Bald Eagle Lake Nutrient TMDL

Prepared for

The Rice Creek Watershed
District

March 2012

Wenck

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Bald Eagle Lake
Nutrient TMDL
Report

Prepared for:

RICE CREEK WATERSHED DISTRICT

March 2012

Prepared by:

WENCK ASSOCIATES, INC.
1800 Pioneer Creek Center
P.O. Box 249
Maple Plain, Minnesota 55359-0249
(763) 479-4200

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HUC 0701020
Bald Eagle Lake was added to the 303(d) list in 2002 because of excess nutrient concentrations impairing aquatic recreation, as set forth in Minnesota Rules 7050.0150. This TMDL is prioritized to start in 2008 and be completed by 2012.</td><td>1-1</td></tr>
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TMDL Summary

TMDL Summary Table			
EPA/MPCA Required Elements	**Summary**		**TMDL Page #**
	Watershed Runoff	1.6	
	Upstream Lakes	0.4	
	Atmospheric Load	0.7	
	Internal Load	0.5	
Margin of Safety	The margin of safety is implicit in each TMDL due to the conservative assumptions of the model.		4-3
Seasonal Variation	Seasonal variation is accounted for by developing targets for the summer critical period where the frequency and severity of nuisance algal growth is greatest. Although the critical period is the summer, lakes are not sensitive to short-term changes but rather respond to long-term changes in annual load.		4-7
Reasonable Assurance	Reasonable assurance is provided by implementing the TMDL through the Rice Creek Watershed District's watershed management plan, local water management plans adopted by White Bear Township and the cities of Hugo, Lino Lakes, Dellwood, Grant, and White Bear Lake, and activities conducted by the Bald Eagle Lake Association.		7-1
Monitoring	The Rice Creek Watershed District and Minnesota DNR monitors this lake and will continue to do so through the implementation period.		7-4
Implementation	This TMDL sets forth an implementation framework and general load reduction strategies that will be expanded and refined through the development of an Implementation Plan. Implementation costs will range between $1,500,000 and $5 Million.		6-1
Public Participation	Stakeholder and Public participation was accomplished through a series of technical and public meetings. Feedback garnered from these meetings was incorporated into the TMDL Report.		5-1

Executive Summary

This Total Maximum Daily Load (TMDL) study addresses a nutrient impairment in Bald Eagle Lake (62-0002). The goal of this TMDL is to quantify the pollutant reductions needed to meet State water quality standards for nutrients.

Bald Eagle Lake is located primarily in White Bear Township in Ramsey County, Minnesota but also extends into the City of Hugo in Washington County and the City of Lino Lakes in Anoka County in the Upper Mississippi River watershed. It is a highly used recreational water body with an active fishery and provides other aesthetic values as well. The drainage area to the lake is 10,835 acres of land that is predominantly single family residential and undeveloped land cover with a large proportion of wetlands. The drainage area contains portions of White Bear Township within which most of the lake is located, but also includes portions of the cities of Hugo, Grant, Dellwood, White Bear Lake, and Lino Lakes. The outlet for Bald Eagle Lake is (a channel at the north end of the lake where it flows into Clearwater Creek. Water quality is considered moderately degraded, with the lake still viewed as a popular resource for recreational activities by riparian land owners as well as the general public.

A P8 model and BATHTUB lake response model were developed for Bald Eagle Lake to develop current phosphorus budget for Bald Eagle Lake. Internal loading was estimated by quantifying anoxia over the sediments and measuring the anoxic release rate from profundal sediments. The calibrated lake response model was then used to determine the assimilative capacity for Bald Eagle Lake.

The TMDL for Bald Eagle Lake is 5.2 pounds/day phosphorus. Wasteload and Load Allocations to meet state standards indicate that average nutrient load reductions of 58% would be required to consistently meet standards. Internal load management (91% reduction) and reduction of phosphorus from watershed runoff (38% reduction) will be required for Bald Eagle Lake to meet state standards. All three response variables (total phosphorus, chlorophyll-a, and Secchi depth) will be met with the allocated loads.

1.0 Introduction

1.1 PURPOSE

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

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

1.2 PROBLEM IDENTIFICATION

Bald Eagle Lake (DNR Lake # 62-0002), located primarily in White Bear Township, Ramsey County, Minnesota, was placed on the 2002 State of Minnesota's 303(d) list of impaired waters. Bald Eagle Lake was identified for impairment of aquatic recreation. Water quality does not meet state standards for nutrient concentration for deep lakes in the North Central Hardwood Forest ecoregion.

The primary recreation activities supported by the lake include boating and fishing. The lake is well known recreational water body within Ramsey County, one of the counties comprising the Twin Cities Metropolitan Area and has a public access. It has a very active Lake Association comprised of lake shore property owners who are active in the management of the lake.

Water quality in Bald Eagle Lake has been periodically monitored over the past 30 years with the most intensive monitoring occurring between 1999 and 2007 as a part of various lake management planning efforts. During this monitoring period, the average summer mean values (June 1 through September 30) for total phosphorus ranged from 69 to 123 µg/L and averaged 90 µg/L. Chlorophyll-a concentrations ranged from 16.4 to 51.8 µg/L and averaged 34.2 µg/L. Finally, Secchi depth transparencies averaged about 1.2 m with a range over the monitoring years of 1.0 to 1.7 m. Values for all three parameters exceeded the state standards for lakes in the North Central Hardwood Forest ecoregion.

1.3 IMPAIRED WATERS AND MINNESOTA WATER QUALITY STANDARDS

1.3.1 State of Minnesota Water Quality Standards and Designated Uses

Bald Eagle Lake is located in the Central Hardwood Forests ecoregion and is designated as a class 2B water. The Class 2B designation specifies aquatic life and recreation as the protected beneficial use of the water body.

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

The numeric target used to list this lake was the phosphorus standard for Class 2B waters in the Central Hardwood Forest ecoregion (40 µg/L). This TMDL presents load and wasteload allocations and estimated load reductions for the 40 µg/L target. Although the TMDL is set for the total phosphorus standard, the two other lake eutrophication standards (chlorophyll-a and Secchi depth) must also be met (Table 1-1). All three of these parameters were assessed in this TMDL to assure that the TMDL will result in compliance with state standards. Numeric standards applicable to Bald Eagle Lake for chlorophyll-a and Secchi depth are 14 µg/L and 1.4 meters, respectively, as a growing season mean. All values are growing season means.

Table 1-1. Numeric targets for deep lakes in the Central Hardwood Forest ecoregion.

Parameters	North Central Hardwood Forest (Deep Lakes)[1]
Phosphorus Concentration (µg/L)	40
Chlorophyll-a Concentration (µg/L)	14
Secchi disk transparency (meters)	>1.4

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

2.0 Watershed and Lake Characterization

2.1 LAKE AND WATERSHED DESCRIPTION

Bald Eagle Lake is a 1,071 acre lake located in the northeast portion of the Twin Cities Metropolitan Area in Ramsey County and about 10 miles north of the City of St. Paul (Figure 2-1). Public access is via a county-owned park along State Highway 61 on the east shore of the lake. The lake's maximum depth is 39 feet and about 61% of the lake is less than 15 feet deep or littoral (Table 2-1). Typically, the greater the percentage of the lake that is littoral, the greater the influences of biological processes (fish, zooplankton, and plants) on water quality. Bald Eagle Lake likely will respond to both watershed inputs as well as changes in the lake's biological system. Bald Eagle Lake is a moderately hardwater lake with somewhat high phosphorous fertility.

Bald Eagle Lake has a moderate residence time, averaging approximately 1.3 years. The watershed-to-lake area ratio is just over 10:1, which indicates that the lake will be somewhat sensitive to watershed nutrient inputs. The Bald Eagle Lake watershed and the general flow patterns of the contributing tributaries are present in Figure 2-2.

Table 2-1. Bald Eagle Lake morphometric and watershed characteristics.

Parameter	
Surface Area[1] (acres)	1,071
Average Depth (ft)	12
Maximum Depth (ft)	39
Volume (ac-ft)	13,174
Residence Time (years)	1.3
Littoral Area[1] (acres)	652
Littoral Area (%)	61%
Watershed (acres)	10,835
Watershed:Lake Area ratio	10:1

[1]Data used is from Lakemaster Contour Pro: Minnesota Edition

2.2 DRAINAGE PATTERNS

Bald Eagle Lake has a fairly complex drainage area that includes three primary subwatersheds and connections to both White Bear and Otter Lakes (Figure 2-2). The largest subwatershed is Judicial Ditch 1 (JD1) which drains the eastern part on the watershed and includes Shuneman marsh, Fish and Pine Tree Lakes, and a golf course. JD1 represents approximately 75% of the land area draining to Bald Eagle Lake.

Bald Eagle Lake is also connected by a channel to Otter Lake. To evaluate the potential for Otter Lake to discharge to Bald Eagle Lake, DNR-measured elevations in each lake were compared over the past 50 years. In all cases where lake elevations were measured simultaneously, Bald Eagle Lake elevations were higher than Otter Lake. Consequently, it was determined that Bald Eagle Lake only discharges to Otter Lake and Otter Lake is not a source of nutrients to Bald Eagle Lake.

White Bear Lake also has an overflow channel that can discharge to Bald Eagle Lake. To determine the importance of flow from White Bear Lake, an existing HydroCAD model was used to determine outflow volumes for the 2, 10, and 100 year recurrence intervals. The 100 year flow event was estimated to only discharge 70 acre-feet of water to Bald Eagle Lake. Therefore it was concluded that outflow from White Bear Lake is not an important source of water or nutrients to Bald Eagle Lake.

2.3 LAND USE

Land use data for the Bald Eagle Lake watershed are presented in Table 2-2 and Figure 2-3. Land use is primarily undeveloped and single family residential land (35% and 26% respectively); however, much of the undeveloped land is in the upper portion of the JD1 subwatershed that drains to Pine Tree Lake. There is also a fairly large agricultural area (13%) mostly in the JD1 subwatershed.

Table 2-2. Land use in the Bald Eagle Lake watershed.

Land Use*		
	Acres	**Percent**
Agricultural	1,361	13%
Industrial	23	0.2%
Institutional	50	0.5%
Major Highway	81	1%
Multi-Family Residential	66	1%
Open Water	1,778	16%
Park and Recreation	727	7%
Single Family Residential	2,811	26%
Undeveloped	3,817	35%
Commercial	71	1%
Mixed Use	13	0.1%
Airport	37	0.3%
TOTAL	10,835	100%

*Source: Metropolitan Council

2.4 RECREATIONAL USES

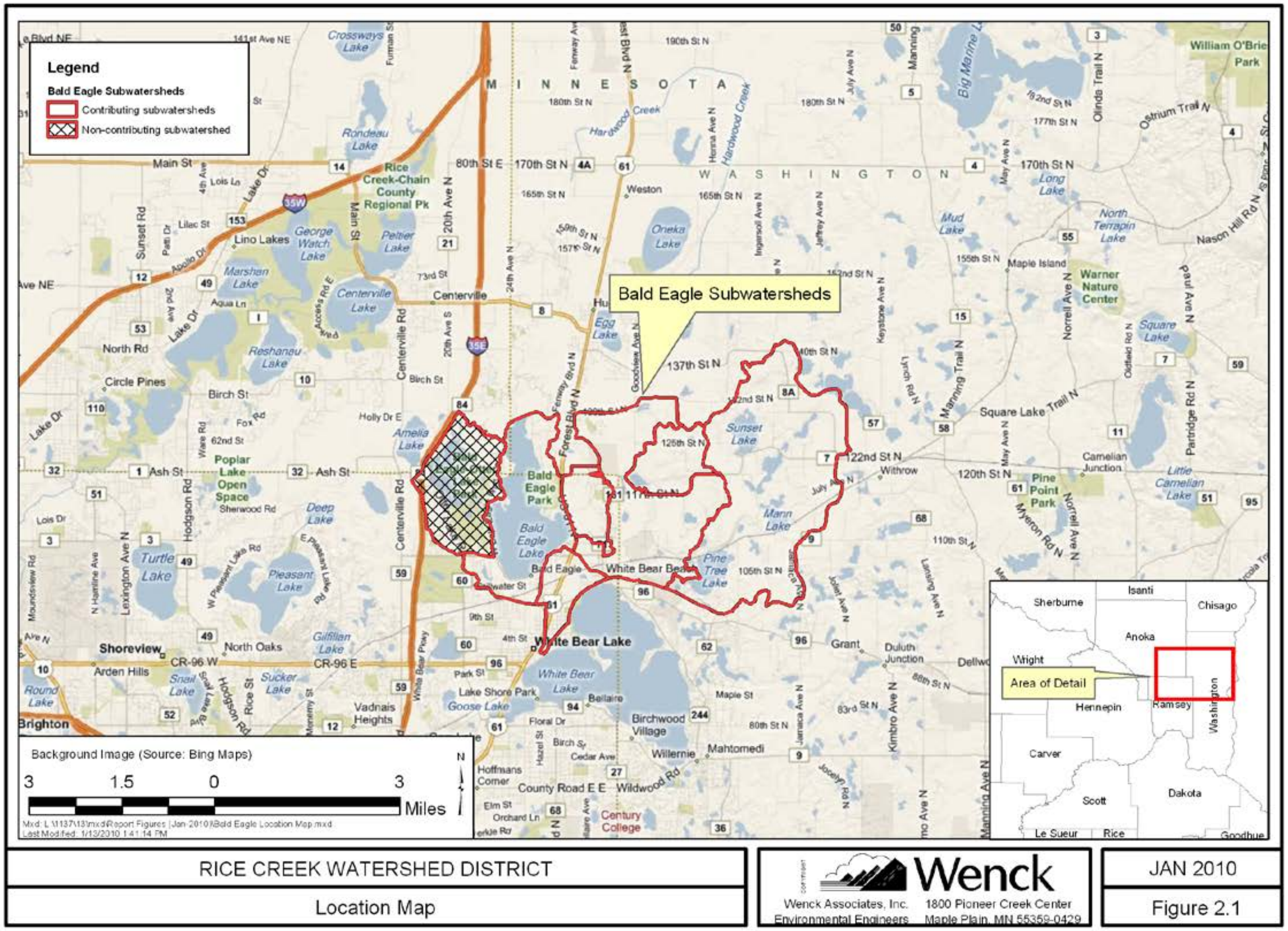
Bald Eagle Lake supports a variety of recreational uses, including open water and ice fishing, swimming, and boating. The most recent MN Department of Natural Resources (MnDNR) lake management plan available for the lake was compiled based on 1996 data and indicated a fishing use of 72 angler-hours per lake surface acre in 1994 compared to 37 angler-hours/acre in 1977. The latter figure is toward the upper end of the range for Twin Cities Metropolitan Area (TCMA) lakes. MnDNR also assessed other surface uses and compiled a comparison between 1974 and 1994 use rates (Table 2-3).

Table 2-3. Bald Eagle surface use comparison (non-angling)

Use (hours per acre)	1974 Survey	1994 Survey
Runabouts	15.3	7.6
Waterskiing	2.3	8.6
Sailboats	12.3	3.3
Canoes/rowboats	1.2	0.8
House/pontoon boats	4.3	7.1
Paddle boats	0	0.4
Other uses	0	0.6

In July and August of 2000, the Bald Eagle Area Association also conducted a boat inventory for the lake. The surveys were made on weekdays when boat usage on the lake was light and boats operating on the lake were excluded from inventory in order to avoid potential double counting. The survey showed that about 600 boats are stored at private docks, on shore, or at mooring facilities, with almost 90% of these associated with individual riparian single family residences. There is no information available on the number of boaters using the lakes on high use weekends.

DNR safety guidelines suggest 20 acres per boat suggesting that Bald Eagle Lake can sustain approximately 50 boats safely. The number of boats owned by shoreline residents, together with usage by the general public suggests that crowding could be an issue. Further, high boat traffic in shallow areas, even at low or no wake speeds can increase sediment disturbance and direct vegetation impacts through cutting (Asplund and Cook 1997). Maintaining high quality habitats such as these is essential in maintaining the appropriate fish assemblage to protect water quality. Healthy shallow lake systems often depend on piscivorous fish such as bass to keep the panfish population in balance. Because Bald Eagle Lake is relatively shallow (61% less than 15 feet in depth) and is highly used by recreational boaters, it may be susceptible to water quality degradation caused by boating impacts.



RICE CREEK WATERSHED DISTRICT

Location Map

Wenck

Wenck Associates, Inc.
Environmental Engineers

1800 Pioneer Creek Center
Maple Plain, MN 55359-0429

JAN 2010

Figure 2.1

Figure 2-1. Location map.

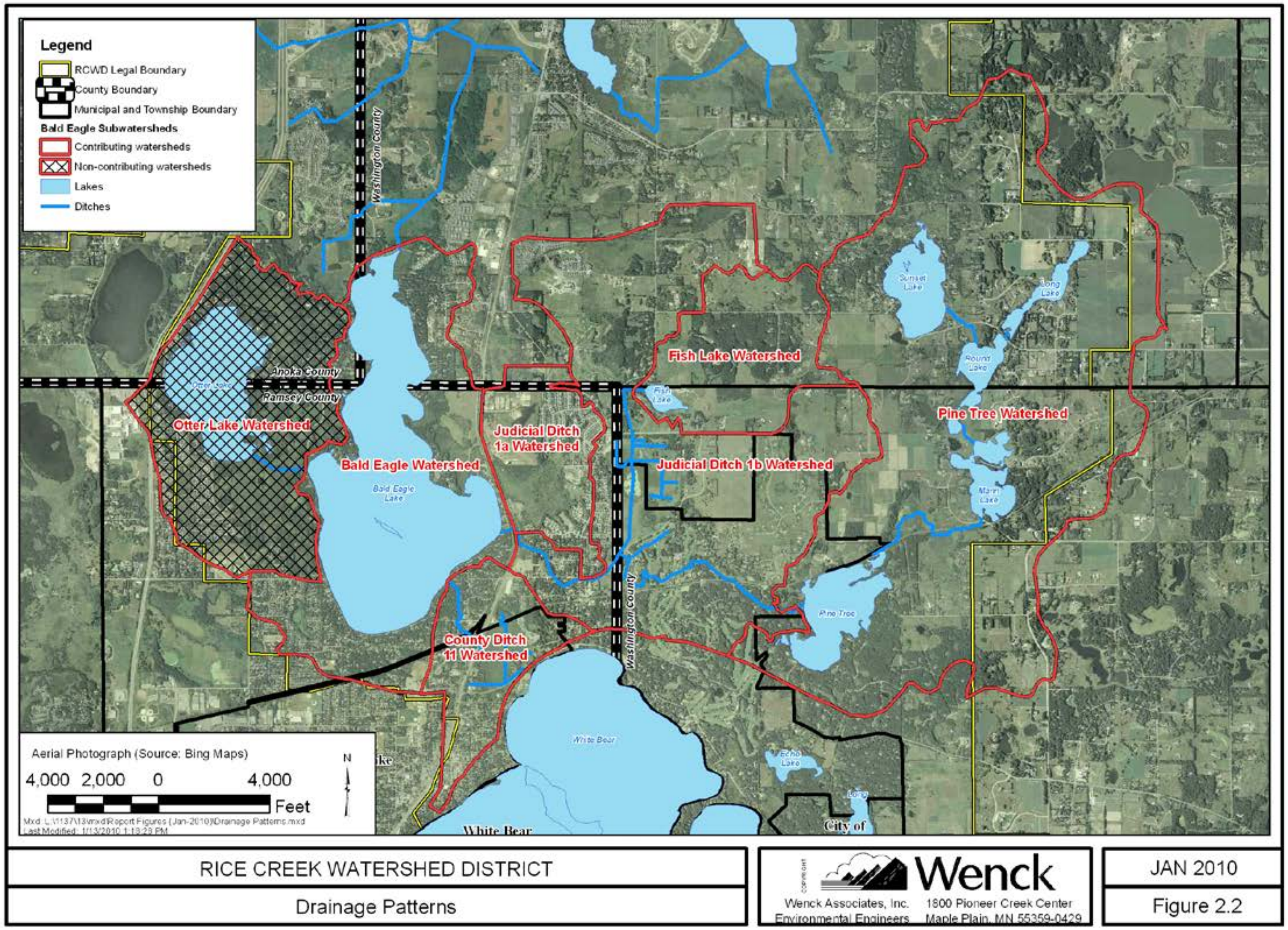


Figure 2-2. Drainage patterns.

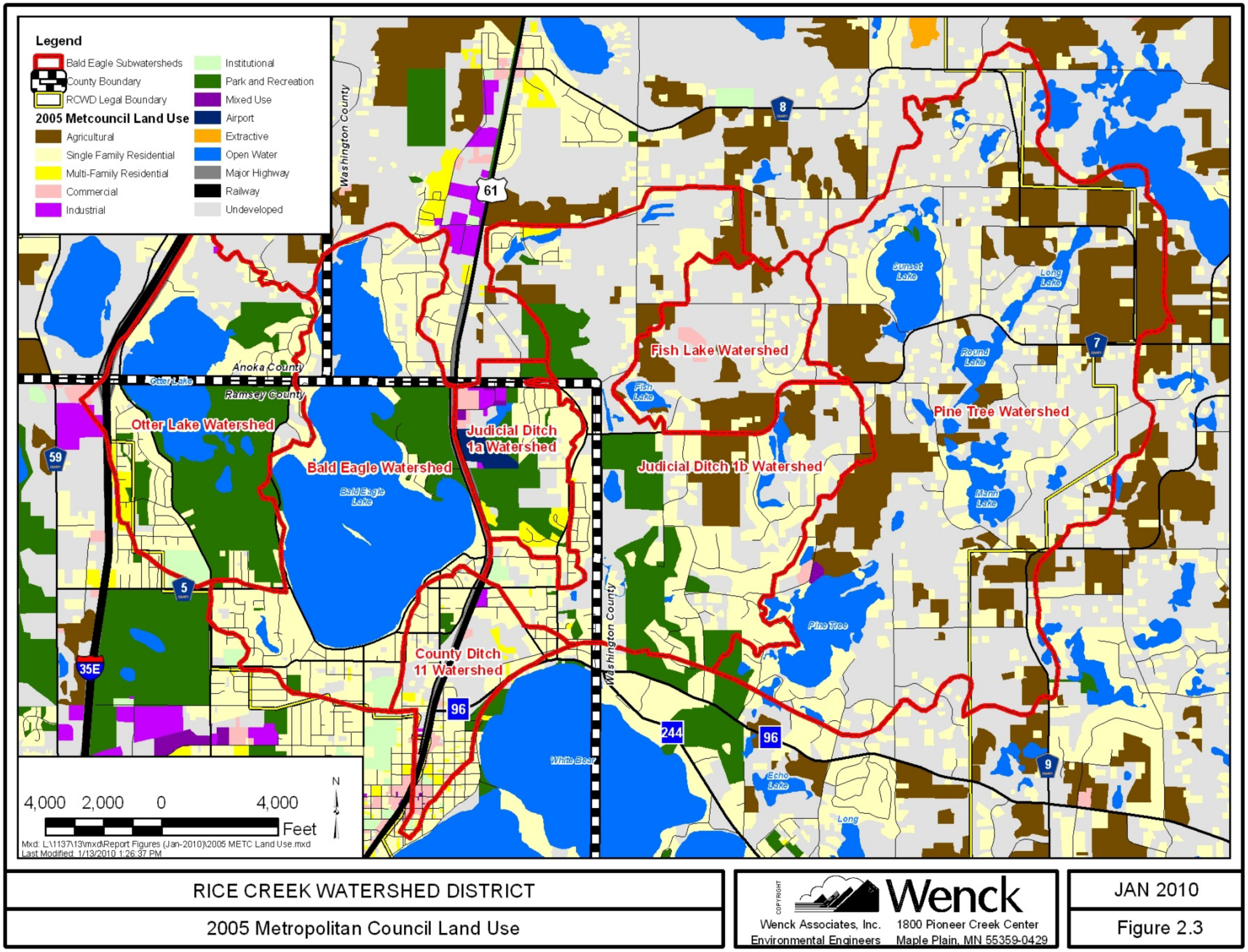


Figure 2-3. 2005 Metropolitan Council land use.

2.5 WATER QUALITY

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

2.5.1 Monitoring in Bald Eagle Lake

Water quality monitoring has been conducted at several locations on Bald Eagle Lake under a variety of efforts. The main sampling station (#5401) on Bald Eagle Lake is the deep hole near the middle of the south basin just east of the island. Samples have been taken almost yearly at this location since 1980, though there is some in-lake phosphorus data from other sites as far back as 1972. Two other sites – 5402 and 5403 – have been sampled starting in 1999. Collection efforts have been conducted by the Ramsey County, the MN Department of Natural Resources, the MN Pollution Control Agency, the Metropolitan Council, and the Rice Creek Watershed District. There were also monitoring efforts conducted on Judicial Ditch 1-one of the main watershed inputs discharging to the lake – from 1998 through 2002 and again in 2004-2006.

2.5.2 Temperature and Dissolved Oxygen

Temperature and dissolved oxygen profile data have been collected consistently over the last 30 years. Temperature profiles suggest reasonably stable stratification in areas of the lake deeper than 7 m during the summer (Appendix A). Dissolved oxygen (DO) concentration in Bald Eagle Lake also demonstrates stratification with hypoxia (DO ≤ 2 mg/L) measured as shallow as 5 meters. Temperature and dissolved oxygen conditions in Bald Eagle Lake demonstrate the potential for internal loading of phosphorus.

2.5.3 Total Phosphorus

Summer average total phosphorus concentrations at the mid-lake monitoring site (#5401) in Bald Eagle Lake exceeded the State standard of 40 µg/L in all monitoring years (Figure 2-4). The highest summer average concentration was measured in 2000 and reached over 120 µg/L. Excluding 2000, summer average total phosphorus concentrations have ranged from 48 µg/L to 101 µg/L between the early 1980s and 2007, suggesting that the lake has been consistently above the state eutrophication standard of 40 µg/L for almost 30 years.

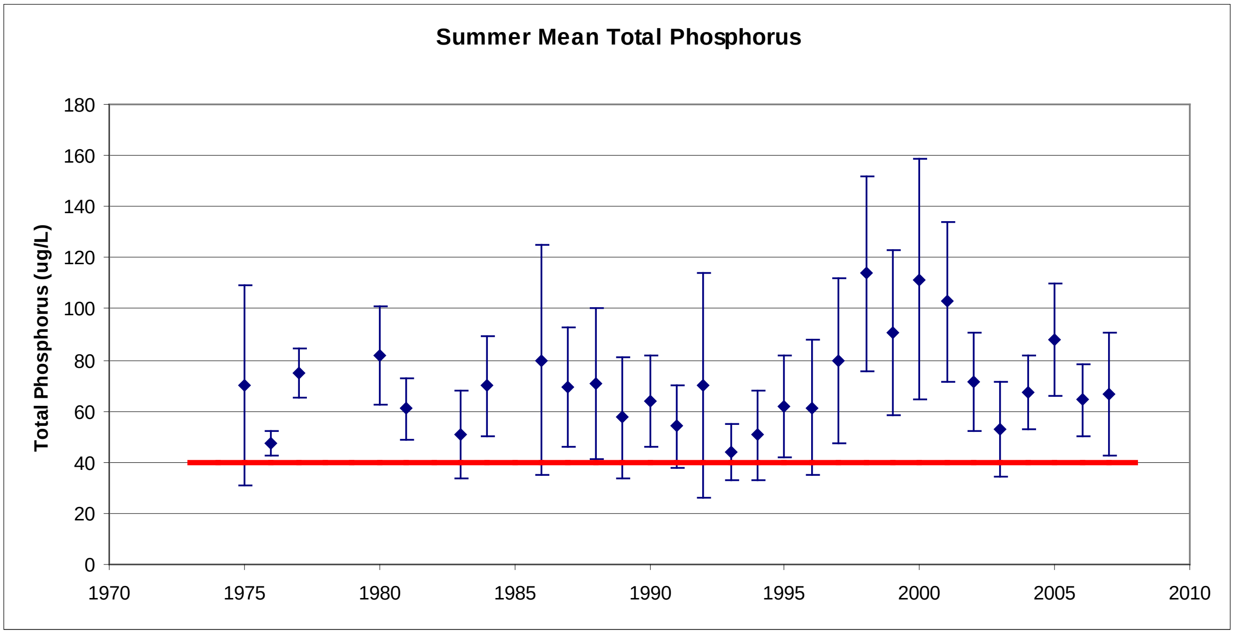


Figure 2-4. Summer (June 1 –September 30) mean total phosphorus concentrations for Bald Eagle Lake. The red line indicates the current State standard for the Northern Central Hardwood Forest ecoregion.

2.5.4 Chlorophyll-a

Between the mid-1980’s and 2007, chlorophyll-a concentrations in Bald Eagle Lake ranged from just over 16 to as high as 51.8 µg/L for years with four samples or more during the summer season (Figure 2-5). Recent chlorophyll-a concentrations range from 24 to 45 µg/L, which are still about 2-3 times the State standard. Chlorophyll-a concentrations in this range indicate a high incidence of nuisance algae blooms.

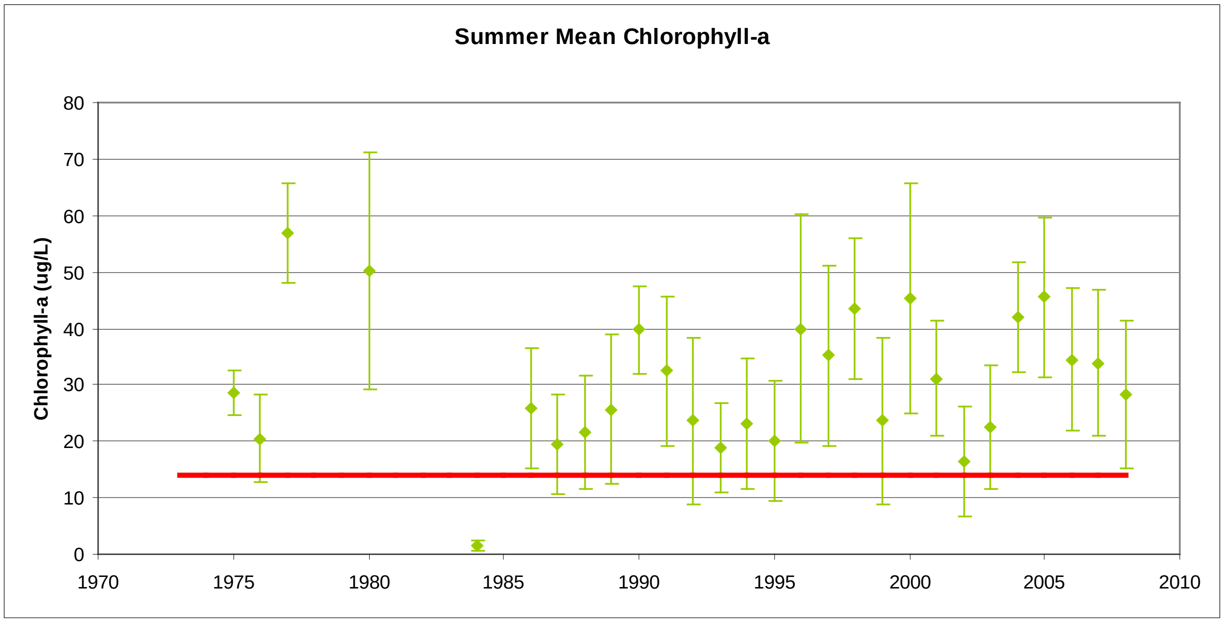


Figure 2-5. Summer (June 1 –September 30) mean chlorophyll-a concentrations for Bald Eagle Lake. The red line indicates the current State standard for the Northern Central Hardwood Forest ecoregion.

2.5.5 Secchi Depth

Water clarity (Secchi depth) followed the same trend as TP and chlorophyll-a and has not met the state standard over the past 30 years (Figure 2-6). There is no apparent trend in the Secchi depth data suggesting that the lake has demonstrated similar water quality over the past 30 years.

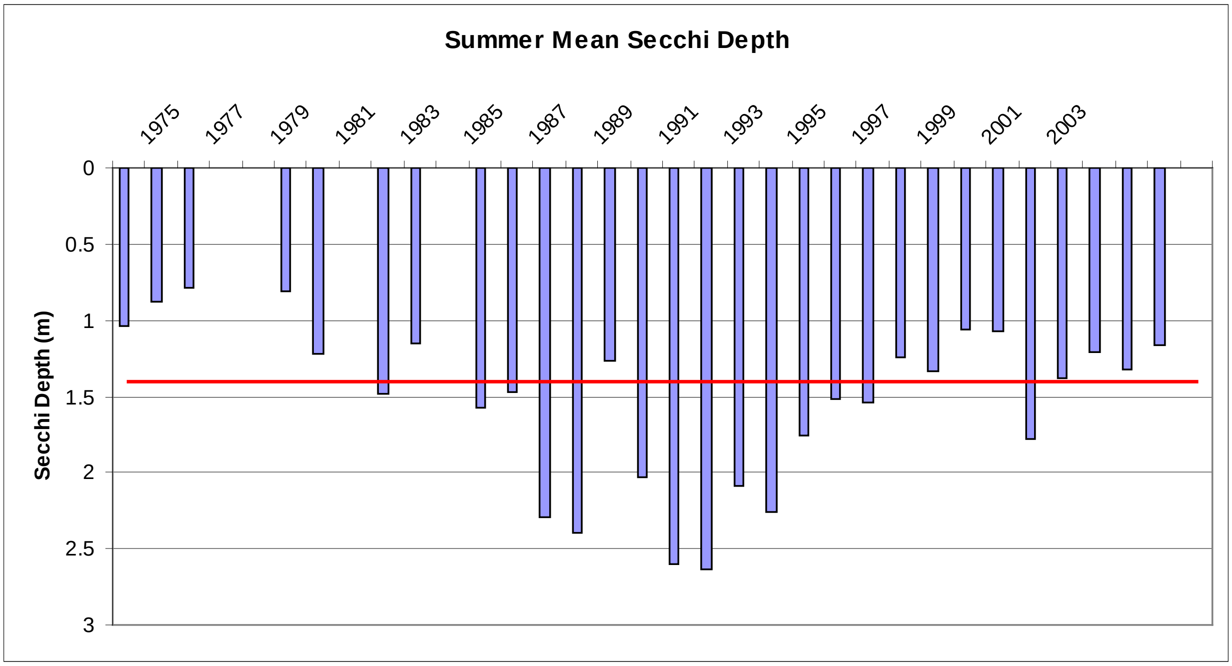


Figure 2-6. Summer (June 1 –September 30) mean Secchi depth (meters) for Bald Eagle Lake. The red line indicates the current State standard for the Northern Central Hardwood Forest ecoregion.

2.5.6 Conclusions

Overall, Bald Eagle Lake has not met current state standards since the early 1980s when data collection began. While there is some variability in the monitoring data from year to year, trends over that time show that the water quality is relatively stable in its current state. There has not been a significant decline or improvement in the water quality of Bald Eagle Lake over this time period. However, it is important to note that a rigorous trend analysis has not been conducted on the data set.

2.6 FISH POPULATIONS AND FISH HEALTH

2.6.1 Fish Populations

The fisheries lake management plan and fish survey reports for Bald Eagle Lake were provided by the DNR East Metro Area Fisheries Office. The initial DNR fish survey for Bald Eagle Lake was conducted in 1954. There have been seven additional surveys since that time, with a survey being conducted about every five years since 1982. Standard survey methods used by the DNR include gill net and trap nets. These sampling methods do have some sampling bias, including focusing on game management species (i.e., northern pike and walleye), under representing small minnow and darter species presence/abundance, and under representing certain management species such as largemouth bass. The current methods also likely under represent carp populations in the lakes. However, in our experience, when carp are present in the lakes, the sampling methods do capture some of the population. So, although carp density is likely under represented, the methods do provide a reasonable year to year comparison.

The lake management plan developed by the East Metro Fisheries Office for Bald Eagle Lake indicates the lake is primarily managed for walleye and muskellunge, with secondary management emphasis on largemouth bass, bluegills, and black crappie. There have been 17 species collected during DNR surveys:

- Black Bullhead
- Black Crappie
- Bluegill
- Bowfin
- Common Carp
- Golden shiner
- Green Sunfish
- Hybrid Sunfish
- Largemouth Bass
- Muskellunge
- Northern Pike
- Pumpkinseed
- Shortnose gar
- Walleye
- White Crappie
- Yellow Bullhead
- Yellow Perch

Fish community data was summarized by trophic groups (Figures 2-7 and 2-8). Species within a trophic group serve the same ecological process in the lake (i.e., panfish species feed on zooplankton and invertebrates; may serve as prey for predators). Analyzing all the species as a group is often a more accurate summary of the fish community then analyzing individual species trends. The following conclusions can be drawn from the fish data:

- Panfish species, including Black Crappie and Bluegill, are the most abundant group during the most recent DNR surveys.
- Between 1957 and 1982, the surveys showed rough fish (primarily black bullhead) as both most abundant and having the highest biomass in the lake.
- Top predators now comprise the largest percentage of the total biomass catch during each of the DNR surveys, with largemouth bass, walleye, northern pike, and muskellunge all well represented. However, their abundance is relatively low suggesting a few large individuals. The low abundance may not be able to adequately control the panfish population.
- The large panfish population may be able to produce significant grazing pressure on the zooplankton community in the lake. However, since no zooplankton data have been collected on the lake, it is difficult to determine the impact on the zooplankton community.
- Rough fish abundance and biomass is low and is comprised mainly of yellow and black bullheads and some carp. It should be noted that common carp abundance may not be accurately assessed using DNR surveys. However, the current methods allow reasonable year-to-year comparisons. A carp specific survey would ultimately assess the actual carp abundance in the lake.

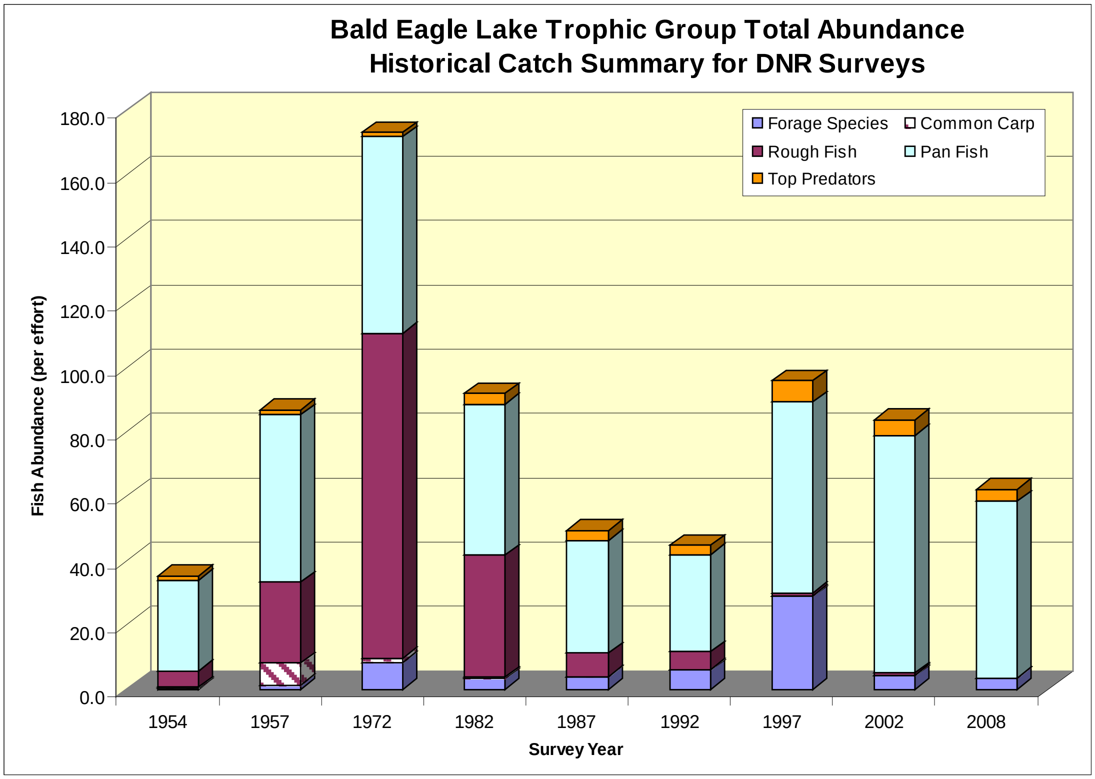


Figure 2-7. Historical fish survey results for trophic group abundance in Bald Eagle Lake.

