LAKE ASSESSMENT PROGRAM: 2006

Long Lake (47-0177)
&
Hope Lake (47-0183)

Meeker County, Minnesota

Environmental Analysis and Outcomes Division
Water Assessment and Environmental Information Section
February 2007

Minnesota Pollution
Control Agency

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Lake Assessment Program

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SUMMARY AND RECOMMENDATIONS

Hope and Long Lakes are located in Meeker County, approximately 3 miles south of Grove City, Minnesota. Hope Lake has a surface area of 250 acres with a maximum depth of 10 feet and a mean depth of 5.4 feet. Long Lake covers 771 acres with a maximum depth of 11 feet and a mean depth of 5.7 feet. The total watershed for Hope Lake is 7.2 square miles and for Long Lake, 28.3 square miles. Land use in the watersheds is predominantly agricultural, wetland, and forested land uses. The general land use composition is representative of lakes in the transition zone between the *North Central Hardwoods Forest (NCHF)* and *Western Corn Belt Plains (WCBP)* ecoregions.

Hope and Long Lakes were sampled during the summer of 2006 by Minnesota Pollution Control Agency (MPCA) staff and Roger Hanson from the Long Lake Association of Grove City (Association). Water quality data collected during the study for Hope and Long Lakes, respectively, reveal summer-mean total phosphorus (TP) concentrations of 264 µg/l and 385 µg/l; chlorophyll-*a* concentrations of 238 µg/l and 232 µg/l; and Secchi transparency of 0.6 feet (0.2 m) for both lakes. All of these measures greatly exceed the range of values exhibited by reference lakes in both the NCHF and WCBP ecoregions. Total phosphorus, chlorophyll-*a*, and Secchi transparency values help to characterize the trophic status of a lake. These measures indicate hypereutrophic conditions for Hope and Long Lakes. Both lakes are well above the threshold for shallow lakes (NCHF 60 µg/l and WCBP 90 µg/l) for placement on the "impaired waters" 303(d) list.

A good database is available for assessing trends in transparency for Long Lake. Secchi transparency data date back to 1996. Based on eleven years of record, the long-term mean Secchi is 1.1 feet (0.3 m). No significant improvement or decline in Secchi transparency over time was noted based on the data. Hope Lake has no historical data available to perform trend analysis for Secchi transparency.

Two lake water quality models were used to estimate the water quality of the lakes based on morphometry and watershed characteristics. These models provide a means to compare the measured water quality of the lake relative to the predicted water quality. The first model, MINLEAP, predicted a summer-mean total phosphorus concentration of 68 ± 20 µg/l using NCHF ecoregion inputs and 170 ± 58 µg/l based on WCBP ecoregion inputs for Hope Lake. These are both significantly different than the observed total phosphorus concentration of 264 ug/l for Hope Lake. For Long Lake, the predicted values were 71 ± 21 µg/l and 182 ± 61 µg/l, respectively, for the NCHF and WCBP ecoregions. These TP values were significantly different and considerably lower than the observed concentration (385 µg/l) in the summer of 2006. These results indicated that the water quality of Hope and Long is quite degraded compared to expected water quality based on MINLEAP (for lakes of similar size, depth, and region of the state).

BATHTUB, a model developed by Dr. William Walker for the U.S. Army Corps of Engineers (ACOE), to assess lakes and reservoirs was also used. This model provides additional diagnostics and allows us the link the two lakes in a network (route the water and P loading from Hope to Long Lake), evaluate the individual responses of Hope and Long Lakes, and refine nutrient and water budgets for the lakes. In the future, BATHTUB could be used to estimate the impact of reduced phosphorus loading on in-lake water quality. Based on estimates used in the 2006 study, BATHTUB estimates that about 81% of water entering Hope Lake arises as runoff from the watershed, with the remainder attributed to rainfall on the lake. In terms of phosphorus loading, approximately 50% arises from the watershed, 2% from precipitation, and 48% from internal loading. For Long Lake, BATHTUB estimates that approximately 65 % of its water input arises from runoff from its immediate watershed, 18% as inflow from Hope Lake, and about 15% from precipitation. Relative contributions to Long Lake's phosphorus loading are estimated at: 26% from the immediate watershed, 8% from Hope Lake, 2% from septic systems, 1% from rainfall, and 41% from internal loading. However, this leaves 22% of the phosphorus load unaccounted for (based on the observed in-lake P concentration). This implies that loading from the watershed and/or internal recycling was likely higher than our estimates.

Following are a few general observations and recommendations based on analysis of data collected in 2006:

1. Further increases in the nutrient loading rates from any watershed or in-lake sources that increase in-lake total phosphorus concentration could further degrade Hope and Long Lakes. It is essential, therefore, that lake protection efforts be conveyed to all local government groups with land use/zoning authorities for Meeker County.

If one does not exist, Long and Hope Lakes could benefit from the development of a plan for improving the water quality of the lakes. This plan, referred to as a lake management plan, should incorporate a series of activities in a prioritized fashion which will aid in the long-term protection and improvement of the lake. The plan should be developed cooperatively by a committee consisting of representatives from state agencies (e.g. DNR, BWSR, and MPCA), local units of government, and if applicable to each specific lake, lake association members. The reference document, Developing a Lake Management Plan, is available on the web at: http://www.shorelandmanagement.org/depth/plan.pdf. The following activities could be included in the plan:

A. Secchi transparency monitoring: Monitoring Secchi transparency provides a good basis for estimating trophic status and detecting trends. Routine participation is essential to allow for trend analysis; Secchi measurements should be taken weekly at consistent sites from June to September. While Long Lake has a continuous Secchi record since 1996, Hope Lake has never had a participant in the CLMP. Participation in CLMP will contribute to the historical database and allow for future trend assessments.

B. Education of homeowners around the lake regarding septic systems, lawn maintenance, and shoreline protection may be beneficial. Staff from the MPCA and DNR, along with county officials, such as staff from the University of Minnesota Extension Service, the Meeker County Soil and Water Conservation District (SWCD), and the Meeker County Planning and Zoning Office could provide assistance in these areas.

C. Further development in the immediate watershed of the lake should occur in a manner that minimizes water quality impacts on the lake. Consideration to setback provisions, lot size, and septic systems will be important in providing water quality protection. The DNR and county shoreland regulations will be important in these regards and should be strictly enforced. In writing a plan, exploring additional safeguards in land-use, zoning, and shoreline protection that could be included in a long-term plan to address future development activity within the watershed is recommended.

D. Maintenance of shoreline vegetation (both upland and aquatic) is very important. Emergent and submergent macrophytes serve to stabilize shorelines and bottom sediments from wind and wave erosion and may also serve as competition to algae for available nutrients. At this point curly-leaf pondweed appears to be the dominant macrophyte in Long Lake. Over the long term it would be beneficial to have a reduction in the extent (dominance) of curly-leaf in the lake and ideally see an increase in the number and extent of native macrophyte species, which would be beneficial to both the water quality and ecology of the lake.

E. Representation on boards or commissions that address land management activities would be beneficial, so that the impacts of these activities can be minimized. Safeguarding the shoreland ordinance from those who would choose to weaken it should be a priority for all the lakes in this study, as well as other lakes in Meeker County. The pamphlet "Your Lake and You," available from the North American Lake Management Society (www.nalms.org), may be a useful educational tool in this area.

F. Awareness of possible nutrient and sediment sources such as urban and agricultural runoff, septic systems, lawn fertilizer, and the effects of activities in the total watershed that change drainage patterns, such as wetland removal, creating new wetland discharges to the lake, ditch modifications, or major alterations in lake use is important. As these activities occur within the watershed, lake residents are encouraged to make sure that the water quality effects are minimized with the use of best management practices (BMPs) for water quality. Some of the county and state offices mentioned previously may be of help in this regard.

G. Severe blue-green algal blooms were noted on both lakes throughout the summer. Some blue-greens have the ability to produce toxins. One of these toxins, microcystin, was measured on several dates. Several samples exhibited concentrations in the "moderate" to "high risk" range, based on World Health Organization guidelines. These results suggest there is a possibility for animal and human health problems from either drinking or coming into contact with the water when microcystin levels are high. Since we cannot accurately predict which blooms are toxic, it is advisable to keep animals out of the water and avoid whole body contact when severe blue-green blooms are evident.

2. The 2006 water quality of Hope and Long Lakes was poor relative to other lakes in the NCHF and WCBP ecoregions. The water quality of both lakes was well above the impairment criteria

thresholds in 2006. Poor land use practices, poor management of shorelands, failure to maintain (pump) septic tanks, and draining of wetlands in the watershed are often among the causes of excess phosphorus loading to lakes. Over the course of this study limited monitoring of inflowing water from CD 26 and Hope Lake outlet revealed very high TP concentrations on several occasions, which suggests the need to take a closer look at land use practices in the watersheds of Long and Hope Lakes.

Conversely, a reduction of the amount of nutrients that enter the lake may result in improved transparency and a reduction in algal concentrations. One means of reducing nutrient input is by implementing BMPs in the watershed (land management activities used to control nonpoint source pollution). Technical assistance in BMP implementation may be available through local resource management agencies. The Meeker County SWCD is a local agency that could help examine land use practices in the watershed and develop strategies for reducing the transport of nutrients to the lake. It may be wise to first focus efforts on the water of the watershed nearest the lake. There may be few opportunities (or the need) to implement BMPs on existing land use. However, opportunities may arise during road building, construction, ditch maintenance, or other activities which may result in increased sediment and phosphorus loading to the lake.

Restoring or improving wetlands in the watershed may also be beneficial for reducing the amount of nutrients or sediments which reach a lake. The U.S. Fish and Wildlife Service may be able to provide technical and financial assistance for these activities.

3. It is evident that a very large reduction in P loading is necessary in order to improve the water quality of these lakes. This will require a much more detailed study, such as those conducted as a part of the Clean Water Partnership (CWP) Program, to help develop an accurate water and phosphorus budget for these lakes. From this information strategies can be developed to target and implement the needed reductions. This report serves as a foundation upon which further studies and assessments may be based. The most frequent entry point into CWP is via Minnesota's 303(d) "Impaired Waters" listing process. The next listing is scheduled for 2008 and the process to create that list begins early in 2007. Long and Hope Lakes will be assessed as a part of this process. Details on the Impaired Waters process may be found at: http://www.pca.state.mn.us/water/tmdl/index.html .

LAKE ASSESSMENT PROGRAM: 2006

Introduction

Hope and Long Lakes were sampled by the MPCA and the Long Lake Association of Grove City during the summer of 2006 as part of the Lake Assessment Program (LAP). This program is designed to assist lake associations or municipalities in the collection and analysis of baseline water quality data in order to assess the trophic status of their lakes. The general work plan for LAP includes Association participation in the Citizen Lake-Monitoring Program (CLMP), cooperative examination of land use and drainage patterns in the watershed of the lake, and an assessment of the water quality data by MPCA staff.

This study was conducted at the request of the Long Lake Association of Grove City (Association). Hope and Long Lakes were sampled on five occasions in the spring and summer of 2006. Participants in this effort included Steve Heiskary, Matt Lindon, and Kacy Bobzien from the MPCA and Roger Hanson from the Association. Watershed information for Hope and Long Lakes was assembled from information in the Minnesota Department of Natural Resources' (DNR) Data Deli webpage. Land use information was complied from the University of Minnesota Remote Sensing Lab's 2000 LANDSAT imagery. Phytoplankton analysis was conducted by Dr. Howard Markus, MPCA.

Ecoregion Based Lake Water Quality

Table 1 provides the draft ecoregion-based nutrient criteria. These criteria were developed by MPCA in response to an EPA requirement that states develop nutrient criteria for lakes, rivers, wetlands and estuaries. Our approach to developing these criteria are consistent with our previous phosphorus criteria (Heiskary and Wilson, 1989) that have been used extensively for goal setting and evaluating the condition of Minnesota's lakes for our 305(b) report to Congress and have provided a basis for evaluating lakes for the 303(d) "impaired waters" list. Details on the development of the criteria may be found in Heiskary and Wilson (2005). In general, lakes that are at or below the criteria levels will have adequately high transparency and sufficiently low amounts of algae to support swimmable use throughout most of the summer. Whenever possible, these lakes should be protected from increases in nutrient concentrations, which would tend to stimulate algal and plant growth and reduce transparency. For lakes above the criteria level, the criteria may serve as a restoration goal for the lake and may lead to the lake being included on the 303(d) list that is submitted to EPA biennially.

Table 1. Proposed eutrophication criteria by ecoregion and lake type
(Heiskary and Wilson, 2005)

Ecoregion	TP	Chl-a	Secchi
	ppb	ppb	meters
NLF – Lake trout (Class 2A)	< 12	< 3	> 4.8
NLF – Stream trout (Class 2A)	< 20	< 6	> 2.5
NLF – Aquatic Rec. Use (Class 2B)	< 30	< 9	> 2.0
CHF – Stream trout (Class 2a)	< 20	< 6	> 2.5
CHF – Aquatic Rec. Use (Class 2b)	< 40	< 14	> 1.4
CHF – Aquatic Rec. Use (Class 2b) Shallow lakes	< 60	< 20	> 1.0
WCP & NGP – Aquatic Rec. Use (Class 2B)	< 65	< 22	> 0.9
WCP & NGP – Aquatic Rec. Use (Class 2b) Shallow lakes	< 90	< 30	> 0.7

Table 2 represents the typical summer-mean water quality for lakes in each ecoregion. This data is derived from extensive sampling (1985-1988) of several reference lakes in each of the ecoregions. These "reference" lakes are not necessarily the most pristine lakes in each ecoregion; rather these lakes are "representative" of the ecoregion and are minimally impacted by humans. As is evident, the relative impact by human activities does vary among ecoregions. Further details may be found in Heiskary and Wilson (2005). These data provide an objective basis for comparing data from other lakes and, in the case of this study; data from the NCHF and WCBP ecoregions will be used as a basis for comparing the water quality of lakes sampled in 2006.

Table 2. Reference Lake Data Base Water Quality Summary
(Summer Average Water Quality Characteristics for Lakes by Ecoregion)*

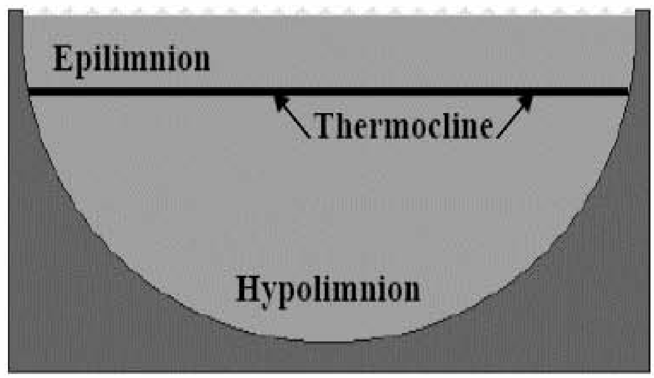
Parameter	NLF	CHF	WCP	NGP
# of lakes	**32**	**43**	**16**	**13**
Total Phosphorus (ug/l)	**14 - 27**	**23 - 50**	**65 - 150**	**122 - 160**
Chlorophyll mean (ug/l)	**4 - 10**	**5 - 22**	**30 - 80**	**36 - 61**
Chlorophyll maximum (ug/l)	**< 15**	**7 - 37**	**60 - 140**	**66 - 88**
Secchi Disk (feet) (meters)	**8 - 15 (2.4 - 4.6)**	**4.9 - 10.5 (1.5 - 3.2)**	**1.6 - 3.3 (0.5 - 1.0)**	**1.3 – 2..6 (0.4 – 0.8)**
Total Kjeldahl Nitrogen (mg/l)	**0.4 – 0.75**	**< 0.60 - 1.2**	**1.3 - 2.7**	**1.8 - 2.3**
Nitrite + Nitrate-N (mg/l)	**<0.01**	**<0.01**	**0.01 - 0.02**	**0.01 - 0.1**
Alkalinity (mg/l)	**40 – 140**	**75 - 150**	**125 - 165**	**160 - 260**
Color (Pt-Co Units)	**10 – 35**	**10 - 20**	**15 - 25**	**20 - 30**
pH (SU)	**7.2 - 8.3**	**8.6 - 8.8**	**8.2 - 9.0**	**8.3 - 8.6**
Chloride (mg/l)	**0.6 – 1.2**	**4 - 10**	**13 - 22**	**11 - 18**
Total Suspended Solids (mg/l)	**< 1 – 2**	**2 - 6**	**7 - 18**	**10 - 30**
Total Suspended Inorganic Solids (mg/l)	**< 1 – 2**	**1 - 2**	**3 - 9**	**5 - 15**
Turbidity (NTU)	**< 2**	**1 - 2**	**3 - 8**	**6 - 17**
Conductivity (umhos/cm)	**50 – 250**	**300 - 400**	**300 - 650**	**640 - 900**
TN:TP ratio	**25:1 - 35:1**	**25:1 - 35:1**	**17:1 - 27:1**	**13:1 - 17:1**

*Based on Interquartile range (25th - 75th percentile) for ecoregion reference lakes.
Derived in part from Heiskary, S. A. and C. B. Wilson (1990).

