LAKE ASSESSMENT NOTES

1997

LAKE ORONO
(ID # 71-0013)
Sherburne County, Minnesota

Minnesota Pollution Control Agency
Water Quality Division

Prepared by:

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for
February 11, 1997 Meeting in Elk River

Lake Orono (71-0013) - Notes for February 11, 1997 meeting in Elk River.

The following assessment was prepared based on existing MPCA, U.S. Geological Survey (USGS), and consultant data at the request of the City of Elk River. Water quality data from a 1994 MPCA survey was used to characterize the condition of Lake Orono. During that survey samples were collected at two sites on the lake (Figure 1). Citizen Lake Monitoring Program (CLMP) data are available as well for comparison. These data will be compared to reference lake data from reference lakes in the North Central Hardwoods Forest (NCHF) ecoregion. Available data for Lake Orono from STORET, USEPA's water quality data base, are appendixed.

Morphometry and Watershed Characteristics: Lake Orono is located on the mainstem of the Elk River. With a maximum depth of 18 feet it is a very shallow lake (Table 1). The entire drainage of the Elk River, which is approximately 630 square miles, represents the majority of its watershed. This results in a very large watershed to lake surface ratio of about 1,260:1. Lakes with large watersheds relative to their size often receive very high water and nutrient loadings.

Hydrology: The hydrology of Lake Orono is dominated by the Elk River. A USGS gauge station immediately upstream at the city of Big Lake can be used to estimate inflow into Lake Orono. This gauge has been in operation since 1911. A distribution of flows from the entire period of record are as follows:

Percentile	**10th**	**50th**	**90th**
Long-term	67 cfs	165 cfs	557 cfs

Flows during the 1994 water year averaged about 292 cfs which is slightly above the long-term water-year mean of 277 cfs. However flow during the May to September period was quite similar to the long-term average (Figure 2) with high flows in May and declining flows during the summer. The slight increase in flow in July was in response to storm events in late June and early July. The lowest flow of summer 1994 occurred on August 23.

Elk River Water Quality - Water quality data was available for the Elk River and Tibbets Brook based on recent collections by Wenck Engineering as a part of a contract with the City of Elk River and two Elk River samples collected by MPCA in 1994. These data and a comparison to typical stream total phosphorus (TP) and total suspended soldis (TSS) measures for the NCHF ecoregion are summarized below:

	----------Elk River----------			Tibbets Brook	NCHF Ecoregion
	summer 1994	summer 1996	fall 1996	fall 1996	25th-75th percentile
# of obs.	(N=2)	(N=1)	(N=4)	(N=4)	
parameter					
total phosphorus	125 µg/L	132 µg/l	70 µg/L	151 µg/L	70-130 µg/L
total suspended solids		23 mg/L	8 mg/L	3.5 mg/L	4-13 mg/L

Based on these data it appears that Elk River TP concentrations are close to the typical range for minimally impacted streams in the NCHF ecoregion--however no data are available from the critical spring period when much of the loading can be expected and summer data are rather scant as well. Fall concentrations are slightly lower than summer which is reasonable if the majority of the TP is arising from nonpoint source runoff in the watershed. The single summer TSS measure is high but this likely reflects suspended algae as well as sediment in the stream. Tibbets Brook TP concentrations are slightly higher but it is likely that its load is substantially less than Elk River.

Lake Water Quality: Data was collected at two sites on the lake in 1994--site 102 in the upper portion of the lake and site 101 in the lower portion of the lake (Figure 1). A summary of the 1994 data is presented in Table 2 and is compared to the typical range of concentrations for minimally-impacted lakes in the NCHF ecoregion. In general most of the measurements from Lake Orono are high relative to the reference lakes. This is not surprising considering its large watershed and small volume. A few notes follow.