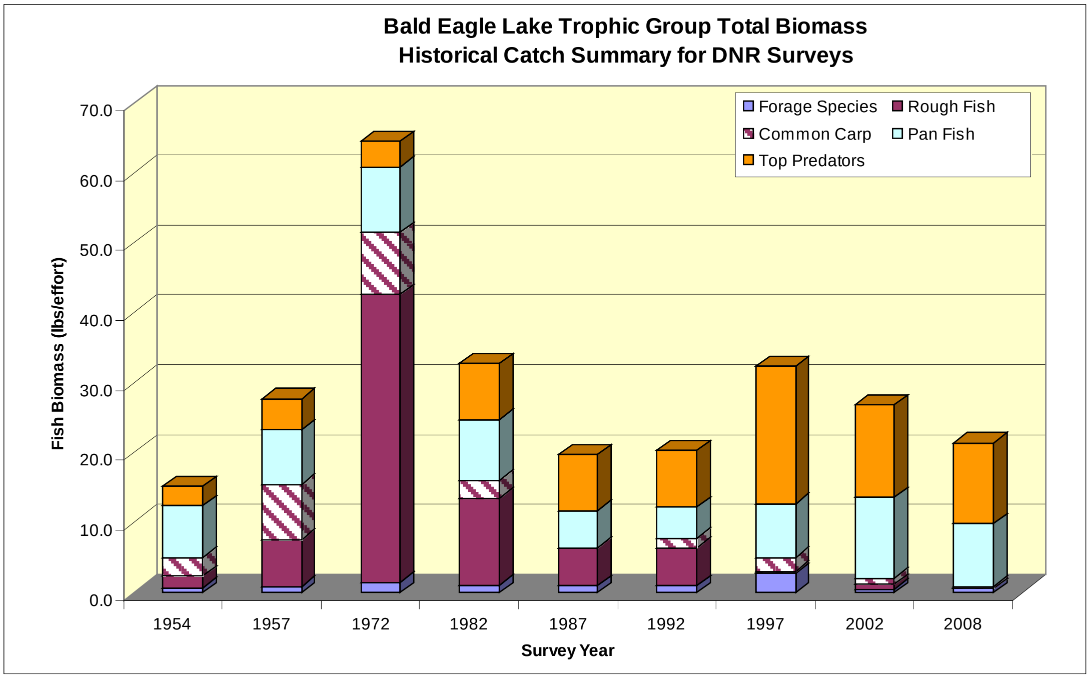


Figure 2-8. Historical fish survey results for trophic group biomass in Bald Eagle Lake.

2.6.2 Carp

Common carp have both direct and indirect effects on aquatic environments. Carp uproot aquatic macrophytes during feeding and spawning and re-suspend bottom sediments and nutrients. These activities can lead to increased nutrients in the water column ultimately resulting in increased nuisance algal blooms. There may be carp and other rough fish present in Bald Eagle Lake, but the size and composition is currently unclear. Standard DNR methods are not particularly effective at capturing carp. However, when carp populations are quite large, the DNR methods often do catch some. At least some common carp have been captured in seven out of the eight DNR surveys conducted since the 1950s. Further analysis may be needed to better characterize the carp population in Bald Eagle Lake. However, based on year to year comparisons from DNR surveys, current carp populations appear to be relatively small and likely are having little impact on lake water quality. Due to sampling bias in current DNR survey methods, only a targeted assessment of the carp density would verify this assumption.

2.7 AQUATIC PLANTS

2.7.1 Introduction

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

2.7.2 Littoral Zone

The littoral zone is defined as that portion of the lake that is less than 15 feet in depth and is where the majority of the aquatic plants are found. The littoral zone of the lake also provides the essential spawning habitat for most warm water fishes (e.g. bass, walleye, and panfish). Bald Eagle Lake is approximately 61% littoral and should support a healthy rooted aquatic plant community. The key is fostering a diverse population of rooted aquatic plants that is dominated by native (non-invasive) species.

2.7.3 Aquatic Plants in Bald Eagle Lake

Plant surveys have been conducted on Bald Eagle Lake dating back to 1989 by the DNR, the Bald Eagle Area Association, and the Rice Creek Watershed District. A thorough summary of vegetation in Bald Eagle Lake can be found in Appendix B. Additional vegetation information is available with many of the fish surveys dating back to the 1950's. However, this section focuses on the most recent data in Bald Eagle Lake which reflects current conditions.

Bald Eagle Lake possesses a moderately diverse aquatic plant community with 21 different species observed across the various surveys, with a mix of emergent, floating leaf and submerged plant species. The 2003 DNR lake management plan underlines the importance of protecting the remaining shoreline marshes for habitat purposes. In addition, emergent species like water lily, spatterdock, bulrush and even cattails are very important to the ecology of the lake by providing shoreline protection, maintaining water quality, and providing critical spawning, rearing, and feeding habitat for a number of the predatory gamefish species in the lake.

There have been 17 different submerged species observed across the recent aquatic plant surveys (Figure 2-9). Two of these species are invasive. Eurasian water milfoil was first noted in the lake during a 1989 survey by DNR, while curly leaf pond weed was recorded in the lake in 1992. Several species showed increases in coverage between the 1997 and 2002 surveys, with several milfoil species – two native, one invasive – as well as water celery, coontail, and Illinois pondweed (the latter all natives species) showing the greatest increase in abundance. The two most common native submergent plant species observed across all plant surveys were water celery, coontail, water stargrass, and Chara. Other important native submerged plant species such as large leaf pondweed, sago pondweed, and clasping leaf pondweed have been observed at varying densities over the years.

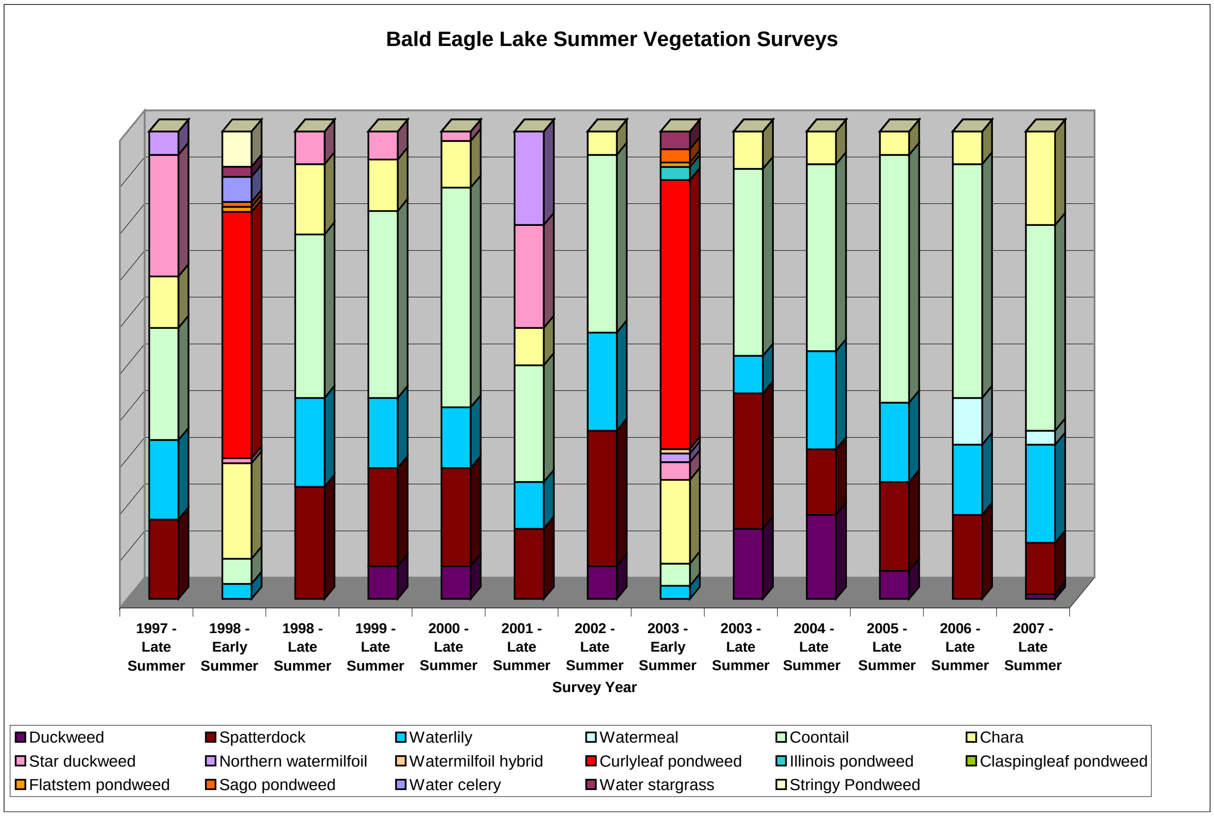


Figure 2-9. Historical vegetation survey data for Bald Eagle Lake.

2.7.4 Curly-leaf Pondweed

Curly-leaf pondweed is an invasive, like Eurasian watermilfoil, that can easily take over a lake's aquatic macrophyte community. Curly-leaf pondweed presents a unique problem in that it is believed to significantly affect the in-lake availability of phosphorus, contributing to the eutrophication problem. Curly-leaf pondweed begins growing in late-fall, continues growing under the ice, and dies back relatively early in summer, releasing nutrients into the water column as it decomposes, possibly contributing to algal blooms. Curly-leaf pondweed can also out-compete more desirable native plant species.

Curly-leaf pondweed was first observed during a 1992 DNR survey and was found to be common in the lake during that time even though the survey was conducted in August, well after the typical seasonal peak in biomass for the plant had passed. Recent surveys (1998 and 2003) demonstrate that curly-leaf pondweed covered approximately 30% of the lake area representing 300 acres (Appendix B) and was at nuisance levels in 180 acres of lake area. The Bald Eagle Area Association began an aggressive curly-leaf pondweed management program in 2000 that included mechanical harvesting from 2000 – 2004 and herbicide applications in 2005 – 2007. These efforts were meant to reduce the biomass of curly-leaf pondweed before summer die-back and decomposition, thus limiting phosphorus contributions. A summary of the program can be found in Appendix B. Data from the monitoring suggest that the herbicide treatments are effectively reducing the abundance of curly-leaf pondweed in Bald Eagle Lake within each treatment year. Long-term control remains elusive.

2.8 SHORELINE HABITAT AND CONDITIONS

The shoreline areas are defined as the areas adjacent to the lake's edge, with hydrophytic vegetation and water up to 1.5 feet deep or a water table within 1.5 feet from the surface. Natural shorelines provide water quality treatment, wildlife habitat, and increased biodiversity of plants and aquatic organisms. Natural shoreline areas also provide important habitat to fisheries including spawning areas and refugia as well as aesthetic values. In addition to the ecological benefits, natural shorelines can stabilize sediments, and protect lake edges from wave-induced erosion. Natural shoreland exists around Bald Eagle Lake; however, no quantitative data have been collected to date. Much of the shoreline area has been impacted by development. Naturalization of the shorelines could have a positive effect on Bald Eagle Lake and water quality.

3.0 Nutrient Sources and Lake Response

3.1 INTRODUCTION

Understanding the sources of nutrients to a lake is a key component in developing an excess nutrient TMDL for lakes. To that end, a phosphorus budget that sets forth the current phosphorus load contributions from each potential source was developed using the modeling and collected data described below. Additionally, lake response models can be developed to understand how different lake variables respond to changes in nutrient loads.

3.2 MODELING APPROACH

Several models were used to develop the nutrient budget necessary to establish load and wasteload allocations.

3.2.1 P8 Model

The first step in understanding nutrient loading to Bald Eagle Lake is to develop an estimate of watershed water and nutrient loads. To estimate watershed loading a P8 model was developed for the JD1 subwatershed where the 2001 monitoring season represents a reasonable calibration data set. Runoff from the P8 model is then combined with water quality data where available to estimate nutrient loading. Where no water quality data are available, the P8 model was used with default (NURP50) inputs to estimate watershed loading. Ultimately, three P8 models were constructed including one each for JD1, CD11, and Direct subwatersheds.

P8 (Program for Predicting Polluting Particle Passage thru Pits, Puddles, & Ponds; Walker 1990) is a public domain (**http://wwwalker.net/p8/**), industry standard model developed to assess pollutant loading in urban watersheds. P8 was developed using National Urban Runoff Program (NURP) data and provides loading estimates based on data collected as a part of the NURP program. The model estimates the build-up and wash-off of particulates from impervious surfaces in the watershed. The NURP 50th percentile particle file was used to estimate watershed pollutant loading.

To estimate a long term nutrient load record for JD1, a P8 model was hydrologically calibrated to the 2001 intensive monitoring data set (Figure 3-1). Details of the model construction and calibration can be found in Appendix C. The model was constructed by first identifying major water quality treatment devices (ponds, swales, etc.) in the watershed and delineating drainage areas to those devices. Watershed characteristics were developed using Minnesota Land Cover Classification System (MLCCS) data for the Bald Eagle Lake watershed. These data were used to estimate the impervious and pervious fractions of the watershed. The pervious areas were assigned a composite curve number based on land cover and soil type.

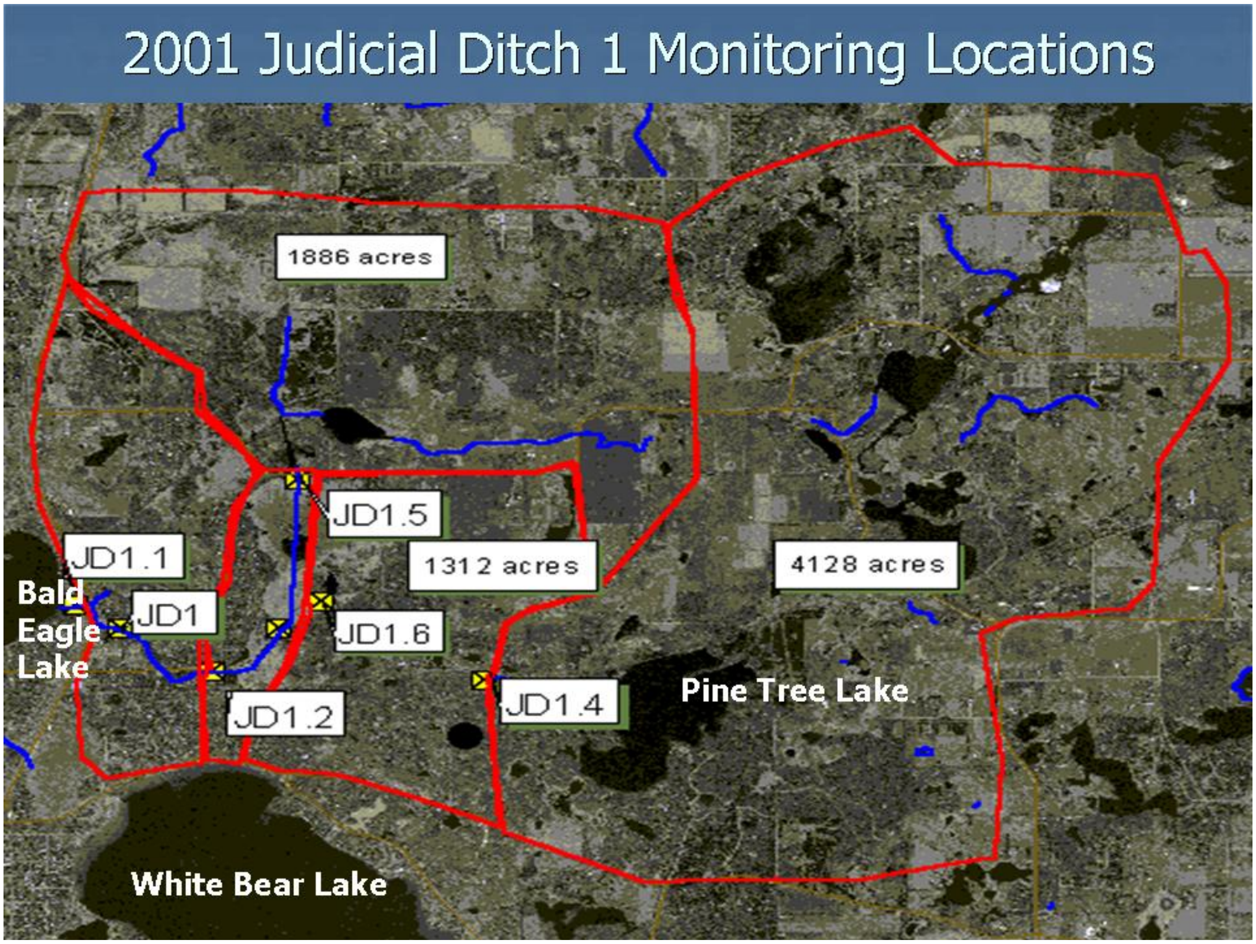


Figure 3-1. 2001 Judicial Ditch monitoring sites.

Once the model was constructed, the default parameter model was compared to measured annual runoff in 2001 where the most complete data set was available. The model under-predicted runoff with default values, so the precipitation factor was increased (from 1 to 1.35) until annual volumes matched between the model and measured values at each of the monitoring sites. It is important to note that the precipitation factor applies to the whole JD1 subwatershed and is not adjusted individually by subwatershed within the JD1 drainage. Because no monitoring data were available for either the CD11 or Direct subwatersheds, no adjustment was made to the precipitation factor. Rather, the model was used with default values.

No water quality calibration was applied to the models. For JD1, the confounding effects of Shuneman marsh prevented water quality calibration of the P8 model. So, nutrient loads from JD1 were estimated by multiplying the average total phosphorus concentration and annual flow volume estimated from the P8 model. For CD11 and the Direct subwatersheds, P8 with default values (NURP50) was used to estimate nutrient loading on an annual basis.

3.2.2 Internal Loading

The next step in developing an understanding of nutrient loading to Bald Eagle Lake is to estimate internal nutrient loads. Internal phosphorus loading from lake sediments has been demonstrated to be an important aspect of the phosphorus budgets of lakes. However, measuring or estimating internal loads can be difficult, especially in shallow lakes that may mix many times throughout the year.

To estimate internal loading, an anoxic factor (Nürnberg 2004), which estimates the period where anoxic conditions exist over the sediments, is estimated from the dissolved oxygen profile data. The anoxic factor is expressed in days but is normalized over the area of the lake. The anoxic factor is then used along with a sediment release rate to estimate the total phosphorus load from the sediments. Phosphorus release rates were estimated by collecting cores from Bald Eagle Lake and incubating them in the lab under anoxic conditions (ACOE-ERD 2008; Appendix D).

3.2.3 Atmospheric Load

The atmospheric load refers to the load applied directly to the surface of the lake through atmospheric deposition. Atmospheric inputs of phosphorus from wet and dry deposition are estimated using rates set forth in the MPCA report "Detailed Assessment of Phosphorus Sources to Minnesota Watersheds" (Barr Engineering, 2004), and are based on annual precipitation. The values used for dry (< 25 inches), average, and wet precipitation years (>38 inches) for atmospheric deposition are 24.9, 26.8, and 29.0 kg/km^2-year, respectively. These values are equivalent to 0.22, 0.24, and 0.26 pounds/acre-year for dry, average, and wet years in English units, respectively.

3.2.4 BATHTUB Model (Lake Response)

Once the nutrient budget for a lake has been developed, the response of the lake to those nutrient loads must be established. The focus of the lake response modeling is on total phosphorus, chlorophyll-a and Secchi depth.

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

3.3 ESTIMATION OF SOURCE LOADS

3.3.1 Atmospheric Load

The atmospheric load (pounds/year) for Bald Eagle Lake was calculated by multiplying the lake area (acres) by the atmospheric deposition rate (pounds/acre-year). For example, in an average precipitation year the atmospheric load to Bald Eagle Lake would be 0.239 pounds/acre-year times the lake surface area (1,071 acres), which is 255.9 pounds/year. The watershed is small enough that it is unlikely that there are significant geographic differences in rainfall intensity and amounts across the watershed.

3.3.2 Watershed Nutrient Loading

There are three primary drainage areas for Bald Eagle Lake including Judicial Ditch 1 (JD1), County Ditch 11 (CD11), and the direct Bald Eagle Lake watershed. Long term water quality data are available for JD1 including a more detailed monitoring data set collected in 2001 that includes estimates of flow. These data were used to estimate loading in 2001. Next, a P8 model was calibrated to flow from the 2001 data set. The calibrated model was then used to estimate annual flow volumes for the past eleven years. The P8 estimated flow volumes were multiplied by the annual average total phosphorus concentrations to estimate the annual load from the JD1 subwatershed. The P8 model was also applied to the unmonitored portions of the Bald Eagle Lake watershed (CD11 and Direct Watershed) to estimate nutrient loads from these portions of the watershed. Following is a detailed description of the results of the estimation of watershed nutrient loads.

3.3.2.1 Judicial Ditch 1 Nutrient Loading

Annual discharge estimated by the P8 model was used with monitoring data collected at the outlet of JD1 to estimate annual nutrient loads to Bald Eagle Lake from the JD1 subwatershed (Table 3-1). The outflow monitoring site was moved a short distance in 2003 (from JD1 to JD1.1) so estimates after 2003 are based on average total phosphorus data from the new site (Figure 3-1). Loads were calculated by multiplying the average TP concentration at the outflow by the total volume to get annual load in pounds per year.

Table 3-1. Average total phosphorus concentration and loading at the outlet of Judicial Ditch 1 (JD1 and JD1.1) and entering Shuneman marsh (JD 1.5).

Year	P8 Estimated Volume (acre-feet)	Average Total Phosphorus (µg/L)			Estimated Load (pounds/year)
		JD1	JD1.1	JD1.5	
1998	3,229	205	--	--	2,620
1999	4,328	138	--	--	1,515
2000	3,476	181	--	--	1,125
2001	4,533	157	--	--	1,450
2002	4,330	146	--	222	1,719
2003	2,705	129	113	--	831
2004	2,841	--	114	--	880
2005	3,219	--	170	--	2,360
2006	2,235	--	169	--	1,027
2007	3,181	--	129	--	1,116
2008	2,086	--	157	--	890

3.3.2.2 Shuneman Marsh

One of the primary features of the JD1 drainage is a wetland complex at the bottom of the watershed known as Shuneman marsh. The marsh has historically been thought to add phosphorus to runoff from the watershed. Consequently, several studies were conducted by the RCWD focused on identifying the source of phosphorus from the JD1 watershed and to develop potential solutions for reducing the phosphorus load (Appendix E). However these studies found that over 50% of the phosphorus loading from the JD1 subwatershed was from above the marsh in the Fish lake area of the watershed.

For the purposes of this TMDL, nutrient loading from JD1 is calculated as a single load and is not allocated from the various sources within the watershed. However, the previously collected data provide a wealth of information regarding sources of nutrients within the JD1 subwatershed. These data are used to develop more specific actions in the Bald Eagle Lake Implementation Plan.

3.3.2.3 Upstream Lakes

There are two upstream lakes in the JD1 subwatershed including Fish Lake and Pine Tree Lake. Although loading from these two lakes are included in the JD1 loading estimates, it is important to understand their role in nutrient loading from the JD1 subwatershed to Bald Eagle Lake which allows for a better source assessment and the ability to allocate loads to these water bodies. Long term water quality data sets were not available for the lakes, so the average of the few monitored years of data were applied to each year to estimate loading. It is important to note that these estimates only represent a subset of the JD1 nutrient load to evaluate the importance of upstream lakes on the JD1 watershed loading.

Drainage coming from Pine Tree Lake and its subwatershed comprises approximately 40% of the water balance for the JD1 subwatershed (Table 3-2). Consequently, outflow from Pine Tree Lake has a significant influence on nutrient loading from the JD1 subwatershed. Pine Tree Lake has relatively good water quality (31 µg/L total phosphorus as a growing season mean) resulting in a positive influence on loading from the JD1 subwatershed. Pine Tree Lake and its subwatershed warrant protection from degradation to reduce or maintain loadings to Bald Eagle Lake.

Fish Lake represents a much smaller portion of the water balance for JD1 representing 10% of the water balance for the JD1 subwatershed (Table 3-2). Although only two good years of data are available for Fish Lake, water quality degradation is likely occurring in the lake. Fish Lake had a summer average TP concentration of 171 µg/L in 2002 and 42 µg/L in 2007. Both of these summer averages exceed the current state eutrophication standards for deep lakes. Consequently, part of the required load reductions for JD1 will need to be addressed through restoration of Fish Lake.

Table 3-2. Estimates of loading from upstream lakes in the JD1 subwatershed.

Year	P8 Estimated Volume (acre-feet)		Average Total Phosphorus (µg/L)		Estimated Load (pounds/year)	
	Fish Lake	Pine Tree Lake	Fish Lake[1]	Pine Tree Lake	Fish Lake	Pine Tree Lake
1998	382	1,458	42	31	44	123
1999	458	1,650	42	31	52	139
2000	433	1,609	42	31	49	135
2001	555	2,000	42	31	63	168
2002	479	1,753	42	31	55	148
2003	283	1,062	42	31	32	89
2004	311	1,194	42	31	35	101
2005	347	1,295	42	31	40	109
2006	216	865	42	31	25	73
2007	346	1,291	42	31	39	109
2008	190	758	42	31	22	64

[1] Note that 42 µg/L was used because the most recent data from Fish Lake was a summer average of 42 µg/L total phosphorus. However, limited data from previous years suggests that water quality may be poorer than represented here.

3.3.2.4 Direct Drainage and Judicial Ditch 11

Monitoring data was not available for JD11 and the Direct Bald Eagle Lake subwatershed, so the P8 model was used to estimate nutrient loads from these subwatersheds (Table 3-3). P8 was applied using the default values for estimating runoff (see Section 3.2.1) and the 50th percentile particle data set from the National Urban Runoff Program studies.

Table 3-3. Watershed volume, concentration, and phosphorus load estimated for County Ditch 11 and the Bald Eagle Lake direct drainage.

Year	P8 Estimated Volume (acre-feet)		Average Total Phosphorus (µg/L)		Estimated Load (pounds/year)	
	CD11	Bald Eagle Lake Direct	CD11	Bald Eagle Lake Direct	CD11	Bald Eagle Lake Direct
1998	465	889	319	294	402	711
1999	494	923	300	281	402	705
2000	470	905	288	267	368	656
2001	510	959	291	272	404	709
2002	595	1,116	279	263	451	798
2003	370	697	298	278	300	527
2004	450	850	300	281	368	648
2005	513	955	296	277	412	720
2006	393	732	332	311	355	619
2007	449	864	283	262	345	615
2008	319	598	367	340	318	553

CD11 and the direct watershed drainage represent approximately 30% of the total water budget for Bald Eagle Lake (10% and 20% respectively). These watersheds are relatively developed and have limited water quality treatment prior to discharging to Bald Eagle Lake.

3.3.3 Septic systems

Septic systems in the Bald Eagle Lake watershed have received attention historically as a possible source of nutrients to the lake. However, a 2003 lake management plan for Bald Eagle Lake concluded that from a water quality perspective, septic systems do not appear to be a significant nutrient source to the lake (Blue Water Science 2003). The conclusion is based on some rudimentary modeling of the known septic systems around Bald Eagle Lake. If all the systems were failing, phosphorus loading from septic systems would represent less that 10% of the phosphorus budget. However, it is unlikely that all of the systems are failing. The most likely scenario where less than 15% of the systems are failing resulted in a phosphorus load less than 1% of the overall load to Bald Eagle Lake.

For this TMDL, septic systems were assumed to be a minimal contributor of phosphorus and were assigned an allowable load of 0 pounds per year. Current loading is assumed to be a part of the total watershed load and no effort was made to separate the septic system load from the watershed load.

3.3.4 Internal Phosphorus Loading

Bald Eagle Lake demonstrates significant anoxia over the bottom sediments throughout the summer with peak anoxic areas typically occurring in mid to late summer (Figure 3-2). Anoxic conditions in lakes are often expressed as the number of days anoxia occurs over the area equal to the entire lake; this term is referred to as the anoxic factor. The anoxic factor ranged from 11 to 29 days for Bald Eagle Lake.

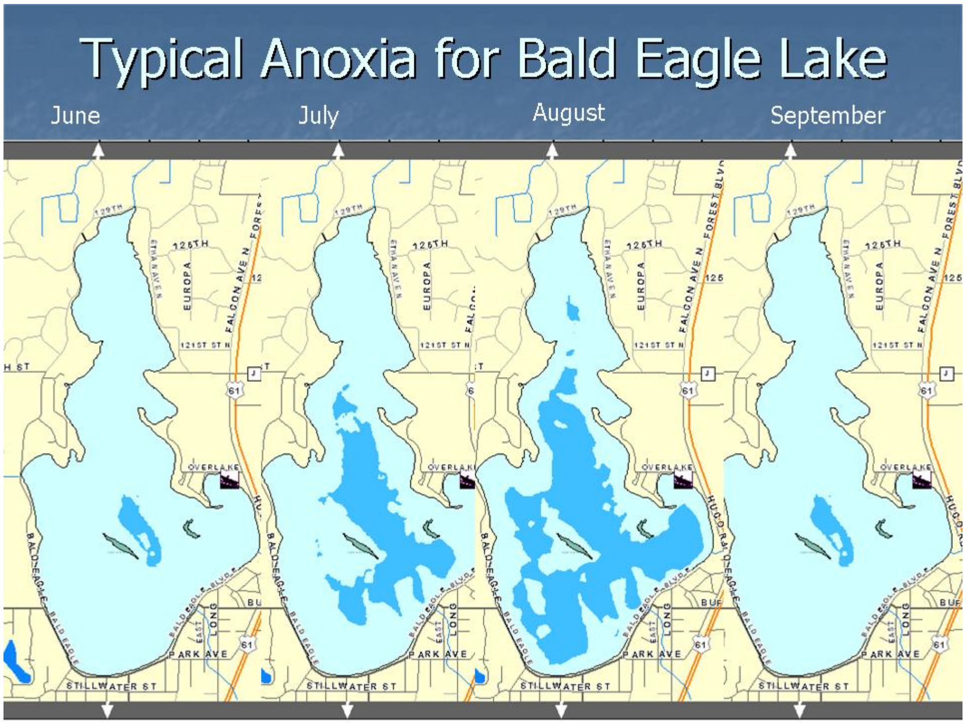


Figure 3-2. Depiction of change in anoxia over the summer period for Bald Eagle Lake.
The figure is for demonstration purposes only – annual changes in anoxia were analyzed using field data, and is represented as the "Anoxic Factor" in Table 3-4.

Once anoxia is quantified, the next step is to identify the rate at which sediments release phosphorus under anoxic conditions. The measured rate of phosphorus release from anoxic sediments in Bald Eagle Lake is 10.8 mg/m^2/day (ACOE-ERDC 2007). This rate can then be used to estimate the gross internal loading based on the anoxic factor for the lake (Nürnburg 2004). The estimated gross loads for Bald Eagle Lake are presented in Table 3-4. Gross internal loading for Bald Eagle Lake ranges from 1,157 to 2,945 pounds per year. The estimates are then inserted in the lake response model to estimate the role of internal loading on current lake water quality.

Table 3-4. Estimated gross internal loading from anoxic phosphorous release in Bald Eagle Lake.

Year	Anoxic Factor (days)	Release Rate (mg/m^2/day)	Gross Load (kg)	Gross Load (lbs)
1998	28.6	10.8	1,339	2,945
1999	13.8	10.8	648	1,426
2000	11.9	10.8	558	1,227
2001	21.0	10.8	984	2,165
2002	22.5	10.8	1,055	2,320
2003	19.2	10.8	898	1,975
2004	13.4	10.8	626	1,377
2005	19.2	10.8	898	1,975
2006	27.5	10.8	1,289	2,835
2007	15.7	10.8	735	1,618
2008	11.2	10.8	526	1,157

[1] Based on a shallow lake equation developed to estimate anoxic factors in polymictic lakes.

Another line of evidence evaluated to assess the importance of internal nutrient loading to Bald Eagle Lake is nutrient concentration in the hypolimnion, the cool bottom water that is too dense to mix to the surface. Bald Eagle Lake demonstrates significant build-up of phosphorus in the hypolimnion with bottom total phosphorus concentrations typically reaching as high as 200 µg/L and even approaching 1 mg/L (Figure 3-3).

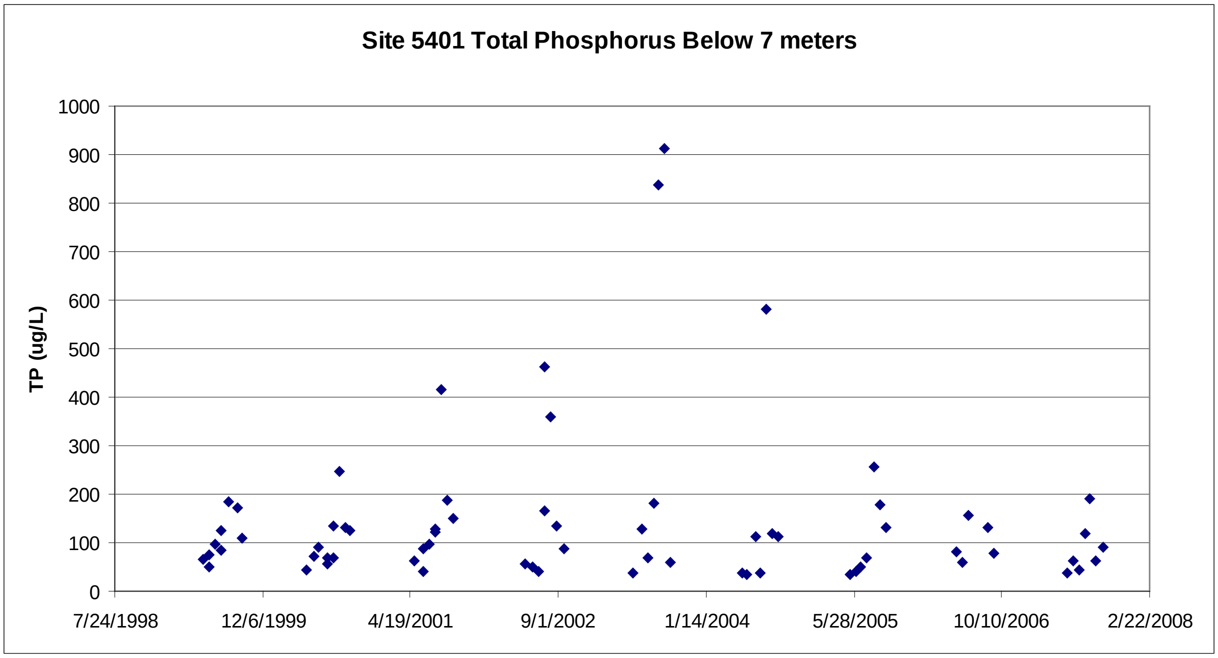


Figure 3-3. Average hypolimnetic total phosphorus concentrations for Bald Eagle Lake.

Sediment cores were collected to analyze sediment chemistry in Bald Eagle Lake. The redox-sensitive loosely-bound and iron-bound P fractions accounted for a considerable proportion of the sediment total P for Bald Eagle (ACOE-ERDC 2008). Redox-sensitive P versus anoxic P release rates for sediments in the present study were comparable to published regression relationships developed by Nürnberg (1988), suggesting that anoxia, reduction of iron, and desorption of P were drivers in internal P loading.

3.4 SOURCE SUMMARY AND CURRENT PHOSPHORUS BUDGET

Phosphorus and water budgets were developed for 1998 through 2008 to summarize the sources of nutrients to Bald Eagle Lake (Appendix F). The 2002 through 2008 average is presented here because the lake response model performed well in these years (Figure 3-4; see Section 3.5). The 1998 through 2001 period appears to be missing a nutrient source. The change in model performance changes at the same time active curly-leaf pondweed control was implemented in Bald Eagle Lake. Since loading attributed to curly-leaf pondweed decomposition is not explicitly accounted for in the BATHTUB model, it is likely that curly-leaf pondweed was an active phosphorus source that was eliminated when control measures were undertaken.

Nutrient loading to Bald Eagle Lake is fairly evenly split between internal and external loading. The primary external load is from JD1 because this represents a fairly large proportion of the watershed. However, it is important to note that reductions in nutrient loadings from JD1 may be more difficult to achieve because inflow concentrations are fairly low, typically between 100 and 200 µg/L. Conversely, both CD11 and the direct drainage are estimated to have higher concentrations, typically between 300 and 400 µg/L. The focus on nutrient reductions from the watershed needs to focus on all of the subwatersheds.

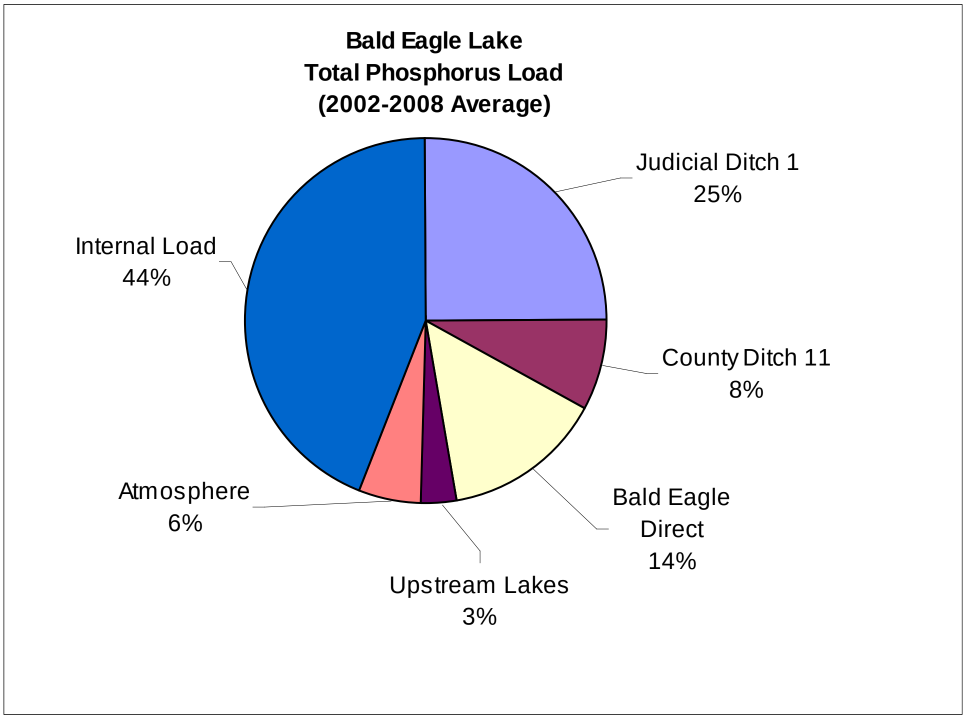


Figure 3-4. Average (2002 through 2008) total phosphorus budget for Bald Eagle Lake.

3.5 LINKING WATER QUALITY TARGETS AND SOURCES

The final step in understanding lake response to nutrient loads is to link the previously described nutrient budgets to lake water quality. This step is accomplished through the use of lake response models previously described in Section 3.2.5. The lake response model was applied using default model values and the water and nutrient budgets previously described in this section. Physical lake attributes such as volume, average depth, and surface area were derived from GIS and LakeMaster contour maps. All model inputs are detailed in Appendix G.

3.6 FIT OF THE MODEL

Eleven years were modeled for Bald Eagle Lake to evaluate the performance of the lake response model (Figure 3-5). The model performed reasonably well from the 2002 through 2008 time period (typically within 15% of measured values) but under predicted in-lake phosphorus concentrations for the 1998 through 2001 period. There are a few possible explanations for the sudden change in model performance. The most likely explanation is that the 1998 through 2001 nutrient budgets were affected by the presence of curly-leaf pondweed. Curly-leaf pondweed control in Bald Eagle Lake started in 2002, and curly-leaf pondweed has been effectively managed since. Curly-leaf pondweed, which senesces in mid-summer, was unaccounted for as a modeled phosphorus source during the 1998 through 2001 time period. The model accounts for annual variability in precipitation, runoff and loading so it is unlikely that these differences can account for the change in model performance. Carp could be a possible explanation for the difference, however, DNR trap net data suggests that the carp and rough fish populations were likely not large enough to have this kind of impact. There is no conclusive evidence to explain the difference in the model periods, however, the changes in curly-leaf pondweed management seems to be the most plausible explanation.

Since there is an unexplained phosphorus source during the 1998 through 2001 time period, the 2002 through 2008 time period was used to develop the TMDL.

