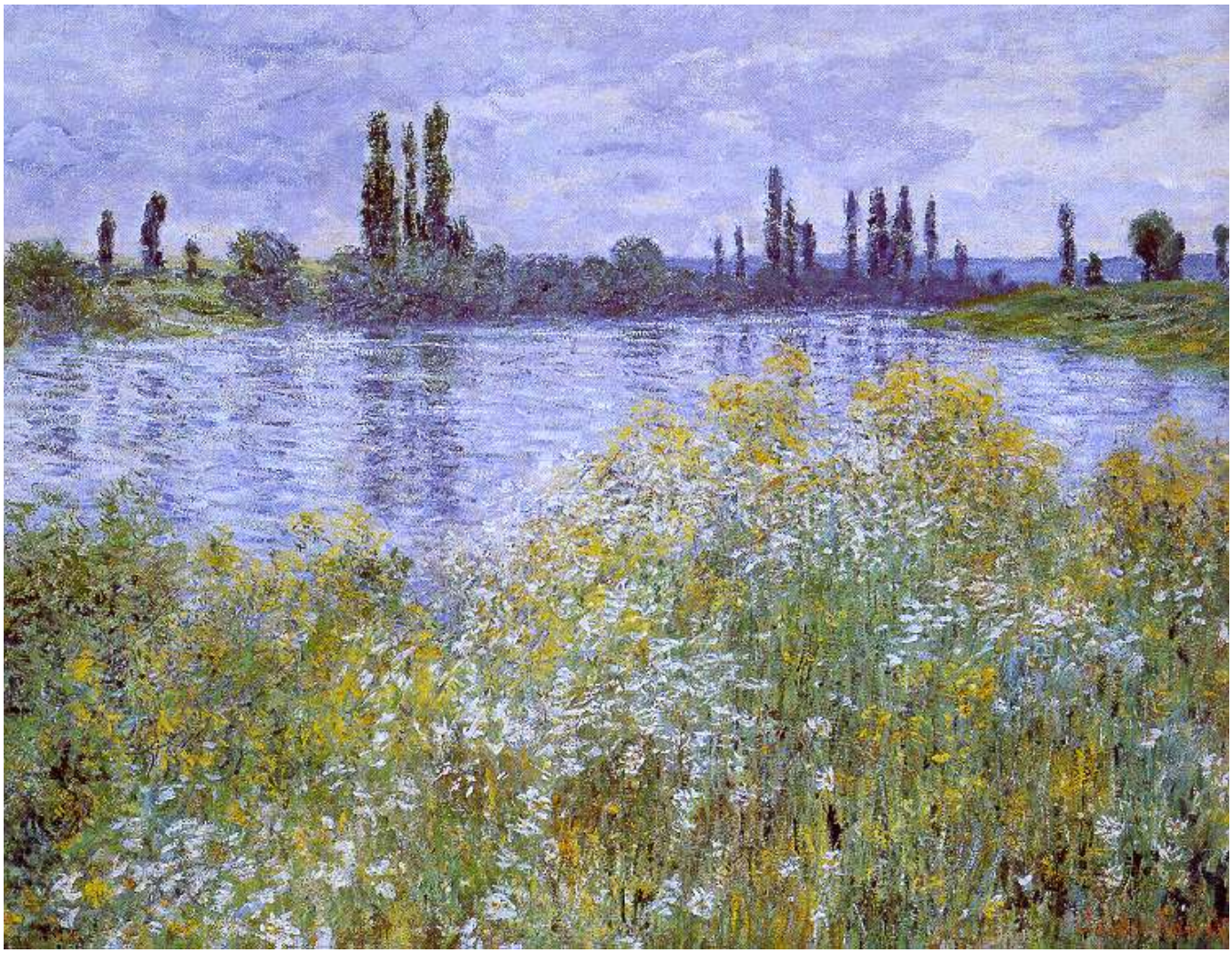

Claude Monet: *Banks on the Seine*, **1880**

Chisago Lakes Water Quality Monitoring Program for 2007

May 2008

Submitted to:
Chisago Lakes Lake Improvement District
Center City, Minnesota

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Chisago Lakes Water Quality Monitoring Program for 2007

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The Chisago Lakes Improvement District Board, 2007

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Chisago Lakes Water Quality Monitoring Program for 2007

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Chisago Lakes Water Quality Monitoring Program for 2007

SUMMARY

The summer of 2007 was the 14th year of an ongoing water quality improvement program for the Chisago Chain of Lakes. In 1994 a water quality study was started on seven lakes (North and South Lindstrom, North and South Center, Chisago, Green and Little Green) in Chisago County. Many factors influence water quality in the Chisago Chain of Lakes. Summer monitoring characterizes existing conditions and over the years, water quality trends can be detected.

Goals: The goals of this monitoring program are to:

- Gather background information on the Chisago Chain of Lakes,
- Characterize existing lake conditions,
- Develop lake management plans that protect, maintain, and enhance the lakes' water quality.

Water Quality and Quantity Monitoring Methods for 2007

- Pat Collins collected Secchi disc readings as well as conducted phosphorus monitoring in June, July, and August in 2007 in all seven lakes.
- For 2007, lake water was analyzed for total phosphorus by MVTL Labs, New Ulm, Minnesota.

Water Clarity for 2007

For all lakes, water transparency, as measured with a Secchi disc, ranged from good to poor. North Lindstrom Lake had the best water clarity in 2007. North Center had the poorest summer average of 2.8 feet. Typical summertime transparencies for unimpacted lakes in this area should be 5 feet or more.

Nutrients for 2007

Phosphorus is the nutrient most often associated with causing nuisance algae blooms. Phosphorus concentrations in several lakes were above regional averages. North Lindstrom had a total phosphorus concentration of 11, which was the lowest in the District. North Center had the highest phosphorus concentration of 64 ppb.

Summary of water clarity readings and phosphorus summer averages (June, July, and August) for the Chisago Lakes for 2007.

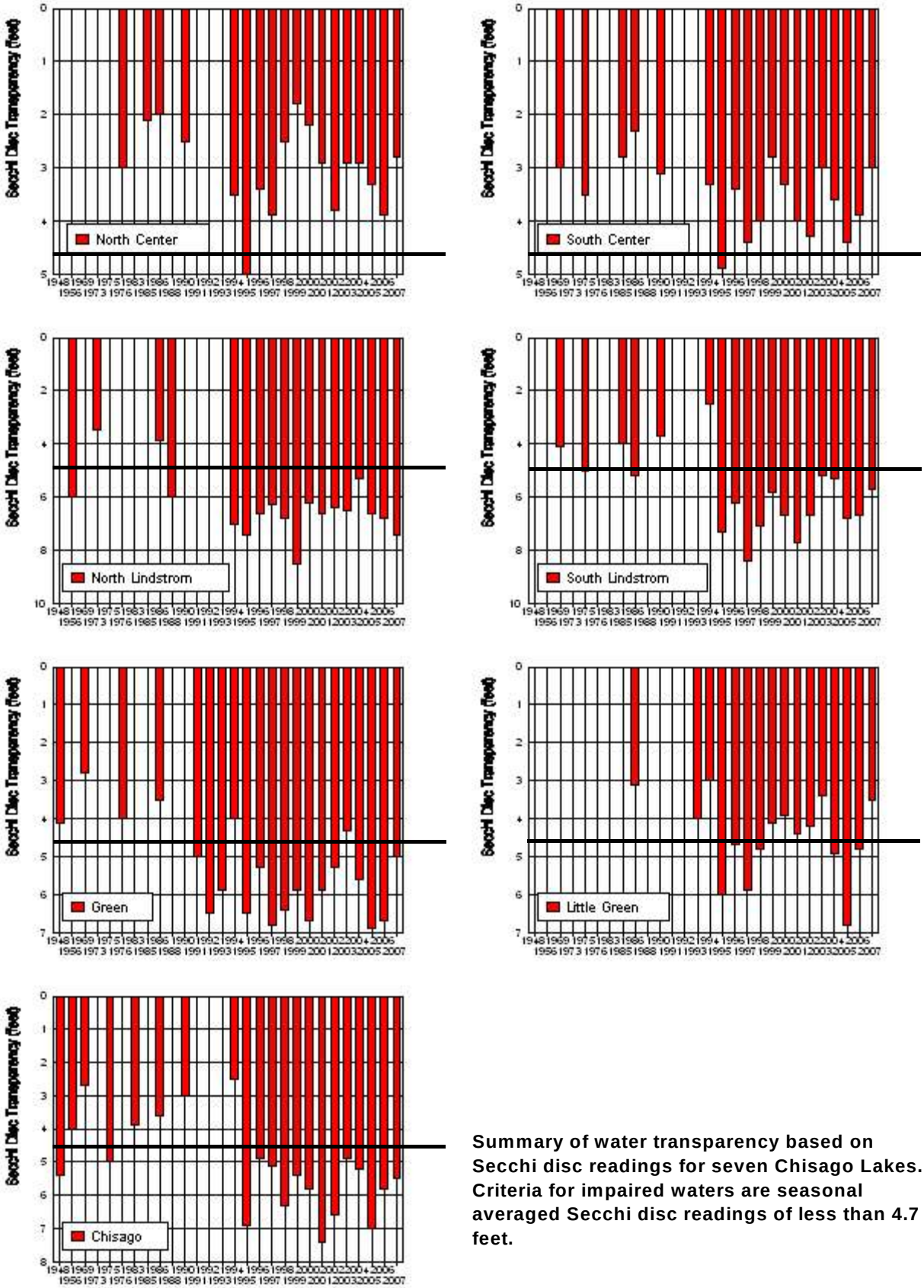
Lake	Secchi Disc (feet)	Total Phosphorus (ppb)
Chisago	5.5	31
Green	5.0	34
Little Green	3.5	30
North Center	2.8	64
South Center	3.0	39
North Lindstrom	7.4	11
South Lindstrom	5.7	32