Lake depth can have a significant influence on lake processes and water quality. One such process is *thermal stratification* (formation of distinct temperature layers, see Figure 1a), in which deep lakes (maximum depths of 30 - 40 feet or more) often stratify (form layers) during the summer months and are referred to as *dimictic* (Figure 1c). These lakes full-mix or turn-over twice per year; typically in spring and fall (Figure 1d). Shallow lakes (maximum depths of 20 feet or less) in contrast, typically do not stratify and are often referred to as *polymictic* (Figure 1b). Some lakes, intermediate between these two, may stratify intermittently during calm periods. Measurement of temperature throughout the water column (surface to bottom) at selected intervals (e.g. every meter) can be used to determine whether the lake is well-mixed or stratified. It can also identify the depth of the thermocline (zone of maximum change in temperature over the depth interval). In general, the upper, well-mixed layer (epilimnion) is warm and has high oxygen concentrations. In contrast, the lower layer (hypolimnion) is much cooler and often has little or no oxygen. Most of the fish in the lake will be found in the epilimnion or near the thermocline. The combined effect of depth and stratification can influence overall water quality.

Figure 1. Thermal Stratification and Lake Mixing

1a



1b **Polymictic Lake**
Shallow, No Layers,
Mixes Continuously
Spring, Summer & Fall

Wind

1c **Dimictic Lake**
Deep, Form Layers,
Mixes Few Times
Summer

Wind

Epilimnion

Metalimnion

Hypolimnion

1d **Dimictic Lake**
Deep, Form Layers,
Mixes Few Times
Spring/Fall

Wind

Table 3 represents the percentile distribution of summer-mean in-lake TP concentrations for each ecoregion based on the mixing (temperature stratification) status of the lake as follows:

- dimictic — Deep lake, fully mixes in spring and fall but remains stratified in summer.
- polymictic — Shallow lake, remains well mixed from spring through fall.
- intermittent — Lake with moderate depths, may stratify temporarily during summer, but may mix with strong wind action.

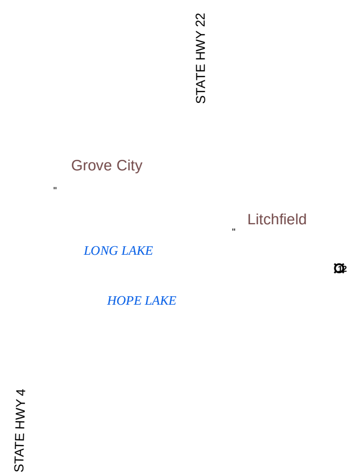
Sorting TP concentrations within each mixing type creates this distribution (by ecoregion) from low to high. These percentiles can provide an additional basis for comparing observed summer-mean TP and may further serve as a guide for deriving an appropriate TP goal for the lake.

Table 3. Distribution of Total Phosphorus (μg/L) Concentrations by Mixing Status and Ecoregion. Based on all assessed lakes for each ecoregion.
D = Dimictic, **I** = Intermittent, **P** = Polymictic

	Northern Lakes and Forests			**North Central Hardwood Forest**			**Western Corn Belt Plains**		
Mixing Status:	**D**	**I**	**P**	**D**	**I**	**P**	**D**	**I**	**P**
Percentile value for [TP]									
90 %	37	53	57	104	263	344	--	--	284
75 %	29	35	39	58	100	161	101	195	211
50 %	20	26	29	39	62	89	69	135	141
25 %	13	19	19	25	38	50	39	58	97
10 %	9	13	12	19	21	32	25	--	69
# of obs.	257	87	199	152	71	145	4	3	38

Background

Figure 2. Location of 2006 Lakes



Hope and Long Lakes are located in Meeker County, approximately three miles south of Grove City, Minnesota (Figure 2). Hope Lake has a surface area of 250 acres with a maximum depth of 10 feet and a mean depth of 5.4 feet. Long Lake covers 771 acres and has a maximum depth of 11 feet and a mean depth of 5.7 feet. Both lakes are shallow and are completely littoral (area of lake with a depth of 15 feet or less and potential area that can support rooted aquatic plant growth). Shallow lakes often remain well-mixed from top to bottom during the summer, in contrast to deep lakes that will typically form distinct thermal layers.

For Hope Lake, the watershed lies to the south and east, and for Long Lake, the majority of the drainage is from the west of the lake (Table 4b). Hope Lake has a total watershed of 7.2 square miles and Long Lake's total watershed (which includes the watershed of Hope Lake) comprises 28 square miles. Immediate watershed refers to that portion of the watershed that drains directly to the lake without flowing first through other lakes; while total watershed refers to the entire watershed upstream of the lake. Differentiating between immediate and total is important as nutrient and water budgets are determined for the lake (typically requires total watershed as an input); whereas when focusing best management practices and protection efforts, the immediate watershed is the first target. Total watershed to lake area ratio also provides an important perspective on the size of the watershed relative to the lake. Hope and Long Lakes have similar total watershed to lake area ratios, 18:1 and 23.5:1, respectively.

The soils found near Hope and Long Lakes are defined as medium to fine textured prairie border soils from the Lester-LeSueur-Glencoe series. These tend to be dark colored soils, varying greatly in drainage (well drained to poorly drained) found in gently rolling hills and were formed from medium textured glacial till (Arneman, 1963). Hope and Long Lakes were likely formed by irregular deposition of glacial till (Zumberge, 1952).

Since land use affects water quality, it has proven helpful to divide the state into regions where land use and water resources are similar. Minnesota is divided into seven regions, referred to as ecoregions, as defined by soils, land surface form, natural vegetation, and current land use. Data gathered from representative, minimally-impacted (reference) lakes within each ecoregion serve as a basis for comparing the water quality and characteristics of other lakes. Hope and Long Lakes are located near the border of the North Central Hardwood Forest and Western Corn Belt Plains ecoregions (Figure 3). Land use in the watershed of these lakes is rather typical of an ecoregion transitional zone mix, with a dominance of agriculture followed by water/wetland and forested land uses based on data from the early 1990s (Table 4b).

Figure 3. Minnesota's Seven Ecoregions and Location of Study Lakes

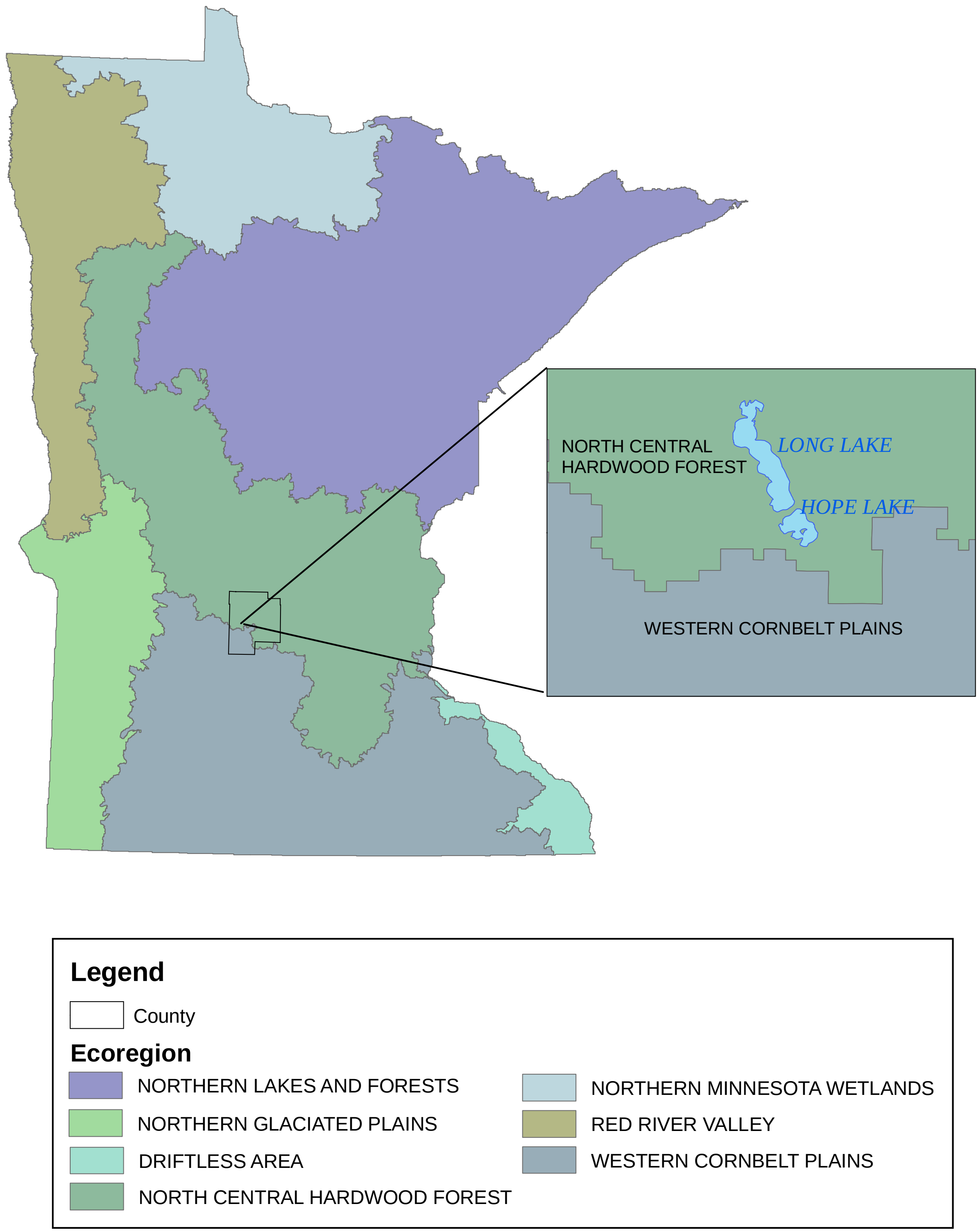
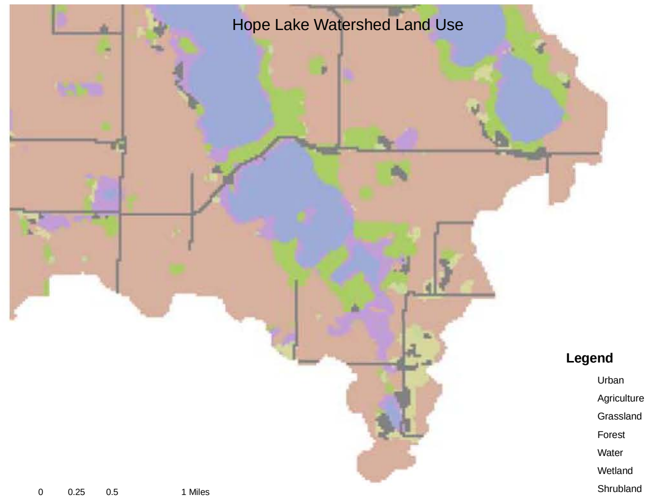


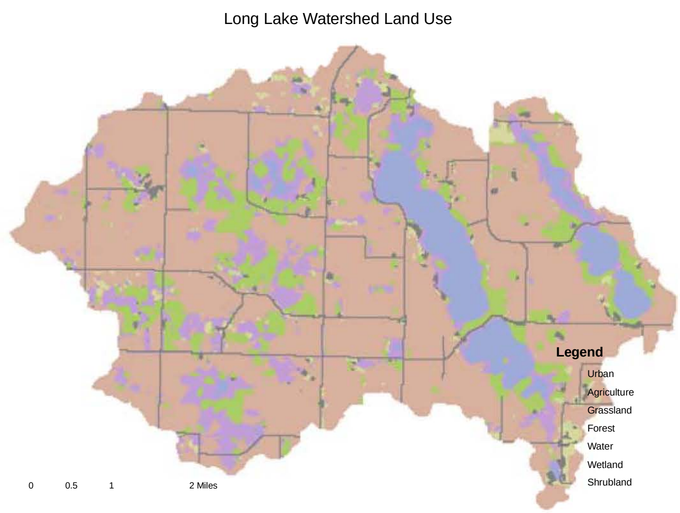
Table 4a. Lake morphometry and watershed characteristics.

Lake Name Name	Lake ID	Lake Basin Acres	Littoral Area Acres	 % Littoral	Immediate Watershed Acres	Total Watershed Area Acres	Total Watershed To Lake Ratio	Max. Depth Ft.	Average Depth Ft.	Lake Volume Acre-Ft.
Hope	47-0183	250	250	100	2,713	4,587	18:1	10	5.4	1,350
Long	47-0177	771	771	100	13,553	18,140	23.5:1	11	5.7	4,395

Table 4b. Watershed land use as compared to Ecoregion Interquartile Ranges

Land Use (%)	Hope	Long	NCHF Ecoregion	WCBP Ecoregion
Forest	9	12	6 – 25	0 – 15
Water/wetlands	17	19	14 – 30	3 – 26
Pasture/grasslands	3	2	11 – 25	0 - 7
Cultivated	65	62	22 – 50	42 - 75
Urban	6	5	2 - 9	0 - 16





History of Hope and Long Lake – contributed by the Association

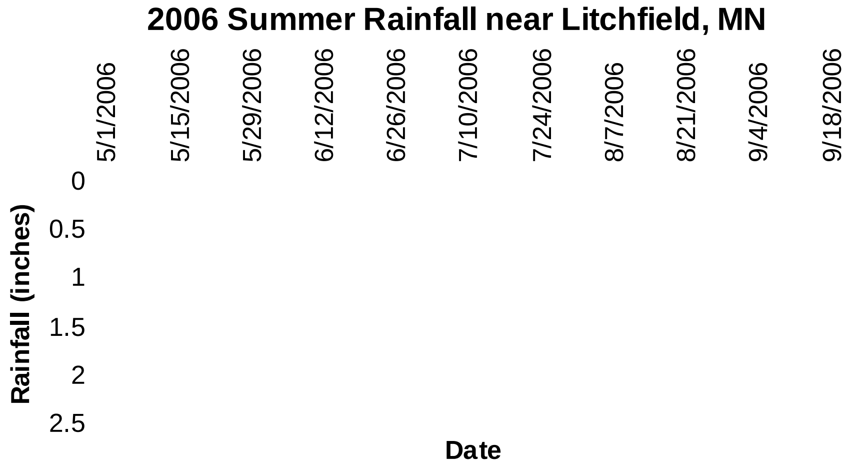
1920s-1930s	Post office, general store, and creamery were all established in Acton (between Long and Hope Lakes). A number of settlers had homes on the east and south sides of Long Lake.
1930s	North half of Long Lake dried out. Threshing machines were driving back and forth across the lake bed. Two to two and a half feet of water was left in the south end of the lake. Hope Lake never dried out.
1968	County Ditch 26 was dredged from Long Lake west, past Highway 4.
1970s	DNR designation of the Long Lake was changed from recreational to environmental. Ditch was dredged again late in the decade.
1982	A culvert replaced the lift station on County Ditch 26 as it entered Long Lake. After the installation of the culvert, the water was noticeably murkier than when the lift station was in use.
1988	Long Lake exhibited very low water levels. It was estimated that deepest point was five feet deep. It was possible to walk across the lake from shore to opposite shore that year. One landowner on the west side of the lake mowed the vegetation out 100 feet from his normal shoreline.
1989	The lake froze out (winter killed) the winter of 1988-1989. Three days of rain in May refilled the lake, and it has remained at that level since.
1995	The Long Lake Association of Grove City was formed by concerned landowners. The Association has conducted water quality and clarity monitoring for many years and currently has 42 families participating in the association (65% of the shoreland residences).

Precipitation

The summer of 2006 was marked by low precipitation. From May to September 2006, 14.73 inches were recorded near Litchfield. Rainfall amounts greater than one inch occurred on June 16th-18th, June 24th, July 31st-August 1st, and September 4th, 18th, and 22nd.

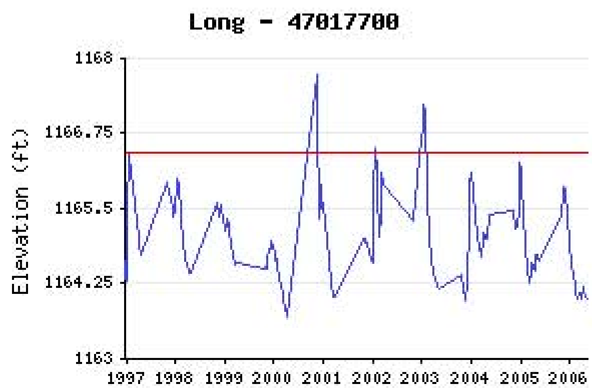
Normal rainfall averages 28 inches annually. The summer of 2006 was particularly dry; however, for the 2006 water year (October 1, 2005 to September 30, 2006) precipitation was found to be near normal levels. The normal and deviation from normal maps can be found in Appendix F.

