions for Meadow Lake.**

Year	Chlorophyll-a (µg/L)		Total Phosphorus (mg/L)		Secchi Depth (m)		Total Kjeldahl Nitrogen (mg/L)	
	N	Mean	N	Mean	N	Mean	N	Mean
1994					15	0.3		
1996	8	93.2	8	0.266	8	0.3	8	3.3
1999	8	125.6	8	0.191	8	0.3	8	3.0
2002	5	192.0	6	0.242	6	0.3	6	4.1
2005	6	90.7	6	0.257	6	0.4	6	3.2

### 1.3.2 Temperature and Dissolved Oxygen

There are no temperature or dissolved oxygen data available for Meadow Lake.

### 1.3.3 Phosphorus

As can be seen in Figures 1.1 and 1.2, total phosphorus concentration generally increases throughout the summer, with maximum concentration generally occurring in August or early September.

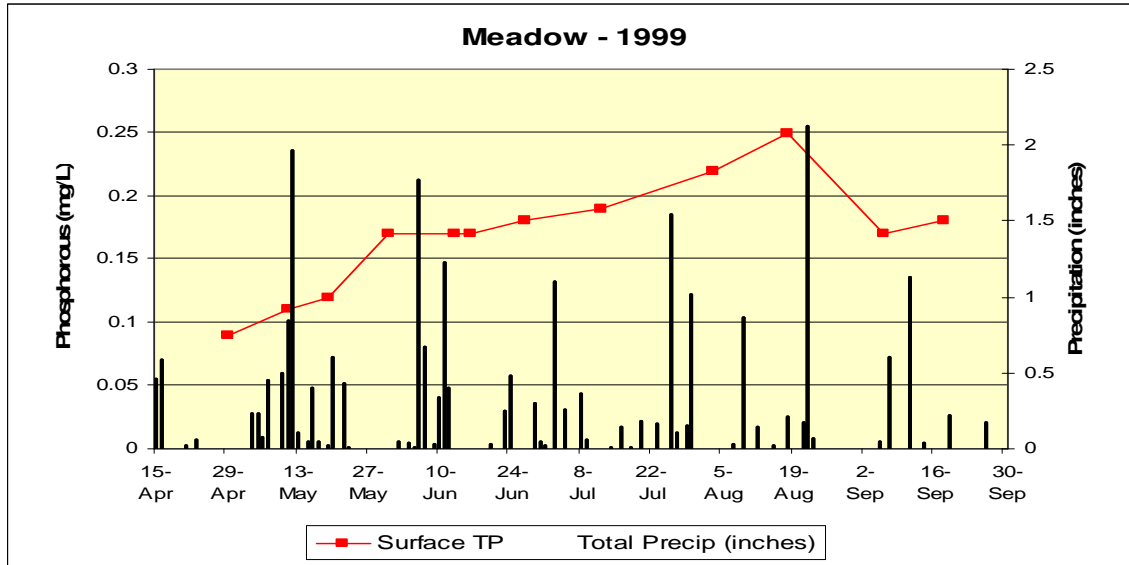


Figure 1.1. Surface total phosphorus concentrations and total precipitation for Meadow Lake in 1999.

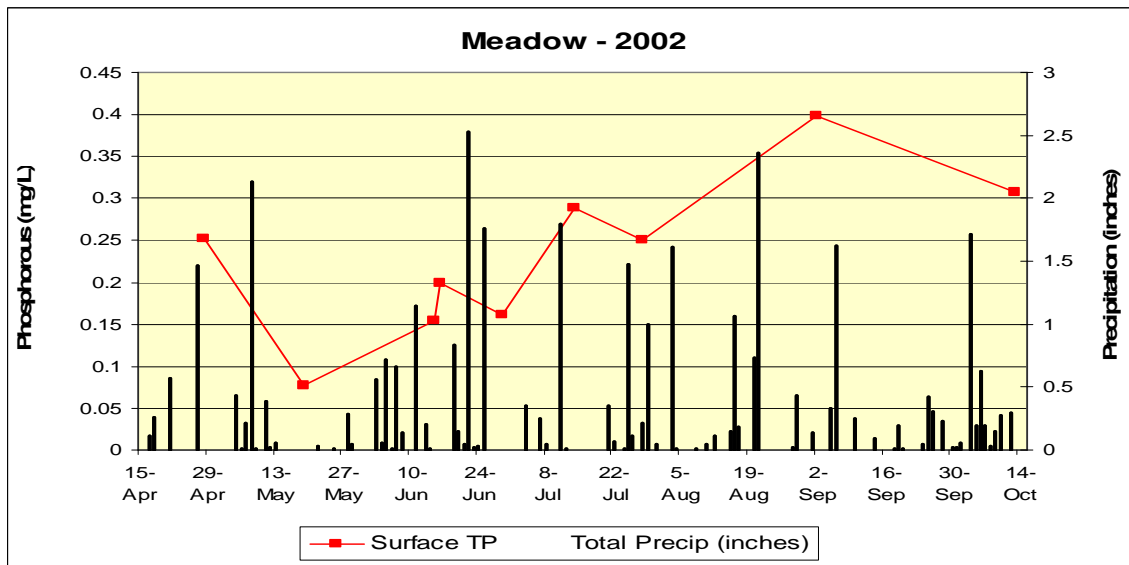


Figure 1.2. Surface total phosphorus concentrations and total precipitation for Meadow Lake in 2002.