Lake Status

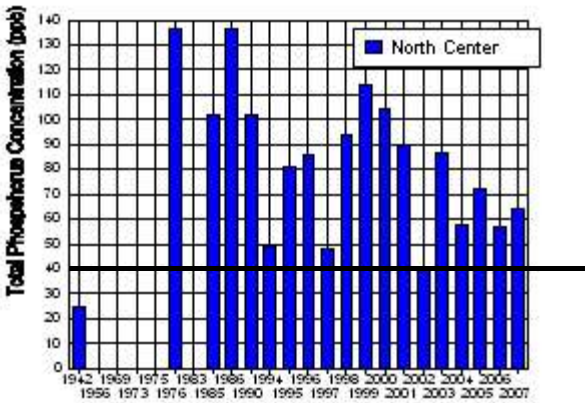
- The data base for the Chisago Lakes is increasing yearly. Looking at the transparency and phosphorus data over the years, it appears the Chisago Lakes are staying about the same.
- The lakes apparently have been eutrophic for a number of years and recovery to better clarity conditions will take proactive action.

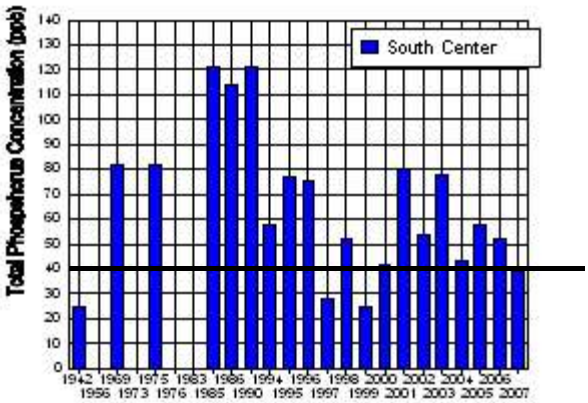
Proposed MPCA eutrophication criteria for lakes.

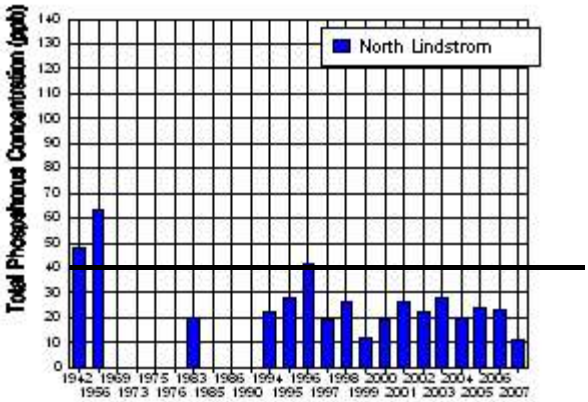
Central Hardwood Forest Ecoregion	Secchi Disc		Total Phosphorus (ppb)
	(m)	(ft)	
Deep lake	>1.4	>4.6	<40
Shallow Lake	>1.0	>3.3	<60

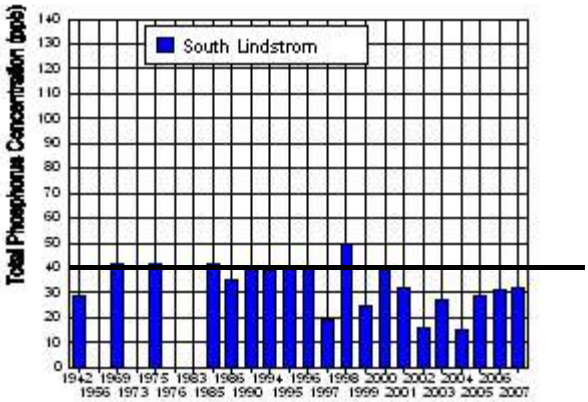


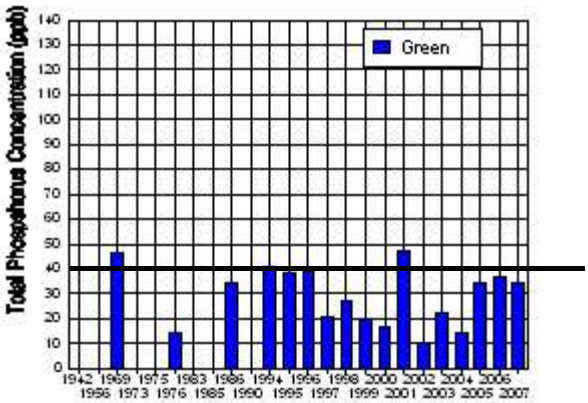
Summary of water transparency based on Secchi disc readings for seven Chisago Lakes. Criteria for impaired waters are seasonal averaged Secchi disc readings of less than 4.7 feet.

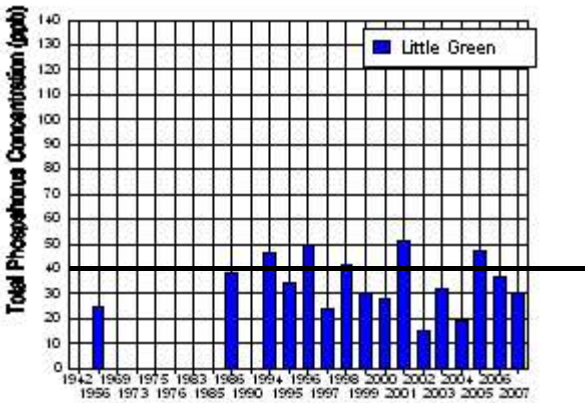


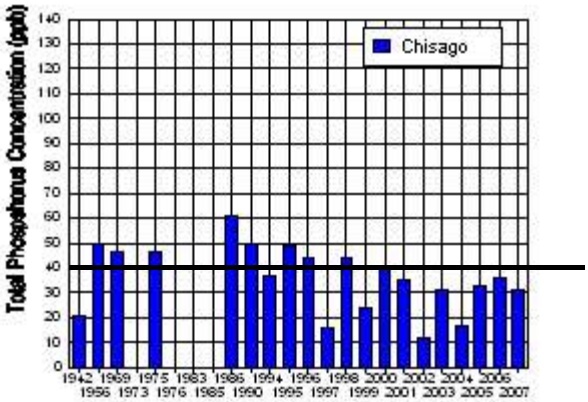












Summary of lake phosphorus concentrations for seven Chisago Lakes. Criteria for impaired waters are season phosphorus averages greater than 40 ppb.

1. Introduction and Project Setting

The Chisago Chain of Lakes represent seven lakes with a combined surface acreage of over 5,400 acres.

The Chisago Lakes located in Chisago County, Minnesota (Figure 1) receive water from rainfall, runoff, and springs. A watershed map is shown in Figure 2. The Chisago Lakes are eutrophic meaning they are fertile and can produce excessive summer algae

The lake water quality monitoring effort in 2007 represented the 14th year of monitoring conducted by the Chisago Lakes Lake Improvement District. It is expected that this will be an on-going program with the level of effort dependent on manpower and on funds.

The goals of this program are to examine existing lake conditions, collect water chemistry data, perform plant surveys and to develop lake management plans to protect, maintain, and enhance lake water quality for the short term and long term.

Figure 1. Project location is in Chisago County, Minnesota.