Figure 4. 2006 Summer Rainfall Amounts near Litchfield, MN.



Lake Level

The DNR Division of Waters, with the cooperation of volunteer readers, monitored water levels in Long Lake in 2006. During the period of record (1997 – 2006) the lake has varied by 4.05 feet, based on 229 readings. The highest and lowest recorded elevations are 1167.88 feet on 5/29/01 and 1163.68 feet on 10/3/00, respectively. The OHW (ordinary high water mark) for Long Lake is 1166.4 feet.



Fisheries

DNR fisheries managers utilize netting survey information to assess the well-being of fish communities and measure the efficacy of management programs. Presence, absence, abundance, physical condition of captured fishes, and community relationships among fish species within survey catch information also provide good indicators of current habitat conditions and trophic state of a lake (Schupp and Wilson, 1993). This data is stored in a long-term fisheries survey database, which has proven valuable in qualifying and quantifying changes in environmental and fisheries characteristics over time. The fishery of Hope and Long Lakes is managed by the Minnesota Department of Natural Resources Fisheries Office located in Hutchinson, Minnesota. The most recent version of the Status of the Fishery is summarized below.

Hope – Status of the Fishery (as of 6/28/2004)

Hope Lake was surveyed to assess the current fish population and evaluate the lake management goals. Hope Lake has a long history of winterkills, and the fish population fluctuates greatly depending on how frequently and severely the lake freezes. Hope Lake does not have a developed public access. The lake is shallow and very fertile, with patches of emergent bulrush and cattail. The majority of the shoreline and island remain undeveloped.

Yellow perch were found in high numbers in the 2004 survey and 69% of the fish were at least 8 inches long. High numbers of northern pike were also found, with an average length of 24.5 inches. Black bullhead and carp were found in moderate numbers in 2004.

In 1991 during the previous netting, the only game fish found were small numbers of bluegill and yellow perch. Black bullheads dominated the sample.

Long – Status of the Fishery (as of 7/26/2004)

Long Lake was surveyed to assess the current fish population and evaluate the lake management goals. Similar to Hope Lake, Long Lake also has a history of winterkills, which cause great fluctuation in the fishery of the lake. Long Lake is also shallow and fertile, but has dense patches of curly leaf pondweed on the north end of the lake. The shoreline is mostly undeveloped, and consists of a narrow band of woodlands.

Yellow perch were found in high numbers in the 2004 survey, with 83% of the sample at least 8 inches long. In addition, moderate numbers of northern pike were gill netted, with an average length of 21.4 inches. Black bullhead dominated the gill net catch in 2004. Carp were also netted.

In the 1991 survey, no yellow perch were sampled and black bullheads dominated the catch.

Connections to both Hope Lake and the North Fork of the Crow River allow fish to migrate into and out of Long Lake when water levels are high enough.

Results and Discussion

Water quality data was collected in May, June, July, August, and September 2006. Site 101 was used on both Hope and Long Lakes. Lake surface samples were collected with an integrated sampler, a PVC tube 6.6 feet (2 meters) in length with an inside diameter of 1.24 inches (3.2 centimeters). Phytoplankton (algae) samples were taken at site 101 with an integrated sampler. Seasonal averages were calculated using June through September data.

Sampling procedures were employed as described in the MPCA Quality Control Manual. Laboratory analyses were performed by the Minnesota Department of Health Laboratory using U.S. Environmental Protection Agency (EPA) approved methods. Samples were analyzed for nutrients, color, solids, alkalinity, chloride, and chlorophyll-*a* (Table 5). Temperature, pH, conductivity, and dissolved oxygen profiles were taken with a meter and Secchi disk transparency measurements were also taken at the site.

A good historical database of Secchi data for Long Lake was available for comparison. All data was stored in STORET, the EPA's national water quality data bank. The following discussion assumes that the reader is familiar with basic water quality terminology as used in the Citizen's Guide to Lake Protection.

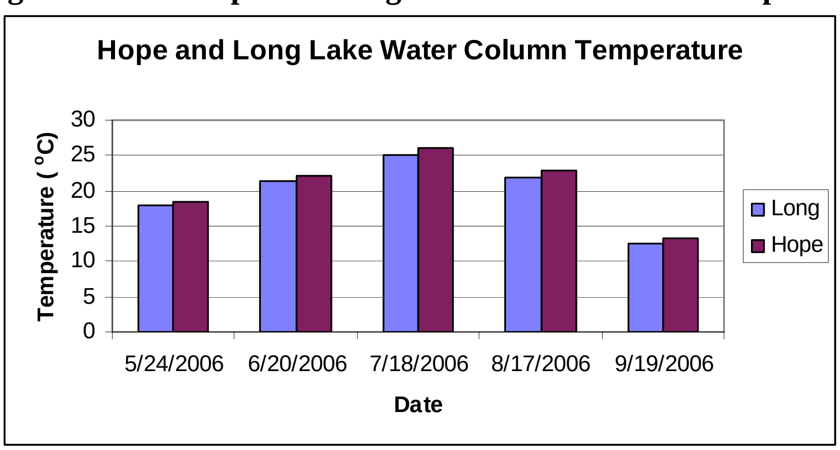
Table 5. Lake Summer Mean Water Quality

Parameter	Hope 101	Long 101	Typical Range for NCHF Ecoregion	Typical Range for WCBP Ecoregion
Total Phosphorus (µg/l)	264	385	23 – 50	65 – 150
Chlorophyll-a (µg/l) mean	238	232	5 – 22	30 – 80
Chlorophyll-a (µg/l) max	384	382	7 – 37	60 – 140
Secchi disk (feet)	0.6	0.6	4.9 – 10.5	1.6 – 3.3
Secchi disk (m)	0.2	0.2	1.5 – 3.2	0.5 – 1.0
Total Kjeldahl Nitrogen (mg/l)	5.5	5.9	<0.60 – 1.2	1.3 – 2.7
Alkalinity (mg/l)	138	135	75 – 150	125 – 165
Color (Pt-Co Units)	20	35	10 – 20	15 – 25
Chloride (mg/l)	18	22	4 – 10	13 – 22
Total Suspended Solids (mg/l)	90	138	2 – 6	7 – 18
Total Suspended Inorganic Solids (mg/l)	34	53	1 – 2	3 - 9
Conductivity (µmhos/cm)	277	295	300 – 400	300 – 650
TN:TP Ratio	21:1	15:1	25:1 – 33:1	17:1 – 27:1

<u>In-lake Conditions</u>: Hope Lake 2006

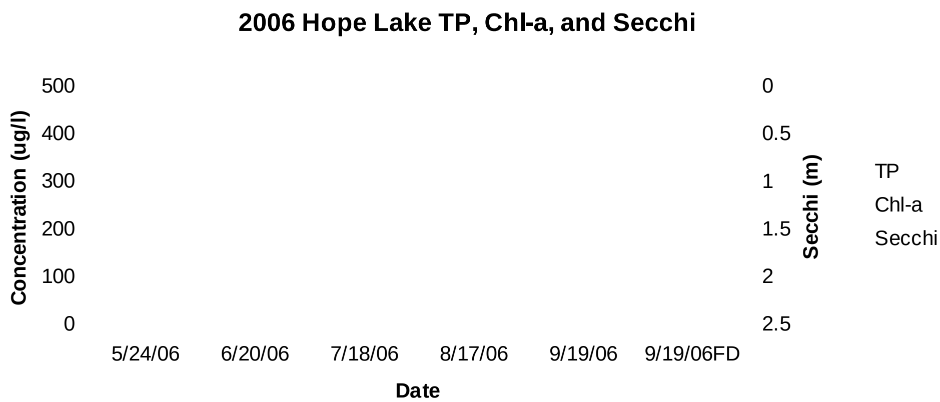
Dissolved oxygen and temperature profiles were taken at one meter intervals at site 101 on each date for Hope Lake. Dissolved oxygen ranged from a low of 7.1 mg/l in August to a high of 11.6 mg/l in June on Hope Lake. Game fish require a minimum dissolved oxygen concentration of 5 mg/l to survive. Temperatures ranged from a low of 13.2 ^{0}C in September to a peak of 26 ^{0}C in July on Hope Lake (Figure 5). These profiles would indicate that the lakes are well mixed, or polymictic.

Figure 5. 2006 Hope and Long Lake Water Column Temperature



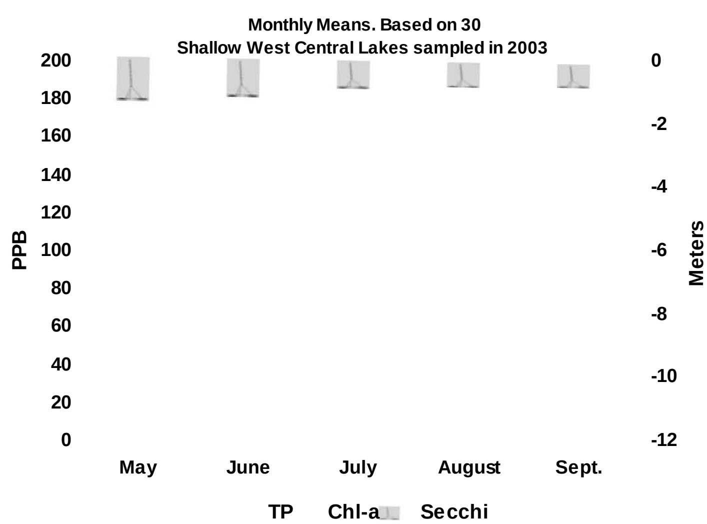
Total phosphorus (TP) concentrations (an important nutrient for plant growth) for 2006 averaged 264 µg/l (micrograms per liter or parts per billion) on Hope Lake (Figure 6). This mean is well above the typical range of concentrations for reference lakes found in either the NCHF or WCBP ecoregions (Table 5). TP concentrations increased over the summer on Hope Lake, reaching peak concentrations in August and then declining slightly. Hope Lake concentrations range from a low of 141 µg/l in May to a high of 313 µg/l in August. Field duplicates were collected on the September date, and are indicated on the graphs by ‘FD’ (Figure 6).

Figure 6. 2006 Concentrations and Transparency on Hope Lake.



This seasonal increase in TP is similar to what we see in other shallow well-mixed lakes. Figure 7 depicts monthly mean phosphorus patterns across the season in shallow lakes of west central Minnesota (Heiskary and Lindon, 2005). As summer progresses, there tends to be a marked increase in total phosphorus and chlorophyll-*a*, with internal recycling of phosphorus being the likely cause of this phenomenon. There are several factors that contribute to this phosphorus recycling, including: die-off of curly-leaf pondweed, wind mixing, mixing of sediment by bottom dwelling fish (i.e., carp and bullhead), and water temperature in excess of 21 ^{o}C (Heiskary and Lindon, 2005). This pattern also seems to follow the seasonal change in temperature (Figure 5).

Figure 7. Shallow West Central Lakes Phosphorus and Chlorophyll-*a* Patterns.



Total Kjeldahl nitrogen (TKN) averaged 5.5 mg/l for Hope Lake. This is well above the range of values for TKN in both the NCHF and WCBP ecoregion reference lakes (Table 5). The ratio of TN:TP can provide an indication as to which nutrient is limiting the production of algae in the lake. For Hope Lake, the TN:TP ratio is about 21:1. This suggests that phosphorus is the limiting nutrient in Hope Lake. Generally, phosphorus is the least abundant nutrient, and therefore, is the limiting nutrient for biological productivity in a lake. The ratios are below the reference lake ecoregion range for the NCHF lakes and on the low end or below the range for the WCBP lakes.

Chlorophyll-*a* concentrations provide an estimate of the amount of algal production in a lake. During the summer of 2006, chlorophyll-*a* concentrations on Hope Lake ranged from 149 µg/l to 384 µg/l with an average of 264 µg/l (Figure 6). Concentrations greater than 30 µg/l may be perceived as a severe nuisance algal bloom (Heiskary and Walker, 1988). Based on data collected in 2006, a severe nuisance bloom would have been present on all dates. Concentrations increased across the season, with Hope Lake peaking in August. The average and maximum chlorophyll-*a* concentrations for Hope Lake were well above the range of values compared to NCHF and WCBP reference lakes (Table 5).

Secchi disk transparency is generally a function of the amount of algae in the water. Suspended sediments or color due to dissolved organic material may also reduce water transparency. Color averaged 20 Pt-Co units for Hope Lake. Total suspended solids (TSS) averaged 90 mg/l and total suspended inorganic solids (i.e., clay) averaged 34 mg/l for Hope Lake (Table 5). Organic matter (primarily algae) was the dominant contributor to TSS. However, both the TSS and TSIS values were well above the ecoregion values for lakes in the NCHF and WCBP reference lakes.

For Hope Lake, the Secchi disk transparency ranged from a low of 0.3 feet (0.1 meters) in August to a high of 1.3 feet (0.4 m) in May, with an average 0.6 feet (0.2 m) (Figure 6). The observed decline in transparency from May to August is consistent with the increase in algae over that period. These transparency measures are well below (worse than) the ecoregion range of NCHF and WCBP reference lakes (Table 5).

Along with the transparency measurements, subjective measures of Hope Lake's "physical appearance" and "recreational suitability" were made. Physical appearance ratings range from "crystal clear" (Class 1) to "dense algal blooms, odor, etc." (Class 5) and recreational suitability ratings range from "beautiful, could not be any nicer" (Class 1) to "no recreation possible" (Class 5) in this rating system (Heiskary and Wilson, 1988). Based on 2006 data on Hope Lake, lake conditions were characterized as "high algae levels" and "dense algal blooms, odor, etc" (Classes 4 and 5) and "enjoyment substantially reduced" and "no recreation possible" (Classes 4 and 5) throughout the summer.

While the transparency is very limited Hope Lake, the change in the transparency over the course of the summer was typical of many lakes in Minnesota. Typically, transparency is high in the spring when the water is cool and algae populations are low. Frequently, zooplankton (small crustaceans which feed on algae) populations are high at this time of year also, but will decline later in the summer because of predation by young fish. As the summer goes on, the waters warm and the algae make use of available nutrients. As the algae become more abundant, the transparency declines. The decrease in the abundance of zooplankton may allow for further increases in the amount of algae. Later in the summer, surface blooms of algae may appear and further limit transparency.

Algal composition on Hope Lake in 2006 was dominated by blue-green algae for most of the summer (Figure 8). The May sample was predominately diatoms, with some yellow-brown and some blue-green algae present. A rapid transition from diatoms to blue-green is common in hypereutrophic Minnesota lakes. Once chlorophyll-*a* concentrations increased above 100 µg/l, the blue-green algae were dominant for the remainder of the season and would have accounted for a vast majority of this measured chlorophyll-*a* (Figure 9).