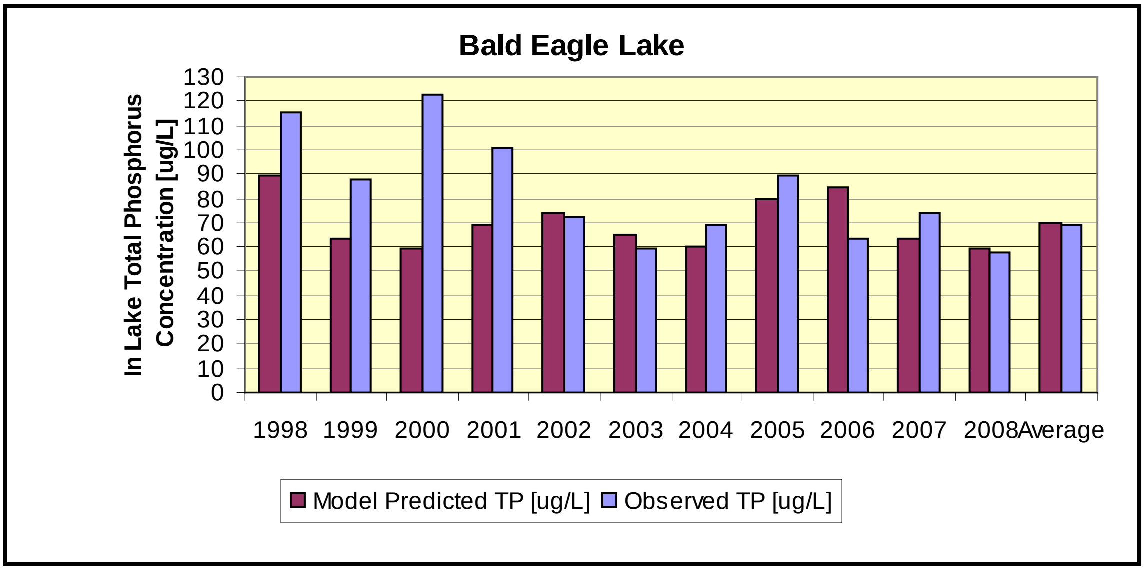


Figure 3-5. Model predicted and observed total phosphorus concentrations in Bald Eagle Lake. To set the TMDL, the average of 2002 through 2008 was used.

The chlorophyll-a response model performed reasonably well, predicting chlorophyll-a concentrations typically within 20% of the measured values (Figure 3-6).

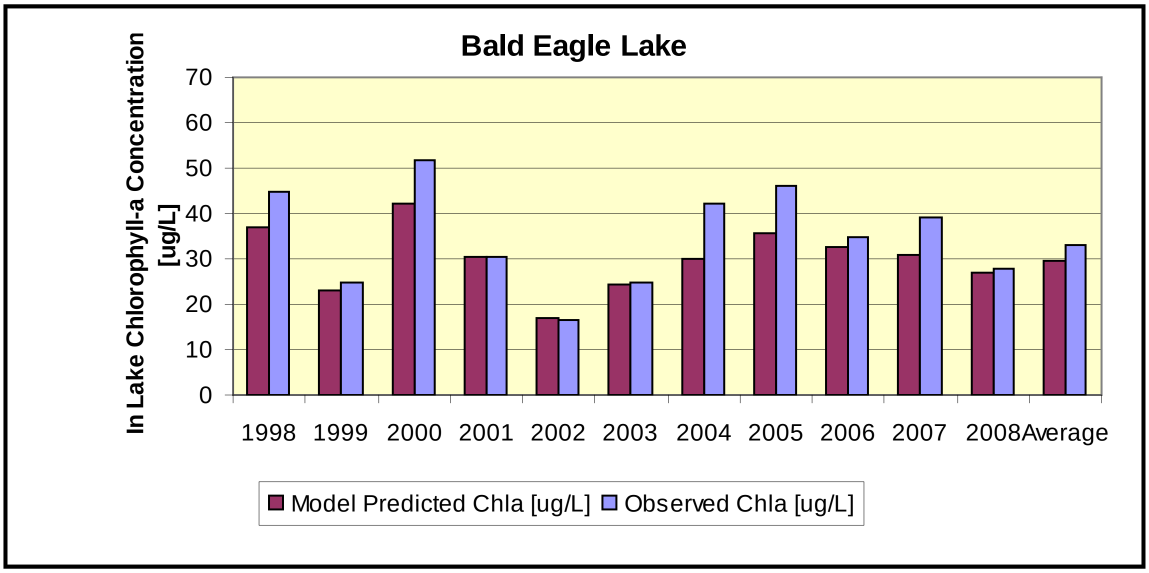


Figure 3-6. Model predicted and observed chlorophyll-a concentrations in Bald Eagle Lake.

The Secchi disk transparency response model also performed reasonably well, predicting values typically within 20% of the measured values with nine of the eleven years within 10% of the predicted values (Figure 3-7).

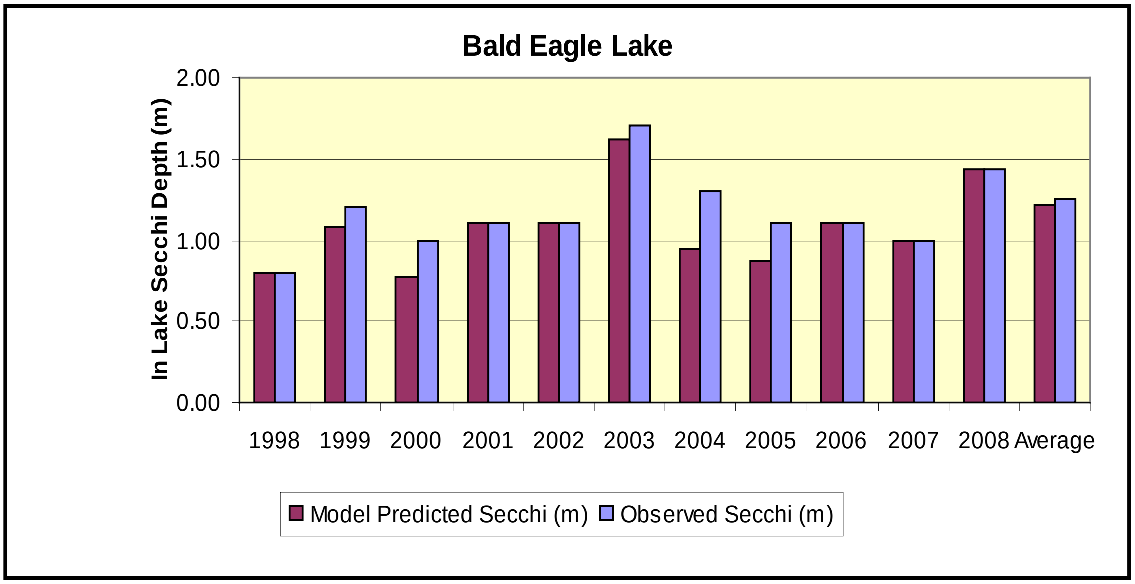


Figure 3-7. Model predicted and observed Secchi disk transparency in Bald Eagle Lake.

Each of the previous three figures also includes an average response for Bald Eagle Lake. The average is for the 2002 through 2008 time period and is simply the average of the nutrient and water budgets over that period of time. This average period and associated lake response was used to develop the TMDL allocations described in the next section.

4.0 TMDL Allocation

4.1 TOTAL MAXIMUM DAILY LOAD CALCULATIONS

The numerical TMDL for Bald Eagle Lake was calculated as the sum of the Wasteload Allocation, Load Allocation and the Margin of Safety (MOS) expressed as phosphorus mass per unit time. Nutrient loads in this TMDL are set for phosphorus, since this is typically the limiting nutrient for nuisance aquatic algae. However, both the chlorophyll-a and Secchi response were predicted to determine if nutrient reductions would result in meeting all three state standards. This TMDL is written to solve the TMDL equation for a numeric target of 40 μg/L of total phosphorus as a summer growing season average.

4.1.1 Total Loading Capacity

The first step in developing an excess nutrient TMDL for lakes is to determine the total nutrient loading capacity for the lake. To determine the total loading capacity, the current nutrient budget and the lake response modeling (average of 2002-2008) presented in Section 3 were used as the starting point. The nutrient inputs were then systematically reduced until the model predicted that Bald Eagle Lake met the current total phosphorus standard of 40 μg/L as a growing season mean. The reductions were applied first to the internal load and then the watershed sources. Once the total phosphorus goal is met, both the chlorophyll-a and Secchi response models are reviewed to ensure they are predicted to meet the state standards as well. Further details of how this was applied are included in the following sections.

Some portions of the MS4 communities are not covered under NPDES permits, specifically areas not served by stormwater conveyances owned by the MS4. Consequently, the permitted and nonpermitted areas are split between the wasteload and load allocation categories. Also, the allowable phosphorus load export on a per acre basis is set equally between the land uses falling in the wasteload and load categories. To account for future growth in the watershed, land use projections for 2020 are used as shown in Figure 4-1 (data source: Metropolitan Council). Only upland, developed and developable land areas were used to assign land areas between the load and wasteload allocations. Furthermore, only land areas below Fish and Pine Tree Lake were used because the upstream lakes are explicitly accounted for in the TMDL table. Those 2020 land use areas designated as agriculture, open space, parks and recreation, mixed use, and rural residential were assigned to the load allocation. All other 2020 land use areas were assigned to the wasteload allocation. The total developed and developable land area was 3,517 acres with 1,956 and 1,561 acres falling within the wasteload and load categories, respectively.

It may be necessary to transfer load in the future. This can occur in the following situations:

1. New development occurs within a regulated MS4. Newly developed areas that are not already included in the WLA must be given additional WLA to accommodate the growth. This will involve transferring LA to the WLA.

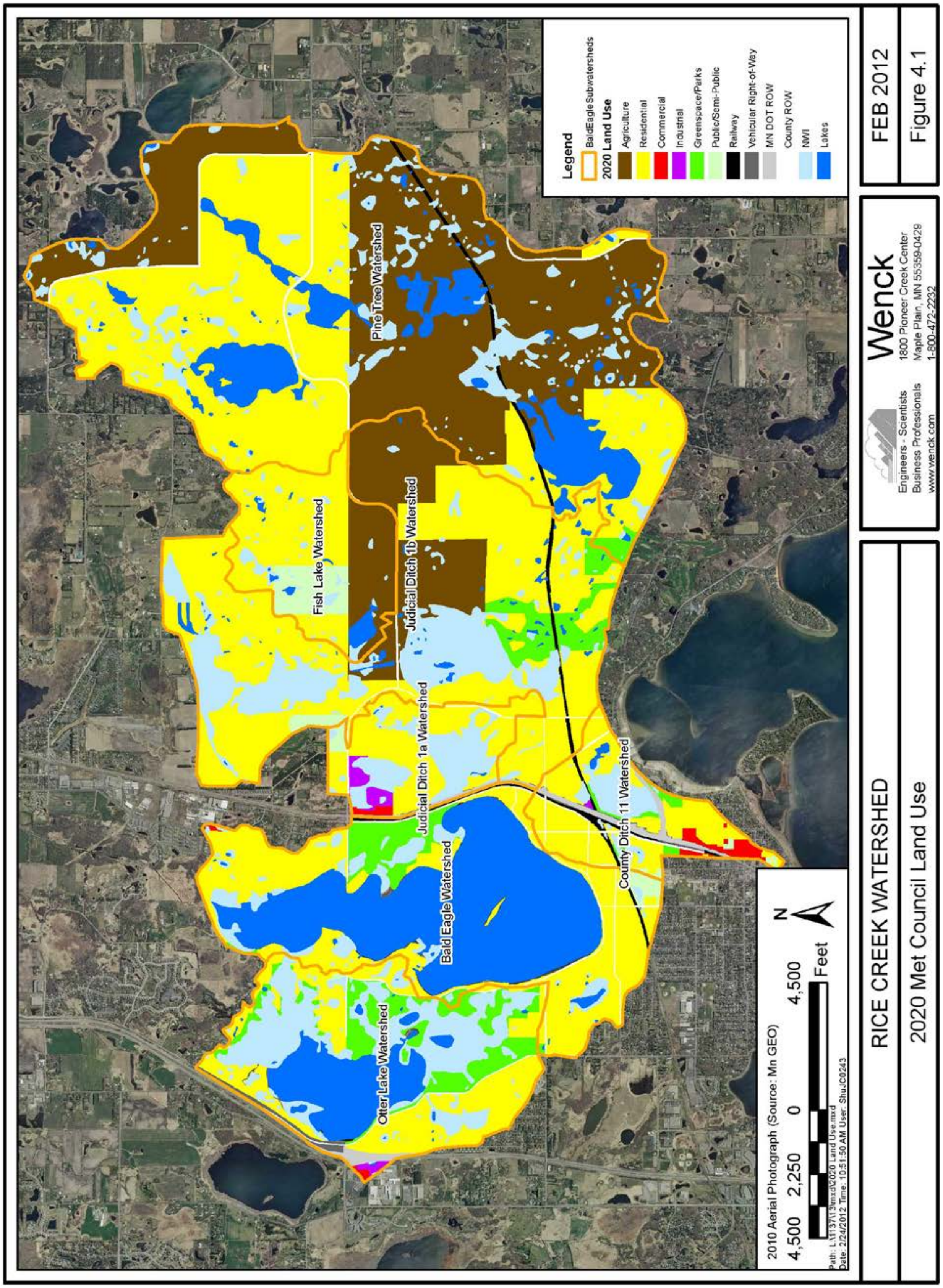


Figure 4-1. 2020 Met Council land use.

2. One regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more non-regulated MS4s become regulated. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of an urban area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an Urban Area at the time the TMDL was completed, but are now inside a newly expanded Urban Area. This will require either a WLA to WLA transfer or a LA to WLA transfer.
5. A new MS4 or other stormwater-related point source is identified. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting allocations in the TMDL. In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer.

4.1.2 Load Allocations

The Load Allocation includes all nonpermitted sources including stormwater runoff not covered by a state or federal permit, atmospheric deposition and internal loading.

No changes were expected for atmospheric deposition because this source is impossible to control. Both the upstream lakes were held at current conditions assuming Fish Lake will be restored to meet state eutrophication standards and Pine Tree Lake will be protected under nondegradation.

One of the first steps in determining the allowable phosphorus loads to Bald Eagle Lake is setting the appropriate internal load release rate. There are two methods for determining the appropriate allowable internal load including looking at similar reference lakes and determining the achievable release rates based on available technology. Measured release rates in Bald Eagle Lake (anoxic release of 10.1 $mg/m^2/day$) were compared to expected release rates for mesotrophic lakes (Figure 4-2; Nurnberg 1997). Mesotrophic lakes demonstrate internal phosphorus release rates ranging from 0 to 12 $mg/m^2/day$ with a median release rate around 4 $mg/m^2/day$. Although the median is 4 $mg/m^2/day$, there is a broad range of internal loads in mesotrophic lakes, which makes selecting an appropriate number difficult. Furthermore, 61% of Bald Eagle Lake is littoral and can be expected to release little or no phosphorus when maintained in a healthy state. Anoxic release rates in nearby Oneka Lake, a shallow submerged aquatic vegetation dominated lake, were below detection.

The internal load was also assessed using the potential effectiveness of internal load control technologies such as hypolimnetic aeration, hypolimnetic withdrawal, and alum treatment. These control methods have been demonstrated to show an 80 to 90% reduction in internal loading when applied to lakes similar to Baled Eagle Lake. This would result in an expected internal release rate between 1 and 2 $mg/m^2/day$.

An internal release rate of 1 $mg/m^2/day$ was determined to be reasonable for Bald Eagle Lake based on the release rates demonstrated in nearby lakes and the expected results from internal load controls. It is also important to note that the selected Canfield-Bachmann lake response model implicitly accounts for some internal loading because the response is predicted from external loads from a lake database that includes lakes with internal loading. Therefore, the assigned internal load in these models is included above and beyond the implicitly included internal load. Therefore, the lake can likely demonstrate an internal load greater than what is explicitly identified in the TMDL and still meet state water quality standards.

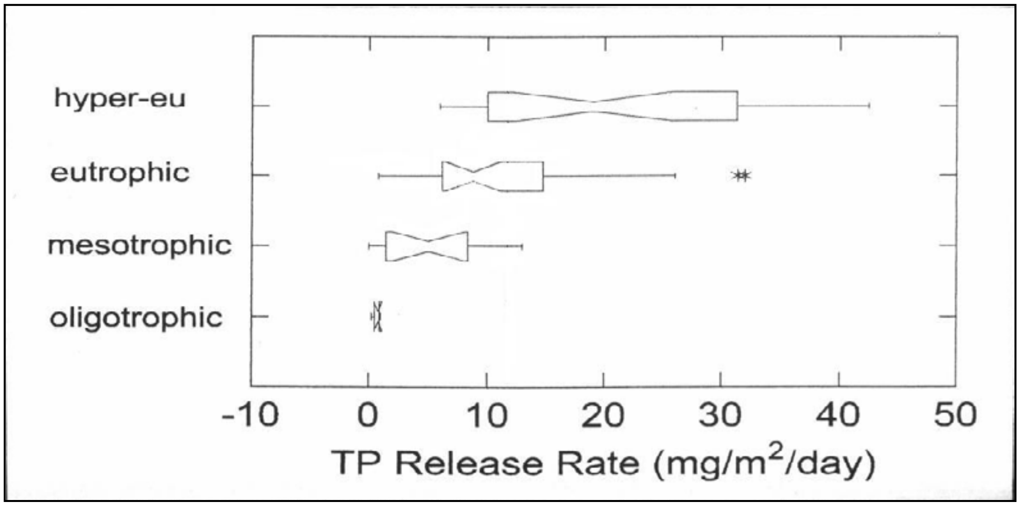


Figure 4-2. Sediment phosphorus release rates by eutrophic condition. (Nürnberg 1997).

4.1.3 Wasteload Allocations

The Wasteload Allocation includes permitted discharges such as industrial point source and regulated stormwater discharges. Stormwater discharges are regulated under NPDES, and allocations of nutrient reductions are considered wasteloads that must be divided among permit holders. Wasteload allocations were combined in this TMDL into a Categorical Wasteload allocation. Using categorical wasteload allocations was justified for several reasons. First, there is considerable uncertainty regarding current loading based on municipal boundaries, as monitoring data based on municipal boundaries are not available. Additionally, the Rice Creek Watershed District plans to act as the aggregator regarding implementation. The categorical approach will allow the Watershed District to focus on watershed-based water quality improvement projects that span municipal boundaries. The approach will also allow the Watershed District to utilize its funding sources and grant programs for water quality improvement projects. With the exception of the Minnesota Department of Transportation, MS4 permit representatives attending technical stakeholder meetings (see Section 5.2) were unanimous in support of the categorical approach. Based on their request, Mn/DOT will be provided with an individual Wasteload Allocation. The individual wasteload allocation was calculated by determining the percent of total watershed area maintained as right of way by Mn/DOT (65 acres), then applying that percentage to the watershed load.

Although industrial stormwater is included in the Categorical Wasteload Allocation, there are currently no industrial permits in the watershed. There are also no wastewater treatment plants and no NPDES-permitted CAFOs in the watershed. Following are the MS4 permit holders in the Bald Eagle Lake watershed:

Lino Lakes – MS400100
White Bear Lake– MS400060
White Bear Township– MS400163
Hugo– MS400094
Grant– MS400091
Dellwood– MS400084
Washington County- MS400160
Ramsey County – MS400191
Mn/DOT Metro District – MS400170
Industrial Stormwater–Various
Construction Stormwater - Various

To determine the allowable watershed phosphorus load, the lake response model was updated with the selected allowable internal load as determined in the previous section. Next, current estimated watershed loading in the lake response models was reduced until the models predicted an in-lake phosphorus concentration of 40 µg/L. This method resulted in a required 38% reduction of watershed nutrient loads to Bald Eagle Lake. To put this target in perspective, the average inflow concentration from the Bald Eagle Lake watershed would need to be 177 µg/L total phosphorus. Ecoregion reference streams has an interquartile range (25th to 75th) of 70 to 170 µg/L total phosphorus, suggesting that the target load is an aggressive goal for a watershed impacted by agriculture and urban development.

4.1.4 Margin of Safety

This TMDL used a conservative modeling approach, which provides an implicit margin of safety. The lake response model for total phosphorus used for this TMDL uses the rate of lake sedimentation, or the loss of phosphorus from the water column as a result of settling, to predict total phosphorus concentration. Sedimentation can occur as algae die and settle, as organic material settles, or as algae are grazed by zooplankton. Sedimentation rates in lakes defined as shallow (80 percent or more littoral area) or with extensive littoral areas such as Bald Eagle Lake (61 percent littoral) can be higher than rates for lakes with more limited littoral areas. Shallow lakes and many near-shallow also differ from deeper lakes in that they tend to exist in one of two stable states: turbid water and clear water.

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

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

In addition to the conservative modeling described above it is worth noting the following points regarding the high degree of confidence in the analysis and modeling done:

1. Modeling was performed for seven years without any adjustment to model coefficients. Because the model performed well without any adjustments over several years, there is a high level of confidence in the model.
2. An extensive database is available and was utilized in the development of this TMDL reducing the uncertainty in the estimates of the various components of the phosphorus budget.

4.1.5 Reserve Capacity and Future Development

Future loading capacity was accounted for by using the 2020 land use to divide the loads between Load and Wasteload Allocations (See Section 4.1.1). Future discharges are included in the WLA. Also, the Rice Creek Watershed District, under Minnesota Watershed Law, maintains a set of rules meant to govern land development and re-development. These rules require developers and municipalities to provide water quality treatment for any new impervious surface, and in some cases, for altercations to existing impervious surface. Currently, the RCWD requires the 2.1 inches of rainfall over new impervious surface to be infiltrated or ponded. This is an aggressive volume control (and by proxy, water quality control) requirement. Additionally, erosion control measures must be taken during construction phase of development and re-development. The RCWD maintains the legal authority to issue stop work orders, and employs two inspectors and a permit coordinator to enforce rules. Because of these aggressive rules, development in the watershed will improve water quality loads from the developed land beyond the requirements of this TMDL. For this reason, the RCWD expects watershed phosphorus loads to diminish as development and re-development occurs.

4.1.6 Summary of TMDL Allocations

Table 4-1 summarizes the TMDL allocations for Bald Eagle Lake. A margin of safety is implicit in the TMDL equation and therefore not presented in the tables. An overall 58% nutrient reduction is required for Bald Eagle Lake to meet state standards.

Table 4-1. TMDL total phosphorus daily loads partitioned among the major sources for Bald Eagle Lake assuming the lake standard of 40 µg/L.

Allocation	Source	Existing TP Load [1]		TP Allocations (WLA & LA)		Load Reduction
		(lbs/year)	(lbs/day)[2]	(lbs/year)	(lbs/day)[2]	(lbs/year)
Wasteload	Stormwater	1,194	3.3	741	2.0	453 (38%)
Load	Watershed Runoff	938	2.6	582	1.6	356 (38%)
	Upstream Lakes	135	0.4	133	0.4	2 (<1%)
	Atmosphere	254	0.7	254	0.7	0
	Internal Load	1,991	5.5	180	0.5	1,811 (91%)
	MOS	**--**	**--**	**Implicit**	**Implicit**	**--**
TOTAL LOAD		**4,512**	**12.4**	**1,890**	**5.2**	**2,622 (58%)**

[1] Existing load is the average for the years 2002-2008.

[2] Annual loads converted to daily by dividing by 365.25 days per year accounting for leap years

Table 4-2 summarizes the Wasteload Allocations for Bald Eagle Lake. Per their request, Mn/DOT was assigned an individual Wasteload Allocation. The categorical allocation includes Construction and Industrial Stormwater permits.

Table 4-2. Wasteload Allocations for Bald Eagle Lake

Permit Type	Permit Name	Permit Number	Existing WLA TP Load (lbs/year)	WLA (lbs/year)	Percent Reduction
MS4 Stormwater	Lino Lakes	MS400100	1,158	719	38
MS4 Stormwater	White Bear Lake	MS400060			
MS4 Stormwater	White Bear Twp.	MS400163			
MS4 Stormwater	Hugo	MS400094			
MS4 Stormwater	Grant	MS400091			
MS4 Stormwater	Dellwood	MS400084			
MS4 Stormwater	Washington Co.	MS400160			
MS4 Stormwater	Ramsey Co.	MS400191			
Industrial Stormwater	No current permitted sources	n/a			
Construction Stormwater	Various	Various			
MS4 Stormwater	Mn/DOT	MS400170	36	22	38

4.2 LAKE RESPONSE VARIABLES

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

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

4.2.1 Total Phosphorus

Modeled total phosphorus concentrations expected at various phosphorus loads are presented in Figure 4-3. The lake response model predicts that Bald Eagle Lake would meet the state standard of 40 µg/L total phosphorus as a growing season mean at the TMDL designated load (1,890 pounds/year).

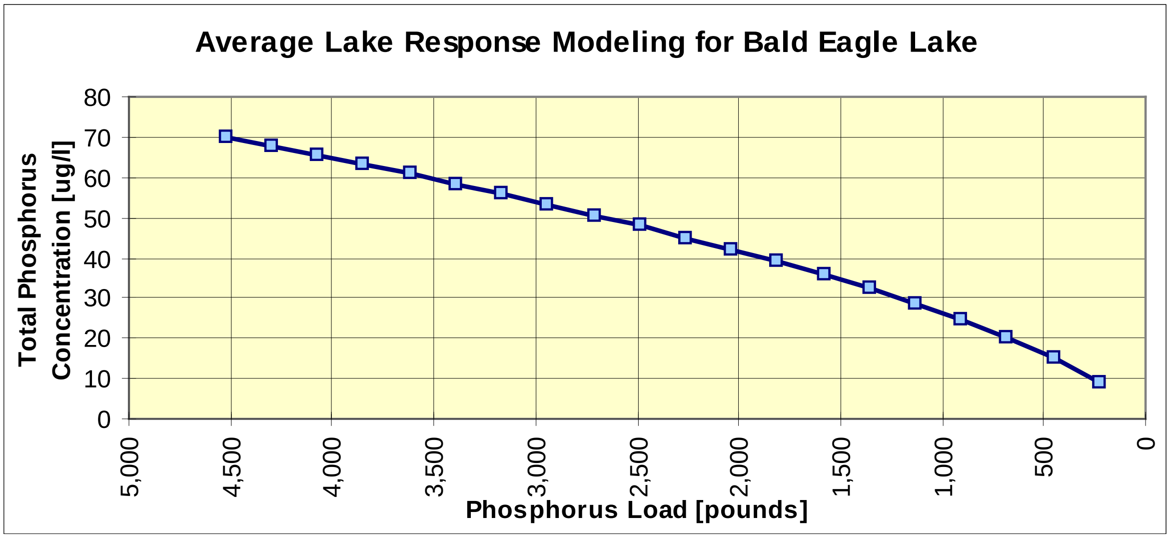


Figure 4-3. In-lake total phosphorus concentrations predicted for total phosphorus load reductions applied to all sources.

4.2.2 Chlorophyll-a

Modeled chlorophyll-a concentrations expected at various phosphorus loads are presented in Figure 4-4. The lake response model predicts that the chlorophyll-a target of 14 µg/L as a summer growing season mean would be met at the TMDL designated load (1,890 pounds/year).

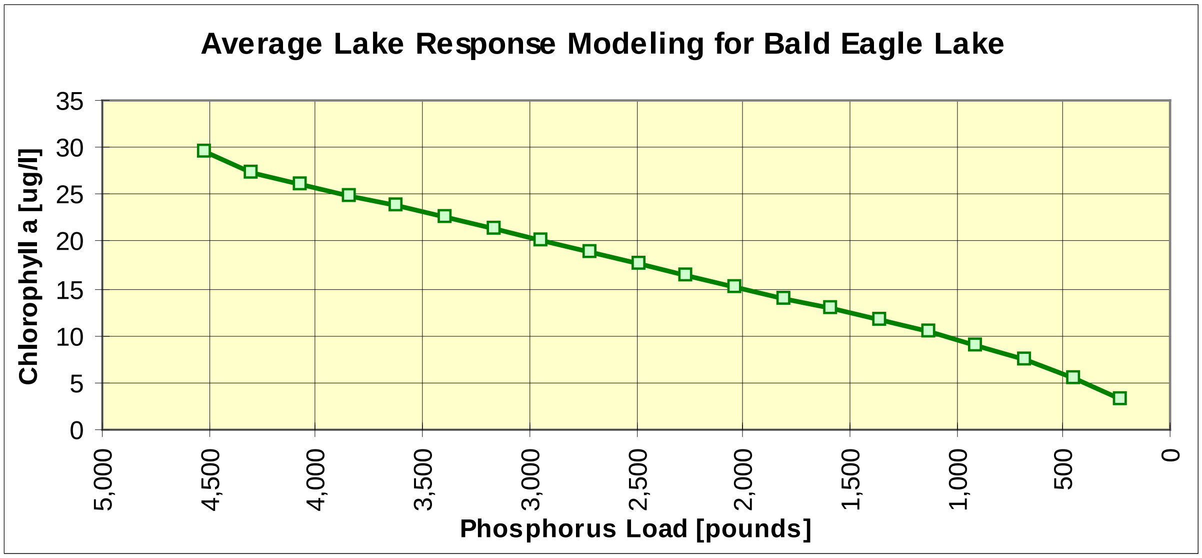


Figure 4-4. In-lake chlorophyll-a concentrations predicted for total phosphorus load reductions applied to all sources.

4.2.3 Secchi Depth

Model-predicted water clarity with incremental load reductions is presented in Figure 4-5. The lake response model predicts that the Secchi depth target of greater than 1.4 meters Secchi depth as a summer growing season mean would be exceeded at the TMDL designated load (1,890 pounds/year).

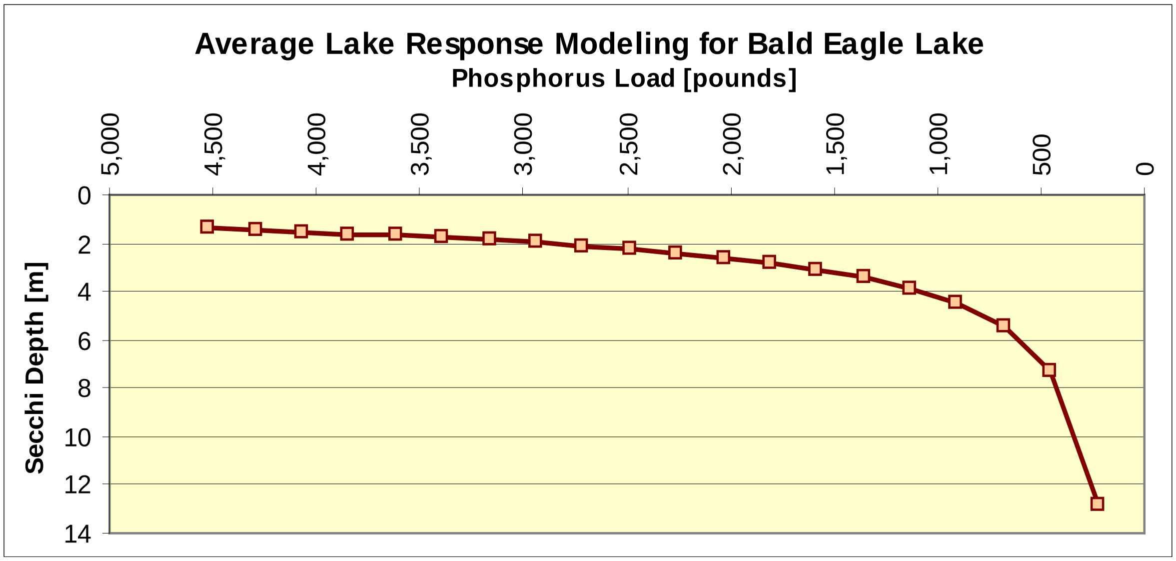


Figure 4-5. Secchi depth predicted for total phosphorus load reductions applied to all sources.

4.3 SEASONAL AND ANNUAL VARIATION

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

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

5.0 Public Participation

5.1 INTRODUCTION

TMDL development should be a stakeholder-driven process that develops an understanding of the issues and the processes driving the impairments. To that end, a detailed stakeholder process was employed that included working with a Technical Advisory Committee comprised of local stakeholders. These groups represent the stakeholders ultimately responsible for implementation of the TMDLs who need to be fully engaged in the applied science. It is our goal for this TMDL to result in a science based, implementable TMDL with a full understanding of the scientific tools developed to make informed, science based decisions. In addition to the meetings below the draft TMDL was made available for a 30-day public comment period from February 28, 2011, through March 30, 2011.

5.2 TECHNICAL ADVISORY COMMITTEE AND STAKEHOLDER MEETINGS

A technical advisory committee was established so that interested stakeholders could be involved in key decisions involved in developing the TMDL. Representatives invited to participate in the Technical Advisory process included:

City Staff and Engineers	County Public Works
County Conservation Districts	MN Board of Water and Soil Resources
MN Dept. of Natural Resources	MN Dept. of Transportation
MN Center for Environmental Advocacy	MN Pollution Control Agency
Bald Eagle Area Association	Blue Water Science, Inc.
County Park Departments	Rice Creek Watershed District

All meetings were open to interested individuals and organizations. Technical Advisory Committee meetings were held on July 9, 2009, and September 24, 2009. Stakeholders interested in greater participation in the process were encouraged to contact the Rice Creek Watershed District.

5.3 PUBLIC MEETINGS

Public meetings were held to present information to lakeshore owners and interested individuals. Presentations were used to introduce topics such as lake ecology, pollution sources, and the TMDL process. Findings of the TMDL study, and associated management options were also presented. Meetings were held on January 28, 2009, and March 11, 2010.

6.0 Implementation

6.1 INTRODUCTION

The purpose of the implementation section of the TMDL is to develop an implementation strategy for meeting the load and wasteload allocations set forth in this TMDL. This section is not meant to be a comprehensive implementation plan; rather it is the identification of a strategy that will be further developed in an implementation plan separate from this document.

6.2 REDUCTION STRATEGIES

Restoration options for lakes are numerous with varying rates of success. Consequently, each technology must be evaluated in light of our current understanding of physical and biological processes in that lake. Following is a description of potential actions for controlling nutrients in the Bald Eagle Lake watershed that will be further developed in the Bald Eagle Lake Implementation Plan. The estimated cost of implementing these and other potential BMPs ranges from $1,500,000 to $5,000,000.

6.3 IMPLEMENTATION FRAMEWORK

6.3.1 Watershed and Local Plans

Numerous governing units have water quality responsibilities in the watershed, including all MS4 permit holders and the Rice Creek Watershed District. These agencies are focused on protecting water quality through implementation of their watershed and local plans as well as MS4 Stormwater Pollution Prevention Programs (SWPPPs). These plans and permits will outline the activities to be undertaken by each governing unit, including best management practices and capital improvements. A TMDL implementation plan will be developed separate from this TMDL document and the plan can help guide the governing units in the implementation of BMPs focused on achieving the TMDL. In the event that MS4 permit holders are not demonstrating progress on WLA reductions the MPCA may reallocate the categorical WLA and assign individual WLAs to MS4s. MS4s will be notified and will have an opportunity to comment on the reallocation.

6.3.2 Adaptive Management

The load allocations in the TMDL represent aggressive goals for nutrient reductions. Consequently, implementation will be conducted using adaptive management principles (Figure 6-1). Adaptive management is appropriate because it is difficult to predict the lake response that will occur from implementing strategies with the paucity of information available to demonstrate expected reductions. Future technological advances may alter the course of actions detailed here. Continued monitoring and “course corrections” responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL.

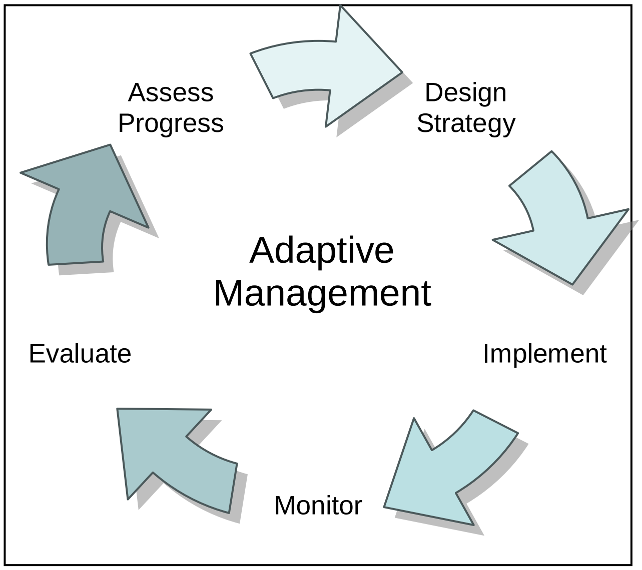


Figure 6-1. Adaptive management.

6.4 NUTRIENT REDUCTION STRATEGIES

Following is a description of potential actions for controlling nutrients in the Bald Eagle Lake watershed that will be further developed in the Implementation Plan.

6.4.1 External Nutrient Load Reductions

This TMDL for Bald Eagle Lake requires a 38% reduction from watershed sources. To meet the required load reduction, various watershed management activities will be implemented on an opportunistic basis, including the following:

Amend rules regulating development and redevelopment. The Rice Creek Watershed District recently revised its rules and standards to adopt more stringent stormwater management rules. The rules revision requires new development to incorporate Better Site Design principles into site plans, and to retain on site through infiltration or other volume management the runoff from a 2-year (2.8 inch in 24 hours) rain event. Small events convey the majority of the annual phosphorus and sediment load (Pitt 1998) to downstream receiving waters. Redevelopment is also required to provide volume management. Adoption of this volume management rule limits new phosphorus and sediment loading to the lakes.

These rules will be a critical step toward reducing nutrient loading in the Bald Eagle Lake watershed as the current agriculture areas develop. Future land use projections assume that over 300 acres of agricultural land will be converted to residential developments in the relatively near future.

Maximize load reduction through development and redevelopment. As redevelopment occurs, areas with little or no treatment will be required to meet current water quality standards. It may be possible to “upsize” water quality treatment BMPs for both development and redevelopment projects to increase treatment efficiency beyond the minimum required by the rules.

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

Increase infiltration and filtration in the watershed. As described above, the new RCWD rules require Better Site Design minimizing new impervious surface and management of new runoff volumes on new development and redevelopment. On existing development, the use of rain gardens, native plantings, and reforestation should be encouraged as a means to increase infiltration, evapotranspiration, and filtration of runoff conveying pollutant loads to the lakes. Residents will be encouraged to apply to the RCWD’s Water Quality Cost-Share program.

Target street sweeping. Cities will be asked to identify key areas and target those areas for more frequent street sweeping.

Retrofit BMPs. Street or highway reconstruction projects, park improvements, and other projects may provide opportunities to incorporate BMPs to add or increase treatment in the watershed. The RCWD will utilize its “Urban Stormwater Remediation Cost-Share” program to subsidize projects.

Encourage shoreline restoration. Most property owners maintain a turfed edge to the shoreline. Property owners should be encouraged to restore their shoreline with native plants to reduce erosion and capture direct runoff. Shoreline restoration can cost $30-50 per linear foot, depending on the width of the buffer installed. The RCWD will develop some demonstration projects as well as work with all willing landowners to naturalize their shorelines. Residents will be encouraged to apply to the RCWD’s Water Quality Cost-Share program.

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

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

Implement Agricultural BMPs. Approximately 883 acres are currently considered agricultural land with over half of that area designated for future residential development. So, only about 13% of the upland area below Fish and Pine Tree Lake is used for agriculture. Furthermore, very little of the land area appears to be row crops, rather the land is used for hay and other nontraditional crops such as tree farms and orchards. With that said, agricultural BMPs should be encouraged on these properties including practices such as buffers, conservation tillage, and infiltration.

Minimize Golf Course Impacts. Several golf courses are present in the Bald Eagle Lake watershed including the Oneka Ridge Golf Course and the Dellwood Hills Golf Course. The RCWD has recently received a Clean Water Fund grant for a project that will collect and store stormwater runoff from a 915 acre subwatershed and use it instead of well water to irrigate 116 acres within the Oneka Ridge Golf Course. Based on the estimated runoff volume reduction and monitored concentrations of phosphorus in this water, this project has the potential to reduce the phosphorus load directed to Bald Eagle Lake from this watershed by between 75 and 300 pounds annually. The district will, to the extent possible, evaluate the golf courses in the watershed to determine the nature of their stormwater discharge and the presence or absence of conveyances.

6.4.2 Internal Nutrient Load Reductions

Internal nutrient loads will need to be reduced to meet the TMDL allocations presented in this document. There are numerous options for reducing internal nutrient loads ranging from simple chemical inactivation of sediment phosphorus to complex infrastructure techniques including hypolimnetic aeration.

Internal load reduction technical review. Prior to implementation of any strategy to reduce internal loading in Bald Eagle Lake, a technical review needs to be completed to evaluate the cost and feasibility of the lake management techniques available to reduce or eliminate internal loading. Several options could be considered to manage internal sources of nutrients including hypolimnetic withdrawal, alum treatment, vegetation management and hypolimnetic aeration. A technical review will be completed to provide recommendations for controlling internal loading in Bald Eagle Lake. Following is a brief description of some of the techniques that could be considered for controlling internal loading in Bald Eagle Lake.

