IPS ENVIRONMENTAL AND ANALYTICAL SERVICES
Appleton, Wisconsin

PHASE I
LAKE MANAGEMENT PLAN
LOWER CHAIN O' LAKES
WAUPACA COUNTY, WISCONSIN

REPORT TO:
CHAIN O' LAKES PROPERTY OWNERS ASSOCIATION

August, 1993

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ACKNOWLEDGEMENTS

This plan was prepared with guidance provided by the Advisory Committee of the Chain O' Lakes Property Owners Association.

Development of this plan was made possible with funds provided by the Wisconsin Department of Natural Resources Lake Management Planning Grant Program, the Waupaca County Water Quality Maintenance Program, and the Chain O' Lakes Property Owners Association.

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SUMMARY

The Chain O' Lakes (Chain) is a recreationally popular group of lakes located in Waupaca County, Wisconsin. Generally, the lakes are spring fed, relatively deep and clear. For plan development, the Chain was divided into Upper, Middle, Lower, East and Little Chain subgroups. Specific Phase I objectives were to establish a water quality monitoring strategy to assess current status and track trends, to improve public awareness and participation, and to initiate assessment of recreational use opinions and options.

The Lower Chain (Columbia, Ottman, Youngs, Bass, Beasley and Long Lakes) is relatively diverse (compared to other Chain project groups) and includes the Chain's smallest, shallowest (Youngs) and one of the largest, deepest lakes (Long). The Lower Chain accounts for about 30 percent of the total Chain surface area, drains the entire Chain watershed and receives significant direct overland inflow via Emmon's Creek.

Water quality for Lower Chain lakes was good to excellent, generally similar to that of other Chain project groups and indicative of **oligotrophic**[1] to **mesotrophic** status. Nutrient levels were relatively higher in smaller, shallower well mixed lakes, but near or below expected levels overall. Water quality, despite such a large watershed, reflects substantial spring inflows, marl precipitation of phosphorus, and minimal surface runoff.

Macrophyte populations, where present, appear to benefit the resource through provision of fish and forage habitat, shoreline stabilization and nutrient uptake. Potentially nuisance species are present in some areas but the habitat, overall, does not appear conducive to development of nuisance abundance levels.

Water quality monitoring, recreational use management and prevention of exotic plant or animal introductions are recommended to protect the excellent quality of this resource.

* Water quality trend monitoring should be continued on a similar schedule to supplement the small amount of historic data available; event samples should be taken as appropriate in areas of concern and in the Emmon's Creek basin. Volunteers should be solicited to take **Secchi depth** readings on each lake.

* Riparian land owner education and diligence with respect to runoff control, and yard waste and fertilizer management, should be encouraged to maximize aesthetics and minimize sediment and nutrient input to the lakes.

* Recreational use survey results (presently being tabulated) should be analyzed, with appropriate correlations, to assess perceptions and attitudes and develop practical options for future management and minimization of use conflicts.

* Measures to prevent or reduce the potential for invasion of exotic species (e.g., Eurasian milfoil and purple loosestrife which are present and spreading in Waupaca County) should be identified and implemented.

[1] Text terms in bold print defined in glossary (pp. vi-vii)

INTRODUCTION

The Chain O' Lakes (Chain) is a group of 22 interconnected lakes located in the southwest corner of Waupaca County near the City of Waupaca and the Villages of Rural and King. The lakes are mostly deep, clear, spring lakes; the Chain and associated wetlands, and undeveloped shoreline areas have been designated as environmentally sensitive areas (4).

The Chain O' Lakes Property Owners Association (CLPOA) was formed in the 1960's to provide leadership and coordination of lake preservation and educational activities pertinent to the Chain. Currently, the CLPOA has 13 elected officers on the Executive Committee and about 600 members.

The CLPOA, in 1990, decided to pursue the development of a long range management plan for the Chain under the Wisconsin Department of Natural Resources (WDNR) Lake Management Planning Grant Program. The CLPOA officers selected IPS Environmental & Analytical Services (IPS) of Appleton, Wisconsin as its consultant to develop the plans. Grant applications, one each for five project groups of the Chain (Table 1), were prepared and submitted in January, 1991. The Lower Chain application incorporated the following required or recommended program components including:

- assessment of current water quality in the Lower Chain and implementation of a strategy to track trends,
- increase the awareness of the lake property owners of lake problems and establishment a base of support for lake management efforts,
- determine event related, nonpoint source runoff to the lakes,
- locate, identify and quantify aquatic plant concentrations in Long Lake,
- development of options for recreational use management.

The Lower Chain grant application was approved in April, 1991.

Table 1. Project Groups, Lake Management Planning, Chain O' Lakes, Waupaca County, WI.

Upper Chain	Middle Chain	Lower Chain
Otter Lake	Nessling Lake	Ottman Lake
Taylor Lake	McCrossen Lake	Bass Lake
George Lake	Round Lake	Youngs Lake
Sunset Lake	Limekiln Lake	Beasley Lake
Rainbow Lake		Long Lake
		Columbia Lake

East Chain	Little Chain
Dake Lake	Orlando Lake
Miner Lake	Knight Lake
	Manomin Lake
	Pope Lake
	Marl Lake

DESCRIPTION OF AREA

The Chain O' Lakes is a group of "kettle" lakes located in the southwest corner of Waupaca County, WI (Figure 1). Kettle lakes are typically formed when large ice blocks are pushed into the soil by a retreating glacier; the depression subsequently fills with water when the ice blocks melt.

The general topography of Waupaca County is related to glacial activity; the Chain is located in moranic hills left after the retreat of the Cary Glacier (5). Topography adjacent to the lakes is level to steeply sloping. Major soil types near the Lower Chain are well-drained Rosholt sandy loam on 6-20 percent slopes, very poorly drained Seelyeville muck on 0-2 percent slopes and Oesterle sandy loam on 0-3 percent slopes. Erosion potential is low (Seelyeville, Oesterle) to moderate (Rosholt) (6).

Predominant **littoral** substrates are sand, muck and **marl**; scattered reaches of rubble are present (Personal communication WDNR). **Macrophytes** (aquatic plants) are more prevalent in the Lower Chain than in most other Chain project groups. The small shallow lakes (Ottman, Bass and Youngs) have substantial macrophytic growth, whereas localized areas of abundant macrophytes are present on Long and Beasley Lakes. Two exotic

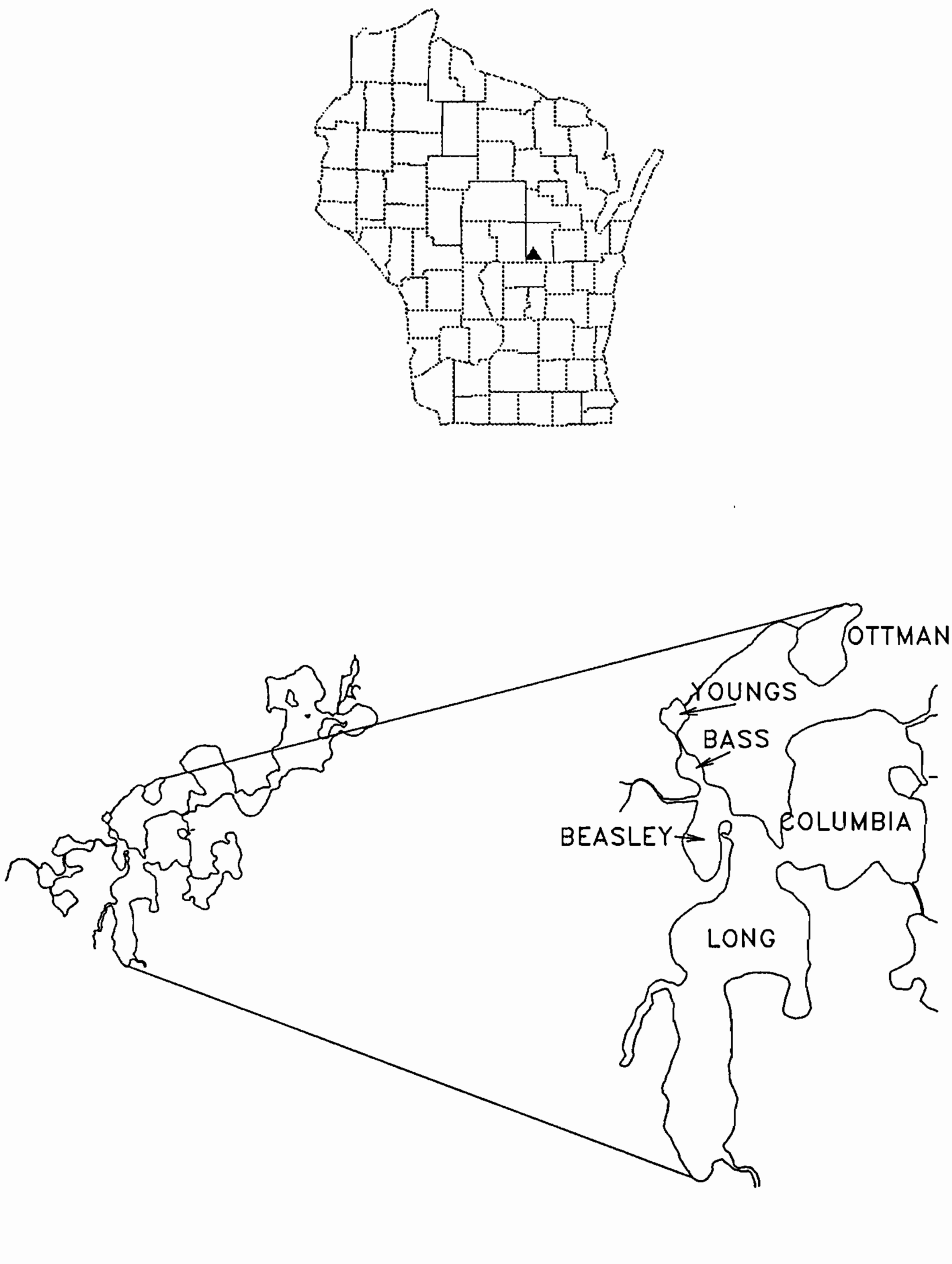

Figure 1. Location Map, Chain O' Lakes, Waupaca County, WI.

nuisance plant species, Eurasian milfoil (Myriophyllum spicatum) and purple loosestrife (Lythrum salicaria), are established in Waupaca County and are capable of spreading to the Chain O' Lakes system.

The Chain O' Lakes watershed, about 20,000 acres overall, is predominantly forested with open/agricultural areas. Native trees include maple, ash, oak, and pine, and dairy farming is the chief agricultural activity in the watershed (Pers. comm. WDNR). There are no known point source discharges to the Lower Chain. Sanitary sewerage collection and treatment is provided for all Chain residences through the Chain O' Lakes Sanitary Lake District but no direct discharge to the Chain occurs from the treatment facility.

Lower Chain lake area ranges from 2 acres (Youngs) to 104 acres (Long) (Table 2). Lake volume ranges from 10 (Bass) to 3094 acre-feet (Long) (Pers. comm. WDNR). Thermal **stratification** develops during summer in the larger deeper lakes of the Lower Chain (Columbia, Long, Beasley) and restricts mixing of the lake volume to spring and fall overturns: Ottman, Youngs and Bass Lakes remain mixed throughout the year. The Lower Chain lakes have very different morphology and are classified as either **spring**, **seepage** or **drainage lakes**.

Table 2. Physical Characteristics of the Lower Chain Lakes, Waupaca County, WI.

Lake Name	COLUMBIA	OTTMAN	YOUNGS	BASS	BEASLEY	LONG
Location						
Township(s)	21,22N	22N	22N	21,22N	21N	21N
Range	11E	11E	11E	11E	11E	11E
Section(s)	33,4	33	32,33	33,4	4	4,5
Lake Type	Drainage	Seepage	Spring	Drainage	Drainage	Spring
Area (acres)	81	13	2	3	12	104
Max. Depth (ft)	72	15	15	8	47	76
Ave. Depth (ft)	25	6	8	4	21	30
Volume (acre-feet)	2028	82	14	10	254	3094
Shoreline (miles)	1.8	0.6	0.2	0.3	0.7	3.0
Fetch (miles)	0.49	0.22	0.08	0.12	0.16	0.95
Fetch Orientation	NE-SW	SW-NE	W-E	NW-SE	SW-NE	SW-NE
Width (miles)	0.40	0.16	0.08	0.06	0.10	0.36
Lake Shore Soils						
Major Type	Rosholt[1]	Rosholt[1]	Rosholt[1] Seelyeville[2]	Rosholt[1]	Rosholt[1]	Rosholt[1]
% Slope	6-12	12-20	12-20/0-2	12-20	12-20	12-20

[1] = Rosholt sandy loam
[2] = Seelyeville muck

The Chain supports warmwater and coldwater fisheries (Table 3). Some trout from the Chain are known to migrate into Emmon's Creek to spawn; splake and rainbow trout were stocked in the past by the WDNR to supplement the cold water fishery. Hybrid muskellunge were stocked in the Chain from 1979 to 1986. No stocking presently occurs in the Chain (Pers. comm. WDNR). A WDNR consumption advisory (for mercury) currently exists for largemouth bass taken from Columbia Lake. Fish from Rainbow Lake have also been tested for mercury but no advisory was issued (7).

Table 3. Chain O' Lakes Fish Species.

COMMON NAME	SCIENTIFIC NAME
Warmwater Game Fish	
Muskellunge	Esox masquinongy
Hybrid muskellunge (muskellunge X northern pike)	
Northern pike	Esox lucius
Walleye	Stizostedion vitreum
Largemouth bass	Micropterus salmoides
Smallmouth bass	Micropterus dolomieui
Lake sturgeon	Acipenser fulvescens
Coldwater Game Fish	
Brown trout	Salmo trutta
Rainbow trout	Salmo gairdneri
Hybrid splake (lake trout X brook trout)	
Cisco	Coregonus artedii
Warmwater Panfish	
Bluegill	Lepomis macrochirus
Black crappie	Pomoxis nigromaculatus
Green sunfish	Lepomis cyanellus
Pumpkinseed	Lepomis gibbosus
Rock bass	Ambloplites rupestris
Warmouth	Lepomis gulosus
Yellow perch	Perca flavescens
Black bullhead	Ictalurus melas
Brown bullhead	Ictalurus nebulosus
Yellow bullhead	Ictalurus natalis
Rough Fish	
Bowfin	Amia calva
White sucker	Catostomus commersoni
Hog sucker	Hypentelium nigricans
Bigmouth buffalo	Ictiobus cyprinellus
Shorthead redhorse	Moxostoma macrolepidotum
Burbot	Lota lota
Forage Fish	
Brook silverside	Labidesthes sicculus
Western mudminnow	Umbra limi
Golden shiner	Notemigonus crysoleucas
Bluntnose	Pimephales notatus
Central stoneroller	Campostoma anomalum
Northern common shiner	Notropis cornutus
Northern creek chub	Semotilus atromaculatus
Blackside darter	Percina maculata
Slimy muddler	Cottus cognatus
Central johnny darter	Etheostoma nigrum

Public boat ramps are available at about ten locations on the Chain. Most of the connecting channels on the Chain are navigable for powerboats and all but one (Ottman - Youngs) are navigable with a canoe. The Lower Chain has a boat ramp access point off Cleghorn Drive on Columbia Lake (Pers. comm. WDNR).

Because of intensive recreational use during summer, the Towns of Dayton and Farmington and the CLPOA adopted ordinances to regulate boat traffic on the Chain. Except for the largest lakes (Columbia, Long, Rainbow and Round), all lakes on the Chain have a "no wake" speed limit (Pers. comm. CLPOA). Water skiing on these lakes is limited to 10:00 a.m. - 2:30 p.m. on weekends and Holidays, 10:00 a.m. - 4:00 p.m. on Monday and Friday, and 10:00 a.m. - 7:00 p.m. on Tuesday through Thursday.

METHODS

FIELD PROGRAM

Except for Ottman Lake where access is somewhat limited, water sampling was conducted May 29 or June 10, August 6 and September 4th or 5th, 1991 and January 30 or February 4, and May 5th or 6th, 1992 at the deepest point of each lake in the Lower Chain (Table 4, Figure 2). The Emmon's Creek inlet and Crystal River outlet sites were sampled on all dates except during winter (unsafe ice) and Ottman Lake was sampled during June and September, 1991, and February, 1992. Samples were taken three feet below the surface (designated "S") and three feet above the bottom (designated "B") or at mid-depth (designated "M").

Physicochemical parameters measured in the field were Secchi depth, water temperature, pH, dissolved oxygen (DO), and conductivity. Field measurements were taken using a standard Secchi disk and a Hydrolab Surveyor II multiparameter meter; the Hydrolab was calibrated prior to and subsequent to daily use.

Samples were taken for laboratory analyses with a Kemmerer water bottle. Samples were labelled, preserved if necessary, and packed on ice in the field; samples were delivered by overnight carrier to the laboratory.

Table 4. Sample Station Descriptions, Lower Chain, Chain O' Lakes, 1991 - 1992.

WATER QUALITY

Lake	Site	Latitude (North) / Longitude (West)	Depth
Ottman (Deepest Pt.)	1208	44° 20' 04" / 89° 10' 38"	15.0 ft.
Youngs (Deepest Pt.)	1207	44° 19' 59" / 89° 11' 00"	15.0 ft.
Bass (Deepest Pt.)	1206	44° 19' 52" / 89° 10' 58"	8.0 ft.
Beasley (Deepest Pt.)	1205	44° 19' 42" / 89° 10' 56"	47.0 ft.
Columbia (Deepest Pt.)	1201	44° 19' 48" / 89° 10' 31"	72.0 ft.
Long (Deepest Pt.)	1202	44° 19' 27" / 89° 10' 52"	76.0 ft.
Long (Emmon's Creek)	1203	44° 19' 22" / 89° 11' 03"	3.0 ft.
Long (Crystal River)	1204	44° 19' 00" / 89° 10' 57"	3.0 ft.

