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United States Department of the Interior

GEOLOGICAL SURVEY

Water Resources Division
6417 Normandy Lane
Madison, Wisconsin 53719-1133
608 274-3535 (Fax 608 276-3817)

TAKE PRIDE IN AMERICA

July 6, 1992

Mr. Gerald Kafka
Balsam Lake Protection and
Rehabilitation District
1230 East Como Boulevard
St. Paul, Minnesota 55117

Dear Mr. Kafka:

This letter describes the progress on the evaluation of the water quality of Balsam Lake according to the data collected from October 1990 to September 1991 as stated in our agreement. Please read the enclosure, "U.S. Geological Survey Lake Monitoring Program in Wisconsin", before proceeding with this letter.

In a brief summary, based on the 1991 data:

- The water quality of Balsam Lake varies throughout the lake. Balsam Lake off Cedar Island ranges from fair to very good; Balsam Lake off Little Narrows ranges from fair to good; and Balsam Lake off Rock Island ranges from poor to good.

- Balsam Lake is a mesoeutrophic lake or a lake with moderate nutrients.

- In Balsam Lake off Cedar Island, algal growth appears to be dependent upon the amount of available phosphorus rather than nitrogen.

- In July and August, during summer stratification, oxygen disappears from the bottom portion of the lake which is then unable to support a fish population.

- During the summer anoxic (devoid of oxygen) period, there are minor amounts of phosphorus being released from the bottom sediments (off Cedar Island).

- The data enclosed herein are provisional until published.

Balsam Lake has a surface area of 3.21 mi^2 (2,054 acres) and a drainage area at the outlet of 52.7 mi^2, for a drainage area/lake size ratio of 16:1. Lakes with drainage area/lake size ratios of greater than 10:1 tend to develop water-quality problems. (Uttormark, Paul D., and Mark L. Hutchins, 1978, Input/output models as decision criteria for lake restoration. University of Wisconsin-Madison, Wisconsin, Water Resources Center technical report No. 78-03, 61 pp.)

Three sites were sampled in Balsam Lake. They are located off Cedar Island (center) at a depth of about 30 feet, off Little Narrows at a depth of about 20 feet, and off Rock Island at a depth of about 10 feet. All sites are shown in figure 1.

The data for this report are found in the following tables and figures:

Table 1. Lake stages for Balsam Lake off Cedar Island (center), 1991 water year

Table 2. Lake-depth profiles for Balsam Lake off Cedar Island (center) at Balsam Lake, Wisconsin, 1991 water year

Table 3. Balsam Lake off Cedar Island (center) water clarity and water-quality analyses and their associated Trophic State Indices (TSI), 1991 water year

Table 4. Balsam Lake off Little Narrows water clarity and water-quality analyses and their associated Trophic State Indices (TSI), 1991 water year

Table 5. Balsam Lake off Rock Island water clarity and water-quality analyses and their associated Trophic State Indices (TSI), 1991 water year

Table 6. Lake water-quality data for Balsam Lake off Little Narrows and Balsam Lake off Rock Island at Balsam Lake, Wisconsin, 1991 water year

Figure 1. Location of sampling sites and staff gage

Figure 2. Lake water-quality data for Balsam Lake off Cedar Island (center) at Balsam Lake, Wisconsin, 1991 water year

Figure 3. Trophic state indices for Balsam Lake off Cedar Island (center) at Balsam Lake, Wisconsin

Figure 4. Trophic State Indices for Balsam Lake off Little Narrows at Balsam Lake, Wisconsin

Figure 5. Trophic State Indices for Balsam Lake off Rock Island at Balsam Lake, Wisconsin

All the water-quality samples collected were analyzed by the Wisconsin State Laboratory of Hygiene at Madison, Wisconsin. The water-quality data was published in our annual publication, "Water Resources Data for Wisconsin, 1991".

LAKE-STAGE FLUCTUATIONS

Lake-stages were read at the wing wall of the culvert between Balsam Lake and the Mill Pond on County Highway I by Bob Zuehlke. Lake-stage data are listed in table 1. Lake stages fluctuated 0.78 feet and ranged from 7.63 feet on September 4 to 8.41 feet on September 18.

LAKE-DEPTH PROFILES

Profiles of water temperature, dissolved oxygen, pH, and specific conductance at the deep hole are listed in table 2 and shown in figure 2. No abnormalities in the data are apparent. Among our sampling dates, complete water-column mixing was observed on May 1. The remainder of the profile data show incomplete mixing. The lake thermally stratifies during summer. During July and August, the bottom 9 feet of water became anoxic (devoid of oxygen) and were unable to support fish. The levels of pH are within acceptable limits to support aquatic life. Because of the buffering capacity of the lake water, Balsam Lake is not susceptible to the effects of acid rain.

SELECTED ANALYSES

Analyses of selected constituents for May 7 for Balsam Lake off Cedar Island for samples collected at 1.5 and 32-foot depths are listed in figure 2. The water-quality values for color, chlorophyll a, chlorides, calcium, magnesium, pH, alkalinity, total nitrogen, and total phosphorus are within regional values for this area as described by Lillie and Mason in "Limnological Characteristics of Wisconsin Lakes," 1983, Technical Bulletin No. 138, Department of Natural Resources.

To compute the nitrogen-phosphorus ratio, only the sample collected from the 1.5-foot sampling depth for May was used. This depth was used because algae grow in the upper part of the lake rather than at the bottom. The ratio of total nitrogen to phosphorus was calculated as 25:1 and suggests the lake is phosphorus-limited. This means algal growth appears to be dependent on the amount of available phosphorus rather than nitrogen.

APRIL, JUNE, JULY AND AUGUST WATER QUALITY

The data for total phosphorus, chlorophyll a, and Secchi-depth readings are listed in tables 3, 4 and 5 and on figure 2 for the center site off Cedar Island.

The water quality of the three sampling sites varies. Each sampling site is discussed separately.

Balsam Lake off Cedar Island

Total phosphorus: Total phosphorus concentrations sampled at a 1.5-foot depth range from 0.012 mg/L in July to 0.019 mg/L in May and August. All values fall within the regional values previously referenced.

Concentration of total phosphorus 1.5 feet above the lake bottom ranged from 0.024 mg/L in May to 0.140 mg/L in August. These concentrations are indicative of minor phosphorus release from the bottom sediments during anoxic (absence of oxygen) periods.

Chlorophyll a: Chlorophyll a concentrations, which indicate algal biomass, ranged from 3 µg/L in June to 16 µg/L in August. These data are within the regional values.

Secchi disc: Secchi-disc depths, which indicate water clarity, ranged from 9.8 feet in August to 17 feet in June. These data are within the regional values.

Balsam Lake off Little Narrows

Total phosphorus: Total phosphorus concentrations sampled at a 1.5-foot depth range from 0.021 mg/L in August to 0.430 mg/L in June. All values fall within the regional values previously referenced.

Chlorophyll a: Chlorophyll a concentrations ranged from 6 µg/L in August to 22 µg/L in June. These data are within the regional values.

Secchi disc: Secchi-disc depths ranged from 5.9 feet in June and July to 6.9 feet in May. These data are within the regional values.

Balsam Lake off Rock Island

Total phosphorus: Total phosphorus concentrations sampled at a 1.5-foot depth range from 0.010 mg/L in May to 0.032 mg/L in August. All values fall within the regional values previously referenced.

Chlorophyll a: Chlorophyll a concentrations ranged from 2 µg/L in May and June to 22 µg/L in August. These data are within the regional values.

Secchi disc: Secchi-disc depths ranged from 4.3 feet in August to 20 feet in June. These data are within the regional values.

TROPHIC STATUS

Lillie and Mason (1983) classified Wisconsin lakes using a random data set (summer, July and August) according to total phosphorus and chlorophyll a concentrations, and Secchi-disc depth. This evaluation is shown below:

Water quality index	Approximate total phosphorus equivalent (mg/L)	Approximate chlorophyll a equivalent (µg/L)	Approximate water clarity equivalent (Secchi-disc depth in ft)
Excellent	<0.001	< 1	>19.7
Very good	.001-.010	1-5	9.8-19.7
Good	.010-.030	5-10	6.6-9.8
Fair	.030-.050	10-15	4.9-6.6
Poor	.050-.150	15-30	3.3-4.9
Very poor	>.150	>30	< 3.3

The water quality of the three sampling sites varies. Therefore, each site is evaluated separately. Using the above criteria to evaluate the mean summer (July-August) 1991 data shown in tables 3, 4 and 5 for Balsam Lake off Cedar Island, surface total phosphorus concentrations indicate good water quality, chlorophyll a concentrations indicate fair water quality, and Secchi-disc

depths indicate very good water quality. At Balsam Lake off Little Narrows, surface total phosphorus and chlorophyll a concentrations indicate good water quality and Secchi-disc depths indicate fair water quality. At Balsam Lake off Rock Island, surface total phosphorus concentrations indicate good water quality, chlorophyll a concentrations indicate poor water quality, and Secchi-disc depths indicate fair water quality.

Using the data from "Limnological Characteristics of Wisconsin Lakes," 1983, by Lillie and Mason, a comparison of the 1991 mean summer data (July and August) for total phosphorus, chlorophyll a, and Secchi depths for all three Balsam Lake sites to other lakes in northwest Wisconsin are shown below:

	Parameter		Percentage of distribution of lakes in northwest Wisconsin within these concentrations
	Total phosphorus (mg/L)		
	<.010	Best condition	12
	.010-.020	↓	35
Balsam Lake →	.020-.030	↓	23
	.030-.050	↓	18
	.050-.100	↓	8
	.100-.150	↓	3
	>.150	Worst condition	1
	Chlorophyll a (µg/L)		
	0- 5	Best condition	29
	5-10	↓	36
Balsam Lake →	10-15	↓	14
	15-30	↓	14
	30	Worst condition	9
	Secchi depth (in feet)		
	>19.7	Best condition	0
	9.8-19.7	↓	22
Balsam Lake →	6.6- 9.8	↓	29
	3.3- 6.6	↓	30
	<3.3	Worst condition	19

The above data show that, during the period 1966 to 1979, 30 percent of the lakes had higher total phosphorus concentrations, 23 percent had higher chlorophyll a concentrations, and 49 percent had less water clarity.

A second approach to assessing the "health" or trophic status of a lake is to use Carlson's Trophic State Index (TSI). A graphic illustration of the Trophic State Index for Balsam Lake is shown on figures 3, 4 and 5. The data from 1991 show Balsam Lake to be mesoeutrophic or one with moderate nutrients.

The data that has been collected for Balsam Lake from 1991 is extremely important for understanding the lake's water quality and managing the lake. To continue with the monitoring will help to build on this very valuable data base.

If you have any questions regarding this evaluation, please contact me at 608/276-3842.

Sincerely,

Stephen J. Field
Biologist

Enclosures

cc: Dan Ryan, Spooner

Table 1.--Lake stages for Balsam Lake off Cedar Island (center), 1991 water year

ST. CROIX RIVER BASIN

452755092264600 BALSAM LAKE, OFF CEDAR ISLAND, AT BALSAM LAKE, WI

LOCATION.--Lat 45°27'55", long 92°26'46", in NW 1/4 SW 1/4 sec.2, T.34 N., R.17 W., Polk County, Hydrologic Unit 07030005, 1 mi north of Balsam Lake.

DRAINAGE AREA.--52.7 mi^2.

LAKE-STAGE RECORDS

PERIOD OF RECORD.--December 1987 to current year. December 1987 to November 1989 (fragmentary), data unpublished in district files.

GAGE.--Staff read by Bob Zuenlke. Staff on wingwall of culvert between Balsam Lake and Mill Pond on CTH "I". From December 1987 to May 1991, gage at different location on lake. Elevation of lake is 1,133 ft, from topographic map.

EXTREMES FOR PERIOD OF RECORD.--Maximum gage hiengt observer, 8.41 ft, Sept. 18, 1991; minimum observed, 6.74 ft, Aug. 3, 1988.

EXTREMES FOR CURRENT YEAR.--Maximum gage height observed, 8.41 ft, Sept. 18; minimum observed, 7.63 ft, Sept. 4.

GAGE HEIGHT, FEET, WATER YEAR OCTOBER 1990 TO SEPTEMBER 1991
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	---	---	---	---	---	---	---	8.03	---	---	---	---
2	---	---	---	---	---	---	---	---	---	---	---	---
3	---	---	---	---	---	---	---	---	---	---	---	---
4	---	---	---	---	---	---	---	---	---	---	---	7.63
5	---	---	---	---	---	---	---	---	---	---	---	---
6	---	---	---	---	8.07	---	---	---	---	---	7.85	---
7	---	---	---	---	---	---	---	8.31	---	---	---	---
8	---	---	---	---	---	---	---	---	---	---	---	---
9	---	---	---	---	---	---	---	---	---	---	---	---
10	---	---	---	---	---	---	---	---	---	---	---	---
11	---	---	---	---	---	---	---	---	8.23	---	---	---
12	---	---	---	---	---	---	---	---	---	---	---	8.27
13	---	---	---	---	---	---	---	---	---	---	---	---
14	---	---	---	---	---	---	---	---	---	---	7.79	---
15	---	---	---	---	---	---	---	---	---	---	---	---
16	---	---	---	---	---	---	---	---	---	7.69	---	---
17	---	---	---	---	---	---	---	---	---	---	---	---
18	---	---	---	---	---	---	---	---	---	---	---	8.41
19	---	---	---	---	---	---	---	---	---	---	---	---
20	---	---	---	---	---	---	---	---	---	---	---	---
21	---	---	---	---	---	---	---	---	---	---	7.73	---
22	---	---	---	---	---	---	---	---	---	---	---	---
23	---	---	---	---	---	---	---	---	---	---	---	---
24	---	---	---	---	---	---	---	---	---	---	---	---
25	---	---	---	---	---	---	---	---	---	7.73	---	---
26	---	---	---	---	---	---	---	---	---	---	---	8.03
27	---	---	---	---	---	---	---	---	---	---	---	---
28	---	---	---	---	---	---	---	---	---	---	7.71	---
29	---	---	---	---	---	---	---	---	---	---	---	---
30	---	---	---	---	---	---	---	---	---	---	---	---
31	---	---	---	---	---	---	---	---	---	7.73	---	---

Table 2.--Lake-depth profiles for Balsam Lake off Cedar Island (center) at Balsam Lake, Wisconsin, 1991 water year

DISTRICT CODE 55 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10-29-91

452755092264600 - BALSAM LAKE OFF CEDAR ISLAND AT BALSAM LAKE, WI

WATER QUALITY DATA

DATE	SAMPLING DEPTH (FEET) (00003)	TEMPERATURE WATER (DEG C) (00010)	SPECIFIC CONDUCTANCE (US/CM) (00095)	PH (STANDARD UNITS) (00400)	OXYGEN, DISSOLVED (MG/L) (00300)
FEB 1991					
06...	2.00	1.0	197	8.3	12.5
06...	4.00	2.0	193	8.2	12.0
06...	6.00	3.0	191	8.2	11.6
06...	8.00	3.0	190	8.1	11.4
06...	10.0	3.0	189	8.1	11.0
06...	12.0	3.5	188	8.0	10.5
06...	14.0	3.5	187	8.0	10.2
06...	16.0	3.5	189	7.9	9.8
06...	18.0	3.5	189	7.9	9.4
06...	20.0	3.5	189	7.8	9.1
06...	22.0	3.5	191	7.8	8.4
06...	24.0	4.0	192	7.7	7.7
06...	26.0	4.0	195	7.7	6.7
06...	28.0	4.0	200	7.6	5.4
06...	30.0	4.0	206	7.6	5.2
06...	32.0	--	--	--	--
MAY					
01...	1.50	9.5	181	8.1	11.3
01...	3.00	9.5	180	8.0	11.2
01...	6.00	9.5	181	8.0	11.1
01...	9.00	9.5	181	7.9	11.0
01...	12.0	9.5	181	7.9	10.9
01...	15.0	9.5	181	7.9	10.8
01...	18.0	9.5	180	7.9	10.8
01...	21.0	9.5	180	7.9	10.8
01...	24.0	9.5	180	7.9	10.8
01...	27.0	9.5	180	7.9	10.8
01...	30.0	9.5	179	7.9	10.8
01...	32.0	--	--	--	--
JUN					
11...	0.50	23.0	168	8.4	9.3
11...	1.50	23.0	168	8.4	9.2
11...	3.00	23.0	168	8.4	9.1
11...	6.00	23.0	168	8.4	9.1
11...	9.00	23.0	167	8.4	9.2
11...	12.0	22.5	167	8.3	8.6
11...	15.0	21.0	170	8.0	8.1
11...	18.0	17.0	175	7.8	7.5
11...	21.0	14.0	175	7.7	6.0
11...	24.0	12.5	179	7.5	3.6
11...	27.0	11.5	185	7.4	1.8
11...	30.0	11.5	184	7.4	1.8
11...	32.0	--	--	--	--
JUL					
16...	0.50	24.0	163	8.8	9.2
16...	3.00	24.0	162	8.7	9.0
16...	6.00	24.0	162	8.7	8.9
16...	9.00	24.0	162	8.8	8.9
16...	12.0	24.0	161	8.8	8.8
16...	15.0	24.0	162	8.7	8.8
16...	18.0	22.5	164	8.2	6.0
16...	21.0	18.5	172	7.9	0.2
16...	24.0	14.5	182	7.8	0.1
16...	27.0	13.0	187	7.8	0.1
16...	30.0	12.0	194	7.7	0.1
16...	32.0	--	--	--	--

Table 2.--Lake-de[illegible] profiles for Balsam Lake off [illegible]dar Island (center) at Balsam Lake, Wisconsin, 1991 water year--continued

DISTRICT CODE 55 UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10-29-91
452755092264600 - BALSAM LAKE OFF CEDAR ISLAND AT BALSAM LAKE, WI

WATER QUALITY DATA

DATE	SAMPLING DEPTH (FEET) (00003)	TEMPERATURE WATER (DEG C) (00010)	SPECIFIC CONDUCTANCE (US/CM) (00095)	PH (STANDARD UNITS) (00400)	OXYGEN, DISSOLVED (MG/L) (00300)
AUG 1991					
21...	0.50	22.5	171	9.1	9.2
21...	1.50	22.5	170	9.0	9.3
21...	3.00	22.5	169	9.0	9.4
21...	6.00	22.5	171	9.0	9.5
21...	9.00	22.5	170	9.0	9.4
21...	12.0	22.5	170	9.0	9.3
21...	15.0	22.5	171	9.0	9.0
21...	18.0	21.5	172	8.6	6.3
21...	21.0	20.0	177	8.1	0.8
21...	24.0	17.0	200	7.7	0.1
21...	27.0	14.5	220	7.7	0.1
21...	30.0	13.0	228	7.6	0.1
21...	31.0	--	--	--	--