1. Alum Addition. One of the most common methods for controlling internal nutrient loading in lakes is the addition of aluminum sulfate to permanently bind phosphorus in the sediments. When aluminum sulfate reacts with sediment phosphorus, the aluminum permanently binds phosphorus eliminating anoxic phosphorus release. Although alum can be quite effective and is relatively inexpensive, the floc blanket must remain relatively undisturbed it ensure long term effectiveness.

2. Hypolimnetic Withdrawal. Another option that may be considered is the removal of phosphorus rich water from the bottom, or hypolimnion, of a lake and discharging or treating that water. Hypolimnetic withdrawal can be fairly expensive and often has a long lag period before positive results are realized in the lake. However, hypolimnetic withdrawal does eliminate the need to add chemicals the lake.

3. Hypolimnetic Aeration. Sediment phosphorus release from sediments is primarily controlled by anoxia over the sediments. Consequently, one solution is to aerate the hypolimnion to prevent anoxic conditions from occurring over the sediments. To maintain oxygenated conditions in the hypolimnion, or bottom water, aerators are placed at the bottom of the lake, but are covered so that artificial mixing of the lake does not occur. Hypolimnetic aeration is a relatively costly approach and is dependent of relatively large amount of infrastructure that must be maintained.

4. Other Options. There are also other sources of internal loading to consider. One area that may need to be addressed is the resuspension of sediments in shallow areas of the lake as a result of recreational boating activities. Curlyleaf pondweed and carp can both add to internal loading and should be considered. The presence of invasive species and recreational activities will need to be considered when selecting the appropriate approach for controlling internal nutrient loads.

6.4.3 Studies and Biological Management Plans

Following are recommended studies needed to further refine management actions in the Lino Lakes chain of lakes:

Vegetation management. Curly-leaf pondweed is present in all lakes, and is at nuisance levels in some. Senescence of the curly-leaf pondweed in summer can be a significant source of internal phosphorus load that often results in a late summer nuisance algal bloom. Vegetation management, such as several successive years of chemical treatment, will be required to keep this exotic invasive species at non-nuisance levels.

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

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

6.4.4 Education

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

Because Bald Eagle Lake is a highly used recreational lake, there is a potential for the recreation activities to have an impact on the water quality in the lake. To address these potential impacts, educational materials will be developed for lake users to make them aware of the potential impacts to the lake. The educational materials will also identify sensitive areas of the lake.

7.0 Reasonable Assurance

7.1 INTRODUCTION

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

TMDL implementation will be implemented on an iterative basis so that implementation course corrections based on periodic monitoring and reevaluation can adjust the strategy to meet the standard. After the first phase of nutrient reduction efforts, reevaluation will identify those activities that need to be strengthened or other activities that need to be implemented to reach the standards. This type of iterative approach is more cost effective than over engineering to conservatively inflated margins of safety (Walker 2003). Implementation will also address other lake problems not directly linked to phosphorus loading such as invasive plant species (curly-leaf pondweed) and invasive fish (carp and rough fish). These practices go beyond the traditional nutrient controls and provide additional protection for lake water quality.

7.2 RICE CREEK WATERSHED DISTRICT

The Rice Creek Watershed District was formed in 1972 under Minnesota Watershed Law. The District is over 200 square miles in size, and contains parts of 29 municipalities and townships in four counties. The District's mission is "To conserve and restore the water resources of the District for the beneficial use of current and future generations."

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

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

Minnesota Rules Chapter 8410 requires watershed management plans to address eight management areas and to include specific goals and policies for each to serve as a management framework. To implement its approved watershed management plan, the RCWD has undertaken a number of activities, including administering rules and standards regulating stormwater runoff quantity and quality from development and redevelopment in the district; developing Resource Management Plans for resources in the district; and constructing improvements in the District such as a project to re-meander Rice Creek.

Agricultural Practices. The RCWD actively pursues partnerships with local agricultural groups and land owners to pursue implementation of stormwater practices within the District. RCWD staff routinely works with landowners to provide technical support to identify, design and implement water quality BMPs to improve water quality conditions in the District.

Grants and Funding. RCWD has set aside a significant portion of their budget for TMDL implementation and provides cost sharing and technical support to obtain grant funds to implement a wide range of stormwater BMPs including agricultural BMPs. RCWD routinely works with willing land owners to secure funds and technical expertise to complete water quality projects aimed at improving water quality in the District.

7.3 NPDES MS4 STORMWATER PERMITS

NPDES Phase II stormwater permits are in place for all of the cities draining to the Bald Eagle Lake watershed as well as the Rice Creek Watershed District, Anoka and Ramsey Counties and Mn/DOT. Under the stormwater program, permit holders are required to develop and implement a Stormwater Pollution Prevention Program (SWPPP; MPCA, 2004). The SWPPP must cover six minimum control measures:

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

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

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

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

Prevention Program, as appropriate, within 18 months after the TMDL is approved.

MS4s contributing stormwater to the lakes will comply with this requirement during the implementation planning period of the TMDL. The implementation plan will identify specific BMP opportunities sufficient to achieve their load reduction. Individual SWPPPs will be modified as necessary to meet the WLA. BMP opportunities described in the implementation plan can guide MS4s in modifying their SWPPPs.

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

Lino Lakes – MS400100
White Bear Lake– MS400060
White Bear Township– MS400163
Hugo– MS400094
Grant– MS400091
Dellwood– MS400084
Washington County- MS400160
Ramsey County – MS400191
Mn/DOT Metro District – MS400170
Industrial Stormwater–Various
Construction Stormwater - Various

Stormwater discharges are regulated under NPDES, and allocations of nutrient reductions are considered wasteloads that must be divided among permit holders. Mn/DOT was provided with an individual WLA, per their request during the technical advisory process. The remaining MS4 permit holders share a categorical WLA. The LA is also allocated in the same manner. This collective approach allows for greater reductions for some permit holders with greater opportunity and less for those with greater constraints. The collective approach is to be outlined in an implementation plan developed by the Rice Creek Watershed District.

7.4 BALD EAGLE LAKE IMPROVEMENT DISTRICT

In 2008, the Bald Eagle Area Association, after demonstrating nearly unanimous support from lakeshore owners, asked the Rice Creek Watershed District to begin the process of creating a Water Management District around Bald Eagle Lake. A Water Management District established a special tax district around a given waterbody. The Bald Eagle Lake Water Management District (BEL-WMD) was created by the Rice Creek Watershed District in September of 2009. The BEL-WMD will provides annual funds to be used on many different water quality improvement and protection projects, including invasive species control, shoreline stabilization, and emergent plant protection.

7.5 WASHINGTON CONSERVATION DISTRICT

The Washington Conservation District’s mission is to enhance, protect, and preserve the natural resources of Washington County through conservation projects, technical guidance, and educational services to citizens and local government. Protecting natural resources is paramount to the WCD. To bring this protection, the WCD provides technical and financial assistance to county residents, local government units, and watershed organizations as well as other agencies and organizations. WCD also assists individuals and organizations with the planning, preparation, and implementation of natural resource management plans, implementation of the Wetland Conservation Act, natural resource education, and application of sound natural resource practices.

WCD programs are funded through a variety of sources including county allocation, grants, contracts with local government units and watershed organizations, state and federal cost share, and a small amount from private industry. The projects implemented through their programs and partnerships benefit the environment countywide and in turn increase property values and aesthetic appeal for all. The WCD's goal is not to profit financially from their services, but to provide sound environmental services at cost to individuals and organizations, cities and townships, Washington County, and watershed organizations.

7.6 MONITORING

7.6.1 Monitoring Implementation of Policies and BMPs

A key piece in understanding progress toward meeting a TMDL is monitoring implementation activities and the effectiveness of those activities. An annual report will be developed that outlines all of the activities completed that relate to the TMDL.

7.6.2 Follow-up Monitoring

The Rice Creek Watershed District maintains a monitoring program that includes flow and water quality monitoring for key subwatersheds. The RCWD currently monitors continuous flow and water quality at the outlet of Judicial Ditch 1, and will continue to do so as the Bald Eagle TMDL is implemented. Whenever possible, stormwater water quality samples will also be collected from the County Ditch 11 and direct watershed outfall locations. This monitoring would be done in conjunction with implementation activities (i.e. “effectiveness monitoring”).

Currently, in-lake water quality samples, along with measures of physical lake characteristics (temp, DO, etc), are collected by Ramsey County Public Works. Samples are collected from two locations in the lake, and at varying depths, on a bi-monthly basis. Ramsey County plans to continue sampling throughout and after the TMDL implementation process.

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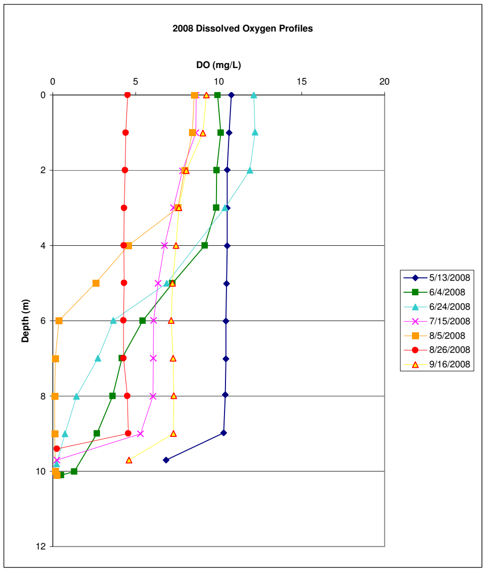
Appendix A

Temperature and Dissolved Oxygen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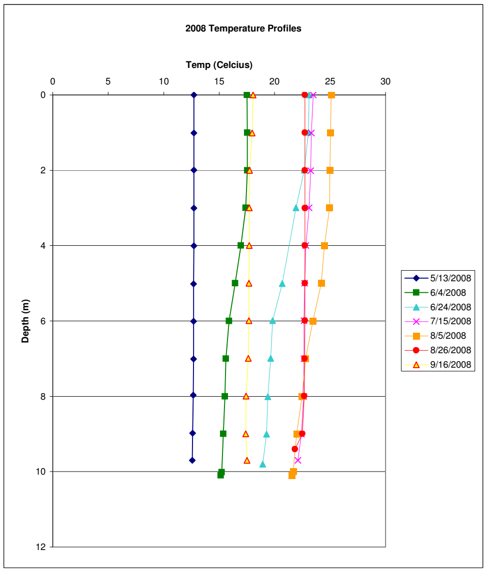
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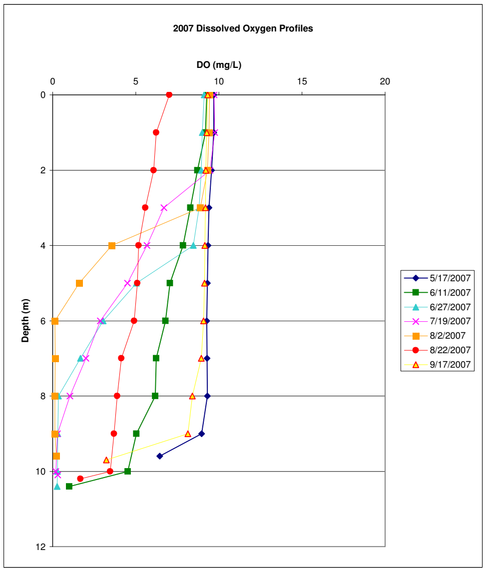
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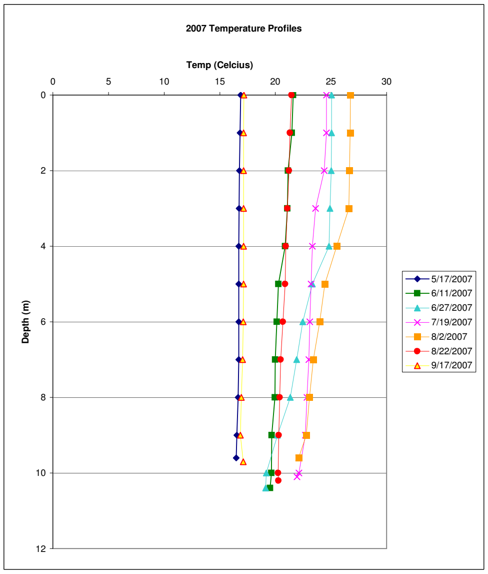
8/2/2007
8/22/2007
9/17/2007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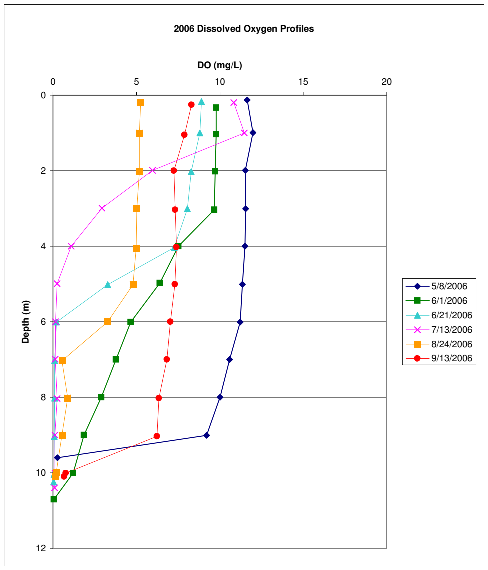
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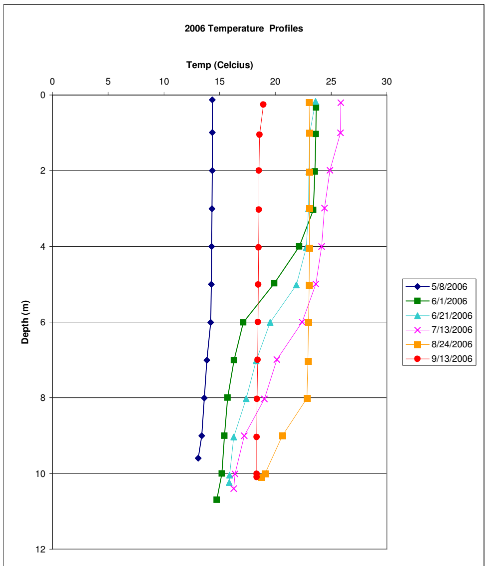
9/13/2006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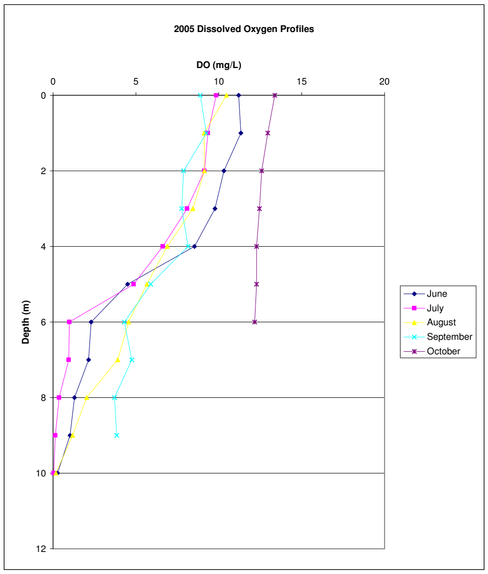
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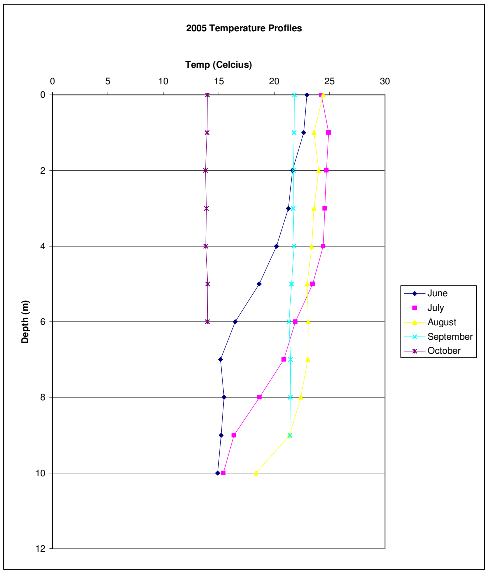
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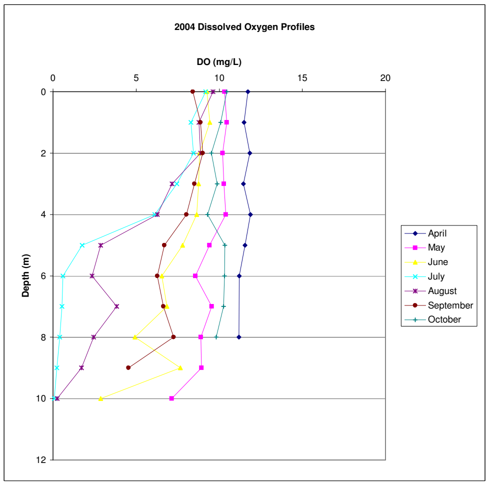
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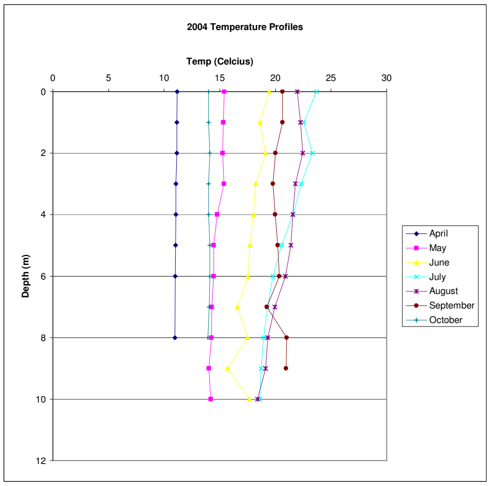
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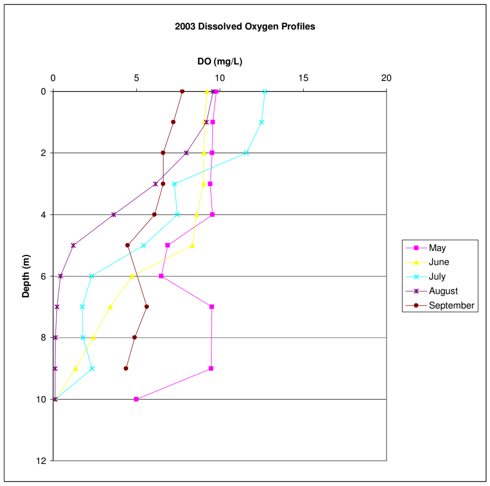
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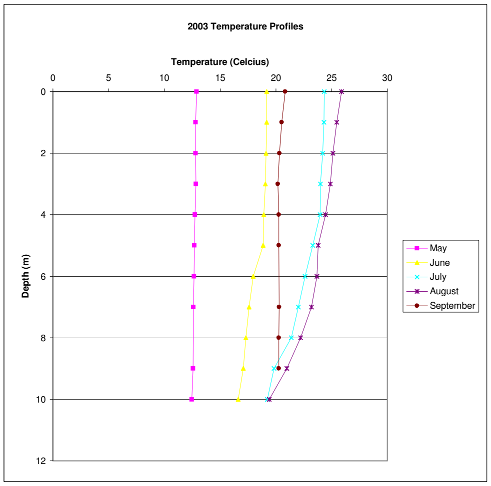
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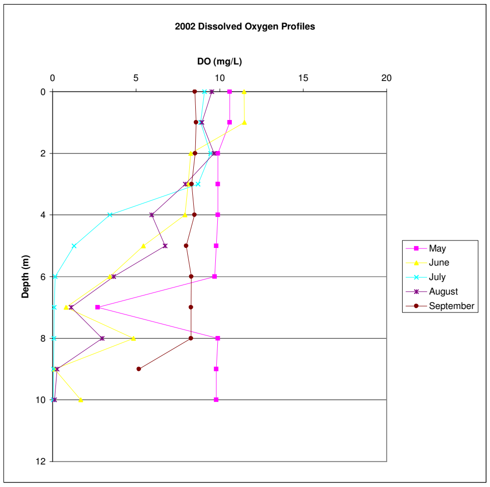
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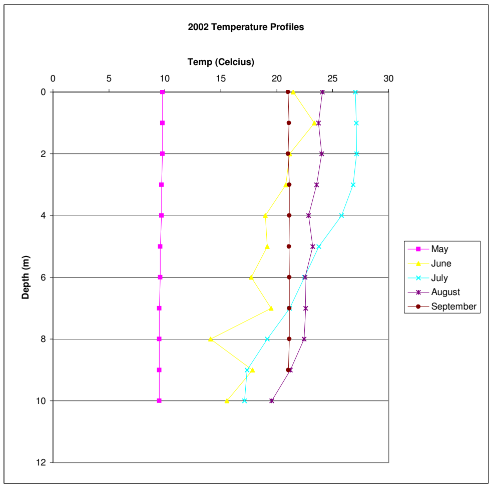
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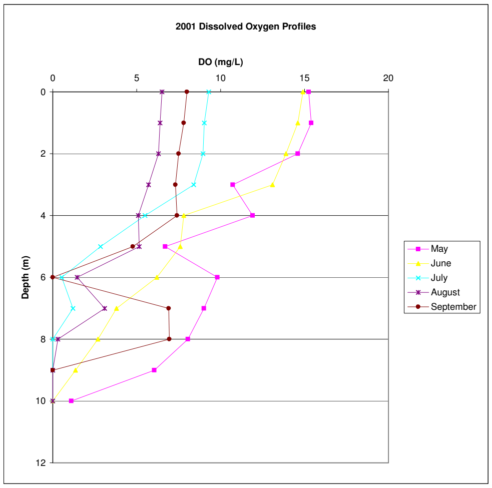
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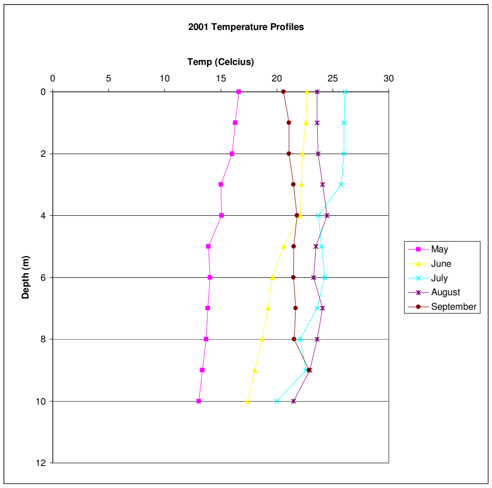
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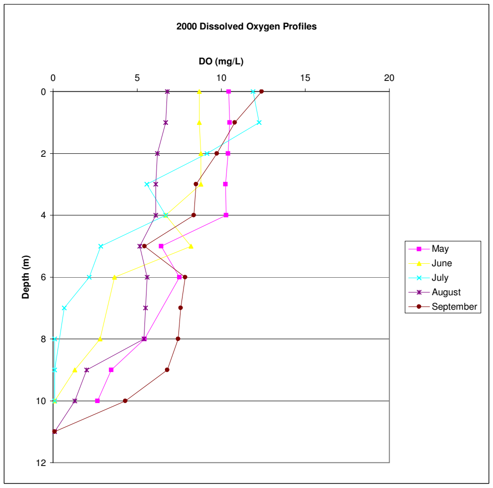
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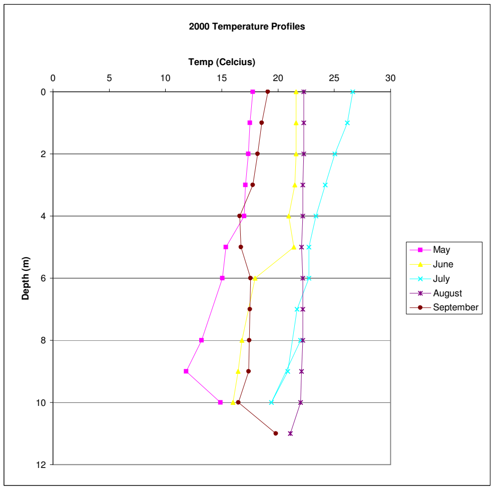
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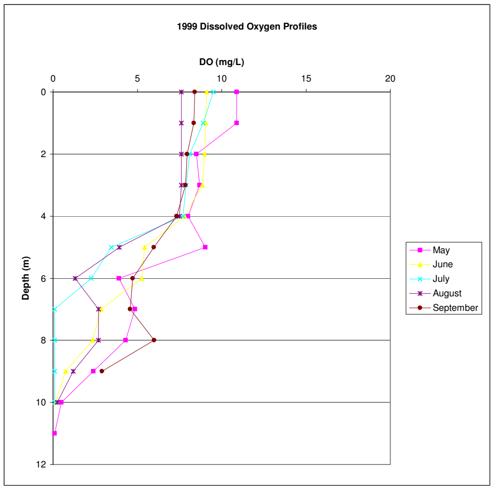
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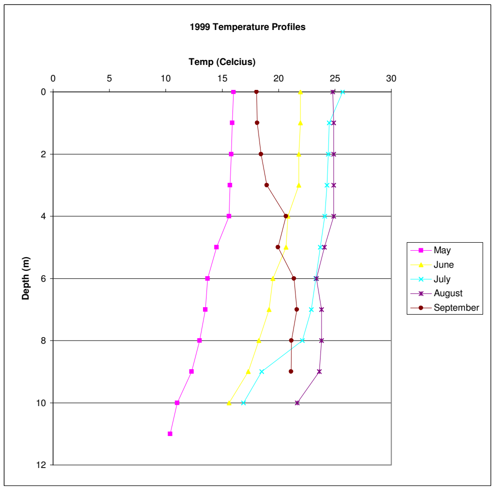
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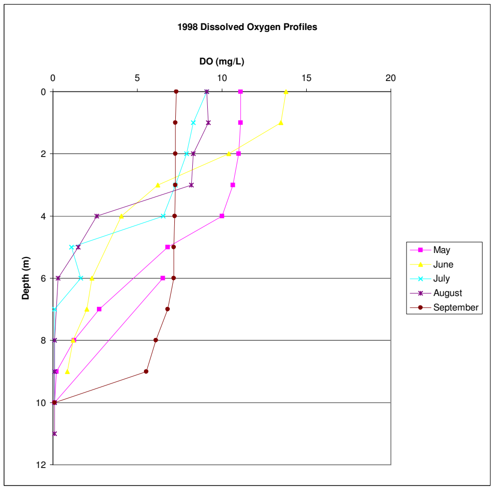
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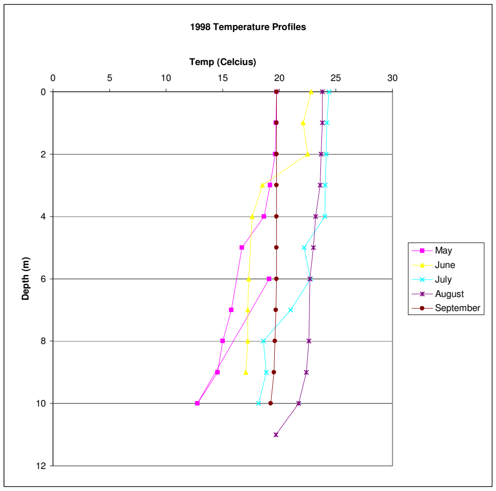
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Appendix B

Vegetation Surveys

Zvonimar Mihanovic: *At Rest*

Aquatic Plant Evaluations for Bald Eagle Lake, Ramsey County, 2007

[Early Summer Curlyleaf Stem Densities: April 23, 2007]
[Late Summer Survey: August 17, 2007]

Prepared for:
Bald Eagle Area Association
and
Rice Creek Watershed District

Prepared by:
Steve McComas and
Jo Stuckert
Blue Water Science
(651) 690.9602

Prepared January 2008

Aquatic Plant Evaluations for Bald Eagle Lake, Ramsey County, 2007

Summary

Early Summer Aquatic Plant Status

Although a quantitative early summer aquatic plant survey was not conducted in 2007 curlyleaf pondweed stem densities were evaluated. The stem density evaluation was conducted on April 23, 2007 and represented pre-herbicide conditions. In June, the entire curlyleaf community had died back from the effects of an herbicide application applied in April. Native plants were just beginning to sprout. Curlyleaf stem density results are shown in Table S-1.

Aggressive herbicide treatments have been applied to Bald Eagle Lake to achieve long-term control of curlyleaf pondweed. Herbicides were applied in 2005 (98 ac), 2006 (138 ac), and 2007 (138 ac). The herbicide treatment, using Aquathol K, has reduced the density of curlyleaf pondweed in Bald Eagle Lake in 2007 compared to the pre-project stem densities taken in 2003, prior to the first treatment (Table 1). These data indicate the herbicide treatments appear to be accomplishing one of the primary objectives of reducing the abundance of the invasive curlyleaf pondweed.

Curlyleaf stem densities on April 23, 2007 were above nuisance densities (arbitrarily set at 150 stems/m^2) at two sites. However, the effects of the herbicide application from April 11 and 14 prevented nuisance growth. The curlyleaf was controlled by the herbicide application.

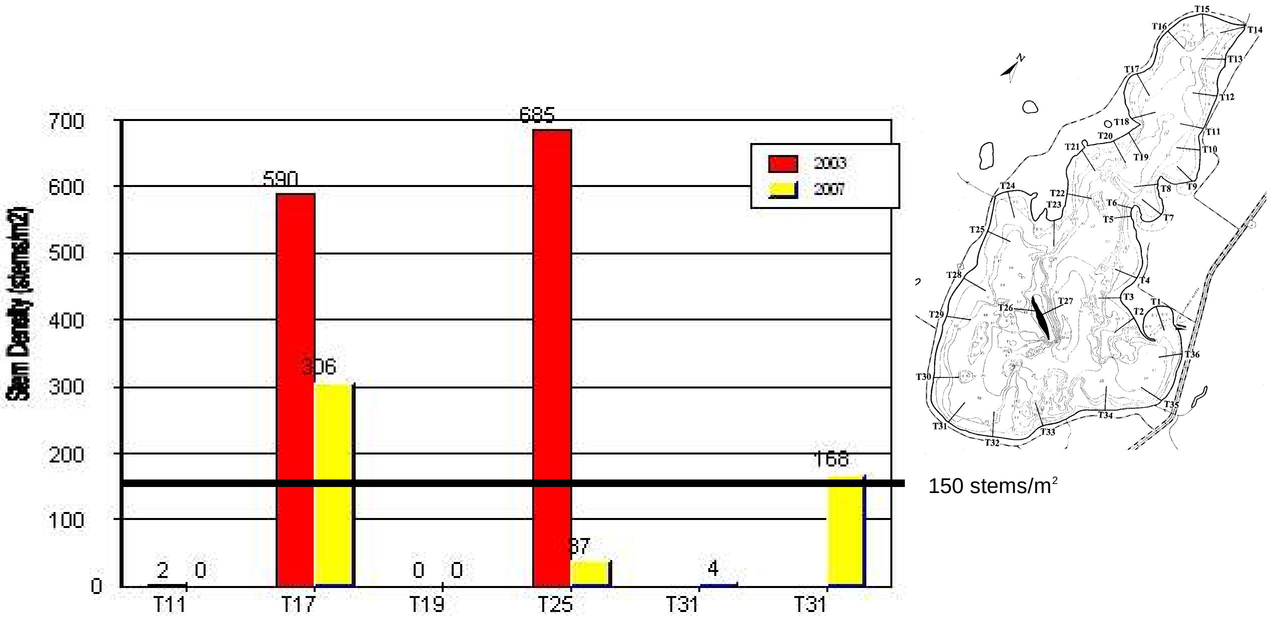


Table S-1. Curlyleaf pondweed stem density for 2003 and 2007 at six transects around the Bald Eagle Lake.

Curlyleaf Pondweed Growth Characteristics

Light Growth Conditions

Plants rarely reach the surface.

Navigation and recreational activities are not generally hindered.

Stem density: 0 - 160 stems/m^2
Biomass: 0 - 50 g-dry wt/m^2
Estimated TP loading: <1.7 lbs/ac

MnDNR rake sample density equivalent for non-nuisance conditions: 1, 2, or 3.

Moderate Growth Conditions

Broken surface canopy conditions.

Navigation and recreational activities may be hindered.

Lake users may opt for control.

Stem density: 100 - 280 stems/m^2
Biomass: 50 - 85 g-dry wt/m^2
Estimated TP loading: 2.2 - 3.8 lbs/ac

MnDNR rake sample density equivalent for light nuisance conditions: 3 or 4.

Heavy Growth Conditions

Solid or near solid surface canopy conditions.

Navigation and recreational activities are severely limited.

Control is necessary for navigation and/or recreation.

Stem density: 400+ stems/m^2
Biomass: >300 g-dry wt/m^2
Estimated TP loading: >6.7 lbs/ac

MnDNR rake sample density has a scale from 1 to 4. For heavy nuisance conditions where plants top out at the surface, the scale has been extended: 4.5 is equivalent to a near solid surface canopy and a 5 is equivalent to a solid surface canopy.

Late Summer Aquatic Plant Status

Results from the aquatic plant survey conducted on August 17, 2007 found plant coverage extended to a depth of 7 feet. The native plant coverage after the curlyleaf pondweed die back in Bald Eagle Lake is approximately 30% of the bottom or about 300 acres. This has remained the same for the last few surveys.

In 2007, the hybrid milfoil was identified at 22 out of the 72 stations (31%). The hybrid milfoil species had attributes of Eurasian watermilfoil in the lower portion of the stem in terms of up to 15 leaflet pairs on a bract. In the upper part of the stem, there were 12-13 leaflet pairs.

Fourteen species of submerged aquatic plants were identified. The most common plant in Bald Eagle Lake was water celery. Coontail was the next most common plant found.

Comparing Late Summer Survey Results from 1997 - 2007

Several minor positive changes in the aquatic plant community have been observed from 1997 through 2007 (Table S-2). Several species have increased in coverage and include chara, milfoil, and coontail. Two milfoil species are present, including an Eurasian watermilfoil hybrid. This hybrid grew to the surface in areas along the western shoreline in 2004, but did not appear as a nuisance in 2005, 2006, or 2007.

Table S-2. Comparison of percent occurrence of plants for the late summer plant surveys from 1997 through 2007 out to a depth of 7 feet. A curlyleaf pondweed control program has consisted of mechanical harvesting from 2000 - 2004 (yellow shading) and herbicide applications in 2005 - 2007 (pink shading).

	Percent Occurrence										
	1997 (72 stat on 36 trans)	1998 (72 stat on 36 trans)	1999 (72 stat on 36 trans)	2000 (72 stat on 36 trans)	2001 (72 stat on 36 trans)	2002 (72 stat on 36 trans)	2003 (72 stat on 36 trans)	2004 (72 stat on 36 trans)	2005 (72 stat on 36 trans)	2006 (72 stat on 36 trans)	2007 (72 stat on 36 trans)
Bulrush (*Scirpus sp*)	P	P	6	3	P	3	3	1	P	P	P
Cattails (*Tyhpa sp*)	P	P	7	4	3	8	P	P	P	P	P
Duckweed (*Lemna sp*)	--	--	7	7	--	7	15	18	6	--	1
Spatterdock (*Nuphar variegatum*)	17	24	21	21	15	29	29	14	19	18	11
Water waterlily (*Nymphaea sp*)	17	19	15	13	10	21	8	21	17	15	21
Watermeal (*Wolffia columbiana*)	--	--	--	--	--	--	--	--	--	10	3
Coontail (*Ceratophyllum demersum*)	24	35	40	47	25	38	40	40	53	50	44
Chara (*Chara sp*)	11	15	11	10	8	19	22	51	19	50	28
Elodea (*Elodea canadensis*)	--	--	1	--	1	--	--	4	--	--	--
Star duckweed (*Lemna trisulca*)	26	8	18	15	22	29	33	36	28	39	18
Northern watermilfoil (*Myriophyllum sibiricum*)	13	18	18	13	36	17	25	13	25	14	17
Watermilfoil hybrid (*Myriophyllum sp*)	--	--	--	22	4	9	32	43	17	14	31
Eurasian watermilfoil (*M. spicatum*)	--	--	--	--	--	--	--	--	--	--	1
Naiads (*Najas sp*)	1	--	4	--	3	1	4	4	--	--	3
Nitella (*Nitella sp*)	--	--	--	--	--	--	--	6	--	--	1
Cabbage (*Potamogeton. amplifolius*)	3	7	1	--	--	3	6	--	--	6	1
Curlyleaf pondweed (*P. crispus*)	15	--	7	--	4	7	28	4	1	1	--
Illinois pondweed (*P. illinoensis*)	--	--	8	7	7	13	14	21	3	1	8
Floatingleaf pondweed (*P. natans*)	--	--	--	--	--	--	--	--	--	1	--
Whitestem pondweed (*P. praelongus*)	--	--	--	--	--	--	--	--	3	6	1
Claspingleaf pondweed (*P. richardsonii*)	4	6	7	7	4	8	7	10	--	3	--
Robbins pondweed (*P. robbinsii*)	—	3	--	--	--	--	--	--	--	--	--
Stringy pondweed (*P. sp*)	--	3	--	1	--	--	3	--	--	--	--
Flatstem pondweed (*P. zosteriformis*)	17	1	7	--	13	7	6	22	--	--	--
Sago pondweed (*Stuckenia pectinata*)	6	--	4	6	4	7	7	--	--	8	7
Water celery (*Vallisneria americana*)	39	51	63	63	64	61	63	50	57	57	51
Water stargrass (*Zosterella dubia*)	19	28	32	33	31	21	40	24	14	17	15
Number of submerged species	12	11	14	11	14	14	15	14	10	14	14

Aquatic Plant Evaluations for Bald Eagle Lake for 2007

Introduction

Curlyleaf pondweed stem densities were evaluated on April 23, 2007 in Bald Eagle Lake as part of the curlyleaf management program. Later in the summer a full aquatic plant survey was conducted on August 17, 2007. The objective of the aquatic plant survey was to evaluate the distribution of curlyleaf pondweed and Eurasian watermilfoil as well as the native plant species in Bald Eagle Lake.

Methods

Several techniques were used to conduct the aquatic plant surveys in Bald Eagle Lake, a 1,269 acre, eutrophic lake located in Ramsey County. Curlyleaf pondweed stem density was evaluated at five sampling locations on April 23, 2007. Sampling locations were at Transects 11, 17, 19, 25, and 31. At each of the five sites, ten stem density samples were randomly collected along a 50 meter transect line that ran parallel to shore in 4 to 7 feet of water. Stem densities were determined using a 0.10 meter^2 quadrat. The quadrat, which is a square frame measuring 33 cm x 33 cm is placed on the sediments and all stems within the square frame are counted.

For the full survey on August 17, 2007, we used 36 line transects (Figure 1) and a recording sonar (Lowrance X-16) to delineate the depths of plant colonization. Two depths (0-3 feet and 4-7 feet) on a transect were sampled with a rake to characterize plant species presence and density. A total of 72 stations were checked.

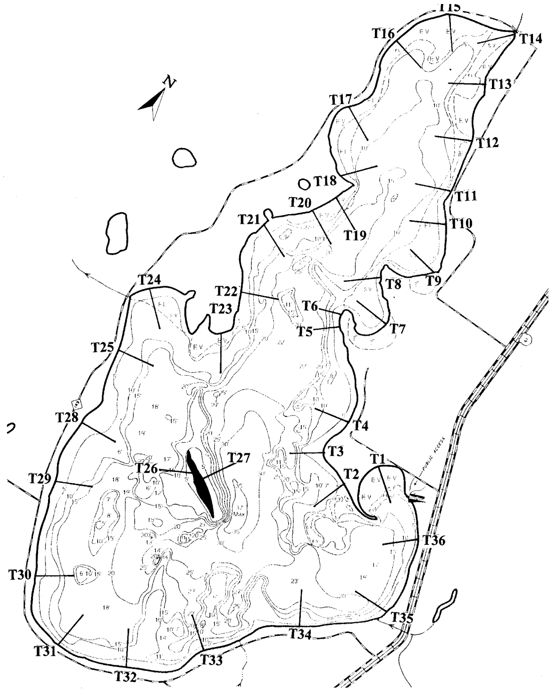


Figure 1. Transect map for the aquatic plant surveys conducted on Bald Eagle Lake in 2007.

Methods - continued

Aquatic plant density was estimated based on a scale from 1-5 with 1 being the less dense and 5 representing plants matting at the surface. Plant density ratings were based on the amount of plants collected on a rake head. A single stem or a trace of an identifiable plant was rated at a density of “1". If plants were collected up to at least one half of the rake head (7 out of 14 tines) it was rated at a density of “2". If plants covered all of the rake tines, the density was a “3". If plants covered all 14 tines and was dense on all tines (even obscuring them) the density was a “4". A density of “5" was only assigned to plants matting at the surface. Examples of plant density ratings are shown in Figure 2.

Two to four rake samples were collected at each depth interval. A density for each plant species was determined for each rake sample and the species density was averaged based on the number of rake samples for a depth interval.