Figure 8. 2006 Hope Lake Algal Composition

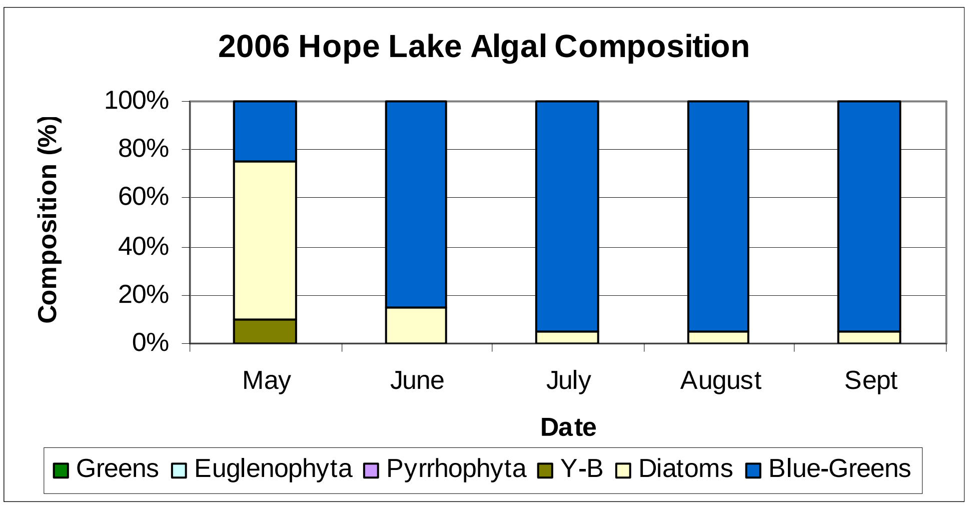
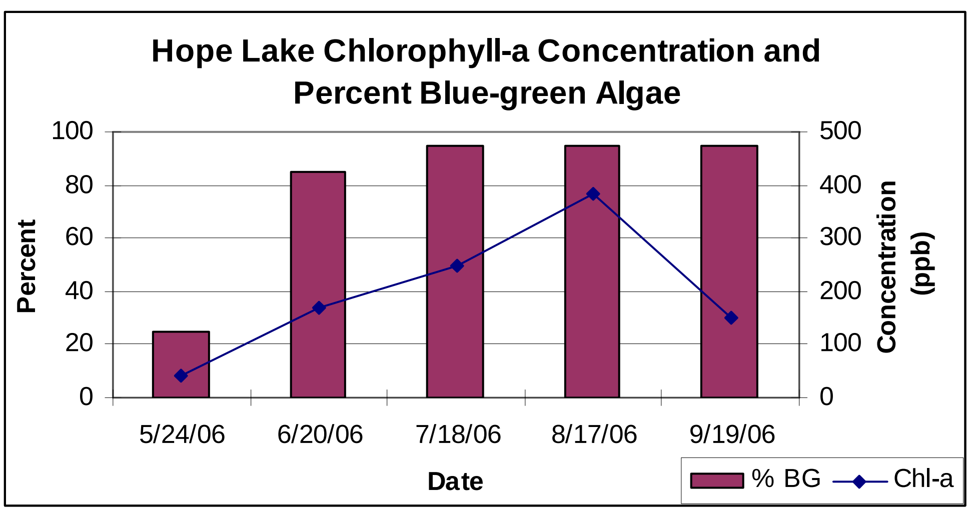


Figure 9. Hope Lake Chlorophyll-*a* Concentration and Percent Blue-Green Algae

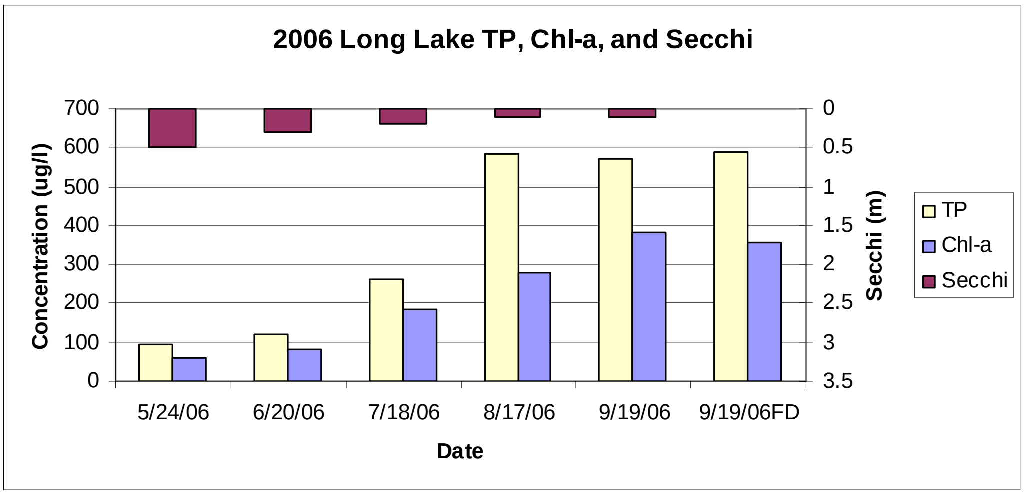


In-lake Conditions: Long Lake 2006

Dissolved oxygen and temperature profiles were taken at one meter intervals at site 101 on each date for Long Lake. Dissolved oxygen ranged from a low of 5.6 mg/l in August to a high of 9.4 mg/l in May on Long Lake. Temperatures ranged from a low of 12.5 ^{0}C in September to a peak of 25 ^{0}C in July on Long Lake. These profiles would indicate that the lake is well mixed, or polymictic. Like Hope Lake, Long Lake also exhibited high temperatures (> 21 ^{o}C) during the June, July, and August sampling dates (Figure 5). This elevated temperature combined with the shallow nature of the lake, would allow for phosphorus release from the bottom sediments into the water column on these dates.

Total phosphorus (TP) concentrations (an important nutrient for plant growth) for 2006 averaged 385 µg/l (micrograms per liter or parts per billion) on Long Lake (Figure 10). This mean concentration is well above the typical range of concentrations for reference lakes found in either the NCHF or WCBP ecoregions (Table 5) and among the highest concentrations observed in Minnesota lakes. TP concentrations increased over the summer on Long Lake, reaching peak concentrations in August. Long Lake concentrations range from a low of 94 µg/l in May to a high of 585 µg/l in August. Field duplicates were collected on the September date, and are indicated on the graphs by 'FD' (Figure 10). The seasonal increase in TP is likely the result of several factors including; high temperatures (> 21 ^{o}C) in June, July and August would promote internal recycling of TP from the sediments, die-back of curly-leaf pondweed in July may contribute phosphorus and would also allow for increased wind mixing (sediment resuspension) as well.

Figure 10. 2006 Concentrations and Transparency on Long Lake.



Total Kjeldahl nitrogen (TKN) averaged 5.9 mg/l for Long Lake. This is well above the range of values for TKN in both the NCHF and WCBP ecoregion reference lakes (Table 5). The ratio of TN:TP can provide an indication as to which nutrient is limiting the production of algae in the lake. For Long Lake, the TN:TP ratio is about 15:1. This suggests that phosphorus is the limiting nutrient in Long Lake. Generally, phosphorus is the least abundant nutrient, and therefore, is the limiting nutrient for biological productivity in a lake. The ratios are below the reference lake ecoregion range for the NCHF lakes and on the low end or below the range for the WCBP lakes.

Chlorophyll-*a* concentrations provide an estimate of the amount of algal production in a lake. During the summer of 2006, chlorophyll-*a* concentrations on Long Lake ranged from 81.4 µg/l to 382 µg/l with an average of 232 µg/l (Figure 10). Concentrations greater than 30 µg/l may be perceived as a severe nuisance algal bloom (Heiskary and Walker, 1988). Based on data collected in 2006, severe nuisance blooms were present on all dates. Concentrations increased across the season, with Long Lake peaking in September. The average and maximum chlorophyll-*a* concentrations for Long Lake were well above the range of values compared to NCHF and WCBP reference lakes (Table 5). The largest relative increase in chlorophyll-*a* occurred between the June and July dates when it doubled. This coincided with the curly-leaf pondweed die back and an increase in TP (Figure 10).

Secchi disk transparency is generally a function of the amount of algae in the water. Suspended sediments or color due to dissolved organic material may also reduce water transparency. Color averaged 35 Pt-Co units for Long Lake. Total suspended solids (TSS) averaged 138 mg/l and total suspended inorganic solids averaged 53 mg/l for Long Lake. Organic matter (primarily algae) was the dominant contributor to TSS. However, both the TSS and TSIS values were well above the ecoregion values for lakes in the NCHF and WCBP reference lakes and serve to limit the transparency of the lake.

For Long Lake, the Secchi disk transparency ranged from a low of 0.3 feet (0.1 meters) in August and September to a high of 1.6 feet (0.5 m) in May, with an average 0.6 feet (0.2 m) (Figure 10). The observed decline in transparency from May to September is consistent with the increase in algae over that period. These transparency measures are well below (worse than) the ecoregion range of NCHF and WCBP reference lakes (Table 5).

Along with the transparency measurements, subjective measures of Long Lake's "physical appearance" and "recreational suitability" were made. Physical appearance ratings range from "crystal clear" (Class 1) to "dense algal blooms, odor, etc." (Class 5) and recreational suitability ratings range from "beautiful, could not be any nicer" (Class 1) to "no recreation possible" (Class 5) in this rating system (Heiskary and Wilson, 1988). Based on 2006 data on Long Lake, lake conditions were characterized as "high algae levels" and "dense algal blooms, odor, etc" (Classes 4 and 5) and "enjoyment substantially reduced" and "no recreation possible" (Classes 4 and 5) throughout the summer.

Like Hope Lake, the transparency was very limited on Long Lake; however the change in the transparency over the course of the summer was typical of many lakes in Minnesota. Typically, transparency is high in the spring when the water is cool and algae populations are low. Frequently, zooplankton (small crustaceans which feed on algae) populations are high at this time of year also, but will decline later in the summer because of predation by young fish. As the summer goes on, the waters warm and the algae make use of available nutrients. As the algae become more abundant, the transparency declines. The decrease in the abundance of zooplankton may allow for further increases in the amount of algae. Later in the summer, surface blooms of algae may appear and further limit transparency.

Algal composition on Long Lake was dominated throughout the season by blue-green algae. While diatoms were present each of the months, they never comprised more than 30% of the total algal composition (Figure 11). As such, a majority of the chlorophyll-*a* (algal biomass) can be attributed to the blue-green algae (Figure 12).

Figure 11. 2006 Long Lake Algal Composition

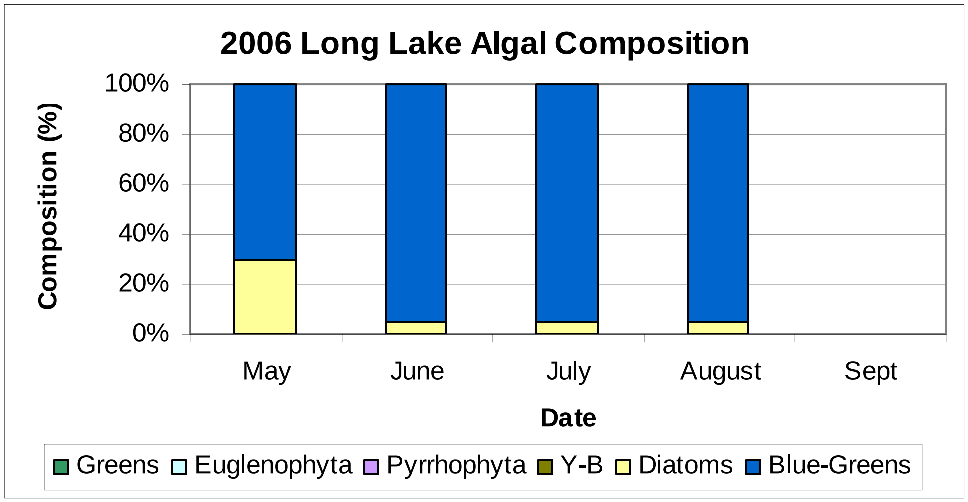
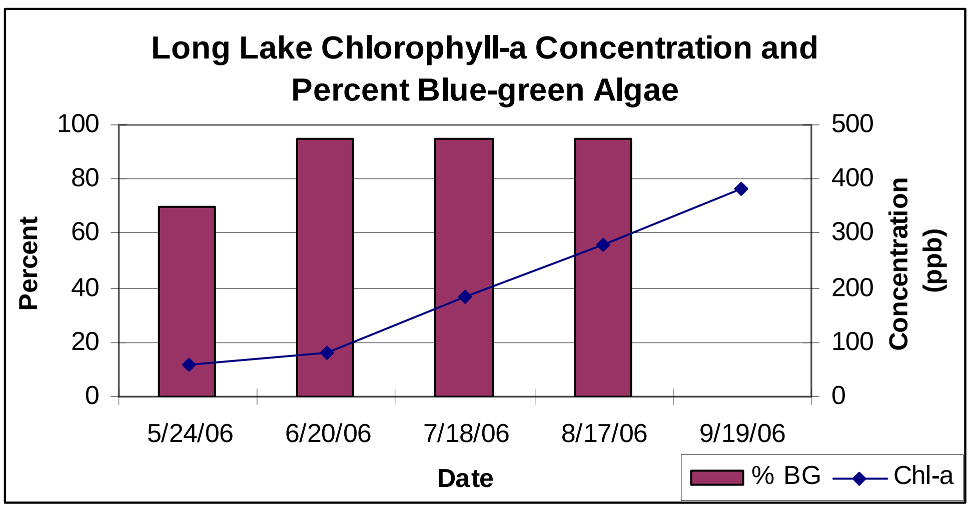


Figure 12. Long Lake Chlorophyll-*a* Concentration and Percent Blue-Green Algae



Algal toxins

Blue-green algae, more appropriately referred to as Cyanobacteria, are a common component of the algal community in lakes and rivers in Minnesota and elsewhere in the world. It has been long known that certain forms of blue-greens have the ability to produce toxins and these toxins have been implicated in animal deaths and human-health related problems. For example, in August and September of 2004 three dog deaths due to blue-green algal toxins were reported in central and southwestern Minnesota. These toxins, which include anatoxin, saxitoxin, microcystin and a more recently described toxin, cylindrospermopsin, vary in their toxicity. And of these, microcystin (MC) is the most commonly measured in most studies.

As previously noted algal concentrations were quite high on Long and Hope Lakes in 2006 and blue-greens were the dominant algal form (Figures 9, 10, 11 and 12). As a part of the Long and Hope LAP study and to complement another study, MC concentrations were measured on several dates during 2006 (Table 6). While there are no water quality standards for microcystin toxin, we can use guidelines provided by the World Health Organization (WHO; Chorus and Bartrum, 1999) to help place these results in perspective. The guidelines are as follows:

- Low risk: 0.075 – 10 ppb
- Moderate risk: 10 - 20 ppb
- High risk: 20– 2,000 ppb
- Very high risk: >2,000

Based on the WHO thresholds, most samples from Long and Hope would be characterized as "moderate" to "high" risk for MC toxicity. Two of the samples – Long on August 26 and the sample from CD-26 on September 19 would be considered "very high" risk. For further perspective, based on 74 MC samples from 12 lakes in south-central Minnesota in 2006 about 20% were in the "moderate" to "high" risk category and the remainder (over 80%) were in the "low" risk category (Lindon and Heiskary, 2007)

Table 6. Long and Hope Lake Microcystin Concentrations for 2006.

Date	Location	Concentration (ppb)
May 24	Long mid-lake	7.9
June 20	Long mid-lake	34.0
August 17	Long near-shore	16.0
August 26	Long mid-lake	9,500.0
Sept. 19	Long mid-lake	62.0
Sept. 6	Long CD-26	18,000.0
May 24	Hope mid-lake	2.3
June 20	Hope mid-lake	18.0
June 20	Hope near-shore	62.0
August 17	Hope near-shore	16.0
Sept. 12	Hope mid-lake	16.0

Tributary Monitoring

Data was collected four times on County Ditch 26 and three times on a tributary that runs between Harold and Hope Lakes (see photo at right) in 2006. In addition, the Association collected stream data on the county ditch, as well as from the outlet of Hope Lake in recent years.

Grab samples were collected only on dates when water was flowing. As seen in Figure 13, both the County Ditch and Harold Lake outlet flow primarily in the spring and dry up later in the summer. Based on the color of the water leaving Harold Lake (see photo at right), and the elevated total phosphorus concentration, Harold Lake is likely hypereutrophic as well.

In 2006, total phosphorus concentrations ranged from a low of 94 µg/l in May to a high of 587 µg/l in September on County Ditch 26. At the Harold Lake outlet, a low of 108 µg/l was observed in May, with a high of 145 µg/l in early June (Figure 13). Most of the readings were above the interquartile (IQ) range for minimally impacted streams in the NCHF ecoregion (Table 7).