Table 3.--Balsam Lake off Cedar Island (center) water clarity and water-quality analyses and their associated Trophic State Indices (TSI), 1991 water year

[- indicates not applicable; -- indicates no data available]

Date	Water Clarity		Sampling	Total Phosphorus		Chlorophyll a		Dissolved Orthophosphate
	Depth (in feet)	T.S.I.	depth (in feet)	Concentration (in mg/L)	T.S.I.	Concentration (in µg/L)	T.S.I.	Phosphorus (concentration in mg/L)
5/1/91	12.8	40	1.5	0.019	49	5	46	0.006
	-	-	32.0	0.024	-	-	-	0.005
6/11/91	17.0	36	1.5	0.017	47	3	42	--
	-	-	30.0	0.038	-	-	-	-
7/16/91	11.2	42	1.5	0.012	42	6	47	--
	-	-	30.0	0.081	-	-	-	-
8/21/91	9.8	44	1.5	0.019	49	16	55	--
	-	-	30.0	0.140	-	-	-	-

Table 4.--Balsam Lake off Little Narrows water clarity and water-quality analyses and their associated Trophic State Indices (TSI), 1991 water year

[- indicates not applicable; -- indicates no data available]

Date	Water Clarity		Sampling	Total Phosphorus		Chlorophyll a		Dissolved Orthophosphate
	Depth (in feet)	T.S.I.	depth (in feet)	Concentration (in mg/L)	T.S.I.	Concentration (in µg/L)	T.S.I.	Phosphorus (concentration in mg/L)
5/1/91	6.9	49	1.5	0.025	53	12	53	--
	-	-	--	--	-	-	-	-
6/11/91	5.9	52	1.5	0.043	61	22	57	--
	-	-	--	--	-	-	-	-
7/16/91	5.9	52	1.5	0.026	54	11	52	--
	-	-	--	--	-	-	-	-
8/21/91	6.6	50	1.5	0.021	51	6	47	--
	-	-	--	--	-	-	-	-

Table 5.--Balsam Lake off Rock Island water clarity and water-quality analyses and their associated Trophic State Indices (TSI), 1991 water year

[- indicates not applicable; -- indicates no data available]

Date	Water Clarity		Sampling	Total Phosphorus		Chlorophyll a		Dissolved Orthophosphate
	Depth (in feet)	T.S.I.	depth (in feet)	Concentration (in mg/L)	T.S.I.	Concentration (in µg/L)	T.S.I.	Phosphorus (concentration in mg/L)
5/1/91	9.8	44	1.5	0.010	40	2	39	--
	-	-	--	--	-	-	-	-
6/11/91	20.0	34	1.5	0.011	41	2	39	--
	-	-	--	--	-	-	-	-
7/16/91	6.9	49	1.5	0.018	48	13	53	--
	-	-	--	--	-	-	-	-
8/21/91	4.3	56	1.5	0.032	57	22	57	--
	-	-	--	--	-	-	-	-

Table 6.--Lake water-quality data for Balsam Lake off Little Narrows and Balsam Lake off Rock Island at Balsam lake, Wisconsin, 1991 water year

452858092265300 BALSAM LAKE, OFF LITTLE NARROWS, NEAR BALSAM LAKE, WI

LOCATION.--Lat 45°28'58", long 92°26'53", in NE 1/4 NE 1/4 sec.34, T.35 N., R.17 W., Polk County, Hydrologic Unit 07030005, 2.1 mi north of Balsam Lake.

PERIOD OF RECORD.--May to September 1991.

REMARKS.--Lake sampled about 0.25 mi northwest of Little Narrows. Water-quality analyses by Wisconsin State Laboratory of Hygiene.

WATER-QUALITY DATA, MAY 01 TO AUGUST 21, 1991
(Milligrams per liter unless otherwise indicated)

	May 01	June 11	July 16	Aug. 21
Depth of sample (ft)	1.5	1.5	1.5	1.5
Lake stage (ft)	8.03	8.23	7.69	7.73
Specific conductance (µS/cm)	203	171	181	202
pH (units)	7.80	8.20	8.46	8.40
Water temperature (°C)	10.3	24.5	24.8	22.3
Secchi-depth (meters)	2.1	1.8	1.8	2.0
Dissolved oxygen	10.8	8.7	9.7	8.9
Phosphorus, total (as P)	0.025	0.043	0.026	0.021
Chlorophyll a, phytoplankton (µg/L)	12.0	22.0	11.0	6.0

452754092234300 BALSAM LAKE, OFF ROCK ISLAND, NEAR BALSAM LAKE, WI

LOCATION.--Lat 45°27'54", long 92°23'43", in NW 1/4 NE 1/4 sec.6, T.34 N., R.16 W., Polk County, Hydrologic Unit 07030005, 3 mi northeast of Balsam Lake.

PERIOD OF RECORD.--May to September 1991.

REMARKS.--Lake sampled in eastern bay about 0.25 mi northeast of Rock Island. Water-quality analyses by Wisconsin State Laboratory of Hygiene.

WATER-QUALITY DATA, MAY 01 TO AUGUST 21, 1991
(Milligrams per liter unless otherwise indicated)

	May 01	June 11	July 16	Aug. 21
Depth of sample (ft)	1.5	1.5	1.5	1.5
Lake stage (ft)	8.03	8.23	7.69	7.73
Specific conductance (µS/cm)	174	164	165	170
pH (units)	8.04	8.30	8.67	8.93
Water temperature (°C)	10.65	23.40	24.60	22.40
Secchi-depth (meters)	3.0	6.1	2.1	1.3
Dissolved oxygen	11.0	8.3	8.7	8.6
Phosphorus, total (as P)	0.010	0.011	0.018	0.032
Chlorophyll a, phytoplankton (µg/L)	2.0	2.0	13.0	22.0

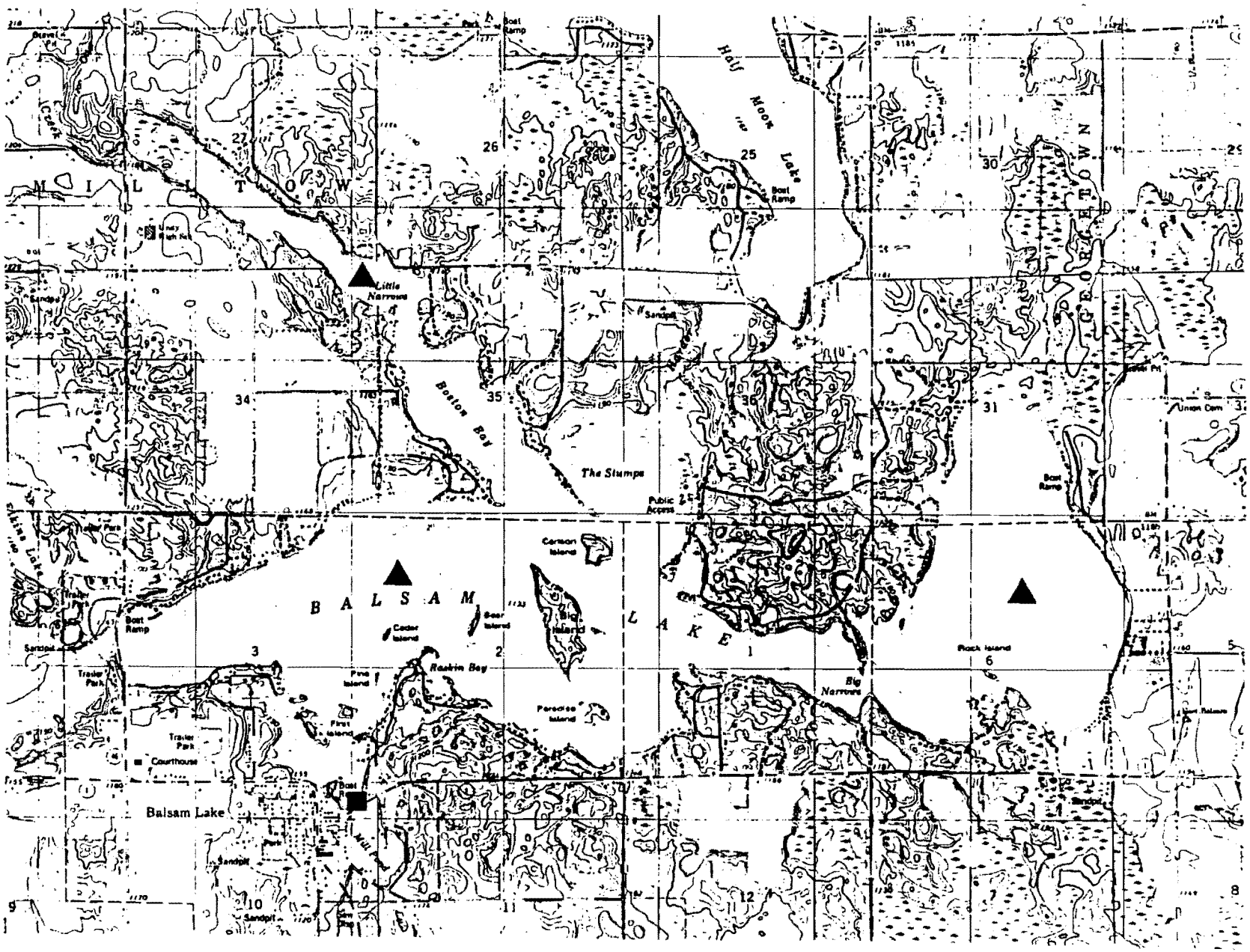

Figure 1.--Location of sampling sites and staff gage

452755092264600 BALSAM LAKE, OFF CEDAR ISLAND, AT BALSAM LAKE, WI--CONTINUED

WATER-QUALITY RECORDS

PERIOD OF RECORD.--February to September 1991.

REMARKS.--Lake sampled about 0.25 mi north of Cedar Island at a lake depth of about 34 ft. Lake ice-covered during February sampling. Water-quality analyses by Wisconsin State Laboratory of Hygiene.

WATER-QUALITY DATA, FEBRUARY 06 TO AUGUST 21, 1991
(Milligrams per liter unless otherwise indicated)

	Feb. 06		May 01		June 11		July 16		Aug. 21	
Depth of sample (ft)	2.0	30.0	1.5	32.0	1.5	30.0	1.5	30.0	1.5	30.0
Lake stage (ft)	8.07		8.03		8.23		7.69		7.73	
Specific conductance (µS/cm)	197	206	181	179	168	184	163	194	170	228
pE (units)	8.27	7.60	8.05	7.90	8.39	7.42	8.75	7.71	8.98	7.63
Water temperature (°C)	0.93	4.02	9.49	9.66	22.80	11.30	24.20	12.20	22.60	13.20
Color (Pt-Co. scale)	---	---	5.0	10.0	---	---	---	---	---	---
Turbidity (NTU)	---	---	0.8	0.6	---	---	---	---	---	---
Secchi-depth (meters)	---		3.9		5.2		3.4		3.0	
Dissolved oxygen	12.45	5.21	11.30	10.80	9.20	1.80	9.20	0.10	9.30	0.10
Hardness, as CaCO3	---	---	86	86	---	---	---	---	---	---
Calcium, dissolved (Ca)	---	---	21	21	---	---	---	---	---	---
Magnesium, dissolved (Mg)	---	---	8.0	8.0	---	---	---	---	---	---
Sodium, dissolved (Na)	---	---	4.0	4.0	---	---	---	---	---	---
Potassium, dissolved (K)	---	---	1.57	1.37	---	---	---	---	---	---
Alkalinity, as CaCO3	---	---	80	80	---	---	---	---	---	---
Sulfate, dissolved (SO4)	---	---	<5.0	<5.0	---	---	---	---	---	---
Fluoride, dissolved (F)	---	---	0.06	0.07	---	---	---	---	---	---
Chloride, dissolved (Cl)	---	---	8.0	8.0	---	---	---	---	---	---
Silica, dissolved (SiO2)	---	---	9.2	9.2	---	---	---	---	---	---
Solids, dissolved, at 180°C	---	---	114	112	---	---	---	---	---	---
Nitrogen, NO2 + NO3, diss. (as N)	---	---	0.075	0.088	---	---	---	---	---	---
Nitrogen, ammonia, dissolved (as N)	---	---	0.022	0.019	---	---	---	---	---	---
Nitrogen, amm. + org., total (as N)	---	---	0.40	0.40	---	---	---	---	---	---
Phosphorus, total (as P)	---	---	0.019	0.024	0.017	0.038	0.012	0.081	0.019	0.140
Phosphorus, ortho, dissolved (as P)	---	---	0.006	0.005	---	---	---	---	---	---
Iron, dissolved (Fe) µg/L	---	---	<50	<50	---	---	---	---	---	---
Manganese, dissolved (Mn) µg/L	---	---	<40	<40	---	---	---	---	---	---
Chlorophyll a, phytoplankton (µg/L)	---	---	5.0	---	3.0	---	6.0	---	16.0	---

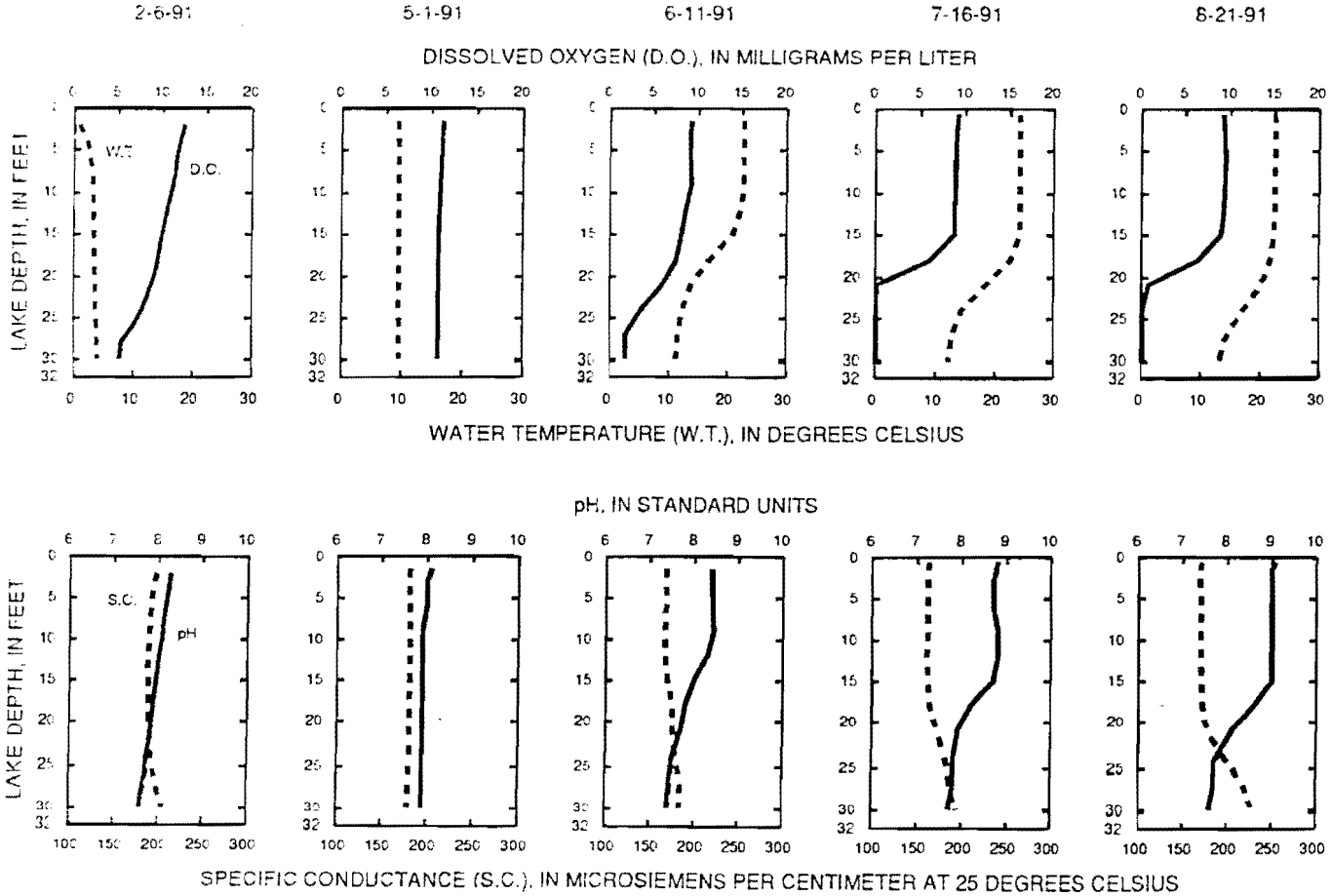

Figure 2.--Lake water-quality data for Balsam Lake off Cedar Island (center) at Balsam Lake, Wisconsin, 1991 water year