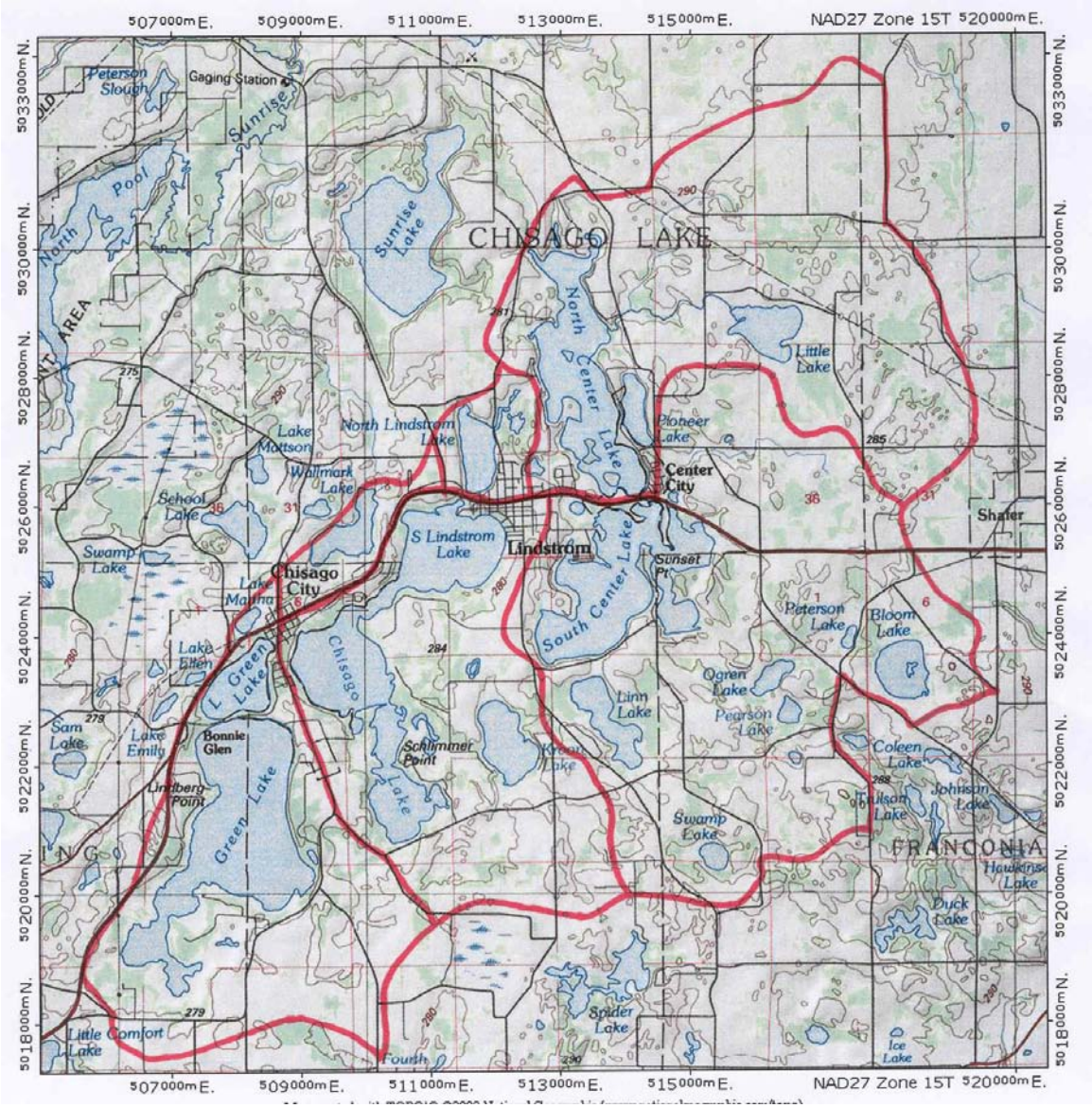


Figure 2. Chisago Lake Watershed map.

2. Projects Conducted in 2007

Listed below are details of the tasks accomplished in 2007. Monitoring is scheduled to continue in 2008. Details of the 2007 program are shown below.

- Pat Collins, a science teacher at Chisago Lake Middle School organized a Secchi disc monitoring program involving students and adult volunteers to collect data on Chisago Area Lakes.

- Volunteers and Pat Collins made Secchi disc readings in June, July, and August.

- Volunteers and Pat Collins took water samples in June, July, and August.

3. Lake and Watershed Water Quality Summary

A summary lake characteristics is shown in Table 1 followed by lake monitoring results for the summer of 2007.

Table 1. Lake characteristics for six lakes in the Chisago Chain. Lake surface areas and Watershed sizes are from B. Wilson, MPCA report (1986) except for South Lindstrom and Chisago Lake surface areas which are from MnDNR Fisheries Information Report, 1990.

	Surface Area (acres)	Maximum Depth (feet)	Average Depth (feet)	Watershed Area (acres)
Chisago	873	32	--	--
Green	1,940	33	19	2,092
North Center	868	46	10	2,163
South Center	1,003	109	16	2,950
North Lindstrom	225	29	16	512
South Lindstrom	450	34	--	--

2007 Lake Secchi Disc Results

Summer Secchi disc readings for seven Chisago area lakes in 2007 are shown in Table 2 and Figure 3. North and South Lindstrom, Green, and Chisago Lakes had summer average transparencies of over 5 feet in 2007. North Center and South Center Lakes had the lowest summer average transparency.

Table 2. 2007 Summer Secchi disc readings (feet) for the Chisago Lakes.

	North Center	South Center	North Lindstrom	South Lindstrom	Chisago	Green	Little Green
June							
Week 1*							
Week 2*	6	6.5					
Week 3*			11/9	10.5/7	10.5/8.5	10	7.5
Week 4*	4.5	3.5	8	7	7	7/6.5	4/4.5
July							
Week 1							
Week 2	3	2.5	7.5	6.5	5	4.5	3.5
Week 3	3	2	8	5.5	5.5	4	3
Week 4	2	2	8	4	4	4.5	3.5
August							
Week 1	2	2	6.5	4.5	4.5	4	2.5
Week 2	1.5	2.5	6	4.5	4	3.5	2
Week 3	2	2.5	5	4	3	3	2
Week 4	1.5	3.5	4.5	3	3	3	2
Jun-Aug Summer Avg	*2.8*	*3.0*	*7.4*	*5.7*	*5.5*	*5.0*	*3.5*

*Week 1 = Days 0-7; Week 2 = Days 8-14; Week 3 = Days 15-21; Week 4 = Days 22+

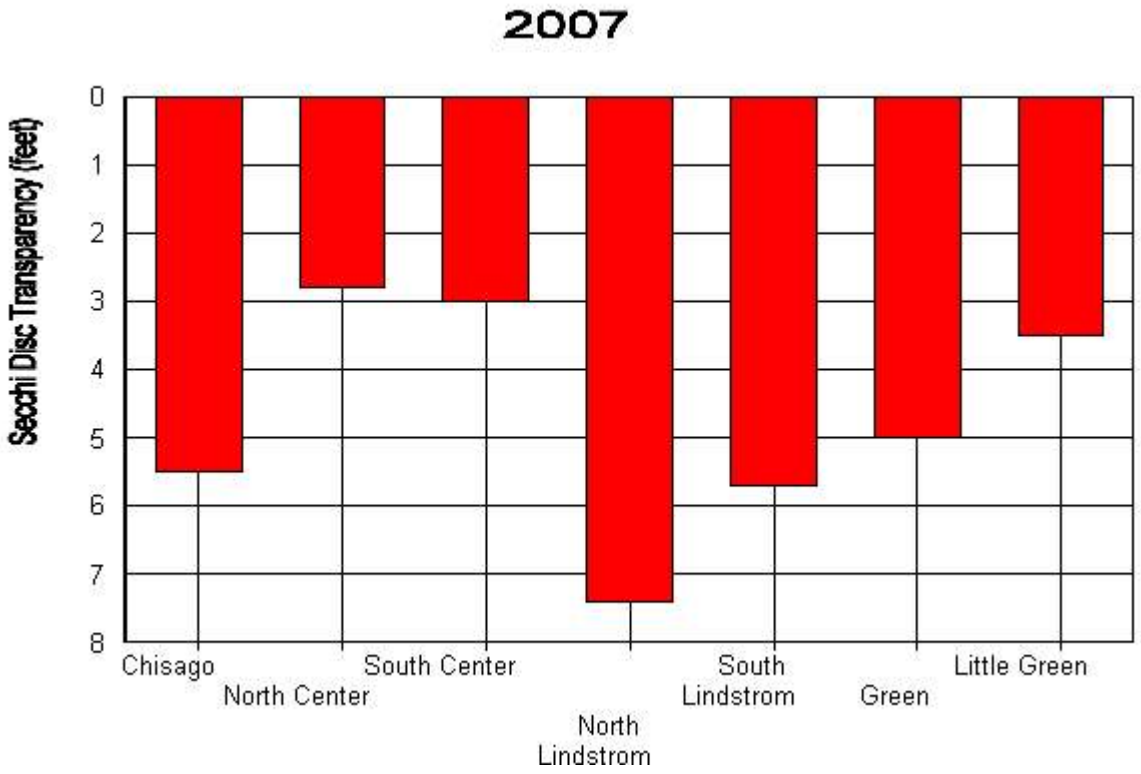


Figure 3. 2007 summer average (June - August) lake transparency for seven Chisago Lakes. Averages represent Secchi disc data collected by Pat Collins.