- *Total phosphorus* (TP) - In most lakes TP is considered to be the nutrient which limits the amount of algal growth in a lake. For Lake Orono TP concentrations were very high in 1994 as compared to the reference lakes. No significant difference is noted between the concentrations at the two sites. A slight peak occurs in August.
- *Chlorophyll-a* - Chlorophyll-a is used as an estimate of the amount of algae in a lake. In 1994 chlorophyll-a concentrations were very high with a maximum concentration of over 120 µg/L. All dates (Figure 4) would have been characterized as having nuisance algal blooms and three of four dates would have been considered "severe-nuisance blooms." Concentrations at site 101 were slightly higher than the upstream site 102. Since there as no difference in the amount of TP at both sites the higher value may be the result of slightly less suspended solids, allowing more light for algal growth, at site 101.

- *Total suspended solids (TSS)* - TSS is a measure of the amount of organic solids, also referred to as volatile (e.g. algae), and inorganic solids, also referred to as nonvolatile (e.g. soil particles). TSS concentrations in Lake Orono were very high in 1994 (Figure 5). The organic portion generally accounted for 50 percent or more of the TSS on three of four dates. Inorganic SS ranged between 10-15 mg/L on all four sample dates.
- *Secchi transparency* - The high amount of algae and suspended solids in general results in very low transparency in Lake Orono (Table 2). Transparency ranges from 0.6-0.8 meters (2-2.5 ft) in the early summer to 0.4-0.6 meters later in the summer (Figure 6).
- *Trophic state index (TSI)* - The measures TP, chlorophyll-a and Secchi are used to characterize the trophic status of lakes. Carlson's TSI values for Lake Orono are noted in Table 2. These TSI values suggest hypereutrophic conditions for the lake. The TP and chlorophyll-a values agree quite well, while the Secchi TSI is slightly lower. This means that the transparency is slightly higher than expected based on the TP and chlorophyll-a concentrations. Relative to TSI measures from about 600-700 lakes, for which we have data in the NCHF ecoregion, the TSI values for Lake Orono rank between the 10th to the 20th percentile which means that 80-90 percent of the lakes have lower TSI values.

The **MINLEAP model** was run for Lake Orono. This model is based on data from the ecoregion reference lakes, minimally impacted streams, and regional patterns in precipitation, evaporation, and runoff. The MINLEAP model predicts a summer-mean P concentration of 132 µg/L for Lake Orono (Table 3) which is very comparable to the observed P concentration in 1994. The predicted chlorophyll a concentration (based upon predicted TP) is 83 µg/L, which again is quite similar to the observed value for 1994. As a result the predicted transparency is quite comparable to the observed . The model also estimates the frequency of occurrence of nuisance (30 µg/L) and severe nuisance (60 µg/L) algal blooms. Based on an observed mean chlorophyll-a of 72 µg/L nuisance blooms likely occurred 94 percent of the summer and very severe nuisance blooms would occur about 56 percent of the summer. Again the predicted values are similar to the observed.

The predicted P loading rate for Lake Orono, using MINLEAP inputs for the NCHF ecoregion, is about 31,420 kg P/yr. This estimate is based on the size of its watershed and an average inflow concentration of 148 µg/L P. The estimated inflow P concentration and water loading used in the model are similar to the observed water loading and P concentrations in the Elk River based on 1994 and 1996 data.

MINLEAP also provides an approximation of the water budget for the lake. The areal water load (water load from runoff and precipitation divided by lake surface area) is about 175.3 m/yr and outflow from the lake is estimated at 212 HM^3/yr (237 cfs). The outflow estimated in the model is somewhat similar to the observed flows in the Elk River based on USGS data. Water residence time (time it would take to fill the lake if it were empty) for Orono Lake is estimated at 3-4 days on average.

Conclusion

These data suggest that Lake Orono is responding as expected for a lake of its size (area and depth) in the NCHF ecoregion. The current water quality is not surprising considering Lake Orono's very small volume and size relative to the size of its watershed. With a watershed over 1,200 times larger than the surface area of the lake the resulting water and P loadings are enormous. This leads to the very short water residence times (3-4 days), low retention of P in the lake (about 10 percent), very high in-lake P (136 µg/L) and subsequently the severe-nuisance algal blooms and very low transparency which are common in the lake. Based on this data it is likely that very large reductions in the amount of TP entering the lake would be needed to provide measurable and perceptible improvements in the water quality of the lake.