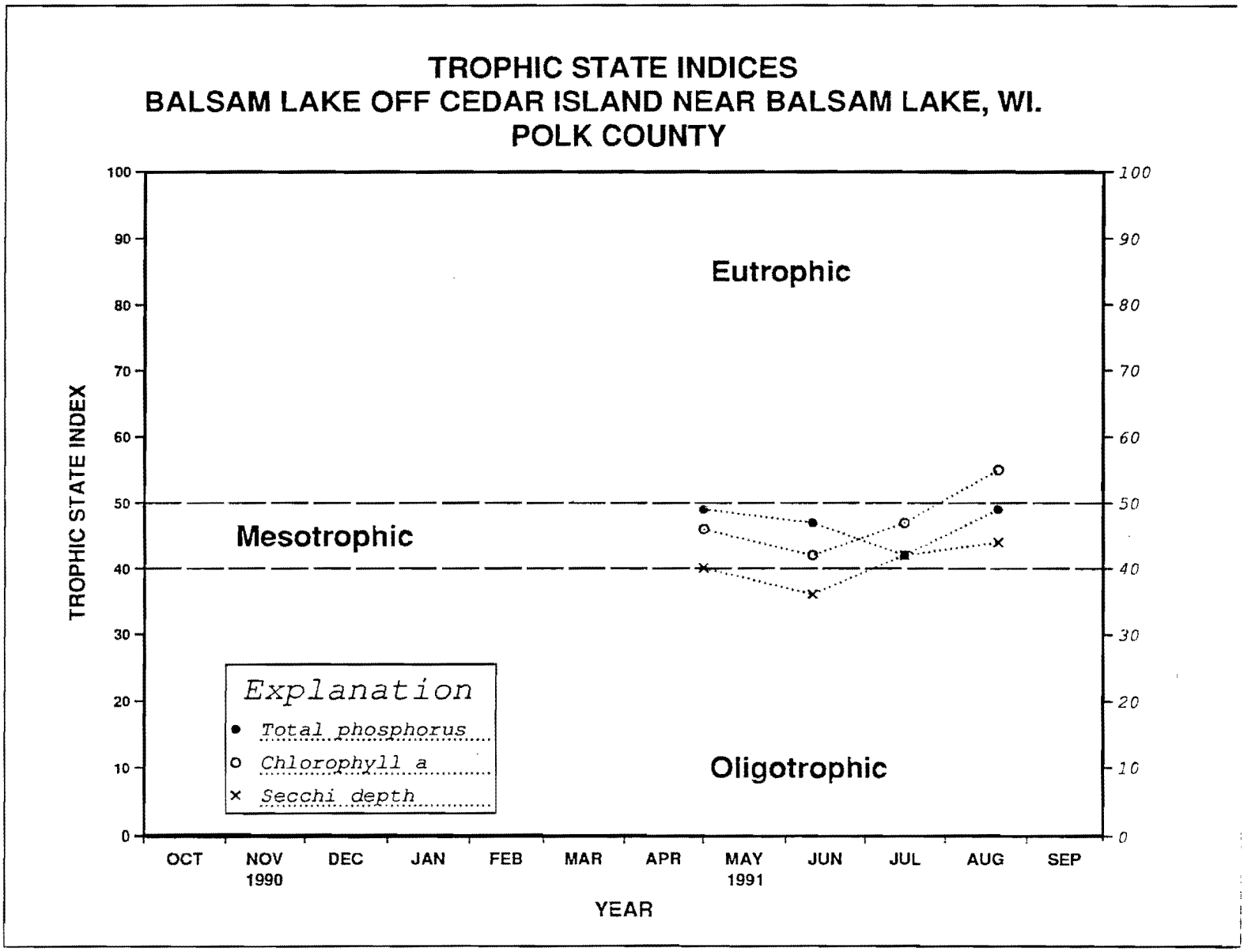

Figure 3.--Trophic State Indices for Balsam Lake off Cedar Island (center) at Balsam Lake, Wisconsin

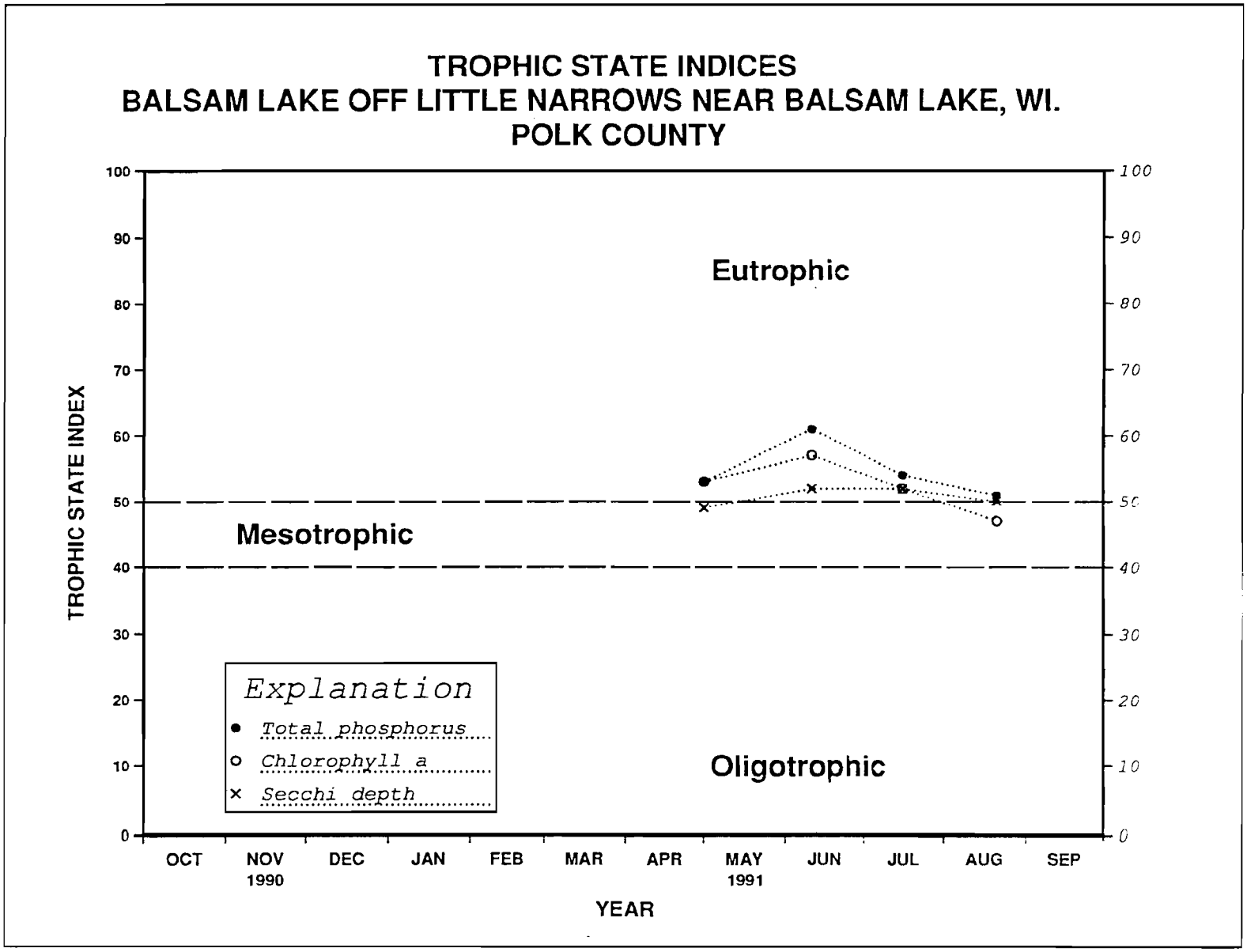

Figure 4.--Trophic State Indices for Balsam Lake off Little Narrows at Balsam Lake, Wisconsin

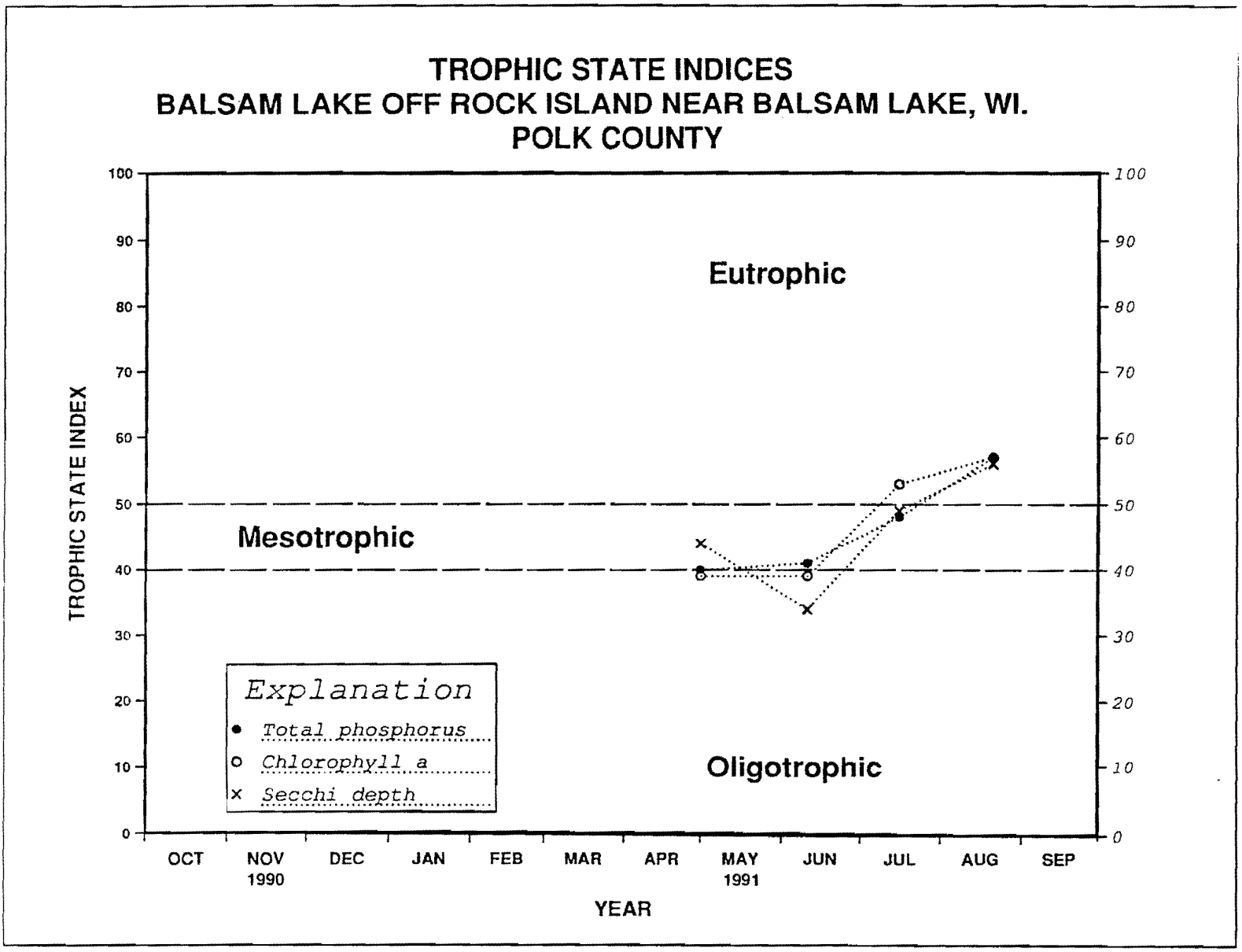

Figure 5.--Trophic State Indices for Balsam Lake off Rock Island at Balsam Lake, Wisconsin

United States Department of the Interior

GEOLOGICAL SURVEY

Water Resources Division
6417 Normandy Lane
Madison, Wisconsin 53719-1133
608 274-3535 (Fax 608 276-3817) July 13, 1993

Mr. Gerald Kafka
Balsam Lake Protection and
Rehabilitation District
1230 East Como Boulevard
St. Paul, Minnesota 55117

Dear Mr. Kafka:

This letter describes the progress on the evaluation of the water quality of Balsam Lake according to the data collected from October 1991 to September 1992 as stated in our agreement. Please read the enclosure, "U.S. Geological Survey Lake Monitoring Program in Wisconsin", before proceeding with this letter; the equations for computing the Trophic State Index have been changed from last year as described on pages 6-8.

In a brief summary, based on the 1992 data:

- The water quality of Balsam Lake varies throughout the lake. The water quality of Balsam Lake off Cedar Island is good; Balsam Lake off Little Narrows ranges from fair to good; and Balsam Lake off Rock Island ranges from good to very good.

- Balsam lake is a meso-eutrophic lake or one with moderate to many nutrients.

- Algal growth appears to be dependent upon the amount of available phosphorus rather than nitrogen.

- In July and August, during summer stratification, oxygen disappears from the bottom portion of the lake which is then unable to support a fish population.

- During the summer anoxic (devoid of oxygen) period, there are minor amounts of phosphorus being released from the bottom sediments.

- The data enclosed herein are provisional until published.

Balsam Lake has a surface area of 2,054 acres (3.21 square miles) and a drainage area at the outlet of 52.7 square miles for a drainage area/lake size ratio of 16:1. Lakes with drainage area/ lake size ratios of greater than 10:1 tend to develop water-quality problems. (Uttormark, Paul D., and Mark L. Hutchins, 1978, Input/output models as decision criteria for lake restoration. University of Wisconsin-Madison, Wisconsin, Water Resources Center technical report No. 78-03, 61 pp.).

Three sites were sampled in Balsam Lake. They are located off Cedar Island (center) at a depth of about 32 feet, off Little Narrows at a depth of about 20 feet, and off Rock Island at a depth of about 10 feet. All sites are shown in figure 1.

The data for this report are found in the following tables and figures:

Table 1. Lake stages for Balsam Lake off Cedar Island at Balsam Lake, Wisconsin, 1992 water year

Table 2. Lake-depth profiles for Balsam Lake off Cedar Island (center) at Balsam Lake, Wisconsin, 1992 water year

Table 3. Lake water-quality data for Balsam Lake off Little Narrows and Balsam Lake off Rock Island near Balsam Lake, Wisconsin, 1992 water year

Table 4. Water clarity and water-quality analyses and their associated Trophic State Indices (TSI) for Balsam Lake off Cedar Island (center), at Balsam Lake, Wisconsin, 1992 water year

Table 5. Water clarity and water-quality analyses and their associated Trophic State Indices (TSI) for Balsam Lake off Little Narrows, at Balsam Lake, Wisconsin, 1992 water year

Table 6. Water clarity and water-quality analyses and their associated Trophic State Indices (TSI) for Balsam Lake off Rock Island, at Balsam Lake, Wisconsin, 1992 water year

Figure 1. Location of sampling sites and staff gage on Balsam Lake at Balsam Lake, Wisconsin

Figure 2. Lake water-quality data for Balsam Lake off Cedar Island, at Balsam Lake, Wisconsin, 1992 water year

Figure 3. Trophic state indices for Balsam Lake off Cedar Island (center) at Balsam Lake, Wisconsin

Figure 4. Trophic state indices for Balsam Lake off Little Narrows near Balsam Lake, Wisconsin

Figure 5. Trophic state indices for Balsam Lake off Rock Island near Balsam Lake, Wisconsin

All the water-quality samples collected were analyzed by the Wisconsin State Laboratory of Hygiene at Madison, Wisconsin. The water-quality data is published in our annual publication, "Water Resources Data for Wisconsin, 1992".

LAKE-STAGE FLUCTUATIONS

Lake-stages were read at the wing wall of the culvert between Balsam Lake and Mill Pond on County Highway I by Bob Zuehlke. Lake-stage data are listed in table 1. Lake stages fluctuated 0.67 feet and ranged from 7.48 feet on February 25 to 8.15 feet on December 26. An attempt should be made to obtain more lake-stage readings.

LAKE-DEPTH PROFILES

Profiles of water temperature, dissolved oxygen, pH, and specific conductance at the deep hole are listed in table 2 and shown in figure 2. No abnormalities in the data are apparent. Among our sampling dates, almost complete water-column mixing was observed on May 7. The remainder of the profile data show incomplete mixing. The lake thermally stratifies during summer. During July and August, approximately the bottom 6 feet of water became anoxic (devoid of oxygen) and were unable to support fish. The levels of pH are within acceptable limits to support aquatic life. Because of the buffering capacity of the lake water, Balsam Lake is not susceptible to the effects of acid rain.

SELECTED ANALYSES

Analyses of selected constituents for May 7 for samples collected at 1.5 and 32-foot depths are listed in figure 2. The water-quality values for color, chlorophyll a, chlorides, calcium, magnesium, pH, alkalinity, total nitrogen, and total phosphorus are within regional values for this area as described by Lillie and Mason in "Limnological Characteristics of Wisconsin Lakes," 1983, Technical Bulletin No. 138, Department of Natural Resources.

To compute the nitrogen-phosphorus ratio, only the sample collected from the 1.5-foot sampling depth for May was used. This depth was used because algae grow in the upper part of the lake rather than at the bottom. The ratio of total nitrogen to phosphorus was calculated as 66:1 and suggests the lake is phosphorus-limited and is consistent with previous data. This means algal growth appears to be dependent on the amount of available phosphorus rather than nitrogen.

MAY, JUNE, JULY AND AUGUST WATER QUALITY

The data for total phosphorus, chlorophyll a, and Secchi-depth readings, are listed in table 4 and on figure 2 for the center site off Cedar Island, table 3 and figure 5 for the north site off Little Narrows, and table 3 and figure 6 for the east site off Rock Island.

The water quality of the three sampling sites varies. The site off Little Narrows has slightly poorer quality than the other two sites. Each sampling site is discussed separately.

Balsam Lake off Cedar Island

Total phosphorus: Total phosphorus concentrations sampled at a 1.5-foot depth range from 0.009 mg/L in May to 0.020 mg/L in August. All values fall within the regional values previously referenced.

Concentration of total phosphorus 1.5 feet above the lake bottom ranged from 0.008 mg/L in May to 0.060 mg/L in July. These concentrations are indicative of minor phosphorus release from the bottom sediments during anoxic (absence of oxygen) periods.

Chlorophyll a: Chlorophyll a concentrations, which indicate algal biomass, ranged from 2 µg/L in June to 9.6 µg/L in August. These data are within the regional values.

Secchi disc: Secchi-disc depths, which indicate water clarity, ranged from 7.9 feet in August to 18.0 feet in June. These data are within the regional values.

Balsam Lake off Little Narrows

Total phosphorus: Total phosphorus concentrations sampled at a 1.5-foot depth range from 0.014 mg/L in June to 0.030 mg/L in August. All values fall within the regional values previously referenced.

Chlorophyll a: Chlorophyll a concentrations, which indicate algal biomass, ranged from 4 µg/L in May to 20 µg/L in August. These data are within the regional values.

Secchi disc: Secchi-disc depths, which indicate water clarity, ranged from 4.9 feet in August to 9.5 feet in May. These data are within the regional values.

Balsam Lake off Rock Island

Total phosphorus: Total phosphorus concentrations sampled at a 1.5-foot depth range from 0.013 mg/L in June and July to <0.020 mg/L in May. All values fall within the regional values previously referenced.

Chlorophyll a: Chlorophyll a concentrations, which indicate algal biomass, ranged from 5 µg/L in June and July to 8 µg/L in August. These data are within the regional values.

Secchi disc: Secchi-disc depths, which indicate water clarity, ranged from 8.9 feet in August to 11.2 feet in July. These data are within the regional values.

TROPHIC STATUS

Lillie and Mason (1983) classified Wisconsin lakes using a random data set (summer, July and August) according to total phosphorus and chlorophyll a concentrations, and Secchi-disc depth. This evaluation is shown below:

Water quality index	Approximate total phosphorus equivalent (mg/L)	Approximate chlorophyll a equivalent (µg/L)	Approximate water clarity equivalent (Secchi-disc depth in ft)
Excellent	<0.001	<1	<19.7
Very good	.001-.010	1-5	9.8-19.7
Good	.010-.030	5-10	6.6-9.8
Fair	.030-.050	10-15	4.9-6.6
Poor	.050-.150	15-30	3.3-4.9
Very poor	>.150	>30	<3.3

Using the above criteria to evaluate the mean summer (July-August) 1992 data shown in table 4 for Balsam Lake off Cedar Island, surface total phosphorus and chlorophyll a concentrations and Secchi-disc depths indicate good water quality.