For plant surveys of this type, depth intervals are determined based on the maximum depth of plants found in the lake. Two depth intervals are used if plant growth is 10 feet or less and three depth intervals are used if plant growth is 12 feet or greater. Aquatic plants colonized out to 7 feet in Bald Eagle Lake, so two depth zones were used and they were: 0 - 3 feet and 4 - 7 feet.

Figure 2. Aquatic plant density was estimated based on the amount of plants collected on a rakehead. In the example above, chara has an assigned density of a “3" and water celery has a density of a “2".

Results of the April 2007 Aquatic Plant Stem Density Evaluation

Aggressive herbicide treatments have been applied to Bald Eagle Lake to achieve long-term control of curlyleaf pondweed. Herbicides were applied in 2005 (98 ac), 2006 (138 ac), and 2007 (138 ac). The herbicide treatment, using Aquathol K, has reduced the density of curlyleaf pondweed in Bald Eagle Lake in 2007 compared to the pre-project stem densities taken in 2003, prior to the first treatment (Table 1). These data indicate the herbicide treatments appear to be accomplishing one of the primary objectives of reducing the abundance of the invasive curlyleaf pondweed.

Curlyleaf stem densities on April 23, 2007 were above nuisance densities (arbitrarily set at 150 stems/m^2) at two sites. However, the effects of the herbicide application from April 11 and 14 prevented nuisance growth. The curlyleaf was controlled by the herbicide application.

Table 1. Summary of curlyleaf pondweed stem densities for 2003 and 2007.

	Stem Density (#/m^2)					
	T11	T17	T19	T25	T31	
2003 Pre-Project (June 8)	2 (5 ft)	590 (6-7 ft)	0 (5 ft)	685 (6-7 ft)	--	
2007 On-Going Project (April 23)	0* (5 ft)	306 (6 ft)	0* (5 ft)	37 (6 ft)	4 (4-5 ft)	168 (6 ft)

* estimated

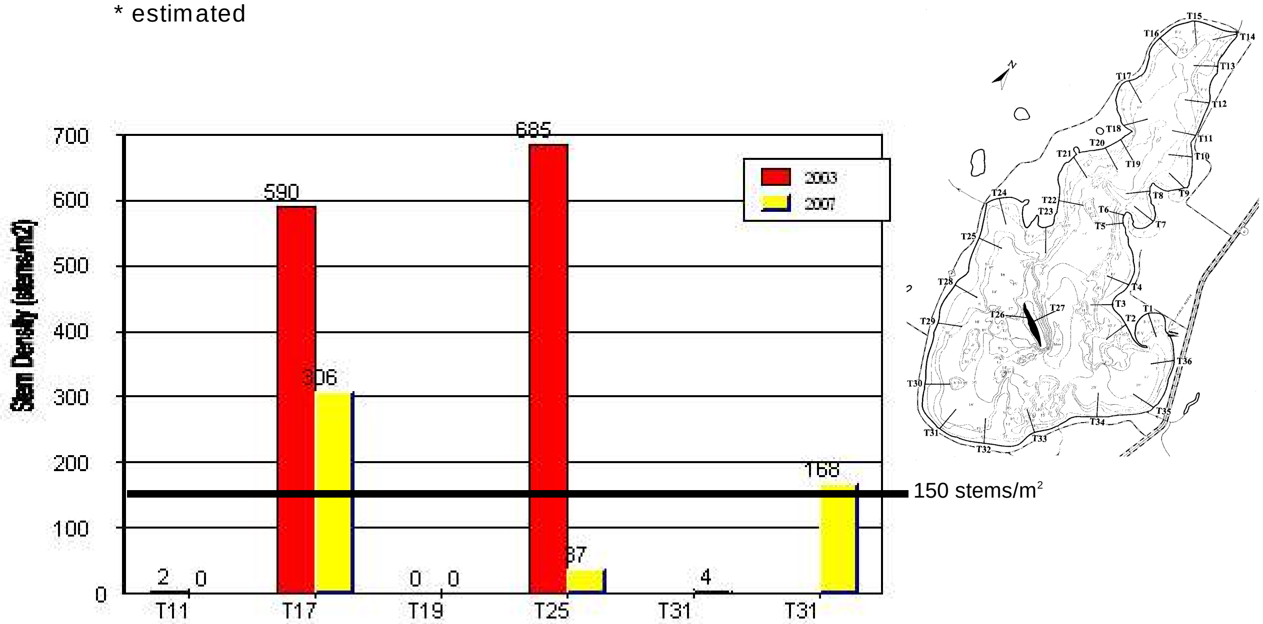


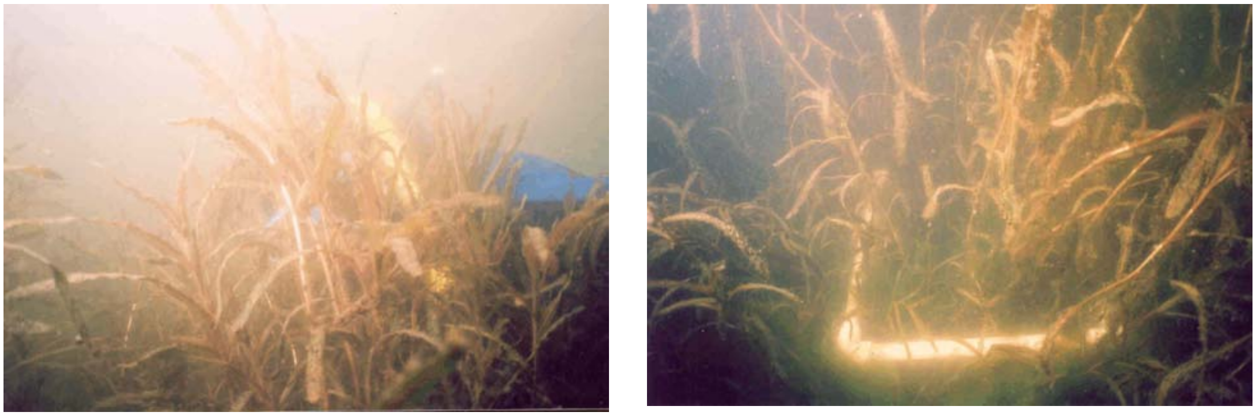
Figure 3. Stem density results for Bald Eagle Lake in 2003 (red) and 2007 (yellow).

Table 2. Representative curlyleaf pondweed stem densities prior to herbicide applications. Bald Eagle Lake curlyleaf stem counts for June 8, 2003 for four sites (locations are shown in Figure 1). Plant data collected by Steve McComas and Jo Stuckert, Blue Water Science.

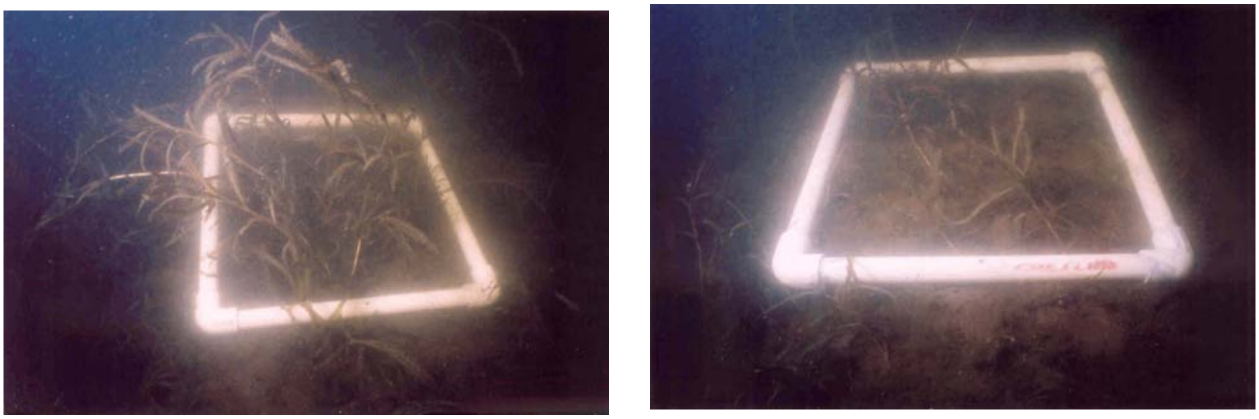
JUNE 8, 2003	**Site**			
	T11	**T17**	**T19**	**T25**
Quadrat	**Stem/m^2**	**Stem/m^2**	**Stem/m^2**	**Stem/m^2**
	5 ft	**6-7 ft**	**5 ft**	**6-7 ft**
1	0	560	0	490
2	0	1,040	0	670
3	0	550	0	640
4	0	960	0	1,160
5	10	520	0	680
6	--	460	--	720
7	--	380	--	460
8	--	640	--	490
9	--	440	--	720
10	--	350	--	820
Average Curlyleaf Stem Density (stems/m^2)	***2***	***590***	***0***	***685***

Table 3. Bald Eagle Lake curlyleaf stem counts for April 23, 2007 for three sites (locations are shown in Figure 1). Plant data collected by Steve McComas and Jo Stuckert, Blue Water Science.

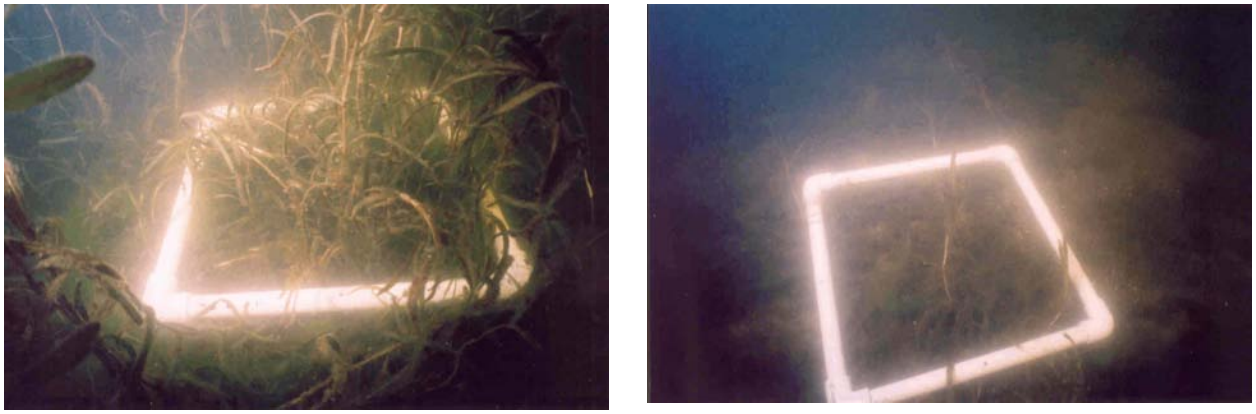
APRIL 23, 2007	**Site**			
SD= 6.5 ft	**T17**	**T25**	**T31**	
Quadrat	**Stem/m^2**	**Stem/m^2**	**Stem/m^2**	
	6 ft	**6 ft**	**4-5 ft**	**6 ft**
1	420	40	10	100
2	270	20	20	150
3	300	10	0	200
4	330	0	0	240
5	680	30	0	110
6	100	60	0	140
7	200	20	0	80
8	240	100	10	220
9	220	40	0	190
10	300	50	0	250
Average Curlyleaf Stem Density (stems/m^2)	***306***	***37***	***4***	***168***



Transect 17: April 24, 2007 **Transect 17: April 24, 2007**



Transect 25: April 24, 2007 **Transect 25: April 24, 2007**



Transect 31: April 24, 2007 **Transect 31: April 24, 2007**

Figure 4. Underwater curlyleaf pondweed conditions in Bald Eagle Lake at three transect locations on April 24, 2007.

Comparison of Early Season Plant Surveys for Bald Eagle Lake

Two early season plant surveys have been conducted in Bald Eagle Lake in 1998 and in 2003. Results are shown in Table 4. The early summer aquatic plant community was similar in 1998 and 2003. An early summer survey is recommended in the near future to evaluate aquatic plant changes from 2003.

Table 4. Bald Eagle Lake aquatic plant occurrences and densities for the 1998 survey based on 96 stations and for the 2003 survey based on 108 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Early Summer Surveys	
	1998 (n=96)	2003 (n=108)
Water lily/Spatterdock (*Nymphaea sp*/Nuphar variegatum)	3	3
Chara (*Chara sp*)	19	19
Coontail (*Ceratophyllum demersum*)	5	5
Star duckweed (*Lemna trisulca*)	1	4
Northern watermilfoil (*Myriophyllum sibiricum*)	0	2
Watermilfoil (*Myriophyllum sp*)	0	1
Curlyleaf pondweed (*Potamogeton crispus*)	49	61
Illinois pondweed (*P. Illinoensis*)	0	3
Flatstem pondweed (*Potamogeton zosteriformis*)	1	1
Broadleaf pondweed (P. sp	1	0
Stringy pondweed (P. sp	7	0
Sago pondweed (*Potamogeton pectinatus*)	1	3
Water celery (*Vallisneria americana*)	5	0
Water stargrass (*Zosterella dubia*)	2	4
Number of Aquatic Plant Species	11	11

Results of the August 2007 Aquatic Plant Survey

Results from the aquatic plant survey on August 17, 2007 found plant coverage extended to a depth of 7 feet (Figure 5). The native plant coverage after the curlyleaf pondweed die back in Bald Eagle Lake is approximately 30% of the bottom or about 300 acres. This has remained the same for the last few surveys.

Northern watermilfoil was found at 12 out of the 72 stations and the hybrid milfoil was found at 22 out of 72 stations. The hybrid milfoil species has attributes of Eurasian watermilfoil in the lower portion of the stem in terms of up to 15 leaflet pairs on a bract. In the upper part of the stem, there were 12-13 leaflet pairs.

Fourteen species of submerged aquatic plants were identified. The most common plant in Bald Eagle Lake was water celery. Coontail and milfoil were the next most common plants found (Table 5).

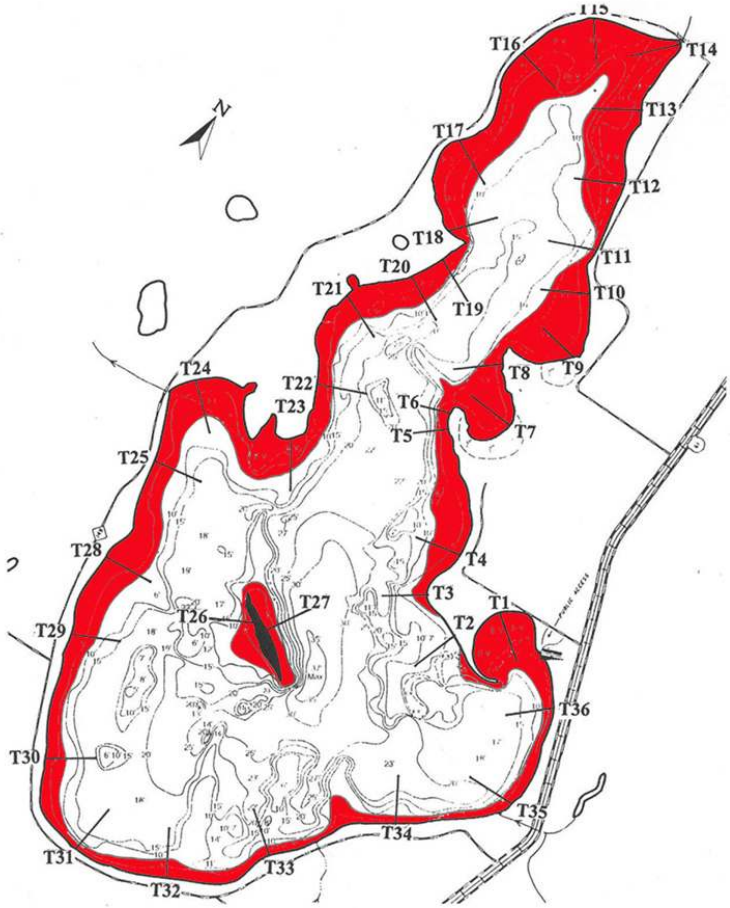


Figure 5. Submerged aquatic plant coverage for Bald Eagle Lake on August 17, 2007. Plants grow out to about 7 feet of water depth.

Table 3. Bald Eagle Lake aquatic plant occurrences and densities for the August 17, 2007 survey based on 36 transects and 2 depths, for a total of 72 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-3 feet (n=36)			Depth 4-7 feet (n=36)			All Stations (n=72)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Duckweed (*Lemna sp*)	1	3	0.5	--	--	--	1	1	0.5
Spatterdock (*Nuphar variegatum*)	7	19	2.7	1	3	0.7	8	11	2.5
Water lily (*Nymphaea sp*)	12	33	2.8	3	7	1.5	15	21	2.6
Watermeal (*Wolffia columbiana*)	2	6	0.7	--	--	--	2	3	0.7
Coontail (*Ceratophyllum demersum*)	16	44	3.2	16	44	2.3	32	44	2.7
Chara (*Chara sp*)	9	25	1.6	11	31	1.7	20	28	1.6
Star duckweed (*Lemna trisulca*)	3	8	0.7	10	28	0.6	13	18	0.6
Northern watermilfoil (*Myriophyllum sibiricum*)	5	14	1.4	7	19	0.6	12	17	0.9
Watermilfoil (*Myriophyllum spp*)	11	31	1.5	11	31	1.1	22	31	1.3
Eurasian watermilfoil (*Myriophyllum spicatum*)	--	--	--	1	3	0.5	1	1	0.5
Naiads (*Najas flexilis*)	2	6	1.0	--	--	--	2	3	1.0
Nitella (*Nitella spp.*)	--	--	--	1	3	0.5	1	1	0.5
Cabbage (*Potamogeton amplifolius*)	1	3	3.0	--	--	--	1	1	3.0
Illinois pondweed (*P. Illinoensis*)	4	11	1.3	6	6	0.8	6	8	1.1
Claspingleaf pondweed (*P. Richardsonii*)	1	3	1.0	--	--	--	1	1	1.0
Sago pondweed (*Stuckenia pectinata*)	3	8	0.8	2	6	2.0	5	7	1.3
Water celery (*Vallisneria americana*)	25	69	2.1	12	33	1.2	37	51	1.8
Water stargrass (*Zosterella dubia*)	7	19	1.6	4	11	1.5	11	15	1.5
Filamentous algae	4	11	0.9	3	8	1.1	7	10	1.0

Table 6. Aquatic plant occurrence and density for individual transects in Bald Eagle Lake, August 17, 2007.

	T1		T2		T3		T4		T5		T6		T7		T8		T9		T10	
Depth (ft)	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**
Duckweed																				
Spatterdock													3	0.7			3			
Water lily	5	2											3				3			
Watermeal																				
Coontail	5	3.5				0.5		1					4.5	2.2	1		2	2	3	
Chara			2	1.5	1		1	1		0.3									1	
Star duckweed								0.5		0.3				0.3		0.5				0.5
Northern watermilfoil															2	1			1	0.5
Watermilfoil								1.5	0.5	1.3							2			
Eurasian watermilfoil		0.5																		
Naiads																				
Nitella																				
Cabbage																				
Illinois pondweed							2	0.5			1	1								
Claspingleaf pondweed																				
Sago pondweed					1													2		2
Water celery					3	0.5	3		0.5		2	0.5	0.5		3	0.5	1	2	1	
Water stargrass									2	0.3	2	2							2	
Filamentous algae			1																	

	T11		T12		T13		T14		T15		T16		T17		T18		T19		T20	
Depth (ft)	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**
Duckweed											0.5									
Spatterdock					4		3								2		3			
Water lily			2.5		4		2		3		2		4	2	4		1			
Watermeal			0.3				1													
Coontail			2.5	4	4.5	4.5	5	4	5	4	4.5	1.5	4.5	3.5	4	0.7				
Chara		3																	2	0.5
Star duckweed		0.5									0.5				1			0.3		
Northern watermilfoil																				
Watermilfoil										1	0.5	0.5			1		1	1.5		
Eurasian watermilfoil																				
Naiads																				
Nitella																				
Cabbage	3																			
Illinois pondweed																				
Claspingleaf pondweed																				
Sago pondweed	1																			
Water celery	3					0.5											1		1	2
Water stargrass	2																			
Filamentous algae			1											1						

Table 6. Concluded.

	T21		T22		T23		T24		T25		T26		T27		T28		T29		T30	
Depth (ft)	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**
Duckweed																				
Spatterdock	1																			
Water lily	0.5	0.5																		
Watermeal																				
Coontail	1			1			1	0.3							0.5					
Chara					2	2			2	1	2				1	2				2
Star duckweed	0.5			2				0.3		0.7										
Northern watermilfoil			2	1				0.3		0.3	1			0.5			1	0.5		
Watermilfoil							1	0.7											2	1
Eurasian watermilfoil																				
Naiads									1								1			
Nitella																		0.5		
Cabbage																				
Illinois pondweed											1		1							
Claspingleaf pondweed													1							
Sago pondweed																				
Water celery			3		2		4	0.7	3		2	2	1				3		3	2
Water stargrass	1		1									3		0.5						
Filamentous algae						2	1	0.3							0.5					

	T31		T32		T33		T34		T35		T36	
Depth (ft)	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**	**0-3**	**4-7**
Duckweed												
Spatterdock												
Water lily												
Watermeal												
Coontail				1							3	3
Chara				2				3				
Star duckweed												
Northern watermilfoil												
Watermilfoil	2	2	1			1			1	1	4.5	1
Eurasian watermilfoil												
Naiads												
Nitella												
Cabbage												
Illinois pondweed												
Claspingleaf pondweed												
Sago pondweed											0.5	
Water celery	3	1	3	2	2		2		2	0.7	1	
Water stargrass					1							
Filamentous algae												

Comparing Late Summer Survey Results from 1997 - 2007

Several minor positive changes in the aquatic plant community have been observed from 1997 through 2007 (Table 7). Several species have increased in coverage and include chara, milfoil, and coontail. Two milfoil species are present, including an Eurasian watermilfoil hybrid. This hybrid grew to the surface in areas along the western shoreline in 2004, but did not appear as a nuisance in 2005 - 2007.

Table 7. Comparison of percent occurrence of plants for the late summer plant surveys from 1997 through 2007 out to a depth of 7 feet. A curlyleaf pondweed control program has consisted of mechanical harvesting from 2000 - 2004 (yellow shading) and herbicide applications in 2005 - 2007 (pink shading).

	Percent Occurrence										
	1997 (72 stat on 36 trans)	1998 (72 stat on 36 trans)	1999 (72 stat on 36 trans)	2000 (72 stat on 36 trans)	2001 (72 stat on 36 trans	2002 (72 stat on 36 trans	2003 (72 stat on 36 trans)	2004 (72 stat on 36 trans)	2005 (72 stat on 36 trans)	2006 (72 stat on 36 trans)	2007 (72 stat on 36 trans)
Bulrush (*Scirpus sp*)	P	P	6	3	--	3	3	1	--	--	--
Cattails (*Tyhpa sp*)	P	P	7	4	3	8	--	--	--	--	--
Duckweed (*Lemna sp*)	--	--	7	7	--	7	15	18	6	--	1
Spatterdock (*Nuphar variegatum*)	17	24	21	21	15	29	29	14	19	18	11
Water waterlily (*Nymphaea sp*)	17	19	15	13	10	21	8	21	17	15	21
Watermeal (*Wolffia columbiana*)	--	--	--	--	--	--	--	--	--	10	3
Coontail (*Ceratophyllum demersum*)	24	35	40	47	25	38	40	40	53	50	44
Chara (*Chara sp*)	11	15	11	10	8	19	22	51	19	50	28
Elodea (*Elodea canadensis*)	--	--	1	--	1	--	--	4	--	--	--
Star duckweed (*Lemna trisulca*)	26	8	18	15	22	29	33	36	28	39	18
Northern watermilfoil (*Myriophyllum sibiricum*)	13	18	18	13	36	17	25	13	25	14	17
Watermilfoil hybrid (*Myriophyllum sp*)	--	--	--	22	4	9	32	43	17	14	31
Eurasian watermilfoil (*M. spicatum*)	--	--	--	--	--	--	--	--	--	--	1
Naiads (*Najas sp*)	1	--	4	--	3	1	4	4	--	--	3
Nitella (*Nitella sp*)	--	--	--	--	--	--	--	6	--	--	1
Cabbage (*Potamogeton. amplifolius*)	3	7	1	--	--	3	6	--	--	6	1
Curlyleaf pondweed (*P. crispus*)	15	--	7	--	4	7	28	4	1	1	--
Illinois pondweed (*P. illinoensis*)	--	--	8	7	7	13	14	21	3	1	8
Floatingleaf pondweed (*P. natans*)	--	--	--	--	--	--	--	--	--	1	--
Whitestem pondweed (*P. praelongus*)	--	--	--	--	--	--	--	--	3	6	1
Claspingleaf pondweed (*P. richardsonii*)	4	6	7	7	4	8	7	10	--	3	--
Robbins pondweed (*P. robbinsii*)	—	3	--	--	--	--	--	--	--	--	--
Stringy pondweed (*P. sp*)	--	3	--	1	--	--	3	--	--	--	--
Flatstem pondweed (*P. zosteriformis*)	17	1	7	--	13	7	6	22	--	--	--
Sago pondweed (*Stuckenia pectinata*)	6	--	4	6	4	7	7	--	--	8	7
Water celery (*Vallisneria americana*)	39	51	63	63	64	61	63	50	57	57	51
Water stargrass (*Zosterella dubia*)	19	28	32	33	31	21	40	24	14	17	15
Number of submerged species	12	11	14	11	14	14	15	14	10	14	14

The average number of submerged plant species per transect may have increased slightly since the 1997 plant survey from 3.25 species per transect in 1997 to 4.06 species per transect in 2007 (Table 8). Maybe the curlyleaf control program which started in 2000 has created openings allowing an increase in native plant distribution.

Table 8. Number of plant species per transect based on surveys conducted by Blue Water Science from 1997-2007.

Transect	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1	4	2	3	5	2	5	3	5	3	2	3
2	2	3	2	3	2	1	3	1	0	1	1
3	2	2	2	3	1	2	6	2	1	2	3
4	1	2	4	6	3	4	4	9	2	5	6
5	3	5	4	3	3	2	5	7	3	5	5
6	3	2	1	1	3	5	2	6	3	3	3
7	7	5	4	7	7	8	9	6	4	2	5
8	3	6	1	3	3	5	6	7	3	4	4
9	7	4	5	4	6	9	9	7	5	5	6
10	5	5	5	5	6	6	7	7	5	7	7
11	4	3	6	6	5	5	3	5	3	4	6
12	7	4	4	4	5	7	5	6	6	3	3
13	5	5	4	4	6	5	4	7	3	6	4
14	6	3	4	4	6	5	--	6	4	5	4
15	2	6	3	5	6	8	4	6	5	5	3
16	4	3	5	6	5	7	6	5	4	4	5
17	6	2	4	4	9	8	7	6	6	4	2
18	7	4	4	2	5	5	6	7	7	4	5
19	2	2	6	2	5	4	4	6	2	5	5
20	1	3	4	1	1	5	4	6	4	3	2
21	4	4	6	5	3	5	6	9	2	6	5
22	4	4	3	3	1	4	4	7	4	5	5
23	4	4	4	6	1	6	5	4	4	6	2
24	3	4	3	5	3	2	5	6	4	5	5
25	0	4	4	3	4	3	4	6	3	5	5
26	2	6	2	2	2	4	4	7	4	4	5
27	1	4	2	2	3	4	4	6	3	5	5
28	2	1	4	3	3	2	4	6	4	4	2
29	1	2	5	2	2	1	5	2	2	2	4
30	3	3	4	2	4	1	6	4	3	3	3
31	1	2	3	4	3	6	4	7	4	5	2
32	3	2	4	2	4	2	5	6	4	4	4
33	1	2	3	2	3	1	5	3	3	5	3
34	1	1	3	1	2	1	2	2	1	3	2
35	3	2	5	2	4	4	6	3	2	3	2
36	3	3	2	3	6	5	8	5	3	6	4
Range of species	0 - 7	1 - 6	1 - 6	1 - 7	1 - 7	1 - 9	2 - 9	1 - 9	0 - 7	1 - 7	1 - 7
Average Number per Transect	3.3	3.3	3.7	3.5	3.8	4.4	4.8	5.6	4.7	4.1	3.9
Number of Submerged Plant Species	12	11	14	11	14	14	15	14	10	14	14

Curlyleaf Pondweed Status: Curlyleaf pondweed is a non-native plant that grows to nuisance conditions in early summer in Bald Eagle Lake. It is the dominant plant in early summer covering about 29% of the lake representing about 293 acres based on survey data from 1998 and 2003. It grows out to 12 feet of water depth but grows to the surface in water depths out to 8 feet. It's distribution had stabilized around 300 acres of lake bottom coverage with approximately 180 acres of nuisance growth that reached the surface in 2000. Since the curlyleaf control program began in 2000, nuisance levels of curlyleaf pondweed have been estimated to decline to around 160 acres prior to treatment measures.

The Bald Eagle Area Association has sponsored a curlyleaf management program from 2000 - 2007 emphasizing mechanical harvesting from 2000 - 2004 and herbicide applications in 2005 - 2007. A summary of the program from 2000 - 2007 is found in Table 9.

Figure 6. [top] Transect 16 still exhibited nuisance curlyleaf growth in 2002 after two years of harvesting.
[bottom] Transect 15, at the north end of the lake, had moderate growth in 2004 after five years of harvesting. In the past this area had thick plant growth.

Curlyleaf Management Summary for 2000 - 2007: Mechanical harvesting has been employed on Bald Eagle Lake from 2000 - 2005, with the first five years of harvesting representing the primary curlyleaf control option. In the sixth year, 2005, herbicide treatments were the primary control option and harvesting was done on an "as-needed basis". In 2006 and 2007, only herbicides were used. Curlyleaf management results are shown in Table 9.

Table 9. Annual summary of harvesting and herbicide results from 2000 through 2007 for Bald Eagle Lake.

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2005**	**2006**	**2007**	**Totals**
Start date	Apr 27	May 14	May 17	May 2	May 10	Jun 5	Apr 28	Apr 27	Apr 11, 14	--
End date	Jun 17	Jun 21	Jun 20	Jun 13	Jun 2	Jun 11	--	--	--	--
Harvesting season	52 days	37 days	35 days	43 days	24 days	6 days	--	--	--	--
Harvesting Days	--	31	30	38	23	6	--	--	--	--
Harvester loads of plant removed	206	193	207	279	248	30	--	--	--	1,163
Area harvested (acres) or Treated (acres)	76 harvested	98 harvested	124 harvested	162 harvested	155 harvested	30 (est) harvested	98 treated	138 treated	138 treated	--
Pounds of curlyleaf removed from lake (lbs-wet wt)	420,240	353,190	378,810	510,570	453,840	54,900	0	0	0	2,171,550
Pounds of phosphorus removed from lake (lbs)	126	106	114	153	136	17	0	0	0	652
Cubic yards of plants removed (cu yds)	1,037	872	935	1,261	1,119	140	0	0	0	5,364
Actual hours of harvesting plants on the lake (hrs)	103	121	230	266	159	36	--	--	--	--
Total hours billed (hrs)	366	260	298	381	312	61	--	--	--	--
Harvesting efficiency	28%	47%	77%	70%	51%	60%	--	--	--	--
Costs	$43,387	$33,800	$35,492	$45,309	$37,128	$8,000	$30,000	$28,000	$28,000	$289,116
Cost per acre	$571	$345	$286	$280	$258	$267	$306	$286	$286	--
Hours per harvested acre (hrs/ac)	4.8	2.7	2.4	2.4	2.1	2.0	--	--	--	--

Eurasian Watermilfoil Status: Eurasian watermilfoil was first discovered in Bald Eagle Lake in 1989 and its distribution may have peaked in 1994. It was not detected in 1996 but was detected in a June 30, 1997 survey conducted by Ramsey County. A milfoil species with northern milfoil and Eurasian watermilfoil characteristics has been found in the lake since 1999 and was verified as a true milfoil hybrid in 2004 (pers. comm. MnDNR).

From 1999 through 2007 milfoil plants with characteristics of Eurasian watermilfoil were found and have been characterized as either an unidentified milfoil species or a milfoil hybrid. Maps of milfoil distribution in Bald Eagle Lake are shown in Figures 7 and 8.

Curlyleaf pondweed has been the primary plant managed in Bald Eagle Lake, but on occasion the milfoil hybrid has grown to the surface.

In mid summer of 2004, about 2 acres of the milfoil hybrid were harvested with a mechanical harvester on the west side of the lake (Transect 29 area). There was no Association-sponsored milfoil treatment in 2005, 2006, or 2007.

Figure 7. Typical form of the Bald Eagle Lake milfoil in September 2002. Milfoil typically grew in shallow water in bunches out to about 4 feet of water depth. The same type of milfoil was found in 2004 - 2007.

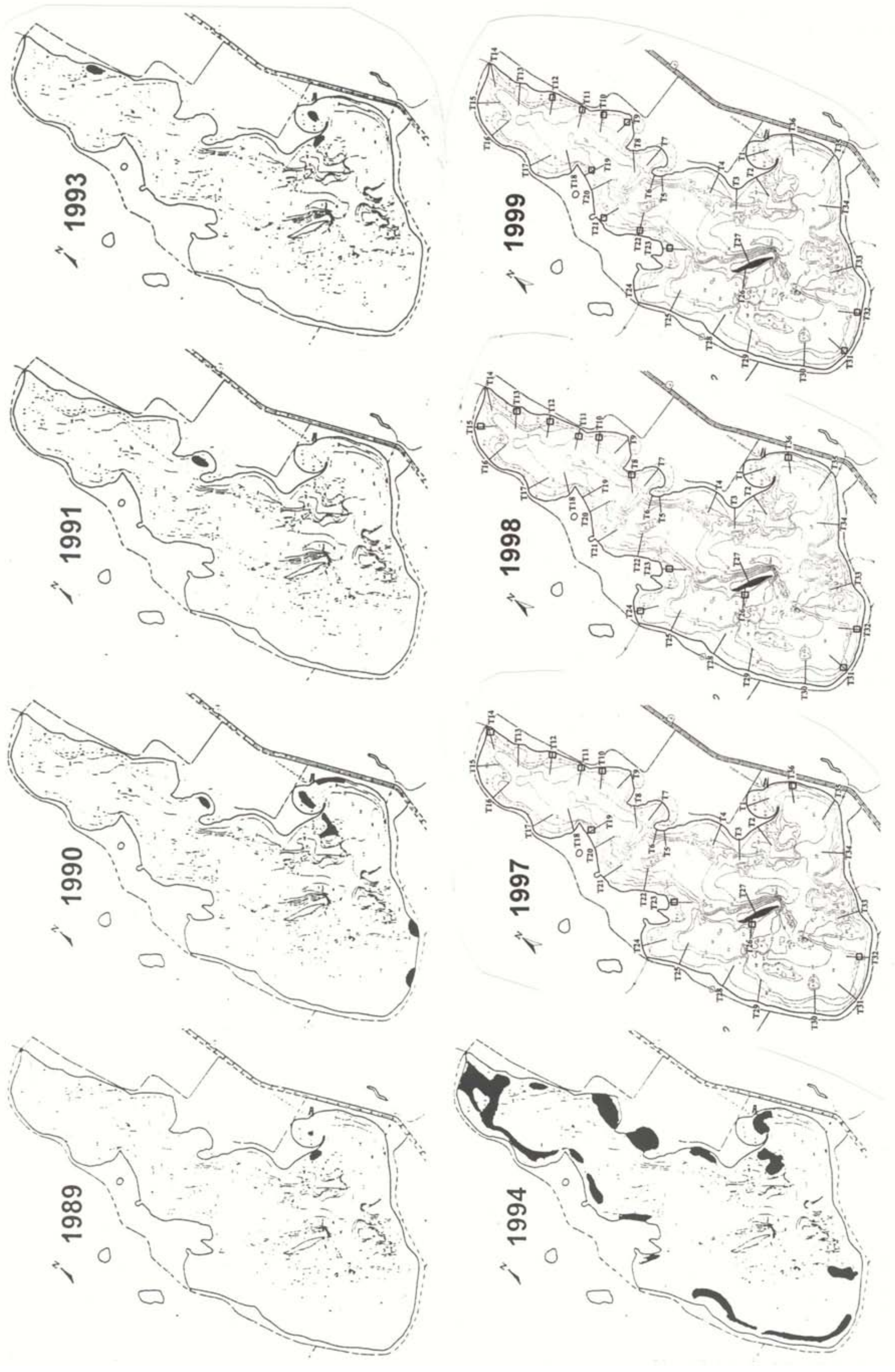


Figure 8. Eurasian watermilfoil distribution in Bald Eagle Lake from 1989-1994 is shown with black shading. For 1997-2004 northern milfoil shown with a G, and milfoil species with Eurasian watermilfoil characteristics shown with a M. Sources: MnDNR surveys in 1989, 1991, 1993, 1994; Midwest Aquacare in 1990; Ramsey County, 1997; and Blue Water Science, 1997-2007. Eurasian watermilfoil was not identified in Bald Eagle Lake in 1992, 1995, 1996, and 1998 - 2006.

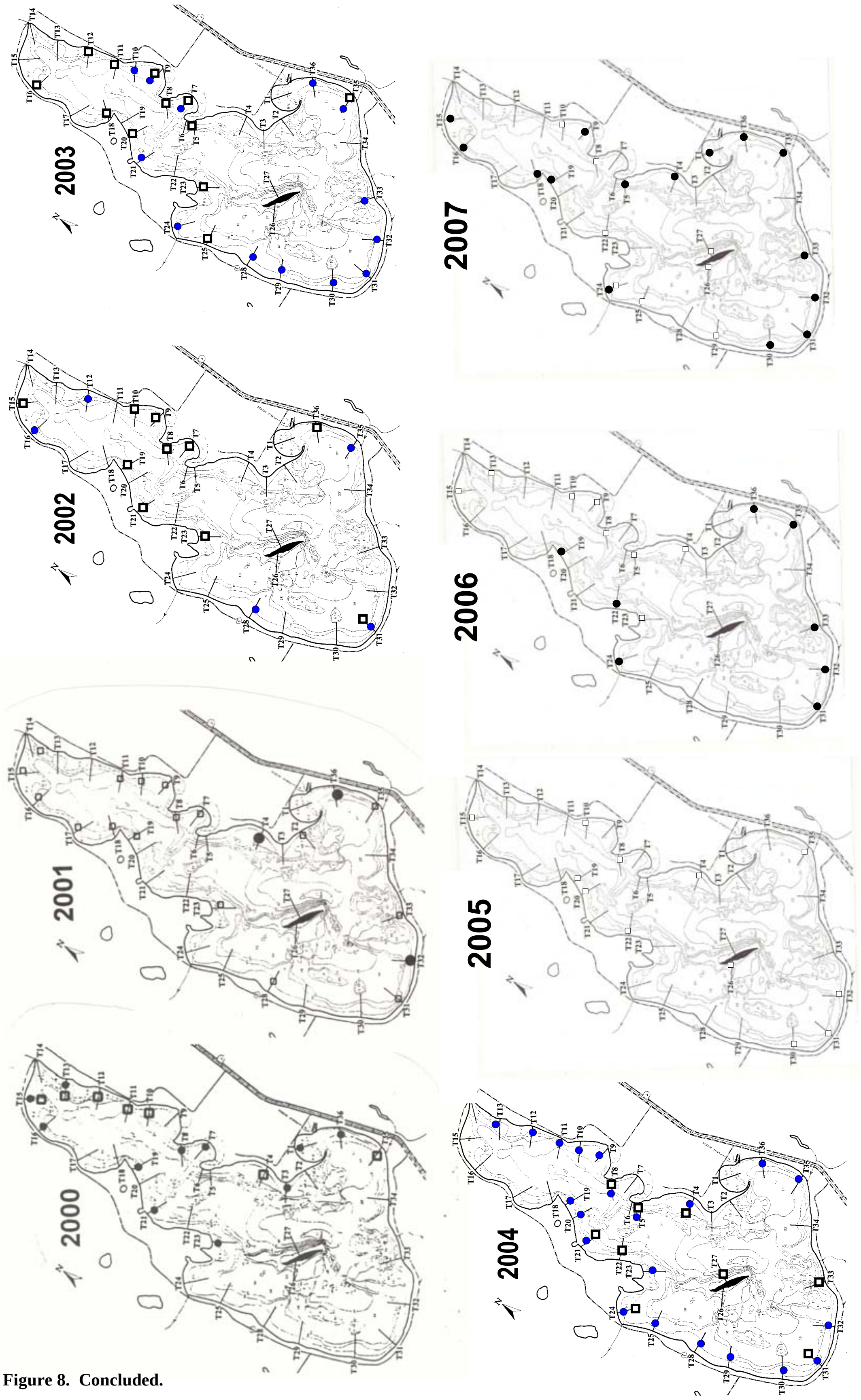


Figure 8. Concluded.