TABLE 1. MORPHOMETRIC, WATERSHED, FISHERY CHARACTERISTICS
Lake Orono (Elk River watershed)

STORET I.D. # 71-0013 Orono

Area[1]: 300 acres (121 ha)

Mean Depth: 5 feet (1.5 m) (estimated)

Maximum Depth 18 feet (5.5 m)

Volume[1]: 1,500 acre-feet (1.85 hm^3)

Watershed Area[2]: 403,200 acres (~630 mi^2) (163,239 ha)(includes lake surface)

Watershed Area Lake Surface Ratio: ~ 1,260: 1

Estimated Average Water Residence Time: 3-4 days

Fisheries[4] - Ecological type: Roughfish-gamefish
Management class: Warm-water gamefish
Schupp's Lake class:

Public Access: 1
Inlets: 1
Outlets: 1

LAND USE (Percentage)	Forest	Water & Marsh	Pasture & Open	Cultivated	Urban
Lake Orono (Elk River) Watershed North Central Hardwoods Forests[2]	6-25 %	14-30 %	11-25 %	36-68 %	2-9 %

Shoreland Zoning: general

Development[3]	Seasonal	Permanent	Total
1967	1	1	2
1982	0	0	0
1996			

[1]Planimetered by MPCA.
[2]Derived from Heiskary and Wilson (1990) Table 6.
[3]SWIM data base, State Planning Agency, Information Center, St. Paul, MN.

TABLE 2: AVERAGE SUMMER WATER QUALITY AND TROPHIC STATUS INDICATORS

Lake Orono - Based on 1994 epilimnetic data.

Parameters	1994 Mean	Typical Range for NCHF Ecoregion[1]
Total Phosphorus (µg/L)	136	23-50
Chlorophyll a (µg/L)[3]		
Mean	72	5-22
Maximum	121	7-37
Secchi disk (feet)	2.4 (0.7 m)	4.9-10.5
Total Kjeldahl Nitrogen (mg/l)	1.8	0.6-1.2
Nitrite + Nitrate-N (mg/l)	0.1	< 0.01
Alkalinity (mg/l)	155	75-150
Color (Pt-Co Units)	25	10-20
pH (SU)	8.6	8.6-8.8
Chloride (mg/l)	11	4-10
Total Suspended Solids (mg/l)	28	2-6
Total Suspended Inorganic Solids	13	1-2
Turbidity (NTU)	14	1-2
Conductivity (µmhos/cm)	300	300-400
TN:TP Ratio	14:1	25:1 - 35:1

Trophic Status Indicators: 1994

	Trophic Status Index Values	NCHF Ecoregion Percentile
TP TSIP =	75	20
Chl a TSIC =	73	13
Secchi TSIS =	67	12
Mean (All) TSI =	72	13

TABLE 3. MINLEAP Model Results for Lake Orono. USGS flow data as measured at Big Lake used to represent 1994 lake outflow volume.

Lake Orono

Parameter	Observed:1994	Predicted
TP µg/L	136	132
chl-a µg/L	72	83
% chl-a >20 µg/L	99 %	100 %
% chl-a >30 µg/L	94 %	97 %
% chl-a >60 µg/L	56 %	67 %
Secchi m	0.7	0.6
P loading rate		31,420 kg P/yr
P retention		10 %
P inflow	~ 130 µg/L	148 µg/L
water load		175.3 m/yr
outflow volume	~ 260 hm^3/yr (292 cfs)	212 hm^3/yr (237 cfs)
"background P"		
residence time		3-4 days.