From the data shown in table 5 for Balsam Lake off Little Narrows, surface total phosphorus concentrations indicate good water quality, chlorophyll a concentrations indicate poor water quality, and Secchi-disc depths indicate fair water quality.

From the data shown in table 6 for Balsam Lake off Rock Island, surface total phosphorus and chlorophyll a concentrations indicate good water quality, while Secchi-disc depths indicate very good water quality.

Using the data from "Limnological Characteristics of Wisconsin Lakes," 1983, by Lillie and Mason, a comparison of the 1992 mean summer data (July and August) for total phosphorus, chlorophyll a, and Secchi depths for all Balsam Lake sites to other lakes in northwest Wisconsin are shown below:

	Parameter	Percentage of distribution of lakes in northwest Wisconsin within these concentrations	
	Total phosphorus (mg/L)		
	<.010	Best condition	12
Balsam Lake values →	.010-.020	↓	35
	.020-.030		23
	.030-.050		18
	.050-.100		8
	.100-.150	↓	3
	>.150	Worst condition	1
	Chlorophyll a (µg/L)		
	0- 5	Best condition	29
	5-10	↓	36
Balsam Lake values →	10-15	↓	14
	15-30	↓	14
	>30	Worst condition	9
	Secchi depth (in feet)		
	9.8	Best condition	22
Balsam Lake values →	6.6- 9.8	↓	29
	3.3- 6.6	↓	30
	<3.3	Worst condition	19

Comparing other lakes in northwest Wisconsin to the 1992 data for Balsam Lake, the above data show, during the period 1966 to 1979, 53 percent had higher total phosphorous concentrations, 23 percent had higher chlorophyll a concentrations, and 49 percent had less water clarity.

A second approach to assessing the "health" or trophic status of a lake is to use Carlson's Trophic State Index (TSI). Graphic illustrations of the Trophic State Index for the three sites on Balsam Lake are shown on figures 3, 4, and 5. The data from 1992 show Balsam Lake to be meso-eutrophic or one with moderate to many nutrients.

The data that has been collected for Balsam Lake from 1991-1992 is extremely important for understanding the lake's water quality and managing the lake. To continue with the monitoring as in the past will help to build on this very valuable data base.

If you have any questions regarding this evaluation, please contact me at 608/276-3842.

Sincerely,

Stephen J. Field
Biologist

Enclosures

cc: Dan Ryan, DNR, Spooner

Table 1. Lake stages for Balsam Lake off Cedar Island at Balsam Lake, Wisconsin, 1992 water year

ST. CROIX RIVER BASIN

452755092264600 BALSAM LAKE, OFF CEDAR ISLAND, AT BALSAM LAKE, WI

LOCATION.--Lat 45°27'55", long 92°26'46", in NW 1/4 SW 1/4 sec.2, T.34 N., R.17 W., Polk County, Hydrologic Unit 07030005, 1 mi north of Balsam Lake.

DRAINAGE AREA.--52.7 mi^2.

LAKE-STAGE RECORDS

PERIOD OF RECORD.--December 1987 to current year. December 1987 to November 1989 (fragmentary), data unpublished in district files.

GAGE.--Staff on wingwall of culvert between Balsam Lake and Mill Pond on CTH "I". From December 1987 to May 1991, gage at different location on lake. Elevation of lake is 1,133 ft, from topographic map.

EXTREMES FOR PERIOD OF RECORD.--Maximum gage height observed, 8.41 ft, Sept. 18, 1991; minimum observed, 6.74 ft, Aug. 3, 1988.

EXTREMES FOR CURRENT YEAR.--Maximum gage height observed, 8.15 ft, Dec. 26; minimum observed, 7.48 ft, Feb. 25.

GAGE HEIGHT, FEET, WATER YEAR OCTOBER 1991 TO SEPTEMBER 1992
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	---	---	---	---	---	---	---	---	---	---	---	---
2	---	---	---	---	---	---	---	---	---	---	---	---
3	---	---	---	---	---	---	---	---	---	---	---	---
4	---	---	---	---	---	---	---	---	---	---	---	---
5	---	---	---	---	---	---	---	---	---	---	---	---
6	---	---	---	---	---	---	---	---	---	---	---	---
7	---	---	---	---	---	---	---	7.50	---	---	---	---
8	---	---	---	---	---	---	---	---	---	---	---	---
9	7.73	---	---	---	---	---	---	---	---	---	---	---
10	---	---	---	---	---	---	---	---	---	---	---	---
11	---	---	---	---	---	---	---	---	---	---	---	---
12	---	---	---	---	---	---	---	---	---	---	---	---
13	---	---	---	---	---	---	---	---	---	---	---	---
14	---	---	---	---	---	---	---	---	---	---	---	---
15	---	---	---	---	---	---	---	---	---	---	---	---
16	7.63	---	---	---	---	---	---	---	---	---	---	---
17	---	---	---	---	---	---	---	---	---	---	7.51	---
18	---	---	---	---	---	---	---	---	---	---	---	---
19	---	---	---	---	---	---	---	---	---	---	---	---
20	---	---	---	---	---	---	---	---	---	---	---	---
21	---	---	---	---	---	---	---	---	---	7.79	---	---
22	---	---	---	---	---	---	---	---	---	---	---	---
23	7.58	---	---	---	---	---	---	---	---	---	---	---
24	---	---	---	---	---	---	---	---	---	---	---	---
25	---	---	---	---	7.48	---	---	---	---	---	---	---
26	---	---	8.15	---	---	---	---	---	---	---	---	---
27	---	---	---	---	---	---	---	---	---	---	---	---
28	---	---	---	---	---	---	---	---	---	---	---	---
29	---	---	---	---	---	---	---	---	---	---	---	---
30	---	---	---	---	---	---	---	---	---	---	---	---
31	7.55	---	---	---	---	---	---	---	---	---	---	---

Table 2. Lake-[illegible]pth profiles for Balsam Lake of[illegible]edar Island (center) at Balsam Lake, Wisconsin, 1992 water year

DATE	SAMPLING DEPTH (FEET) (00003)	TEMPERATURE WATER (DEG C) (00010)	SPECIFIC CONDUCTANCE (US/CM) (00095)	PH WATER WHOLE FIELD (STANDARD UNITS) (00400)	OXYGEN, DISSOLVED (MG/L) (00300)
	WATER-QUALITY DATA				
FEB 1992					
25...	1.50	1.5	184	9.1	11.0
25...	3.00	1.5	185	9.0	10.8
25...	6.00	3.0	180	8.9	9.7
25...	9.00	3.5	180	8.8	9.3
25...	12.0	4.0	179	8.7	8.5
25...	15.0	4.0	179	8.6	7.2
25...	18.0	4.0	182	8.6	5.7
25...	21.0	4.5	185	8.5	5.0
25...	24.0	4.5	191	8.4	4.0
25...	27.0	4.5	203	8.3	2.2
25...	30.0	5.0	213	8.2	0.8
25...	32.0	--	--	--	--
MAY					
07...	1.50	11.5	176	8.5	11.0
07...	3.00	11.0	176	8.5	11.0
07...	6.00	11.0	176	8.4	11.0
07...	9.00	11.0	176	8.4	11.0
07...	12.0	11.0	176	8.4	11.0
07...	15.0	11.0	176	8.3	11.0
07...	18.0	11.0	176	8.3	11.0
07...	21.0	11.0	176	8.3	11.0
07...	24.0	11.0	177	8.3	10.8
07...	27.0	10.0	177	8.2	9.2
07...	30.0	9.5	177	8.1	9.5
07...	33.0	9.5	178	8.1	9.0
07...	34.0	--	--	--	--
JUN					
08...	1.50	20.0	173	8.3	8.5
08...	3.00	20.0	174	8.3	8.5
08...	6.00	20.0	174	8.3	8.5
08...	9.00	20.0	174	8.2	8.5
08...	12.0	20.0	174	8.2	8.5
08...	15.0	19.5	174	8.2	8.0
08...	18.0	17.0	175	8.2	6.6
08...	21.0	15.5	175	8.0	5.1
08...	24.0	14.0	177	8.0	3.3
08...	27.0	13.0	184	7.9	1.4
08...	30.0	12.0	184	7.8	0.6
08...	31.5	12.0	189	7.7	0.1
08...	32.0	--	--	--	--
JUL					
21...	1.50	21.0	174	7.8	9.0
21...	3.00	21.0	174	8.0	9.0
21...	6.00	21.0	175	8.0	9.0
21...	9.00	21.0	175	8.2	9.0
21...	12.0	21.0	175	8.2	9.0
21...	15.0	20.5	175	8.2	8.2
21...	18.0	20.5	176	8.2	7.8
21...	21.0	19.0	179	8.0	5.0
21...	24.0	18.0	183	7.9	2.0
21...	27.0	17.0	191	7.8	0.1
21...	30.0	16.5	195	7.8	0.1
21...	31.0	--	--	--	--
AUG					
17...	1.50	21.5	177	8.2	8.9
17...	3.00	21.5	177	8.3	8.9
17...	6.00	21.5	177	8.4	8.9
17...	9.00	21.5	177	8.4	8.9
17...	12.0	21.5	177	8.4	8.9
17...	15.0	21.5	177	8.5	8.8
17...	18.0	21.5	176	8.5	8.8
17...	21.0	21.5	177	8.5	7.3
17...	24.0	19.5	182	8.3	0.3
17...	27.0	18.0	200	8.1	0.1
17...	30.0	16.5	218	8.0	0.1
17...	31.5	--	--	--	--

Table 3. Lake water-quality data for Balsam Lake off Little Narrows and Balsam Lake off Rock Island near Balsam Lake, Wisconsin, 1992 water year

ST. CROIX RIVER BASIN

452858092265300 BALSAM LAKE, OFF LITTLE NARROWS, NEAR BALSAM LAKE, WI

LOCATION.--Lat 45°28'58", long 92°26'53", in NE 1/4 NE 1/4 sec.34, T.35 N., R.17 W., Polk County, Hydrologic Unit 07030005, 2.1 mi north of Balsam Lake.

PERIOD OF RECORD.--May 1991 to current year.

REMARKS.--Lake sampled about 0.25 mi northwest of Little Narrows. Water-quality analyses by Wisconsin State Laboratory of Hygiene.

WATER-QUALITY DATA, MAY 07 TO AUGUST 17, 1992
(Milligrams per liter unless otherwise indicated)

	May 07	June 08	July 21	Aug. 17
Depth of sample (ft)	1.5	1.5	1.5	1.5
Lake stage (ft)	7.93	7.51	7.79	7.51
Specific conductance (µS/cm)	212	208	213	223
pH (units)	8.5	8.8	8.2	8.3
Water temperature (°C)	13.5	20.5	22.5	21.5
Secchi-depth (meters)	2.9	2.1	1.8	1.5
Dissolved oxygen	11.2	10.2	10.5	9.9
Phosphorus, total (as P)	<0.020	0.014	0.023	0.030
Chlorophyll a, phytoplankton (µg/L)	4.0	6.0	15	20

452754092234300 BALSAM LAKE, OFF ROCK ISLAND, NEAR BALSAM LAKE, WI

LOCATION.--Lat 45°27'54", long 92°23'43", in NW 1/4 NE 1/4 sec.6, T.34 N., R.16 W., Polk County, Hydrologic Unit 07030005, 3 mi northeast of Balsam Lake.

PERIOD OF RECORD.--May 1991 to current year.

REMARKS.--Lake sampled in eastern bay about 0.25 mi northeast of Rock Island. Water-quality analyses by Wisconsin State Laboratory of Hygiene.

WATER-QUALITY DATA, MAY 07 TO AUGUST 17, 1992
(Milligrams per liter unless otherwise indicated)

	May 07	June 08	July 21	Aug. 17
Depth of sample (ft)	1.5	1.5	1.5	1.5
Lake stage (ft)	7.93	7.51	7.79	7.51
Specific conductance (µS/cm)	162	167	163	168
pH (units)	8.5	8.3	8.0	7.9
Water temperature (°C)	12.5	20.5	22.0	22.0
Secchi-depth (meters)	3.2	3.0	3.4	2.7
Dissolved oxygen	10.6	8.3	8.5	8.1
Phosphorus, total (as P)	<0.020	0.013	0.013	0.018
Chlorophyll a, phytoplankton (µg/L)	6.0	5.0	5.2	8.4

Table 4.--Water clarity and water-quality analyses and their associated Trophic State Indices (TSI) for Balsam Lake off Cedar Island (center), 1992 water year

[- indicates not applicable; -- indicates no data available]

Date	Secchi Disk			Sampling	Total Phosphorus			Chlorophyll a		Dissolved Ortho-phosphate Phosphorus
	Depth (meters)	Depth (feet)	T.S.I.	Depth (feet)	Conc. (mg/L)	Conc. (µg/L)	T.S.I	Conc. (µg/L)	T.S.I.	Conc. (mg/L)
5/07/92	3.4	11.2	42	1.5	0.009	9	45	5.0	47	<0.002
	-	-	-	32	0.008	8	-	-	-	0.003
6/08/92	5.5	18.0	35	1.5	0.010	10	46	2.0	40	--
	-	-	-	30	0.035	35	-	-	-	--
7/21/92	3.0	9.8	44	1.5	0.016	16	50	7.7	50	--
	-	-	-	29	0.060	60	-	-	-	--
8/17/92	2.4	7.9	47	1.5	0.020	20	51	9.6	52	--
	-	-	-	30	0.040	40	-	-	-	--

Table 5.--Water clarity and water-quality analyses and their associated Trophic State Indices (TSI) for Balsam Lake off Little Narrows, 1992 water Year

[- indicates not applicable; -- indicates no data available]

Date	Secchi Disk			Sampling	Total Phosphorus			Chlorophyll a		Dissolved Ortho-phosphate Phosphorus
	Depth (meters)	Depth (feet)	T.S.I.	Depth (feet)	Conc. (mg/L)	Conc. (µg/L)	T.S.I	Conc. (µg/L)	T.S.I.	Conc. (mg/L)
5/07/92	2.9	9.5	45	1.5	0.020	20	51	4	45	--
6/08/92	2.1	6.9	49	1.5	0.014	14	49	6	48	--
7/21/92	1.8	5.9	52	1.5	0.023	23	52	15	55	--
8/17/92	1.5	4.9	54	1.5	0.030	30	55	20	57	--

Table 6.--Water clarity and water-quality analyses and their associated Trophic State Indices (TSI) for Balsam Lake off Rock Island, 1992 water year

[- indicates not applicable; -- indicates no data available]

Date	Secchi Disk			Sampling	Total Phosphorus			Chlorophyll a		Dissolved Ortho-phosphate Phosphorus
	Depth (meters)	Depth (feet)	T.S.I.	Depth (feet)	Conc. (mg/L)	Conc. (µg/L)	T.S.I	Conc. (µg/L)	T.S.I.	Conc. (mg/L)
5/07/92	3.2	10.5	43	1.5	0.020	20	51	6.0	48	--
6/08/92	3.0	9.8	44	1.5	0.013	13	48	5.0	47	--
7/21/92	3.4	11.2	42	1.5	0.013	13	48	5.2	47	--
8/17/92	2.7	8.9	46	1.5	0.018	18	51	8.4	51	--

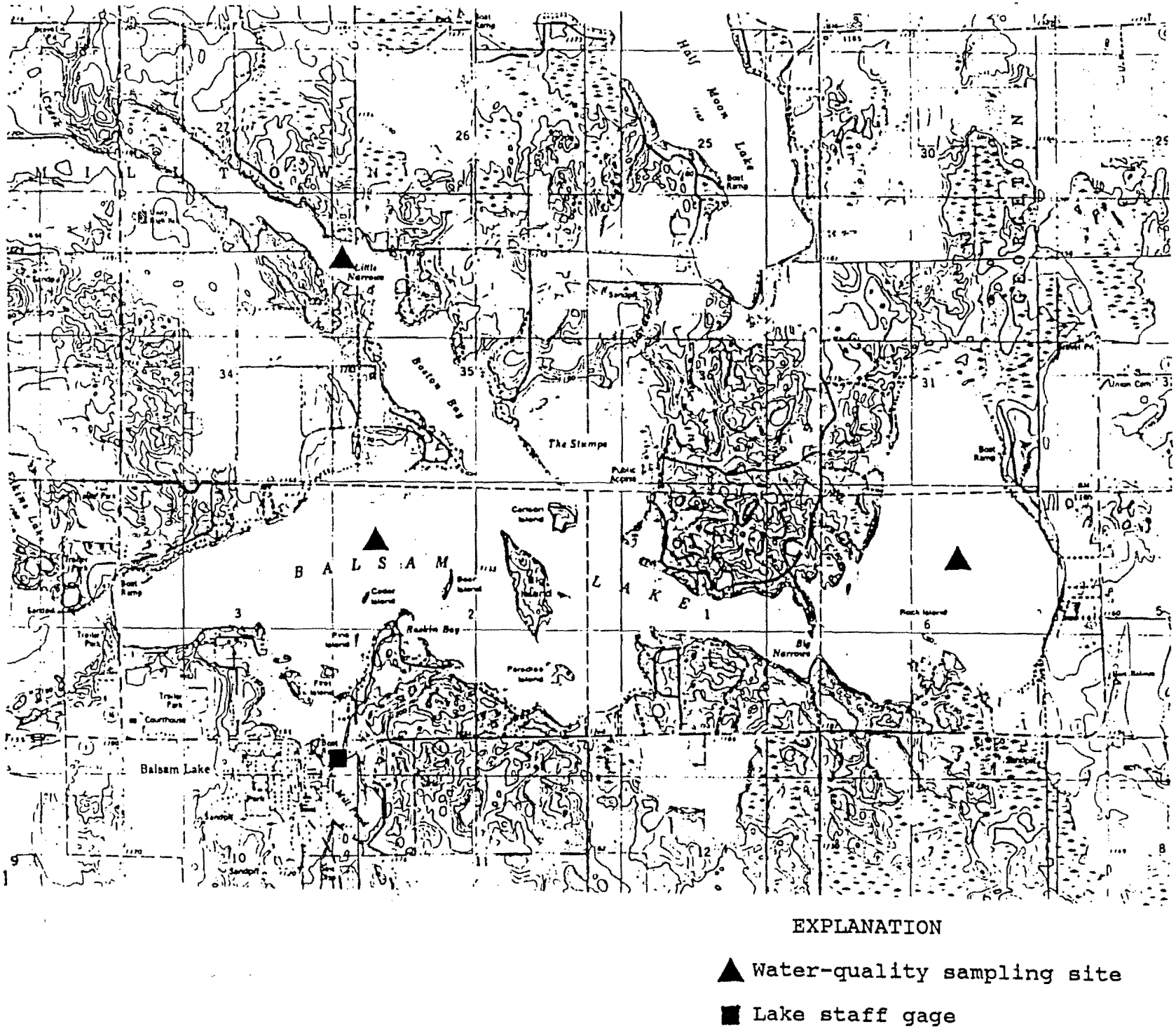

Figure 1. Location of sampling sites and staff gage for Balsam Lake.