Figure 13. Total Phosphorus Concentration on Hope and Long Lake Tributaries

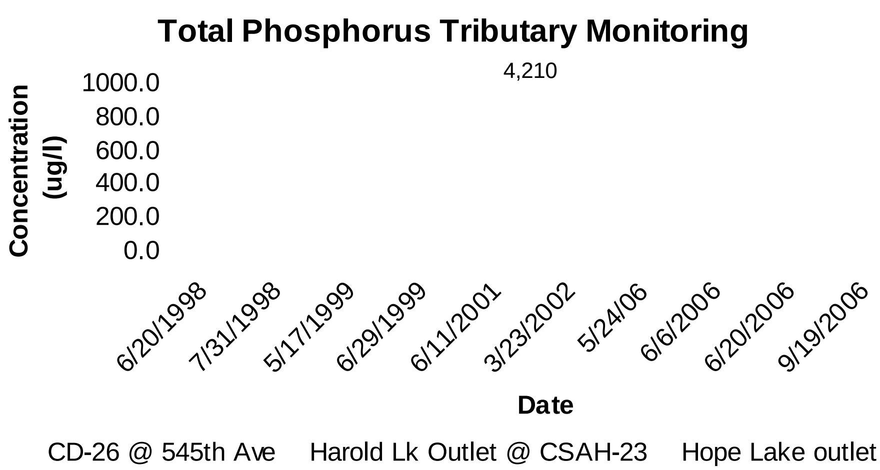


Table 7. IQ Range of Concentrations for Minimally Impacted Streams in Minnesota.
Data from 1970-1992 (McCollor and Heiskary, 1993)

	Total Phosphorus (µg/L)			**Total Suspended Solids (mg/L)**		
Region/Percentile	**25%**	**50%**	**75%**	**25%**	**50%**	**75%**
NLF	20	40	50	1.8	3.3	6.0
NMW	40	60	90	4.8	8.6	16.0
NCHF	60	90	150	4.8	8.8	16.0
NGP	90	160	250	11.0	34.0	63.0
RRV	110	190	300	11.0	28.0	59.0
WCBP	160	240	330	10.0	27.0	61.0

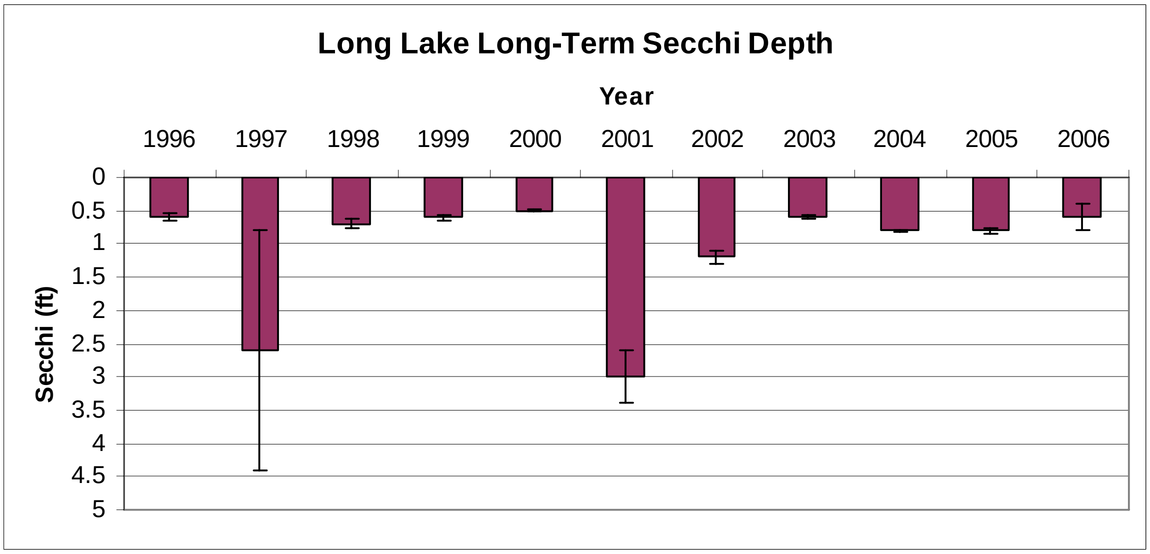
Water Quality Trends

For this report trends were examined for lakes with at least eight years of Secchi and/or four or more years of TP or chlorophyll-*a* data. Unless noted otherwise, most graphs will depict summer-mean measurements plus or minus the standard error (SE) of the mean. A large SE implies either high variability among seasonal measures and/or very few measures were taken. When comparing mean measures among years, the SE provides somewhat of a “confidence interval” for the mean; if the mean plus or minus the SE overlaps with another mean then it is likely the two means (measurements) are not significantly different.

Long Lake

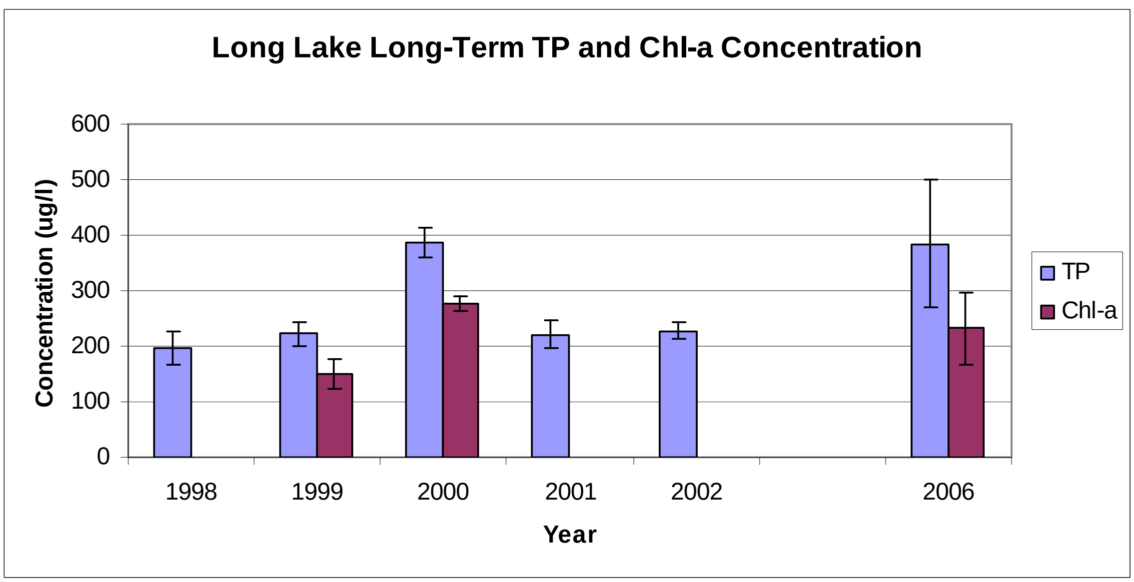
A good database is available for assessing trends in transparency for Long Lake. Individual summer-mean data for each year may be found in Appendix D. The majority of the data was collected by citizen volunteers through the CLMP and monitoring conducted by the MPCA. Secchi transparency data date back to 1996. Based on eleven years of record, the long-term mean (June through September data) Secchi is 1.1 feet (0.3 meters) (Figure 14). Based on analysis completed as part of the Citizen Lake-Monitoring Program, no significant change in Secchi transparency over time was noted based on the data; however 1997, 2001, and 2002 were years of relatively high transparency. All other years ranged from 1.6 feet (0.5 m) to 2.6 feet (0.8 m). It is interesting to note that the three years of relatively high transparency also corresponded with 3 of the 4 wettest summers over the eleven year period. All of the other years, except for 2005, were normal or below normal precipitation and low transparency.

Figure 14. Long Lake Long-Term Secchi Transparency



Six years of total phosphorus and three years of chlorophyll-*a* data are available from 1998 to 2006. The long-term average concentration is 273 µg/l for total phosphorus and 220 µg/l for chlorophyll-*a*, based on data from all sites over the period of record (Figure 15). These are well above (worse than) the expected range for reference lakes in the NCHF and WCBP ecoregions (Table 5). No trend is evident in these data.

Figure 15. Long Lake Long-Term Total Phosphorus and Chlorophyll-*a*



Trophic Status

One means to evaluate the trophic status of a lake and to interpret the relationship between total phosphorus, chlorophyll-*a*, and Secchi disk readings is Carlson's Trophic State Index (TSI) (Carlson, 1977). The index was developed from the interrelationships of summer Secchi disk transparency and the concentrations of surface water chlorophyll-*a* and total phosphorus. TSI values are calculated as follows:

Total Phosphorus TSI (TSIP)	=	14.42 ln (TP) + 4.15
Chlorophyll-*a* TSI (TSIC)	=	9.81 ln (Chl-*a*) + 30.6
Secchi disk TSI (TSIS)	=	60 – 14.41 ln (SD)

TP and chlorophyll-*a* are in µg/l and Secchi disk transparency is in meters. TSI values range from 0 (ultra-oligotrophic) to 100 (hypereutrophic). In this index, each increase of ten units represents a doubling of algal mass.

Average values for the trophic variables in Hope and Long Lakes are respective TSIs are presented in Figure 16. Based on these values and an average TSI score of 85 and 86, respectively for Hope and Long Lake, the lakes would be characterized as *hypereutrophic*. The individual TSI values for TP, chlorophyll-*a*, and Secchi transparency agree very well with one another for each lake. As such, Secchi transparency should provide a good estimation of trophic status for both lakes.

FIGURE 16. Carlson's Trophic State Index for Hope and Long Lakes
R.E. Carlson

TSI < 30 Classical Oligotrophy: Clear water, oxygen throughout the year in the hypolimnion, salmonid fisheries in deep lakes.

TSI 30 - 40 Deeper lakes still exhibit classical oligotrophy, but some shallower lakes will become anoxic in the hypolimnion during the summer.

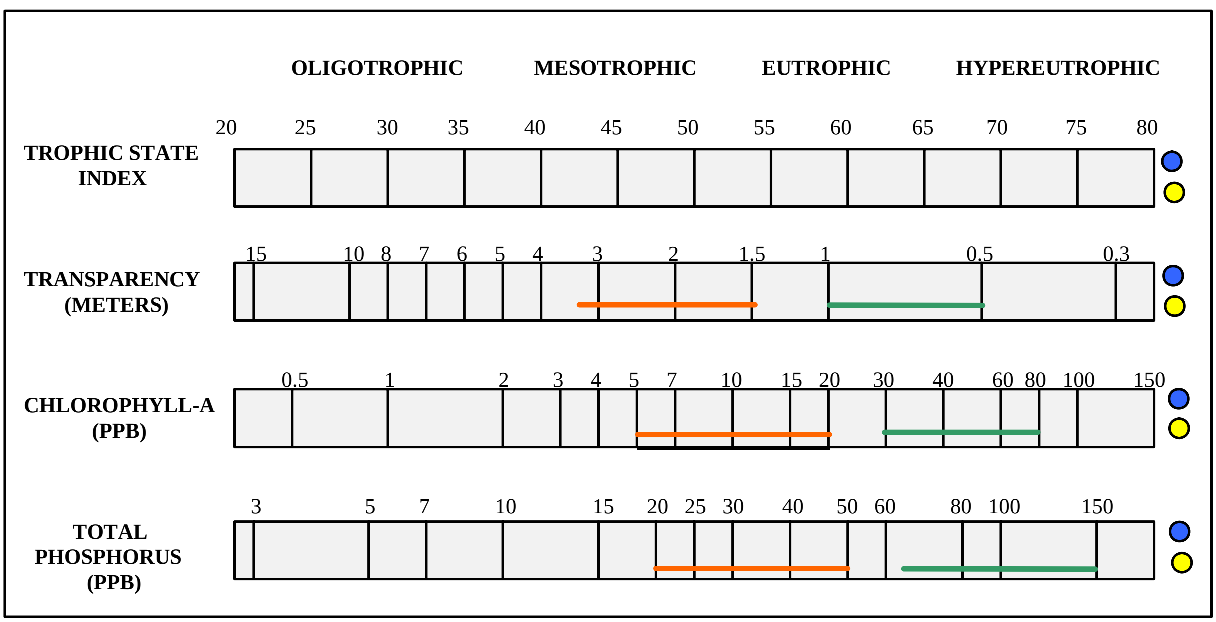
TSI 40 - 50 Water moderately clear, but increasing probability of anoxia in hypolimnion during summer.

TSI 50 - 60 Lower boundary of classical eutrophy: Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems evident, warm-water fisheries only.

TSI 60 - 70 Dominance of blue-green algae, algal scums probable, extensive macrophyte problems.

TSI 70 - 80 Heavy algal blooms possible throughout the summer, dense macrophyte beds, but extent limited by light penetration. Often would be classified as hypereutrophic.

TSI > 80 Algal scums, summer fish kills, few macrophytes, dominance of rough fish.



After Moore, l. and K. Thornton, [Ed.]1988. Lake and Reservoir Restoration Guidance Manual. USEPA>EPA 440/5-88-002.

NCHF Ecoregion Range: Hope : Long:
WCBP Ecoregion Range:

Modeling

Numerous complex mathematical models are available for estimating nutrient and water budgets for lakes. These models can be used to relate the flow of water and nutrients from a lake's watershed to observed conditions in the lake. Alternatively, they may be used for estimating changes in the quality of the lake as a result of altering nutrient inputs to the lake (e.g., changing land uses in the watershed) or altering the flow or amount of water that enters the lake. To analyze the 2006 water quality of Hope and Long Lakes, MINLEAP (Wilson and Walker, 1989) was used.

MINLEAP, which refers to "Minnesota Lake Eutrophication Analysis Procedures," was developed by MPCA staff based on an analysis of data collected from the ecoregion reference lakes. It is intended to be used as a screening tool for estimating lake conditions with minimal input data and is described in greater detail in Wilson and Walker (1989).

The model BATHTUB was developed by Dr. William Walker for the United States Army Corps of Engineers to assess lakes and reservoirs. This model provides additional diagnostics and allows the linkage of the two lakes in a segmented network and evaluates the individual responses of Hope and Long Lakes. This model is routinely used in CWP projects and allows for advanced evaluation of lakes and reservoirs. For Hope and Long Lakes, BATHTUB could be used to estimate the impact of future land used changes in the watershed of the lakes. Following is a summary of model inputs and assumptions used in the current study of these lakes:

- Septic system inputs were estimated based on lake association data of 48 homes around Long Lake. Of these, 20 were estimated to be year-round and 28 as seasonal. Standard per capita estimates of P-loading to the systems and a soil retention coefficient of 80% (implies that 80% of the phosphorus loaded to the systems remains in the system or soils) were used in this case.
- Land use composition was estimated from the 2000 LANDSAT satellite imagery and the DNR’s minor watershed data.
- Estimated precipitation, runoff, and evaporation were used, based on data collected from this part of the state.
- Phosphorus concentrations for runoff were assigned to the four land use categories as follows: forest (50 µg/l), wetland (50 µg/), cultivated/open/grasslands (300 µg/l), and urban/residential (300 µg/l) based on past monitoring and modeling experience. In addition, some tributary monitoring data for County Ditch 26 and the Harold and Hope Lake Outlets were available for comparison. A runoff value of 0.1 m/yr was applied to the forest and wetland land uses. For agricultural and urban land uses, the runoff value assigned was 0.2 m/yr.
- While both lakes are shallow and polymictic, internal loading of phosphorus likely occurred on the June, July, and August sampling dates, based on temperature data collected at each site. In conjunction with elevated pH, high temperature can cause the release of phosphorus from the bottom sediments of the lake. In this case, typical aerobic (in the presence of oxygen) total phosphorus release rates were used.

MINLEAP uses the total watershed area of the lake (minus lake surface area) combined with ecoregion based typical runoff and stream TP as a basis for predicting P-loading to the lake. Since all lakes located in the transition zone between the NCHF and WCBP ecoregions, the model was run twice for each lake to frame the expected range of concentrations, using the specific ecoregion-based inputs for precipitation, runoff, evaporation, and average stream TP. It should be noted that the model predicts in-lake TP from these inputs and subsequently predicts chlorophyll-*a* based on a regression equation with TP, and Secchi based on a regression equation based on chlorophyll-*a*. A comparison of MINLEAP predicted vs. observed values is presented in Table 8.

Table 8. MINLEAP Model Results for Hope and Long Lakes.

Parameter	Hope 2006	Hope NCHF MINLEAP	Hope WCBP MINLEAP	Long 2006	Long NCHF MINLEAP	Long WCBP MINLEAP
TP (µg/l)	264	68 ± 20	170 ± 58	385	71 ± 21	182 ± 61
P loading rate (kg/yr)	-	387	1,406	-	1,506	5,533
P retention (%)	-	57	70	-	54	68
P inflow conc. (µg/l)	-	158	568	-	156	569
Water Load (m/yr)	-	2.43	2.45	-	3.1	3.12
Outflow volume (hm^3/yr)	-	2.45	2.47	-	9.67	9.73
Residence time (yrs)	-	0.7	0.7	-	0.5	0.5

There was a significant difference between observed and MINLEAP predicted TP for both Hope and Long Lakes, regardless of the ecoregion based parameters used (Table 8). In simple terms this means that the observed TP is not consistent with and considerably more degraded than what is expected for lakes of that size and depth and size watershed in the NCHF or WCBP ecoregions.

The BATHTUB model provided an additional perspective on the two lakes, including the relative contributions to their water budget and phosphorus loading and interactions between the two lakes (Figures 17 and 18, respectively). Detailed inputs and model output may be found in Appendix E. As with MINLEAP, the original, un-calibrated, model run gave predicted values for both lakes that were considerably lower than observed values in 2006 (Table 9). The model was then calibrated to account for internal loading, increased septic contributions, and increased contribution from urban and agricultural land uses. This run provided predictions similar to observed for total phosphorus, chlorophyll-*a*, and Secchi values for Hope Lake, but did not account for the observed in-lake total phosphorus for Long Lake. In terms of water-loading, 81% comes from runoff in the watershed and 19% from precipitation on Hope Lake (Figure 17). For Long Lake, relative contributions to the water-load are as follows: 15% precipitation, 65% watershed runoff, and 18% from Hope Lake (Figure 15). For Hope Lake, the model estimates suggest that about one-half of the phosphorus load comes from the watershed and a similar amount may arise from internal recycling in the lake (Figure 18).