Lake Orono LAKEID=71-0013

DATE	SITE	D	TP	RTP	TKN	N2N3	RN2N3	TSS	TSIN	ALK	PHF	CL	CONF	TURB	COLOR	CHLA	PHEO	SDF	PHYS	REC	DO	TEMP
810629	101	0	.130		1.40	0.18		.	.	110	.	.	.	.	50	17.90	1.79	2.3			5.8	21.5
940629	101	0	.132		1.45	0.30		25.0	14.0	160	8.5	11	330	8.3	30	91.00	16.0	1.6	2	2	10.6	22.8
940629	102	1	.129													70.10	4.27					
940721	101	0	.130		1.76	0.05	K	25.0	10.0	160	8.8	10	300	12	30	124.00	0.85	1.6		2	12.8	23.8
940721	102	1	.134													71.80	0.85					
940830	101	0	.157		1.90	0.05	K	38.0	16.0	150	8.8	10	280	19	20	47.40	0.64	1.3	3	3	10.7	21.1
940830	102	1	.150													39.10	1.28					
940921	101	0	.120		1.56	0.20		26.0	12.0	150	8.4	12	290	15	20	70.90	2.56	1.6	4	4	12.3	22.7
940921	102	1	.135		.	.		.	.	.	.	.	.	.	.	64.10	1.28	.			.	.

SITE	DATE	D	DO	TEMP	TP
101	940629	0	10.6	22.8	0.132
101	940629	3	10.6	22.8	.
101	940629	6	10.3	22.7	.
101	940629	9	10.3	22.6	.
101	940721	0	12.8	23.8	0.130
101	940721	3	12.8	23.8	.
101	940721	6	11.1	23.5	.
101	940721	9	9.8	23.0	.
101	940830	0	10.7	21.1	0.157
101	940830	3	10.8	21.1	.
101	940830	6	10.8	21.1	.
101	940830	9	10.7	21.1	.
101	940830	13	10.6	20.9	.
101	940921	0	12.3	22.7	0.120
101	940921	3	11.0	20.0	.
101	940921	6	8.6	19.0	.
101	940921	9	7.8	18.4	.

Water Quality Data Abbreviations and Units

DATE= yr-mo-da
SITE= sampling site ID, 100 series=MPCA, 200=CLMP, etc.
DM= sample depth in meters (0=0-2 m integrated)
TP= total phosphorus in mg/l (decimal) or ug/L as whole number
OP= total ortho-phosphorus in mg/l
DP= dissolved phosphorus in mg/l
TKN= total Kjeldahl nitrogen in mg/l
N2N3= nitrite+nitrate N in mg/l
NH4= ammonia-N in mg/l
TNTP=TN:TP ratio
PH= pH in SU (F=field, L or =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
SI= total silica in mg/L
DO= dissolved oxygen in mg/l
TEMP= temperature in degrees centigrade
SD= Secchi disk in meters (SDF=feet)
CHLA= 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

Commonly used statistical abbreviations in data printouts

NTP, NSD,....=number of observations
MTP, MSD,....=mean TP, Secchi, etc. (typically June-Sept. mean)
STP, SSD, ...=standard error of the mean for TP, Secchi, etc.
[std err=std deviation/square root of number of observations]
TPCV, SDCV, .=coefficient of variation of mean for TP, Secchi, etc.
[CV=(100*std deviation)/mean]; and is expressed as a % of the mean

LAKEID=71-0013 SITE=201

DATE	SDM	PHYS	REC
940516	0.6	2	2
940523	0.6	2	2
940530	0.8	2	2
940607	0.6	2	2
940613	0.8	2	2
940621	0.6	2	2
940627	0.6	2	2
940704	0.6	2	2
940711	0.6	2	2
940718	0.5	2	2
940725	0.5	2	2
940801	0.5	2	2
940811	0.6	2	2
940815	0.5	2	2
940822	0.6	2	2
940906	0.6	2	2
940914	0.5	2	2
940920	0.5	2	2
940926	0.5	2	2
950512	0.8	3	2
950515	0.9	3	2
950524	0.9	3	2
950530	0.9	3	2
950605	0.8	3	2
950613	0.8	3	2
950619	0.8	3	2
950626	0.6	3	2
950702	0.8	3	2
950712	0.6	3	2
950717	0.6	3	2
950814	0.5	3	4
950821	0.6	3	4
950830	0.5	3	4
950905	0.9	2	4
950912	0.8	2	4
950918	0.8	2	4
950926	0.9	2	4