Bald Eagle Water Quality Summary from 1957 - 2007

Bald Eagle is a eutrophic lake based on phosphorus, clarity, and chlorophyll criteria. Seasonal average clarity measurements from 1957 through 2007 are shown in Figure 9. There was a water clarity improvement trend from 1981 through 1993 and then a water clarity decline from 1993 through 2001. Water clarity started to improve in 2002 and has continued through 2007 (using 2001 as a starting point).

Maybe the curlyleaf control program has had an influence in improving water clarity in the last few years.

A summary of water quality data for Secchi disc, chlorophyll a, and phosphorus is shown in Table 10.

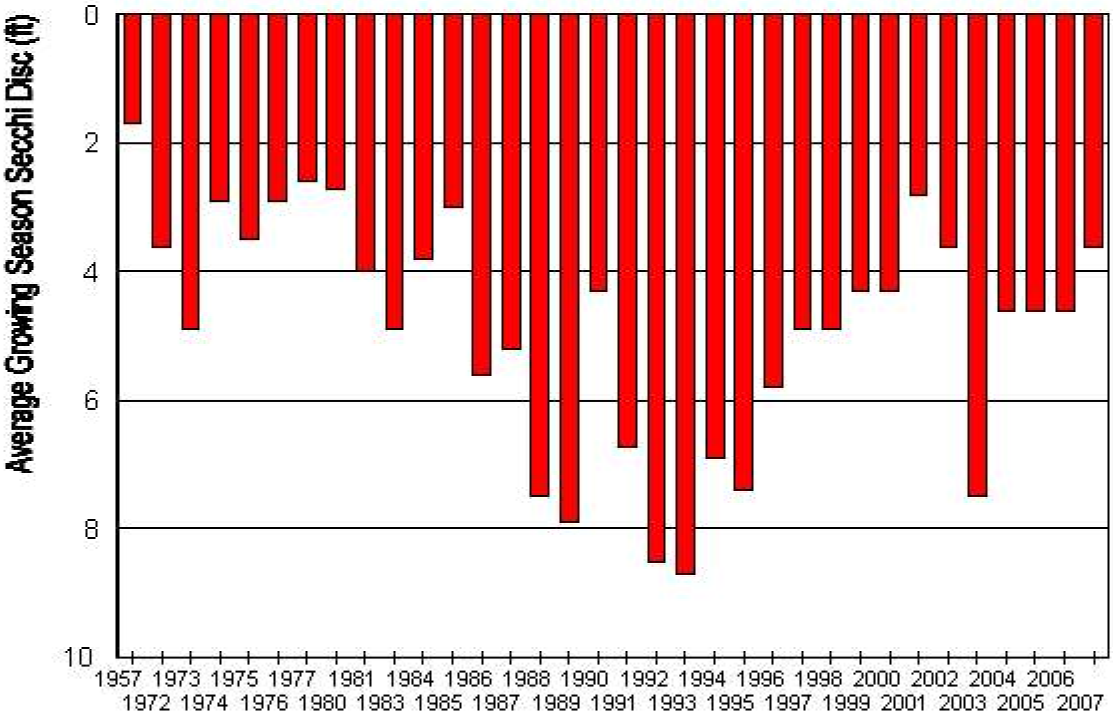


Figure 9. Water clarity seasonal averages.

Table 10. Summary of yearly means of STORET (1957-1997) and Ramsey County data (1998-present for May - September) for the given water quality parameters for Bald Eagle Lake. SD = stand deviation.

Year	Secchi Depth				Chlorophyll a			Total Phosphorus			Dissolved Ortho-P			Total Nitrogen (TKN)		
	m	ft	SD (m)	n	ug/l	SD	n	ug/l	SD	n	ug/l	SD	n	ug/l	SD	n
1957	0.53	1.7	0.88	1				100	114	1						
1971														2370	390	2
1972	1.1	3.6	0.88	1				177	66	3						
1973	1.48	4.9	0.24	14												
1974	0.88	2.9	0.24	13												
1975	1.08	3.5	0.2	20				60	47	6						
1976	0.88	2.9	0.44	4				48	57	4						
1977	0.79	2.6	0.21	18	20	25	4	75	57	4	20	25	4			
1980	0.81	2.7	0.33	7				82	43	7				1954	208	7
1981	1.22	4.0	0.4	5				63	38	9				1977	318	3
1983	1.48	4.9	0.4	5				64	30	14				1583	318	3
1984	1.15	3.8	0.62	2	20	19	7	12	38	9	20	19	7	1172	275	4
1985	0.91	3.0	0.88	1				13	66	3						
1986	1.71	5.6	0.16	30	38	7	56	121	14	65	38	7	56	1215	76	53
1987	1.58	5.2	0.18	24	50	8	39	114	17	45	50	8	39	1191	85	42
1988	2.29	7.5	0.31	8	24	8	36	73	19	36	24	8	36	1345	115	23
1989	2.4	7.9	0.36	6	40	10	26	108	22	26	40	10	26	1372	110	25
1990	1.3	4.3	0.16	30	33	9	31	81	20	31	33	9	31	1208	100	30
1991	2.03	6.7	0.28	10	34	8	36	89	19	36	34	8	36	1388	93	35
1992	2.6	8.5	0.33	7	12	10	28	64	22	28	13	10	28	1021	106	27
1993	2.64	8.7	0.31	8	18	9	32	51	20	32	18	9	32	981	304	28
1994	2.09	6.9	0.33	7	17	9	29	53	21	29	18	9	29	1015	102	29
1995	2.26	7.4	0.31	8	23	9	34	79	20	33	23	9	34	1321	123	20
1996	1.76	5.8	0.33	7	28	10	28	79	21	30	18	10	28	1580	106	27
1997	1.51	4.9	0.33	7	22	8	31	115	20	31	22	9	31	1559	108	26
1998	1.5	4.9	1.4	8	34	23	8	89	59	8	20	13	8	2000	900	8
1999	1.3	4.3	0.8	7	23	17	13	93	47	23	12	15	23	1650	460	19
2000	1.32	4.3	0.97	24	35	31	47	93	61	58						
2001	0.8	2.8	0.35	21	31	67	21	101	38	21						
2002	1.1	3.6		21	28		21	72		21						
2003	2.3	7.5		21	18		21	47		21						
2004	1.4	4.6	0.7	21	29		21	60		21				1237	363	45
2005	1.4	4.6	1.3	21	26	19	21	79	50	21	11	4	57			
2006	1.4	4.6	0.8	20	31	18	37	63	19	52				2	0.26	11
2007	1.1	3.6		21	34		21	64		21						

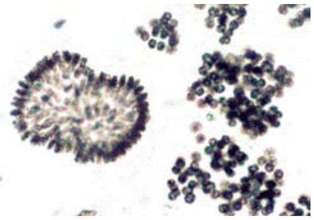
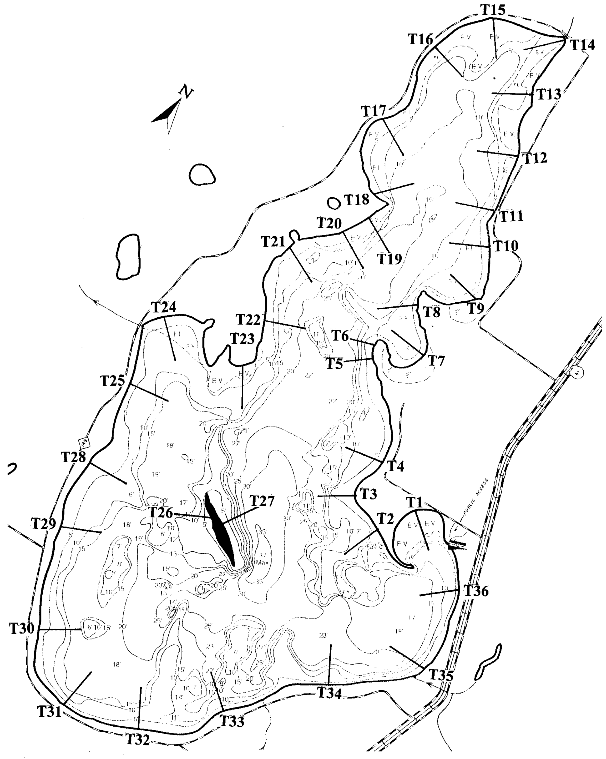


Figure 9. The dominant algae in Bald Eagle Lake in August are blue-green algae. The algae shown above are from Bald Eagle Lake on August 12, 2004 and are magnified 600 times.

APPENDIX

Appendix A. Transect Map and Location Description
Appendix B. Data from Previous Aquatic Plant Surveys

Appendix A. Transect Map and Location Description



Transect markers.

Transect Number	GPS Coordinates		Marker
	East	North	
1	04 99 713	49 95 369	Public access.
2			Fish house next to a cement seating area.
3	04 99 063	49 95 364	Point.
4	04 99 069	49 95 682	Small brown cabin with tan brick on the lower half.
5	04 99 032	49 95 832	
6	04 98 801	49 96 064	On the point south of the bar.
7	04 98 823	49 96 313	Sorenson’s bay.
8	04 98 855	49 96 399	Left of the yellow house.
9	04 98 935	49 96 683	Blue house in the cove.
10	04 99 000	49 96 828	Yard with a cyclone fence on the shoreline.
11	04 98 805	49 97 162	Boat marina/landing area.
12	04 98 629	49 97 508	Last home before the outlet.
13/14	04 98 669	49 97 677	Into cattail beds.
14			Head toward outlet.
15			To the left of Bobbers.
16	04 98 505	49 97 471	Right of a large 3-story house with a large wood retaining wall.
17	04 98 520	49 97 091	Left of the marina.
18	04 98 505	49 96 930	Gray shed.
19	04 98 668	49 96 582	Right of the bulrush beds.
20	04 98 431	49 96 276	Left of the bulrush beds, by a gazebo.
21	04 98 341	49 96 087	Left of a big boulder wall.
22	04 98 462	49 95 868	House with a rock wall below a wood retaining wall with a flag pole.
23	04 98 504	49 95 603	Came in on a point.
24	04 98 055	49 95 543	To the left of a cyclone fence.
25	04 97 983	49 95 323	To the right of the harvester landing.
26	04 98 763	49 94 993	On the side of the island.
27	04 98 652	49 94 860	On the side of the island.
28	04 98 164	49 94 897	Brick house to the left of a 3-story house.
29	04 98 106	49 94 496	In between 3 shoreline structures.
30	04 98 213	49 94 162	Left of a summer gazebo built on a keystone wall.
31	04 98 418	49 93 917	Left of a landing off the street.
32	04 98 714	49 93 920	Left of a yellow road sign.
33	04 99 034	49 94 080	Seating area on shore with a gray house in back. Boulder with rock riprap.
34	04 99 365	49 94 530	Left of a rock pile coming in on a jumble of big rocks.
35	04 99 700	49 94 790	In between two wood retaining walls that are off the shore a bit.
36	04 99 817	49 95 239	Last house before the park.

Appendix B. Data from Previous Aquatic Plant Surveys

2006: Bald Eagle Lake aquatic plant occurrences and densities for the September 4, 2006 survey based on 36 transects and 2 depths, for a total of 72 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-3 feet (n=36)			Depth 4-7 feet (n=36)			All Stations (n=72)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Star duckweed (*Lemna trisulca*)	11	31	1.0	17	47	0.6	28	39	0.7
Spatterdock (*Nuphar variegatum*)	9	25	3.0	4	11	0.9	13	18	2.3
Water lily (*Nymphaea sp*)	6	17	4.3	5	14	1.6	11	15	3.1
Watermeal (*Wolffia columbiana*)	4	11	1.5	3	8	0.4	7	10	1.0
Coontail (*Ceratophyllum demersum*)	14	39	1.8	22	61	1.2	36	50	1.5
Chara (*Chara sp*)	19	53	1.7	17	47	11	36	50	1.4
Northern watermilfoil (*Myriophyllum sibiricum*)	6	17	1.3	4	11	0.4	10	14	0.9
Watermilfoil (*Myriophyllum spp*)	5	14	1.6	5	14	0.6	10	14	0.8
Cabbage (*Potamogeton amplifolius*)	3	8	2.5	1	3	0.5	4	6	2.0
Curlyleaf pondweed (*P. crispus*)	--	--	--	1	3	0.2	1	1	0.2
Illinois pondweed (*P. Illinoensis*)	1	3	1.0	--	--	--	1	1	1.0
Floatingleaf pondweed (*P. natans*)	1	3	1.0	--	--	--	1	1	1.0
Whitestem pondweed (*P. praelongus*)	1	3	1.0	3	8	0.8	4	6	0.8
Claspingleaf pondweed (*P. Richardsonii*)	1	3	1.0	1	3	0.3	2	3	0.7
Sago pondweed (*Stuckenia pectinata*)	4	11	1.0	2	6	0.4	6	8	0.8
Water celery (*Vallisneria americana*)	24	67	2.0	17	47	1.1	41	57	1.6
Water stargrass (*Zosterella dubia*)	7	19	1.1	5	14	1.0	12	17	1.1
Filamentous algae	4	11	2.0	8	22	0.9	12	17	1.2

2005: Bald Eagle Lake aquatic plant occurrences and densities for the September 5, 2005 survey based on 36 transects and 2 depths, for a total of 72 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-3 feet (n=36)			Depth 4-7 feet (n=36)			All Stations (n=72)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Star duckweed (*Lemna trisulca*)	12	33	1.3	8	22	0.7	20	28	1.0
Duckweed (*Lemna sp*)	4	11	1.5	--	--	--	4	6	1.5
Spatterdock (*Nuphar variegatum*)	9	25	3.1	5	14	1.1	14	19	2.4
Water lily (*Nymphaea sp*)	9	25	3.4	3	8	1.4	12	17	2.9
Coontail (*Ceratophyllum demersum*)	19	53	1.9	19	53	1.4	38	53	1.6
Chara (*Chara sp*)	8	22	1.1	6	17	1.3	14	19	1.2
Northern watermilfoil (*Myriophyllum sibiricum*)	10	28	1.2	8	22	0.9	18	25	1.0
Watermilfoil (*Myriophyllum spp*)	5	14	1.2	7	19	0.7	12	17	0.9
Curlyleaf pondweed (*Potamogeton crispus*)	--	--	--	1	3	0.3	1	1	0.3
Illinois pondweed (*P. Illinoensis*)	2	6	1.0	--	--	--	2	3	1.0
Whitestem pondweed (*P. praelongus*)	--	--	--	2	6	0.9	2	3	0.9
Water celery (*Vallisneria americana*)	22	61	1.6	19	53	1.0	41	57	1.3
Water stargrass (*Zosterella dubia*)	5	14	1.8	5	14	1.0	10	14	1.4
Filamentous algae	--	--	--	1	3	1.0	1	1	1.0

2004: Bald Eagle Lake aquatic plant occurrences and densities for the August 12, 2004 survey based on 36 transects and 2 depths, for a total of 72 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-3 feet (n=36)			Depth 4-7 feet (n=36)			All Stations (n=72)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Bulrush - hardstem (*Scirpus acutus*)	1	3	1.0	--	--	--	1	1	1.0
Star duckweed (*Lemna trisulca*)	8	22	1.1	18	50	0.6	26	36	0.7
Duckweed (*Lemna sp*)	9	25	2.7	4	11	0.9	13	18	2.1
Spatterdock (*Nuphar variegatum*)	7	19	2.7	3	8	1.3	10	14	2.3
Water lily (*Nymphaea sp*)	11	31	2.5	4	11	0.8	15	21	2.0
Coontail (*Ceratophyllum demersum*)	10	28	3.2	17	53	2.0	29	40	2.4
Chara (*Chara sp*)	19	53	2.3	18	50	1.3	37	51	1.8
Elodea (*Elodea canadensis*)	2	6	1.0	1	3	0.5	3	4	0.8
Northern watermilfoil (*Myriophyllum sibiricum*)	3	8	1.7	6	17	0.8	9	13	1.1
Watermilfoil (*Myriophyllum spp*)	15	42	2.1	16	44	1.4	31	43	1.8
Naiads (*Najas sp*)	2	6	2.5	1	3	0.5	3	4	1.8
Nitella (*Nitella sp*)	--	--	--	4	11	0.9	4	6	0.9
Curlyleaf pondweed (*Potamogeton crispus*)	--	--	--	3	8	0.5	3	4	0.5
Illinois pondweed (*P. illinoensis*)	7	9	1.6	8	22	1.0	15	21	1.3
Claspingleaf pondweed (*P. richardsonii*)	4	11	1.3	3	8	0.4	7	10	1.0
Flatstem pondweed (*P. zosteriformis*)	5	14	1.4	11	31	1.0	16	22	1.1
Water celery (*Vallisneria americana*)	23	64	1.9	13	36	1.2	36	50	1.6
Water stargrass (*Zosterella dubia*)	8	22	1.5	9	25	0.9	17	24	1.2
Filamentous algae	2	6	2.0	5	14	0.6	7	10	1.0

2003: Bald Eagle Lake aquatic plant occurrences and densities for the May 2003 survey based on 36 transects and 2 depths, for a total of 72 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-3 feet (n=36)			Depth 4-7 feet (n=36)			Depth 8-11 feet (n=36)			All Stations (n=108)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Bulrush (*Scirpus sp*)	1	3	3.0	--	--	--	--	--	--	1	1	3.0
Star duckweed (*Lemna trisulca*)	2	6	1.0	2	6	0.5	--	--	--	4	4	0.8
Water lily (*sp*)	2	6	1.0	1	3	0.5	--	--	--	3	3	0.8
Coontail (*Ceratophyllum demersum*)	3	8	1.3	2	6	1.0	--	--	--	5	5	1.2
Chara (*Chara sp*)	7	19	1.4	10	28	0.9	3	8	0.5	20	19	1.0
Northern watermilfoil (*Myriophyllum sibiricum*)	1	3	1.0	1	3	0.5	--	--	--	2	2	0.8
Watermilfoil (*Myriophyllum spp*)	--	--	--	1	3	2.5	--	--	--	1	1	2.5
Curlyleaf pondweed (*Potamogeton crispus*)	15	42	2.4	27	75	2.6	24	67	2.4	66	61	2.5
Illinois pondweed (*Potamogeton illinoensis*)	1	3	1.0	1	3	1.0	1	3	0.5	3	3	0.8
Flatstem pondweed (*P. zosteriformis*)	1	3	1.0	--	--	--	--	--	--	1	1	1.0
Sago pondweed (*Stuckenia pectinata*)	1	3	0.5	1	3	0.5	1	3	0.5	3	3	0.5
Water stargrass (*Zosterella dubia*)	3	8	1.3	1	3	2.0	--	--	--	4	4	1.5
Filamentous algae	13	36	1.2	13	36	0.7	3	8	0.7	29	27	0.9

2003: Bald Eagle Lake aquatic plant occurrences and densities for the September 17, 2003 survey based on 36 transects and 2 depths, for a total of 72 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-3 feet (n=36)			Depth 4-7 feet (n=36)			All Stations (n=72)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Bulrush (*Scirpus sp*)	1	3	3.0	1	3	1.5	2	3	2.3
Star duckweed (*Lemna trisulca*)	7	19	1.0	17	47	0.7	24	33	0.8
Duckweed (*Lemna sp*)	6	17	1.5	5	14	0.7	11	15	1.1
Spatterdock (*Nuphar variegatum*)	11	31	3.5	10	28	1.5	21	29	2.5
Water lily (*Nymphaea sp*)	3	8	1.7	3	8	0.7	6	8	1.2
Coontail (*Ceratophyllum demersum*)	13	36	2.2	16	44	1.3	29	40	1.7
Chara (*Chara sp*)	7	19	1.7	9	25	0.9	16	22	1.3
Northern watermilfoil (*Myriophyllum sibiricum*)	9	25	2.1	9	25	1.1	18	25	1.6
Watermilfoil (*Myriophyllum spp*)	11	31	3.1	12	33	1.5	23	32	2.3
Naiads (*Najas sp*)	1	3	1.0	2	6	0.5	3	4	0.7
Cabbage (*Potamogeton amplifolius*)	2	6	1.5	2	6	1.5	4	6	1.5
Curlyleaf pondweed (*P. crispus*)	3	8	1.7	17	47	0.7	20	28	0.8
Illinois pondweed (*P. illinoensis*)	4	11	1.5	6	17	0.8	10	14	1.1
Claspingleaf pondweed (*P. richardsonii*)	3	8	0.8	2	6	0.5	5	7	0.7
Flatstem pondweed (*P. zosteriformis*)	--	--	--	4	11	0.8	4	6	0.8
Stringy pondweed (*P. sp*)	1	3	3.0	1	3	2.0	2	3	2.5
Sago pondweed (*Stuckenia pectinata*)	3	8	2.0	2	6	1.0	5	7	1.6
Water celery (*Vallisneria americana*)	24	67	2.2	21	58	1.1	45	63	1.7
Water stargrass (*Zosterella dubia*)	15	42	1.7	14	39	0.9	29	40	1.3
Filamentous algae	8	22	1.3	10	28	0.8	18	25	1.0

2002: Bald Eagle Lake aquatic plant occurrences and densities for the September 9, 2002 survey based on 36 transects and 2 depths, for a total of 72 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-3 feet (n=36)			Depth 4-7 feet (n=36)			All Stations (n=72)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Bulrush (*Scirpus sp*)	1	3	3.0	1	3	1.5	2	3	2.3
Cattails (*Typha sp*)	6	17	4.0	--	--	--	6	8	4.0
Star duckweed (*Lemna trisulca*)	12	33	1.4	9	25	0.9	21	29	1.2
Duckweed (*Lemna sp*)	4	11	2.0	1	3	1.0	5	7	1.8
Spatterdock (*Nuphar variegatum*)	12	33	2.8	9	25	1.7	21	29	2.3
Water lily (*Nymphaea sp*)	11	31	2.2	4	11	0.8	15	21	1.8
Cabbage (*Potamogeton amplifolius*)	1	3	1.0	1	3	2.0	2	3	1.5
Chara (*Chara sp*)	10	28	1.3	4	11	1.4	14	19	1.3
Claspingleaf pondweed (*Potamogeton richardsonii*)	3	8	1.2	3	8	0.8	6	8	0.9
Coontail (*Ceratophyllum demersum*)	13	36	0.8	14	39	1.0	27	38	1.3
Curlyleaf pondweed (*P. crispus*)	3	8	1.2	2	6	0.5	5	7	0.9
Eurasian watermilfoil (*Myriophyllum spicatum*)	--	--	--	1	3	1.0	1	1	1.0
Flatstem pondweed (*Potamogeton zosteriformis*)	1	3	0.5	4	11	0.8	5	7	0.7
Illinois pondweed (*Potamogeton illinoensis*)	1	3	1.0	8	22	0.8	9	13	0.8
Naiads (*Najas sp*)	1	3	1.0	--	--	--	1	1	1.0
Northern watermilfoil (*Myriophyllum sibiricum*)	8	22	0.8	4	11	0.6	12	17	0.8
Watermilfoil (*Myriophyllum spp*)	4	11	1.1	2	6	1.5	6	8	1.3
Sago pondweed (*Potamogeton pectinatus*)	3	8	1.3	2	6	0.8	5	7	1.1
Water celery (*Vallisneria americana*)	23	64	1.7	21	58	1.1	44	61	1.4
Water stargrass (*Zosterella dubia*)	11	31	0.8	4	11	0.5	15	21	1.1
Filamentous algae									

2001: Bald Eagle Lake aquatic plant occurrences and densities for the September 2, 2001 survey based on 36 transects and 2 depths, for a total of 72 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-3 feet (n=36)			Depth 4-7 feet (n=36)			All Stations (n=72)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Purple loosestrife (*Lythrum salicaria*)	2	6	0.8	--	--	--	2	3	0.8
Cattails (*Typha sp*)	2	6	5.0	--	--	--	2	3	5.0
Star duckweed (*Lemna trisulca*)	8	22	1.3	8	22	0.9	16	22	1.1
Spatterdock (*Nuphar variegatum*)	8	22	3.0	3	8	3.3	11	15	3.1
Water lily (*Nymphaea sp*)	6	17	2.9	1	3	4.0	7	10	3.1
Chara (*Chara sp*)	5	14	1.3	1	3	2.0	6	8	1.4
Claspingleaf pondweed (*Potamogeton richardsonii*)	1	3	1.0	2	6	1.0	3	4	1.0
Coontail (*Ceratophyllum demersum*)	8	22	2.4	10	28	1.6	18	25	1.9
Curlyleaf pondweed (*P. crispus*)	1	3	1.0	2	6	1.0	3	4	1.0
Elodea (*Elodea canadensis*)	--	--	--	1	3	1.0	1	1	1.0
Flatstem pondweed (*Potamogeton zosteriformis*)	6	17	0.8	3	8	0.7	9	13	0.8
Illinois pondweed (*Potamogeton illinoensis*)	4	11	1.0	1	3	0.5	5	7	0.9
Naiads (*Najas sp*)	2	6	0.8	--	--	--	2	3	0.8
Northern watermilfoil (*Myriophyllum sibiricum*)	15	42	1.3	11	31	0.9	26	36	1.1
Watermilfoil (*Myriophyllum spp*)	2	6	2.0	1	3	1	3	4	1.7
Sago pondweed (*Potamogeton pectinatus*)	2	6	0.8	1	3	0.5	3	4	0.7
Water celery (*Vallisneria americana*)	26	72	1.8	20	56	1.1	46	64	1.5
Water stargrass (*Zosterella dubia*)	17	47	1.2	5	14	1.0	22	31	1.2
Filamentous algae	1	3	1.0	2	6	1.5	3	4	1.3

2000: Bald Eagle Lake aquatic plant occurrences and densities for the September 23, 2000 survey based on 36 transects and 2 depths, for a total of 72 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-3 feet (n=36)			Depth 4-7 feet (n=36)			All Stations (n=72)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Bulrush (*Scirpus sp*)	1	3	3.0	1	3	2.0	2	3	2.5
Cattails (*Typha sp*)	3	8	4.3	--	--	--	3	4	4.3
Duckweed (*Lemna sp*)	4	11	2.0	1	3	1.0	5	7	1.8
Star duckweed (*Lemna trisulca*)	7	19	1.4	4	11	1.0	11	15	1.3
Spatterdock (*Nuphar variegatum*)	9	25	2.4	6	17	1.5	15	21	2.1
Water lily (*Nymphaea sp*)	6	17	1.8	3	8	1.3	9	13	1.7
Chara (*Chara sp*)	4	11	1.0	3	8	1.0	7	10	1.0
Claspingleaf pondweed (*Potamogeton richardsonii*)	2	6	1.0	3	8	1.0	5	7	1.0
Coontail (*Ceratophyllum demersum*)	15	42	2.2	19	53	1.7	34	47	1.9
Illinois pondweed (*Potamogeton illinoensis*)	2	6	1.0	3	8	1.0	5	7	1.0
Northern watermilfoil (*Myriophyllum sibiricum*)	4	11	1.0	5	14	1.0	9	13	1.0
Watermilfoil (*Myriophyllum spp*)	9	25	1.4	7	19	1.1	16	22	1.3
Sago pondweed (*Potamogeton pectinatus*)	3	3	1.3	1	3	1.0	4	6	1.3
Stringy pondweed (*Potamogeton spp*)	1	3	1.0	--	--	--	1	1	1.0
Water celery (*Vallisneria americana*)	23	64	1.8	22	61	1.4	45	63	1.6
Water stargrass (*Zosterella dubia*)	15	42	1.4	9	25	1.3	24	33	1.4

1999: Bald Eagle Lake aquatic plant occurrences and densities for the September 13 & 14, 1999 survey based on 36 transects and 3 depths, for a total of 108 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-3 feet (n=36)			Depth 4-7 feet (n=36)			Depth 8-11 feet (n=36)			All Stations (n=108)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Bulrush (*Scirpus sp*)	2	6	2.0	2	6	3.0	--	--	--	4	4	2.5
Cattails (*Typha sp*)	5	14	3.6	--	--	--	--	--	--	5	5	3.6
Duckweed (*Lemna sp*)	4	11	2.5	1	3	1.0	--	--	--	5	5	2.2
Star duckweed (*Lemna trisulca*)	6	17	1.8	7	19	1.0	--	--	--	13	12	1.4
Spatterdock (*Nuphar variegatum*)	8	22	3.0	7	19	1.7	--	--	--	15	14	2.4
Water lily (*Nymphaea sp*)	6	17	1.2	5	14	1.2	--	--	--	11	10	1.2
Cabbage (*P. amplifolius*)	1	3	1.0	--	--	--	--	--	--	1	1	1.0
Chara (*Chara sp*)	2	6	1.0	6	17	1.2	--	--	--	8	7	1.1
Claspingleaf pondweed (*Potamogeton richardsonii*)	2	6	1.0	3	8	1.0	--	--	--	5	5	1.0
Coontail (*Ceratophyllum demersum*)	14	39	2.4	15	42	1.6	--	--	--	29	27	2.0
Curlyleaf pondweed (*Potamogeton crispus*)	--	--	--	4	11	1.0	2	6	1.0	6	6	1.0
Elodea (*Elodea canadensis*)	1	3	1.0	--	--	--	--	--	--	1	1	1.0
Flatstem pondweed (*Potamogeton zosteriformis*)	4	11	1.0	1	3	1.0	--	--	--	5	5	1.0
Illinois pondweed (*Potamogeton illinoensis*)	3	8	1.0	3	8	1.0	--	--	--	6	6	1.0
Naiads (*Najas sp*)	2	6	1.0	1	3	1.0	--	--	--	3	3	1.0
Northern watermilfoil (*Myriophyllum sibiricum*)	8	22	1.0	5	14	1.0	--	--	--	13	12	1.0
Sago pondweed (*Potamogeton pectinatus*)	3	8	1.0	--	--	--	--	--	--	3	3	1.0
Water celery (*Vallisneria americana*)	24	67	2.2	21	58	2.0	--	--	--	45	42	2.1
Water stargrass (*Zosterella dubia*)	14	39	1.4	9	25	1.3	--	--	--	23	21	1.3

1998: Bald Eagle Lake aquatic plant occurrences and densities for the June 1 and 5, 1998 survey based on 36 transects and 3 depths, for a total of 108 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-3 feet (n=36)			Depth 4-7 feet (n=36)			Depth 8-11 feet (n=24)			All Stations (n=96)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Star duckweed (*Lemna trisulca*)	--	--	--	1	3	1.0	--	--	--	1	1	1.0
Water lily/Spatterdock (*Nymphaea sp*/Nuphar variegatum)	1	3	1.0	1	3	2.0	1	4	5.0	3	3	2.7
Chara (*Chara sp*)	7	19	2.7	10	28	2.9	1	4	1.0	18	19	2.7
Coontail (*Ceratophyllum demersum*)	2	6	2.5	3	8	1.7	--	--	--	5	5	2.0
Curlyleaf pondweed (*Potamogeton crispus*)	2	6	1.0	23	64	3.4	22	92	3.9	47	49	3.5
Flatstem pondweed (*Potamogeton zosteriformis*)	1	3	1.0	--	--	--	--	--	--	1	1	1.0
Broadleaf pondweed (P. sp	--	--	--	--	--	--	1	4	1.0	1	1	1.0
Stringy pondweed (P. sp	1	3	3.0	6	17	2.8	--	--	--	7	7	2.8
Sago pondweed (*Potamogeton pectinatus*)	--	--	--	1	3	1.0	--	--	--	1	1	1.0
Water celery (*Vallisneria americana*)	3	8	1.3	2	6	1.0	--	--	--	5	5	12
Water stargrass (*Zosterella dubia*)	1	3	1.0	1	3	1.0	--	--	--	2	2	1.0

1998: Bald Eagle Lake aquatic plant occurrences and densities for the September 4, 1998 survey based on 36 transects and 2 depths, for a total of 72 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-3 feet (n=36)			Depth 4-7 feet (n=36)			All Stations (n=72)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Star duckweed (*Lemna trisulca*)	4	11	1.5	2	6	1.8	6	8	1.6
Spatterdock (*Nuphar variegatum*)	9	25	2.0	8	22	2.0	17	24	2.0
Water lily (*Nymphaea sp*)	7	19	1.8	7	19	1.4	14	19	1.6
Cabbage (*Potamogeton amplifolius*)	4	11	1.0	1	3	1.0	5	7	1.0
Chara (*Chara sp*)	8	22	1.9	3	8	1.3	11	15	1.7
Claspingleaf pondweed (*P. richardsonii*)	4	11	1.0	--	--	--	4	6	1.0
Coontail (*Ceratophyllum demersum*)	12	33	2.8	13	36	2.7	25	35	2.7
Flatstem pondweed (*P. zosteriformis*)	1	3	1.0	--	--	--	1	1	1.0
Northern watermilfoil (*Myriophyllum sibiricum*)	7	19	1.3	6	17	1.5	13	18	1.4
Robbins pondweed (*P. robbinsii*)	--	--	--	2	6	1.0	2	3	1.0
Stringy pondweed (*P. sp*)	1	3	2.0	1	3	1.0	2	3	1.5
Water celery (*Vallisneria americana*)	22	61	2.5	15	42	2.5	37	51	2.5
Water stargrass (*Zosterella dubia*)	11	31	1.6	9	25	1.6	20	28	1.6

1997: Bald Eagle Lake aquatic plant occurrences and densities for the September 24, 1997 survey based on 36 transects and 2 depths, for a total of 72 stations. Density ratings are 1-5 with 1 being low and 5 being most dense.

	Depth 0-3 feet (n=36)			Depth 4-7 feet (n=36)			All Stations (n=72)		
	Occur	% Occur	Density	Occur	% Occur	Density	Occur	% Occur	Density
Bulrush (*Scirpus sp*)	--	--	--	2	6	1.0	2	3	1.0
Cattails (*Typha sp*)	4	11	1.3	1	3	1.0	5	7	1.2
Duckweed (*Lemna sp*)	2	6	2.0	1	3	1.0	3	4	1.7
Star duckweed (*Lemna trisulca*)	6	17	3.0	13	36	2.3	19	26	2.5
Spatterdock (*Nuphar variegatum*)	7	19	2.6	5	14	3.0	12	17	2.8
Water lily (*Nymphaea sp*)	6	17	2.2	6	17	2.2	12	17	2.2
Cabbage (*P. amplifolius*)	2	6	1.5	--	--	--	2	3	1.5
Chara (*Chara sp*)	3	8	2.0	5	14	1.6	8	11	1.8
Claspingleaf pondweed (*Potamogeton richardsonii*)	1	3	1.0	2	6	1.0	3	4	1.0
Coontail (*Ceratophyllum demersum*)	6	17	3.9	11	131	2.5	17	24	3.0
Curlyleaf pondweed (*Potamogeton crispus*)	2	6	1.0	9	25	2.1	11	15	1.8
Flatstem pondweed (*Potamogeton zosteriformis*)	4	11	1.5	8	22	1.8	12	17	1.7
Naiads (*Najas sp*)	1	3	1.0	--	--	--	1	1	1.0
Northern watermilfoil (*Myriophyllum sibiricum*)	5	14	1.0	4	11	1.5	9	13	1.2
Sago pondweed (*Potamogeton pectinatus*)	1	3	3.0	1	3	1.0	4	6	1.0
Water celery (*Vallisneria americana*)	11	31	2.1	17	47	2.7	28	39	2.4
Water stargrass (*Zosterella dubia*)	6	17	1.8	8	44	2.0	14	19	1.9

Summary of Milfoil Occurrences from 1997 - 2006

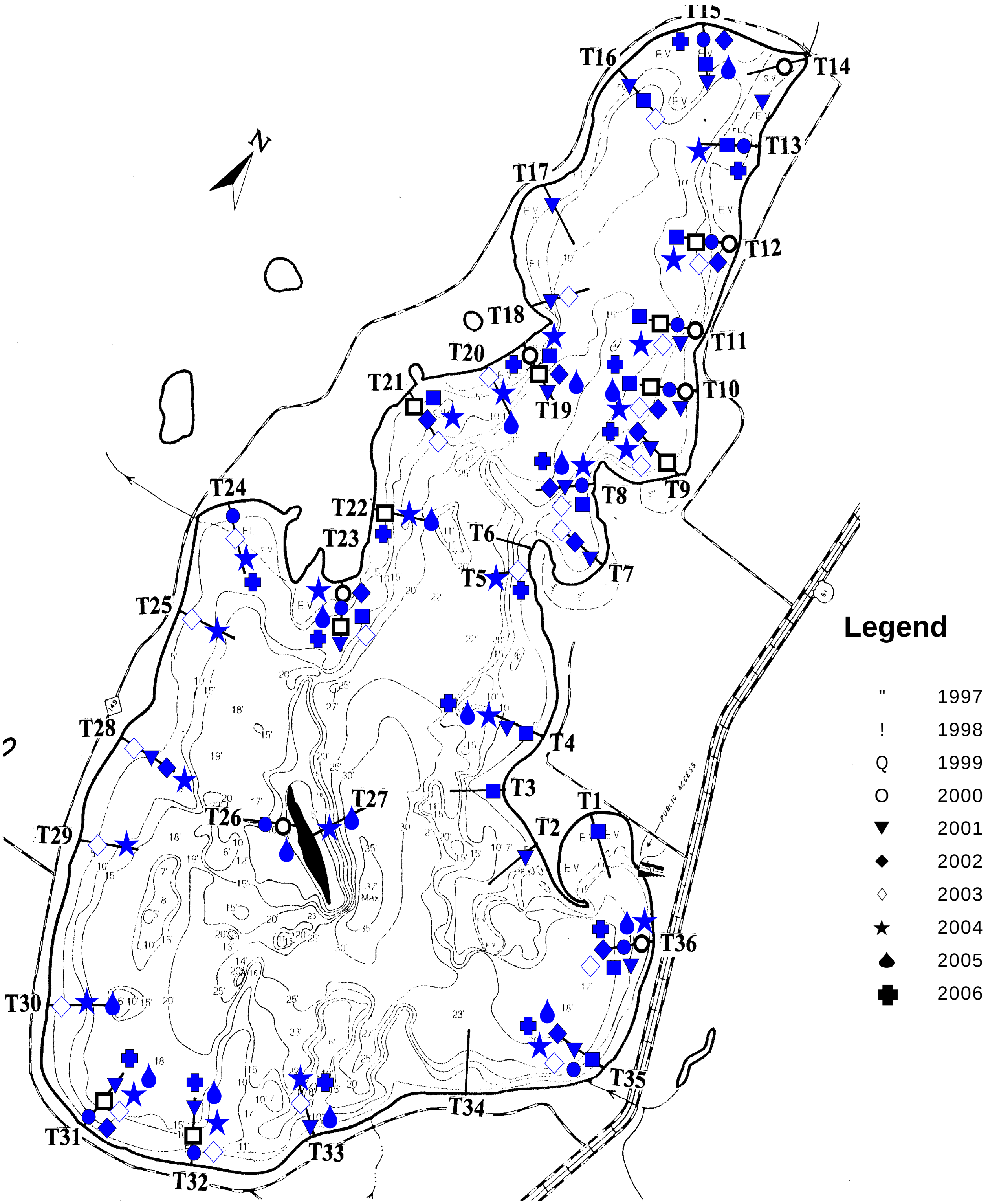


Figure 7. Distribution of all watermilfoil species in Bald Eagle Lake from 1997 through 2006.