In order to balance the phosphorus budget for Long Lake, we needed to “increase” the phosphorus loading beyond that used in the “calibrated” run. In this case, this was referred to as an “unknown” source, though it is quite likely that the lake may have much greater internal recycling of phosphorus than was presumed in the original and calibrated model runs. Based on these estimates, watershed loading may contribute on the order of 34%, with a majority arising from County Ditch 26 and the immediate watershed of Long Lake. On a percentage basis, septic systems are likely a very small contributor, on the order of 2%. Internal recycling is likely the most significant source and may contribute 40% to 60% of the phosphorus budget for Long Lake (Figure 16).

Figure 17. Estimated Water Budget by Source for Hope and Long Lakes

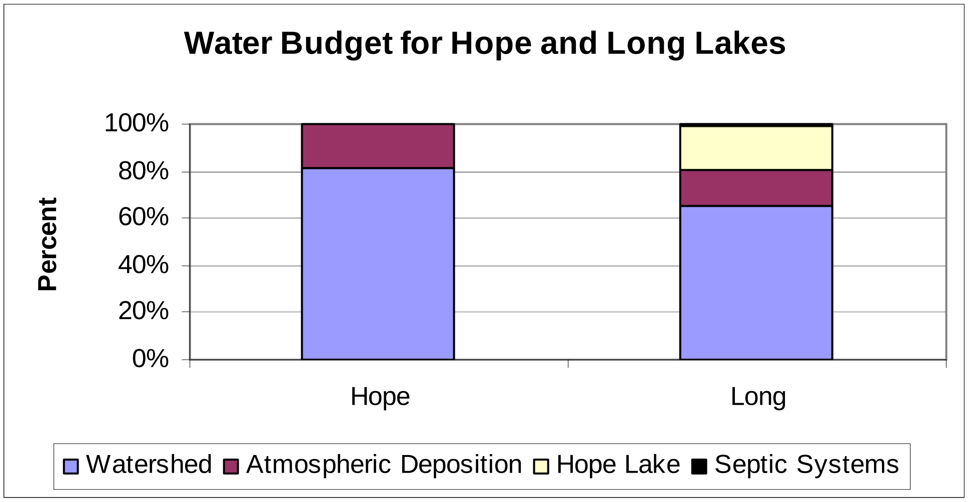
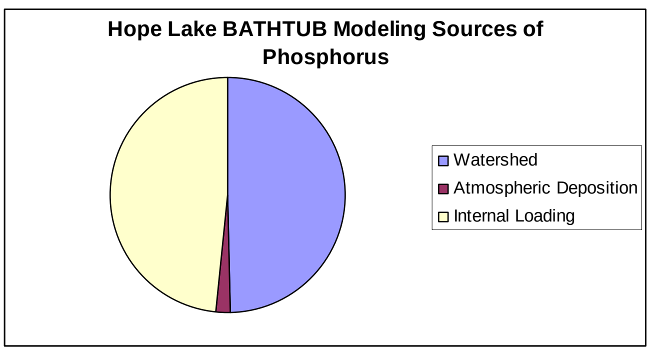


Figure 18. Estimated Phosphorus Budgets by Source for Hope and Long Lake



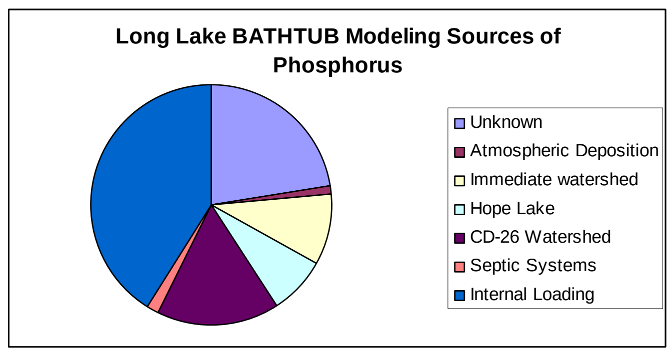


Table 9. BATHTUB Model Results for Hope and Long Lakes

Parameter	Hope 2006	BATHTUB	Calibrated BATHTUB	Long 2006	BATHTUB	Calibrated BATHTUB
TP (µg/l)	264	99 ± 27	273 ± 66	385	93 ± 25	262 ± 63
Chl-a (µg/l)	238	66 ± 31	292 ± 126	232	61 ± 29	275 ± 121
Secchi (m)	0.2	0.5 ± 0.2	0.2 ± 0.05	0.2	0.5 ± 0.2	0.2 ± 0.05
P loading rate (kg/yr)			1,511			5,524
P retention (%)			54			49
P inflow conc. (µg/l)			435			406
Total inflow vol. (hm3/yr)			3.5			13.6
Total outflow vol. (hm3/yr)			2.5			10.8
Residence time (yrs)			0.6			0.5

Goal Setting

The phosphorus criteria values for shallow lakes in the North Central Hardwoods Forests and Western Corn Belt Plains ecoregions are less than 60 µg/l and less than 90 µg/l, respectively, for support of aquatic recreation use. At or below 30 µg/l, "nuisance algal blooms" (chlorophyll-*a* > 20 µg/l) should occur less than 10 percent of the summer and transparency should remain at or above 3 meters (9.8 feet) over 85 percent of the summer.

For Hope and Long Lakes, it would be desirable to reduce in-lake TP concentrations below levels observed in 2006. Given their shallowness, proximity to the WCBP ecoregion, and dominance of agriculture in the watershed, these lakes appear to be most similar to the WCBP lakes and hence the WCBP shallow lakes criteria (Table 1) should apply to them. This implies a large reduction in phosphorus loading would be required to achieve a concentration on the order of 90 µg/l for either of the lakes. Further, based on the data assembled in this report, it will be important to reduce not only the external (watershed) load, but also the internal load. A more comprehensive study will be needed to more precisely estimate the phosphorus budgets for the lakes and the amount of reduction needed.

Appendix A   Glossary

Acid Rain: Rain with a higher than normal acid range (low pH). Caused when polluted air mixes with cloud moisture; can cause lakes to be devoid of fish.

Algal Bloom: An unusual or excessive abundance of algae.

Alkalinity: Capacity of a lake to neutralize acid.

Bioaccumulation: Build-up of toxic substances in fish flesh. Toxic effects may be passed on to humans eating the fish.

Biomanipulation: Adjusting the fish species composition in a lake as a restoration technique.

Dimictic: Lakes which thermally stratify and mix (turnover) once in spring and fall.

Ecoregion: Areas of relative homogeneity. EPA ecoregions have been defined for Minnesota based on land use, soils, landform, and potential natural vegetation.

Ecosystem: A community of interaction among animals, plants, and microorganisms, and the physical and chemical environment in which they live.

Epilimnion: Most lakes form three distinct layers of water during summertime weather. The epilimnion is the upper layer and is characterized by warmer and lighter water.

Eutrophication: The aging process by which lakes are fertilized with nutrients. *Natural eutrophication* will very gradually change the character of a lake. *Cultural eutrophication* is the accelerated aging of a lake as a result of human activities.

Eutrophic Lake: A nutrient-rich lake – usually shallow, "green" and with limited oxygen in the bottom layer of water.

Fall Turnover: Cooling surface waters, activated by wind action, sink to mix with lower levels of water. As in spring turnover, all water is now at the same temperature.

Hypolimnion: The bottom layer of lake water during the summer months. The water in the hypolimnion is denser and much colder than the water in the upper two layers.

Lake Management: A process that involves study, assessment of problems, and decisions on how to maintain a lake as a thriving ecosystem.

Lake Restoration: Actions directed toward improving the quality of a lake.

Lake Stewardship: An attitude that recognizes the vulnerability of lakes and the need for citizens, both individually and collectively, to assume responsibility for their care.

Limnetic Community: The area of open water in a lake providing the habitat for phytoplankton, zooplankton and fish.

Littoral Community: The shallow areas around a lake's shoreline, dominated by aquatic plants. The plants produce oxygen and provide food and shelter for animal life.

Mesotrophic Lake: Midway in nutrient levels between the eutrophic and oligotrophic lakes

Meromictic: A lake that does not mix completely

Nonpoint Source: Polluted runoff – nutrients and pollution sources not discharged from a single point: e.g. runoff from agricultural fields or feedlots.

Oligotrophic Lake: A relatively nutrient- poor lake, it is clear and deep with bottom waters high in dissolved oxygen.

pH Scale: A measure of acidity.

Photosynthesis: The process by which green plants produce oxygen from sunlight, water and carbon dioxide.

Phytoplankton: Algae – the base of the lake's food chain, it also produces oxygen.

Point Sources: Specific sources of nutrient or polluted discharge to a lake: e.g. Stormwater outlets.

Polymictic: A lake that does not thermally stratify in the summer. Lake tends to mix periodically throughout summer via wind and wave action.

Profundal Community: The area below the limnetic zone where light does not penetrate. This area roughly corresponds to the hypolimnion layer of water and is home to organisms that break down or consume organic matter.

Respiration: Oxygen consumption

Secchi Disk: A device measuring the depth of light penetration in water.

Sedimentation: The addition of soils to lakes, a part of the natural aging process, makes lakes shallower. The process can be greatly accelerated by human activities.

Spring Turnover: After ice melts in spring, warming surface water sinks to mix with deeper water. At this time of year, all water is the same temperature.

Thermocline: During summertime, the middle layer of lake water. Lying below the epilimnion, this water rapidly loses warmth.

Watershed storage area The percentage of a drainage area labeled lacustrine (lakes) and palustrine (wetlands) on U.S. Fish and Wildlife Service National Wetlands Inventory Data.

Zooplankton: The animal portion of the living particles in water that freely float in open water, eat bacteria, algae, detritus and sometimes other zooplankton and are in turn eaten by planktivorous fish.

Appendix B Water Quality Data: Abbreviations and Units

TP= total phosphorus in mg/l(decimal) or ug/L as whole number
TKN= total Kjeldahl nitrogen in mg/l
TNTP=TN:TP ratio
pH= pH in SU (F=field, or L=lab)
ALK= alkalinity in mg/l (lab)
TSS= total suspended solids in mg/l
TSV= total suspended volatile solids in mg/l
TSIN= total suspended inorganic solids in mg/l
TURB= turbidity in NTU (F=field)
CON= conductivity in umhos/cm (F=field, L=lab)
CL= chloride in mg/l
DO= dissolved oxygen in mg/l
TEMP= temperature in degrees centigrade
SD= Secchi disk in meters (SDF=feet)
Chl-a= chlorophyll-a in ug/l
TSI= Carlson's TSI (P=TP, S=Secchi, C=Chla)
PHEO= pheophytin in ug/l
PHYS= physical appearance rating (classes=1 to 5)
REC= recreational suitability rating (classes=1 to 5)
RTP, RN2N3...= remark code; k=less than, Q=exceeded holding time

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Appendix D Surface water results

Lake Name	Lake ID	Date	Site	Sample Depth		TP	Chl-a	Secchi	Total Alk	Cl	TKN	Color, Apparent	TSS	VSS
				Up	Lwr	ug/l	ug/l	m	mg/l	mg/l	mg/l	PCU	mg/l	mg/l
Hope	47-0183	5/24/06	101	0	2	141	42.1	0.4	200	16	3.2	20	45	18
		6/20/06	101	0	2	217	169		190	17	9.34	20	66	38
		7/18/06	101	0	2	286	248	0.2	110	18	4.6	20	110	70
		8/17/06	101	0	2	313	384	0.1	120	19	4.67	20	110	66
		9/19/06	101	0	2	241	149	0.2	130	19	3.57	20	72	42
		9/19/06	101 FD	0	2	238	133		130	19	3.63	20	74	44
Long	47-0177	5/24/06	101	0	2	94	58.1	0.5	130	18	2.11	20	35	15
		6/20/06	101	0	2	120	81.4	0.3	130	19	2.9	30	38	27
		7/18/06	101	0	2	263	185	0.2	130	22	4.07	30	93	61
		8/17/06	101	0	2	585	281	0.1	140	23	8.03	40	200	110
		9/19/06	101	0	2	572	382	0.1	140	23	8.78	40	220	110
		9/19/06	101FD	0	2	587	355		150	23	8.62	40	220	110

Long-Term Secchi, TP, and Chl-a for Long Lake 47-0177

Year	TP	TP SE	Chl-a	Chl-a SE	Year	Secchi ft	SE
1998	197	29			1996	0.6	0.05
1999	222	21	151	26	1997	2.6	1.8
2000	388	27	277	12	1998	0.7	0.07
2001	221	25			1999	0.6	0.04
2002	227	15			2000	0.5	0.01
					2001	3	0.4
2006	385	116	232	64	2002	1.2	0.09
					2003	0.6	0.03
					2004	0.8	0.02
					2005	0.8	0.05
					2006	0.6	0.2

Appendix E BATHTUB Modeling Inputs and Outputs

Original BATHTUB Model Run – No Calibrations

File: D:\BATHTUB\HopeLong.btb
Description:

Global Variables	**Mean**	**CV**
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.66	0.0
Evaporation (m)	0.92	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	**Mean**	**CV**
Conserv. Substance	0	0.00
Total P	30	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	**Code**	**Description**
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	5	P, JONES & BACHMAN
Secchi Depth	4	VS. TP, CARLSON TSI
Dispersion	0	NONE
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	**Name**	**Segment**	**Group**	**km^2**	**m**	**km**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
1	Long	0	1	3.1	1.7	3.7	1.7	0	0	0	0	0	0	0	0	0	0	0
2	Hope	1	2	1	1.6	0.9	1.6	0	0	0	0	0	0	0	0	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
1	0	0	385	115	0	0	232	64	0.175	0.05	0	0	0	0	0	0	0	0
2	0	0	264	21.6	0	0	238	53	0.17	0.03	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	**Trib Name**	**Segment**	**Type**	**km^2**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
1	Harold Watershed	2	2	6.2	0	0	0	0	0.126	0	0	0	0	0	0	0
2	Hope	2	2	9.7	0	0	0	0	0	0	0	0	0	0	0	0
3	Long Immediate	1	2	19.4	0	0	0	0	0	0	0	0	0	0	0	0
4	Long CD26	1	2	32.3	0	0	0	0	0.318	0	0	0	0	0	0	0

Tributary Non-Point Source Drainage Areas (km^2)

		Land Use Category--->							
Trib	**Trib Name**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	Harold Watershed	1.2	0.8	3.9	0.3	0	0	0	0
2	Hope	1	0.7	7.4	0.6	0	0	0	0
3	Long Immediate	3	2.7	12.6	1.1	0	0	0	0
4	Long CD26	3.8	4.7	22.3	1.5	0	0	0	0

Non-Point Source Export Coefficients

		Runoff (m/yr)		Conserv. Subs.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Categ	**Land Use Name**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
1	Forest	0.1	0	0	0	50	0	0	0	0	0	0	0
2	Wet Land	0.1	0	0	0	50	0	0	0	0	0	0	0
3	Crop	0.2	0	0	0	250	0	0	0	0	0	0	0
4	Urban	0.2	0	0	0	200	0	0	0	0	0	0	0
5		0	0	0	0	0	0	0	0	0	0	0	0
6		0	0	0	0	0	0	0	0	0	0	0	0
7		0	0	0	0	0	0	0	0	0	0	0	0
8		0	0	0	0	0	0	0	0	0	0	0	0

Model Coefficients	**Mean**	**CV**
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

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Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment:	3	Area-Wtd Mean				
	Predicted Values--->			Observed Values--->		
Variable	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	94.2	0.27	77.4%	355.5	98.08	98.7%
CHL-A MG/M3	61.7	0.47	99.3%	233.5	61.26	100.0%
SECCHI M	0.5	0.29	16.2%	0.2	0.05	0.8%
ANTILOG PC-1	2795.0	0.67	96.8%	26911.7	47.06	100.0%
ANTILOG PC-2	12.9	0.20	90.7%	13.7	33.58	92.4%
ZMIX / SECCHI	3.3	0.29	26.1%	9.6	0.04	88.7%
CHL-A * SECCHI	31.5	0.31	94.4%	40.6	50.12	97.4%
CHL-A / TOTAL P	0.7	0.29	97.1%	0.7	88.76	97.4%
FREQ(CHL-a>10) %	99.6	0.01	99.3%	100.0	0.00	100.0%
FREQ(CHL-a>20) %	93.4	0.11	99.3%	100.0	0.04	100.0%
FREQ(CHL-a>30) %	80.3	0.27	99.3%	99.9	0.34	100.0%
FREQ(CHL-a>40) %	65.1	0.44	99.3%	99.4	1.23	100.0%
FREQ(CHL-a>50) %	51.1	0.60	99.3%	98.5	2.92	100.0%
FREQ(CHL-a>60) %	39.6	0.74	99.3%	97.0	5.41	100.0%
CARLSON TSI-P	69.7	0.06	77.4%	88.7	13.96	98.7%
CARLSON TSI-CHLA	71.0	0.07	99.3%	84.1	5.76	100.0%
CARLSON TSI-SEC	69.7	0.06	83.8%	85.2	0.01	99.2%