LONG LAKE MACROPHYTE TRANSECTS

Transect	Latitude/Longitude Origin	End	Transect Length(m)	Bearing (Degrees)	Depth Range[1]	Interval End (m)
A	44° 18' 57"	89° 11' 03"	60	10	1/2/3	9/45/60
B	44° 19' 11"	89° 10' 55"	35	265	1/2/3	8/20/35
C	44° 19' 10"	89° 11' 08"	35	95	1/2/3	15/20/35
D	44° 19' 22"	89° 11' 03"	20	200	1/2	14/20
E	44° 19' 23"	89° 10' 41"	15	90	1/2/3	6/ 9/15
F	44° 19' 35"	89° 10' 42"	40	225	1/2	10/40

[1] 1 = 0.0 - 0.5m (0.0 - 1.7ft)
2 = 0.5 - 1.5m (1.7 - 5.0ft)
3 = 1.5 - 3.0m (5.0 - 10.0ft)

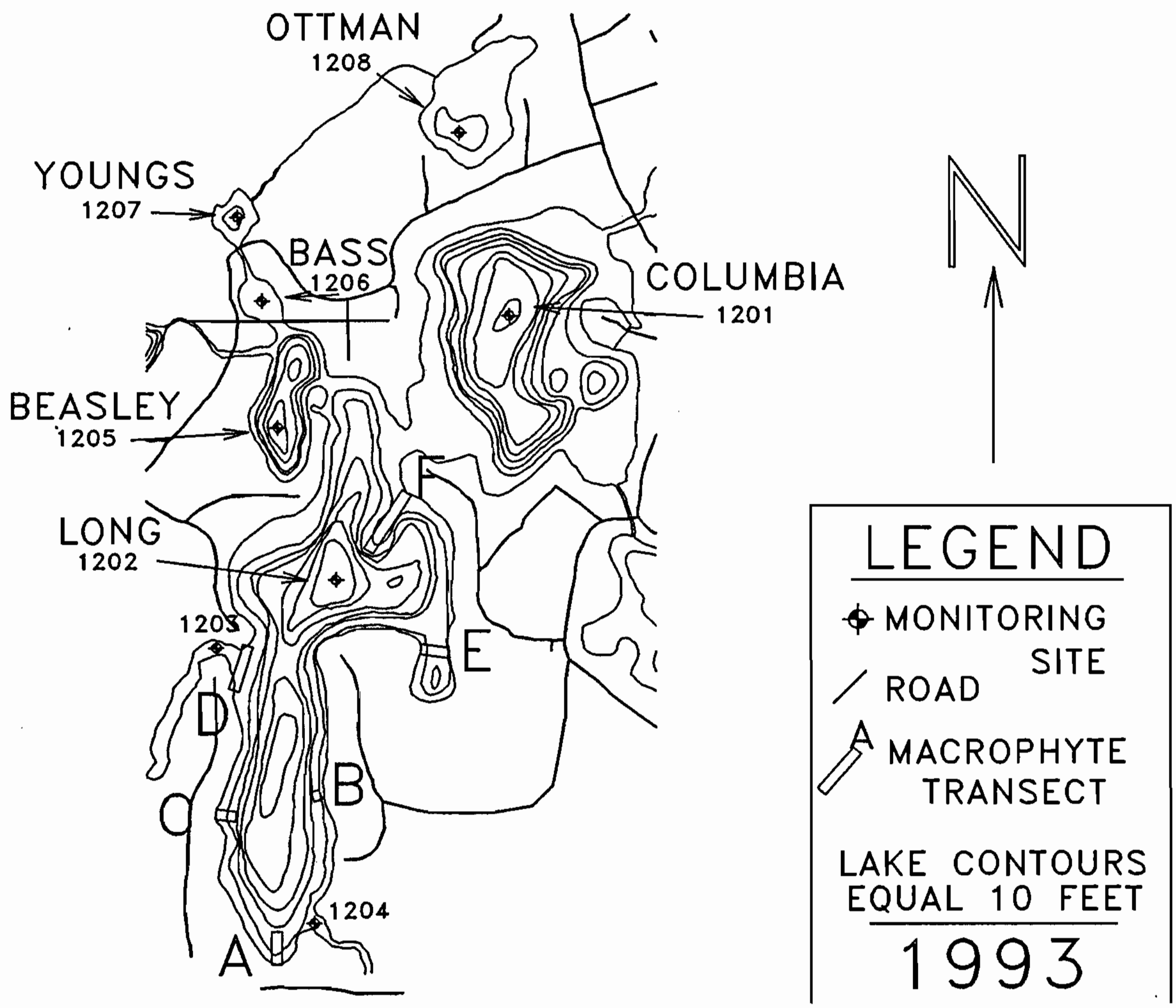

Figure 2. Sample Station Locations, Lower Chain, Chain O' Lakes, Waupaca County, WI.

All laboratory analyses were conducted at the State Laboratory of Hygiene (Madison, WI) using WDNR or APHA (8) methods. Spring parameters determined by the laboratory included laboratory pH, total alkalinity, total Kjeldahl nitrogen, ammonia nitrogen, nitrate/nitrite nitrogen, total phosphorus and dissolved phosphorus, total solids, and **chlorophyll a**. Summer and late summer laboratory analyses included total Kjeldahl nitrogen, ammonia nitrogen, nitrate/nitrite nitrogen, total phosphorus, dissolved phosphorus, and chlorophyll a. Winter water quality parameters included total Kjeldahl nitrogen, ammonia nitrogen, nitrate/nitrite nitrogen, total phosphorus and dissolved phosphorus.

Macrophyte surveys were conducted in Long Lake and near the Emmon's Creek inlet in early (May 29) and late (September 5) summer during 1991 using a method developed by Sorge et al and modified by the WDNR-Lake Michigan District (WDNR-LMD) for use in the Long Term Trend Lake Monitoring Program (9). Transect endpoints were established on and off shore for use as reference from one sampling period to the next. Points were determined using a Loran Voyager Sportnav latitude/longitude locator and recorded with bearing and distance of the transect (line of collection) for future surveys. Six transects sampled in 1991 were chosen to provide information from various habitats and areas of interest.

Data were recorded from three depth ranges, i.e., 0 to 0.5 meters (1.7 feet), 0.5 to 1.5 meters (5.0 feet), and 1.5 to 3.0 meters (10.0 feet), as appropriate along each transect. Plants were identified (collected for verification as appropriate), density ratings assigned (see below), and substrate type recorded along a six foot wide path on the transect using a garden rake, snorkel gear or SCUBA where necessary. Aquatic plant density ratings, assigned by species, were: 1 = Rare, 2 = Occasional, 3 = Common, 4 = Very Common, and 5 = Abundant. These ratings were treated as numeric data points for the purpose of simple descriptive statistics in the Field Data Discussion section of this report.

OTHER

Water Quality Information

Additional lake information was retrieved from the WDNR Surface Water Inventory (5) and the Wisconsin Lake Bulletin Board System.

Land Use Information

Details of zoning and specific land uses were obtained from the UW-Extension, Waupaca County zoning maps, United States Soil Conservation Service soil maps (6), aerial photographs, and United States Geological Survey quadrangle maps. This information, when considered questionable or outdated, was confirmed by field reconnaissance.

Ordinance information was taken from Waupaca County Zoning Ordinance and Waupaca County Soil Erosion Control and Animal Wastewater Pollution Control Plans which were acquired from the Waupaca County Land Conservation Department.

Public Involvement Program

Public involvement activities coordinated with the lake management planning process are summarized in Appendix I.

Recreational Use Survey

A survey was distributed to CLPOA for subsequent distribution to members. The survey form was designed to assess current types and levels of use and opinions regarding them. The survey was furnished to CLPOA in June and returned August, 1992; tabulation and analysis are plan development Phase II activities.

FIELD DATA DISCUSSION

The Lower Chain is comprised of six natural lakes. It receives direct drainage from a relatively large watershed, compared to other Chain project groups, and receives drainage (direct or indirect) from all Chain project groups. Flow within the Lower Chain is from Ottman to Youngs Lake, to Bass, Beasley and then to Long Lake. Columbia Lake, which receives flow from the Upper and Middle Chains through the outlet from Limekiln Lake and from the East Chain through the outlet from Dake Lake, flows into Long Lake. Beasley Lake receives flow from the Little Chain through the outlet from Orlando Lake and also drains to Long Lake. Long Lake also has a permanent inlet (Emmon's Creek) which drains over 40% of the overall Chain O' Lakes watershed. The Crystal River (originating from Long Lake) eventually drains the entire Chain O' Lakes system.

The Chain O' Lakes watershed consists of wooded/wooded residential, open/agricultural, open/residential and wetland areas. The Lower Chain direct watershed (i.e., 8500 acres, not including drainage from other project groups) is the largest of the Chain project groups. Areas adjacent to the Lower Chain are predominantly wooded/wooded residential and are relatively more wooded than areas adjacent to the Upper and Middle Chain project groups (Figure 3).

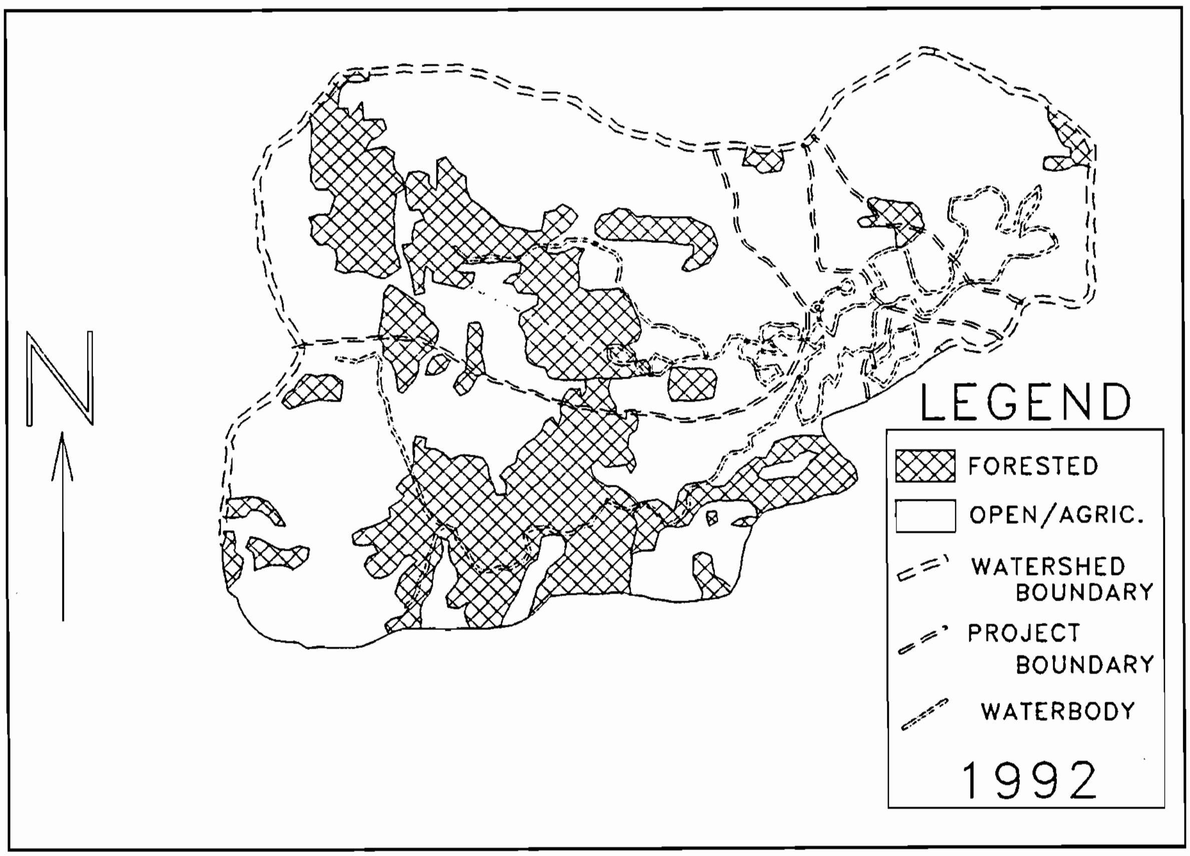

Figure 3. Land Uses in the Chain O' Lakes Watershed, Waupaca and Portage Counties, WI.

The Lower Chain has a direct watershed to lake ratio (W/L ratio, land drained directly to the Lower Chain) of about 40:1 which means that 40 times more land than lake surface area drains to the Lower Chain lakes. The overall W/L ratio is 92:1. W/L ratios for seepage lakes and drainage lakes in Wisconsin are 8:1 and 88:1, respectively. Despite the relatively high W/L value of 92:1 (which suggests a relatively high potential for nutrient and sediment input from nonpoint sources), water quality remains quite similar through the Chain as a whole and apparently reflects the substantial groundwater input to the system.

Monitoring in 1991-1992 (Tables 5-12), indicated water quality to be varied in the Lower Chain. Total nitrogen, which can be highly variable among lakes, is best considered on a trend or relative basis. Surface or mid-depth total nitrogen ranged from 0.589 mg/l (milligrams per liter or parts per million) (Columbia) to 2.89 mg/l (Youngs) with an average of 1.419 mg/l for all Lower Chain lakes. Highest average surface or mid-depth total nitrogen levels were observed in Youngs Lake (2.107 mg/l) with relatively high levels in Bass and Long Lakes and Emmon's Creek. Youngs and Bass Lake readings appear to reflect the shallow, highly productive mixed nature of the lakes while levels in Long Lake may relate to inputs from Emmon's Creek. Highest levels in the lakes were generally observed during unstratified (e.g., during spring) or ice covered conditions.

Table 5. Water Quality Parameters, Station 1201, Columbia Lake, Waupaca County, WI.

PARAMETER	SAMPLE[1]	05/29/91	08/06/91	09/04/91	01/30/92	05/06/92
Secchi (feet)		12.0	15.0	11.5	NR[2]	9.0
Cloud Cover (%)		50	80	0	100	0
Temperature (°C)	S	23.24	22.74	22.87	3.04	12.00
	B	8.5	4.89	5.41	3.63	4.48
pH (S.U.)	S	8.22	8.42	8.47	7.81	9.20
	B	7.43	6.40	6.42	NR	7.80
D.O. (mg/l)	S	8.55	8.57	8.82	9.87	10.98
	B	2.55	0.10	0.10	3.52	0.38
Conductivity (µmhos/cm)	S	322	307	293	333	311
	B	398	427	385	NR	340
Laboratory pH (S.U.)	S	8.3	NR	NR	NR	NR
	B	7.5	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	157	NR	NR	NR	NR
	B	201	NR	NR	NR	NR
Total Solids (mg/l)	S	216	NR	NR	NR	NR
	B	254	NR	NR	NR	NR
Total Kjeldahl N (mg/l)	S	0.4	0.5	0.4	0.9	0.6
	B	2.8	3.9	3.9	2.2	1.7
Ammonia Nitrogen (mg/l)	S	0.097	0.056	0.015	0.470	0.162
	B	2.16	3.20	2.97	1.51	1.03
NO_2 + NO_3 Nitrogen(mg/l)	S	0.547	0.233	0.189	0.491	0.817
	B	<0.015	ND[3]	ND	ND	0.051
Total Nitrogen (mg/l)	S	0.947	0.733	0.589	1.391	1.417
	B	<2.815	<3.900	<3.900	<2.200	1.751
Total Phosphorus (mg/l)	S	0.009	0.009	0.005	0.010	0.008
	B	0.065	0.063	0.050	0.108	0.044
Diss. Phosphorus (mg/l)	S	ND	0.003	ND	0.003	ND
	B	0.007	0.006	0.002	0.029	ND
N/P Ratio	S	105.2	81.4	117.8	139.1	177.1
	B	<43.3	<62.0	78.1	<20.4	39.8
Chlorophyll a (µg/l)	S	2[4]	2[4]	4	NR	5

[1] S = Near Surface; B = Near Bottom; [2] NR = No Reading; [3] ND = Not Detectable; [4] = Results Approximate

Table 6. Water Quality Parameters, Station 1208, Ottman Lake, Waupaca County, WI.

PARAMETER	SAMPLE[1]	06/10/91	09/05/91	02/04/92
Secchi (feet)		7.0	>9.0	NR[2]
Cloud Cover (%)		80	90	100
Temperature (°C)	M	24.50	21.66	3.80
pH (S.U.)	M	8.55	8.37	8.25
D.O. (mg/l)	M	10.47	8.25	8.44
Conductivity (µmhos/cm)	M	245	223	282
Laboratory pH (S.U.)	M	8.7	NR	NR
Total Alkalinity (mg/l)	M	107	NR	NR
Total Solids (mg/l)	M	168	NR	NR
Total Kjeldahl N (mg/l)	M	0.8	0.9	1.3
Ammonia Nitrogen (mg/l)	M	0.030	0.033	0.434
NO_2 + NO_3 Nitrogen(mg/l)	M	0.015[3]	0.023	0.100
Total Nitrogen (mg/l)	M	0.815	0.923	1.4
Total Phosphorus (mg/l)	M	0.014	0.015	0.011
Diss. Phosphorus (mg/l)	M	0.005	ND[3]	ND
N/P Ratio	M	58.2	61.5	127.3
Chlorophyll *a* (µg/l)	M	16	4	NR

[1] M = Mid-Depth; [2] NR = No Reading; [3] ND = Not Detectable

Table 7. Water Quality Parameters, Station 1207, Youngs Lake, Waupaca County, WI.

PARAMETER	05/29/91	08/06/91	09/04/91	02/04/92	05/06/92	05/06/92
Sample Depth	7.5	7.5	6.0	7.5	3.0	12.0
Secchi (feet)	>15.0	NR[1]	>12.0	NR	10.0	NR
Cloud Cover (%)	0	NR	0	100	0	NR
Temperature (°C)	18.44	19.26	18.89	4.80	11.41	7.94
pH (S.U.)	8.03	8.46	8.23	9.20	8.44	7.15
D.O. (mg/l)	9.81	11.13	10.24	8.62	12.71	0.44
Conductivity (µmhos/cm)	328	315	297	339	280	325
Laboratory pH (S.U.)	8.1	NR	NR	NR	NR	NR
Total Alkalinity (mg/l)	150	NR	NR	NR	NR	NR
Total Solids (mg/l)	218	NR	NR	NR	NR	NR
Total Kjeldahl N (mg/l)	0.4	0.4	0.4	0.4	0.4	0.6
Ammonia Nitrogen (mg/l)	0.027	0.106	0.095	0.147	0.016	0.066
NO_2 + NO_3 Nitrogen (mg/l)	1.96	1.24	1.16	2.49	1.65	1.52
Total Nitrogen (mg/l)	2.36	1.64	1.56	2.89	2.05	2.12
Total Phosphorus (mg/l)	0.010	0.012	0.008	0.010	0.016	0.021
Diss. Phosphorus (mg/l)	ND[2]	0.002	0.002	0.002	ND	ND
N/P Ratio	236.0	136.7	195.0	289.0	128.1	101.0
Chlorophyll a (µg/l)	2	3	6	NR	4	NR

[1] NR = No Reading; [2] ND = Not Detectable

Table 8. Water Quality Parameters, Station 1206, Bass Lake, Waupaca County, WI.

PARAMETER	SAMPLE[1]	05/29/91	08/06/91	09/04/91	02/04/92	05/06/92
Secchi (feet)		>8.0	>5.0	>6.0	NR[2]	>6.0
Cloud Cover (%)		NR	40	0	NR	0
Temperature (°C)	M	24.41	21.41	20.52	4.05	12.54
pH (S.U.)	M	8.37	8.89	8.44	9.66	8.25
D.O. (mg/l)	M	9.5	13.50	10.03	9.32	13.11
Conductivity (µmhos/cm)	M	296	268	271	315	283
Laboratory pH (S.U.)	M	8.3	NR	NR	NR	NR
Total Alkalinity (mg/l)	M	146	NR	NR	NR	NR
Total Solids (mg/l)	M	202	NR	NR	NR	NR
Total Kjeldahl N (mg/l)	M	0.4	0.4	0.4	0.3	0.5
Ammonia Nitrogen (mg/l)	M	0.034	0.025	0.019	0.038	0.031
NO_2 + NO_3 Nitrogen(mg/l)	M	1.20	0.790	0.751	2.34	1.19
Total Nitrogen (mg/l)	M	1.60	1.19	1.151	2.64	1.69
Total Phosphorus (mg/l)	M	0.019	0.014	0.011	0.006	0.017
Diss. Phosphorus (mg/l)	M	ND[3]	0.002	0.002	0.002	ND
N/P Ratio	M	84.2	85.0	104.6	440.0	99.4
Chlorophyll a (µg/l)	M	5	2	4	NR	4

[1] M = Mid-Depth; 2 NR = No Reading; [3] ND = Not Detectable

Table 9. Water Quality Parameters, Station 1205, Beasley Lake, Waupaca County, WI.