Historical Secchi Disc Measurements: The long-term Secchi disc data base for the seven Chisago lakes is summarized in Table 3. Nearly all the lakes have fluctuating water clarity of about a foot or more from year to year, but there are differences between lakes (Table 3, Figure 4). North Center Lake has consistently had the lowest water clarity of the monitored lakes, and South Lindstrom had the highest transparency. The high transparencies for Chisago and South Center Lakes in 1942 are somewhat misleading. This transparency is based on a single reading in May when lakes typically have their highest transparency of the summer.

Table 3. Chisago Lake Secchi disc results are shown in feet. The numbers in the parenthesis either represent the date the sample was collected, or represent the number of (n) of readings.

	North Center	South Center	North Lindstrom	South Lindstrom	Green	Little Green	Chisago
1942		12 (5-22)		6.0 (5-26)			10.0 (5-25)
1948					4.1 (6-22)		5.4 (6-17)
1956			6.0 (7-9)				4.0 (7-15)
1969		3.0 (8-18)		4.1 (8-4)	2.8 (8-11)		2.7 (7-28)
1973			3.5 (7-26)				
1975		3.5 (9-3)		5.0 (8-22)			5.0 (8-22)
1976	3.0 (7-1)				4.0 (7-19)		
1983							3.9 (8-8)
1985	2.1 (7-29)	2.8 (7-22)		4.0 (7-15)			
1986	2.0 (7-31)	2.3 (7-31)	3.9 (7-31)	5.2 (7-31)	3.5 (7-31)	3.1 (7-31)	3.6 (7-31)
1988			6.0 (8-8)				
1990	2.5 (7-30)	3.1 (7-23)		3.7 (7-16)			3.0 (7-18)
1991					5.0 (7.22)		
1992					6.5 (n=23)		
1993					5.9 (n=19)	4.0 (n=8)	
1994	3.5 (8.4)	3.3 (n=2)	7.0 (8.2)	2.5 (8.2)	4.0 (n=2)	3.0 (n=2)	2.5 (8.2)
1995	5.0 (n=13)	4.9 (n=15)	7.4 (n=14)	7.3 (n=11)	6.5 (n=13)	6.0 (n=10)	6.9 (n=13)
1996	3.4 (n=5)	3.4 (n=8)	6.6 (n=4)	6.2 (n=6)	5.3 (n=7)	4.7 (n=7)	4.9 (n=7)
1997	3.9 (n=8)	4.4 (n=9)	6.3 (n=8)	8.4 (n=8)	6.8 (n=8)	5.9 (n=7)	5.1 (n=7)
1998	2.5 (n=9)	4.0 (n=15)	6.8 (n=6)	7.1 (n=9)	6.4 (n=10)	4.8 (n=10)	6.3 (n=14)
1999	1.8 (n=12)	2.8 (n=8)	8.5 (n=7)	5.8 (n=6)	5.9 (n=14)	4.1 (n=14)	5.4 (n=6)
2000	2.2 (n=10)	3.3 (n=7)	6.2 (n=8)	6.7 (n=8)	6.7 (n=15)	3.9 (n=13)	5.8 (n=8)
2001	2.9 (n=11)	4.0 (n=9)	6.6 (n=7)	7.7 (n=13)	5.9 (n=9)	4.4 (n=13)	7.4 (n=12)
2002	3.8 (n=11)	4.3 (n=7)	6.4 (n=8)	6.7 (n=8)	5.3 (n=6)	4.2 (n=6)	6.6 (n=10)
2003	2.9 (n=7)	3.0 (n=6)	6.5 (n=5)	5.2 (n=6)	4.3 (n=5)	3.4 (n=5)	4.9 (n=5)
2004	2.9 (n=8)	3.6 (n=8)	5.3 (n=8)	5.3 (n=8)	5.6 (n=8)	4.9 (n=8)	5.2 (n=8)
2005	3.3 (n=9)	4.4 (n=9)	6.6 (n=9)	6.8 (n=9)	6.9 (n=9)	6.8 (n=9)	7.0 (n=9)
2006	3.9 (n=16)	3.9 (n=15)	6.8 (n=14)	6.7 (n=15)	6.7 (n=8)	4.8 (n=8)	5.8 (n=16)
2007	2.8 (n=9)	3.0 (n=9)	7.4 (n=10)	5.7 (n=10)	5.0 (n=10)	3.5 (n=10)	5.5 (n=10)

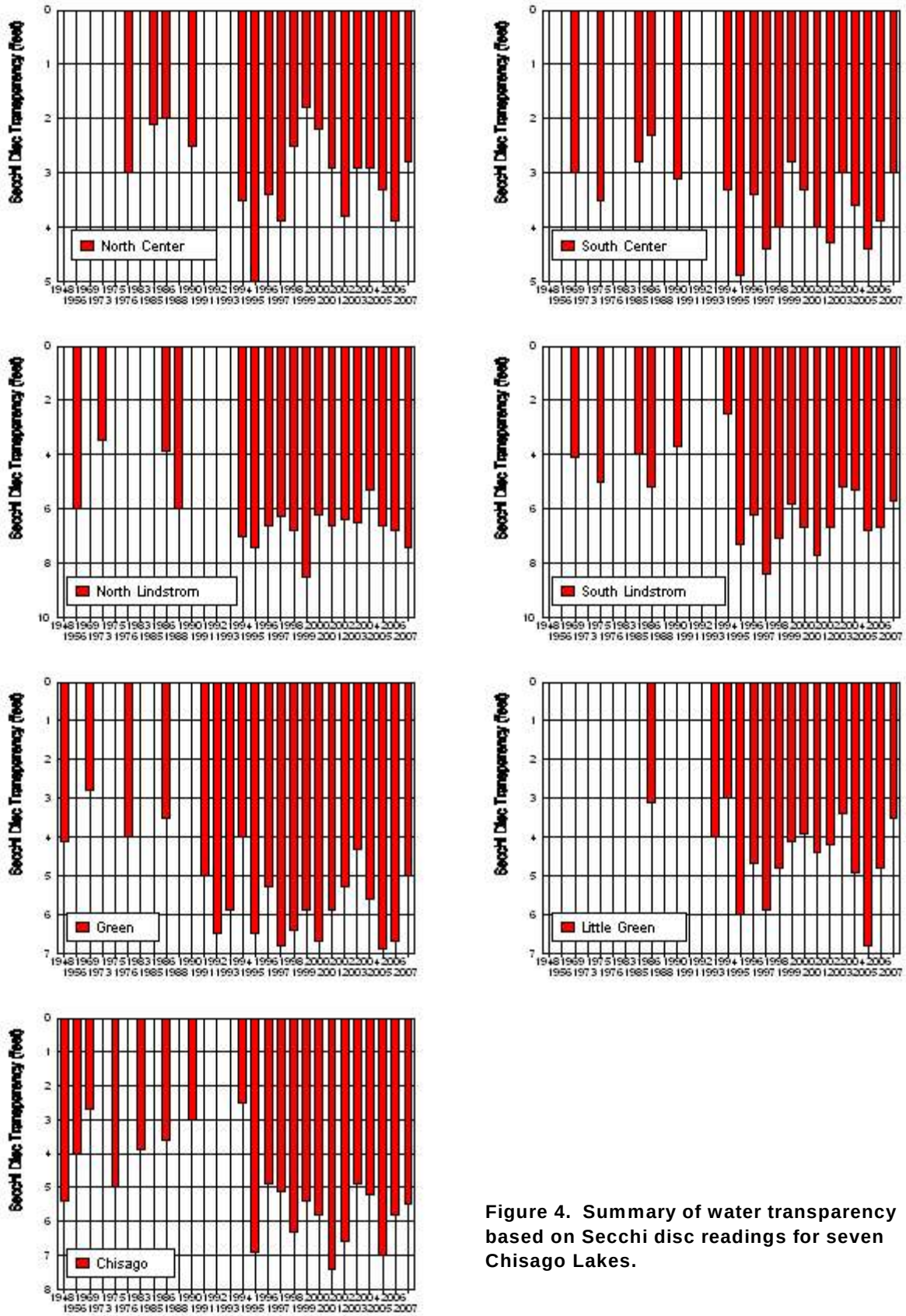


Figure 4. Summary of water transparency based on Secchi disc readings for seven Chisago Lakes.