Segment:	1	Long				
	Predicted Values--->			Observed Values--->		
Variable	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	92.8	0.27	76.9%	385.0	115.00	99.0%
CHL-A MG/M3	60.5	0.47	99.2%	232.0	64.00	100.0%
SECCHI M	0.5	0.29	16.6%	0.2	0.05	0.8%
ANTILOG PC-1	2702.0	0.67	96.7%	26571.0	60.69	100.0%
ANTILOG PC-2	12.9	0.20	90.6%	13.7	42.86	92.4%
ZMIX / SECCHI	3.3	0.29	26.1%	9.7	0.05	88.9%
CHL-A * SECCHI	31.3	0.31	94.3%	40.6	64.00	97.4%
CHL-A / TOTAL P	0.7	0.29	97.0%	0.6	128.69	96.1%
FREQ(CHL-a>10) %	99.5	0.01	99.2%	100.0	0.00	100.0%
FREQ(CHL-a>20) %	93.0	0.11	99.2%	100.0	0.05	100.0%
FREQ(CHL-a>30) %	79.4	0.28	99.2%	99.9	0.44	100.0%
FREQ(CHL-a>40) %	63.9	0.45	99.2%	99.4	1.59	100.0%
FREQ(CHL-a>50) %	49.8	0.61	99.2%	98.5	3.75	100.0%
FREQ(CHL-a>60) %	38.3	0.76	99.2%	96.9	6.95	100.0%
CARLSON TSI-P	69.5	0.06	76.9%	90.0	18.16	99.0%
CARLSON TSI-CHLA	70.8	0.07	99.2%	84.0	7.36	100.0%
CARLSON TSI-SEC	69.5	0.06	83.4%	85.1	0.01	99.2%

Segment:	2	Hope				
	Predicted Values--->			Observed Values--->		
Variable	Mean	CV	Rank	Mean	CV	Rank
TOTAL P MG/M3	98.3	0.27	78.8%	264.0	21.60	97.1%
CHL-A MG/M3	65.7	0.47	99.4%	238.0	53.00	100.0%
SECCHI M	0.5	0.29	14.8%	0.2	0.03	0.7%
ANTILOG PC-1	3083.4	0.68	97.3%	27968.1	50.26	100.0%
ANTILOG PC-2	13.0	0.20	91.0%	13.6	35.50	92.3%
ZMIX / SECCHI	3.3	0.29	25.9%	9.4	0.03	87.9%
CHL-A * SECCHI	32.1	0.31	94.7%	40.5	53.00	97.4%
CHL-A / TOTAL P	0.7	0.29	97.3%	0.9	57.00	99.2%
FREQ(CHL-a>10) %	99.7	0.01	99.4%	100.0	0.00	100.0%
FREQ(CHL-a>20) %	94.6	0.09	99.4%	100.0	0.04	100.0%
FREQ(CHL-a>30) %	83.0	0.24	99.4%	99.9	0.32	100.0%
FREQ(CHL-a>40) %	68.8	0.40	99.4%	99.5	1.18	100.0%
FREQ(CHL-a>50) %	55.2	0.55	99.4%	98.6	2.83	100.0%
FREQ(CHL-a>60) %	43.5	0.69	99.4%	97.2	5.30	100.0%
CARLSON TSI-P	70.3	0.06	78.8%	84.6	3.63	97.1%
CARLSON TSI-CHLA	71.7	0.07	99.4%	84.3	6.08	100.0%
CARLSON TSI-SEC	70.3	0.06	85.2%	85.5	0.00	99.3%

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Segment Mass Balance Based Upon Predicted Concentrations

Component:		**TOTAL P**		**Segment:**	**1**	**Long**	
			Flow	**Flow**	**Load**	**Load**	**Conc**
Trib	**Type**	**Location**	**hm^3/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m^3**
3	2	Long Immediate	3.3	24.5%	702.5	31.0%	212
4	2	Long CD26	5.6	41.5%	1217.5	53.8%	217
PRECIPITATION			2.0	15.1%	93.0	4.1%	45
NONPOINT INFLOW			8.9	66.0%	1920.0	84.8%	215
ADVECTIVE INFLOW			2.5	18.9%	250.6	11.1%	98
***TOTAL INFLOW			13.5	100.0%	2263.6	100.0%	167
ADVECTIVE OUTFLOW			10.7	78.9%	990.1	43.7%	93
***TOTAL OUTFLOW			10.7	78.9%	990.1	43.7%	93
***EVAPORATION			2.9	21.1%	0.0	0.0%	
***RETENTION			0.0	0.0%	1273.5	56.3%	

Hyd. Residence Time = 0.4942 yrs
Overflow Rate = 3.4 m/yr
Mean Depth = 1.7 m

Component:		**TOTAL P**		**Segment:**	**2**	**Hope**	
			Flow	**Flow**	**Load**	**Load**	**Conc**
Trib	**Type**	**Location**	**hm^3/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m^3**
1	2	Harold Watershed	1.0	30.0%	217.0	33.4%	209
2	2	Hope	1.8	51.0%	402.5	62.0%	227
PRECIPITATION			0.7	19.0%	30.0	4.6%	45
NONPOINT INFLOW			2.8	81.0%	619.5	95.4%	220
***TOTAL INFLOW			3.5	100.0%	649.5	100.0%	187
ADVECTIVE OUTFLOW			2.5	73.5%	250.6	38.6%	98
***TOTAL OUTFLOW			2.5	73.5%	250.6	38.6%	98
***EVAPORATION			0.9	26.5%	0.0	0.0%	
***RETENTION			0.0	0.0%	398.9	61.4%	

Hyd. Residence Time = 0.6275 yrs
Overflow Rate = 2.5 m/yr
Mean Depth = 1.6 m

Calibrated Model Run – Increased Land Use for Ag and Urban, added internal loading and septic system contributions

File: D:\BATHTUB\HopeLong.btb
Description:

Global Variables	**Mean**	**CV**
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.66	0.0
Evaporation (m)	0.92	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	**Mean**	**CV**
Conserv. Substance	0	0.00
Total P	30	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	**Code**	**Description**
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	5	P, JONES & BACHMAN
Secchi Depth	4	VS. TP, CARLSON TSI
Dispersion	0	NONE
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Lc Conserv.
Seg	**Name**	**Segment**	**Group**	**km^2**	**m**	**km**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**
1	Long	0	1	3.1	1.7	3.7	1.7	0	0	0	0	0	0
2	Hope	1	2	1	1.6	0.9	1.6	0	0	0	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)	
Seg	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
1	0	0	385	115	0	0	232	64	0.175	0.05	0	0	0	0
2	0	0	264	21.6	0	0	238	53	0.17	0.03	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)	
Seg	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
1	1	0	0.5	0	1	0	1	0	1	0	1	0	1	0
2	1	0	0.5	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (p
Trib	**Trib Name**	**Segment**	**Type**	**km^2**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**
1	Harold Watershed	2	2	6.2	0	0	0	0	0.126	0	0	0	0
2	Hope	2	2	9.7	0	0	0	0	0	0	0	0	0
3	Long Immediate	1	2	19.4	0	0	0	0	0	0	0	0	0
4	Long CD26	1	2	32.3	0	0	0	0	0.318	0	0	0	0
5	Long Septics	1	3	0	0.1	0	0	0	1500	0	0	0	0

Tributary Non-Point Source Drainage Areas (km^2)

		Land Use Category--->							
Trib	**Trib Name**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	Harold Watershed	1.2	0.8	3.9	0.3	0	0	0	0
2	Hope	1	0.7	7.4	0.6	0	0	0	0
3	Long Immediate	3	2.7	12.6	1.1	0	0	0	0
4	Long CD26	3.8	4.7	22.3	1.5	0	0	0	0
5	Long Septics	0	0	0	0	0	0	0	0

Non-Point Source Export Coefficients

		Runoff (m/yr)		Conserv. Subs.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Categ	**Land Use Name**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
1	Forest	0.1	0	0	0	50	0	0	0	0	0	0	0
2	Wet Land	0.1	0	0	0	50	0	0	0	0	0	0	0
3	Crop	0.2	0	0	0	300	0	0	0	0	0	0	0
4	Urban	0.2	0	0	0	300	0	0	0	0	0	0	0
5		0	0	0	0	0	0	0	0	0	0	0	0
6		0	0	0	0	0	0	0	0	0	0	0	0
7		0	0	0	0	0	0	0	0	0	0	0	0
8		0	0	0	0	0	0	0	0	0	0	0	0

Model Coefficients	**Mean**	**CV**
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.025	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

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Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: **3** **Area-Wtd Mean**

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	264.7	0.24	97.1%	355.5	98.08	98.7%
CHL-A MG/M3	279.1	0.44	100.0%	233.5	61.26	100.0%
SECCHI M	0.2	0.26	0.9%	0.2	0.05	0.8%
ANTILOG PC-1	30636.8	0.61	100.0%	26911.7	47.06	100.0%
ANTILOG PC-2	15.9	0.20	95.8%	13.7	33.58	92.4%
ZMIX / SECCHI	9.2	0.26	87.2%	9.6	0.04	88.7%
CHL-A * SECCHI	50.6	0.30	98.8%	40.6	50.12	97.4%
CHL-A / TOTAL P	1.1	0.28	99.6%	0.7	88.76	97.4%
FREQ(CHL-a>10) %	100.0	0.00	100.0%	100.0	0.00	100.0%
FREQ(CHL-a>20) %	100.0	0.00	100.0%	100.0	0.04	100.0%
FREQ(CHL-a>30) %	99.9	0.00	100.0%	99.9	0.34	100.0%
FREQ(CHL-a>40) %	99.8	0.01	100.0%	99.4	1.23	100.0%
FREQ(CHL-a>50) %	99.3	0.01	100.0%	98.5	2.92	100.0%
FREQ(CHL-a>60) %	98.5	0.03	100.0%	97.0	5.41	100.0%
CARLSON TSI-P	84.6	0.04	97.1%	88.7	13.96	98.7%
CARLSON TSI-CHLA	85.8	0.05	100.0%	84.1	5.76	100.0%
CARLSON TSI-SEC	84.6	0.04	99.1%	85.2	0.01	99.2%

Segment: **1** **Long**

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	262.0	0.24	97.0%	385.0	115.00	99.0%
CHL-A MG/M3	275.0	0.44	100.0%	232.0	64.00	100.0%
SECCHI M	0.2	0.26	1.0%	0.2	0.05	0.8%
ANTILOG PC-1	29915.8	0.61	100.0%	26571.0	60.69	100.0%
ANTILOG PC-2	15.9	0.20	95.7%	13.7	42.86	92.4%
ZMIX / SECCHI	9.3	0.26	87.4%	9.7	0.05	88.9%
CHL-A * SECCHI	50.4	0.30	98.8%	40.6	64.00	97.4%
CHL-A / TOTAL P	1.0	0.28	99.6%	0.6	128.69	96.1%
FREQ(CHL-a>10) %	100.0	0.00	100.0%	100.0	0.00	100.0%
FREQ(CHL-a>20) %	100.0	0.00	100.0%	100.0	0.05	100.0%
FREQ(CHL-a>30) %	99.9	0.00	100.0%	99.9	0.44	100.0%
FREQ(CHL-a>40) %	99.7	0.01	100.0%	99.4	1.59	100.0%
FREQ(CHL-a>50) %	99.3	0.01	100.0%	98.5	3.75	100.0%
FREQ(CHL-a>60) %	98.4	0.03	100.0%	96.9	6.95	100.0%
CARLSON TSI-P	84.4	0.04	97.0%	90.0	18.16	99.0%
CARLSON TSI-CHLA	85.7	0.05	100.0%	84.0	7.36	100.0%
CARLSON TSI-SEC	84.5	0.04	99.0%	85.1	0.01	99.2%

Segment: **2** **Hope**

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	272.9	0.24	97.3%	264.0	21.60	97.1%
CHL-A MG/M3	291.8	0.43	100.0%	238.0	53.00	100.0%
SECCHI M	0.2	0.26	0.8%	0.2	0.03	0.7%
ANTILOG PC-1	32872.1	0.61	100.0%	27968.1	50.26	100.0%
ANTILOG PC-2	16.0	0.20	95.9%	13.6	35.50	92.3%
ZMIX / SECCHI	9.1	0.26	86.6%	9.4	0.03	87.9%
CHL-A * SECCHI	51.3	0.30	98.9%	40.5	53.00	97.4%
CHL-A / TOTAL P	1.1	0.28	99.6%	0.9	57.00	99.2%
FREQ(CHL-a>10) %	100.0	0.00	100.0%	100.0	0.00	100.0%
FREQ(CHL-a>20) %	100.0	0.00	100.0%	100.0	0.04	100.0%
FREQ(CHL-a>30) %	100.0	0.00	100.0%	99.9	0.32	100.0%
FREQ(CHL-a>40) %	99.8	0.00	100.0%	99.5	1.18	100.0%
FREQ(CHL-a>50) %	99.4	0.01	100.0%	98.6	2.83	100.0%
FREQ(CHL-a>60) %	98.7	0.02	100.0%	97.2	5.30	100.0%
CARLSON TSI-P	85.0	0.04	97.3%	84.6	3.63	97.1%
CARLSON TSI-CHLA	86.3	0.05	100.0%	84.3	6.08	100.0%
CARLSON TSI-SEC	85.0	0.04	99.2%	85.5	0.00	99.3%

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Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P			Segment:	1	Long		
			Flow	**Flow**	**Load**	**Load**	**Conc**
Trib	**Type**	**Location**	**hm^3/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m^3**
3	2	Long Immediate	3.3	24.3%	850.5	15.4%	257
4	2	Long CD26	5.6	41.2%	1470.5	26.6%	262
5	3	Long Septics	0.1	0.7%	150.0	2.7%	1500
PRECIPITATION			2.0	15.0%	93.0	1.7%	45
INTERNAL LOAD			0.0	0.0%	2264.6	41.0%	
NONPOINT INFLOW			8.9	65.5%	2321.0	42.0%	260
POINT-SOURCE INFLOW			0.1	0.7%	150.0	2.7%	1500
ADVECTIVE INFLOW			2.5	18.7%	695.9	12.6%	273
***TOTAL INFLOW			13.6	100.0%	5524.4	100.0%	406
ADVECTIVE OUTFLOW			10.8	79.1%	2820.4	51.1%	262
***TOTAL OUTFLOW			10.8	79.1%	2820.4	51.1%	262
***EVAPORATION			2.9	20.9%	0.0	0.0%	
***RETENTION			0.0	0.0%	2704.0	48.9%	

Hyd. Residence Time = 0.4896 yrs
Overflow Rate = 3.5 m/yr
Mean Depth = 1.7 m

Component: TOTAL P			Segment:	2	Hope		
			Flow	**Flow**	**Load**	**Load**	**Conc**
Trib	**Type**	**Location**	**hm^3/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m^3**
1	2	Harold Watershed	1.0	30.0%	262.0	17.3%	252
2	2	Hope	1.8	51.0%	488.5	32.3%	276
PRECIPITATION			0.7	19.0%	30.0	2.0%	45
INTERNAL LOAD			0.0	0.0%	730.5	48.3%	
NONPOINT INFLOW			2.8	81.0%	750.5	49.7%	267
***TOTAL INFLOW			3.5	100.0%	1511.0	100.0%	435
ADVECTIVE OUTFLOW			2.5	73.5%	695.9	46.1%	273
***TOTAL OUTFLOW			2.5	73.5%	695.9	46.1%	273
***EVAPORATION			0.9	26.5%	0.0	0.0%	
***RETENTION			0.0	0.0%	815.1	53.9%	

Hyd. Residence Time = 0.6275 yrs
Overflow Rate = 2.5 m/yr
Mean Depth = 1.6 m

Long Lake Calibration – Internal Loading Set to 5 $mg/m^2/day$ to achieve TP close to 2006 Observed Levels

File: D:\BATHTUB\HopeLong.btb
Description:

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.66	0.0
Evaporation (m)	0.92	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	30	0.50
Total N	1000	0.50
Ortho P	15	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	5	P, JONES & BACHMAN
Secchi Depth	4	VS. TP, CARLSON TSI
Dispersion	0	NONE
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean
1	Long	0	1	3.1	1.7	3.7	1.7	0	0	0	0	0	0	0	5
2	Hope	1	2	1	1.6	0.9	1.6	0	0	0	0	0	0	0	2

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	385	115	0	0	232	64	0.175	0.05	0	0	0	0	0	0
2	0	0	264	21.6	0	0	238	53	0.17	0.03	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	0.5	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic I
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean
1	Harold Watershed	2	2	6.2	0	0	0	0	0.126	0	0	0	0	0	0
2	Hope	2	2	9.7	0	0	0	0	0	0	0	0	0	0	0
3	Long Immediate	1	2	19.4	0	0	0	0	0	0	0	0	0	0	0
4	Long CD26	1	2	32.3	0	0	0	0	0.318	0	0	0	0	0	0
5	Long Septics	1	3	0	0.1	0	0	0	1500	0	0	0	0	0	0