Appendix C

P8 Model

Wenck Associates, Inc.
1800 Pioneer Creek Ctr.
P.O. Box 249
Maple Plain, MN 55359-0249

(763) 479-4200
Fax (763) 479-4242
E-mail: wenckmp@wenck.com

TECHNICAL MEMORANDUM

TO: **RCWD**

FROM: **Jeremy Schultz**
Joe Bischoff

DATE: January 15, 2010

SUBJECT: Bald Eagle Lake TMDL P8 Model Construction

CC:

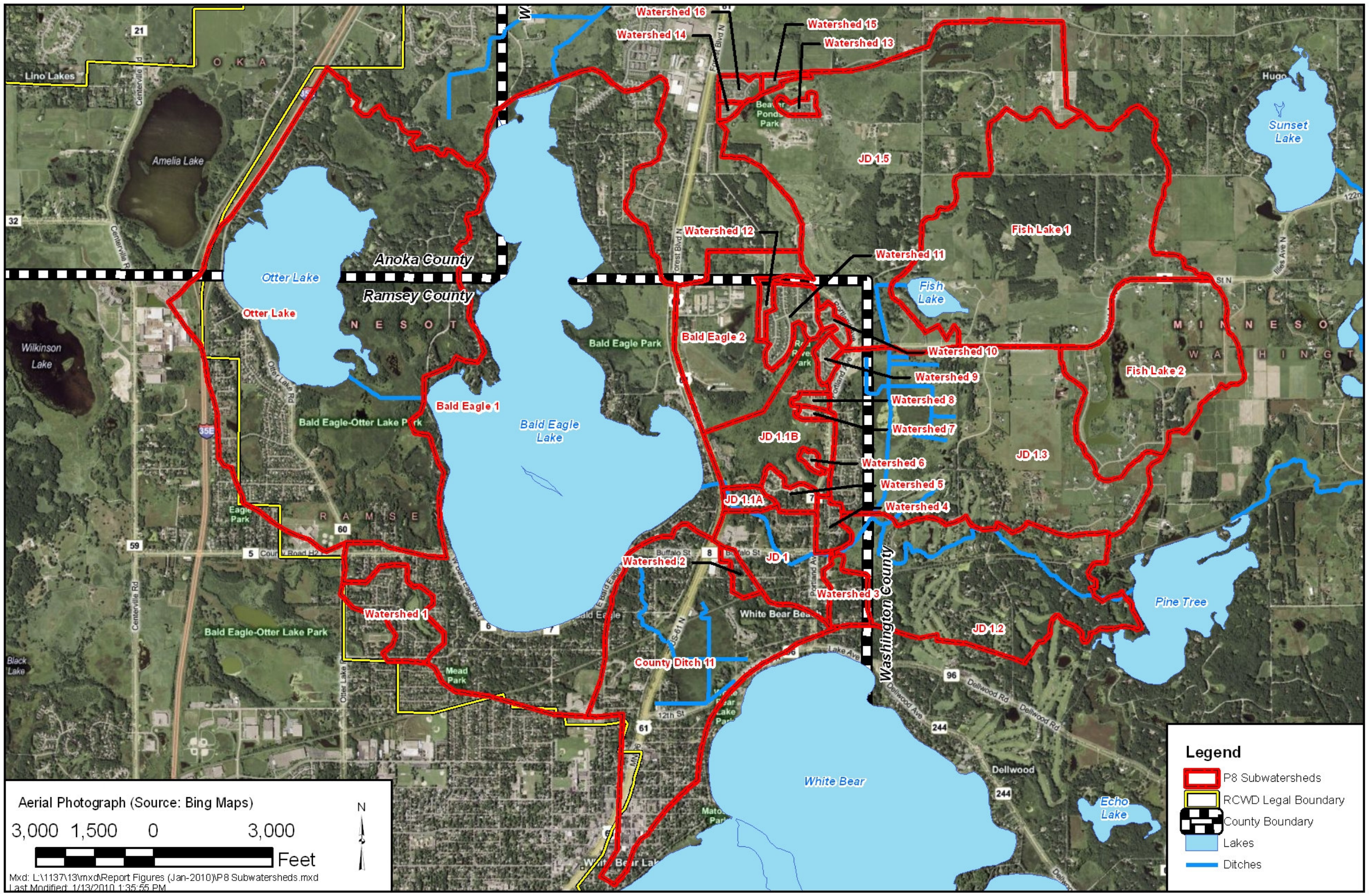
Pollutant Loading

Phosphorous loading due to direct runoff from the lake watersheds was estimated using P8, the Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds (Walker 2007, Version 3.2). P8 models simulate the build up and wash off of stormwater pollutants using mass and water balance calculations through a user defined drainage system. The key components of P8 models are watersheds, devices, particles and water quality components. The rainfall and snowmelt causing runoff is generated by hourly precipitation and daily air temperature files.

The P8 model tracks pollutant loading by building up particles on a watershed, then washing off the particles through the precipitation and temperature files and routing them to devices (ponds, infiltration basins, pipes, etc). The pollutant removal efficiency of the device is then evaluated and the pollutants not removed are routed downstream in the watershed until finally depositing in Bald Eagle Lake.

Watershed Delineation

The P8 model created for the Bald Eagle Lake TMDL separated the Bald Eagle Lake watershed in to 28 sub-watersheds. 18 of the 28 sub-watersheds directed runoff to key stormwater ponds identified through aerial inspection. Sub watershed boundaries to the ponds were delineated using 2' contours and stormsewer pipe networks. The remaining watersheds were also delineated using 2' contours and were based on geographical features such county ditches and monitoring station locations for calibration. The P8 model built for the Bald Eagle TMDL essentially has 3 branches flowing in to the lake. Those branches are for direct runoff to the lake, the County Ditch 11 (CD 11) system and the Judicial Ditch 1 (JD 1) system. Ponds 1.1A and 1.1B on the JD 1 system were constructed in 2002 and were only included in the models in the years 2002-2008. See Figure 1 for sub-watershed boundaries and pond locations.



RICE CREEK WATERSHED DISTRICT

P8 Subwatersheds

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Wenck

Wenck Associates, Inc.
Environmental Engineers

1800 Pioneer Creek Center
Maple Plain, MN 55359-0429

JAN 2010

P8 Model Development

P8 input parameters not discussed within this memo remain as the P8 model default values.

Watersheds

Key watershed input parameters are:

- Area
- Total area impervious fraction
- Pervious area SCS curve number

The area considered in the P8 model watershed is only the upland area and does not include open water.

The impervious fraction of each P8 watershed was determined using the Minnesota Land Cover Classification System (MLCCS) land uses with each land use having an assigned impervious percent. The MLCCS was provided by the Rice Creek Watershed District and the area of each land use within the watershed was determined in GIS. The final impervious fraction was calculated by the area weighted method. Land uses and their assigned impervious percentages are provided in Table 1.

The pervious area curve number was determined by overlaying the MLCCS land uses with the hydrologic soil type. All MLCCS land uses were assigned a ground cover type such as lawn, woods, wetland, ect. Curve numbers are then based on ground cover type and hydrologic soil type. The area of each land with its assigned cover type and soil classification within each watershed was determined in GIS and the pervious area curve number was calculated by the area weighted method. (See Tables 1 and 2)

Table 1 - MLCCS Land Use Categories, Pervious Ground Cover and Impervious Percentages

MLCCS Land Use	Pervious Cover Type	Impervious %
11% to 25% impervious cover with coniferous and/or deciduous shrubs	Open Space/Lawn	17
26% to 50% impervious cover with coniferous trees	Woods-Good	38
26% to 50% impervious cover with perennial grasses and sparse trees	Compacted Lawn	38
4% to 10% impervious cover with perennial grasses and sparse trees	Open Space/Lawn	7
51% to 75% impervious cover with perennial grasses and sparse trees	Compacted Lawn	63
91% to 100% impervious cover	Compacted Lawn	95
All other close grown cropland on upland soils	Close Seeded Legumes - G	0
Altered/non-native deciduous forest	Woods-Fair	0
Altered/non-native deciduous woodland	Woods-Fair	0
Altered/non-native dominated seasonally flooded shrubland	Brush-Good	0
Altered/non-native dominated upland shrubland	Brush-Good	0
Altered/non-native grassland with sparse deciduous trees - saturated soils	Wetland	0
Altered/non-native mixed woodland	Woods-Fair	0
Artificial surfaces with coniferous trees	Woods/Grass-Fair	0
Artificial surfaces with coniferous trees	Woods/Grass-Fair	0
Aspen (forest, woodland) with 11- 25% impervious cover	Woods-Good	17
Aspen (forest, woodland) with 4-10% impervious cover	Woods-Good	7
Aspen forest	Woods-Good	0

MLCCS Land Use	Pervious Cover Type	Impervious %
Aspen forest - saturated soils	Wetland	0
Aspen forest - temporaily flooded	Woods-Good	0
Aspen woodland	Woods-Good	0
Black ash swamp - seasonally flooded	Wetland	0
Boxelder-green ash (forest) with 26-50% impervious cover	Woods-Fair	38
Buildings and pavement with 76-90% impervious cover	Compacted Lawn	83
Buildings and pavement with 91-100% impervious cover	Compacted Lawn	95
Buildings and/or pavement	Compacted Lawn	50
Cattail marsh - intermittently exposed	Wetland	0
Cattail marsh - saturated soils	Wetland	0
Cattail marsh - seasonally flooded	Wetland	0
Coniferous trees on upland soils	Woods-Good	0
Corn	Row Crop-Good	0
Deciduous trees on upland soils	Woods-Good	0
Dry prairie with 11-25% impervious cover	Meadow-Good	17
Dry prairie with 26-50% impervious cover	Meadow-Good	38
Dry prairie with 4-10% impervious cover	Meadow-Good	7
Eastern Red Cedar woodland	Woods-Good	0
Floodplain forest	Woods-Good	0
Floodplain forest swamp white oak subtype	Woods-Good	0
Grassland with sparse conifer or mixed deciduous/coniferous trees	Meadow-Good	0
Grassland with sparse conifer or mixed deciduous/coniferous trees – altered/non-native dominated	Meadow-Good	0
Grassland with sparse deciduous trees - altered/non-native dominated vegetation	Meadow-Good	0
Hayfield	Meadow-Good	0
Hayfield on hydric soils	Meadow-Good	0
Hydric soils - close grown cropland	Close Seeded Legumes - G	0
Hydric soils with planted or maintained grasses	Small Grain-SR Good	0
Hydric soils with planted or maintained grasses and sparse tree cover	Woods/Grass Combo-Good	0
Hydric soils with planted, maintained or cultivated mixed coniferous/deciduous trees	Woods/Grass Combo-Good	0
Intermittently exposed altered/non-native dominated vegetation	Woods/Grass-Fair	0
Long grasses and mixed trees with 4-10% impervious cover	Woods/Grass Combo-Good	7
Long grasses on upland soils	Meadow-Good	0
Long grasses with sparse tree cover on upland soils	Meadow-Good	0
Lowland hardwood forest	Woods-Good	0
Maple-basswood forest	Woods-Good	0
Medium-tall grass altered/non-native dominated grassland	Meadow-Good	0
Mesic brush-prairie	Brush-Good	0
Mixed emergent marsh	Wetland	0
Mixed emergent marsh - seasonally flooded	Wetland	0
Mixed hardwood swamp	Wetland	0
Mixed hardwood swamp seepage subtype	Wetland	0
Mixed pine-hardwood (forest) with 11-25% impervious cover	Woods-Good	17
Native dominated disturbed upland shrubland	Brush-Good	0
Native dominated temporarily flooded shrubland	Brush-Good	0
Non-native dominated long grasses with 11-25% impervious cover	Meadow-Good	17
Northern hardwood (forest) with 11- 25% impervious cover	Woods-Good	17

MLCCS Land Use	Pervious Cover Type	Impervious %
Northern hardwood (forest) with 26-50% impervious cover	Woods-Fair	38
Northern hardwood forest	Woods-Good	0
Oak (forest or woodland) with 11- 25% impervious cover	Woods-Fair	18
Oak (forest or woodland) with 26-50% impervious cover	Woods-Fair	38
Oak (forest or woodland) with 4-10% impervious cover	Woods-Good	7
Oak forest	Woods-Good	0
Oak forest dry subtype	Woods-Good	0
Oak forest mesic subtype	Woods-Good	0
Oak woodland-brushland	Woods-Good	0
Oats	Small Grain-SR Good	0
Other deciduous trees with 11- 25% impervious cover	Woods-Fair	18
Other deciduous trees with 26-50% impervious cover	Woods-Fair	38
Other deciduous trees with 4-10% impervious cover	Woods-Good	7
Other exposed/transitional land with 0-10% impervious cover	Fallow-Good	5
Other planted conifers with 11- 25% impervious cover	Woods-Fair	18
Pavement with 76-90% impervious cover	Compacted Lawn	83
Pavement with 91-100% impervious cover	Compacted Lawn	95
Planted mixed coniferous/deciduous trees with 11-25% impervious cover	Woods-Fair	18
Planted mixed coniferous/deciduous trees with 26-50% impervious cover	Woods-Fair	38
Poor fen	Wetland	0
Poor fen sedge subtype	Wetland	0
Red pine forest	Woods-Good	0
Red pine trees on upland soils	Woods-Good	0
Rich fen sedge subtype	Wetland	0
Saturated altered/non-native dominated graminoid vegetation	Wetland	0
Saturated deciduous shrubland	Wetland	0
Saturated graminoid vegetation	Wetland	0
Seasonally flooded altered/non-native dominated emergent vegetation	Wetland	0
Seasonally flooded deciduous shrubland	Woods/Grass-Fair	0
Short grasses and mixed trees with 11-25% impervious cover	Woods/Grass-Fair	18
Short grasses and mixed trees with 26-50% impervious cover	Woods/Grass-Fair	38
Short grasses and mixed trees with 4-10% impervious cover	Woods/Grass Combo-Good	7
Short grasses and mixed trees with 51-75% impervious cover	Woods/Grass-Fair	63
Short grasses on hydric soils	Open Space/Lawn	0
Short grasses with 11-25% impervious cover	Open Space/Lawn	18
Short grasses with 26-50% impervious cover	Compacted Lawn	38
Short grasses with 4-10% impervious cover	Open Space/Lawn	7
Short grasses with 51-75% impervious cover	Compacted Lawn	63
Short grasses with sparse tree cover on hydric soils	Open Space/Lawn	0
Spruce/fir trees on upland soils	Woods-Good	0
Tamarack swamp sphagnum subtype	Wetland	0
Temporarily flooded altered/non-native dominated grassland	Meadow-Good	0
Upland deciduous forest	Woods-Good	0
Upland deciduous woodland	Woods-Good	0
Upland soils - close grown cropland	Close Seeded Legumes - G	0
Upland soils with planted or maintained grasses	Open Space/Lawn	0
Upland soils with planted or maintained grasses and sparse tree cover	Open Space/Lawn	0

MLCCS Land Use	Pervious Cover Type	Impervious %
Upland soils with planted, maintained or cultivated mixed coniferous/deciduous trees	Woods/Grass Combo-Good	0
Upland soils with planted, maintained, or cultivated coniferous trees	Woods/Grass Combo-Good	0
Wet meadow	Wetland	0
Wet meadow - temporarily flooded soils	Wetland	0
Wet meadow shrub subtype	Wetland	0
Wet meadow shrub subtype - saturated soils	Wetland	0

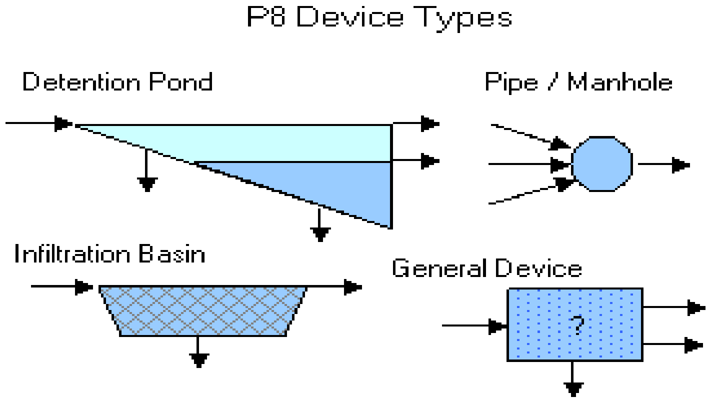
Table 2 - Curve Numbers by Ground Cover and Hydrologic Soil Type

	SOIL HYDROLOGIC GROUP							
GROUND COVER	A	B	C	D	A/D	B/D	C/D	W
Open Space / Lawn	39	61	74	80	39	61	74	100
Wetland	78	78	78	78	78	78	78	100
Small Grain - SR Good	63	75	83	87	63	75	83	100
Woods - Fair	36	60	73	79	36	60	73	100
Woods - Good	30	55	70	77	30	55	70	100
Brush - Good	30	48	65	73	30	48	65	100
Woods/Grass Combo - Good	32	58	72	79	32	58	72	100
Open Water	100	100	100	100	100	100	100	100
Row Crop - Good	67	78	85	89	67	78	85	100
Fallow - Good	74	83	88	90	74	83	88	100
Meadow - Good	30	58	71	78	30	58	71	100
Woods / grass - Fair	43	65	76	85	43	65	76	100
Close Seeded Legumes - Good	58	72	81	85	58	72	81	100
Compacted Lawn	50	74	80	85	50	74	80	100

Devices

The table and diagram below describe the type of devices used to evaluate phosphorus removal and are taken directly from the P8 help website at http://wwwalker.net/p8/webhelp/p8HelpWebMain.html. .

Device Type	Input Values	Description	Removes Particles	Infiltration Outlet	Normal Outlet	Spillway/ Overflow
Detention Pond	Permanent & flood pool areas & volumes infiltration rates outlet type & size	configured as wet, dry, or extended detention	X	X	X	X
Infiltration Basin	storage pool area & volume, infiltration rate; void fraction	storage area with infiltration	X	X		X
General Device	area & discharge vs. elevation,3 outflow streams (normal, overflow, infiltration)	user-defined hydraulics from independent model/ analysis	X	X	X	X
Pipe / Manhole	time of concentration (linear reservoir)	collects watershed and/or device outflows and directs them to downstream device			X	



The deadpool and livepool storage volumes used in this model were estimated based on the pond surface area assuming typical NURP pond requirements. Ponds were assumed to have a 10' bench with a 10:1 slope centered on the normal water level. The deadpool was assumed to be 4 feet in depth with 3:1 side slopes. The livepool was assumed to have 3 feet of storage above the normal water level with 4:1 side slopes. Pond outlets were provided by the Cities and Townships. The water quality devices built in to the model are listed in Table 3.

Table 3 – Water Quality Devices

P8 Device Name	Device Type	Contributing Watershed
Pond 1	Pond	Watershed 1
Pond 2	Pond	Watershed 2
Pond 3	Pond	Watershed 3
Pond 4	Pond	Watershed 4
Pond 5	Pond	Watershed 5
Pond 6	Pond	Watershed 6
Pond 7	Pond	Watershed 7
Pond 8	Pond	Watershed 8
Pond 9	Pond	Watershed 9
Pond 10	Pond	Watershed 10
Pond 11	Pond	Watershed 11
Pond 12	Pond	Watershed 12
Pond 13	Pond	Watershed 13
Pond 14	Pond	Watershed 14
Pond 15	Pond	Watershed 15
Pond 16	Pond	Watershed 16
Pond 1.1 A	Pond	Watershed JD 1.1A
Pond 1.1 B	Pond	Watershed JD 1.1B

Particles

Particle values are provided with the P8 model that are based on "typical urban runoff" concentrations and settling velocities measured under NURP (Athayede et al.,1983,1986; Driscoll, 1983). The NURP 50th % particle values were determined to be reasonable and therefore used to predict phosphorus runoff.

The particle calibration as stated by the P8 website http://wwwalker.net/p8/webhelp/p8HelpWebMain.html is as follows:

Washoff parameters for particle fractions P10% - P80% are contained in particle files NURP50.P8P, NURP90.P8C, & SIMPLE.P8C have been calibrated as follows:

Accumulation Rate = 1.75 lbs/ac-day (P10%,P30%,P50%), = 3.5 lbs/ac-day (P80%) calibrated to provide median EMC = 100 ppm Total Susp. Solids ; using Providence Airport weather data.

Accum. Decay Rate = .25 1/day; assumes buildup on impervious surfaces reaches 90% of steady-state after 10 days of dry weather without sweeping

Washoff Exponent = 2; provides intensity-dependent washoff, as in SWMM (Huber et al., 1988)

Washoff Coefficient = 20 calibrated so that load/volume relationship for impervious watersheds saturates at ~1 inch of rainfall; provides 92% washoff for a 1-inch, 8-hour storm.

Impervious Runoff Conc = 0; buildup/washoff dynamics are used to predict impervious runoff conc.

Pervious runoff concentration parameters contained in particle files NURP50.P8C, NURP90.P8C, & SIMPLE.P8C have been calibrated as follows:

Model:
$\text{CONC} = a\ \text{RUNOFF}^{\ b}$

Variables:
CONC = concentration in pervious runoff (ppm)
RUNOFF = runoff intensity from pervious areas (inches/hr)

Parameters:

a = intercept = conc. @ runoff intensity of 1 in/hr = 100 ppm; calibrated so that flow-weighted mean TSS EMC from pervious watersheds = 100 ppm; calibration period = 1983-1987; Curve Number = 74; Providence Rhode Island Rainfall.

b = exponent = 1; linear log(c) vs. log(q) relationship; typical of stream sediment rating curves (Huber & Dikinson,1988)

Water Quality Components

The default NURP 50th % values were also used for water quality components. As stated by the P8 website

http://wwwalker.net/p8/webhelp/p8HelpWebMain.html :

Particle Compositions (mg/kg) have been calibrated so that median, event-mean runoff concentrations correspond to values reported by the Nationwide Urban Runoff Program:

Component	NURP50.P8P Particle File	% Dissolved
Total Suspended Solids	100	0
Total Phosphorus	.22	30

Precipitation

Runoff is a direct result from rainfall and snowmelt. P8 combines rainfall and snowmelt in to one precipitation file. The precipitation file used for the Bald Eagle Lake TMDL followed the same derivation process that was used in the Lino Lakes TMDL. The derived rainfall for the years 1998 – 2008 as follows:

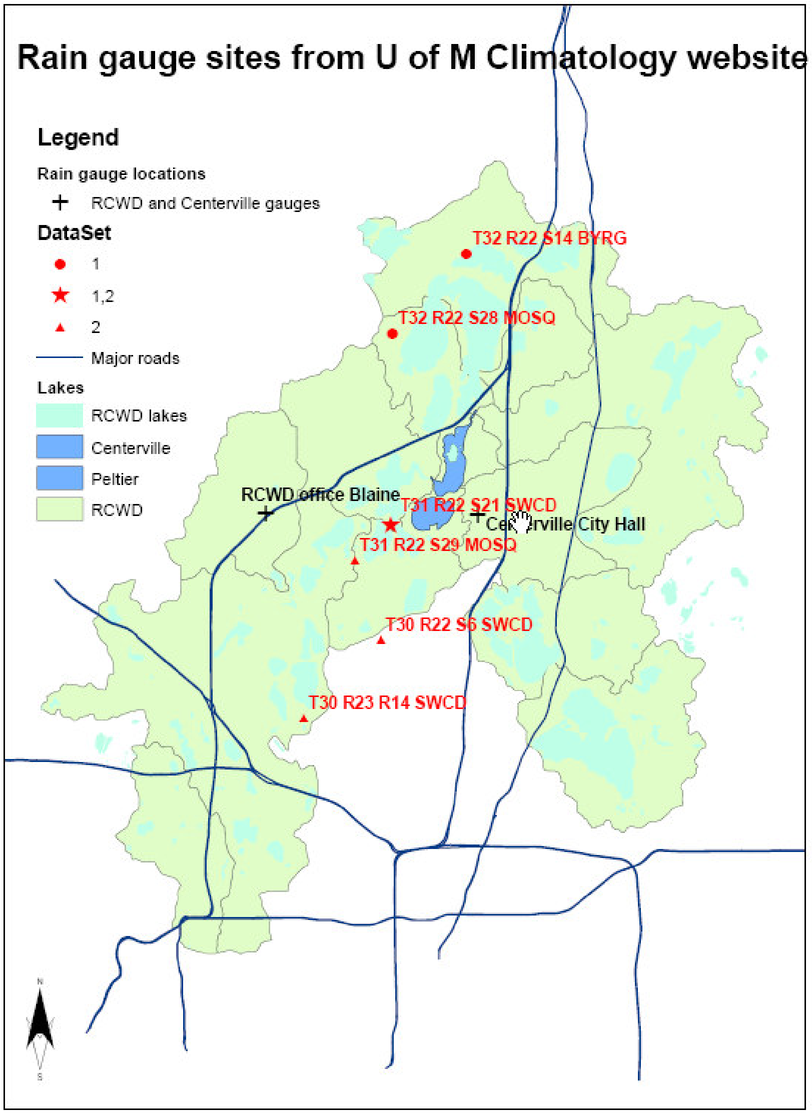
Precipitation data was obtained from the Climatology Working Group (http://climate.umn.edu/) database. With this database, the target location is set using section, township, and range, and the allowable maximum number of missing data points per month. The various sites are then searched so that the closest data set with less than the allowable number of missing data points can be identified.

For the precipitation data, two separate data sets were obtained (see Figure 3), using the following search criteria:

Set 1: Target T31 R22 S28 (located in Upper Rice Creek Watershed); 3 missing days allowed per month

Set 2: Target T38 R22 S21 (located near Peltier Lake); 3 missing days allowed per month

Figure 3. Rain Gauge Sites from U of M Climatology Web-Site



To compile the precipitation data set for the model, the following guidelines were followed:

On days for which precipitation data were recorded in both data sets, the two values were averaged.

On days for which there were data for only one of the sites, that value was used.

If data were missing from both data sets, a value of zero was used.

The daily totals were then distributed based on a SCS 24-hour distribution at hourly intervals.

Temperature

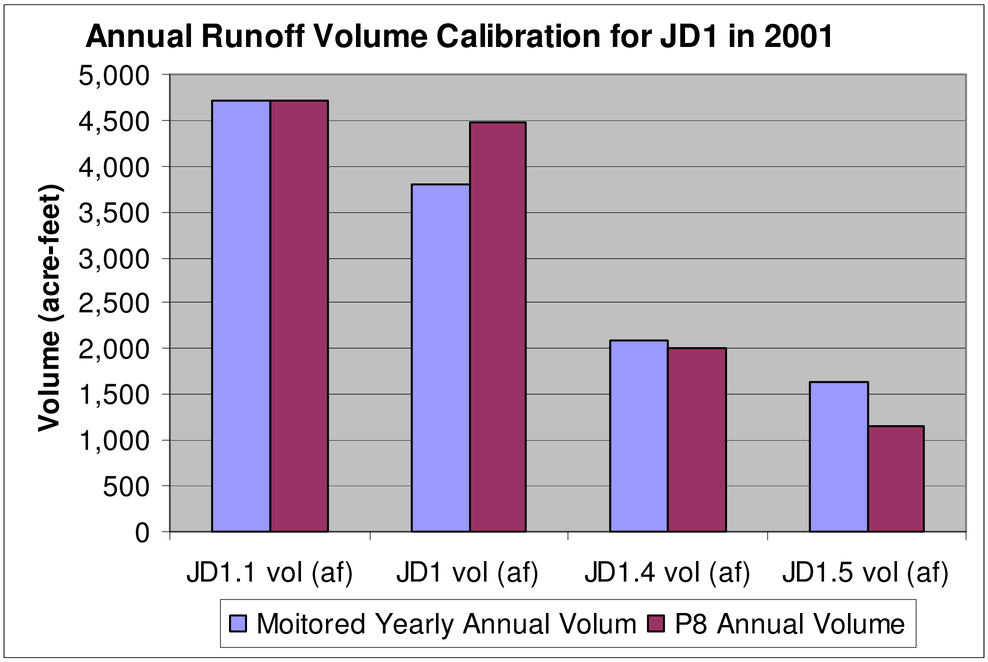
The temperature data was also obtained from the Climatology Working Group (http://climate.umn.edu/) database Centerville station, using average daily temperature values.

Model Calibration

The JD 1 branch of the P8 model was calibrated to the annual runoff volume for the year of 2001, the best known year of monitored data. Four monitoring sites were considered in calibrating the model. Those were sites JD 1, JD 1.1, JD 1.4 and JD 1.5. At all monitored locations the P8 model under predicted the annual runoff volumes. To calibrate the annual flow through these 4 sites the precipitation scale factor was adjusted until volumes predicted by P8 matched the monitored data as close as possible. The monitored volumes versus P8 calibrated volumes are shown in Figure 2 below. After calibrating the model to the JD 1 ditch system annual runoff volumes were combine with monitored water quality data to estimate nutrient loading.

No monitored data existed for either the direct runoff to Bald Eagle Lake or the County Ditch 11 system. For this reason the P8 model was run with default values (no adjustment to the precipitation scale factor) to estimate watershed loading.

Figure 2



Appendix D

Sediment Release Rates

Internal Phosphorus Loading and Mobile and Refractory Phosphorus Fractions in Sediments of Bald Eagle, Fish, and Oneka Lakes, Minnesota

7 December, 2007

William F. James
ERDC Eau Galle Aquatic Ecology Laboratory
W. 500 Eau Galle Dam Road
Spring Valley, Wisconsin 54767

OBJECTIVES

The objectives of this investigation were to determine rates of phosphorus release from sediments under laboratory-controlled anoxic conditions and measure fractions of mobile and refractory phosphorus fractions from profundal sediments collected in Bald Eagle, Fish, and Oneka Lakes, Minnesota.

APPROACH

Laboratory-derived rates of phosphorus release from sediment under anoxic conditions: Triplicate sediment cores were collected by Wenck Associates from Bald Eagle, Fish, and Oneda Lake for determination of rates of iron and phosphorus release from sediment under anoxic conditions. The cores were drained of overlying water and the upper 10 cm of sediment was transferred intact to a smaller acrylic core liner (6.5-cm dia and 20-cm ht) using a core remover tool. Surface water from each lake was filtered through a glass fiber filter (Gelman A-E), with 300 mL then siphoned onto the sediment contained in the small acrylic core liner without causing sediment resuspension. Sediment incubation systems consisted of the upper 10-cm of sediment and filtered overlying water contained in acrylic core liners that were sealed with rubber stoppers. The sediment incubation systems were placed in a darkened environmental chamber and incubated at a constant temperature (20 ^{o}C) for a three week period. The oxidation-reduction environment in each system was controlled by gently bubbling nitrogen (anoxic) through an air stone placed just above the sediment surface.

Water samples for soluble reactive phosphorus and dissolved iron were collected from the center of each sediment incubation system using an acid-washed syringe and filtered through a 0.45 μm membrane syringe filter (Nalge). Sampling was conducted at daily intervals for 5 days, then every other day for an additional 14 days. The water volume removed from each system during sampling was replaced by addition of filtered lake water preadjusted to the proper oxidation-reduction condition. These volumes were accurately measured for determination of dilution effects. Soluble reactive phosphorus was measured colorimetrically using the ascorbic acid method (APHA 1998). Dissolved iron was determined using atomic absorption spectrophotometry. Rates of phosphorus and iron release from the sediment (mg m^{-2} d^{-1}) were calculated as the linear change in concentration in the overlying water divided by time and the area of the incubation core liner. Regression analysis was used to estimate rates over the linear portion of the data.

Profundal sediment chemistry: One additional core taken at the same location in each lake was used for sediment phosphorus fractionation. The upper 10 cm was removed from each core for analysis of moisture content (%), sediment density g/mL), loss on ignition (i.e., organic matter content, %), loosely-bound phosphorus, iron-bound phosphorus, aluminum-bound phosphorus, calcium-bound phosphorus, labile and refractory organic phosphorus, total phosphorus, total iron, and total calcium (all expressed at mg/g). A known volume of sediment was dried at 105 ^{o}C for determination of moisture content and sediment density and ashed at 550 ^{o}C for determination of loss-on-ignition organic matter. Additional sediment was dried to a constant weight, ground, and digested for analysis of total phosphorus, iron, and calcium using standard colorimetric and spectrophotometric methods (APHA 1998). Phosphorus fractionation was conducted according to Hieltjes and Lijklema (1980), Psenner and Puckso (1988), and Nürnberg (1988) for the determination of ammonium-chloride-extractable phosphorus (loosely-bound P), bicarbonate-dithionite-extractable phosphorus (i.e., iron-bound P), sodium hydroxide-extractable phosphorus (i.e., aluminum-bound P), and hydrochloric acid-extractable phosphorus (i.e., calcium-bound P). A subsample of the sodium hydroxide extract was digested with potassium persulfate to determine nonreactive sodium hydroxide-extractable P (Psenner and Puckso 1988). Labile organic P was calculated as the difference between reactive and nonreactive sodium hydroxide-extractable P. Residual organic phosphorus was estimated as the difference between total phosphorus and the sum of the other fractions.

RESULTS AND INTERPRETATION

Fish Lake sediments exhibited the greatest rate of P release under anoxic conditions followed by Bald Eagle Lake sediments (Fig. 1; Table 1). P mass accumulation was linear and most rapid during the first 5 days of incubation for these lakes. In contrast, anoxic sediment P flux was very low for Oneka Lake sediments. DFe accumulation exhibited a different pattern (Fig. 2). For Bald Lake sediment, DFe mass increased slightly during the first 2-3 days, then declined to near zero on day 4. Linear rates of DFe accumulation in the overlying water occurred between day 4 and 11, then DFe mass remained approximately constant until the end of the study. DFe mass increased in the Oneka sediment incubation systems over the first 11 days while linear increases in mass occurred between day 4 and 14 for Fish Lake systems. Overall, rates of DFe release were greatest for Oneka Lake sediments and ~ 2-3 times lower for Bald Eagle and Fish Lake sediments (Table 1). The Fe:P rate ratio for Bald Eagle and Fish Lake sediments was < 1 in conjunction with high rates of P release. It was 37 for Oneka Lake sediments, coincident with a very low rate of P release.

Sediment collected in each lake exhibited very high moisture content and low density, suggesting very fine-grained flocculent material (Table 2). The loss-on-ignition organic matter content was very high at ~68% for Oneka Lake sediments and it represented 37.3% and 18.7% of the sediment dry mass for Bald Eagle and Fish Lake, respectively. Total P, Fe, and Ca concentrations were moderate relative to literature values reported in Barko and Smart (1986), Ostrofsky (1987), and Nürnberg (1988). Higher sediment total P concentrations for Bald Eagle and Fish Lake coincided with higher rates of P release versus a lower sediment total P concentration and a lower anoxic P release rate for Oneka Lake sediment. The Fe:P ratio for sediment varied between ~8 and 13 (Table 2). This pattern contrasted with the very low Fe:P rate ratios observed for Bald Eagle and Fish Lake (Table 1). Differences between the ratios indicated that even though total Fe was high relative to total P in sediment, only a minor portion diffused into the water column as dissolved Fe. Fe reaction with S under anoxic conditions could have reduced DFe flux out of the sediment for these lakes (Caraco et al. 1993; Gächter and Müller 2003).

The redox-sensitive loosely-bound and iron-bound P fractions accounted for a considerable proportion of the sediment total P for Bald Eagle and Fish Lake (Table 2 and 3). In contrast, redox-sensitive P represented a much lower percentage of the total P in Oneka Lake sediments. Redox-sensitive P versus anoxic P release rates for sediments in the present study (Fig. 3) were comparable to published regression relationships developed by Nürnberg (1988), suggesting that anoxia, reduction of iron, and desorption of P were drivers in internal P loading. The labile and refractory organic P fractions accounted for nearly 70% of Oneda Lake sediment total P, which coincided with much higher sediment organic matter content (Table 3). Refractory P forms represented 60 and 67% of the sediment total P for Bald Eagle and Oneda Lake, respectively. In particular, refractory organic P represented 58% of the sediment total P for Bald Eagle Lake. Biologically labile P species dominated the P composition of Fish Lake sediments.

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Table 1. Means (n=3) and standard errors (STDERR) for rates of soluble reactive phosphorus (SRP) and dissolved iron (DFe) release from sediment under anoxic conditions.

Lake	SRP ($mg\ m^{-2}\ d^{-1}$)	STDERR	DFe ($mg\ m^{-2}\ d^{-1}$)	STDERR	Fe:P
Bald Eagle	10.8	2.0	3.2	0.8	0.30
Oneka	0.2	0.0	7.0	1.4	37.00
Fish	15.6	1.8	2.1	0.6	0.13

Table 2. Sediment physical-chemical characteristics. P = phosphorus, redox P = the sum of the loosely-bound and iron-bound P fractions (see Table 3), Fe = iron, Ca = calcium, Fe:P = sediment iron to phosphorus ratio (mass:mass).

Lake	Moisture Content (%)	Density (g/mL)	Loss-on-ignition (%)	Total P (mg/g)	Redox P (mg/g)	Redox P (%)	Total Fe (mg/g)	Total Ca (mg/g)	Fe:P
Bald Eagle	94.2	0.058	37.3	1.765	0.42	23.9%	23.909	47.953	13.54
Oneka	96.3	0.041	67.9	0.826	0.06	6.7%	6.783	7.076	8.21
Fish	90.8	0.095	18.7	1.407	0.67	47.7%	13.336	110.334	9.48

Table 3. Sediment phosphorus (P) fraction concentrations.

Lake	Redox-sensitive and biologically labile P				Refractory P		
	Loosely-bound P (mg/g)	Iron-bound P (mg/g DW)	Iron-bound P (mg/g FW)	Labile organic P (mg/g)	Aluminum-bound P (mg/g)	Calcium-bound P (mg/g)	Refractory organic P (mg/g)
Bald Eagle	0.026	0.396	0.036	0.169	0.101	0.049	1.024
Oneka	0.001	0.054	0.002	0.275	0.198	0.011	0.287
Fish	0.042	0.629	0.037	0.251	0.323	0.009	0.153

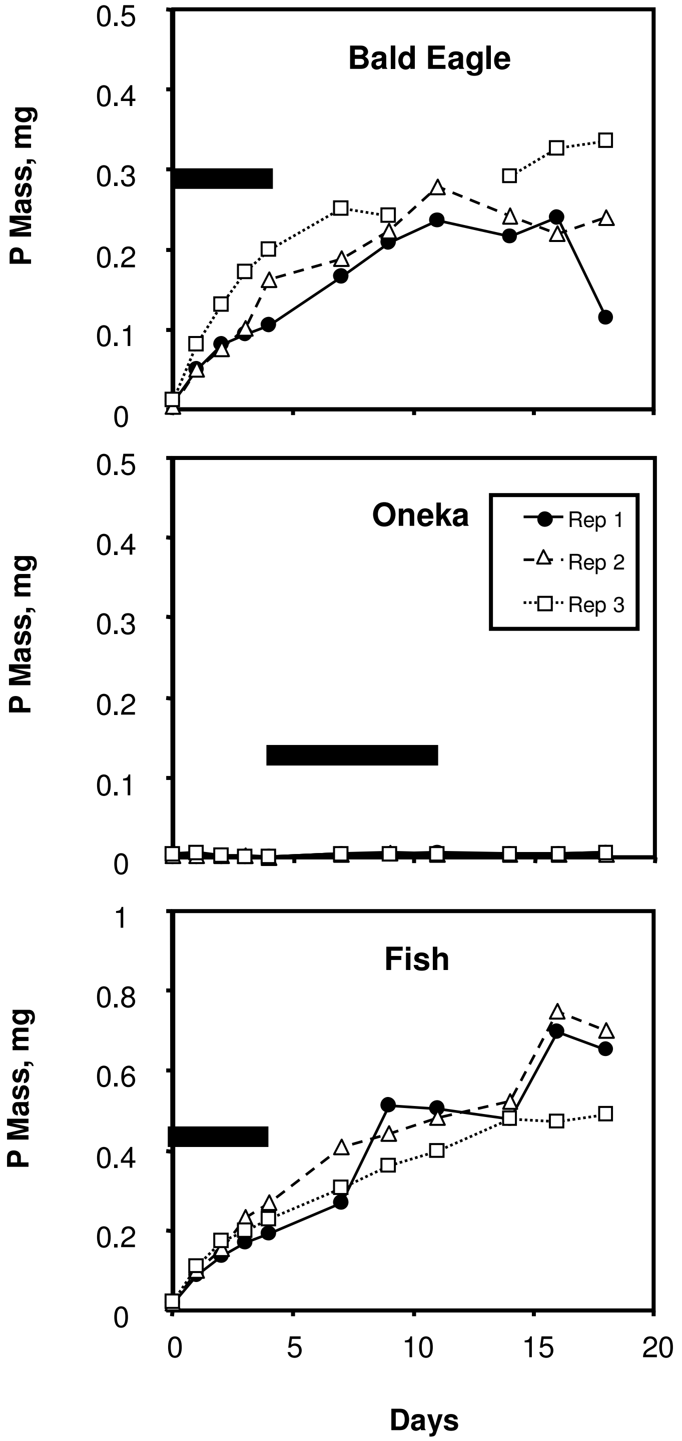


Figure 1. Changes in phosphorus (P) mass in overlying water as a function of time for sediment incubation systems maintained under anoxic conditions. Black horizontal bars represent data used to calculate rates of P release.