2007 Lake Phosphorus Sampling Results

Summer phosphorus readings for seven Chisago area lakes in June, July, and August of 2007 are shown in Table 4 and Figure 5. North Center had the highest summer average. North Lindstrom had the lowest total phosphorus concentration

Table 4. Chisago area lakes total phosphorus results for 2007. Results are shown in parts per billion.

	June 21 & 24 top	July 26, 27 top	August 27, 28 top	3-month Summer Average top
Chisago	21	29	43	31
North Center	61	63	69	64
South Center	57	43	18	39
North Lindstrom	21	6	7	11
South Lindstrom	25	30	41	32
Green	28	17	57	34
Little Green	39	19	33	30

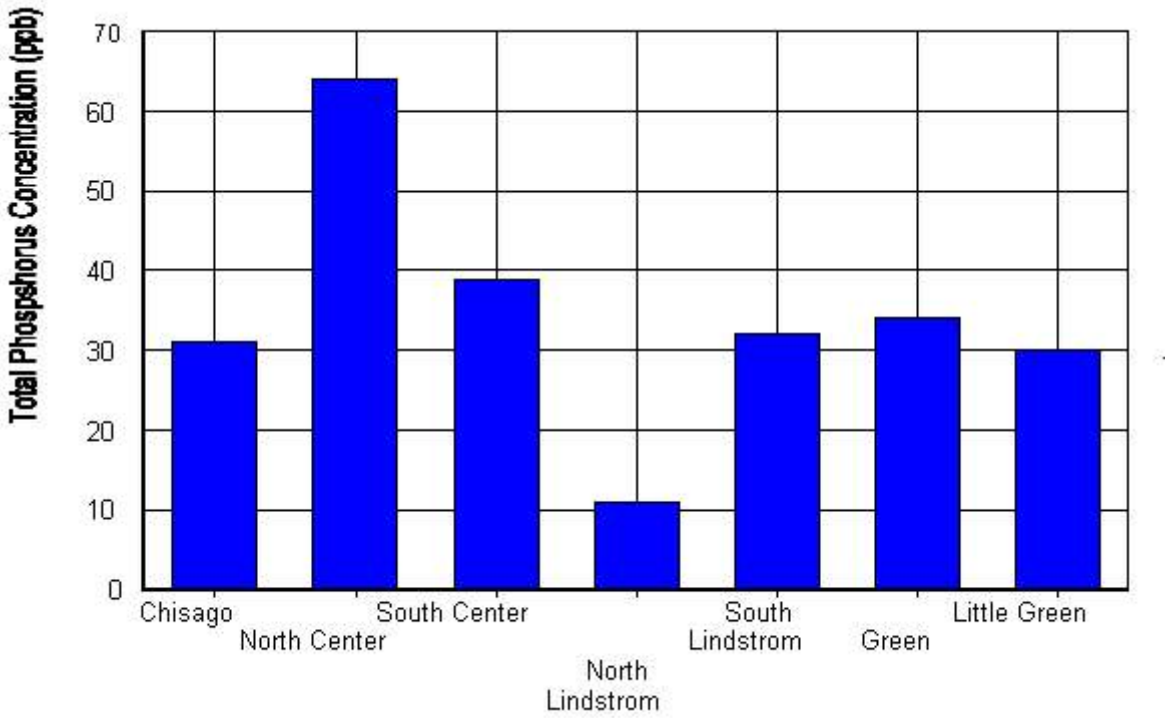


Figure 5. 2007 summer average (June - August) phosphorus concentrations for seven Chisago Lakes.

Historical Lake Phosphorus Concentrations: Long term phosphorus records indicate that phosphorus concentrations fluctuate but do not seem to be increasing in the Chisago Lakes (Table 5 and Figure 6).

A phosphorus goal for these lakes would be to lie within an ecoregion range of roughly 20 to 40 ppb. In the last couple of years, North Lindstrom, South Lindstrom, Chisago, Green, and Little Green Lakes have been in this range.

Table 5. Historical Chisago area lake surface phosphorus concentrations. Lake total phosphorus results are shown in parts per billion. The number in parenthesis either represents the date the sample was collected or the number (n) of samples.

	North Center	South Center	North Lindstrom	South Lindstrom	Green	Little Green	Chisago
1942	25 (5-28)	25 (5-22)	48 (5-21)	29 (5-26)			21 (5-25)
1956		350 (7-6)	63 (7-9)			25 (7-16)	50 (7-15)
1969		82 (8-18)		42 (8-4)	46 (8-11)		46 (7-28)
1973			2000 (7-26)				
1975		82 (9-3)		42 (8-22)			46 (8-22)
1976	136 (7-1)				14 (7-19)		
1983			20 (8-8)				
1985	102 (7-29)	121 (7-22)		42 (7-15)			
1986	136 (7-31)	114 (7-31)		35 (7-31)	34 (7-31)	38 (7-31)	61 (7-31)
1990	102 (7-30)	121 (7.23)		40 (7-16)			50 (7-18)
1994	49 (n=2)	58 (7.26)	22 (7.3)	39 (n=2)	41 (n=3)	46 (n=2)	37 (7.21)
1995	81 (n=2)	77 (n=3)	28 (n=3)	40 (n=3)	38 (n=4)	34 (n=4)	49 (n=4)
1996	86 (n=3)	75 (n=3)	42 (n=3)	40 (n=3)	39 (n=2)	50 (n=3)	44 (n=3)
1997	48 (n=3)	28 (n=2)	19 (n=4)	19 (n=3)	21 (n=2)	24 (n=2)	16 (n=2)
1998	94 (n=3)	52 (n=3)	26 (n=3)	50 (n=3)	27 (n=2)	42 (n=2)	44 (n=3)
1999	114 (n=3)	25 (n=3)	12 (n=3)	25 (n=3)	20 (n=3)	30 (n=3)	24 (n=3)
2000	104 (n=3)	42 (n=3)	19 (n=3)	40 (n=3)	17 (n=3)	28 (n=3)	40 (n=3)
2001	90 (n=3)	80 (n=3)	26 (n=3)	32 (n=3)	47 (n=3)	51 (n=3)	35 (n=3)
2002	40 (n=3)	54 (n=3)	22 (n=3)	16 (n=3)	10 (n=3)	15 (n=3)	12 (n=3)
2003	87 (n=2)	78 (n=2)	28 (n=2)	27 (n=2)	22 (n=2)	32 (n=2)	31 (n=2)
2004	58 (n=3)	43 (n=3)	20 (n=3)	15 (n=3)	14 (n=3)	19 (n=3)	17 (n=3)
2005	72 (n=2)	58 (n=3)	24 (n=3)	29 (n=3)	34 (n=3)	47 (n=3)	33 (n=3)
2006	57 (n=3)	52 (n=3)	23 (n=3)	31 n=3)	37 (n=3)	37 (n=3)	36 (n=3)
2007	64 (n=3)	39 (n=3)	11 (n=3)	32 (n=3)	34 (n=3)	30 (n=3)	31 (n=3)