PARAMETER	SAMPLE[1]	05/29/91	08/06/91	09/04/91	02/04/92	05/06/92
Secchi (feet)		15.0	21.0	16.0	NR[2]	21.0
Cloud Cover (%)		0	NR	0	40	0
Temperature (°C)	S	23.72	22.01	21.83	3.87	12.88
	B	7.90	5.45	6.16	4.42	5.25
pH (S.U.)	S	8.21	8.52	8.46	7.63	7.91
	B	7.52	6.52	7.08	6.81	6.95
D.O. (mg/l)	S	8.41	9.38	9.43	8.17	9.97
	B	2.40	0.15	0.39	0.16	0.63
Conductivity (µmhos/cm)	S	311	297	289	338	297
	B	396	404	378	355	341
Laboratory pH (S.U.)	S	8.3	NR	NR	NR	NR
	B	7.4	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	163	NR	NR	NR	NR
	B	216	NR	NR	NR	NR
Total Solids (mg/l)	S	210	NR	NR	NR	NR
	B	256	NR	NR	NR	NR
Total Kjeldahl N (mg/l)	S	0.3	0.3	0.3	0.3	0.3
	B	2.3	3.4	2.8	1.1	1.1
Ammonia Nitrogen (mg/l)	S	0.085	0.043	0.024	0.183	0.054
	B	1.71	2.67	1.78	0.850	0.843
$NO_2 + NO_3$ Nitrogen(mg/l)	S	0.708	0.519	0.511	1.62	1.13
	B	<0.015	0.008	ND[3]	0.528	0.540
Total Nitrogen (mg/l)	S	1.008	0.819	0.811	1.92	1.43
	B	<2.315	3.408	<2.800	1.628	1.64
Total Phosphorus (mg/l)	S	0.008	0.009	0.005	0.017	0.006
	B	0.31	0.49	0.25	0.094	0.114
Diss. Phosphorus (mg/l)	S	ND	0.002	ND	0.005	ND
	B	0.238	0.36	0.164	0.080	0.068
N/P Ratio	S	126.0	91.0	162.2	112.9	238.3
	B	<7.5	7.0	<11.2	17.3	14.4
Chlorophyll *a* (µg/l)	S	1[4]	2[4]	3	NR	2[4]

[1] S = Near Surface; B = Near Bottom; [2] NR = No Reading; [3] ND = Not Detectable; [4] = Results Approximate

Table 10. Water Quality Parameters, Station 1202, Long Lake (Deepest Point), Waupaca County, WI.

PARAMETER	SAMPLE[1]	05/29/91	08/06/91	09/04/91	01/30/92	05/05/92
Secchi (feet)		17.0	12.0	12.0	NR[2]	16.3
Cloud Cover (%)		20	80	0	100	5
Temperature (°C)	S	22.66	21.25	21.04	1.71	12.26
	B	9.10	5.66	6.22	3.69	4.83
pH (S.U.)	S	8.21	8.42	8.45	7.93	8.03
	B	7.83	6.73	7.12	NR	7.05
D.O. (mg/l)	S	8.34	9.43	9.25	9.96	10.33
	B	3.30	0.10	0.14	2.57	2.06
Conductivity (µmhos/cm)	S	326	325	315	343	312
	B	372	356	335	347	323
Laboratory pH (S.U.)	S	8.3	NR	NR	NR	8.39
	B	7.7	NR	NR	NR	7.88
Total Alkalinity (mg/l)	S	168	NR	NR	NR	170
	B	188	NR	NR	NR	183
Total Solids (mg/l)	S	214	NR	NR	NR	NR
	B	242	NR	NR	NR	NR
Total Kjeldahl N (mg/l)	S	0.4	0.2	0.3	0.6	0.5
	B	0.6	1.0	0.8	1.0	0.4
Ammonia Nitrogen (mg/l)	S	0.073	0.023	0.016	0.274	0.073
	B	0.322	0.709	0.508	0.637	0.151
NO_2 + NO_3 Nitrogen(mg/l)	S	0.950	0.902	0.956	1.34	1.33
	B	0.990	0.512	0.506	0.700	1.39
Total Nitrogen (mg/l)	S	1.35	1.102	1.256	1.94	1.83
	B	1.59	1.512	1.306	1.70	1.79
Total Phosphorus (mg/l)	S	0.009	0.010	0.009	0.020	0.005
	B	0.047	0.57	0.157	0.042	0.017
Diss. Phosphorus (mg/l)	S	ND[3]	0.002	ND	0.002	ND
	B	0.029	0.181	0.111	0.036	0.009
N/P Ratio	S	150.0	110.2	139.6	97.0	366.0
	B	33.8	2.6	8.3	40.5	NR
Chlorophyll *a* (µg/l)	S	1[4]	2	5	NR	1[4]

[1] S = Near Surface; B = Near Bottom; [2] NR = No Reading; [3] ND = Not Detectable; [4] = Results Approximate

Table 11. Water Quality Parameters, Station 1203, Long Lake (Emmon's Creek Inlet), Waupaca County, WI.

PARAMETER	SAMPLE[1]	05/29/91	08/06/91	09/04/91	05/05/92
Secchi (feet)		>3.0	>3.0	>3.0	>3.0
Cloud Cover (%)		0	50	0	10
Temperature (°C)	M	22.66	21.47	20.88	12.03
pH (S.U.)	M	8.16	8.43	8.46	8.19
D.O. (mg/l)	M	8.54	10.01	9.32	12.99
Conductivity (µmhos/cm)	M	329	327	317	329
Laboratory pH (S.U.)	M	8.3	NR[2]	NR	8.48
Total Alkalinity (mg/l)	M	170	NR	NR	185
Total Solids (mg/l)	M	222	NR	NR	NR
Total Kjeldahl N (mg/l)	M	0.3	0.4	0.3	<0.2
Ammonia Nitrogen (mg/l)	M	0.061	0.028	ND[3]	0.029
NO_3 + NO_2 Nitrogen(mg/l)	M	1.01	0.996	0.955	2.06
Total Nitrogen (mg/l)	M	1.31	1.396	1.255	<2.26
Total Phosphorus (mg/l)	M	0.008	0.022	0.009	0.006
Diss. Phosphorus (mg/l)	M	ND	0.002	0.002	0.002
N/P Ratio	M	163.8	63.4	139.4	<376.7
Chlorophyll a (µg/l)	M	NR	4	5	NR

[1] M = Mid-Depth; [2] NR = No Reading; [3] ND = Not Detectable

Table 12. Water Quality Parameters, Station 1204, Long Lake (Crystal River Outlet), Waupaca County, WI.

PARAMETER	SAMPLE[1]	05/29/91	08/06/91	09/04/91	05/05/92
Secchi (feet)		>3.0	>3.0	>3.0	>3.0
Cloud Cover (%)		NR[2]	50	0	5
Temperature (°C)	M	21.57	21.19	20.88	12.88
pH (S.U.)	M	8.11	8.45	8.46	8.14
D.O. (mg/l)	M	8.40	9.50	9.25	10.97
Conductivity (µmhos/cm)	M	331	326	315	310
Laboratory pH (S.U.)	M	8.2	NR	NR	8.40
Total Alkalinity (mg/l)	M	172	NR	NR	171
Total Solids (mg/l)	M	222	NR	NR	NR
Total Kjeldahl N (mg/l)	M	0.3	0.3	0.3	0.2
Ammonia Nitrogen (mg/l)	M	0.077	0.016	ND[3]	0.065
NO_2 + NO_3 Nitrogen(mg/l)	M	1.08	0.955	0.977	1.47
Total Nitrogen (mg/l)	M	1.38	1.255	1.277	1.67
Total Phosphorus (mg/l)	M	0.009	0.011	0.013	0.005
Diss. Phosphorus (mg/l)	M	ND	0.002	ND	0.002
N/P Ratio	M	153.3	114.1	98.2	334.0
Chlorophyll a (µg/l)	M	NR	3	5	NR

[1] M = Mid-Depth; [2] NR = No Reading; [3] ND = Not Detectable

Phosphorus is often the limiting nutrient in plant and algal production in lakes. Surface or mid-depth total phosphorus levels for the Lower Chain ranged from 0.005 (Columbia, Beasley, Long and the Crystal River) to 0.022 mg/l (Emmon's Creek) (Tables 5-12). Surface total phosphorus levels were also variable between lakes of different size, average depth and inflow conditions. Summer levels were, however, much lower than those typical for stratified lakes (0.023 mg/l) and central region lakes (0.020 mg/l) in Wisconsin (10). Only levels in the shallower mixed Ottman, Youngs and Bass Lake levels were typically near or slightly above those typical for the ecoregion in which the Chain is located (0.010-0.014 mg/l) (11) (Figure 4).

Substantially higher values for total phosphorus and other nutrient parameters were observed near bottom at Columbia, Beasley and Long Lakes, and suggested nutrient release from sediments under **anoxic** or near-anoxic conditions in the **hypolimnion** during summer stratification at these relatively deep points. Nitrogen to phosphorus ratios (**N/P ratio**) for surface or mid-depth readings indicated all lakes to be phosphorus limited.

The largest Lower Chain lakes (Beasley, Columbia and Long) thermally stratified during summer monitoring (Figure 5, Appendix II). Depth to the thermocline was lake specific [minimum 15 feet (Beasley Lake), maximum 21 feet (Columbia Lake)]. Hypolimnetic

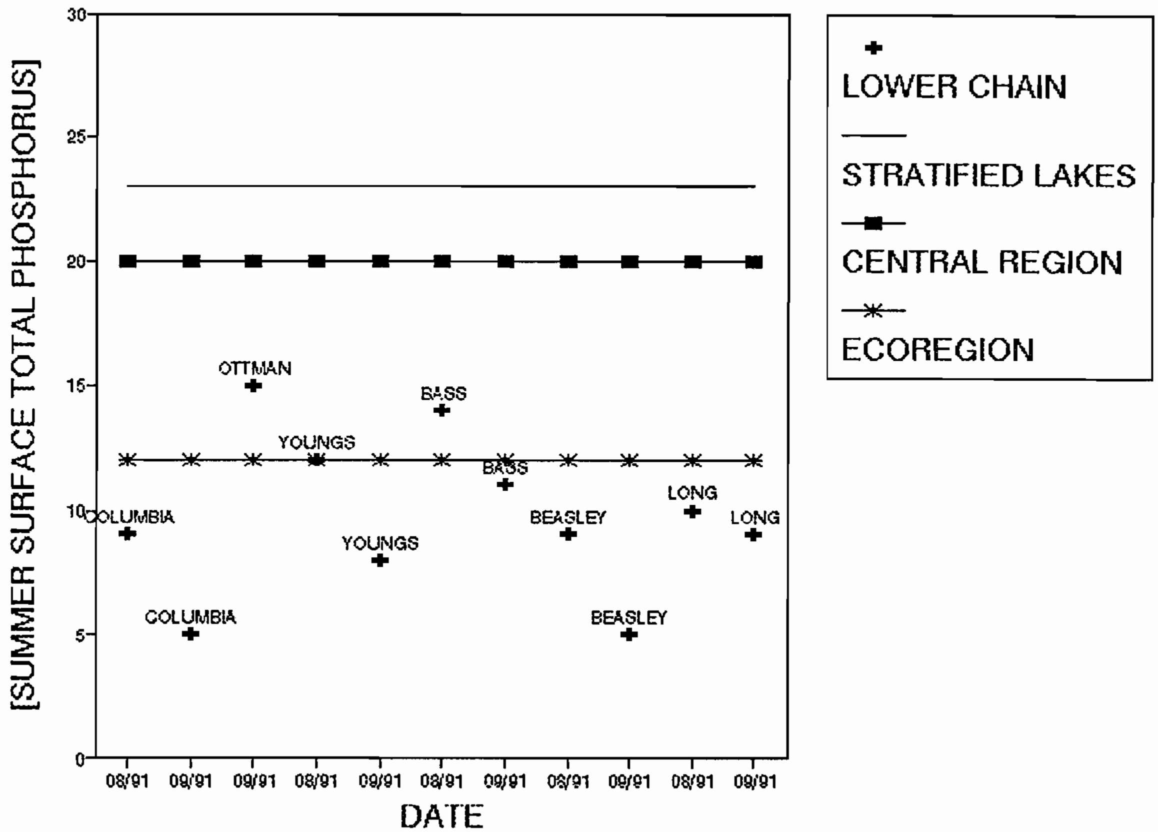

Figure 4. Comparison of Total Phosphorus Levels, Lower Chain, Chain O' Lakes, 1991.

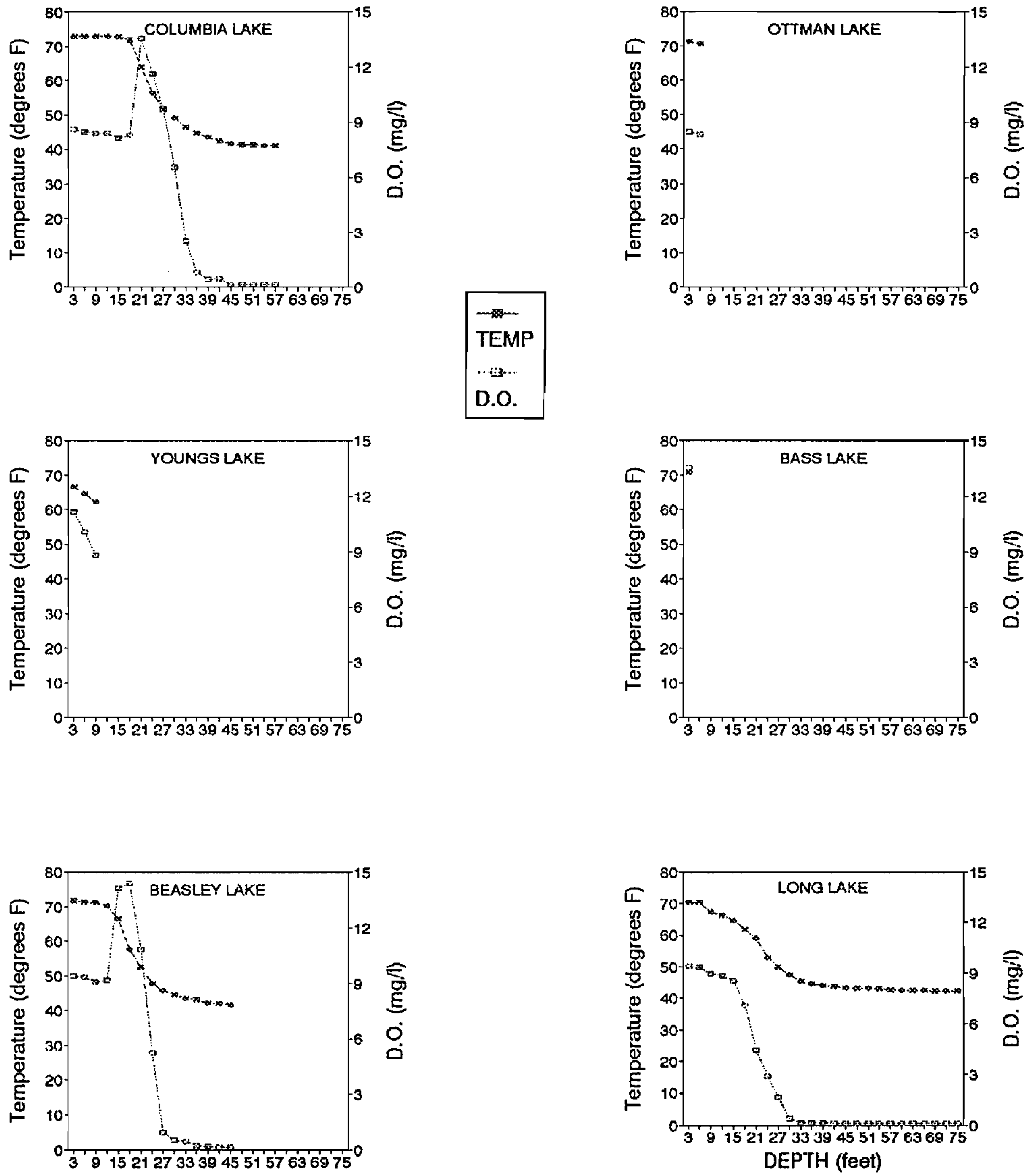

Figure 5. Temperature/DO Profiles, Lower Chain, Chain O' Lakes, Summer, 1991.

oxygen levels were below those generally considered necessary to sustain most aquatic life. Winter water column readings indicated typical unstratified conditions with dissolved oxygen levels decreasing with increasing lake depth (Figure 6).

Numerous summarative indices have been developed to indicate lake **eutrophication** status based on water quality parameters. The Trophic State Index (TSI) developed by Carlson (12) utilizes Secchi transparency, chlorophyll a, and total phosphorus. As with most indices, application is generally most appropriate on a relative and trend monitoring basis. This particular index does not account for natural, regional variability in total phosphorus levels nor in Secchi transparency reduction unrelated to algal growth (e.g. that associated with color). TSI numbers for the Lower Chain sampling sites, in general, indicated oligotrophic to mesotrophic conditions with no readily discernable trend evident from the limited amount of historic data available (Figure 7).

Macrophyte surveys (Tables 13-16, Appendix IV) indicated an abundance of generally beneficial species in Long Lake. Nitella spp. was most abundant (24 of 32 sites) and is typically found in hard water lakes with hard or sandy substrates (13).

Water celery (Vallisneria americana), a common Wisconsin species, was found less frequently (at 21 of 32 sites). Water celery

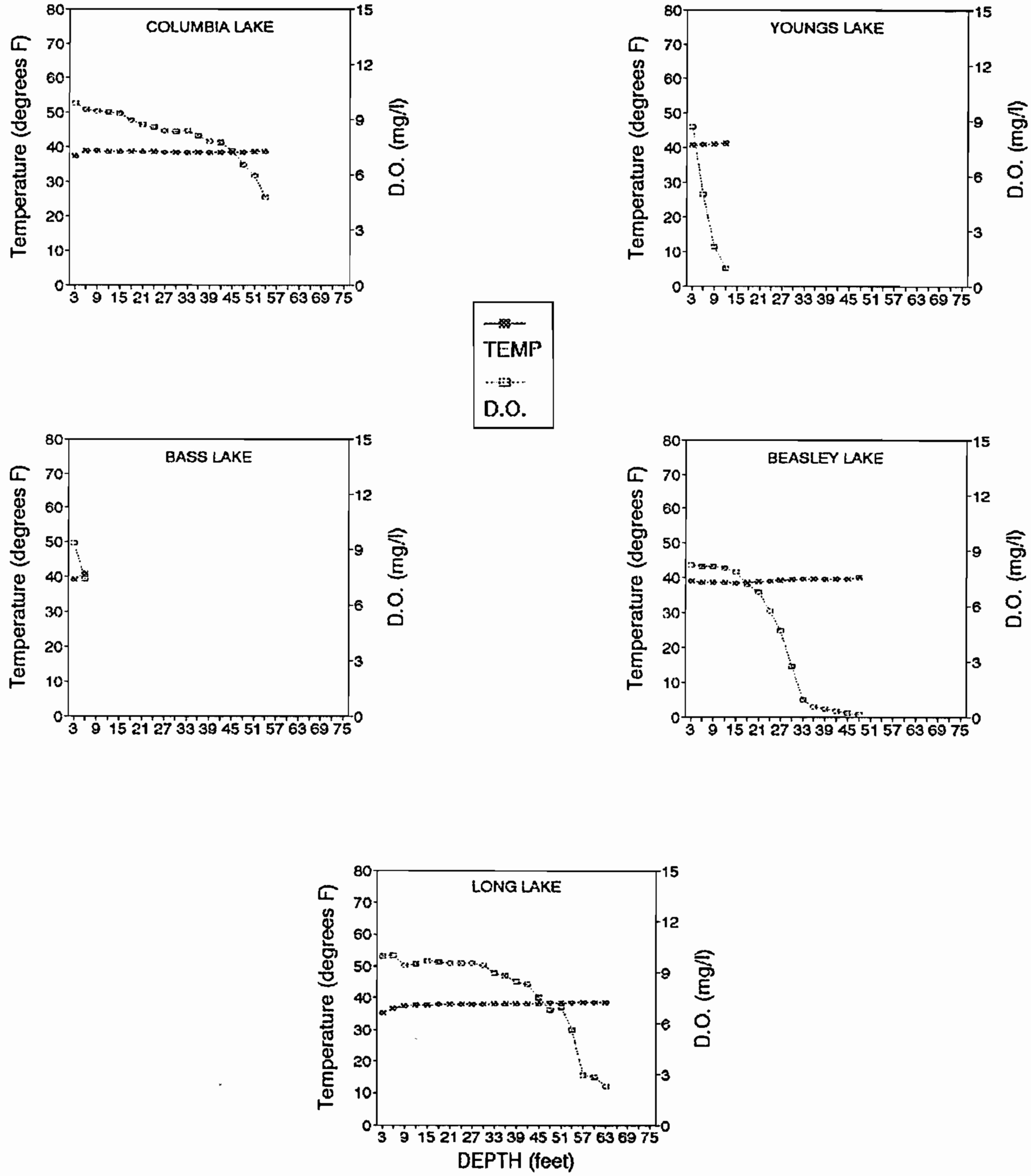

Figure 6. Temperature/DO Profiles, Lower Chain, Chain O' Lakes, Winter, 1992.