LAKEID=71-0013 SITE=202

DATE	SDM	PHYS	REC
940516	0.8	2	2
940523	0.6	2	2
940530	0.6	2	2
940607	0.6	2	2
940613	0.6	2	2
940621	0.6	2	2
940627	0.6	2	2
940704	0.6	2	2
940711	0.6	2	2
940718	0.5	2	2
940725	0.5	2	2
940801	0.5	2	2
940811	0.6	2	2
940815	0.5	2	2
940822	0.6	2	2
940906	0.6	2	2
940914	0.5	2	2
940920	0.5	2	2
940926	0.5	2	2
950512	0.8	3	2
950515	0.9	3	2
950524	0.9	3	2
950530	0.9	3	2
950605	0.8	3	2
950613	0.8	3	2
950619	0.8	3	2
950626	0.6	3	2
950702	0.6	3	2
950712	0.6	3	2
950717	0.6	3	2
950814	0.5	3	4
950821	0.6	3	4
950830	0.5	3	4
950905	0.9	2	4
950912	0.8	2	4
950918	0.8	2	4
950926	0.9	2	4

Figure 1. Lake Orono Bathymetric Map with Sample Sites Noted.

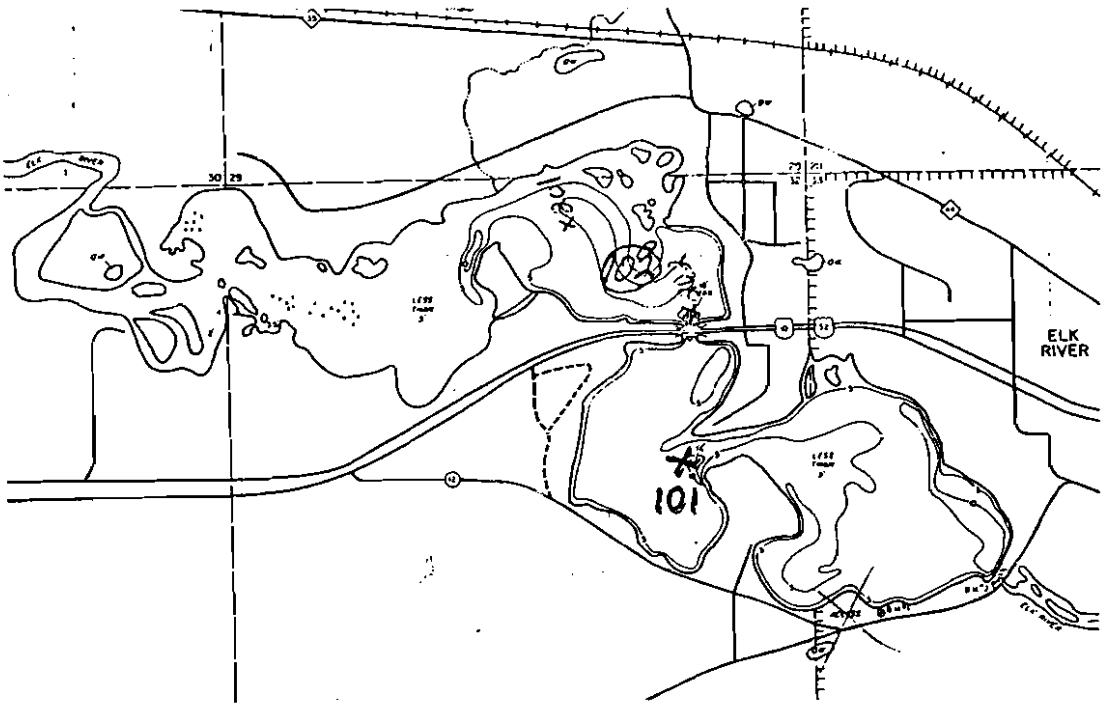

Figure 2. Monthly Mean Flows in Elk River near Big Lake. USGS data for 1994 and long-term mean.