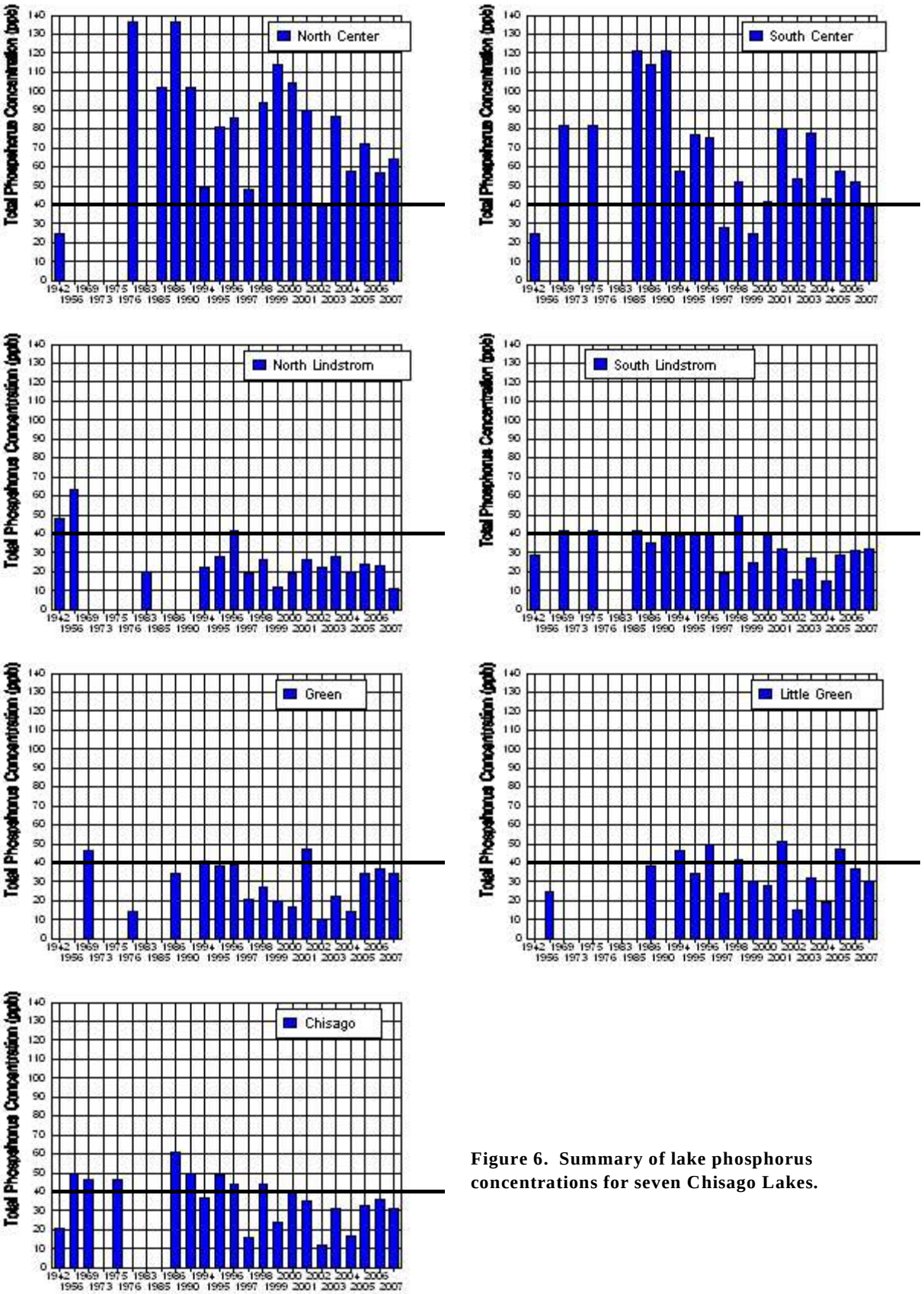


Figure 6. Summary of lake phosphorus concentrations for seven Chisago Lakes.

2006 Chlorophyll a Sampling Results

Summer chlorophyll a readings for five Chisago area lakes in 2006 are shown in Table 6. Data were collected by Jeff Angel and are included here. North Center had the highest summer average. North Lindstrom and South Lindstrom Lakes have chlorophyll a concentrations of 16 and 22 respectfully, otherwise chlorophyll a concentrations were greater than 30 ppb. North Center had the single highest chlorophyll concentration of 116 ppb on July 31, 2006.

Table 6. Chisago area lakes chlorophyll a results for 2006. Results are shown in parts per billion. Data collected by Jeff Angel.

	June							July										August						3-month Summer Average
	2	3	4	16	18	19	30	1	2	4	8	14	15	18	28	30	31	6	14	16	19	20	27	
Chisago	11				10				26				46				74		62					38
North Center		6		15			47					95					116			99				63
South Center			10		25					51				62				73				58		47
North Lindstrom						22					14					14							15	16
South Lindstrom		3		5				17				42			45									22

Individual Lake Summaries

North Center Lake

North Center Lake characteristics and data are shown below in Tables 7-9.

Table 7. North Center Lake Characteristics

Inventory number: 13-0032
Area (Lake): 868 acres (351 ha)
Mean depth: 10 feet (3 m)
Maximum depth: 46 feet (14 m)
Volume: 8,940 acre-feet (1,053 Ha-M)
Watershed area: 2,163 acres (875 ha)
Watershed: Lake surface ratio 2.5:1
Public accesses (#): 2

Table 8. North Center Lake historical Secchi disc data.

Date	Growing Season Averages		Minimum (feet)	Maximum (feet)	Number of Sample Dates
	(feet)	(meters)			
1988	2.5	0.8	1	7	8
1989	4.1	1.2	0.5	8.5	9
1990	3.8	1.2	1.5	8	7
1994	3.5	1.1	3.5	3.5	1
1995	5	1.5	1.5	9	13
1996	3.4	1	1.5	5	5
1997	3.9	1.2	1.5	10	8
1998	2.5	0.8	1.5	4.5	9
1999	1.8	0.5	0.75	2.5	12
2000	2.2	0.7	1.5	3.5	10
2001	2.9	0.9	1.5	6.5	11
2002	3.8	1.2	2	6.5	11
2003	2.9	0.9	1.5	5	7
2004	2.9	0.9	1.75	6	8
2005	3.3	1	2	6	9
2006	3.9	1.2	1.5	9.5	16
2007	2.8	0.8	1.0	6.0	9

Table 9. North Center Lake historical summer total phosphorus concentrations.

Date	Growing Season Average	Minimum	Maximum	Number of Sample Dates
1986 - top	136	136	136	1
- bottom	108	108	108	1
1994 - top	49	48	50	2
- bottom	495	76	914	2
1995 - top	81	65	105	3
- bottom	1079	804	1324	3
1996 - top	86	59	111	3
- bottom	697	488	857	3
1997 - top	48	21	95	3
- bottom	53	36	70	2
1998 - top	94	35	138	3
- bottom	230	44	337	3
1999 - top	114	78	144	3
- bottom	232	101	370	3
2000 - top	104	80	146	3
- bottom	223	85	381	3
2001 - top	90	80	95	3
- bottom	152	95	214	3
2002 - top	40	13	55	3
2003 - top	87	50	123	2
2004 - top	58	38	90	3
2005 - top	72	67	77	2
2006 - top	57	36	74	3
2007 - top	64	61	69	3

South Center Lake

South Center Lake characteristics and data are shown below in Tables 10-12.

Table 10. South Center Lake Characteristics

Inventory number: 13-0027
Area (Lake): 1,003 acres (406 ha)
Mean depth: 16 feet (5 m)
Maximum depth: 109 feet (33 m)
Volume: 15,948 acre-feet (1,949 Ha-M)
Watershed area: 2,950 acres (1,194 ha)
Watershed: Lake surface ratio 3:1
Public accesses (#): 1

Table 11. South Center Lake historical Secchi disc transparencies.

Date	Growing Season Average		Minimum (feet)	Maximum (feet)	Number of Sample Dates
	(feet)	(meters)			
1985	3.4	1	2.5	4	8
1986	4.3	1.3	2	8	11
1987	3.3	1	2	6.5	6
1988	5.8	1.8	2	15	13
1989	8.7	2.7	4	20	8
1990	7.4	2.3	3	17	10
1994	3.3	1	3	3.5	2
1995	4.9	1.5	2.8	8.5	15
1996	3.4	1	1.5	5.5	8
1997	4.4	1.3	2	11	9
1998	4	1.2	1.5	7	15
1999	2.8	0.8	1.5	4.5	7
2000	3.3	1	2	6	7
2001	4	1.2	1.75	7.5	9
2002	4.3	1.3	2.5	6.5	7
2003	3	0.9	2	5	6
2004	3.6	1.1	2	7	8
2005	4.4	1.3	2.5	7	9
2006	3.9	1.2	2	8	15
2007	3.0	0.9	2.0	6.5	9

Table 12. South Center Lake historical summer total phosphorus concentrations.

Date	Growing Season Average	Minimum	Maximum	Number of Sample Dates
1986 - top	114	114	114	1
- bottom	378	378	378	1
1994 - top	58	58	58	1
- bottom	64	36	92	2
1995 - top	77	67	86	3
- bottom	271	207	322	3
1996 - top	75	57	95	3
- bottom	109	49	153	3
1997 - top	28	24	31	2
- bottom	31	15	47	2
1998 - top	52	30	75	3
- bottom	65	37	83	3
1999 - top	25	20	30	3
- bottom	21	14	26	3
2000 - top	42	23	65	3
- bottom	36	19	57	3
2001 - top	80	43	118	3
- bottom	82	33	107	3
2002 - top	54	41	63	3
2003 - top	78	50	106	2
2004 - top	43	16	88	3
2005 - top	58	46	68	3
2006 - top	52	42	71	3
2007 - top	39	18	57	3

North Lindstrom Lake

North Lindstrom Lake characteristics and data are shown below in Tables 13-15.