### 1.3.4 Chlorophyll-a

Chlorophyll-a concentrations generally track with TP concentrations increasing through the spring and early summer. Figure 1.3 and 1.4 show data from 1999 and 2002.

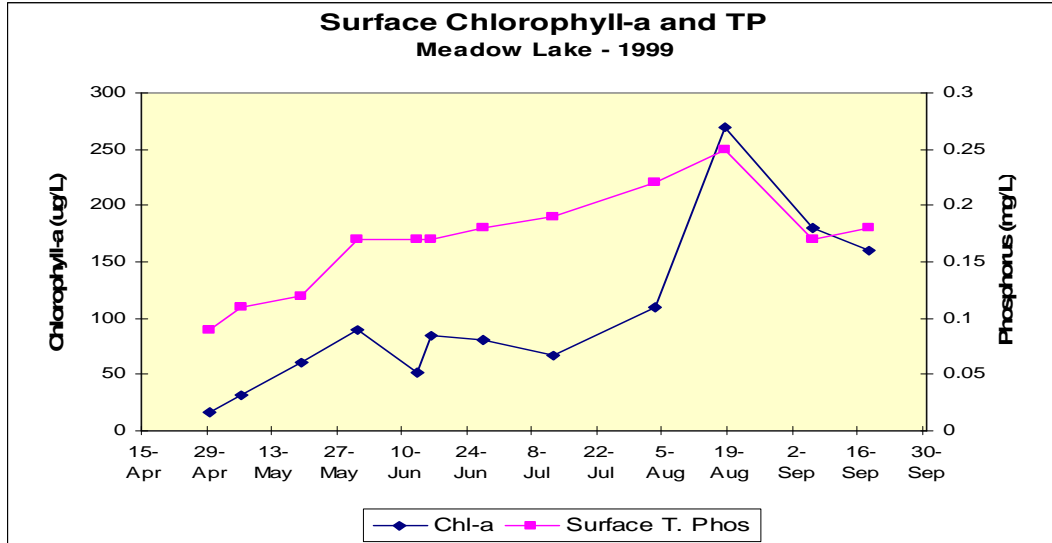


Figure 1.3. Chlorophyll-a and phosphorus concentrations in the epilimnion of the Meadow Lake for 1999.

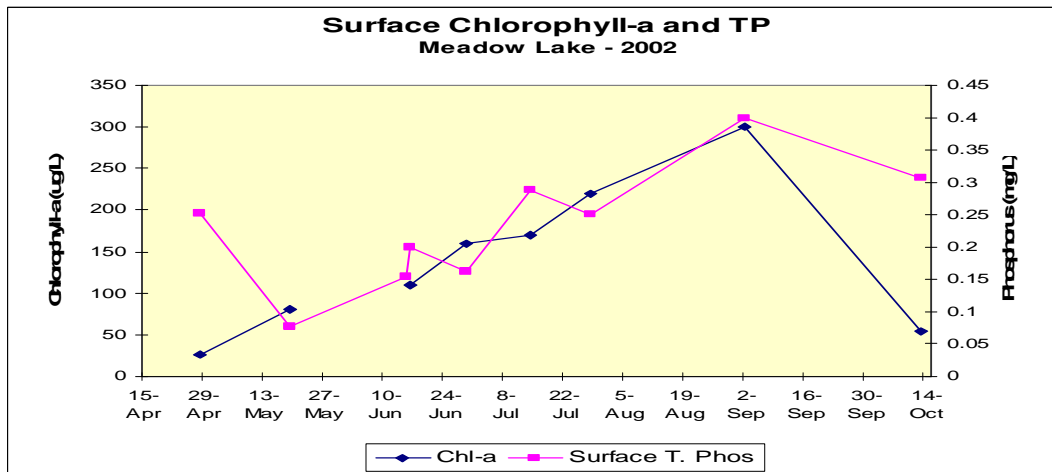


Figure 1.4. Chlorophyll-a and phosphorus concentrations in the epilimnion of the Meadow Lake for 2002.

## 1.4 CONCLUSIONS

Monitoring data suggest that Meadow Lake is a productive system in which water quality significantly exceeds the shallow lake standards for total phosphorus ( $\leq 60\mu\text{g/L}$ ), chlorophyll-a ( $\leq 20\mu\text{g/L}$ ), and Secchi depth ( $\geq 1.0$  meters) in all monitored years. The lake exhibits severe late season algae blooms.