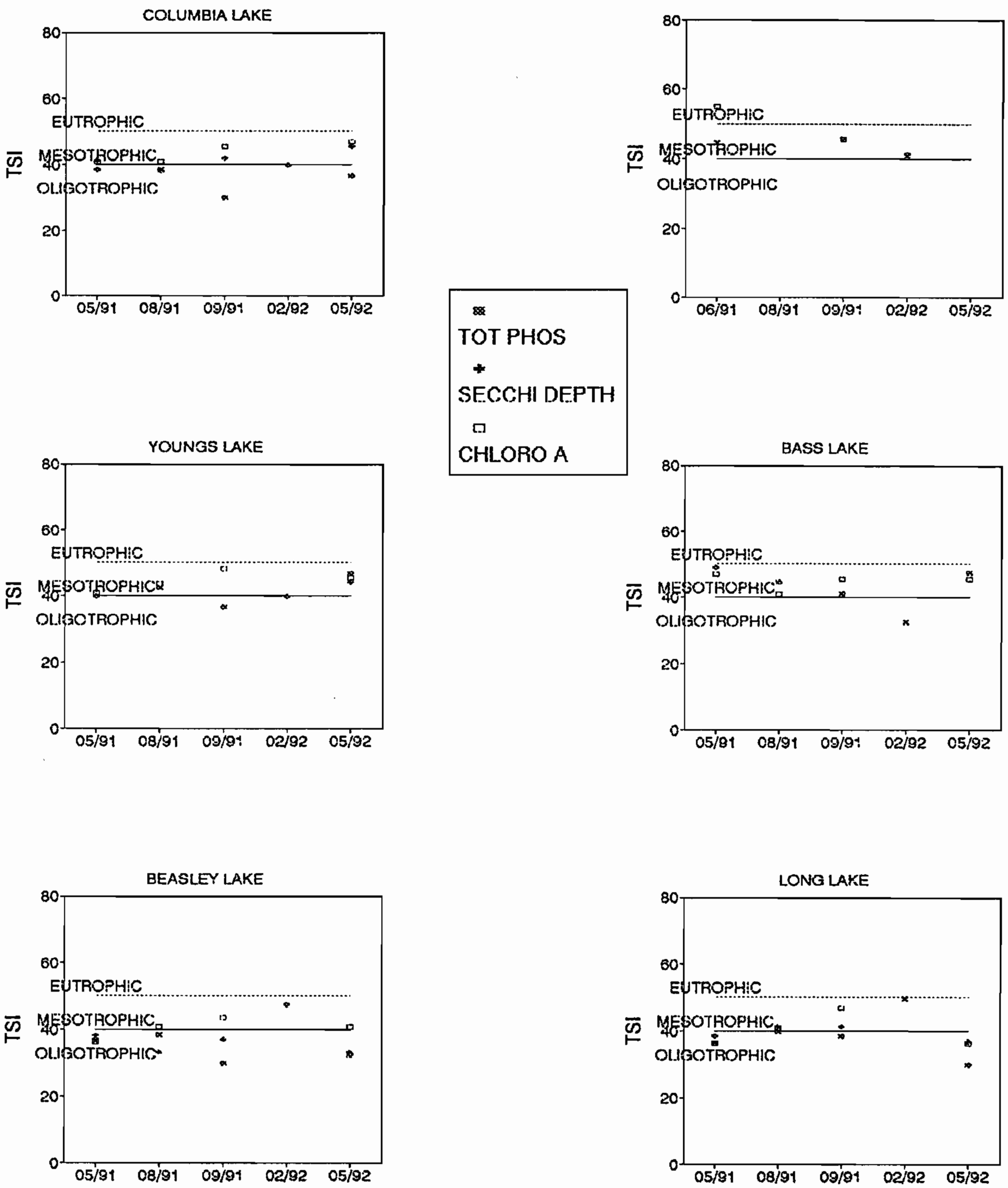

Figure 7. Trophic State Index for Secchi Depth, Total Phosphorus and Chlorophyll a, Lower Chain

Table 13. Macrophyte Species Observed, Long Lake, 1991 (13).

Taxa	Code
Coontail (*Ceratophyllum demersum*)	CERDE
Common waterweed (*Elodea canadensis*)	ELOCA
Filamentous algae	FILAL
Small duckweed (*Lemna minor*)	LEMMI
Water milfoil (*Myriophyllum* spp.)	MYRSP
Bushy pondweed (*Najas* spp.)	NAJSP
Nitella (*Nitella* spp.)	NITSP
No plants found	NOPLT
Yellow pond lily (*Nuphar* spp.)	NUPSP
White pond lily (*Nymphaea* spp.)	NYMSP
Pickerel-weed (*Pontedaria cordata*)	PONCO
Large-leaf pondweed (*Potamogeton amplifolious*)	POTAM
Leafy pondweed (*Potamogeton foliosus*)	POTFO
Variable-leaf pondweed (*Potamogeton gramineus*)	POTGR
Illinois pondweed (*Potamogeton illinoensis*)	POTIL
Floating-leaf pondweed (*Potamogeton natans*)	POTNA
Sago pondweed (*Potamogeton pectinatus*)	POTPE
Clasping-leaf pondweed (*Potamogeton richardsonii*)	POTRI
Unidentified pondweed (*Potamogeton* spp.)	POTSP
Flat-stem pondweed (*Potamogeton zosteriformis*)	POTZO
Arrowhead (*Sagittaria* spp.)	SAGSP
Rush (*Scirpus* spp.)	SCISP
Broad-leaf cattail (*Typha latifolia*)	TYPLA
Water celery (*Vallisneria americana*)	VALAM

Table 14. Occurrence and Abundance of Macrophytes by Depth, Long Lake, May, 1991.

CODE	Depth Ranges 1 (N=6) % of Sites	1 (N=6) Σ Abundance (range)	2 (N=6) % of Sites	2 (N=6) Σ Abundance (range)	3 (N=4) % of Sites	3 (N=4) Σ Abundance (range)
SAGSP	33	4(2)	17	2(2)	0	0
NAJSP	33	6(3)	33	4(1-3)	0	0
NITSP	67	9(1-3)	67	10(1-3)	75	12(4)
POTNA	33	3(1-2)	17	1(1)	0	0
NYMSP	17	2(2)	0	0	0	0
POTPE	83	12(1-4)	33	6(2-4)	25	1(1)
POTFO	17	1(1)	17	2(2)	0	0
VALAM	33	3(3)	83	9(1-2)	100	6(2)
FILAL	17	3(3)	17	3(3)	25	1(1)
POTRI	0	0	50	4(1-2)	75	4(1-2)
MYRSP	0	0	33	2(1)	100	5(1-2)
ELOCA	17	1(1)	17	1(1)	25	1(1)
POTGR	17	1(1)	17	1(1)	0	0
POTZO	0	0	17	2(2)	75	6(2)
NOPLT	17	0	0	0	0	0
LEMMI	17	2(2)	0	0	0	0
CERDE	17	2(2)	17	1(1)	0	0
NUPSP	17	1(1)	0	0	0	0
SCISP	0	0	17	1(1)	0	0
TYPLA	0	0	0	0	0	0
POTIL	0	0	0	0	0	0
POTAN	0	0	0	0	0	0
POTAM	0	0	0	0	0	0
PONCO	0	0	0	0	0	0

(also known as eel grass), has long tape-like leaves, grows completely submerged and is typically found on hard substrates; abundance can increase with turbidity. It is rated as excellent waterfowl food and provides fish with forage, cover and spawning habitat but can reach nuisance levels (13). Water celery produces seeds, but spreads mainly from rhizome growth and reproduces mainly by tubers from one year to the next (14).

Table 15. Occurrence and Abundance of Macrophytes by Depth, Long Lake, September, 1991.

	Depth Ranges					
CODE	1 (N=6)		2 (N=6)		3 (N=4)	
	% of Sites	Σ Abundance (range)	% of Sites	Σ Abundance (range)	% of Sites	Σ Abundance (range)
SAGSP	17	1(1)	0	0	0	0
NAJSP	33	3(1)	17	3(3)	75	7(2-3)
NITSP	67	9(2-3)	83	12(2-3)	100	11(2-3)
POTNA	0	0	0	0	0	0
NYMSP	33	2(1)	0	0	0	0
POTPE	33	2(1)	33	3(1-2)	25	1(1)
POTFO	0	0	17	2(2)	25	1(1)
VALAM	33	3(1)	83	10(1-3)	75	6(2)
FILAL	17	1(1)	17	3(3)	25	3(3)
POTRI	0	0	0	0	0	0
MYRSP	0	0	17	2(2)	100	7(1-3)
ELOCA	0	0	33	4(2)	50	4(2)
POTGR	0	0	0	0	0	0
POTZO	33	3(1-2)	17	2(2)	75	5(1-2)
NOPLT	17	0	0	0	0	0
LEMMI	33	4(2)	0	0	0	0
CERDE	0	0	0	0	25	1(1)
NUPSP	17	2(2)	0	0	0	0
SCISP	17	2(2)	0	0	0	0
TYPLA	33	3(1-2)	0	0	0	0
POTIL	17	2(2)	33	4(2)	50	5(2-3)
POTAN	0	0	33	4(2)	50	2(1)
POTAM	17	2(2)	0	0	0	0
PONCO	17	2(2)	17	2(2)	0	0

Pondweeds (Potamogeton spp.), as a group, were common and abundant; P. pectinatus was the most common and abundant pondweed species. Pondweeds are probably the most beneficial group of plants with respect to wildlife benefits. Pondweeds have leaves with a relatively large surface area which support numerous species of aquatic invertebrates (forage fish food); the plants

Table 16. Abundance Distribution and Substrate Relations for Selected Macrophytes, Long Lake, 1991.

Transect	Substrate	Species Code																			
		NITSP		VALAM		POTPE		NAJSP		POTZO		MYRSP		FILAL		ELOCA		POTIL		POTRI	
		M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S
A1	SAND/SILT	3	3	0	2	1	1	3	1	0	2	0	0	0	0	0	0	0	2	0	0
A2	SAND/SILT	3	2	1	3	0	0	0	0	0	0	1	2	3	3	1	2	0	0	1	0
A3	SILT/MUCK	4	3	2	0	1	0	0	0	0	1	2	3	0	3	0	2	0	3	1	0
B1	SAND	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2	SAND	3	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
B3	MUCK/SAND	4	3	1	2	0	1	0	2	2	0	1	2	0	0	0	2	0	0	0	0
C1	SAND	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C2	SAND	0	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0
C3	SAND/SILT	4	3	1	2	0	0	0	3	2	2	1	1	0	0	1	0	0	2	2	0
D1	MUCK	3	2	0	1	4	1	0	0	0	1	0	0	3	1	1	0	0	0	0	0
D2	MUCK	3	3	2	0	4	2	0	0	2	2	1	0	0	0	0	2	0	0	0	0
E1	SILT/SAND	0	0	2	0	2	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0
E2	SILT/SAND	0	0	2	2	2	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0
E3	SILT	0	2	2	2	0	0	0	2	2	2	1	1	1	0	0	0	0	0	1	0
F1	SAND/GRAVEL	2	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F2	SAND/SILT	1	2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0

also provide cover and spawning habitat and produce roots, shoots, stems, seeds and tubers that are highly desirable waterfowl food (13).

Water milfoil (Myriophyllum spp.) was also present (11 sites) and moderately abundant in Long Lake. Species determination was not verifiable because of a lack of floral bracts during the sample periods. Species may include Eurasian Milfoil, an exotic plant known to spread rapidly, displace native plants and change plant and animal assemblages. The plants did not exhibit the more obvious distinguishing characteristics of Eurasian Milfoil, e.g. red-tinged stems and shoots and more than 12 pair of leaflets, but positive species determination should still be attempted.

BASELINE CONCLUSIONS

The Lower Chain is a group of six interconnected lakes that accounts for about 30 percent of the total lake area of the Chain O' Lakes. The Lower Chain eventually receives, directly or indirectly, inflow from the total Chain O' Lakes watershed.

Despite the relatively large watershed, water quality is good to excellent for all parameters measured and indicates high infiltration of surface runoff, high groundwater inflow and, overall, an oligotrophic to mesotrophic classification. The shallower well mixed lakes (Ottman, Bass, Youngs) had relatively higher nutrient readings, but levels were near or only slightly above those typical of lake type and regional location. Long Lake, the downstream-most lake in the chain which also receives direct inflow via Emmon's Creek, had lower than expected nutrient levels. No trends were evident from the limited amount of historical data available. Very good to excellent water quality is attributable to low overland inflow to the Chain O' Lakes system (as a result of high soil infiltration), a relatively small, predominantly forested watershed, high flushing from groundwater flow and nutrient tie up from marl precipitation.

Macrophyte populations appeared to positively affect the resource (as a whole) through shoreline stabilization, nutrient uptake and fish food and habitat production. Most common plants included Nitella spp., water celery and pondweeds; macrophytes, overall, did not appear to be present at nuisance levels in Long Lake. Plants were present and concentrated near the Emmon's Creek inlet to Long Lake where sedimentation has created a soft, organic layer. Eurasian Milfoil may be present, though observed plants did not possess the more obvious distinguishing characteristics of the species.

Recreational use during summer months is excessive and the towns and lake association have taken steps to control boat traffic. A recreational use survey was distributed during Phase I of this project to identify and quantify the uses.

MANAGEMENT RECOMMENDATIONS

Management of the Lower Chain should target maintenance of existing good water quality through continued monitoring, reduction of nutrient inflow to the system (where possible and practical), protection of important or sensitive areas throughout the watershed and an assessment of the need for further regulation on the Chain to maximize enjoyment of the resource.

Relatively little is known about historic water quality on the Lower Chain; efforts should be made to continue water quality testing. Testing should also include event testing of areas of concern (a compost area adjacent to Bass Lake and in the Emmon's Creek inlet or basin). Regular monitoring should be conducted in a similar schedule; event testing should be conducted after major rain or runoff events. Self-Help Secchi readings should be taken for each lake in the Lower Chain.

Riparian landowners have been involved from the onset of these projects and can lend additional help by implementing lake lot management practices to prevent nutrient and sediment runoff to the lakes. Many of these practices are common sense approaches. Buffer stripping, fertilizer and compost management and runoff control are inexpensive ways to help reduce these inputs and slow lake aging processes.

Fertilizers should be used sparingly, if at all. If used, the land owner should use phosphate-free fertilizers and apply small amounts more often instead of large amounts at one or two times. Composting lawn clippings and leaves away from the lake can reduce nutrient inputs to the lake. If leaves are burned, it should be done in an area where the ash cannot wash directly into the lake, or indirectly to the lake via roadside ditches.

Creation of a buffer strip with diverse plants at least 20 feet wide immediately adjacent to the lake can control wave erosion, trap soil eroded from the land above and increase infiltration (to filter nutrients and soil particles). Buffer strips can also shade areas of the lake to reduce macrophyte growth (especially on south shores) and provide fish cover. Placement of a low berm in this area can enhance effectiveness by further retarding runoff during rainfalls. A buffer zone protects lake water quality, creates habitat for wildlife, and provides privacy.

Sources of local assistance for landowners who would like more information on these or other methods of land management are outlined in Appendix V. Information on pertinent ordinances and plans are presented in Appendix VI.

Because the Lower Chain direct watershed is relatively large, nonpoint source nutrient and sediment inflows are a potential problem at relatively higher flows and in areas of disturbance in the watershed. Efforts should be made to identify sensitive areas throughout the watershed and protect these areas from disturbance. Open/agricultural areas of concern may take advantage of cost share funding to help reduce sediment and nutrient runoff.

Plant populations appear to positively affect the resource through fish and forage production/protection, shoreline stabilization and nutrient uptake. Potentially nuisance species are present in some areas but the habitat, overall, does not appear conducive to development of nuisance abundance levels. Management of these populations should be limited to landowner raking of nuisance species. Species determination should be made for milfoil species present in the Lower Chain.

Recreational use survey data, when compiled and analyzed should indicate the attitudes and preferences of landowners adjacent to the Chain. These data may help to focus recreation management efforts or identify options (e.g., further regulation) to maximize enjoyment of the Chain O' Lakes resource.

The CLPOA, in cooperation with local townships, Waupaca County and the State of Wisconsin, should take an active role in protection of the Chain resource from invasion by exotic, potentially harmful species. The spread of purple loosestrife or introduction of Eurasian milfoil and other exotic species may be slowed or prevented by posting signs at boat landings, providing brochures or other materials to educate the public about harmful species and their prevention. Efforts must also be made to control known populations of purple loosestrife and Eurasian milfoil.

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APPENDIX I
SUMMARY OF PUBLIC INVOLVEMENT ACTIVITIES
Chain O' Lakes Management Plans

The Chain O' Lakes Property Owners Association (CLPOA) initiated steps to develop comprehensive lake management plans under the Wisconsin Department of Natural Resources (WDNR) Lake Management Planning Grant Program in the fall of 1990. The grants were received on April 1, 1991. A public involvement program was immediately initiated as part of the planning process. The following is a summary of major public involvement efforts.

Planning Advisory Committee

An advisory committee comprised of representatives from WDNR, CLPOA, IPS, and Waupaca County UW-Extension was established at the start of the program. The committee provided direction during the planning program and served as main reviewer of the draft plan documents.

Brochures

A brochure entitled "Chain O' Lakes Management Planning" was also produced. Over 1000 copies were made available for CLPOA use and distribution. The brochure described the main features of plan development and pertinent information specific to the Chain O' Lakes management plan.

Meetings

The CLPOA conducted meetings for its board, its members and interested parties. IPS presented progress reports, provided information about the resource and interpretations of these results at board meetings and at the 1991 and 1992 CLPOA annual meetings.