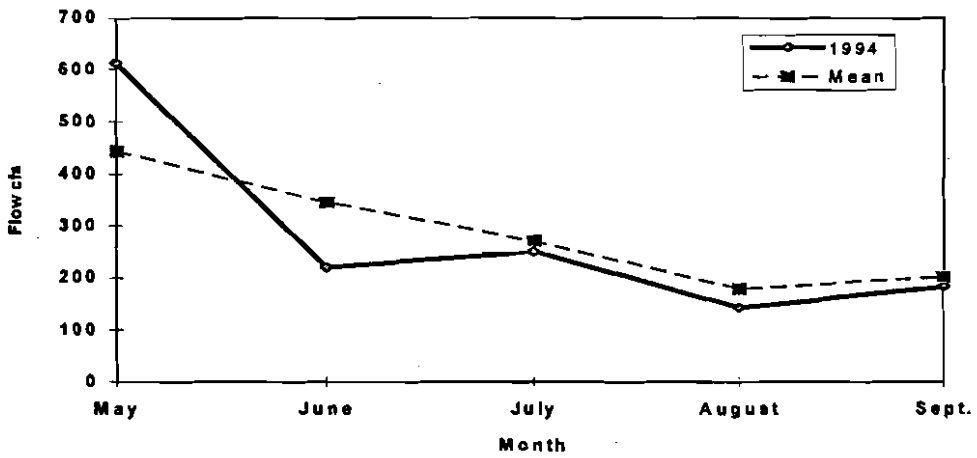

Figure 3. Lake Orono Total Phosphorus Concentrations: 1994

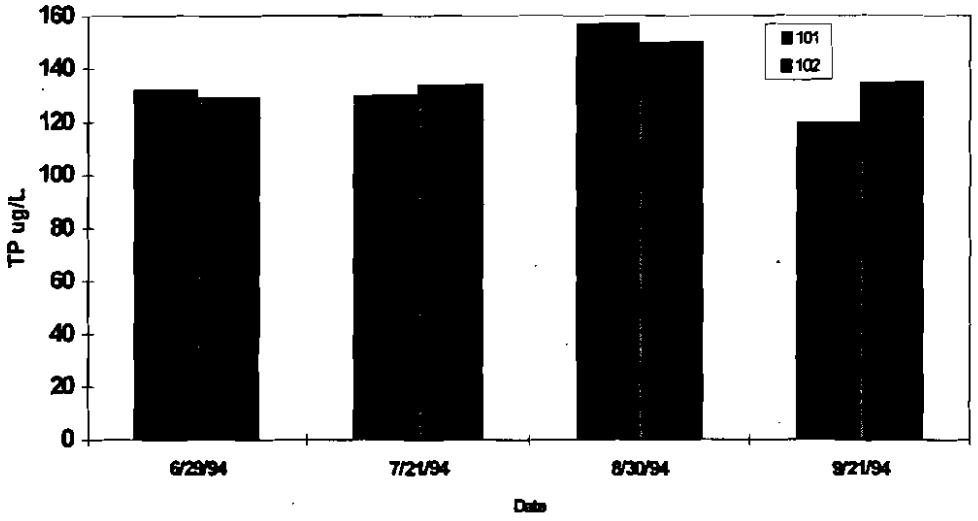

Figure 4. Lake Orono Chlorophyll-a: 1994
Dashed line indicates "severe nuisance blooms."