Tributary Non-Point Source Drainage Areas (km^2)

		Land Use Category--->							
Trib	Trib Name	1	2	3	4	5	6	7	8
1	Harold Watershed	1.2	0.8	3.9	0.3	0	0	0	0
2	Hope	1	0.7	7.4	0.6	0	0	0	0
3	Long Immediate	3	2.7	12.6	1.1	0	0	0	0
4	Long CD26	3.8	4.7	22.3	1.5	0	0	0	0
5	Long Septics	0	0	0	0	0	0	0	0

Non-Point Source Export Coefficients

		Runoff (m/yr)		Conserv. Subs.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Categ	Land Use Name	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Forest	0.1	0	0	0	50	0	0	0	0	0	0	0
2	Wet Land	0.1	0	0	0	50	0	0	0	0	0	0	0
3	Crop	0.2	0	0	0	300	0	0	0	0	0	0	0
4	Urban	0.2	0	0	0	300	0	0	0	0	0	0	0
5		0	0	0	0	0	0	0	0	0	0	0	0
6		0	0	0	0	0	0	0	0	0	0	0	0
7		0	0	0	0	0	0	0	0	0	0	0	0
8		0	0	0	0	0	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15

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Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment:	**3**	**Area-Wtd Mean**				
	Predicted Values--->			**Observed Values--->**		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	352.2	0.25	98.7%	355.5	98.08	98.7%
CHL-A MG/M3	425.8	0.45	100.0%	233.5	61.26	100.0%
SECCHI M	0.1	0.27	0.3%	0.2	0.05	0.8%
ANTILOG PC-1	60820.1	0.64	100.0%	26911.7	47.06	100.0%
ANTILOG PC-2	16.8	0.20	96.6%	13.7	33.58	92.4%
ZMIX / SECCHI	12.3	0.27	94.9%	9.6	0.04	88.7%
CHL-A * SECCHI	57.6	0.30	99.3%	40.6	50.12	97.4%
CHL-A / TOTAL P	1.2	0.28	99.8%	0.7	88.76	97.4%
FREQ(CHL-a>10) %	100.0		100.0%	100.0	0.00	100.0%
FREQ(CHL-a>20) %	100.0	0.00	100.0%	100.0	0.04	100.0%
FREQ(CHL-a>30) %	100.0	0.00	100.0%	99.9	0.34	100.0%
FREQ(CHL-a>40) %	99.9	0.00	100.0%	99.4	1.23	100.0%
FREQ(CHL-a>50) %	99.8	0.00	100.0%	98.5	2.92	100.0%
FREQ(CHL-a>60) %	99.6	0.01	100.0%	97.0	5.41	100.0%
CARLSON TSI-P	88.6	0.04	98.7%	88.7	13.96	98.7%
CARLSON TSI-CHLA	89.8	0.05	100.0%	84.1	5.76	100.0%
CARLSON TSI-SEC	88.6	0.04	99.7%	85.2	0.01	99.2%

Segment:	**1**	**Long**				
	Predicted Values--->			**Observed Values--->**		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	377.7	0.25	98.9%	385.0	115.00	99.0%
CHL-A MG/M3	469.0	0.45	100.0%	232.0	64.00	100.0%
SECCHI M	0.1	0.28	0.2%	0.2	0.05	0.8%
ANTILOG PC-1	69835.6	0.64	100.0%	26571.0	60.69	100.0%
ANTILOG PC-2	17.1	0.20	96.9%	13.7	42.86	92.4%
ZMIX / SECCHI	13.4	0.27	96.2%	9.7	0.05	88.9%
CHL-A * SECCHI	59.6	0.30	99.4%	40.6	64.00	97.4%
CHL-A / TOTAL P	1.2	0.29	99.8%	0.6	128.69	96.1%
FREQ(CHL-a>10) %	100.0		100.0%	100.0	0.00	100.0%
FREQ(CHL-a>20) %	100.0	0.00	100.0%	100.0	0.05	100.0%
FREQ(CHL-a>30) %	100.0	0.00	100.0%	99.9	0.44	100.0%
FREQ(CHL-a>40) %	100.0	0.00	100.0%	99.4	1.59	100.0%
FREQ(CHL-a>50) %	100.0	0.00	100.0%	98.5	3.75	100.0%
FREQ(CHL-a>60) %	99.9	0.00	100.0%	96.9	6.95	100.0%
CARLSON TSI-P	89.7	0.04	98.9%	90.0	18.16	99.0%
CARLSON TSI-CHLA	90.9	0.05	100.0%	84.0	7.36	100.0%
CARLSON TSI-SEC	89.7	0.04	99.8%	85.1	0.01	99.2%

Segment:	**2**	**Hope**				
	Predicted Values--->			**Observed Values--->**		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	272.9	0.24	97.3%	264.0	21.60	97.1%
CHL-A MG/M3	291.8	0.43	100.0%	238.0	53.00	100.0%
SECCHI M	0.2	0.26	0.8%	0.2	0.03	0.7%
ANTILOG PC-1	32872.1	0.61	100.0%	27968.1	50.26	100.0%
ANTILOG PC-2	16.0	0.20	95.9%	13.6	35.50	92.3%
ZMIX / SECCHI	9.1	0.26	86.6%	9.4	0.03	87.9%
CHL-A * SECCHI	51.3	0.30	98.9%	40.5	53.00	97.4%
CHL-A / TOTAL P	1.1	0.28	99.6%	0.9	57.00	99.2%
FREQ(CHL-a>10) %	100.0	0.00	100.0%	100.0	0.00	100.0%
FREQ(CHL-a>20) %	100.0	0.00	100.0%	100.0	0.04	100.0%
FREQ(CHL-a>30) %	100.0	0.00	100.0%	99.9	0.32	100.0%
FREQ(CHL-a>40) %	99.8	0.00	100.0%	99.5	1.18	100.0%
FREQ(CHL-a>50) %	99.4	0.01	100.0%	98.6	2.83	100.0%
FREQ(CHL-a>60) %	98.7	0.02	100.0%	97.2	5.30	100.0%
CARLSON TSI-P	85.0	0.04	97.3%	84.6	3.63	97.1%
CARLSON TSI-CHLA	86.3	0.05	100.0%	84.3	6.08	100.0%
CARLSON TSI-SEC	85.0	0.04	99.2%	85.5	0.00	99.3%

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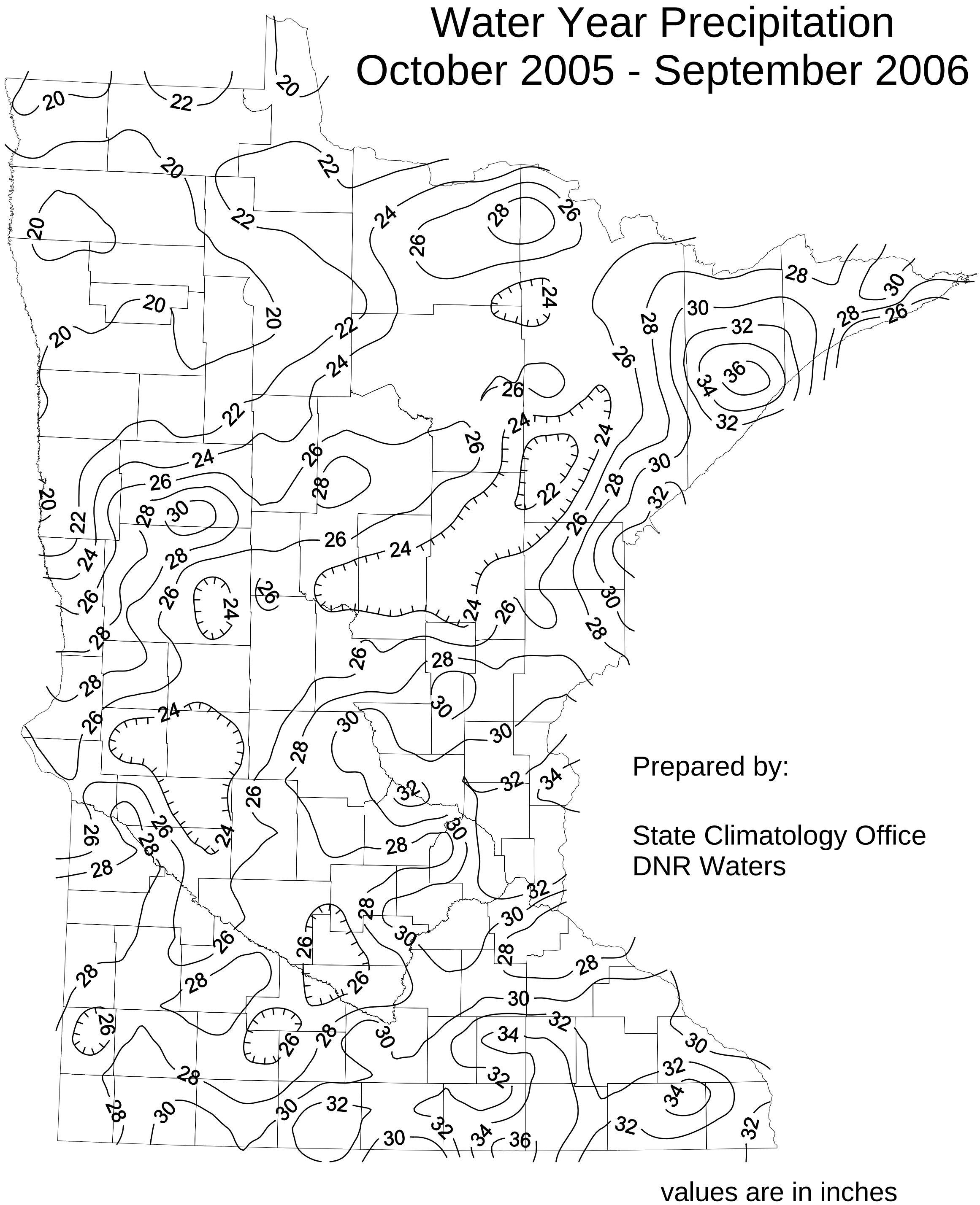
Segment Mass Balance Based Upon Predicted Concentrations

Component:		**TOTAL P**		**Segment:**	**1**	**Long**	
			Flow	**Flow**	**Load**	**Load**	**Conc**
Trib	**Type**	**Location**	**hm^3/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m^3**
3	2	Long Immediate	3.3	24.3%	850.5	9.5%	257
4	2	Long CD26	5.6	41.2%	1470.5	16.5%	262
5	3	Long Septics	0.1	0.7%	150.0	1.7%	1500
PRECIPITATION			2.0	15.0%	93.0	1.0%	45
INTERNAL LOAD			0.0	0.0%	5661.4	63.5%	
NONPOINT INFLOW			8.9	65.5%	2321.0	26.0%	260
POINT-SOURCE INFLOW			0.1	0.7%	150.0	1.7%	1500
ADVECTIVE INFLOW			2.5	18.7%	695.9	7.8%	273
***TOTAL INFLOW			13.6	100.0%	8921.3	100.0%	655
ADVECTIVE OUTFLOW			10.8	79.1%	4066.1	45.6%	378
***TOTAL OUTFLOW			10.8	79.1%	4066.1	45.6%	378
***EVAPORATION			2.9	20.9%	0.0	0.0%	
***RETENTION			0.0	0.0%	4855.2	54.4%	

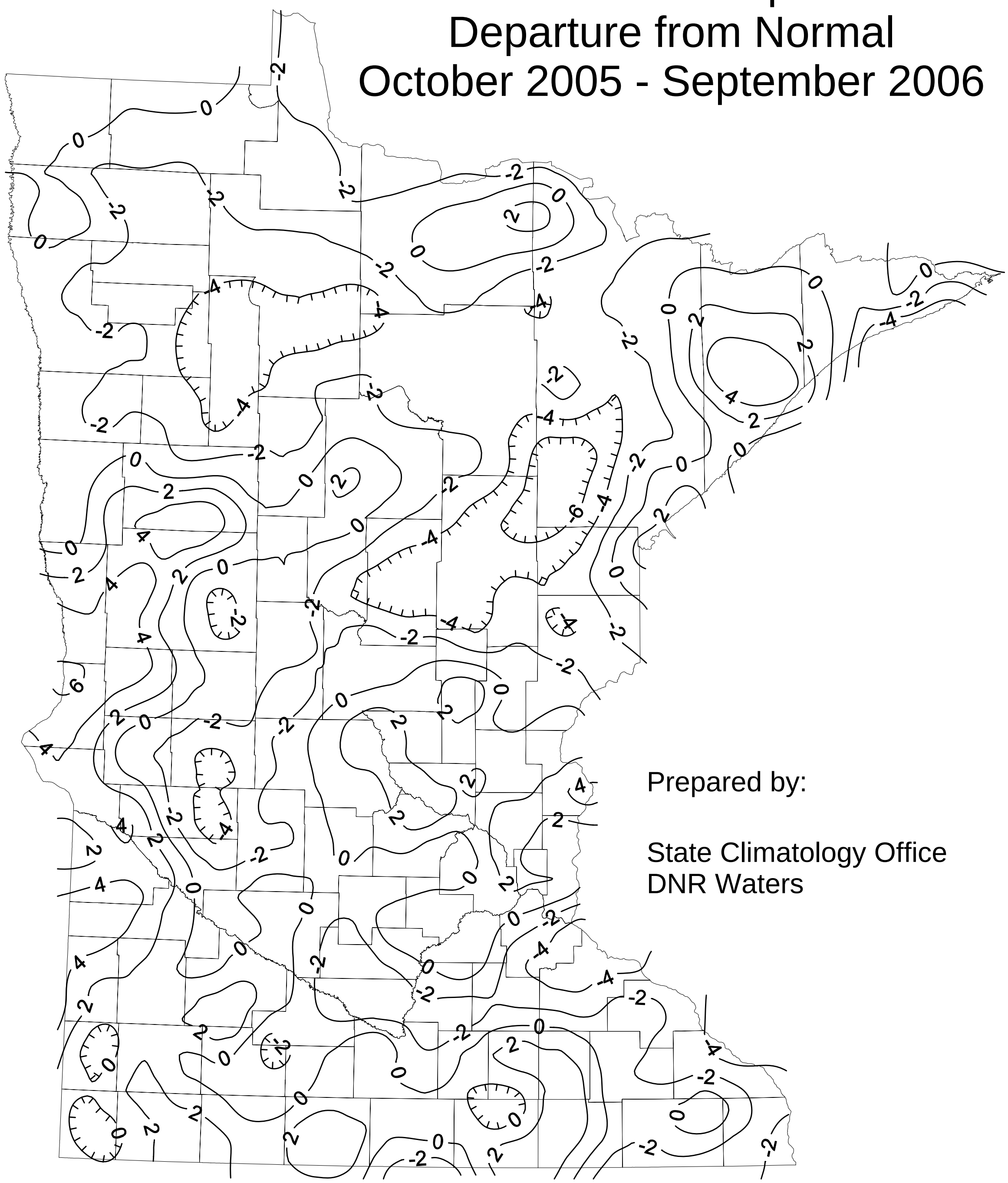
Hyd. Residence Time =	0.4896	yrs
Overflow Rate =	3.5	m/yr
Mean Depth =	1.7	m

Component:		**TOTAL P**		**Segment:**	**2**	**Hope**	
			Flow	**Flow**	**Load**	**Load**	**Conc**
Trib	**Type**	**Location**	**hm^3/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m^3**
1	2	Harold Watershed	1.0	30.0%	262.0	17.3%	252
2	2	Hope	1.8	51.0%	488.5	32.3%	276
PRECIPITATION			0.7	19.0%	30.0	2.0%	45
INTERNAL LOAD			0.0	0.0%	730.5	48.3%	
NONPOINT INFLOW			2.8	81.0%	750.5	49.7%	267
***TOTAL INFLOW			3.5	100.0%	1511.0	100.0%	435
ADVECTIVE OUTFLOW			2.5	73.5%	695.9	46.1%	273
***TOTAL OUTFLOW			2.5	73.5%	695.9	46.1%	273
***EVAPORATION			0.9	26.5%	0.0	0.0%	
***RETENTION			0.0	0.0%	815.1	53.9%	

Hyd. Residence Time =	0.6275	yrs
Overflow Rate =	2.5	m/yr
Mean Depth =	1.6	m


Water Year Precipitation
October 2005 - September 2006
Prepared by:
State Climatology Office
DNR Waters
values are in inches

Water Year Precipitation
Departure from Normal
October 2005 - September 2006



Prepared by:

State Climatology Office
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values are in inches