452755092264600 BA[redacted] LAKE, OFF CEDAR ISLAND, AT BALSAM LAKE, WI--CONTINUED

WATER-QUALITY RECORDS

PERIOD OF RECORD.--February 1991 to current year.

REMARKS.--Lake sampled about 0.25 mi north of Cedar Island at a lake depth of about 34 ft. Lake ice-covered during February sampling. Water-quality analyses by Wisconsin State Laboratory of Hygiene.

WATER-QUALITY DATA, FEBRUARY 25 TO AUGUST 17, 1992
(Milligrams per liter unless otherwise indicated)

	Feb. 25		May 07		June 08		July 21		Aug. 17	
Depth of sample (ft)	1.5	30	1.5	32	1.5	30	1.5	29	1.5	30
Lake stage (ft)	7.48		7.93		7.51		7.79		7.51	
Specific conductance (µS/cm)	184	213	176	178	173	184	174	195	177	218
pH (units)	9.1	8.2	8.5	8.1	8.3	7.8	7.8	7.8	8.2	8.0
Water temperature (°C)	1.5	5.0	11.5	9.5	20.0	12.0	21.0	16.5	21.5	16.5
Color (Pt-Co. scale)	---	---	10	10	---	---	---	---	---	---
Turbidity (NTU)	---	---	0.70	0.90	---	---	---	---	---	---
Secchi-depth (meters)	---		3.4		5.5		3.0		2.4	
Dissolved oxygen	11.0	0.8	11.0	9.0	8.4	0.6	9.0	0.1	8.9	0.1
Hardness, as CaCO3	---	---	84	84	---	---	---	---	---	---
Calcium, dissolved (Ca)	---	---	21	21	---	---	---	---	---	---
Magnesium, dissolved (Mg)	---	---	7.7	7.7	---	---	---	---	---	---
Sodium, dissolved (Na)	---	---	4.3	4.3	---	---	---	---	---	---
Potassium, dissolved (K)	---	---	2	2	---	---	---	---	---	---
Alkalinity, as CaCO3	---	---	76	75	---	---	---	---	---	---
Sulfate, dissolved (SO4)	---	---	<5.0	<5.0	---	---	---	---	---	---
Chloride, dissolved (Cl)	---	---	9.0	9.0	---	---	---	---	---	---
Fluoride, dissolved (F)	---	---	0.1	0.1	---	---	---	---	---	---
Silica, dissolved (SiO2)	---	---	9.6	10	---	---	---	---	---	---
Solids, dissolved, at 180°C	---	---	112	114	---	---	---	---	---	---
Nitrogen, NO2 + NO3, diss. (as N)	---	---	0.19	0.18	---	---	---	---	---	---
Nitrogen, ammonia, dissolved (as N)	---	---	0.03	0.02	---	---	---	---	---	---
Nitrogen, amm. + org., total (as N)	---	---	0.40	0.30	---	---	---	---	---	---
Phosphorus, total (as P)	---	---	0.009	0.008	0.010	0.035	0.016	0.060	0.020	0.040
Phosphorus, ortho, dissolved (as P)	---	---	<0.002	0.003	---	---	---	---	---	---
Iron, dissolved (Fe) µg/L	---	---	<50	<50	---	---	---	---	---	---
Manganese, dissolved (Mn) µg/L	---	---	140	160	---	---	---	---	---	---
Chlorophyll a, phytoplankton (µg/L)	---	---	5.0	---	2.0	---	7.7	---	9.6	---

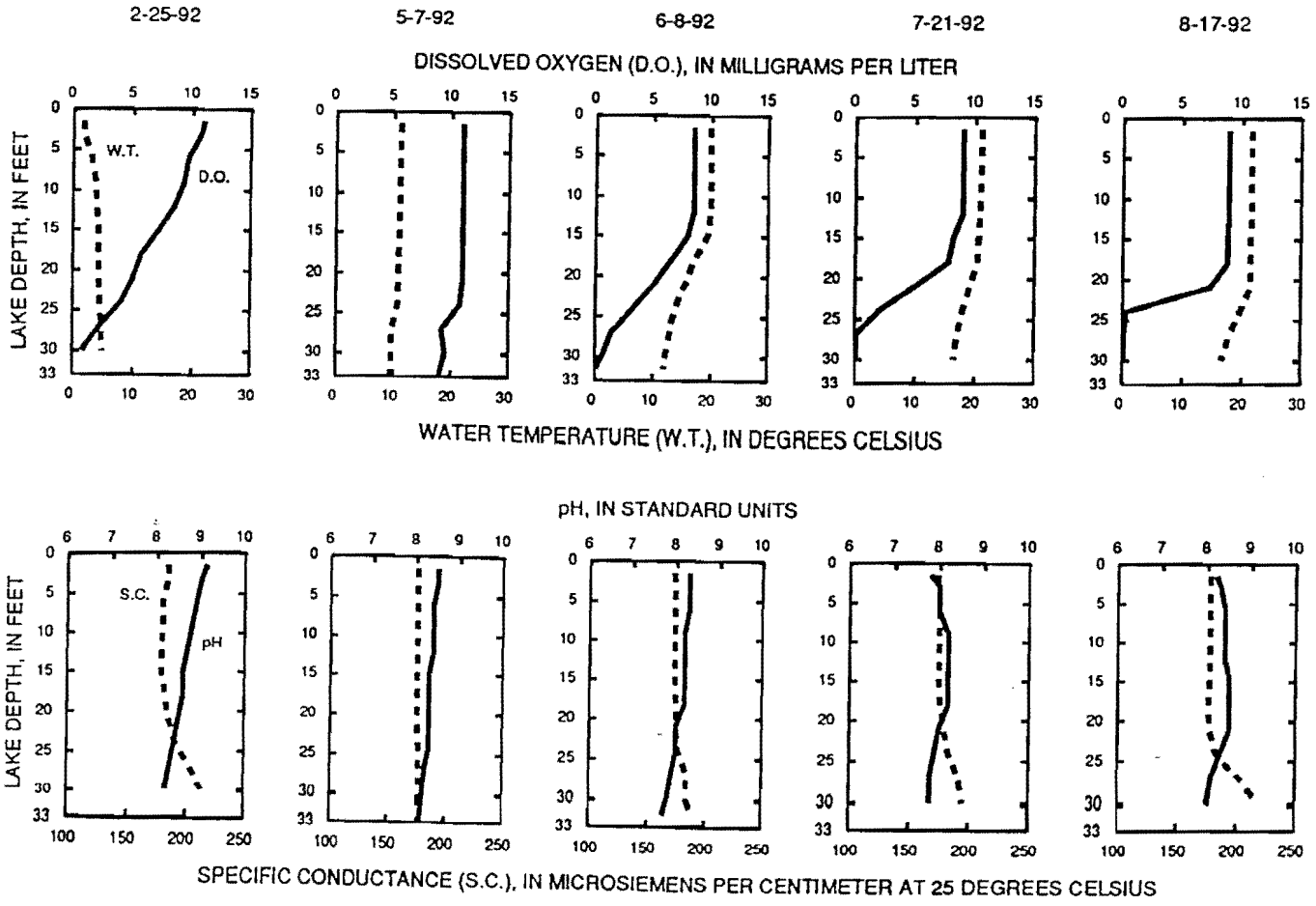

Figure 2. Lake water-quality data for Balsam Lake off Cedar Island at Balsam Lake, Wisconsin, 1992 water year

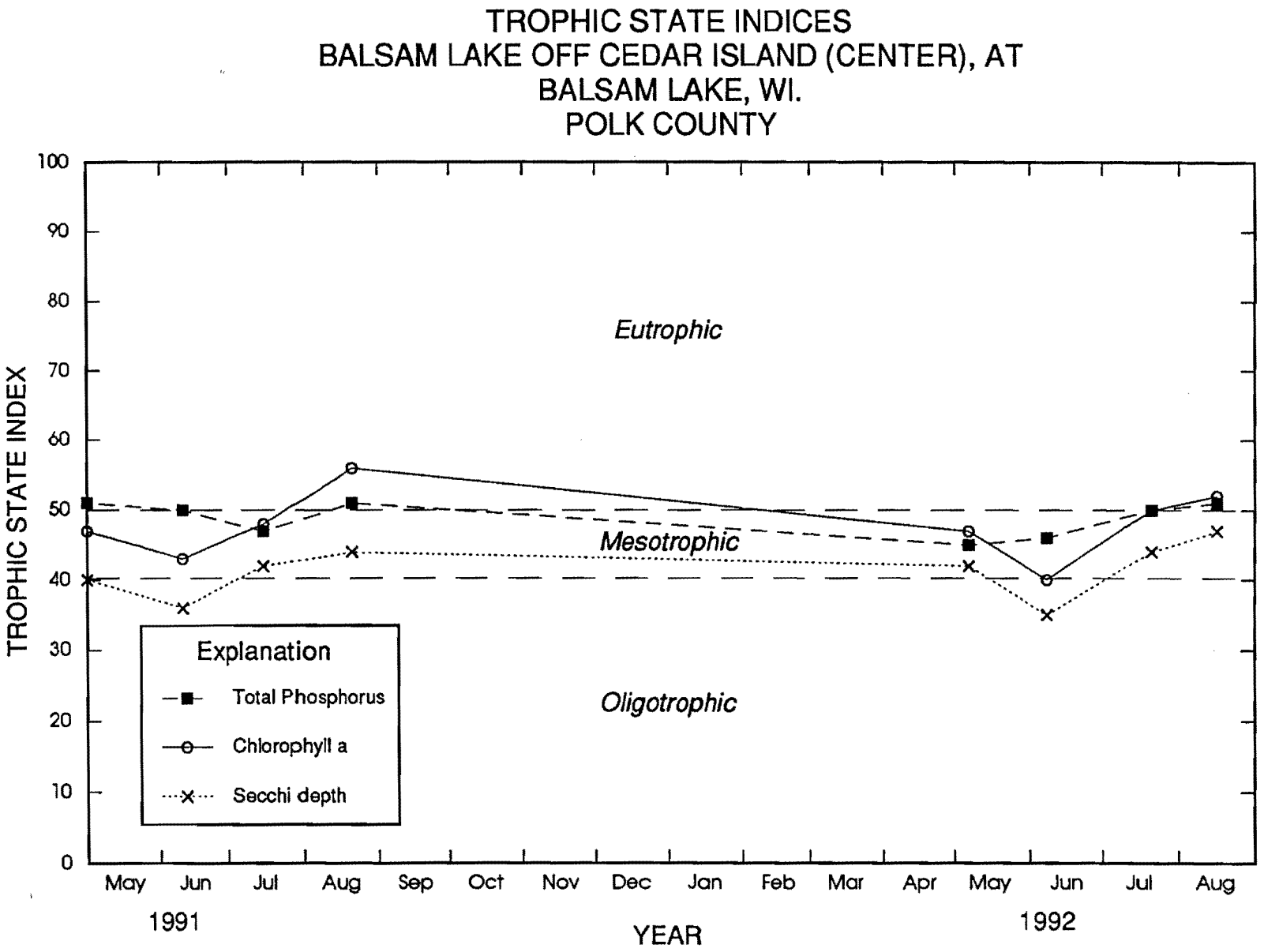

Figure 3. Trophic State Indices for Balsam Lake (center) at Balsam Lake, Wisconsin

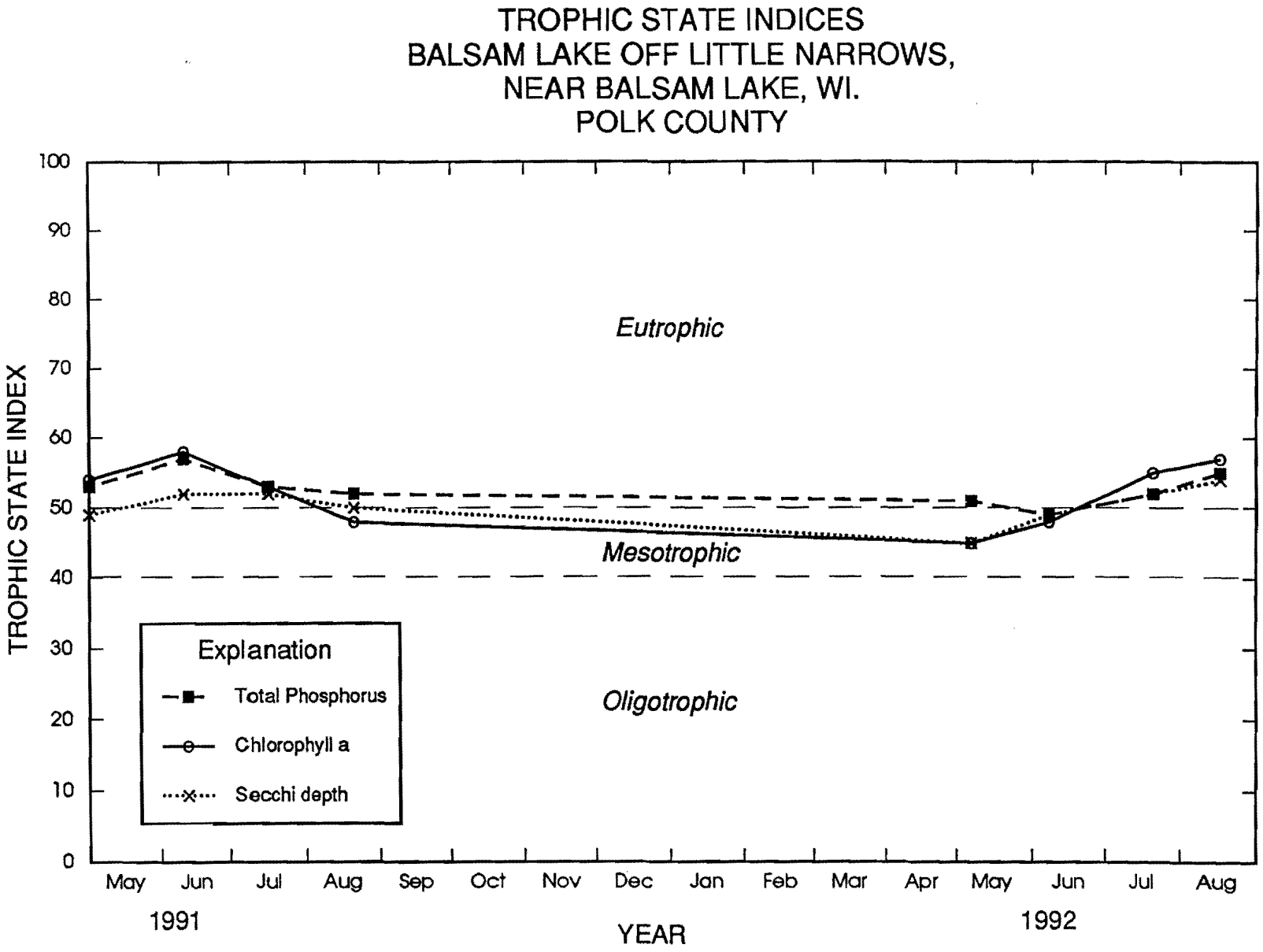

Figure 4. Trophic State Indices for Balsam Lake off Little Narrows near Balsam Lake, Wisconsin

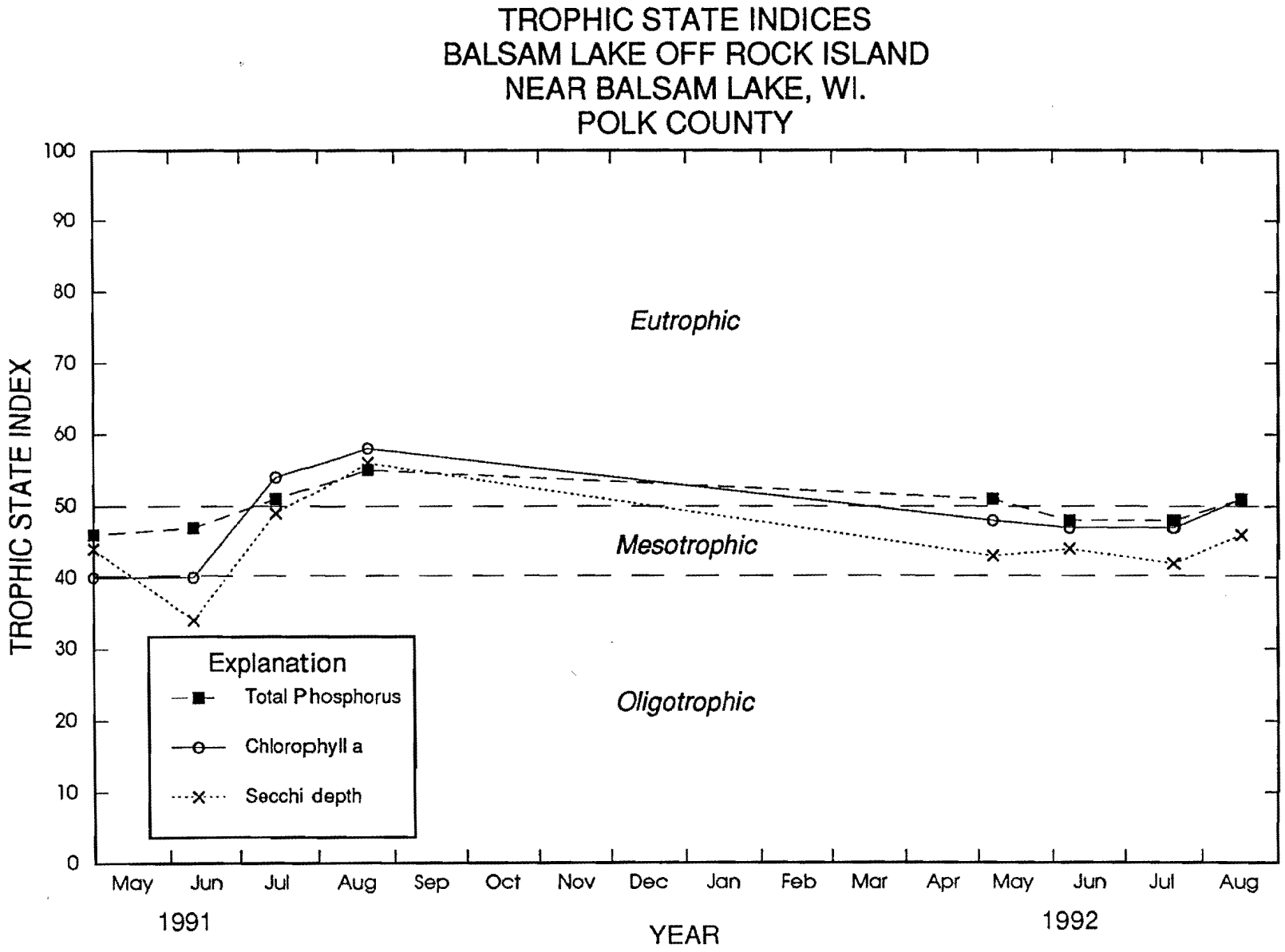

Figure 5. Trophic State Indices for Balsam Lake off Rock Island near Balsam Lake, Wisconsin

United States Department of the Interior

GEOLOGICAL SURVEY

Water Resources Division
6417 Normandy Lane
Madison, Wisconsin 53719-1133
608 274-3535 (Fax 608 276-3817)

June 3, 1994

Mr. Gerald Kafka
Balsam Lake Protection and
Rehabilitation District
1230 East Como Boulevard
St. Paul, Minnesota 55117

Dear Mr. Kafka:

This letter describes the progress on the evaluation of the water quality of Balsam Lake according to the data collected from October 1992 to September 1993 as stated in our agreement. Please read the "U.S. Geological Survey Lake Monitoring Program in Wisconsin", sent to you last year, before proceeding with this letter.