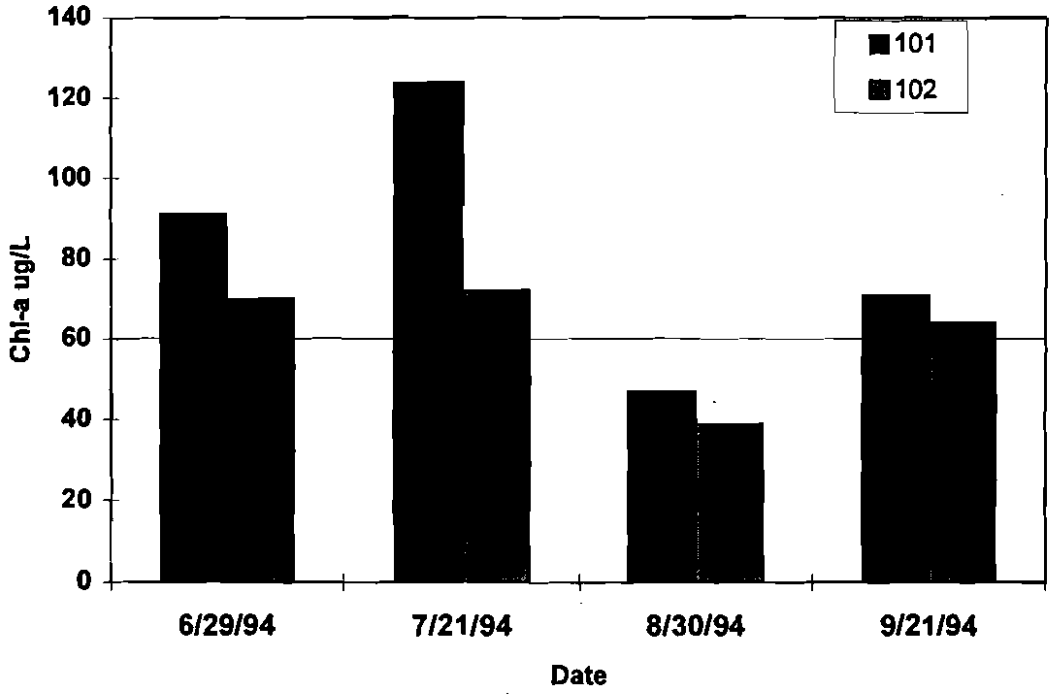

Figure 5. Lake Orono Total Suspended Solids: 1994. Represented as volatile (organic) and non-volatile (inorganic) portions. Dashed line represents "typical" TSS concentration for lakes in NCHF ecoregion.

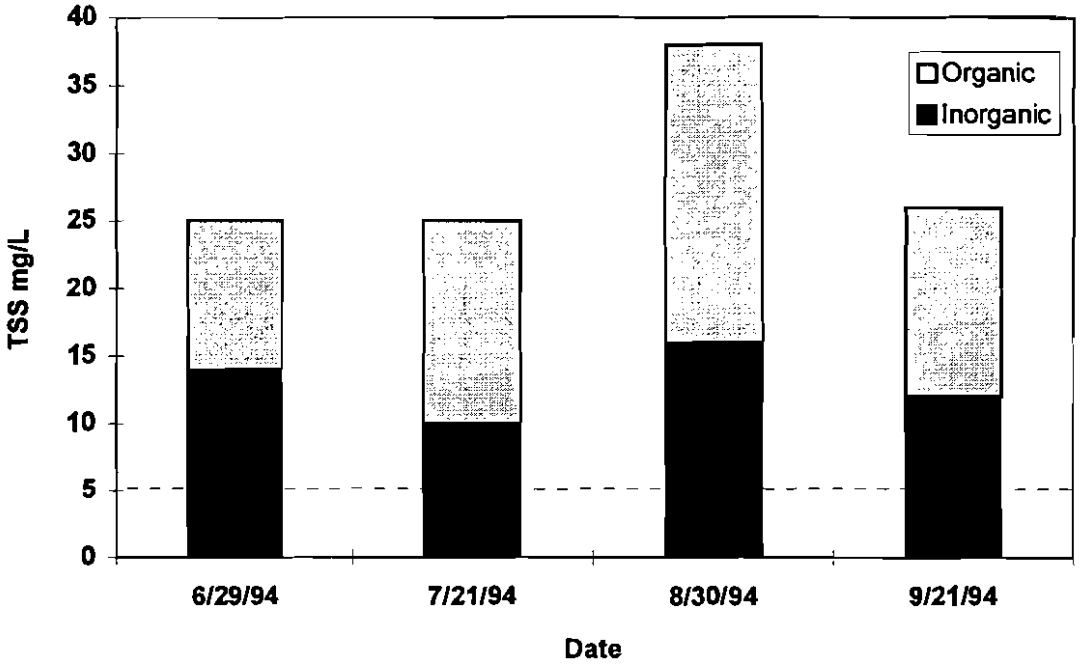

Figure 6. Lake Orono Secchi Transparency: 1994