Table 13. North Lindstrom Lake Characteristics

Area: 225 acres (91 ha)
Mean depth: 16 feet (5 m)
Maximum depth: 29 feet (9 m)
Volume: 3,623 acre-feet (455 Ha-M)
Watershed area: 512 acres (207 ha)
Watershed: Lake surface ratio 2:1

Table 14. North Lindstrom Lake historical Secchi disc transparencies.

Date	Growing Season Averages		Minimum (feet)	Maximum (feet)	Number of Sample Dates
	(feet)	(meters)			
1994	7	2.1	7 .0	7	1
1995	7.4	2.2	4 .0	11.5	14
1996	6.6	2	6 .0	7.5	4
1997	6.3	1.9	3.5	11	8
1998	6.8	2.1	4	12	6
1999	8.5	2.6	7	12	7
2000	6.2	1.9	4	9.5	8
2001	6.6	2	4	11	7
2002	6.4	1.9	2.5	14	8
2003	6.5	2	5	9.5	5
2004	5.3	1.6	3.5	10.5	8
2005	6.6	2	4	10.5	9
2006	6.8	2.1	5.5	9.5	14
2007	7.4	2.2	4.5	11.0	10

Table 15. North Lindstrom Lake historical summer total phosphorus concentrations.

Date	Growing Season Average	Minimum	Maximum	Number of Sample Dates
1994 - top	22	22	22	1
- bottom	142	142	142	1
1995 - top	28	15	35	3
- bottom	190	108	351	3
1996 - top	42	31	49	3
- bottom	233	110	329	3
1997 - top	19	14	24	4
- bottom	63	24	136	3
1998 - top	26	20	35	3
- bottom	113	83	171	3
1999 - top	12	5	20	3
- bottom	104	63	185	3
2000 - top	19	7	40	3
- bottom	130	26	230	3
2001 - top	26	15	39	3
- bottom	80	28	124	3
2002 - top	22	16	30	3
2003 - top	28	15	40	2
2004 - top	20	65	36	3
2005 - top	24	15	31	3
2006 - top	23	21	26	3
2007 - top	11	61	21	3

South Lindstrom Lake

South Lindstrom Lake characteristics and data are shown below in Tables 16-18.

Table 16. South Lindstrom Lake Characteristics

Inventory number: 13-0028
Area (Lake)*: 450 acres (182 ha)
Mean depth: not calculated at this time
Maximum depth: 34 feet (10 m)
Volume: not calculated at this time
Watershed area: not calculated at this time
* data is from MnDNR Fisheries Lake Information Report, 1990.

Table 17. South Lindstrom Lake historical Secchi disc data.

Date	Growing Season Average		Minimum (feet)	Maximum (feet)	Number of Sample Dates
	(feet)	(meters)			
1975	5.2	1.6	3	9.5	14
1985	4	1.2	3.5	4.5	6
1988	4.8	1.5	3.5	7	4
1989	7.3	2.2	6.5	8	3
1990	4.8	1.5	3.5	6	2
1991	7.8	2.4	4.5	11	4
1994	2.5	0.76	2.5	2.5	1
1995	7.3	2.2	4.5	12	11
1996	6.2	1.9	4	10	6
1997	8.4	2.6	4	15	8
1998	7.1	2.2	3	15	9
1999	5.8	1.8	3	10	6
2000	6.7	2	2.5	11	8
2001	7.7	2.3	3	12	13
2002	6.7	2	2.75	13.5	8
2003	5.2	1.6	3	10	6
2004	5.3	1.6	2	11.5	8
2005	6.8	2.1	4.5	10	9
2006	6.7	2	2.5	18	15
2007	5.7	1.7	3.0	10.5	10

Table 18. South Lindstrom Lake historical summer total phosphorus concentrations.

Date	Growing Season Average	Minimum	Maximum	Number of Sample Dates
1986 - top	35	--	--	--
1994 - top	39	30	48	2
- bottom	32	32	32	1
1995 - top	40	15	65	4
- bottom	58	40	87	3
1996 - top	40	28	52	3
- bottom	191	125	289	3
1997 - top	19	17	22	3
- bottom	51	42	66	3
1998 - top	50	22	78	3
- bottom	92	22	165	3
1999 - top	25	18	30	3
- bottom	67	34	123	3
2000 - top	40	19	62	3
- bottom	24	14	33	3
2001 - top	32	12	50	3
- bottom	38	20	52	3
2002 - top	16	5	27	3
2003 - top	27	13	51	2
2004 - top	15	6	30	3
2005 - top	29	<5	43	3
2006 - top	31	23	37	3
2007 - top	32	25	41	3

Chisago Lake

Chisago Lake characteristics and data are shown below in Tables 19-21.

Table 19. Chisago Lake Characteristics

Inventory number: 13-0012
Area (Lake)*: 873 acres (353 ha)
Mean depth: not calculated at this time
Maximum depth: 32 feet (10 m)
Volume: not calculated at this time
Watershed area: not calculated at this time
* data is from MnDNR Fisheries Lake Information Report, 1990

Table 20. Chisago Lake historical Secchi disc transparencies.

Date	Growing Season Averages		Minimum (feet)	Maximum (feet)	Number of Sample Dates
	(feet)	(meters)			
1985	3.7	1.1	3.3	3.9	8
1986	3.6	1.1	3	4.5	11
1987	5	1.5	2	9.5	18
1994	2.5	0.76	2.5	2.5	1
1995	6.9	2.1	3	15.5	13
1996	4.9	1.5	2.5	8	7
1997	6.8	2.1	3.5	13	8
1998	6.3	1.9	2.5	14	14
1999	5.4	1.6	3	10	6
2000	5.8	1.8	1.5	10	8
2001	7.4	2.3	2	17	12
2002	6.6	2	3	12	10
2003	4.9	1.5	3	9.5	5
2004	5.2	1.6	2.75	11	8
2005	7	2.1	4	10	9
2006	5.8	1.8	3	15	16
2007	5.5	1.7	3.0	10.5	10

Table 21. Chisago Lake historical summer total phosphorus concentrations.

Date	Growing Season Average	Minimum	Maximum	Number of Sample Dates
1986 - top	61	50	72	1
- bottom	29	29	29	1
1994 - top	37	37	37	1
- bottom	48	48	48	1
1995 - top	49	31	87	4
- bottom	51	20	76	4
1996 - top	44	34	55	3
- bottom	124	42	259	3
1997 - top	16	12	22	3
- bottom	24	19	27	3
1998 - top	44	27	74	3
- bottom	40	22	64	3
1999 - top	24	18	33	3
- bottom	45	12	109	3
2000 - top	40	9	64	3
- bottom	24	9	37	3
2001 - top	35	17	63	3
- bottom	79	23	163	3
2002 - top	12	5	21	3
2003 - top	31	10	51	2
2004 - top	17	10	31	3
2005 - top	33	5	49	3
2006 - top	36	24	44	3
2007 - top	31	21	43	3

Green Lake

Green Lake characteristics and data are shown below in Tables 22-24.

Table 22. Green Lake Characteristics

Inventory number: 13-0041
Area (Lake): 1,940 acres (785 ha)
Mean depth: 19 feet (6 m)
Maximum depth: 33 feet (10 m)
Volume: 36,666 acre-feet (4,710 Ha-M)
Watershed area: 2,092 acres (847 ha)
Watershed: Lake surface ratio 1.1 :1
Public accesses (#): 1

Table 23. Green Lake historical Secchi disc transparencies.

Date	Growing Season Averages		Minimum (feet)	Maximum (feet)	Number of Sample Date
	(feet)	(meters)			
1988	3.7	1.1	1.5	8	8
1989	5.2	1.6	3	8.5	14
1990	3.9	1.2	2	6.5	9
1991	7	2.1	3	16.5	31
1992	6.5	2	3	14	23
1993	5.9	1.8	3.5	14	19
1994	4	1.2	3.5	4.5	2
1995	6.5	2	2	8.5	13
1996	5.3	1.6	3.3	8	7
1997	5.9	1.8	4	9.5	7
1998	6.4	2	3	14	10
1999	5.9	1.8	3	11.5	14
2000	6.7	2	3.5	14	15
2001	5.9	1.8	2.5	11	9
2002	5.3	1.6	3.5	9.5	6
2003	4.3	1.3	2.5	8	5
2004	5.6	1.7	3	10.5	8
2005	6.9	2.1	3	10.5	9
2006	6.7	2	3	11.5	8
2007	5.0	1.5	3.0	10	10

Table 24. Green Lake historical summer total phosphorus concentrations.