Print Media

An IPS newsletter entitled "Lake Management News" was developed and distributed to the CLPOA for the Board's use and distribution among the membership. A special "Chain O' Lakes Edition" was also developed to notify the CLPOA of any late developments in the planning program.

APPENDIX II
LOWER CHAIN TEMPERATURE/DO PROFILES, 1991 - 1992
(Thermocline denoted in Bold Type)

OTTMAN LAKE
02/04/92

Depth (ft)	Temp. °C	DO (mg/l)
3	3.80	8.44
6	3.90	8.20
9	3.90	8.03
12	3.91	7.63

YOUNGS LAKE

08/06/91

Depth(ft)	Temp. °C	DO(mg/l)
3	19.26	11.13
6	**18.17**	**10.05**
9	**16.79**	**8.80**

02/04/92

Depth(ft)	Temp. °C	DO(mg/l)
3	4.80	8.62
6	4.95	5.01
9	5.00	2.14
12	5.17	1.00

BASS
02/04/92

Depth (ft)	Temp. °C	DO (mg/l)
3	4.05	9.32
6	4.98	7.38

BEASLEY LAKE

08/06/91

Depth(ft)	Temp. °C	DO(mg/l)
3	22.01	9.38
6	21.84	9.29
9	21.73	9.05
12	21.24	9.16
15	**19.20**	**14.10**
18	**14.23**	**14.40**
21	**11.35**	**10.81**
24	**8.87**	**5.28**
27	**7.70**	**0.94**
30	7.00	0.51
33	6.49	0.47
36	6.20	0.24
39	5.66	0.20
42	5.58	0.15
45	5.45	0.15

02/04/92

Depth(ft)	Temp. °C	DO(mg/l)
3	3.87	8.17
6	3.72	8.13
9	3.63	8.10
12	3.64	7.99
15	3.62	7.81
18	3.76	7.12
21	3.79	6.73
24	3.87	5.72
27	4.00	4.64
30	4.13	2.72
33	4.26	0.95
36	4.25	0.56
39	4.25	0.45
42	4.29	0.33
45	4.29	0.22
48	4.42	0.16

APPENDIX II
(Continued)
(Thermocline denoted in Bold Type)

COLUMBIA LAKE

08/06/91			01/30/92		
Depth(ft)	Temp. °C	DO(mg/l)	Depth(ft)	Temp. °C	DO(mg/l)
3	22.74	8.57	3	3.04	9.87
6	22.73	8.45	6	3.82	9.53
9	22.71	8.38	9	3.80	9.42
12	22.71	8.36	12	3.76	9.39
15	22.63	8.12	15	3.76	9.31
18	22.10	8.28	18	3.72	8.94
21	**17.74**	**13.50**	21	3.70	8.71
24	**13.47**	**11.60**	24	3.67	8.56
27	**11.05**	**9.65**	27	3.62	8.40
30	**9.51**	**6.53**	30	3.61	8.35
33	7.95	2.52	33	3.59	8.36
36	6.99	0.79	36	3.60	8.12
39	6.38	0.43	39	3.60	7.82
42	5.80	0.44	42	3.61	7.71
45	5.31	0.15	45	3.60	7.29
48	5.09	0.15	48	3.62	6.53
51	5.05	0.15	51	3.64	5.93
54	5.04	0.15	54	3.63	4.76
57	4.98	0.15	57	3.62	4.11
60	4.94	0.10	60	3.63	3.52
63	4.89	0.10			
66	4.91	0.10			
69	4.91	0.10			
72	4.89	0.10			

LONG LAKE

08/06/91			01/30/92		
Depth(ft)	Temp. °C	DO(mg/l)	Depth(ft)	Temp. °C	DO(mg/l)
3	21.25	9.43	3	1.77	9.96
6	21.22	9.34	6	2.57	9.99
9	19.58	8.96	9	3.02	9.39
12	19.07	8.81	12	3.20	9.49
15	18.20	8.55	15	3.20	9.66
18	**16.57**	**7.07**	18	3.24	9.60
21	**14.98**	**4.42**	21	3.25	9.53
24	**11.57**	**2.86**	24	3.25	9.53
27	**9.83**	**1.62**	27	3.25	9.53
30	**8.53**	**0.38**	30	3.28	9.39
33	**7.43**	**0.13**	33	3.33	8.94
36	6.85	0.13	36	3.37	8.79
39	6.60	0.14	39	3.41	8.48
42	6.46	0.09	42	3.42	8.28
45	6.34	0.09	45	3.46	7.49
48	6.23	0.09	48	3.50	6.77
51	6.20	0.09	51	3.48	6.94
54	6.10	0.09	54	3.53	5.62
57	6.00	0.09	57	3.66	2.93
60	5.85	0.10	60	3.64	2.81
63	5.78	0.10	63	3.69	2.28
66	5.74	0.10	66	3.68	2.40
69	5.68	0.10	70	3.69	2.57
72	5.70	0.10			
74	5.66	0.10			

APPENDIX III
HISTORIC WATER QUALITY DATA
Bass Lake, Waupaca County, WI
Water Chemistry: 06/87; Deepest Site
Source: UW-Stevens Point Environmental Task Force

PARAMETER	Sample Date 06/23/87
Depth (feet)	0
Secchi (meters)	1.7
pH (S.U.)	8.19
Conductivity (μmhos/cm)	244
Total Alkalinity (mg/l $CaCO_3$)	117
Calcium (mg/l $CaCO_3$)	84.0
Magnesium (mg/l $Ca\ CO_3$)	56.0
Hardness (mg/l $CaCO_3$)	140.0
Sodium (mg/l)	2.0
Potassium (mg/l)	0.8
Chloride (mg/l)	3.0
Turbidity (NTU's)	0.5
Color (S.U.)	35
Total Kjeldahl N (mg/l)	0.60
Ammonia Nitrogen (mg/l)	0.16
NO_2 + NO_3 Nitrogen (mg/l)	1.08
Total Nitrogen (mg/l)	1.68
Total Phosphorus (mg/l)	0.016
Phosphate Phos. (mg/l)	<0.002
N/P Ratio	105.0

APPENDIX III
HISTORIC WATER QUALITY DATA
Beasley Lake, Waupaca County, WI
Water Chemistry: 11/84 - 05/85; Deepest Site
Source: UW-Stevens Point Environmental Task Force

PARAMETER	Sample Dates 11/26/84	05/13/85
Depth (feet)	0	0
pH (S.U.)	7.97	8.20
Conductivity (μmhos/cm)	333	335
Total Alkalinity (mg/l $CaCO_3$)	175	171
Calcium (mg/l $CaCO_3$)	99.8	93.6
Magnesium (mg/l Ca CO_3)	86.4	81.5
Hardness (mg/l $CaCO_3$)	186.2	175.1
Sodium (mg/l)	2.1	1.8
Sulfate (mg/l)	9.0	7.5
Potassium (mg/l)	1.0	1.1
Chloride (mg/l)	2.0	0.5
Turbidity (NTU's)	1.2	0.4
Color (S.U.)	11.0	10.0
Total Kjeldahl N (mg/l)	0.57	0.29
Ammonia Nitrogen (mg/l)	0.10	0.26
NO_2 + NO_3 Nitrogen (mg/l)	0.78	0.67
Total Nitrogen (mg/l)	1.35	0.96
Total Phosphorus (mg/l)	0.008	0.015
Phosphate Phos. (mg/l)	0.002	0.010
N/P Ratio	168.8	64.0

APPENDIX III
HISTORIC WATER QUALITY DATA
Columbia Lake, Waupaca County, WI
Water Chemistry: 09/67 - 10/86; Deepest Site
Source: WDNR, UW-Stevens Point Environmental Task Force

PARAMETER	09/07/67	Sample Dates 09/07/67	10/20/86
Depth (feet)	2	30	0
Secchi (meters)	NR[1]	NR	3.4
pH (S.U.)	8.3	7.5	8.39
Conductivity (μmhos/cm)	285	336	292
Total Alkalinity (mg/l $CaCO_3$)	138	160	138
Calcium (mg/l $CaCO_3$)	47.4	67.4	77.3
Magnesium (mg/l Ca CO_3)	88.9	95.9	83.9
Hardness (mg/l $CaCO_3$)	136.3	163.3	161.2
Sodium (mg/l)	2.72	2.72	3.0
Sulfate (mg/l)	16.5	14.7	13.0
Potassium (mg/l)	0.88	1.12	1.2
Iron (mg/l)	0.01	0.03	NR
Chloride (mg/l)	3.70	3.70	7.0
Turbidity (NTU's)	NR	NR	0.5
Color (S.U.)	NR	NR	<5.0
Total Kjeldahl N (mg/l)	NR	NR	0.49
Ammonia Nitrogen (mg/l)	NR	NR	0.10
NO_2 + NO_3 Nitrogen (mg/l)	NR	NR	0.18
NO_3 Nitrogen (mg/l)	0.03	0.02	-
Total Nitrogen (mg/l)	-	-	0.67
Total Phosphorus (mg/l)	0.13	0.05	0.005
Phosphate Phos. (mg/l)	0.02	0.01	<0.002
N/P Ratio	-	-	134.0

NR[1] = No Reading

APPENDIX III
HISTORIC WATER QUALITY DATA
Long Lake, Waupaca County, WI
Water Chemistry: 08/12 - 10/85; Deepest Site
Source: WDNR, UW-Stevens Point Environmental Task Force

	Sample Dates					
PARAMETER	08/16/12	08/15/62	09/07/67	09/07/67	09/16/69	10/15/85
Depth (feet)	-	-	10	36	-	0
Secchi (meters)	3.2	2.7	NR[1]	NR	3.6	NR
pH (S.U.)	NR	NR	8.3	7.3	NR	8.3
Conductivity (μmhos/cm)	NR	NR	333	342	NR	329
Total Alkalinity (mg/l $CaCO_3$)	NR	NR	168	176	NR	188
Calcium (mg/l $CaCO_3$)	NR	NR	69.4	63.7	NR	84.8
Magnesium (mg/l Ca CO_3)	NR	NR	96.4	85.6	NR	78.2
Hardness (mg/l $CaCO_3$)	NR	NR	165.8	149.3	NR	163.0
Sodium (mg/l)	NR	NR	2.40	3.44	NR	2.0
Sulfate (mg/l)	NR	NR	10.0	11.3	NR	8.0
Potassium (mg/l)	NR	NR	0.40	0.92	NR	7.0
Iron (mg/l)	NR	NR	0.03	0.03	NR	NR
Chloride (mg/l)	NR	NR	1.70	1.75	NR	3.0
Turbidity (NTU's)	NR	NR	NR	NR	NR	<1.0
Color (S.U.)	NR	NR	NR	NR	NR	12.0
Total Kjeldahl N (mg/l)	NR	NR	NR	NR	NR	0.29
Ammonia Nitrogen (mg/l)	NR	NR	NR	NR	NR	0.13
NO_2 + NO_3 Nitrogen (mg/l)	NR	NR	NR	NR	NR	1.02
NO_3 Nitrogen (mg/l)	NR	NR	1.19	0.74	NR	NR
Total Nitrogen (mg/l)	-	-	-	-	-	1.31
Total Phosphorus (mg/l)	NR	NR	0.08	0.08	NR	0.008
Phosphate Phos. (mg/l)	NR	NR	0.02	0.02	NR	<0.002
N/P Ratio	-	-	-	-	-	163.8

NR[1] = No Reading

IPS ENVIRONMENTAL AND ANALYTICAL SERVICES
Appleton, Wisconsin

PHASE II
LOWER CHAIN O' LAKES MANAGEMENT PLAN
WAUPACA COUNTY, WISCONSIN

REPORT TO:
CHAIN O' LAKES PROPERTY OWNERS ASSOCIATION

December, 1995

SUMMARY

The Lower Chain project group consists of Columbia, Ottman, Youngs, Beasley, Bass and Long Lakes of the Chain O 'Lakes, a group of 22 mostly interconnected relatively small lakes in Waupaca County, Wisconsin. Water quality is good to very good and related to substantial groundwater inflow. Water quality, along with the Chain's proximity to population centers, contribute to highly developed shoreline areas (many permanent residential) and periodic high to excessive non-resident recreational use. An initial resource assessment was made in 1992 (Phase I Chain O 'Lakes Management Plans); this document supplements the 1992 report with Phase II efforts toward development of a comprehensive lake management plan.

The Chain O 'Lakes watershed, primarily agricultural but with significant forested and wetland areas, is a subwatershed of the Tomorrow/Waupaca River basin which has recently been granted Priority Watershed Project Status. Variable, but generally low groundwater nitrate levels were observed in the Chain subwatershed during the appraisal phase of the Priority Watershed Project. Overland flow nutrient and sediment inputs were estimated to be lower than expected, but field estimates for nutrients were substantially higher. Lake modeling for some Chain lakes indicated a natural process of phosphorus removal by marl precipitation.

Lower Chain water quality monitoring during Phases I and II indicated in-lake nutrient levels below those expected for the region. The shallower well mixed lakes (Ottman, Bass, Youngs) had relatively higher nutrient readings, but levels were near or slightly above those typical of lake type and regional location. Lower Chain characteristics (relatively large watershed and direct or indirect drainage from all Chain project groups) suggests a relatively high potential for nutrient and sediment input from nonpoint sources. Water quality, except for a slight increase in total nitrogen in a downstream progression, remains similar throughout the Chain and apparently reflects the substantial groundwater input to the system.

Lower Chain recreational use survey results were similar to those of the Chain O 'Lakes overall and various resident user groups. Results indicated periodic excessive use during summer weekends or holidays with perceived safety problems and diminished recreational enjoyment of the resource related primarily to non-resident or commercial watercraft. Water safety enforcement was considered adequate at all times, slightly less so during periods of peak use, and no clear concensus was evident regarding the need for additional regulation. Residents agreed there was adequate access, disagreed with the need for a public park or beach, and were evenly divided regarding the need for more water accessible restrooms.

Purple loosestrife, an exotic potentially nuisance plant, was present and locally abundant in the Lower Chain.

Water quality protection and water use conflict minimization are priority management objectives for the Lower Chain and all Chain O 'Lakes residents. Specific recommendations for the Lower Chain include private well testing for nitrates and/or pesticides, more event sampling (coordinated with flow and rainfall monitoring) and removal or management of the purple loosestrife beds. Other recommendations are applicable to the Lower and other Chain project groups and emphasize continued focus and expanded involvement (designated Chain O 'Lakes Property Owners Association individuals or committees) in watershed-wide surface water and groundwater quality issues, use management, and exotic species control. These recommendations are designed to identify potential problem areas or conflicts before they become widespread or severe.

METHODS

Watershed Characteristics

Most watershed information was obtained during the appraisal process of the Tomorrow/Waupaca River Priority Watershed (TWRPW) Project. The appraisal began February, 1994 and was completed in 1995. Pertinent information from the appraisal as it relates to the Chain O' Lakes is included in the Field Data Discussion section of this report.

Water Quality Monitoring

Water quality samples were taken three feet below surface (designated "S") and three feet above bottom (designated "B") in Columbia, Beasley, and Long Lakes during July and September, 1992, February, May, August and October, 1993, and January, February, May, August and September, 1994 (Table 2, Fig. 2). Bass Lake, Emmon's Creek inlet and Crystal River outlet sites were sampled mid-depth (designated "M") during July and September, 1992, May, February, August and October, 1993, and May, August and September 1994. (Emmon's Creek inlet and Crystal River outlet sites were not sampled February, 1993, due to unsafe ice). Ottman and Youngs Lake were sampled mid-depth during July and September, 1992, and February, 1993; Youngs Lake was also sampled in May, 1993. Parameters measured in the field were Secchi depth, water temperature, pH, dissolved oxygen (DO), and

Table 2. Sample Station Descriptions, Lower Chain, 1992 - 1994.

REGULAR MONITORING

Lake	Site Number	Depth
Columbia (Deepest Point)	1201	72 feet
Long (Deepest Point)	1202	76 feet
Emmon's Creek (Inlet)	1203	03 feet
Crystal River (Outlet)	1204	03 feet
Beasley (Deepest Point)	1205	47 feet
Bass (Deepest Point)	1206	08 feet
Youngs (Deepest Point)	1207	15 feet
Ottman (Deepest Point)	1208	15 feet

Event Site	Description
12E1	Emmon's Creek at junction with Rural Road

conductivity (see the Phase I document for specific equipment and methods information). Water samples were also taken by IPS or members of the CLPOA, with IPS instruction, at Site 12E1 on April 5, May 3 and 12, July 6 and August 1, 1994.

Recreational Use

A recreational use survey of the CLPOA membership was conducted to obtain property and lake use, water use opinions and demographics information. About 800 questionnaires were distributed (one per household) by CLPOA neighborhood volunteers to maximize the return rate. A sample survey questionnaire is included in Appendix I.

Public Involvement Program

Public involvement activities were coordinated to inform and educate the CLPOA about lake management in general and specifics regarding the Chain O' Lakes resource. Activities included news releases, IPS newsletters, article preparation for CLPOA newsletters, meeting attendance and presentations to the CLPOA and other interested parties. Public involvement activities are summarized in Appendix II.

FIELD DATA DISCUSSION

Watershed Characteristics

The Chain O' Lakes watershed is estimated to be 33,819 acres or 17% of the entire TWRPW (3). Land use for the Chain O' Lakes subwatershed was determined during the 1994 - 1995 inventory to be: non-irrigated agriculture, 16,931 acres (50%); irrigated agriculture, 2,205 acres (7%); forested, 10,921 acres (32%); wetland (including surface water), 1,673 acres (5%); and developed areas, 2,089 acres (6%) (Fig. 3).

There were 220 landowners who had livestock operations in the TWRPW, of which 168 (76%) had more than 20 animal units and 52 (24%) had 20 or fewer animal units. Sixty-two percent of the barnyards were surface drained; 38% were internally drained (4).

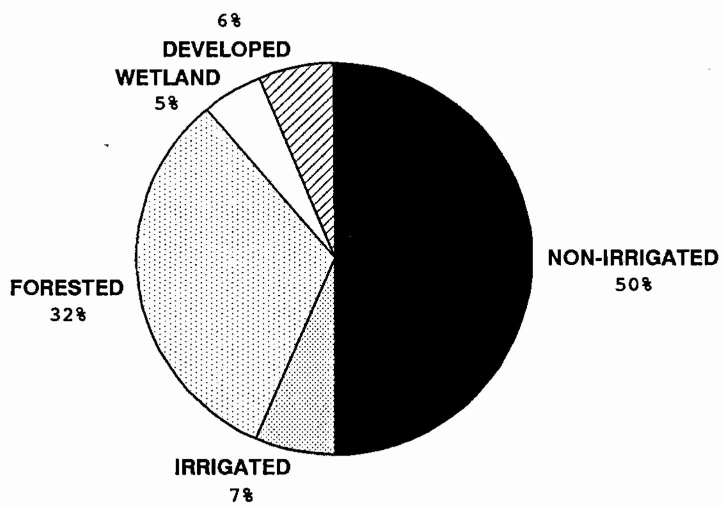

Figure 3. Land Uses in the Chain O' Lakes Subwatershed, 1994.

Groundwater

Nitrate was identified as a contaminant of concern in the Wolf River Basin Plan (5) and was targeted for analyses in the TWRPW Project groundwater appraisal. Relative to other subwatersheds in the TWRPW Project, residential well samples in the Chain O' Lakes subwatershed had the lowest average nitrate levels [2.59 milligrams per liter (mg/l)] (Table 3). Fifty-seven percent of the Chain O' Lakes subwatershed well samples were below 2 mg/l; nitrate levels over 2 mg/l are generally considered indicative of human impact on groundwater. Thirty-two well samples (8.2%) in the Chain O' Lakes subwatershed were over the health standard of 10 mg/l (4).