In a brief summary, based on the 1993 data:

- The water quality of Balsam Lake varies throughout the lake. The water quality of Balsam Lake off Cedar Island is poor to good; Balsam Lake off Little Narrows ranges from poor to good; and Balsam Lake off Rock Island ranges from very poor to fair.

- The reason for the poorer water quality this year, compared to 1991 and 1992, may be due to the excessive amount of runoff in June and July 1993 which may have contributed to excessive phosphorus loading to the lake.

- Balsam lake is a meso-eutrophic lake or one with moderate to many nutrients.

- Algal growth appears to be dependent upon the amount of available phosphorus rather than nitrogen.

- The data enclosed herein are provisional until published.

Balsam Lake has a surface area of 2,054 acres (3.21 square miles) and a drainage area at the outlet of 52.7 square miles for a drainage area/lake size ratio of 16:1. Lakes with drainage area/ lake size ratios of greater than 10:1 tend to develop water-quality problems. (Uttormark, Paul D., and Mark L. Hutchins, 1978, Input/output models as decision criteria for lake restoration. University of Wisconsin-Madison, Wisconsin, Water Resources Center technical report No. 78-03, 61 pp.).

Three sites were sampled in Balsam Lake. They are located off Cedar Island (center) at a depth of about 32 feet, off Little Narrows at a depth of about 20 feet, and off Rock Island at a depth of about 10 feet. All sites are shown in figure 1.

SELECTED ANALYSES

Analyses of selected constituents for May 5 for samples collected at 1.5 and 30-foot depths at the deep hole are listed in figure 2. The water-quality values for color, chlorophyll a, chlorides, calcium, magnesium, pH, alkalinity, total nitrogen, and total phosphorus are within regional values for this area as described by Lillie and Mason in "Limnological Characteristics of Wisconsin Lakes," 1983, Technical Bulletin No. 138, Department of Natural Resources.

To compute the nitrogen-phosphorus ratio, only the sample collected from the 1.5-foot sampling depth for May was used. This depth was used because algae grow in the upper part of the lake rather than at the bottom. The ratio of total nitrogen to phosphorus was calculated as 27:1 and suggests the lake is phosphorus-limited and is consistent with previous data. This means algal growth appears to be dependent on the amount of available phosphorus rather than nitrogen.

MAY, JUNE, JULY AND AUGUST WATER QUALITY

The data for total phosphorus, chlorophyll a, and Secchi-depth readings, are listed in table 3 and on figure 2 for the center (deep hole) site off Cedar Island; tables 2 and 4 for the north site off Little Narrows, and tables 2 and 5 for the east site off Rock Island.

The water quality of the three sampling sites varies. The site off Rock Island has slightly poorer quality than the other two sites. Each sampling site is discussed separately.

Balsam Lake off Cedar Island

Total phosphorus: Total phosphorus concentrations sampled at a 1.5-foot depth range from 0.015 mg/L in May to 0.023 mg/L in August. All values fall within the regional values previously referenced.

Concentration of total phosphorus 1.5 feet above the lake bottom ranged from 0.024 mg/L in June to 0.080 mg/L in July.

Chlorophyll a: Chlorophyll a concentrations, which indicate algal biomass, ranged from 5.68 µg/L in June to 24.5 µg/L in August. These data are within the regional values.

Secchi disc: Secchi-disc depths, which indicate water clarity, ranged from 4.9 feet in August to 13.1 feet in July. These data are within the regional values.

Balsam Lake off Little Narrows

Total phosphorus: Total phosphorus concentrations sampled at a 1.5-foot depth range from <0.02 mg/L in May to 0.027 mg/L in June. All values fall within the regional values previously referenced.

Chlorophyll a: Chlorophyll a concentrations, which indicate algal biomass, ranged from 4.53 µg/L in May to 20.4 µg/L in August. These data are within the regional values.

Secchi disc: Secchi-disc depths, which indicate water clarity, ranged from 3.9 feet in August to 5.9 feet in May. These data are within the regional values.

	Parameter	Percentage of distribution of lakes in northwest Wisconsin within these concentrations	
	Total phosphorus (mg/L)		
	<.010	Best condition	12
	.010-.020	↓	35
Balsam Lake values →	.020-.030	↓	23
	.030-.050	↓	18
	.050-.100	↓	8
	.100-.150	↓	3
	>.150	Worst condition	1
	Chlorophyll a (µg/L)		
	0- 5	Best condition	29
	5-10	↓	36
	10-15	↓	14
Balsam Lake values →	15-30	↓	14
	>30	Worst condition	9
	Secchi depth (in feet)		
	9.8	Best condition	22
	6.6- 9.8	↓	29
Balsam Lake values →	3.3- 6.6	↓	30
	<3.3	Worst condition	19

Comparing other lakes in northwest Wisconsin to the 1993 data for Balsam Lake, the above data show, during the period 1966 to 1979, 47 percent had lower total phosphorous concentrations, 79 percent had lower chlorophyll a concentrations, and 51 percent had more water clarity.

A second approach to assessing the "health" or trophic status of a lake is to use Carlson's Trophic State Index (TSI). Graphic illustrations of the Trophic State Index for the three sites on Balsam Lake are shown on figures 3, 4, and 5. The data from 1993 show Balsam Lake to be meso-eutrophic or one with moderate to many nutrients.

The data that has been collected for Balsam Lake from 1991-1993 is extremely important for understanding the lake's water quality and managing the lake. To continue with the monitoring as in the past will help to build on this very valuable data base.

Table 1. Lake-depth profiles for Balsam Lake off Cedar Island (center) at Balsam Lake, Wisconsin, 1993 water year

452755092264600 - BALSAM LAKE OFF CEDAR ISLAND AT BALSAM LAKE, WI

WATER-QUALITY DATA

DATE	SAMPLING DEPTH (FEET) (00003)	TEMPERATURE WATER (DEG C) (00010)	SPECIFIC CONDUCTANCE (US/CM) (00095)	PH WATER WHOLE FIELD (STANDARD UNITS) (00400)	OXYGEN, DISSOLVED (MG/L) (00300)
MAR 1993					
04...	1.50	1.5	193	8.2	12.8
04...	3.00	2.0	192	8.1	12.1
04...	6.00	3.0	190	8.1	12.1
04...	9.00	3.5	187	8.1	11.8
04...	12.0	3.5	189	8.1	10.7
04...	15.0	4.0	190	8.0	9.6
04...	18.0	4.0	192	8.0	7.6
04...	21.0	3.5	196	8.0	6.7
04...	24.0	3.5	206	7.9	7.0
04...	27.0	4.0	212	7.9	5.7
04...	30.0	5.0	230	7.9	3.8
04...	32.0	--	--	--	--
MAY					
05...	1.50	11.5	189	8.2	12.1
05...	3.00	11.5	189	8.2	12.2
05...	6.00	11.5	188	8.2	12.3
05...	9.00	11.0	188	8.2	12.3
05...	12.0	10.0	188	8.2	12.1
05...	15.0	10.0	188	8.2	12.1
05...	18.0	9.5	188	8.2	11.7
05...	21.0	9.0	188	8.2	11.3
05...	24.0	9.0	188	8.2	11.3
05...	27.0	9.0	188	8.2	10.9
05...	30.0	8.5	188	8.2	9.8
05...	31.5	--	--	--	--
JUN					
26...	1.50	19.5	184	7.6	8.5
26...	3.00	19.5	184	7.7	8.6
26...	6.00	19.5	184	7.7	8.6
26...	9.00	19.5	183	7.7	8.6
26...	12.0	19.5	184	7.7	8.6
26...	15.0	19.5	184	7.7	8.5
26...	18.0	19.5	184	7.6	8.0
26...	21.0	18.0	186	7.6	7.2
26...	24.0	17.0	186	7.6	5.7
26...	27.0	16.5	188	7.5	4.5
26...	30.0	15.5	193	7.5	2.2
26...	32.0	--	--	--	--
JUL					
14...	1.50	21.0	185	8.2	8.9
14...	3.00	21.0	185	8.2	8.9
14...	6.00	21.0	185	8.2	9.0
14...	9.00	21.0	185	8.2	9.0
14...	12.0	21.0	186	8.2	8.9
14...	15.0	21.0	186	8.2	8.9
14...	18.0	21.0	186	8.2	8.9
14...	21.0	20.0	188	8.0	6.4
14...	24.0	19.5	189	7.9	5.0
14...	27.0	19.0	192	7.7	2.8
14...	30.0	18.5	195	7.6	1.2
14...	32.0	--	--	--	--
AUG					
09...	1.50	21.5	180	8.4	8.8
09...	3.00	21.5	180	8.4	8.8
09...	6.00	21.5	180	8.4	8.8
09...	9.00	21.5	180	8.5	8.8
09...	12.0	21.5	180	8.4	8.7
09...	15.0	21.5	181	8.4	8.6
09...	18.0	21.5	181	8.4	8.6
09...	21.0	21.5	180	8.4	8.6
09...	24.0	21.0	181	8.4	8.5
09...	27.0	21.0	183	8.2	6.1
09...	30.0	20.5	188	8.0	3.1
09...	31.5	--	--	--	--

Table 3.--Water clarity and water-quality analyses and their associated Trophic State Indices (TSI) for Balsam Lake off Cedar Island, 1993 water year

[- indicates not applicable; -- indicates no data available]

Date	Secchi Disk			Sampling	Total Phosphorus			Chlorophyll a		Dissolved Ortho-phosphate Phosphorus
	Depth (meters)	Depth (feet)	T.S.I.	Depth (feet)	Conc. (mg/L)	Conc. (µg/L)	T.S.I	Conc. (µg/L)	T.S.I.	Conc. (mg/L)
05/05/93	1.8	5.9	52	1.5	0.015	15	49	6.85	49	<0.002
	-	-	-	30	0.030	30	-	-	-	0.002
06/26/93	3.0	9.8	44	1.5	0.019	19	51	5.68	48	--
	-	-	-	30	0.024	24	-	-	-	--
07/14/93	4.0	13.1	40	1.5	0.020	20	51	7.51	50	--
	-	-	-	30	0.080	80	-	-	-	--
08/09/93	1.5	4.9	54	1.5	0.023	23	52	24.5	59	--
	-	-	-	30	0.040	40	-	-	-	--

Table 5.--Water clarity and water-quality analyses and their associated Trophic State Indices (TSI) for Balsam Lake off Rock Island, 1993 water year

[- indicates not applicable; -- indicates no data available]

Date	Secchi Disk			Sampling	Total Phosphorus			Chlorophyll a		Dissolved Ortho-phosphate Phosphorus
	Depth (meters)	Depth (feet)	T.S.I.	Depth (feet)	Conc. (mg/L)	Conc. (µg/L)	T.S.I	Conc. (µg/L)	T.S.I.	Conc. (mg/L)
05/05/93	3.0	9.8	44	1.5	<0.02	20	51	2.79	43	--
	-	-	-	--	--	--	-	-	-	--
06/26/93	2.7	8.9	46	1.5	0.036	36	56	7.13	50	--
	-	-	-	--	--	--	-	-	-	--
07/14/93	1.7	5.6	52	1.5	0.019	19	51	16.9	56	--
	-	-	-	--	--	--	-	-	-	--
08/09/93	0.9	3.0	62	1.5	0.049	49	58	59.6	66	--
	-	-	-	--	--	--	-	-	-	--

ST. CROIX RIVER BASIN

452755092264600 [redacted]AM LAKE, OFF CEDAR ISLAND, AT BALSAM LAKE[redacted]

LOCATION.--Lat 45°27'55", long 92°26'46", in NW 1/4 SW 1/4 sec.2, T.34 N., R.17 W., Polk County, Hydrologic Unit 07030005, 1 mi north of Balsam Lake.

DRAINAGE AREA.--52.7 mi^2.

PERIOD OF RECORD.--February 1991 to current year.

REMARKS.--Lake sampled about 0.25 mi north of Cedar Island at a lake depth of about 34 ft. Lake ice-covered during March sampling. Water-quality analyses by Wisconsin State Laboratory of Hygiene.

WATER-QUALITY DATA, MARCH 04 TO AUGUST 09, 1993
(Milligrams per liter unless otherwise indicated)

	Mar. 04		May 05		June 26		July 14		Aug. 09	
Depth of sample (ft)	1.5	30	1.5	30	1.5	30	1.5	30	1.5	30
Lake stage (ft)	7.59		7.99		8.24		7.74		7.45	
Specific conductance (µS/cm)	193	230	189	188	184	193	185	195	180	188
pH (units)	8.2	7.9	8.2	8.2	7.6	7.5	8.2	7.6	8.4	8.0
Water temperature (°C)	1.5	5.0	11.5	8.5	19.5	15.5	21.0	18.5	21.5	20.5
Color (Pt-Co. scale)	---	---	10	10	---	---	---	---	---	---
Turbidity (NTU)	---	---	0.90	0.80	---	---	---	---	---	---
Secchi-depth (meters)	---		1.8		3.0		4.0		1.5	
Dissolved oxygen	12.8	3.8	12.1	9.8	8.5	2.2	8.9	1.2	8.8	3.1
Hardness, as CaCO3	---	---	87	87	---	---	---	---	---	---
Calcium, dissolved (Ca)	---	---	22	22	---	---	---	---	---	---
Magnesium, dissolved (Mg)	---	---	7.8	7.8	---	---	---	---	---	---
Sodium, dissolved (Na)	---	---	4.6	4.6	---	---	---	---	---	---
Potassium, dissolved (K)	---	---	2	1	---	---	---	---	---	---
Alkalinity, as CaCO3	---	---	78	77	---	---	---	---	---	---
Sulfate, dissolved (SO4)	---	---	<5.0	<5.0	---	---	---	---	---	---
Chloride, dissolved (Cl)	---	---	9.0	9.0	---	---	---	---	---	---
Fluoride, dissolved (F)	---	---	0.1	<0.0	---	---	---	---	---	---
Silica, dissolved (SiO2)	---	---	10	11	---	---	---	---	---	---
Solids, dissolved, at 180°C	---	---	114	114	---	---	---	---	---	---
Nitrogen, nitrate, total (as N)	---	---	0.01	0.15	---	---	---	---	---	---
Nitrogen, NO2 + NO3, diss. (as N)	---	---	0.01	0.15	---	---	---	---	---	---
Nitrogen, ammonia, dissolved (as N)	---	---	0.01	0.02	---	---	---	---	---	---
Nitrogen, organic, total (as N)	---	---	0.39	0.38	---	---	---	---	---	---
Nitrogen, amm. + org., total (as N)	---	---	0.40	0.40	---	---	---	---	---	---
Nitrogen, total (as N)	---	---	0.41	0.55	---	---	---	---	---	---
Phosphorus, total (as P)	---	---	0.015	0.030	0.019	0.024	0.020	0.080	0.023	0.040
Phosphorus, ortho, dissolved (as P)	---	---	<0.002	0.002	---	---	---	---	---	---
Iron, dissolved (Fe) µg/L	---	---	<50	<50	---	---	---	---	---	---
Manganese, dissolved (Mn) µg/L	---	---	77	84	---	---	---	---	---	---
Chlorophyll a, phytoplankton (µg/L)	---	---	6.9	---	5.7	---	7.5	---	25	---

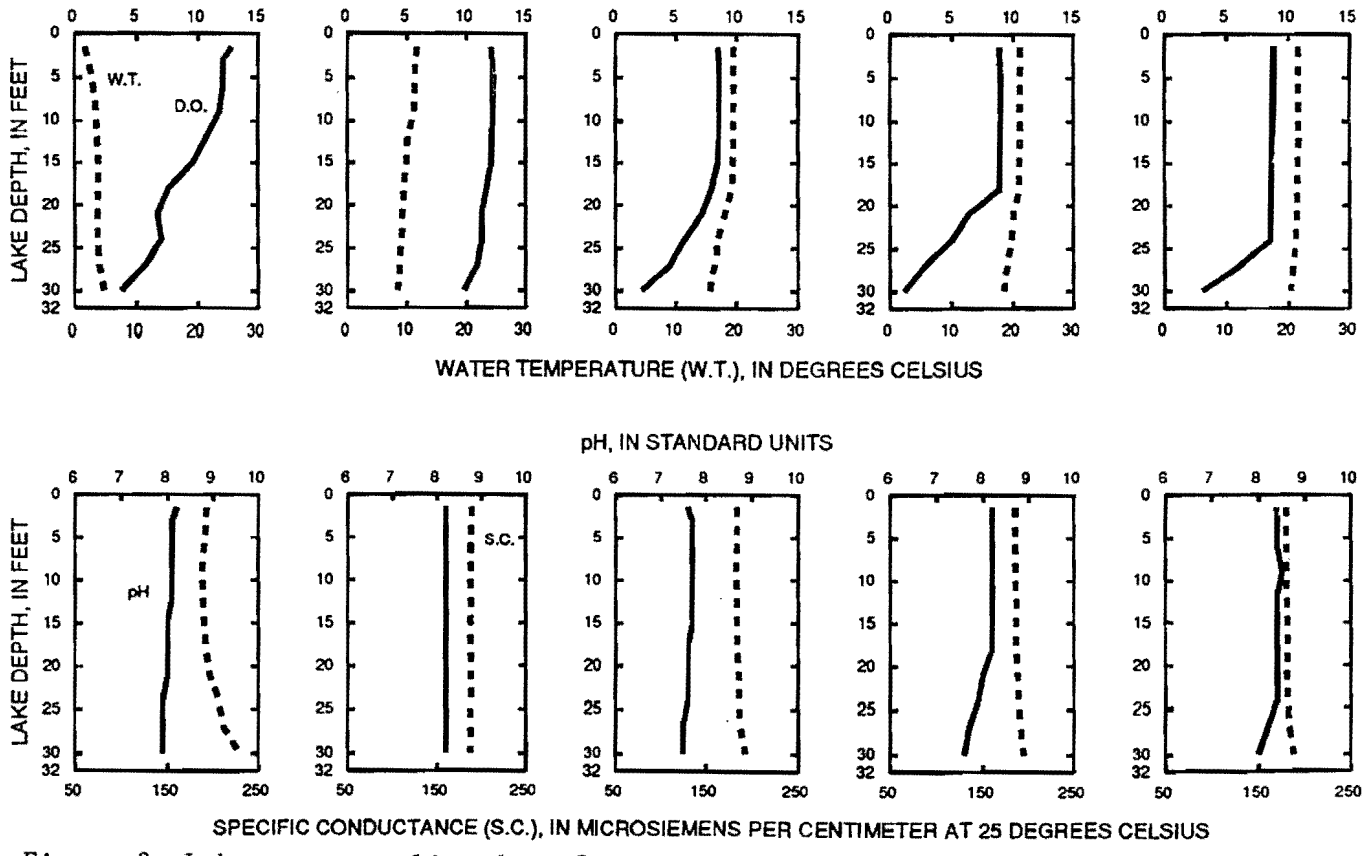

Figure 2. Lake water-quality data for Balsam Lake off Cedar Island, at Balsam Lake, Wisconsin, 1993 water year