Date	Growing Season Average	Minimum	Maximum	Number of Sample Dates
1986 - top	32	32	32	1
- bottom	43	41	44	1
1994 - top	41	39	45	3
- bottom	77	51	153	3
1995 - top	38	23	58	4
- bottom	42	34	50	4
1996 - top	39	30	47	2
- bottom	52	35	69	2
1997 - top	21	19	23	2
- bottom	36	31	41	2
1998 - top	27	16	38	2
- bottom	43	38	47	2
1999 - top	20	9	35	3
- bottom	38	16	71	3
2000 - top	17	10	28	3
- bottom	21	14	35	3
2001- top	47	23	66	3
- bottom	108	75	170	3
2002 - top	10	5	16	3
2003 - top	22	10	34	2
2004 - top	14	9	22	3
2005 - top	34	21	49	3
2006 - top	37	23	47	3
2007 - top	34	17	57	3

Little Green Lake

Little Green Lake data are shown in Tables 25 and 26.

Table 25. Little Green Lake historical Secchi disc transparencies.

Date	Growing Season Averages		Minimum (feet)	Maximum (feet)	Number of Sample Dates
	(feet)	(meters)			
1989	2.5	0.8	2.5	2.5	2
1990	3.5	1.1	1.5	6.5	7
1991	5.1	1.6	2	11	11
1993	4	1.2	2.5	8	8
1994	3	0.9	3	3	2
1995	6	1.8	3	11.5	10
1996	4.7	1.4	2.5	6.5	7
1997	5.1	1.6	3	9	7
1998	4.8	1.5	2.5	10	10
1999	4.1	1.2	1.5	9	14
2000	3.9	1.2	2	6	13
2001	4.4	1.3	2.5	7.5	13
2002	4.2	1.3	2.5	8	6
2003	3.4	1	2	6.5	5
2004	4.9	1.5	2.5	9	8
2005	6.8	2.1	2.3	8	9
2006	4.8	1.5	2	8.5	8
2007	3.5	1.1	2.0	7.5	10

Table 26. Little Green Lake historical summer total phosphorus concentrations.

Date	Growing Season Average	Minimum	Maximum	Number of Sample Dates
1986 - top	38	38	38	1
1994 - top	46	43	49	2
- bottom	68	59	76	2
1995 - top	34	20	45	4
- bottom	56	47	62	4
1996 - top	50	35	72	3
- bottom	60	52	72	3
1997 - top	24	17	30	2
- bottom	30	26	33	2
1998 - top	42	24	59	2
- bottom	52	24	80	2
1999 - top	30	15	38	3
- bottom	35	15	54	3
2000 - top	28	12	57	3
- bottom	38	21	55	3
2001- top	51	17	76	3
- bottom	63	38	87	3
2002 - top	15	13	16	3
2003 - top	32	15	48	2
2004 - top	19	11	26	3
2005 - top	47	24	63	3
2006 - top	37	33	41	3
2007 - top	30	19	39	3

Appendix: Dissolved Oxygen and Temperature Profiles

Dissolved oxygen and temperature profiles were collected over the summer of 2004 by Pat Collins. Except for Little Green Lake, the other six lakes have dissolved oxygen concentrations of less than 1 mg/l for one or more sample dates.

Table A. Dissolved oxygen and temperature profiles for 2004.

North Center

6.25.04			7.26.04			8.22.04		
Depth (m)	Temp (C)	DO (mg/l)	Depth (m)	Temp (C)	DO (mg/l)	Depth (m)	Temp (C)	DO (mg/l)
0	21.2	9	0	26	11.3	0	18	8.8
1	20.5	8.8	1	24.9	9.8	1	17	8.4
2	20.5	7.4	2	24.5	8	2	16.5	7.6
3	20.2	7.1	3	24	7.8	3	16.2	7.2
4	19.5	4.1	4	23.5	4.2	4	16	7
5	18.8	2.7	5	19.1	0.6	5	15.1	4.4
6	16.2	0.4	6	14.9	0.2	6	9.8	0.4
7	14.9		7	14.5		7	9	0.3
8			8	14.5		8		

South Center

6.25.04			7.26.04			8.22.04		
Depth (m)	Temp (C)	DO (mg/l)	Depth (m)	Temp (C)	DO (mg/l)	Depth (m)	Temp (C)	DO (mg/l)
0	21	8.9	0	27	8.4	0	17	8.8
1	20.8	8.4	1	26.5	8.2	1	17	8.8
2	20.5	7.9	2	25.3	7.8	2	16.6	7.4
3	20	7.7	3	24.2	6.9	3	16.2	6.9
4	19.8	7.1	4	22.5	0.4	4	16	6.7
5	17.1	4.6	5	22.2	0.2	5	16	6.2
6	15.8	3.2	6			6	11.5	0.5
7	13	1.1	7			7	10.4	0.4
8	9.9	0.5	8			8	10.2	0.4
9	9.1		9			9	10.2	0.4
10	9.1		10			10		

North Lindstrom

6.26.04			7.27.04			8.20.04		
Depth (m)	Temp (C)	DO (mg/l)	Depth (m)	Temp (C)	DO (mg/l)	Depth (m)	Temp (C)	DO (mg/l)
0	23.1	9	0	24	8.4	0	17	8.2
1	21	8.7	1	23.8	8	1	17	8.2
2	20.5	7.9	2	23.5	6.5	2	17	7.9
3	19.9	7.4	3	19.6	0.8	3	17	7.4
4	19.6	6.2	4	15.8	0.4	4	16.8	6.6
5	19.3	4.2	5	14	0.4	5	14.2	4.4
6	15.4	0.4	6	13.1	0.4	6	12	0.8
7	14	0.4	7	13.1	0.4	7	10.8	0.4
8	13.2		8			8	10.8	0.4
9	12.9		9			9		

South Lindstrom

6.24.04			7.27.04			8.20.04		
Depth (m)	Temp (C)	DO (mg/l)	Depth (m)	Temp (C)	DO (mg/l)	Depth (m)	Temp (C)	DO (mg/l)
0	21.8	8.8	0	24	8.4	0	17	8.1
1	21	7.9	1	24	8.2	1	17	7.9
2	20.2	7.2	2	24	8.2	2	17	7.6
3	19.8	6.7	3	21.5	3.1	3	16.8	6.3
4	19.5	6.2	4	18.2	0.4	4	16.5	6.1
5	19.2	5.9	5	17.8		5	16.5	6
6	18.5	1.4	6	17.8		6	14.1	4.7
7	16.5	0.2	7			7	13.8	0.2
8	15.1	22.2	8			8	13.8	0.2
9	16.1	23.2	9			9		
10	17.1	24.2	10			10		

Chisago

6.26.04			7.27.04			8.20.04		
Depth (m)	Temp (C)	DO (mg/l)	Depth (m)	Temp (C)	DO (mg/l)	Depth (m)	Temp (C)	DO (mg/l)
0	20.8	8.8	0	23.5	8.6	0	17.1	8.3
1	20.5	8.1	1	23.5	9.5	1	17	8.1
2	20.2	7.9	2	23.2	5.8	2	16.8	7.9
3	19.8	7.2	3	23.2	5.6	3	16.2	6.3
4	19.5	6.6	4	23	2.8	4	15.8	5.9
5	19	6.2	5	19		5	14.6	4.6
6	18	5.1	6	17.9		6	12.5	0.6
7	15.9	0.8	7	17.5		7	11.8	0.2
8	15.5	0.4	8			8	10.9	
9			9			9	10.9	
10			10			10		

Green

6.24.04			7.26.04			8.21.04		
Depth (m)	Temp (C)	DO (mg/l)	Depth (m)	Temp (C)	DO (mg/l)	Depth (m)	Temp (C)	DO (mg/l)
0	20	9.2	0	26.4	8.8	0	17	8
1	19.8	8.9	1	26.4	8.6	1	17	7.9
2	19.5	8.1	2	26	8.3	2	17	7.4
3	19.2	6.4	3	25.2	8.9	3	17	6.3
4	19	4.1	4	24.5	7.8	4	16.8	5.6
5	19	3.8	5	23	3.6	5	16.5	4.2
6	19	3.1	6	22.8		6	16.5	0.4
7			7			7	16.5	

Little Green

6.24.04			7.26.04			8.21.04		
Depth (m)	Temp (C)	DO (mg/l)	Depth (m)	Temp (C)	DO (mg/l)	Depth (m)	Temp (C)	DO (mg/l)
0	20.1	9.1	0	26.2	8.4	0	17.4	8.5
1	20.1	8.8	1	25	8.1	1	17	8
2	20	8.6	2	24.8	7.8	2	16.5	5.2
3	20	8.4	3	24.5	6.3	3	16.5	3.4
4	19.5	4.1	4	24.1	4	4	16.5	
5	19	0.6	5	23.8		5		