Table 3. Well Nitrate Data by Subwatershed for the Tomorrow/ Waupaca River Priority Watershed Project, 1995.

Subwatershed	No. of Samples	>2 mg/l	>10 mg/l	>20 mg/l	Average
Lower Tomorrow	258	168	66	20	6.82
Spring Creek	275	154	39	5	4.71
Chain O' Lakes	389	136	30	2	2.59
Crystal River	266	117	22	5	3.27
Waupaca/ Weyauwega	63	15	11	4	5.31
Total	1,251	590	168	36	4.54
Percent	100%	47%	13%	3%	

Surface water nitrate levels were also assessed during periods of highest groundwater contribution to the Tomorrow/Waupaca River system. Various creek samples taken March 1, 1994 or January 20, 1995 averaged 3.06 and 3.52 mg/l, respectively (Table 4). The highest nitrate levels were observed in Radley and Murray Creeks during January, 1995.

Table 4. Nitrate Levels (mg/l) for Surface Water in the Chain O' Lakes Subwatershed, 1994 - 1995.

	03/01/94	01/20/95
Radley Creek (South Road)	3.51	5.06
Radley Creek (1st Avenue)		7.1
Hartman Creek (Rural Road)	0.94	1.03
Emmon's Creek (Rural Road)	2.48	2.18
Emmon's Creek (3rd Avenue)		1.97
Murray Creek (South Road)	2.77	2.37
Murray Creek (10th Road)		6.0
Tomorrow/Waupaca Average	3.06	3.52

Lakes

A computer model applied by WDNR to the western portion of the Chain O' Lakes indicated that the Chain has a natural ability to remove phosphorus from the water column via marl precipitation. Marl (calcium carbonate) binds with phosphorus and settles to the lake bottom.

Overall, the lakes modeled (Marl, Pope, Manomin, Orlando, Knight, Ottman, Youngs, Bass, Beasley and Long) showed a 36% reduction (outflowing versus inflowing) of phosphorus; reduction ranged from 8% for Orlando Lake to 90% for Marl Lake (4). Phosphorus levels measured during Phase I and Phase II efforts for these lakes were near or below levels predicted by the model.

Sediment and Nutrient Delivery

Sediment delivery was estimated to be less than expected for the Chain O' Lakes subwatershed; the Chain subwatershed included 7.7% of the cropland draining to streams for the TWRPW but had only 6.0% of the sediment delivery (146 tons per year). With an estimated nine pounds of phosphorus per ton of sediment, phosphorus delivery is 1,313 pounds per year. Sediment was estimated to be entirely from upland sources, as none of the 21.8 miles of streambank were observed to be degraded (4).

Water Quality

Current data indicated generally similar water quality among the Lower Chain lakes and trends similar to those observed during Phase I. Long and Bass Lakes exhibited somewhat higher nutrients than the other Lower Chain lakes and all nutrient data reflected seasonal influences of stratification/mixing and surface or groundwater inflows (Tables 5-12, Figs. 4 and 5).

Surface or mid-depth total nitrogen (for continuously sampled lakes) ranged from 0.728 mg/l (Columbia) to 2.46 mg/l (Bass) with an average of 1.39 mg/l for all Lower Chain Lakes. Relatively high average total nitrogen levels were observed in Emmon's Creek - Inlet with a range of 1.86 mg/l to 2.67 mg/l and an average of 2.25 mg/l; the Crystal River outlet total nitrogen ranged from 1.32 mg/l to 1.73 mg/l with an average of 1.49 mg/l. Relatively high total nitrogen or phosphorus levels were observed during Winter (after fall overturn and when groundwater influence was probably greatest) or during Spring (un- or weakly stratified and possibly influenced by surface water inflows).

Substantially higher values for total phosphorus and other nutrient parameters were observed near bottom at Columbia, Beasley, and Long Lakes, and suggested nutrient release from sediments under anoxic or near-anoxic conditions during summer stratification at these relatively deep points.

Phosphorus levels for the Lower Chain were generally lower than those typical for stratified lakes (0.023 mg/l) and for lakes in the central region in Wisconsin (0.020 mg/l) (6); levels were at

Table 5. Water Quality Parameters, Station 1201, Columbia Lake, Chain O' Lakes, July 1992 - September 1994.

PARAMETER	SAMPLE[1]	DATE									
		07/14/92	09/22/92	02/02/93	05/19/93	08/16/93	10/04/93	01/25/94	05/02/94	08/02/94	09/21/94
Secchi (feet)		11.4	9.9	NR[2]	10.3	9.1	10.6	NR	9.5	10.5	9.0
Cloud Cover (percent)		70	0	10	90	40	50	0	40	0	100
Temperature (degrees Celsius)	S	20.77	16.90	2.56	15.70	24.30	12.37	2.03	10.21	24.06	21.70
	B	4.76	5.32	3.69	4.74	4.95	5.17	3.03	4.99	5.65	6.14
pH (surface units)	S	8.27	8.42	7.22	NR	8.11	NR	6.88	NR	8.10	NR
	B	6.42	7.11	6.73	NR	5.68	NR	6.54	NR	0.36	NR
D.O. (mg/l)	S	8.82	9.15	9.00	9.89	8.74	9.63	11.10	11.57	8.66	8.50
	B	0.10	0.63	1.63	0.16	0.10	0.98	6.67	0.50	0.36	0.67
Conductivity (umhos/cm)	S	309	287	333	320	287	315	346	328	320	284
	B	371	380	346	353	365	397	362	353	386	359
Laboratory pH (surface units)	S	NR	NR	NR	8.48	NR	NR	NR	8.31	NR	NR
	B	NR	NR	NR	7.75	NR	NR	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	NR	NR	NR	151	NR	NR	NR	163	NR	NR
	B	NR	NR	NR	173	NR	NR	NR	NR	NR	NR
Total Solids (mg/l)	S	NR	NR	NR	214	NR	NR	NR	220	NR	NR
	B	NR	NR	NR	246	NR	NR	NR	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	S	0.4	0.5	0.9	0.5	0.4	0.5	0.9	0.6	0.40[3]	0.41[3]
	B	2.9	3.9	1.7	2.0	0.5	3.0	1.0	1.2	2.64[3]	NR
Ammonia Nitrogen (mg/l)	S	0.040	0.049	0.448	0.104	0.019	0.070	0.422	0.166	0.025	0.048
	B	2.07	2.90	0.919	1.24	0.048	2.47	0.583	0.703	1.88	NR
$NO_2 + NO_3$ Nit. (mg/l)	S	0.452	0.280	0.661	0.703	0.363	0.407	0.473	1.01	0.414	0.318
	B	ND[4]	ND	0.204	0.009	0.357	ND	0.533	0.619	0.022	NR
Total Nitrogen (mg/l)	S	0.852	0.780	1.561	1.203	0.763	0.907	1.373	1.61	0.814	0.728
	B	2.9	3.9	1.904	2.009	0.857	3.0	1.533	1.819	2.662	NR
Total Phosphorus (mg/l)	S	0.006	0.005	0.008	ND	0.008	0.005	0.019	0.009	0.007	0.0060[4]
	B	0.073	0.114	0.062	0.09	0.011	0.035	0.018	0.027	0.039	NR
Dissolved Phos. (mg/l)	S	0.002	0.001	0.003	ND	ND	ND	0.002	NR	ND	ND
	B	0.020	0.042	0.006	ND	ND	0.003	0.001	NR	ND	NR
Nit./Phos Ratio	S	142.0	156.0	195.1	--	95.4	181.4	72.3	178.9	116.3	121.3
	B	39.7	34.2	30.7	22.3	79.9	85.7	85.2	67.37	68.2	NR
Chlorophyll a (ug/l)	S	4	4.29	NR	2.78	4.32	3.66	NR	4.33	4.11	3.10

[1] S = surface, B = bottom; [2] NR = no reading; [3] holding time exceeded by SLOH; [4] ND = not detectable

Table 6. Water Quality Parameters, Station 1202, Long Lake, Chain O' Lakes, July 1992 - September 1994.

PARAMETER	SAMPLE[1]	DATE 07/14/92	09/22/92	02/02/93	05/19/93	08/16/93	10/04/93	01/25/94	05/02/94	08/02/94	09/21/94
Secchi (feet)		23.9	12.1	NR[2]	14.8	14.2	15.2	NR	15.5	10.6	15.0
Cloud Cover (percent)		70	0	10	90	60	50	0	40	0	100
Temperature (degrees Celsius)	S	19.54	15.89	2.12	14.72	21.97	11.43	0.19	10.19	22.67	20.40
	B	5.66	6.36	3.88	5.13	5.66	6.12	3.51	5.50	6.72	7.41
pH (surface units)	S	8.23	8.08	7.24	NR	7.75	NR	7.10	NR	8.14	NR
	B	6.63	7.01	6.72	NR	5.88	NR	6.73	NR	6.17	NR
D.O. (mg/l)	S	8.95	9.08	9.02	9.62	8.42	9.10	10.50	11.61	9.77	9.04
	B	0.10	0.34	0.49	3.16	0.10	0.24	7.34	5.02	0.12	0.57
Conductivity (umhos/cm)	S	310	296	337	321	305	339	345	315	318	291
	B	338	334	357	339	325	345	353	333	351	323
Laboratory pH (surface units)	S	NR	NR	NR	8.39	NR	NR	NR	8.30	NR	NR
	B	NR	NR	NR	7.72	NR	NR	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	NR	NR	NR	161	NR	NR	NR	168	NR	NR
	B	NR	NR	NR	174	NR	NR	NR	NR	NR	NR
Total Solids (mg/l)	S	NR	NR	NR	216	NR	NR	NR	210	NR	NR
	B	NR	NR	NR	232	NR	NR	NR	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	S	0.3	0.4	0.6	0.3	0.4	0.3	0.5	0.3	0.44[3]	0.38[3]
	B	0.9	0.7	0.9	0.5	0.4	0.6	0.4	0.5	0.45[3]	NR
Ammonia Nitrogen (mg/l)	S	0.042	0.043	0.303	0.074	0.030	0.030	0.162	0.041	0.01	0.036
	B	0.547	0.406	0.609	0.272	0.238	0.372	0.119	0.225	0.056	NR
NO_2 + NO_3 Nit. (mg/l)	S	1.10	0.955	1.06	1.17	0.967	1.27	1.42	1.32	0.921	0.868
	B	0.801	0.612	0.667	1.12	0.900	0.638	1.44	1.23	1.4	NR
Total Nitrogen (mg/l)	S	1.40	1.355	1.66	1.47	1.367	1.57	1.92	1.32	1.361	1.248
	B	1.701	1.312	1.567	1.62	1.300	1.238	1.84	1.73	1.85	NR
Total Phosphorus (mg/l)	S	0.005	0.009	0.011	ND[4]	0.009	0.014	0.013	0.008	0.012	0.009
	B	0.238	0.112	0.046	0.02	0.086	0.140	0.008	0.013	0.016	NR
Dissolved Phos. (mg/l)	S	0.003	0.003	0.003	ND	0.002	ND	0.002	NR	ND	ND
	B	0.136	0.082	0.031	0.007	0.054	0.086	0.007	NR	ND	NR
Nit./Phos Ratio	S	280.0	150.2	150.9	–	151.9	112.1	147.7	165.0	113.4	138.7
	B	7.1	11.7	34.1	81.0	15.1	8.8	230.0	133.1	115.6	NR
Chlorophyll a (ug/l)	S	1	5.07	NR	0.899	2.58	6.32	NR	3.97	0.06	1.50

[1] S = surface, B = bottom; [2] NR = no reading; [3] holding time exceeded by SLOH; [4] ND = not detectable

Table 7. Water Quality Parameters, Station 1203 (Emmon's Creek Inlet), Chain O' Lakes, July 1992 - September 1994.

PARAMETER	SAMPLE[1]	DATE							
		07/14/92	09/22/92	05/19/93	08/16/93	10/04/93	05/02/94	08/02/94	09/21/94
Secchi (feet)		>1.5	>1.0	>3.0	>3.0	>3.0	>3.0	>3.0	NR
Cloud Cover (percent)		70	0	90	50	50	40	0	100
Temperature (degrees Celsius)	M	15.05	10.39	10.25	14.12	10.08	8.77	16.5	14.4
pH (surface units)	M	8.73	8.13	NR[2]	8.79	7.28	NR	7.80	NR
D.O. (mg/l)	M	10.00	9.15	12.79	7.23	9.76	12.57	10.89	9.47
Conductivity (umhos/cm)	M	312	329	346	332	358	332	355	323
Laboratory pH (surface units)	M	NR	NR	8.23	NR	NR	8.27	NR	NR
Total Alkalinity (mg/l)	M	NR	NR	180	NR	NR	178	NR	NR
Total Solids (mg/l)	M	NR	NR	232	NR	NR	226	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	M	0.5	0.2	ND	0.4	0.5	0.3	0.25[3]	0.36[3]
Ammonia Nitrogen (mg/l)	M	0.020	0.016	0.021	0.026	0.021	0.021	0.026	0.020
NO2 + NO3 Nit. (mg/l)	M	1.41	1.94	1.86	1.94	2.17	2.12	1.98	2.05
Total Nitrogen (mg/l)	M	1.91	2.14	1.86	2.34	2.67	2.42	2.23	2.41
Total Phosphorus (mg/l)	M	0.011	0.007	ND[4]	0.019	0.035	0.009	0.022	0.16
Dissolved Phos. (mg/l)	M	0.005	0.006	0.002	0.002	ND	NR	0.003	ND
Nit./Phos Ratio	M	173.6	305.7	–	123.2	76.3	268.9	101.4	150.6
Chlorophyll a (ug/l)	M	4	1.89	2.42	3.43	4.36	2.20	4.57	2.92

[1] M = mid-depth; [2] NR = no reading; [3] holding time exceeded by SLOH; [4] ND = not detectable

Table 8. Water Quality Parameters, Station 1204 (Crystal River Outlet), Chain O' Lakes, July 1992 - September 1994.

PARAMETER	SAMPLE[1]	DATE							
		07/15/92	09/22/92	05/19/93	08/16/93	10/04/93	05/02/94	08/02/94	09/21/94
Secchi (feet)		>2.5	>2.0	>3.0	>2.5	>3.0	>3.0	>3.0	>3.0
Cloud Cover (percent)		70	0	90	50	50	40	0	100
Temperature (degrees Celsius)	M	19.26	15.99	14.67	21.94	11.56	10.26	22.5	19.65
pH (surface units)	M	8.22	8.05	NR	7.74	7.40	NR	8.17	NR
D.O. (mg/l)	M	9.35	8.87	9.66	8.50	9.37	12.17	10.07	9.21
Conductivity (umhos/cm)	M	309	295	320	309	341	316	320	300
Laboratory pH (surface units)	M	NR	NR	8.17	NR	NR	8.35	NR	NR
Total Alkalinity (mg/l)	M	NR	NR	159	NR	NR	169	NR	NR
Total Solids (mg/l)	M	NR	NR	212	NR	NR	212	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	M	0.2	0.4	0.3	0.3	0.2	0.3	0.44[3]	0.32[3]
Ammonia Nitrogen (mg/l)	M	0.034	0.034	0.069	0.019	0.014	0.024	0.011	0.041
NO2 + NO3 Nit. (mg/l)	M	1.12	1.04	1.21	1.09	1.41	1.43	0.974	1.16
Total Nitrogen (mg/l)	M	1.32	1.44	1.51	1.39	1.61	1.73	1.414	1.48
Total Phosphorus (mg/l)	M	0.007	0.008	ND[4]	0.011	0.007	0.009	0.012	0.007
Dissolved Phos. (mg/l)	M	0.002	0.004	ND	ND	ND	NR	0.002	ND
Nit./Phos Ratio	M	188.6	180.0	–	126.4	230.0	192.2	117.8	211.4
Chlorophyll a (ug/l)	M	2	2.27	1.21	3.13	5.43	5.60	8.19	1.64

[1] M = mid-depth; [2] NR = no reading; [3] holding time exceeded by SLOH; [4] ND = not detectable

Table 9. Water Quality Parameters, Station 1205, Beasley Lake, Chain O' Lakes, July 1992 - September 1994.

PARAMETER	SAMPLE[1]	07/15/92	09/22/92	02/03/93	05/20/93	08/16/93	10/04/93	02/15/94	05/03/94	08/02/94	09/21/94
Secchi (feet)		16.2	18.7	NR[2]	22.4	15.0	16.3	NR	16.0	12.5	14.0
Cloud Cover (percent)		70	0	10	10	100	50	0	60	0	100
Temperature (degrees Celsius)	S	20.46	16.00	1.60	14.23	22.01	11.63	0.76	11.40	23.37	20.62
	B	5.64	6.18	3.79	5.01	5.49	5.85	3.61	4.68	7.08	NR
pH (surface units)	S	8.46	8.01	7.32	NR	7.76	NR	6.82	7.56	8.22	NR
	B	6.61	6.90	6.82	NR	6.05	NR	6.45	6.50	6.44	NR
D.O. (mg/l)	S	9.77	8.93	8.94	9.76	8.82	11.63	9.79	10.86	10.04	9.72
	B	0.10	0.54	0.33	0.68	0.10	0.49	0.51	0.54	0.37	0.76
Conductivity (umhos/cm)	S	280	292	336	307	294	332	345	306	291	284
	B	371	385	361	388	362	395	357	361	370	356
Laboratory pH (surface units)	S	NR	NR	NR	8.24	NR	NR	NR	8.22	NR	NR
	B	NR	NR	NR	7.79	NR	NR	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	NR	NR	NR	159	NR	NR	NR	163	NR	NR
	B	NR	NR	NR	205	NR	NR	NR	NR	NR	NR
Total Solids (mg/l)	S	NR	NR	NR	196	NR	NR	NR	198	NR	NR
	B	NR	NR	NR	248	NR	NR	NR	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	S	0.4	0.5	0.3	0.4	0.5	0.4	0.4	0.3	0.41[3]	0.43
	B	2.4	0.9	1.1	1.9	0.4	2.2	1.2	1.4	0.92[3]	NR
Ammonia Nitrogen (mg/l)	S	0.036	0.078	0.140	0.078	0.048	0.086	0.152	0.070	0.019	0.025
	B	1.261	0.474	0.808	1.42	0.034	1.64	0.700	1.05	0.468	NR
$NO_2 + NO_3$ Nit. (mg/l)	S	0.669	0.600	1.53	0.750	0.623	0.733	1.51	0.868	0.459	0.610
	B	ND[4]	0.387	0.412	0.046	0.632	0.007	0.420	0.033	0.207	NR
Total Nitrogen (mg/l)	S	1.069	1.100	1.83	1.150	1.123	1.133	1.91	1.168	0.869	1.04
	B	2.4	1.287	1.512	1.946	1.032	2.207	1.620	1.433	1.127	NR
Total Phosphorus (mg/l)	S	0.008	0.014	0.004	ND	0.012	0.010	0.038	0.010	0.013	0.010
	B	0.244	0.020	0.091	0.20	0.009	0.320	0.059	0.083	0.027	NR
Dissolved Phos. (mg/l)	S	0.002	0.003	0.004	0.003	ND	ND	0.002	NR	ND	ND
	B	0.138	0.005	0.080	0.143	ND	0.25	0.043	NR	NR	NR
Nit./Phos Ratio	S	133.6	78.6	457.5	–	93.6	113.3	50.3	116.8	66.8	104.0
	B	9.8	64.4	16.6	9.7	114.7	6.9	27.5	17.3	41.74	NR
Chlorophyll a (ug/l)	S	3	4.16	NR	0.90	2.65	2.87	NR	2.04	4.09	4.26

[1] S = surface, B = bottom; [2] NR = no reading; [3] holding time exceeded by SLOH; [4] ND = not detectable

Table 10. Water Quality Parameters, Station 1206, Bass Lake, Chain O' Lakes, July 1992 - September 1994.