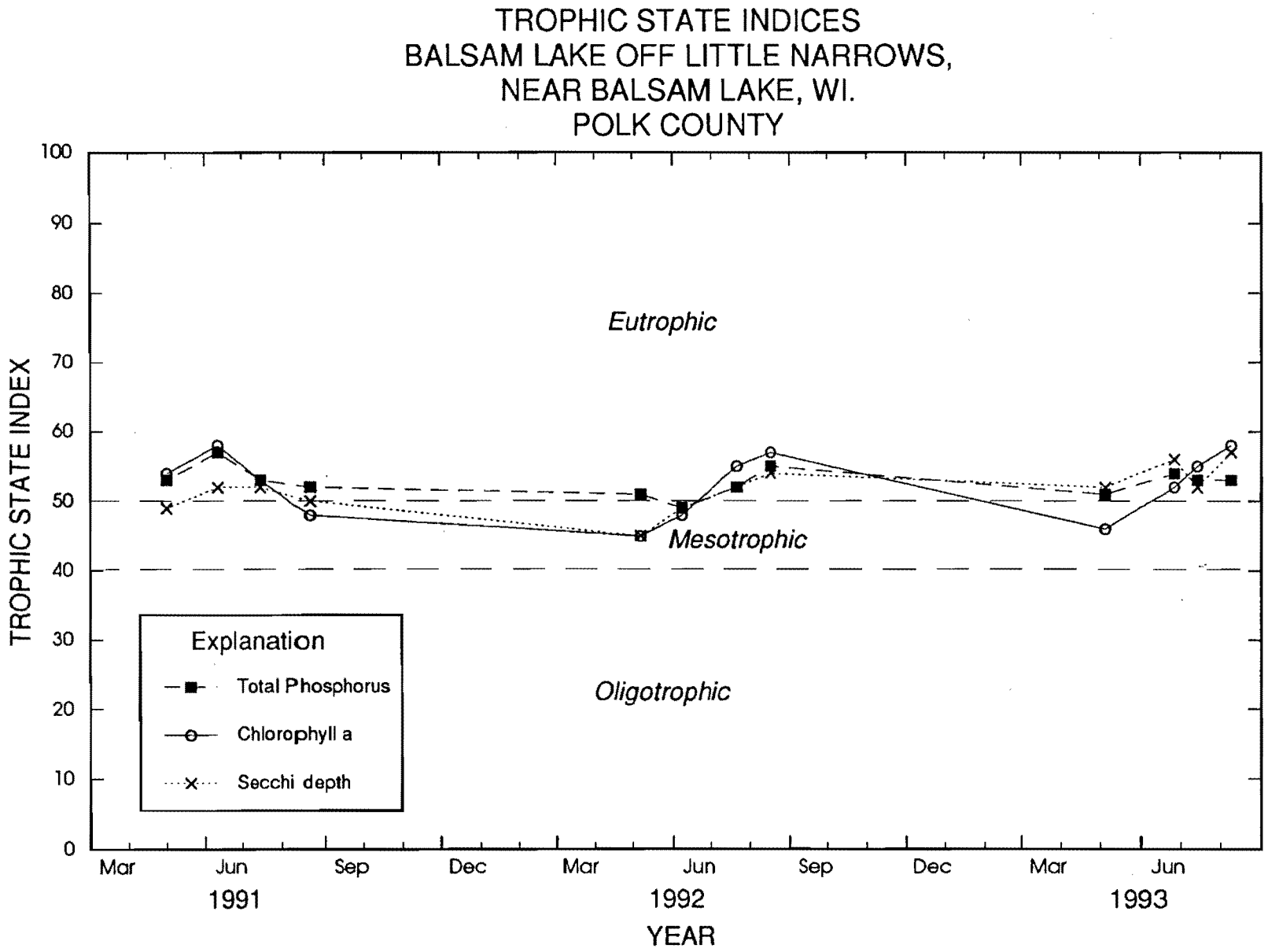

Figure 4. Trophic State Indices for Balsam Lake off Little Narrows near Balsam Lake, Wisconsin

United States Department of the Interior

U.S. GEOLOGICAL SURVEY

Water Resources Division
6417 Normandy Lane
Madison, Wisconsin 53719-1133
608 274-3535 (Fax 608 276-3817)

June 12, 1995

Mr. Gerald Kafka
Balsam Lake Protection and
Rehabilitation District
1230 East Como Boulevard
St. Paul, Minnesota 55117

Dear Mr. Kafka:

This letter describes the progress on the evaluation of the water quality of Balsam Lake according to the data collected from October 1993 to September 1994 as stated in our agreement. Please read the "U.S. Geological Survey Lake Monitoring Program in Wisconsin", sent to you previously, before proceeding with this letter.

In a brief summary, based on the 1994 data:

- The water quality of Balsam Lake varies throughout the lake. The water quality of Balsam Lake off Cedar Island is fair to good; Balsam Lake off Little Narrows ranges from good to poor; and Balsam Lake off Rock Island ranges from fair to good.

- Surface total phosphorus and chlorophyll a concentrations and Secchi-disc depths show little change from 1991 to 1994. However, the water clarity off Cedar Island has decreased slightly.

- Balsam lake is a meso-eutrophic lake or one with moderate to many nutrients.

- Algal growth appears to be dependent upon the amount of available phosphorus rather than nitrogen.

- In June, July, and August, during summer stratification, oxygen disappears from the bottom portion of the lake, which is then unable to support a fish population.

- During the summer anoxic (devoid of oxygen) period, there are moderate amounts of phosphorus being released from the bottom sediments.

- The data enclosed herein are provisional until published.

Balsam Lake has a surface area of 2,054 acres (3.21 square miles) and a drainage area at the outlet of 52.7 square miles for a drainage area/lake size ratio of 16:1. Lakes with drainage area/ lake size ratios of greater than 10:1 tend to develop water-quality problems. (Uttormark, Paul D., and Mark L. Hutchins, 1978, Input/output models as decision criteria for lake restoration. University of Wisconsin-Madison, Wisconsin, Water Resources Center technical report No. 78-03, 61 pp.).

LAKE-STAGE FLUCTUATIONS

Lake-stages were read at the wing wall of the culvert between Balsam Lake and Mill Pond on County Highway I by the USGS at the time of lake sampling. Lake-stage data are listed in figure 2. Lake stages fluctuated 0.46 feet and ranged from 7.45 feet on August 17 to 7.91 feet on May 2. However, the total fluctuation may not have been observed since the stage was only read five times during the water year.

LAKE-DEPTH PROFILES

Profiles of water temperature, dissolved oxygen, pH, and specific conductance at the Cedar Island site (deep hole) are listed in table 1 and shown in figure 2. No abnormalities in the data are apparent. Among our sampling dates, complete water-column mixing was observed on May 2. The remainder of the profile data show incomplete mixing. The lake thermally stratifies during summer. During June, July, and August, the lake bottom water became anoxic (devoid of oxygen) and was unable to support fish. The levels of pH are within acceptable limits to support aquatic life. Because of the buffering capacity of the lake water, Balsam Lake is not susceptible to the effects of acid rain.

SELECTED ANALYSES

Analyses of selected constituents for May 2 for samples collected at 1.5 and 29-foot depths at the deep hole are listed in figure 2. The water-quality values for color, chlorides, calcium, magnesium, pH, alkalinity, total nitrogen, and total phosphorus are within regional values for this area as described by Lillie and Mason in "Limnological Characteristics of Wisconsin Lakes," 1983, Technical Bulletin No. 138, Department of Natural Resources. The value for chlorophyll a is less than the regional minimum, indicating low algal concentrations on that date.

To compute the nitrogen-phosphorus ratio, only the sample collected from the 1.5-foot sampling depth for May was used. This depth was used because algae grow in the upper part of the lake rather than at the bottom. The ratio of total nitrogen to phosphorus was calculated as 34:1 and suggests the lake is phosphorus-limited and is consistent with previous data. This means algal growth appears to be dependent on the amount of available phosphorus rather than nitrogen.

MAY, JUNE, JULY AND AUGUST WATER QUALITY

The data for total phosphorus, chlorophyll a, and Secchi-depth readings, are listed in table 3 and on figure 2 for the center (deep hole) site off Cedar Island; tables 2 and 4 for the north site off Little Narrows, and tables 2 and 5 for the east site off Rock Island.

The water quality of the three sampling sites varies. Each sampling site is discussed separately.

Balsam Lake off Cedar Island

Total phosphorus: Total phosphorus concentrations sampled at a 1.5-foot depth range from 0.015 mg/L in May to 0.032 mg/L in August. All values fall within the regional values previously referenced.

TROPHIC STATUS

Lillie and Mason (1983) classified Wisconsin lakes using a random data set (summer, July and August) according to total phosphorus and chlorophyll a concentrations, and Secchi-disc depth. This evaluation is shown below:

Water quality index	Approximate total phosphorus equivalent (mg/L)	Approximate chlorophyll a equivalent (µg/L)	Approximate water clarity equivalent (Secchi-disc depth in ft)
Excellent	<0.001	<1	<19.7
Very good	.001-.010	1-5	9.8-19.7
Good	.010-.030	5-10	6.6-9.8
Fair	.030-.050	10-15	4.9-6.6
Poor	.050-.150	15-30	3.3-4.9
Very poor	>.150	>30	<3.3

The above criteria were used to evaluate the three sites on Balsam Lake. From the mean summer (July-August) 1994 data shown in table 3 for Balsam Lake off Cedar Island, chlorophyll a concentrations and Secchi-disc depths indicate fair water quality, while surface total phosphorus concentrations indicate good water quality. From the data shown in table 4 for Balsam Lake off Little Narrows, surface total phosphorus and chlorophyll a concentrations indicate good water quality, while Secchi-disc depths indicate poor water quality. From the data shown in table 5 for Balsam Lake off Rock Island, surface total phosphorus concentrations indicate good water quality, while Secchi-disc depths and chlorophyll a concentrations indicate fair water quality.

Using the data from "Limnological Characteristics of Wisconsin Lakes," 1983, by Lillie and Mason, a comparison of the 1994 mean summer data (July and August) for total phosphorus, chlorophyll a, and Secchi depths for all Balsam Lake sites to other lakes in northwest Wisconsin are shown below:

	Parameter	Percentage of distribution of lakes in northwest Wisconsin within these concentrations	
	Total phosphorus (mg/L)		
	<.010	Best condition	12
	.010-.020		35
Balsam Lake values →	.020-.030		23
	.030-.050		18
	.050-.100		8
	.100-.150	↓	3
	>.150	Worst condition	1

Table 1. Lake-depth profiles for Balsam Lake off Cedar Island at Balsam Lake, Wisconsin, 1994 water year

452755092264600 - BALSAM LAKE OFF CEDAR ISLAND AT BALSAM LAKE, WI

WATER-QUALITY DATA

DATE	SAMPLING DEPTH (FEET) (00003)	TEMPERATURE WATER (DEG C) (00010)	SPECIFIC CONDUCTANCE (US/CM) (00095)	PH WATER WHOLE FIELD (STANDARD UNITS) (00400)	OXYGEN, DISSOLVED (MG/L) (00300)
MAR 1994					
07...	1.50	1.0	179	8.9	13.2
07...	3.00	2.0	195	8.8	12.8
07...	6.00	3.0	189	8.7	11.7
07...	9.00	3.0	189	8.7	11.3
07...	12.0	3.0	188	8.6	11.1
07...	15.0	3.0	188	8.6	11.0
07...	18.0	3.5	187	8.5	11.4
07...	21.0	3.5	189	8.5	10.1
07...	24.0	3.5	193	8.4	7.3
07...	27.0	4.0	200	8.4	3.7
07...	30.0	4.5	212	8.2	1.9
07...	31.0	--	--	--	--
MAY					
02...	1.50	9.5	180	8.4	10.3
02...	3.00	9.0	180	8.3	10.2
02...	6.00	9.0	178	8.2	10.1
02...	9.00	9.0	178	8.2	10.0
02...	12.0	8.5	178	8.1	10.1
02...	15.0	8.5	178	8.1	10.0
02...	18.0	8.5	178	8.1	10.0
02...	21.0	8.5	177	8.0	9.5
02...	24.0	8.5	177	8.0	9.5
02...	27.0	8.5	177	8.0	9.5
02...	30.0	8.0	177	8.0	9.7
02...	31.0	--	--	--	--
JUN					
14...	1.50	21.0	176	8.0	9.2
14...	3.00	21.0	175	8.0	9.2
14...	6.00	21.0	175	8.0	9.1
14...	9.00	21.0	174	8.1	9.1
14...	12.0	20.5	174	8.1	9.3
14...	15.0	20.5	174	8.2	9.3
14...	18.0	20.5	175	8.2	9.2
14...	21.0	20.0	174	8.2	8.8
14...	24.0	20.0	174	8.2	3.7
14...	27.0	15.0	182	8.0	1.0
14...	30.0	14.0	188	7.8	0.4
14...	31.5	--	--	--	--
JUL					
12...	1.50	23.0	168	8.3	8.8
12...	3.00	23.0	167	8.3	8.8
12...	6.00	23.0	167	8.3	8.8
12...	9.00	23.0	167	8.3	8.7
12...	12.0	23.0	167	8.3	8.6
12...	15.0	23.0	167	8.3	8.5
12...	18.0	22.5	168	8.2	6.8
12...	21.0	21.5	169	8.1	4.2
12...	24.0	20.0	172	8.0	1.0
12...	27.0	17.0	185	7.8	0.1
12...	30.0	15.5	193	7.8	0.1
12...	31.5	--	--	--	--
AUG					
17...	1.50	22.0	176	8.5	10.1
17...	3.00	22.0	176	8.5	10.1
17...	6.00	22.0	177	8.5	10.0
17...	9.00	21.5	178	8.5	10.0
17...	12.0	21.5	176	8.5	9.9
17...	15.0	21.0	177	8.4	8.0
17...	18.0	20.5	177	8.4	7.7
17...	21.0	20.0	178	8.3	7.0
17...	24.0	20.0	179	8.2	6.8
17...	27.0	19.5	184	8.1	2.5
17...	30.0	16.5	228	7.9	0.2
17...	31.5	--	--	--	--

Table 3.--Water clarity and water-quality analyses and their associated Trophic State Indices (TSI) for Balsam Lake off Cedar Island, 1994 water year

[- indicates not applicable; -- indicates no data available]

Date	Secchi Disk			Sampling	Total Phosphorus			Chlorophyll a		Dissolved Ortho-phosphate Phosphorus
	Depth (meters)	Depth (feet)	T.S.I.	Depth (feet)	Conc. (mg/L)	Conc. (µg/L)	T.S.I	Conc. (µg/L)	T.S.I.	Conc. (mg/L)
05/02/94	6.7	22.0	33	1.5	0.015	15	49	0.299	26	0.010
	-	-	-	29	0.025	25	-	-	-	0.008
06/14/94	2.4	7.9	47	1.5	0.018	18	51	6.08	48	--
	-	-	-	30	0.030	30	-	-	-	--
07/12/94	2.4	7.9	47	1.5	0.019	19	51	7.78	50	--
	-	-	-	30	0.130	130	-	-	-	--
08/17/94	1.3	4.3	56	1.5	0.032	32	55	18.4	57	--
	-	-	-	30	0.040	40	-	-	-	--

Table 5.--Water clarity and water-quality analyses and their associated Trophic State Indices (TSI) for Balsam Lake off Rock Island, 1994 water year

[- indicates not applicable; -- indicates no data available]

Date	Secchi Disk			Sampling	Total Phosphorus			Chlorophyll a		Dissolved Ortho-phosphate Phosphorus
	Depth (meters)	Depth (feet)	T.S.I.	Depth (feet)	Conc. (mg/L)	Conc. (µg/L)	T.S.I	Conc. (µg/L)	T.S.I.	Conc. (mg/L)
05/02/94	4.9	16.1	37	1.5	0.007	7	43	0.442	29	--
	-	-	-	--	--	--	-	-	-	--
06/14/94	2.7	8.9	46	1.5	0.013	13	48	4.82	47	--
	-	-	-	--	--	--	-	-	-	--
07/12/94	2.1	6.9	49	1.5	0.025	25	53	6.1	48	--
	-	-	-	--	--	--	-	-	-	--
08/17/94	1.0	3.3	60	1.5	0.028	28	54	15	55	--
	-	-	-	--	--	--	-	-	-	--

452755092264600 BALSAM LAKE, OFF CEDAR ISLAND, AT BALSAM LAKE, WI

LOCATION.--Lat 45°27'55", long 92°26'46", in NW 1/4 SW 1/4 sec.2, T.34 N., R.17 W., Polk County, Hydrologic Unit 07030005, 1 mi north of Balsam Lake.

DRAINAGE AREA.--52.7 mi^2.

PERIOD OF RECORD.--February 1991 to current year.

REMARKS.--Lake sampled about 0.25 mi north of Cedar Island at a lake depth of about 34 ft. Lake ice-covered during March sampling. Water-quality analyses by Wisconsin State Laboratory of Hygiene.