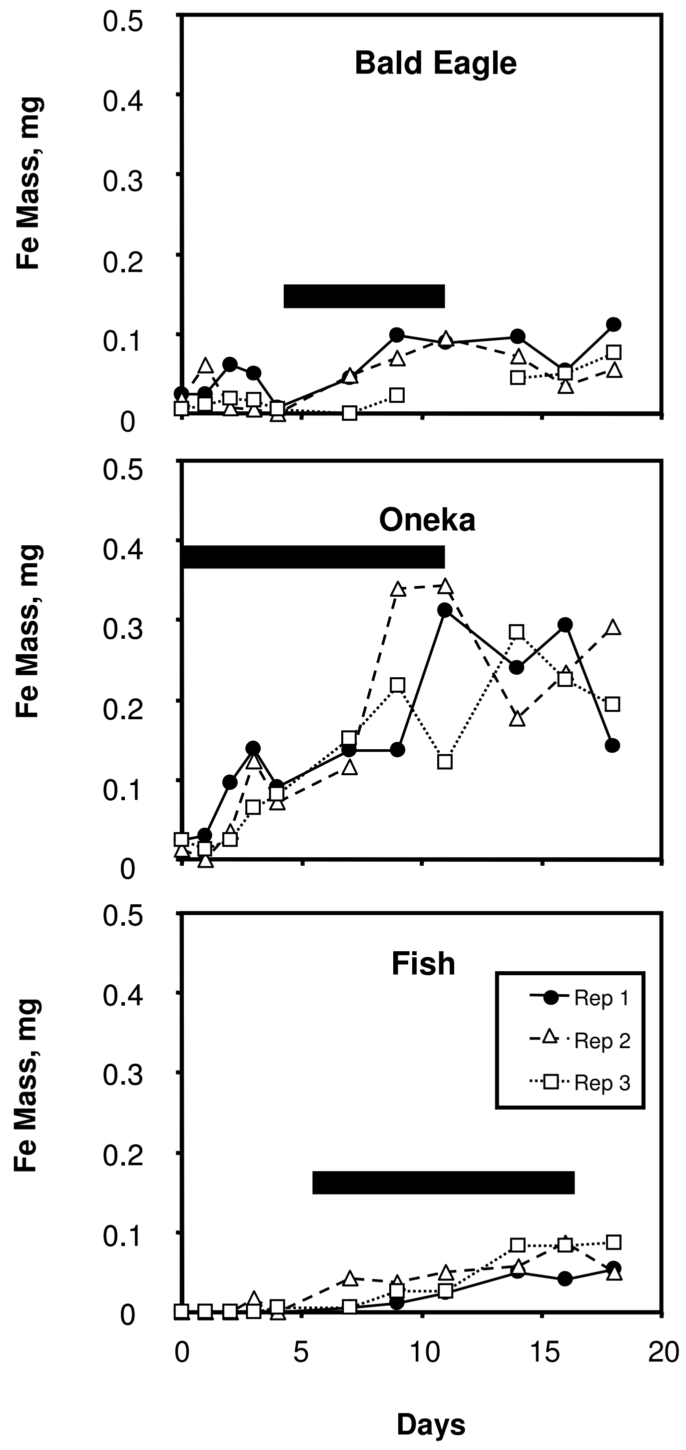


Figure 2. Changes in dissolved iron (Fe) mass in overlying water as a function of time for sediment incubation systems maintained under anoxic conditions. Black horizontal bars represent data used to calculate rates of Fe release.

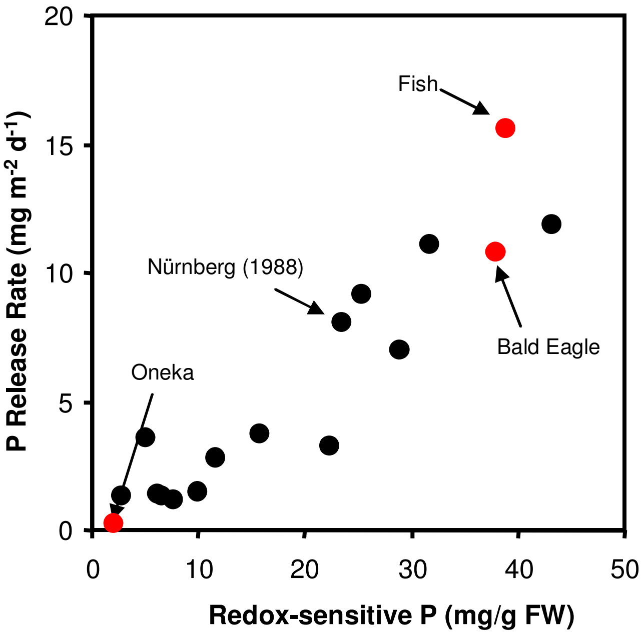


Figure 3. A comparison redox-sensitive phosphorus (P) versus the anoxic P release rate for this study versus research published by Nürnburg (1988).

Appendix E

Shuneman Marsh Studies

INTRODUCTION

The purpose of the Ramsey-Washington Judicial Ditch 1 (RWJD1) Study was to determine the source of both soluble and total phosphorus being transported through the ditch system. The RWJD1 drainage area is 7626 acres and collects drainage from Fish, Sunset, Pine Tree, Mann, and Long Lakes (**Figure 1**).

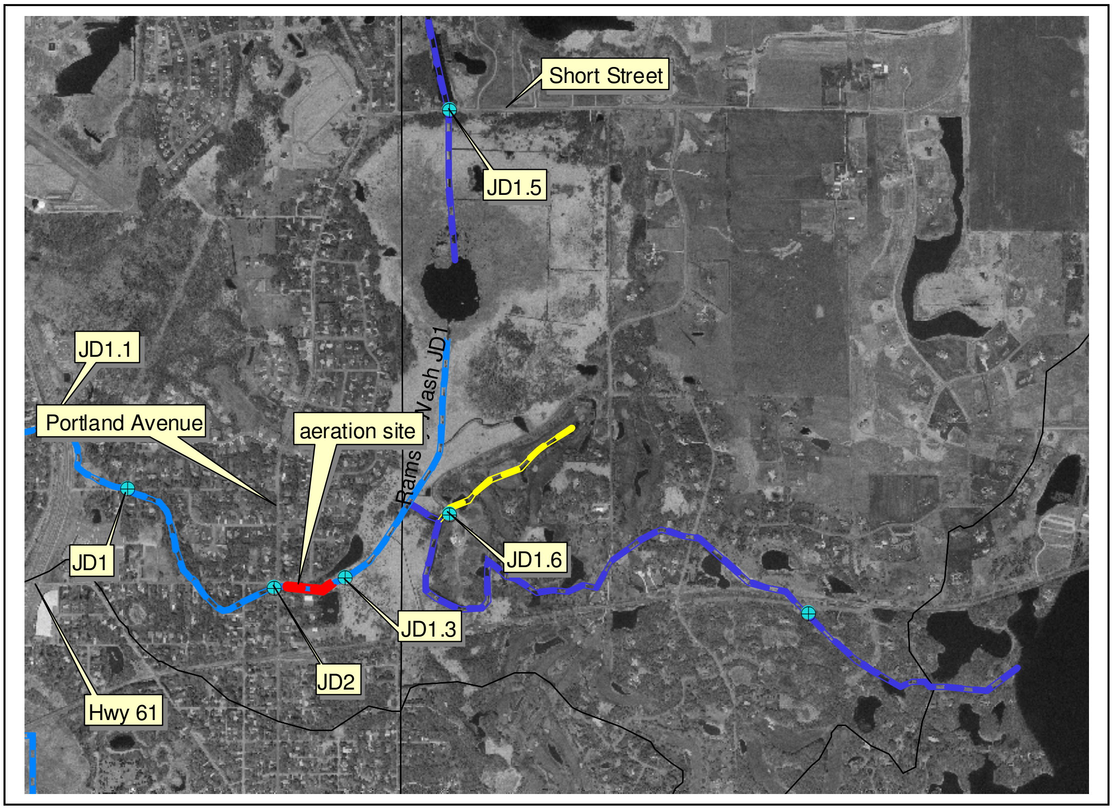
This study included collection of water quality data and flow data from six distinct drainage areas within the ditch system in 2001 (**Figure 1**). The estimated nutrient load from each subwatershed was evaluated by monitoring continuous flow and sampling by periodic grab samples throughout the open water season. In 2000 a shorter monitoring program took place, however the results were inconclusive so the project was expanded during the 2001 season. An aeration system was installed in the ditch above the Portland Avenue crossing. The nutrient transport estimates and potential nutrient reduction estimates from the aeration process are the focal point of this report and will be discussed in detail later in this report.

WATERSHED CHARACTERISTICS

The RWJD1 system was originally a natural waterway. This system was constructed as a fishhook-shaped drainage way that lies immediately north of White Bear Lake. It originates in the wetlands north of Fish Lake in Washington County and flows south for 1 mile before bending west and northwest in Ramsey County. The channel length is approximately 2.4 miles from Fish Lake to the east shore of Bald Eagle Lake. The official judicial ditch length is 1.5 miles. There are also numerous private ditches and drainage ways that enter in and drain into the RWJD1 ditch system. Land use in this area is primarily large lot single family homes with a golf course located just upstream of sampling location JD1.6. There are also a considerable number of wetlands and lakes that this system drains through.

Figure 1

2001 RWJD1 Monitoring Locations



The RWJD1 system lies in the North Central Hardwoods Forest Ecoregion (CHF) (MPCA 1990), however comparison of nutrient outputs from a ditched system should not be compared to a natural system.

SAMPLING METHODOLOGY

Flow Monitoring

Continuous flow monitoring was conducted at six sites in order to establish an accurate hydrologic record of tributary inputs to the RWJD1 system. Flow records were recorded from April 10, 2001 to October 28, 2001 using ISCO flowmeters. These meters record water level (stage) and will convert recorded data into discharge measurements in cubic feet per second (cfs). Stream stage is converted at each site using a site specific stage-discharge rating curve that was developed over the course of the summer. Continuous level measurements were taken automatically by the meters at 15-minute increments for the entire monitoring period. **Figure 2** shows the flow data graphically for all monitoring locations.

Water Quality Sampling

Water quality samples were collected by 15 grab sample events between March 22 and October 8, 2001. Samples were collected at all six locations within a four hour sampling timeframe. The samples were collected using the same methodology and would be comparable when estimating pollutant loads using the FLUX model.

Each sample was collected in a 500 ml sterile whirlpak and a 1000 ml plastic bottle for analysis at the Ramsey County Environmental Laboratory and Braun Intertec. The laboratory was responsible for supplying bottles prepared for sampling. Sample bottles were labeled in the field to include location, unique sample ID number, date, time, crew, and type of preservative. All samples were handled in accordance with EPA-approved methods.

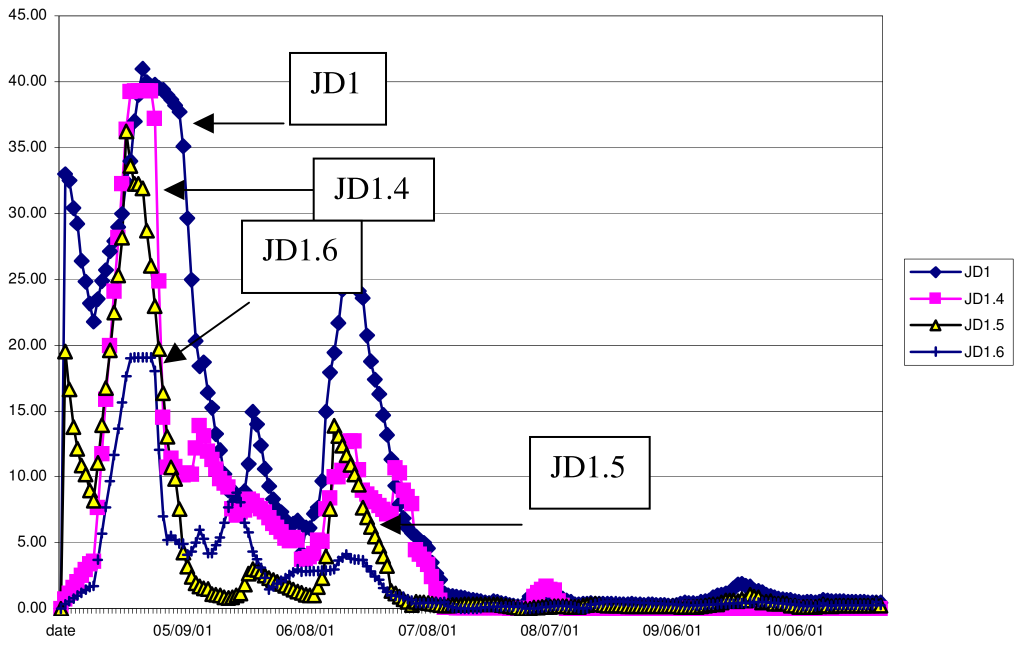
Samples were analyzed for total phosphorus (TP), soluble reactive phosphorus (SRP), total kjeldahl nitrogen (TKN), ammonia (NH3), nitrate-nitrite (Nox), total (TSS) and volatile suspended solids (VSS), total iron (TFE) and dissolved iron (DFE).

Aeration Study

A ditch aeration system was installed in RWJD1 above the Portland Avenue crossing. This system involved the installation of a 300 foot linear aeration system just downstream of Shuneman Marsh. The system ran for about 60 days from late July through late September. The study used two ¾ hp air pumps and four ½ inch by 300 foot long air lines along the ditch bottom. The air lines had 5/16 inch holes drilled in each line at approximately a one foot interval. The purpose of the study was to see if by saturating the

Dissolved Oxygen (DO) concentration of ditch, phosphorus concentrations would decrease by binding it to iron salts. Previous literature review suggested that this method showed some promise in slow moving ditched wetland systems where the wetland pore water was high in ortho phosphate.

FIGURE 2
2001 WRJD1 flows



PHOSPHORUS TRANSPORT MODELING

The overall goal of the project was to better understand the dynamics of nutrient transport within the RWJD1 drainage system. Stream transport pollutant loading was calculated using the FLUX model. FLUX uses daily average flows to calculate the estimated pollutant loads by monitoring site. FLUX modeling also estimates the volume of water passing a monitoring station for the monitored time period.

RESULTS

Table 1 lists estimated volumes of water along with the major nutrient loads that passed each monitoring station during the monitoring period.

Table 1

Estimated Water Volume and Nutrient Loads

By Monitoring Station (March 01-October 01)

Site	Flow Volume (ac-ft)	TP (lb)	SRP (lb)	TSS (lb)	TKN (lb)
JD1.1	4546	1518	748	56736	17134
JD1	3639	1162	528	83230	11748
JD1.2	3639	1181	528	43870	13620
JD1.3	3639	1199	440	43468	14196
JD1.4	2099	216	123	24614	4763
JD1.5	1564	673	266	30360	7000
JD1.6	2350	526	174	13108	7196

Review of the estimated loading data suggest that a high percentage of the phosphorus loading is coming from upstream of the Schuneman Marsh area in the Fish Lake subwatershed (site JD1.5). It is estimated that over 50 percent of the phosphorus load passing the Taylor Avenue site (JD1) is coming from this drainage area. In addition, a very high percentage of the SRP and TKN load is coming from the Fish Lake subwatershed as well. Land use in this subwatershed is wetland, low density residential, and Oneka Ridge Golf course.

JD1.6 is another source of significant phosphorus loading to the ditch system. The JD1.6 drainage area collects runoff from two golf courses, Dellwood and the White Bear Yacht Club. The estimated pollutant (phosphorus and nitrogen) load at JD1.6 is more than double that of JD1.4, located upstream. The only parameter that is significantly lower at

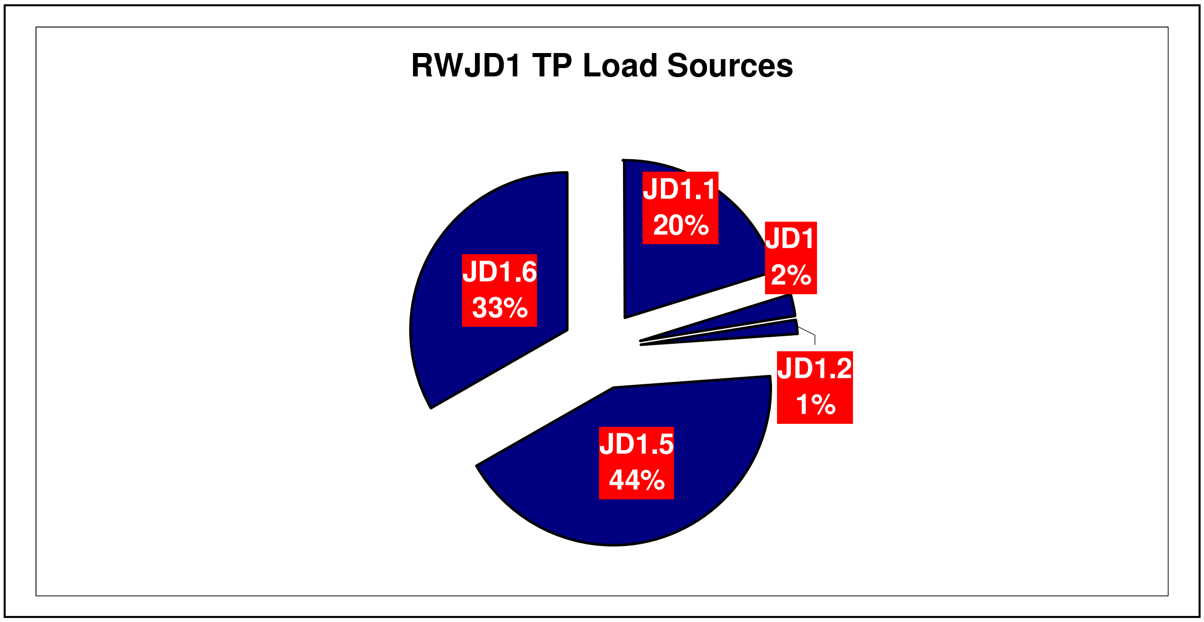
JD1.6 is TSS. This is understandable as the Dellwood golf course has a series of ponds that the drainage system goes through before discharging into RWJD1.

Monitoring data suggests that the majority of the pollutant load is coming from the JD1.5 and JD1.6 subwatersheds. When looking at the JD1 pollutant load, a direct comparison can be made to the loads coming from the JD1.5 and JD1.6 subwatersheds. This is directly relevant when looking at TP and SRP. There does not appear to be a large contribution of nutrient loading coming from the Shuneman Marsh drainage.

Figure 3 shows the graphical presentation of the RWJD1 TP load sources. This pie graph shows that over 77 % of the TP loading is coming from the JD1.5 and JD1.6 subwatersheds.

Figure 3

RWJD1 Phosphorus Load Source Graph



This may be due to the drainage coming from the Oneka Ridge golf course. An estimated export rate of 0.36 lb of phosphorus per acre of drainage area is high when compared to other monitored streams in the RCWD. The monitoring data from throughout the District reveals that a typical range for TP export rates is 0.10 to 0.40 lbs/acre/year. This range was gathered by review of historical small creek monitoring data. A substantial amount of the TP and SRP load is coming from the JD1.5 subwatershed. Also subwatershed JD1.6 is contributing a significant amount of phosphorus to the overall nutrient load of the stream. The lack of substantial nutrient increases from the Shuneman Marsh area suggests that pore water from the drained wetland may not be a major contributing source of phosphorus to the ditch. **Figure 4** shows the phosphorus levels at monitoring site JD1.3 and JD1.2, which are immediately above and below the aeration system.

Figure 4

Total Phosphorus Concentrations

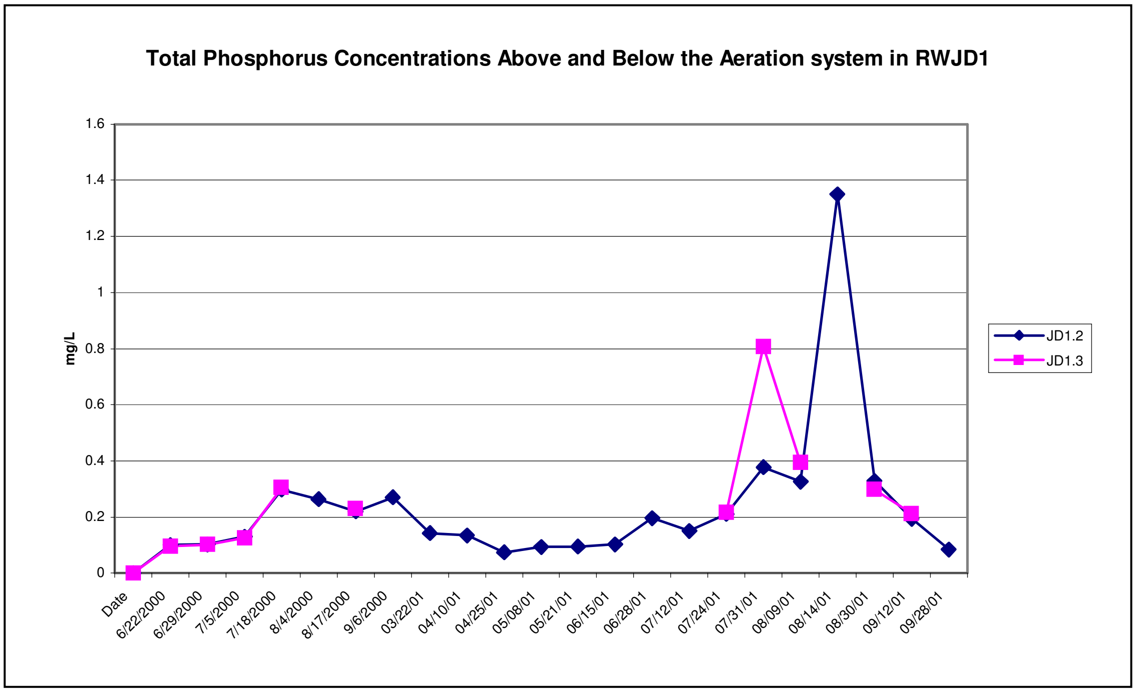
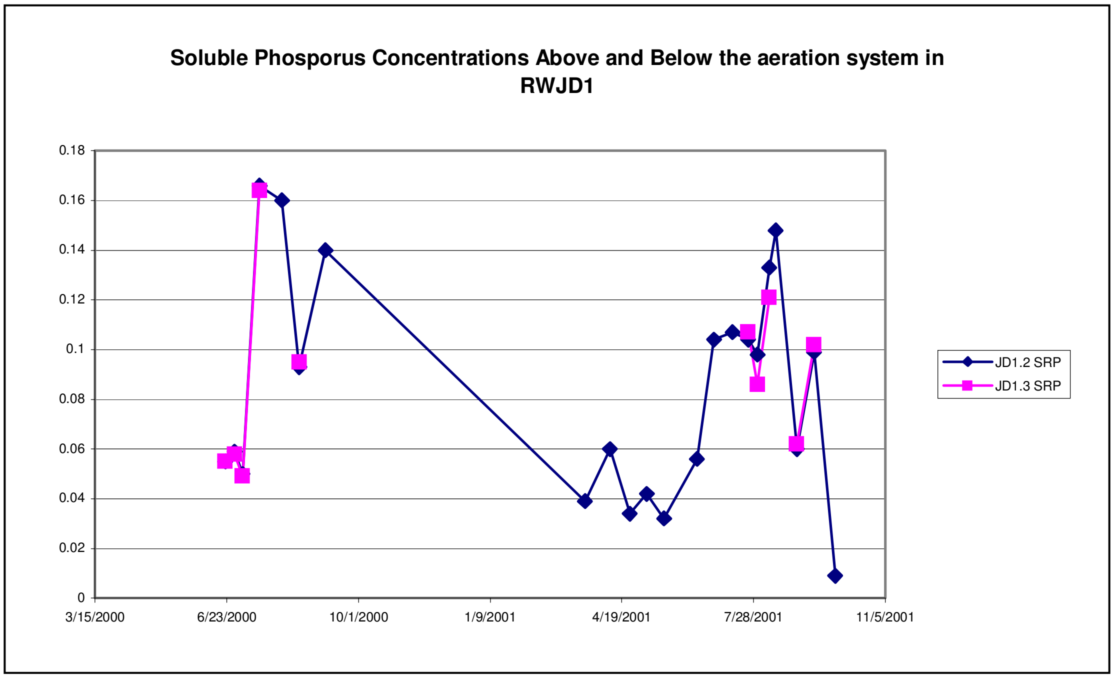


Figure 5 shows the soluble phosphorus or bioavailable phosphorus levels at the aeration site. Review of the data in these two graphs shows virtually identical concentrations for the paired sample events. Review of the D.O. data collected during field visits revealed that oxygen levels during low flow periods were often below 2 mg/l at the JD1.3 sampling point. At the downstream sampling point (JD1.2) D.O. levels were generally 1 to 1.5 mg/l higher. This suggests that possibly the aeration system was not supplying enough oxygen to the system to create the anticipated chemical affect or that the

anticipated chemical affect is only theoretical and not practical. The data from the 2 years of study was inconclusive.

Figure 5

Soluble Phosphorus Concentrations



During both study years, stream flows exhibited flashy flow rates based on storm events, and very low flows during baseflow periods. Flux modeling of the phosphorus transport suggests that storm flows are responsible for the majority of the phosphorus load through the ditch.

CONCLUSIONS AND RECOMMENDATIONS

Review of the data shows that the phosphorus levels above and below the aeration system was not significantly changed. The aeration system did boost the D.O. concentration at the downstream location. The anticipated chemical reaction of iron binding with phosphorus to precipitate out FePO2 did not appear to occur. The stream velocities may have been to fast to adequately oxygenate the water to a point where the chemical reaction could occur. Stream flows were flashy based on storm events. Baseflow conditions were near 0.5 cfs , however the stream velocities were still relatively fast (>0.3 ft/sec). With a 300 foot air line the contact time for stream water would have been around 17 minutes at low flow, and much less at higher flows.

The project was based on the theory that the Shuneman Marsh pore water was exporting high concentrations of SRP. This was believed o be caused from the constant wet and dry cycles that the wetland goes through during a typical rain season. This study found that the majority of the SRP load was coming from above the Shuneman Marsh or from the JD1.6 subwatershed. Land management practices and possible BMP's should be investigated throughout this watershed. Reduction of nutrient transport through this system could be accomplished through BMP's and public education.

Enclosed are photos of the aeration system installed in the creek.

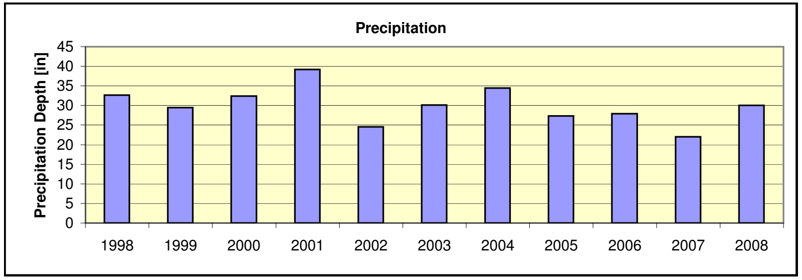
Photo of Aerator Lines at site

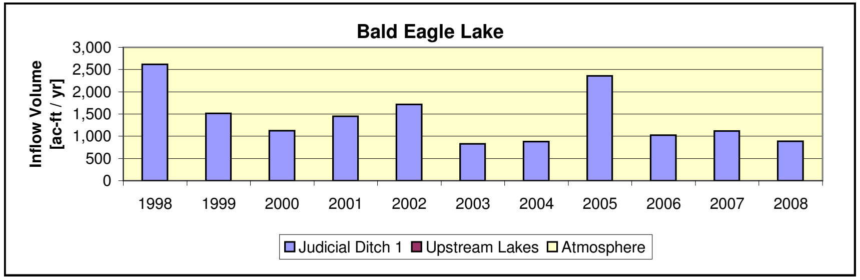
Aeration lines looking downstream toward Portland Avenue

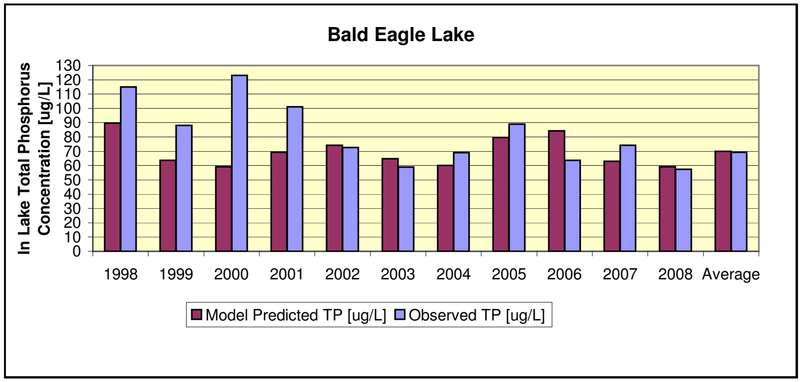
Appendix F

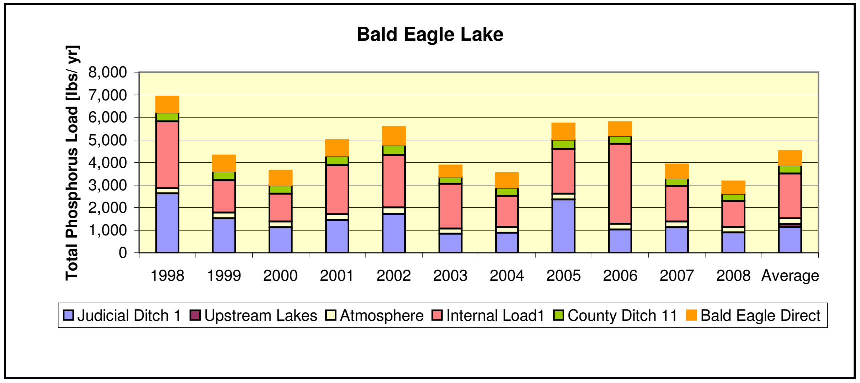
Annual Phosphorus Budgets

Bald Eagle Lake	**Source**	***1998***	***1999***	***2000***	***2001***	***2002***	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***	***Average***
Precipitation Depth [in]		30.02	32.68	29.42	32.4	39.22	24.52	30.12	34.44	27.31	27.93	22.02	30.0
	Residence Time [yr]	2.9	2.3	2.7	2.2	2.2	3.5	3.2	2.8	3.9	2.9	4.4	3.3
Inflow Volume [ac-ft / yr]	Judicial Ditch 1	3229	4328	3476	4533	4330	2705	2841	3219	2235	3181	2086	2,942
	County Ditch 11	465	494	470	510	595	370	450	513	393	449	319	441
	Bald Eagle Direct	889	923	905	959	1116	697	850	955	732	864	598	830
	Upstream Lakes	--	--	--	--	--	--	--	--	--	--	--	--
	Atmosphere	0	0	0	0	0	0	0	0	0	0	0	0
	TOTAL =	**4583**	**5745**	**4851**	**6002**	**6041**	**3772**	**4141**	**4687**	**3360**	**4494**	**3003**	4,214
Total Phosphorus Load [lbs/ yr]	Judicial Ditch 1	2620	1515	1125	1450	1719	831	880	2360	1027	1116	890	1128
	County Ditch 11	402	402	368	404	451	300	368	412	355	345	318	364
	Bald Eagle Direct	711	706	656	709	798	527	649	720	619	615	553	640
	Septic Systems	0	0	0	0	0	0	0	0	0	0	0	0
	Upstream Lakes	--	--	--	--	--	--	--	--	--	--	--	132
	Atmosphere	238	256	256	256	277	238	256	256	256	256	238	254
	Internal Load[1]	2951	1429	1229	2170	2325	1979	1379	1979	3533	1580	1159	1991
	TOTAL =	**6922**	**4308**	**3634**	**4989**	**5570**	**3875**	**3533**	**5727**	**5790**	**3912**	**3158**	**4509**
Model Results	Model Predicted TP [ug/L]	90	64	59	69	74	65	60	79	84	63	59	70
	Observed TP [ug/L]	115	88	123	101	73	59	69	89	64	74	57	69
	Phosphorus Sedimentation [kg]												
	TOTAL OUTFLOW [kg] =												
[1] Internal Load Factors:	*Release Rate [mg/m2-day]*	*10.8*	*10.8*	*10.8*	*10.8*	*10.8*	*10.8*	*10.8*	*10.8*	*10.8*	*10.8*	*10.8*	*10.8*
	Anoxic factor [day]	*29*	*14*	*12*	*21*	*23*	*19*	*13*	*19*	*34*	*15*	*11*	*19*









Appendix G

Lake Response Models

2002-08 Average Loading Summary for Bald Eagle Lake

Water Budgets | **Phosphorus Loading**

Inflow from Drainage Areas

	Name	Drainage Area [km^2]	Runoff Depth [m/yr]	Discharge [10^6 m^3/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [kg/yr]
1	Judicial Ditch 1	13.04				1.0	
2	County Ditch 11	1.89				1.0	
3	Bald Eagle Direct	4.72				1.0	
4						1.0	
5						1.0	
	Summation	*20*	*0*	*5*	*198.0*		*1,029.4*

Failing Septic Systems

	Name	Area [km^2]	# of Systems	Failure [%]	Load / System	[kg/km^2]	[kg/yr]
1	Judicial Ditch 1	13.04					
2	County Ditch 11	1.89					
3	Bald Eagle Direct	4.72					
4							
5							
	Summation	*20*	*0*	*0%*		*0.0*	*0.0*

Inflow from Upstream Lakes

	Name	Discharge [10^6 m^3/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [kg/yr]
1			-	1.0	
2			-	1.0	
3			-	1.0	
	Summation	*0.00*	-		*0*

Atmosphere

Lake Area [km^2]	Precipitation [m/yr]	Evaporation [m/yr]	Net Inflow [10^6 m^3/yr]	Aerial Loading Rate [kg/km^2-yr]	Calibration Factor [--]	Load [kg/yr]
4.33	0.76	0.76	0.00	26.80	1.0	116.2

Dry-year total P deposition = 24.9

Average-year total P deposition = 26.8

Wet-year total P deposition = 29.0

(Barr Engineering 2004)

Groundwater

Lake Area [km^2]	Groundwater Flux [m/yr]	Net Inflow [10^6 m^3/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [kg/yr]
4.33	0.0	0.00	0	1.0	0

Internal

Lake Area [km^2]	Anoxic Factor [days]	Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [kg/yr]
4.33			1.0	905

Net Discharge [10^6 m^3/yr] = 5.20 | **Net Load [kg/yr] = 2,050**

NOTES

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

002-08 Average Lake Response Modeling for Bald Eagle Lake

Modeled Parameter **Equation** **Parameters** **Value [Units]**

TOTAL IN-LAKE PHOSPHORUS CONCENTRATION

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

as f(W,Q,V) from Canfield & Bachmann (1981)

C_P = 1.00 [--]

C_{CB} = 0.162 [--]

b = 0.458 [--]

W (total P load = inflow + atm.) = 2,050 [kg/yr]

Q (lake outflow) = 5.2 $[10^6\ m^3/yr]$

V (modeled lake volume) = 16.3 $[10^6\ m^3]$

T = V/Q = 3.13 [yr]

P_i = W/Q = 394 [ug/l]

Model Predicted In-Lake [TP] 69.9 [ug/l]

Observed In-Lake [TP] 69.3 [ug/l]

CHLOROPHYLL-A CONCENTRATION

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

as f(TP), Walker 1999, Model 4

CB (Calibration factor) = 1.00 [--]

Model Predicted In-Lake [Chl-a] 19.6 [ug/l]

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

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

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

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

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

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

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

CB (Calibration factor) = 1.00

P (Total Phosphorus) = 69 [ug/l]

N (Total Nitrogen) = 1,700 [ug/l]

B_x (Nutrient-Potential Chl-a conc.) = 55.0 [ug/l]

X_{pn} (Composite nutrient conc.)= 61.0 [ug/l]

G (Kinematic factor) = 0.64 [--]

F_s (Flushing Rate) = 0.32 $[\text{year}^{-1}]$

Z_{mix} (Mixing Depth) = 4.50 [m]

C_a (non-algal turbity coefficient) = 0.025 [-]

a (Non algal turbidity) = 0.00 $[m^{-1}]$

S (Secchi Depth) = 1.25 [m]

Maximum lake depth = 12.07 [m]

Model Predicted In-Lake [Chl-a] 29.4 [ug/l]

Observed In-Lake [Chl-a] 33.1 [ug/l]

SECCHI DEPTH

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

as f(Chla), Walker (1999)

CS (Calibration factor) = 1.00 [--]

a (Non algal turbidity) = 0.00 $[m^{-1}]$

Model Predicted In-Lake SD 1.21 [m]

Observed In-Lake SD 1.25 [m]

PHOSPHORUS SEDIMENTATION RATE

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

P_{sed} (phosphorus sedimentation) = 1,687 [kg/yr]

PHOSPHORUS OUTFLOW LOAD

W-P_{sed} = **363 [kg/yr]**

TMDL Loading Summary for Bald Eagle Lake

Water Budgets | **Phosphorus Loading**

Inflow from Drainage Areas

	Name	Drainage Area [km^2]	Runoff Depth [m/yr]	Discharge [$10^6\ m^3/yr$]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [kg/yr]
1	Judicial Ditch 1	13.04	0.14	1.799	69	1.0	124.1
2	County Ditch 11	1.89	0.29	0.544	109.2	1.0	59.5
3	Bald Eagle Direct	4.72	0.22	1.024	102.1	1.0	104.5
4						1.0	
5						1.0	
	Summation	*20*	*1*	*3.37*	*103.6*		*349.0*

Failing Septic Systems

	Name	Area [km^2]	# of Systems	Failure [%]	Load / System	[kg/km^2]	[kg/yr]
1	Judicial Ditch 1	13.04					
2	County Ditch 11	1.89					
3	Bald Eagle Direct	4.72					
4							
5							
	Summation	*20*	*0*	*0%*		*0.0*	*0.0*

Inflow from Upstream Lakes

	Name	Discharge [$10^6\ m^3/yr$]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [kg/yr]
1	Fish	0.38	40.0	1.0	15
2	Pine Tree	1.45	31.0	1.0	45
3			-	1.0	
	Summation	*1.83*	*35.5*		*60*

Atmosphere

Lake Area [km^2]	Precipitation [m/yr]	Evaporation [m/yr]	Net Inflow [$10^6\ m^3/yr$]	Aerial Loading Rate [kg/km^2-yr]	Calibration Factor [--]	Load [kg/yr]
4.33	0.76	0.76	0.00	26.80	1.0	116.2

Dry-year total P deposition = 24.9

Average-year total P deposition = 26.8

Wet-year total P deposition = 29.0

(Barr Engineering 2004)

Groundwater

Lake Area [km^2]	Groundwater Flux [m/yr]	Net Inflow [$10^6\ m^3/yr$]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [kg/yr]
4.33	0.0	0.00	0	1.0	0

Internal

Lake Area [km^2]	Anoxic Factor [days]	Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [kg/yr]
4.33	19.0	4.0	1.0	329

Net Discharge [$10^6\ m^3/yr$] = 5.20 | **Net Load [kg/yr] = 855**

NOTES

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

TMDL Lake Response Modeling for Bald Eagle Lake

Modeled Parameter **Equation** **Parameters** **Value [Units]**

TOTAL IN-LAKE PHOSPHORUS CONCENTRATION

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

as f(W,Q,V) from Canfield & Bachmann (1981)

C_P = 1.00 [--]

C_{CB} = 0.162 [--]

b = 0.458 [--]

W (total P load = inflow + atm.) = 855 [kg/yr]

Q (lake outflow) = 5.2 [10^6 m^3/yr]

V (modeled lake volume) = 16.3 [10^6 m^3]

T = V/Q = 3.13 [yr]

P_i = W/Q = 164 [ug/l]

Model Predicted In-Lake [TP] **40.0 [ug/l]**

Observed In-Lake [TP] **40.0 [ug/l]**

CHLOROPHYLL-A CONCENTRATION

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

as f(TP), Walker 1999, Model 4

CB (Calibration factor) = 1.00 [--]

Model Predicted In-Lake [Chl-a] **11.2 [ug/l]**

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

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

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

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

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

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

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

CB (Calibration factor) = 1.00

P (Total Phosphorus) = 40 [ug/l]

N (Total Nitrogen) = 1,700 [ug/l]

B_x (Nutrient-Potential Chl-a conc.) = 29.5 [ug/l]

X_{pn} (Composite nutrient conc.)= 38.2 [ug/l]

G (Kinematic factor) = 0.87 [--]

F_s (Flushing Rate) = 0.32 [$year^{-1}$]

Z_{mix} (Mixing Depth) = 6.19 [m]

C_a (non-algal turbity coefficient) = 0.025 [-]

a (Non algal turbidity) = 0.36 [m^{-1}]

S (Secchi Depth) = 1.40 [m]

Maximum lake depth = 12.07 [m]

Model Predicted In-Lake [Chl-a] **13.6 [ug/l]**

Observed In-Lake [Chl-a] **14.0 [ug/l]**

SECCHI DEPTH

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

as f(Chla), Walker (1999)

CS (Calibration factor) = 1.00 [--]

a (Non algal turbidity) = 0.36 [m^{-1}]

Model Predicted In-Lake SD **1.40 [m]**

Observed In-Lake SD **1.40 [m]**

PHOSPHORUS SEDIMENTATION RATE

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

P_{sed} (phosphorus sedimentation) = **647** [kg/yr]

PHOSPHORUS OUTFLOW LOAD

W-P_{sed} = **208 [kg/yr]**