PARAMETER	SAMPLE[1]	DATE								
		07/14/92	09/22/92	02/03/93	05/19/93	08/16/93	10/04/93	05/03/94	08/02/94	09/02/94
Secchi (feet)		>5.0	>6.0	NR[2]	>6.0	>7.0	>8.0	>8.0	>6.0	>6.0
Cloud Cover (percent)		70	0	10	90	30	50	60	0	100
Temperature (degrees Celsius)	M	19.84	14.54	1.83	14.15	20.50	11.01	10.50	22.75	20.02
pH (surface units)	M	8.69	7.65	7.35	NR	7.43	NR	7.47	8.38	NR
D.O. (mg/l)	M	11.10	7.57	8.22	8.02	8.72	11.50	11.01	11.69	9.13
Conductivity (umhos/cm)	M	245	284	304	304	297	317	287	273	270
Laboratory pH (surface units)	M	NR	NR	NR	7.92	NR	NR	NR	NR	NR
Total Alkalinity (mg/l)	M	NR	NR	NR	148	NR	NR	NR	NR	NR
Total Solids (mg/l)	M	NR	NR	NR	210	NR	NR	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	M	0.4	0.6	0.2	0.6	0.4	0.3	0.6	0.45[3]	0.44[3]
Ammonia Nitrogen (mg/l)	M	0.040	0.097	0.053	0.122	0.057	0.057	0.108	0.027	0.059
NO2 + NO3 Nit. (mg/l)	M	0.767	0.957	2.26	0.948	0.969	1.08	0.942	0.474	0.700
Total Nitrogen (mg/l)	M	1.167	1.557	2.46	1.548	1.369	1.38	1.542	0.924	1.14
Total Phosphorus (mg/l)	M	0.013	0.012	0.004	0.03	0.025	0.008	0.029	0.014	0.017
Dissolved Phos. (mg/l)	M	0.002	0.004	0.002	0.003	ND[4]	ND	NR	ND	ND
Nit./Phos Ratio	M	89.8	129.8	615.0	51.6	54.8	172.5	53.17	66.0	67.06
Chlorophyll a (ug/l)	M	8	4.65	NR	2.75	3.51	5.98	3.22	2.69	3.88

[1] M = mid-depth; [2] NR = no reading; [3] holding time exceeded by SLOH; [4] ND = not detectable

Table 11. Water Quality Parameters, Station 1207 Youngs Lake, Chain O' Lakes, July 1992 - May 1993.

PARAMETER	SAMPLE[1]	DATE			
		07/14/92	09/22/92	02/03/93	05/20/93
Secchi (feet)		>10.0	11.0	NR[2]	10.1
Cloud Cover (percent)		70	0	10	10
Temperature (degrees Celsius)	M	17.73	13.58	4.13	11.73
pH (surface units)	M	8.11	7.47	7.00	NR
D.O. (mg/l)	M	10.30	4.74	0.76	9.51
Conductivity (umhos/cm)	M	297	301	351	298
Laboratory pH (surface units)	M	NR	NR	NR	7.96
Total Alkalinity (mg/l)	M	NR	NR	NR	147
Total Solids (mg/l)	M	NR	NR	NR	206
Tot. Kjeld. Nitrogen (mg/l)	M	0.4	0.8	0.8	0.4
Ammonia Nitrogen (mg/l)	M	0.086	0.269	0.395	0.032
NO2 + NO3 Nit. (mg/l)	M	1.17	0.956	1.39	1.42
Total Nitrogen (mg/l)	M	1.577	1.756	2.19	1.82
Total Phosphorus (mg/l)	M	0.006	0.017	0.019	ND[3]
Dissolved Phos. (mg/l)	M	0.002	0.002	0.002	0.002
Nit./Phos Ratio	M	262.8	103.3	115.3	--
Chlorophyll _a_ (ug/l)	M	5	3.58	NR	1.58

[1] M = mid-depth; [2] NR = no reading; [3] ND = not detectable;

Table 12. Water Quality Parameters, Station 1208, Ottman Lake, Chain O' Lakes, July 1992 - May 1993.

PARAMETER	SAMPLE[1]	DATE		
		07/16/92	09/28/92	02/03/93
Secchi (feet)		9.1	7.3	NR[2]
Cloud Cover (percent)		70	0	10
Temperature (degrees Celsius)	M	19.40	13.07	4.06
pH (surface units)	M	8.52	7.30	7.02
D.O. (mg/l)	M	9.15	6.21	4.17
Conductivity (umhos/cm)	M	227	323	281
Laboratory pH (surface units)	M	NR	NR	NR
Total Alkalinity (mg/l)	M	NR	NR	NR
Total Solids (mg/l)	M	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	M	0.8	3.8	1.2
Ammonia Nitrogen (mg/l)	M	0.050	ND[3]	0.448
NO2 + NO3 Nit. (mg/l)	M	0.012	ND	0.098
Total Nitrogen (mg/l)	M	0.812	3.8	1.298
Total Phosphorus (mg/l)	M	0.011	0.30	0.014
Dissolved Phos. (mg/l)	M	0.002	0.002	0.002
Nit./Phos Ratio	M	73.8	12.7	92.7
Chlorophyll a (ug/l)	M	2.82	31.7	NR

[1] M = mid-depth; [2] NR = no reading; [3] ND = not detectable;

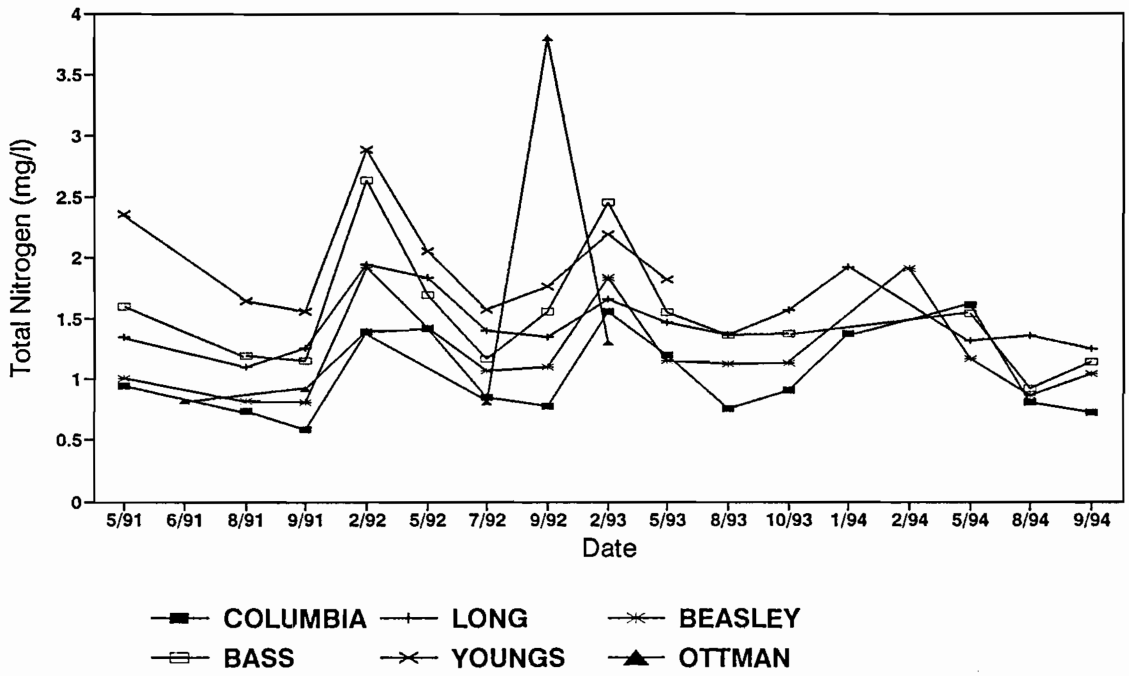

Figure 4. Surface Total Nitrogen Trends for the Lower Chain, 1991 - 1994.

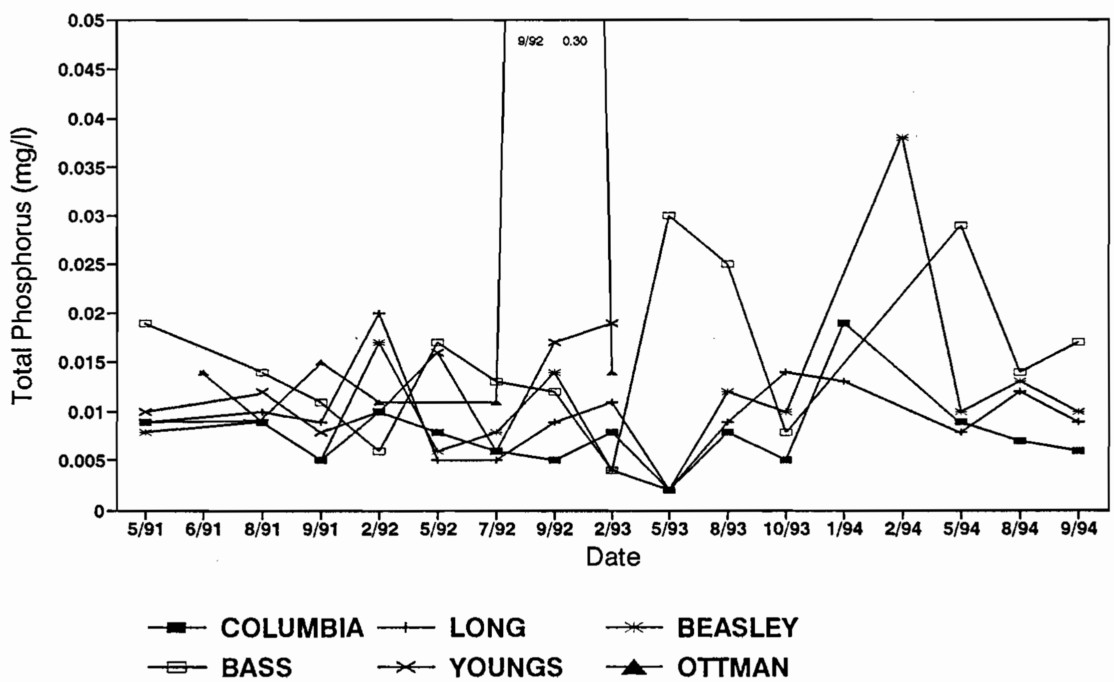

Figure 5. Surface Total Phosphorus Trends for the Lower Chain, 1991 - 1994.

or below those typical for the ecoregion in which the Chain is located (0.010 - 0.014 mg/l) (7). NOTE: Some data were indicated to have exceeded the recommended maximum holding time before analysis. A study has shown, however, that the data remain accurate for samples analyzed well after the 28-day holding time (8).

Nutrient levels at site 12E1 during the single runoff event (July 6, 1994) were not substantially different from those during regular monitoring (all other dates) (Table 13). Average total nitrogen for all dates was 2.19 mg/l; average total phosphorus was 0.027 mg/l.

Emmon's Creek inputs at an average flow of 30.3 cfs (19.6 mgd) were estimated at 1,110 kilograms (2,448 pounds) phosphorus and 46,580 kilograms (102,690 pounds) nitrogen (Fig. 6-8). These inputs far exceeded the TWRPW Project phosphorus input estimate of 1,313 pounds.

Recreational Use

About 43% of all Chain O' Lakes respondents indicated they were permanent residents. Average occupancy for all respondents was 7.8 months (Table 14); seasonal residents averaged 4.7 months. Respondents indicated a total of 1222 watercraft with an average of 2.9 per household. Pro-rated (to include all landowners)

Table 13. Event Water Quality Parameters, Station 12E1, Emmon's Creek at junction with Rural Road, April 1994 - August 1994.

PARAMETER	SAMPLE[1]	DATE				
		04/5/94	05/03/94	05/12/94	07/06/94[2]	08/01/94
Temperature (degrees Celsius)	M	9.5	NR[3]	11.5	17.5	NR
pH (surface units)	M	7.93	NR	8.28	NR	NR
D.O. (mg/l)	M	9.5	NR	11.2	10.1	NR
Conductivity (umhos/cm)	M	228	NR	366	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	M	1.1	<0.2	<0.2	0.4	0.42[4]
Ammonia Nitrogen (mg/l)	M	0.028	0.019	0.020	0.053	0.011
NO_2 + NO_3 Nit. (mg/l)	M	1.02	2.16	2.15	1.52	2.11
Total Nitrogen (mg/l)	M	2.12	ND[5]	ND	1.92	2.53
Total Phosphorus (mg/l)	M	0.06	0.008	0.011	0.034	0.024
Dissolved Phos. (mg/l)	M	NR	NR	NR	0.007	0.003
Nit./Phos Ratio	M	35.3	-	-	56.47	105.4

[1] M = mid-depth; [2] actual runoff event sample; [3] NR = no reading; [4] holding time exceeded by SLOH; [5] ND = not detectable

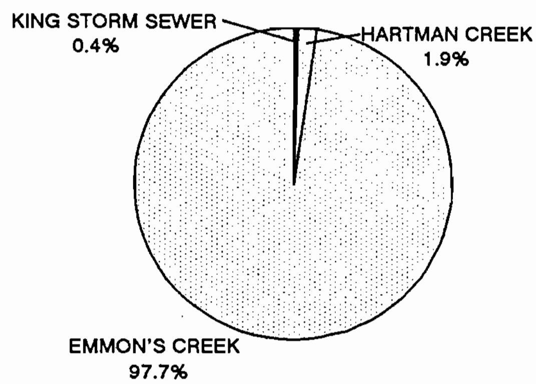

Figure 6. Average Flow Contribution from Overland Sources, Chain O' Lakes, 1994.

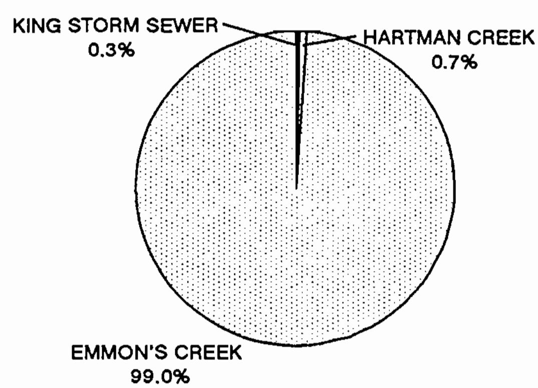

Figure 7. Average Nitrogen Contribution from Overland Sources, Chain O' Lakes, 1994.

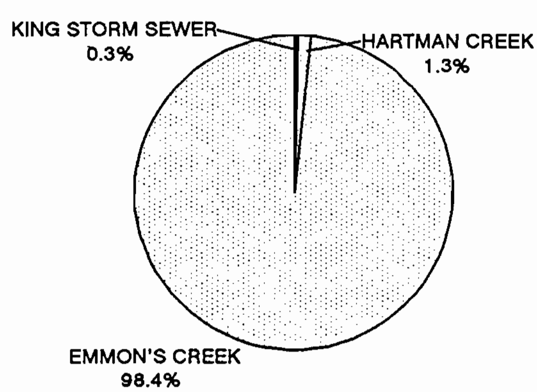

Figure 8. Average Phosphorus Contribution from Overland Sources, Chain O' Lakes, 1994.

Table 14. Comparison of Recreational Use Parameters for Various User Groups, Chain O' Lakes, Waupaca County, Wisconsin.

Parameter	User Group			
	Lower Chain	Fast Lakes	Slow Lakes	Entire Chain
Average monthly occupancy	7.7	7.5	8.1	7.8
Average number of watercraft (per response)	3.0	3.1	2.7	2.9
Average number of adults (per respondent household)	2.3	2.4	2.4	2.4
Average number of children 12 - 18 years old (per respondent household)	0.6	0.6	0.3	0.4
Average number of children less than 12 years old (per respondent household)	0.6	0.5	0.5	0.5
Average respondent age	59.8	59.1	57.7	58.3
Percent of respondents leaving comments	46.0	51.9	44.9	48.0

results would estimate almost 2,300 watercraft on the Chain O' Lakes, or 3.2 boats per acre (not including visitor watercraft). Most common watercraft types (in order) were canoes, pontoon boats, row/paddle boats and boats with less than 25 horsepower motors.

Lower Chain resident responses did not differ substantially from those of the Chain, as a whole, or from "fast" [wake lake residents (Rainbow, Round, Columbia and Long Lakes)] or "slow" [no wake lake residents (all others)]. Lower Chain respondents agreed (79% "strongly agree" or "agree" responses) there are too many watercraft [primarily on weekends and holidays (App. I)] and that the number of watercraft cause safety problems (76%) (primary causes identified as non-resident watercraft) and diminish user enjoyment. They agreed there was adequate water safety enforcement on weekdays (84%); fewer agreed for weekends (61%) and holidays (59%) (Table 15). Overall concensus was only somewhat in favor of enactment of more ordinances and limiting boat numbers.

Respondents agreed that there was adequate public boater access to the Chain (94%) and most disagreed ("strongly disagree" or "disagree" responses) with establishment of a park (74%) or beach (64%) on the Chain. Lower Chain respondents, however, were quite evenly split on the need for more public restrooms.

Exotic Species

Eurasian Water Milfoil was not observed in the Lower Chain O'Lakes; aquatic plant surveys (1991) and visual observations (1991- 1994) indicated only native water milfoil species (mainly *Myriophyllum exalbescens*), present in the Lower Chain. There were no observations of Zebra Mussels.

Table 15. Percentage of "Strongly Agree" and "Agree" Responses for Various User Groups, Chain O' Lakes, Waupaca County, Wisconsin.

Opinion	User Group			
	Lower Chain	Fast Lakes	Slow Lakes	Entire Chain
There are too many watercraft on the Chain	79	79	77	77
The current number of watercraft causes safety problems	76	77	75	76
There is adequate water safety enforcement:				
weekdays	84	82	85	84
weekends	61	60	69	65
holidays	59	58	62	60
Additional water use regulations need to be enacted and enforced	59	62	61	61
There should be limits set on the number of watercraft	51	54	54	54
There is adequate public boater access to the Chain	94	92	90	91
There should be more public restrooms on the Chain	47	52	47	50
There should be a public swimming beach on the Chain	36	36	34	35
There should be a public park on the shoreline of the Chain	26	29	29	29

Purple Loosestrife, however, was present and locally abundant in a several areas of the Lower Chain. Major populations are at the north and south shores of Columbia Lake, the east shore of

Beasley Lake and scattered areas along the shores of Long Lake with greatest density at the inlet of Emmon's Creek and the Crystal River Outlet (Fig. 9).

Purple Loosestrife is an exotic plant with a bright purple flower, originally propagated in the United States by the horticulture industry for flower gardens. It blooms late June to July and produces seeds soon after. The plant is able to outcompete native wetland vegetation and modify entire plant (and thus animal) assemblages.

BASELINE CONCLUSIONS

Watershed Characteristics

TWRPW Program well sample nitrate results, despite some instances of concern (e.g., > 10 mg/l), indicated that the Chain O' Lakes subwatershed had the lowest average nitrate readings for the entire Tomorrow/Waupaca River Watershed. Surface water samples indicated variable nitrate readings for the Chain subwatershed with highest readings in Murray and Radley Creeks.