WATER-QUALITY DATA, MARCH 07 TO AUGUST 17, 1994
(Milligrams per liter unless otherwise indicated)

	Mar. 07		May 02		June 14		July 12		Aug. 17	
Depth of sample (ft)	1.5	30	1.5	29	1.5	30	1.5	30	1.5	30
Lake stage (ft)	7.77		7.91		7.53		7.69		7.45	
Specific conductance (µS/cm)	179	212	180	180	176	188	168	193	176	228
pH (units)	8.9	8.2	8.4	8.0	8.0	7.8	8.3	7.8	8.5	7.9
Water temperature (°C)	1.0	4.5	9.5	8.0	21.0	14.0	23.0	15.5	22.0	16.5
Color (Pt-Co. scale)	---	---	5	10	---	---	---	---	---	---
Turbidity (NTU)	---	---	0.60	<0.50	---	---	---	---	---	---
Secchi-depth (meters)	---		6.7		2.4		2.4		1.3	
Dissolved oxygen	13.2	1.9	10.3	9.7	9.2	0.4	8.8	0.1	10.1	0.2
Hardness, as CaCO3	---	---	81	81	---	---	---	---	---	---
Calcium, dissolved (Ca)	---	---	21	21	---	---	---	---	---	---
Magnesium, dissolved (Mg)	---	---	7.0	7.0	---	---	---	---	---	---
Sodium, dissolved (Na)	---	---	5.0	5.0	---	---	---	---	---	---
Potassium, dissolved (K)	---	---	1	1	---	---	---	---	---	---
Alkalinity, as CaCO3	---	---	76	76	---	---	---	---	---	---
Sulfate, dissolved (SO4)	---	---	5.0	5.0	---	---	---	---	---	---
Chloride, dissolved (Cl)	---	---	9.5	9.5	---	---	---	---	---	---
Fluoride, dissolved (F)	---	---	0.1	0.1	---	---	---	---	---	---
Silica, dissolved (SiO2)	---	---	11	11	---	---	---	---	---	---
Solids, dissolved, at 180°C	---	---	110	112	---	---	---	---	---	---
Nitrogen, NO2 + NO3, diss. (as N)	---	---	0.11	0.11	---	---	---	---	---	---
Nitrogen, ammonia, dissolved (as N)	---	---	0.06	0.06	---	---	---	---	---	---
Nitrogen, amm. + org., total (as N)	---	---	0.40	0.40	---	---	---	---	---	---
Nitrogen, total (as N)	---	---	0.51	0.51	---	---	---	---	---	---
Phosphorus, total (as P)	---	---	0.015	0.025	0.018	0.030	0.019	0.130	0.032	0.040
Phosphorus, ortho, dissolved (as P)	---	---	0.010	0.008	---	---	---	---	---	---
Iron, dissolved (Fe) µg/L	---	---	<50	50	---	---	---	---	---	---
Manganese, dissolved (Mn) µg/L	---	---	44	44	---	---	---	---	---	---
Chlorophyll a, phytoplankton (µg/L)	---	---	0.3	---	6.1	---	7.8	---	18	---

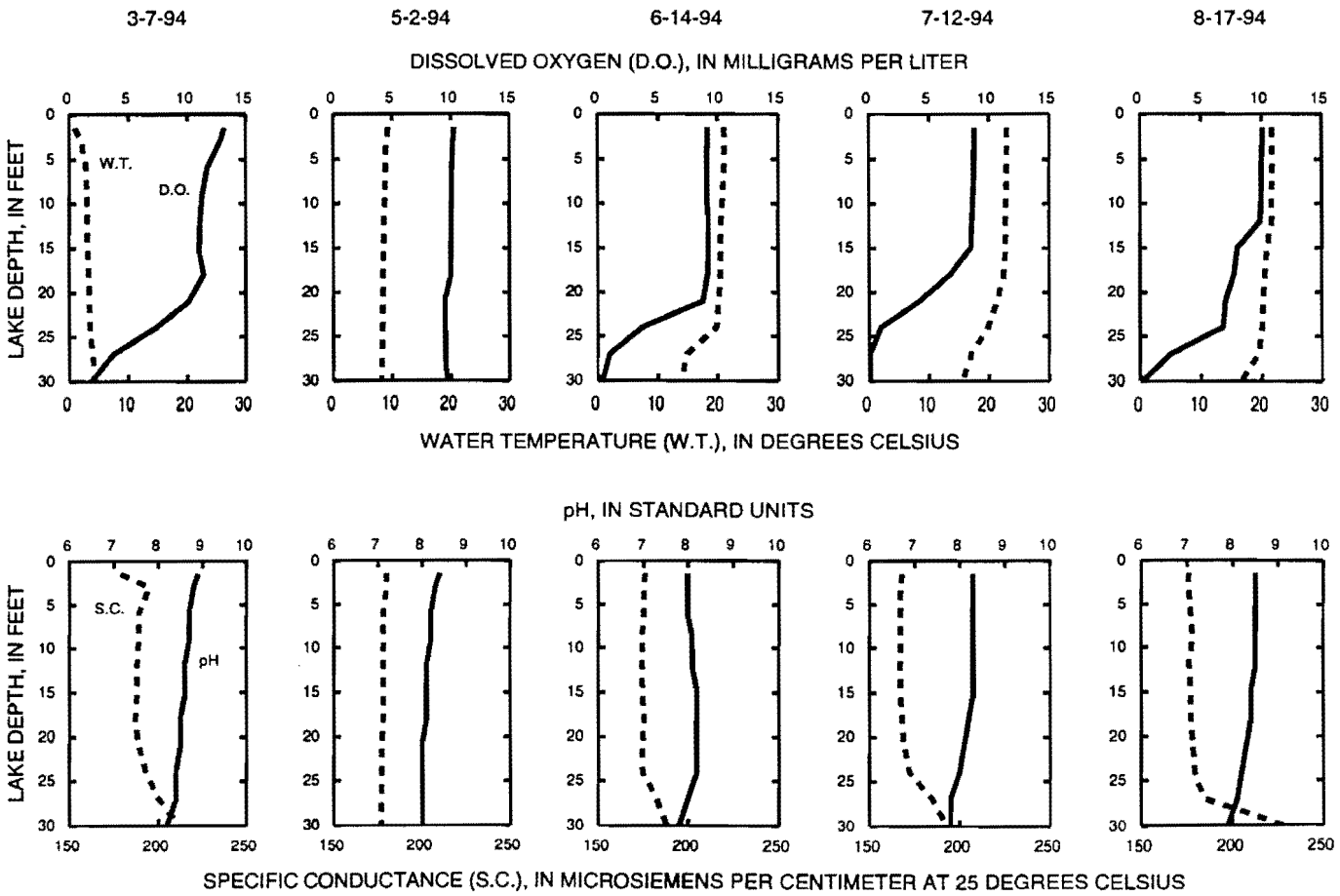

Figure 2. Lake water-quality data for Balsam Lake off Cedar Island at Balsam Lake, Wisconsin, 1994 water year

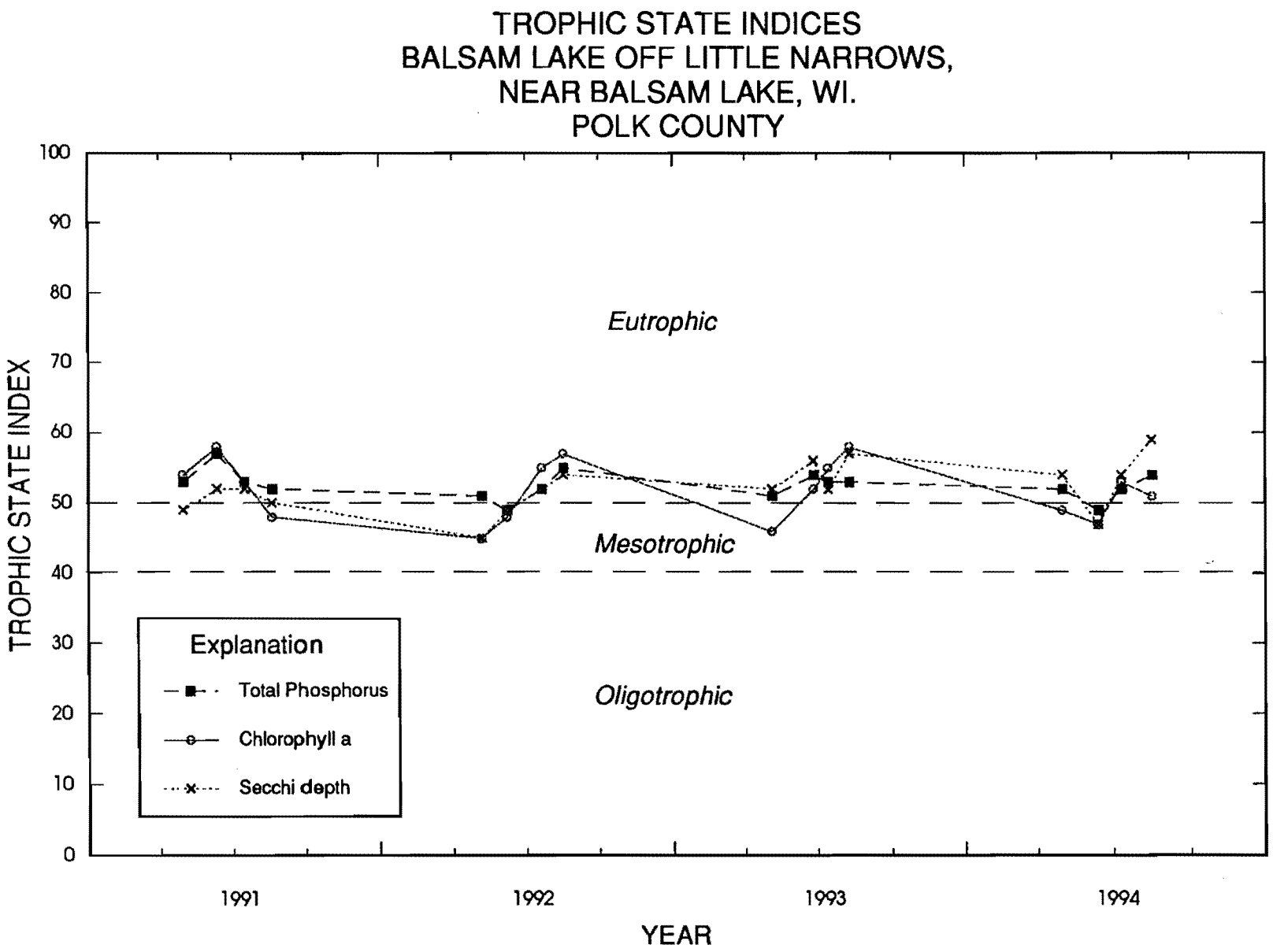

Figure 4. Trophic state indices for Balsam lake off Little Narrows near Balsam Lake, Wisconsin

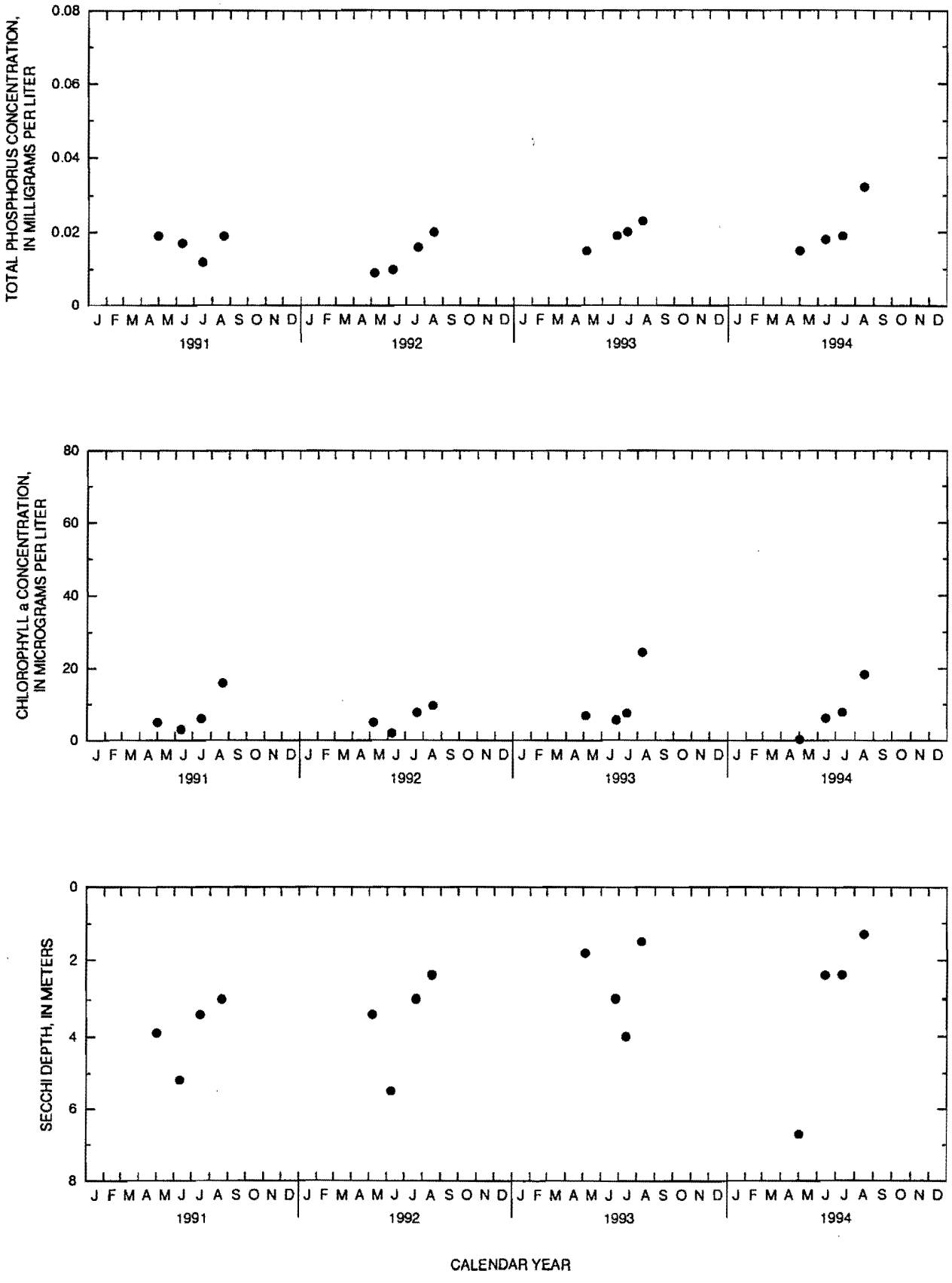

Figure 6.-- Surface total phosphorus and chlorophyll a concentrations, and Secchi depths for Balsam Lake, off Cedar Island, at Balsam Lake, Wisconsin.

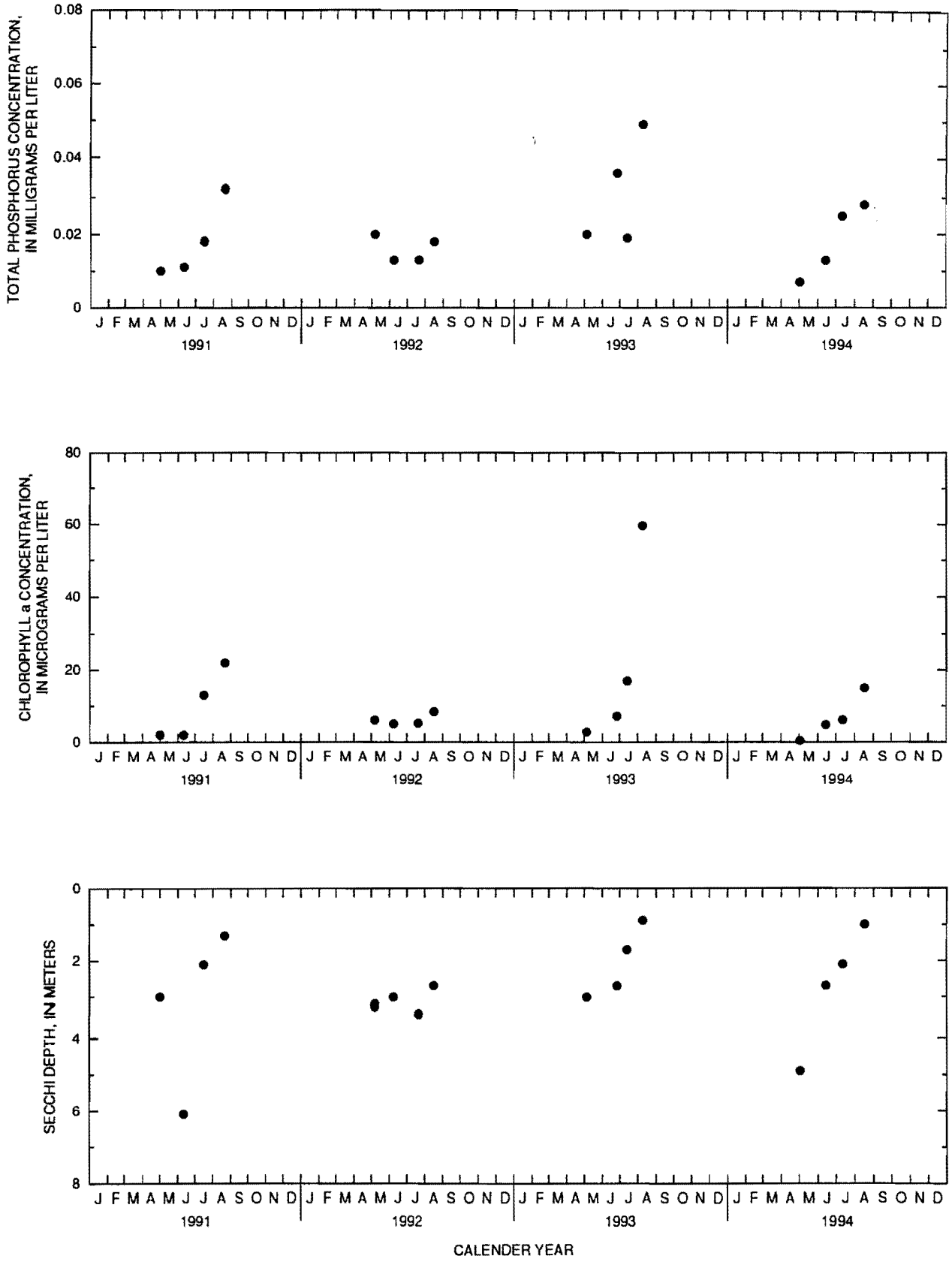

Figure 8.-- Surface total phosphorus and chlorophyll a concentrations, and Secchi depths for Balsam Lake off Rock Island near Balsam Lake, Wisconsin.