Sediment/nutrient delivery for the Chain subwatershed of the TWRPW Project appraisal was estimated to be lower than all other subwatersheds. The Chain O' Lakes subwatershed contained almost 8% of the surface drained farmland but was estimated at only 6% of the sediment delivery; no stream degradation was observed for the 21.8 miles of streams in the Chain subwatershed.

Water Quality

Regular water quality monitoring in the Lower Chain during Phase II, as during Phase I, indicated good to very good water quality. Surface total phosphorus levels were generally similar to that in the other Chain lakes and generally exhibited weak and variable seasonal trends. Total nitrogen levels tended to be slightly higher, as a whole, than in other Chain groups and seasonal trends indicated higher levels during Winter, when groundwater was of greatest influence and lower levels during summer stratification. Most between lake differences observed appeared related to basin depth differences. In-lake surface phosphorus for all lakes continued to be near or below levels expected for stratified lakes, lakes in the central region of Wisconsin and lakes in the ecoregion in which the Chain is located; marl precipitation apparently reduces phosphorus levels in at least some Chain lakes.

Flow and nutrient contribution via Emmon's Creek is relatively significant compared with other overland sources to the Chain (Fig. 6-8). Existing estimates of total overland nutrient input to the Chain appear questionable because of the considerable discrepancy between the TWRPW Project and the estimated flow - field measured phosphorus estimate methods.

Recreational Use

Lower Chain resident responses to the recreational use survey were in general agreement with those from the Chain as a whole and from "fast" and "slow" lake user groups. Watercraft use on the Chain is high and respondents generally agreed that the current number of watercraft caused safety problems. They also indicated that water safety enforcement was adequate, but fewer agreed during weekend or holiday periods of heavy recreational use. Respondents were evenly split as to limiting the number of watercraft and only slightly agreeable to additional use regulations. There was relatively low interest in establishment of a public park or beach on the Chain. Respondents were evenly divided as to the need for more public restrooms on the Chain.

Exotic Species

There were no observations of Zebra Mussels or Eurasian Water Milfoil in the Chain. Purple Loosestrife, which is widely distributed in Wisconsin and Waupaca County, has become established in several areas of the Upper, Middle and Lower Chains.

MANAGEMENT RECOMMENDATIONS

Watershed: The Chain O' Lakes is significantly influenced by groundwater and receives some surface water inflow from the watershed. Residents should be made aware of the potential effects of watershed uses on their resource. In addition to a continuous focus on "yard management", they should be strongly encouraged to keep abreast of and support the TWRPW Project.

- Residents in the Lower Chain watershed should have private wells tested for nitrates and/or pesticide levels.

- Groundwater samples should be collected at various points in the Chain O' Lakes watershed to determine areas of concern.

Water Quality: Water quality in the Lower Chain is currently very good but a focused monitoring strategy should be continued. These data could provide a long term trend assessment and detect detrimental influences before effects become widespread or severe.

- Columbia, Long, Beasley, and Bass (deepest point) Lake sites should be considered "indicator lakes" for Lower Chain trend monitoring. Surface only samples during Winter, after ice out and three times during the Summer would minimize collection and laboratory analysis costs.

- More event samples should be collected at Site 12E1; flow determination and rainfall monitoring would enhance the value of this information.

- Groundwater nutrient and flow direction/rates should be collected for the Chain O' Lakes system when feasible.

Recreational Use: Chain O' Lakes resident recreational use survey results suggest that use, during summer weekends and holidays, is at or near saturation levels and that most perceive the problems related to non-resident and commercial watercraft. There does not appear, however, to be a clear concensus that additional regulations are desirable to address the situation. The CLPOA, then, should form a committee, or enlist some outside assistance, to address direct education or prevention measures to attempt minimization of use conflicts; these may include

- Development of maps for distribution which define best potential use zones for different recreational activities (skiing, fishing, canoeing, SCUBA diving/snorkeling, pleasure boating, dining, snowmobiling, etc.),

- Brochures, for visitors at access points, emphasizing "water use ethics" along with information on available restrooms, access points and applicable regulations and ordinances,

- Development of water accessible restrooms and waste disposal facilities for boaters,

- Initiation of a reasonable ramp fee at some/all access points with the money collected directed toward access maintenance or lake management/protection activities, and

- Riparian landowners education about pertinent ordinances (dock design/size, boat numbers per pier, building near lakeshores, near-lake improvements, etc.).

Exotic Species: Of the three exotic species of most current concern, only purple loosestrife appears to be established in the Chain O' Lakes.

- Identified purple loosestrife stands should be treated as soon as it is practical to do so; localized growth areas or individual plants should be treated first and more extensive growth areas later. It is best to treat plants before flowering (May to mid June). Plants are treated by cutting the top off and spraying the remainder with a Roundup-surfactant mix; plants in standing water should be treated with a Rodeo-surfactant mix. Chemicals can be applied using hand spray bottles or larger chemical sprayers. Sites should be revisited in subsequent years to treat remnant individuals.

- An exotic species watch group should be organized to monitor or remove exotic species (i.e., Purple Loosestrife, Zebra Mussels and Eurasian Water Milfoil) when encountered. Members should coordinate with the WDNR Exotic Species Program and inform the CLPOA membership and public on the hazards of exotic species as they relate to the Chain O' Lakes.

Public Involvement: Informational and educational programs for the CLPOA membership and public should be continued. Meetings, presentations, newsletters and/or news releases should continue to include information on groundwater and surface water quality, recreational use issues and the spread or control of exotic species.

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5. Wisconsin Department of Natural Resources, Water Quality Management Program. 1991. Wolf River Basin Plan. 301 pp.

6. Lillie, R. A. and J. W. Mason. 1983. Limnological Characteristics of Wisconsin Lakes. WDNR Technical Bulletin No. 138. 117 pp.

7. Omernik, James M. et. al. 1988. "Summer Total Phosphorus in Lakes: A Map of Minnesota, Wisconsin, and Michigan, USA." Environmental Management 12(6): 815-825.

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9. Wisconsin Department of Natural Resources. 1994. Flow and Nutrient Data for Hartman Creek, Emmon's Creek and Crystal River. Unpublished.

APPENDIX I
RECREATIONAL USE SURVEY RESULTS
Lower Chain O' Lakes Management Plan

Name of Lake: ________________

RECREATIONAL USE SURVEY
Chain O'Lakes Property Owners Association

The Chain O'Lakes Association is leading a coordinated effort to develop a Comprehensive Lake Management Plan for the Chain O'Lakes. The first phase of this three-phased program is focusing on obtaining and analyzing information about the lakes. One particular area of interest is learning more about your recreational use of the Chain O'Lakes.

Please take the time to complete this questionnaire. After you have completed the questionnaire your Neighborhood Chairperson will pick it up within one week.

All replies are confidential. Please do not sign your name to the survey. Only through your help can we develop a successful, comprehensive plan! The results of the survey will be available before the end of this year. We thank you for your cooperation!

PROPERTY USE

1. What year did you purchase your property on the Chain O'Lakes? _______
   N = 140; Ave.= 1972; Range = 1924-1992
2. What year did you buy or build your current dwelling on the Chain O'Lakes? _______
   N = 129; Ave. = 1974; Range = 1925-1992
   a. No dwelling on property ___
   N = 2
3. If you do not have a dwelling on your property, what year do you plan to build? 1993/1997
   a. Don't plan to build ___

(IF YOU DO NOT HAVE A DWELLING ON YOUR PROPERTY, SKIP TO QUESTION # 7.)

4. How many months per year do you occupy your dwelling on the Chain O'Lakes? _______
   N = 132; Ave. = 7.7; Range = 1-12
5. Do you rent out your dwelling? (Please check (x) your response below.)
   a. Yes ___ b. No ___
   N = 135; Yes = 7; No = 128
   c. If yes, how many weeks per year? _______
   N = 7; Ave. = 20.0; Range = 8-36
6. Do you let others use your dwelling? (Please check (x) your response below)
   a. Yes ___ b. No ___
   N = 134; Yes = 35; No = 99
   c. If yes, how many weeks per year? _______
   N = 35; Ave. = 4.2; Range = 1-28

APPENDIX I
(continued)

WATER USE

7. Please identify the type and number of watercraft/horsepower (HP) you own.

Watercraft Type	Number	Watercraft Type	Number
a. sailboat	35	g. Motor boat 50-100 HP	34
b. canoe or kayak	115	h. motor boat over 100 HP	27
c. row boat/ paddleboat (no motor)	55	i. personalized watercraft; i.e., jet ski	3
d. pontoon boat	84	j. other, please list ______	7
e. motor boat less than 25 HP	65	______	______
f. motor boat 26-50 HP	9		

8. Do you allow others, besides the property owner or renter, to keep water craft on your property? (Please check (x) your response below.)

a. Yes ____ b. No ____

N = 143; Yes = 19; No = 124

c. If yes, please identify the type/horsepower of the watercraft.

Watercraft Type	Number	Watercraft Type	Number
a. sailboat	2	g. motor boat 51-100 HP	8
b. canoe or kayak	1	h. motor boat over 100 HP	3
c. row boat/ paddleboat (no motor)	3	i. personalized watercraft; i.e., jet ski	0
d. pontoon boat	9	j. other, please list ______	0
e. motor boat less than 25 HP	3	______	______
f. motor boat 26-50 HP	1		

APPENDIX I
(continued)

9. Where is the permanent residence(s) of the other watercraft owners? (city/state)

____

____

a. ____ no others have watercraft on our property

Waupaca = 9
Stevens Point = 2
Appleton = 2
Oshkosh= 1
Lockport, IL= 1
King= 1
Chesterfield, MO= 1
Westmont, IL= 1

APPENDIX I
(continued)

(FOR QUESTIONS 10, 11, 12, AND 15, THE TERM "PLEASURE BOATING" REFERS TO THE USE OF THE BOAT FOR RIDING AND SIGHTSEEING ONLY - NOT FOR FISHING OR WATER SKIING. "PONTOONING" REFERS TO PLEASURE BOATING USING A PONTOON.)

10. Please indicate how you spend your time on the Chain O'Lakes. Please check (x) the amount of water use for each surface water use category.

	Amount of Time Spent*			
Surface Water Use	Frequently	Occasionally	Seldom	Never
a. Sailing	5	15	18	60
b. Canoeing	15	52	34	14
c. Pleasure Boating	67	33	9	11
d. Personal Water Craft (i.e., Jet Ski)	1	2	2	85
e. Water Skiing	19	22	19	44
f. Fishing	34	39	23	25
g. Swimming & Sunbathing	67	41	9	4
h. Pontooning	57	26	9	31
i. Bird Watching/ Wildlife Watching	50	34	18	16
j. Viewing Natural Beauty	75	33	8	6
k. Other - please specify	Walk,Bike(4)	Windsurf	Walk	

* Frequently = at least 1 time per week.
Occasionally = at least 1 time per month.
Seldom = 3-4 times a year.

APPENDIX I
(continued)

11. Please indicate how other adults (18 and over) in your residence spend their time on the Chain O'Lakes.

Amount of Time Spent*

Surface Water Use	Frequently	Occasionally	Seldom	Never
a. Sailing	2	12	19	55
b. Canoeing	14	41	36	11
c. Pleasure Boating	50	39	7	8
d. Personal Water Craft (i.e., Jet Ski)	1	4	3	73
e. Water Skiing	23	21	21	32
f. Fishing	27	31	24	21
g. Swimming & Sunbathing	64	32	6	5
h. Pontooning	37	31	8	29
i. Bird Watching/ Wildlife Watching	26	36	17	18
j. Viewing Natural Beauty	48	38	10	6
k. Other - please specify	Walk,Bike(5)	Entertain.	Windsurf	

* Frequently = at least 1 time per week.
Occasionally = at least 1 time per month.
Seldom = 3-4 times a year.

APPENDIX I
(continued)

12. Please indicate how youth (under age 18) in your residence spend their time on the Chain O'Lakes.

Amount of Time Spent

Surface Water Use	Frequently	Occasionally	Seldom	Never
a. Sailing	2	4	9	49
b. Canoeing	9	25	20	17
c. Pleasure Boating	22	30	5	11
d. Personal Water Craft (i.e., Jet Ski)	0	2	4	56
e. Water Skiing	18	14	9	28
f. Fishing	19	23	14	17
g. Swimming & Sunbathing	52	23	5	4
h. Pontooning	23	17	8	25
i. Bird Watching/ Wildlife Watching	9	23	16	20
j. Viewing Natural Beauty	15	27	18	10
k. Other - please specify	Bike(2),Walk			

* Frequently = at least 1 time per week.
Occasionally = at least 1 time per month.
Seldom = 3-4 times a year.

APPENDIX I
(continued)

13. How do you get your boat(s) in the water on the Chain O'Lakes? (Please check (x) your response below.)

a. 25 private launch site   c. 38 commercial launch site

b. 50 public launch site   d. 5 other (please list)

In addition to "other" replies, there were the following multiple responses: 2 - public and commercial; 3 - private and public; 6 - private and commercial; 2 - commercial and other

14. Please indicate how frequently members of your household picnic at the Chain O'Lakes. Please check (x) the frequency for each category.

Amount of Picnicking*

Picnic Location	Frequently	Occasionally	Seldom	Never
a. Own yard	71	43	14	9
b. Neighbor's yard	3	23	26	52
c. Private park or beach	0	7	12	83
d. In a boat on the lake	19	51	25	27
e. County park	0	3	15	83

* Frequently = at least 1 time per week.
Occasionally = at least 1 time per month.
Seldom = 3-4 times a year.

APPENDIX I
(continued)

15. How often do members of your household go to other lakes besides the Chain O'Lakes for recreational uses? Please check (x) the frequency for each category.

Surface Water Use	Amount of Time Spent*			
	Frequently	Occasionally	Seldom	Never
a. Sailing	3	0	8	9
b. Canoeing	2	3	13	92
c. Pleasure Boating	3	9	21	81
d. Personal Water Craft (i.e., Jet Ski)	0	0	2	99
e. Water Skiing	0	3	10	93
f. Fishing	5	22	23	66
g. Swimming & Sunbathing	4	17	20	71
h. Pontooning	2	7	9	96
i. Bird Watching/ Wildlife Watching	4	18	19	71
j. Viewing Natural Beauty	6	23	21	59
k. Other - please specify	Bike	Windsurf	Walk	

* Frequently = at least 1 time per week.
Occasionally = at least 1 time per month.
Seldom = 3-4 times a year

APPENDIX I
(continued)

16. How often do members of your household use water craft on other lakes besides the Chain O'Lakes?

a. 5 frequently
b. 9 occasionally
c. 34 seldom
d. 88 never

17. How often are members of your household likely to participate in the following winter sports activities?

Activity	Amount of Use* Frequently	Occasionally	Seldom	Never
a. Ice fishing	8	23	20	75
b. Cross country skiing	14	32	29	53
c. Snowmobiling	5	10	21	86
d. Ice skating	3	30	31	56
e. Ice boating	0	1	1	114
f. Snow shoeing	0	1	8	108
g. Other - please specify	Walk(2)	Ski	Walk	

* Frequently = at least 1 time per week.
Occasionally = at least 1 time per month.
Seldom = 3-4 times a year

APPENDIX I
(continued)

WATER USE CONFLICTS

18. There are too many watercraft on the Chain. (Please check (x) your response.)

a. 53 strongly agree
b. 59 agree
c. 26 disagree
d. 3 strongly disagree

If you "strongly agree" or "agree", when?

a. 0 weekdays b. 18 weekends c. 15 holidays

In addition to "other" replies, there were the following multiple responses: 1 - weekdays and holidays; 79 - weekends and holidays; 3 - all

d. Please identify lake(s). WAKE LAKES (21) All(17)

19. The current number of watercraft causes water safety problems. (Please check (x) your response below.)

a. 41 strongly agree
b. 66 agree
c. 31 disagree
d. 2 strongly disagree

20. If you "strongly agree" or "agree" with statement #19, what do you feel are the cause(s). (Please check (x) all appropriate responses below.)

a. 4 private residential watercraft
b. 8 commercial watercraft activities and rentals
c. 24 non-residential watercraft
d. 4 other, please specify

In addition to "other" replies, there were the following multiple responses: 37 - b & c; 8 - a, b & c; 1 - a & b; 10 - a & c; 2 - b & c; 5 - c & d; 2 - all

21. The current number of watercraft diminishes the ability to enjoy the Chain O'Lakes from the water or from the shore.

	strongly agree	agree	disagree	strongly disagree
a. weekdays	3	27	55	17
b. weekends	47	58	27	4
c. holidays	56	61	17	4

APPENDIX I
(continued)

22. There is adequate water safety enforcement during: (Please check (x) all appropriate responses below.)

	strongly agree	agree	disagree	strongly disagree
a. weekdays	22	81	12	8
b. weekends	16	65	36	15
c. holidays	16	62	35	18

23. Surface water use conflicts on the Chain O'Lakes are extensive enough that additional surface water use regulations need to be enacted and enforced? (Please check (x) your response below.)

a. 31 strongly agree
c. 43 disagree
b. 47 agree
d. 12 strongly disagree

24. There should be limits set on the number of watercraft that can use the surface water at particular times. (Please check (x) your response below.)

a. 26 strongly agree
c. 43 disagree
b. 40 agree
d. 19 strongly disagree

25. There is adequate public boater access to the Chain. (Please check (x) your response below.)

a. 72 strongly agree
c. 5 disagree
b. 59 agree
d. 4 strongly disagree

APPENDIX I
(continued)

26. There should be more public rest rooms on the Chain. (Please check (x) your response below.)

a. 31 strongly agree c. 46 disagree

b. 31 agree d. 25 strongly disagree

1. If you "strongly agree" or "agree" with statement #26, docking facilities should be provided for the rest rooms.

a. 24 strongly agree c. 5 disagree

b. 35 agree d. 6 strongly disagree

2. These facilities should be provided by:

	strongly agree	agree	disagree	strongly disagree
a. private sector	20	14	9	11
b. public sector	20	31	3	8

27. There should be a public swimming beach on the Chain. (Please check (x) your response below.)

a. 27 strongly agree c. 39 disagree

b. 24 agree d. 51 strongly disagree

28. There should be a public park with picnicking and shelter on the shoreline of the Chain. (Please check (x) your response below.)

a. 15 strongly agree c. 49 disagree

b. 21 agree d. 53 strongly disagree

APPENDIX I
(continued)

DEMOGRAPHICS

29. How many adults (18 years or over) including yourself reside in your household?
N = 138; Ave. = 2.3; Range = 1-8

30. How many children over 12 but under 18 reside in your household? ____
N = 92; Ave. = 0.6; Range = 0-10

31. How many children 12 or under reside in your household? ____
N = 89; Ave. = 0.6; Range = 0-10

32. What was your age on your last birthday? ____
N = 135; Ave. = 59.8; Range = 23-95

33. What are the occupations of you and your spouse? (Please check (x) your response(s) below.)

14	professional, i.e., teacher, doctor, lawyer	0	craftsman, foreman, operator
1	sales/clerical	0	service worker
0	farmer	2	homemaker
3	manager, administrator	13	self-employed business owner
1	student	55	retired
0	unemployed	2	other, please specify ____________

37. If you have comments or suggestions about this survey or the lake management planning effort, please respond below.

66 respondents had comments and which will be reviewed later.

Thank you for your help! Your Neighborhood Chairperson will pick up this survey within one week.