IPS ENVIRONMENTAL AND ANALYTICAL SERVICES
Appleton, Wisconsin

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

REPORT TO:
CHAIN O' LAKES PROPERTY OWNERS ASSOCIATION

June, 1993

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GLOSSARY OF TERMS (1, 2, 3)

Anoxic — Water that has extremely low or no dissolved oxygen.

Chlorophyll a — Green pigment present in all green plant life and needed in photosynthesis. The amount present in lake water is related to the amount of algae and is therefore used as an indicator of water quality.

Eutrophication — The process of lake aging or enrichment with nutrients, generally with associated increases in algae or weeds. The extent to which this process has progressed is described by trophic status terms, e.g., oligotrophic, mesotrophic, or eutrophic.

Fetch — The longest distance over which the wind can sweep unobstructed.

Hypolimnion — Lower, cooler layer of a lake during summertime thermal stratification.

Littoral — The shallow area of a lake from the shore to the depth where light no longer penetrates to the bottom.

Macrophyte — Commonly referred to as lake "weeds", actually aquatic vascular plants that grow either floating, emergent or submergent in a body of water.

Marl — White to gray accumulation on lake bottoms caused by precipitation of calcium carbonate ($CaCO_3$) in hard water lakes. The marl may contain snail and clam shells which are also $CaCO_3$. While it gradually fills in lakes, marl also precipitates phosphorus, resulting in normally low algal populations and good water clarity.

Mesotrophic — A lake of intermediate productivity and clarity.

Morphometry — Pertaining to the shape, depth or structure of a lake.

GLOSSARY OF TERMS
(Continued)

N/P Ratio	Total nitrogen divided by the total phosphorus found in a water sample. A value greater than 15 indicates phosphorus to be limiting primary production.
Oligotrophic	Typically, a lake of low plant productivity and high transparency.
Physicochemical	Pertaining to physical and/or chemical characteristics.
Secchi Depth	A measure of optical water clarity as determined by lowering a weighted Secchi disk (20 cm in diameter) into the water body to a point where it is no longer visible.
Spring Lake	Lakes typically having no inlet but possessing an outlet; the primary source of water is groundwater inflow.
Stratification	Layering of water caused by differences in water density. Thermal stratification is typical of most deep lakes during the Summer. Chemical stratification can also occur.

SUMMARY

The Chain O' Lakes (Chain) is a recreationally popular group of 22 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 Upper Chain consists of Otter, Taylor, George, Sunset and Rainbow Lakes and comprises about 36% of the total Chain lake surface area. There are no inlets to the Upper Chain and all are classified as **spring lakes**[1]. Spring inflow to the Upper Chain occurs primarily in Sunset and Otter Lakes; overall, the number of spring inflows to the Upper Chain is less than to some other lake subgroups (e.g., Little Chain).

While different **morphometry** was apparent among lakes in the Upper Chain, water quality was similar and generally considered to be indicative of **oligotrophic** to **mesotrophic** status. Highest nutrient levels were at or below those typical of Wisconsin lakes overall and of lakes in the Chain O' Lakes' ecoregion. Water quality of the Upper Chain was similar to that of other Chain lakes with similar physical characteristics.

Water quality monitoring, recreational use management, and prevention of exotic plant/animal introductions are recommended to protect and enhance existing good water and aesthetic quality.

Regular water quality trend monitoring should continue on a similar schedule to supplement the small amount of historic data available; event samples should be taken as appropriate in areas of concern. Volunteers should 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 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.

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. Most lakes in the Chain are deep, clear, and spring-fed; the Chain and associated wetlands 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. The CLPOA has an Executive Committee of about 13 elected officers and about 600 members overall.

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 Upper Chain application incorporated required or CLPOA recommended program components including,

- assessment of current water quality in the Upper Chain and implementation of a monitoring strategy to track trends,
- enhancement of lake property owner awareness of lake problems and establishment of a base of support for lake management efforts, and
- development of options for recreational use management.

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

Table 1. Lake Management Planning Project Groups, 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 are 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 Upper Chain consists of five lakes in the northeast portion of the Chain.

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 moderately to steeply sloping. Major soil types near the Upper Chain are well drained Rosholt sandy loam on 12-20 percent slopes and Richford loamy sand on 2-6 percent slopes (6). Erosion potential ranges from moderate (Rosholt) to slight (Richford).

Predominant **littoral** substrates are sand and **marl**; scattered reaches of rubble and muck are present (Personal communication WDNR). **Macrophytes** (aquatic plants) are present in certain littoral areas but are not considered a problem in the Upper Chain where predominantly sandy littoral zones are not conducive to nuisance plant growth. Two exotic nuisance plant species, Eurasian milfoil (Myriophyllum spicatum) and purple loosestrife

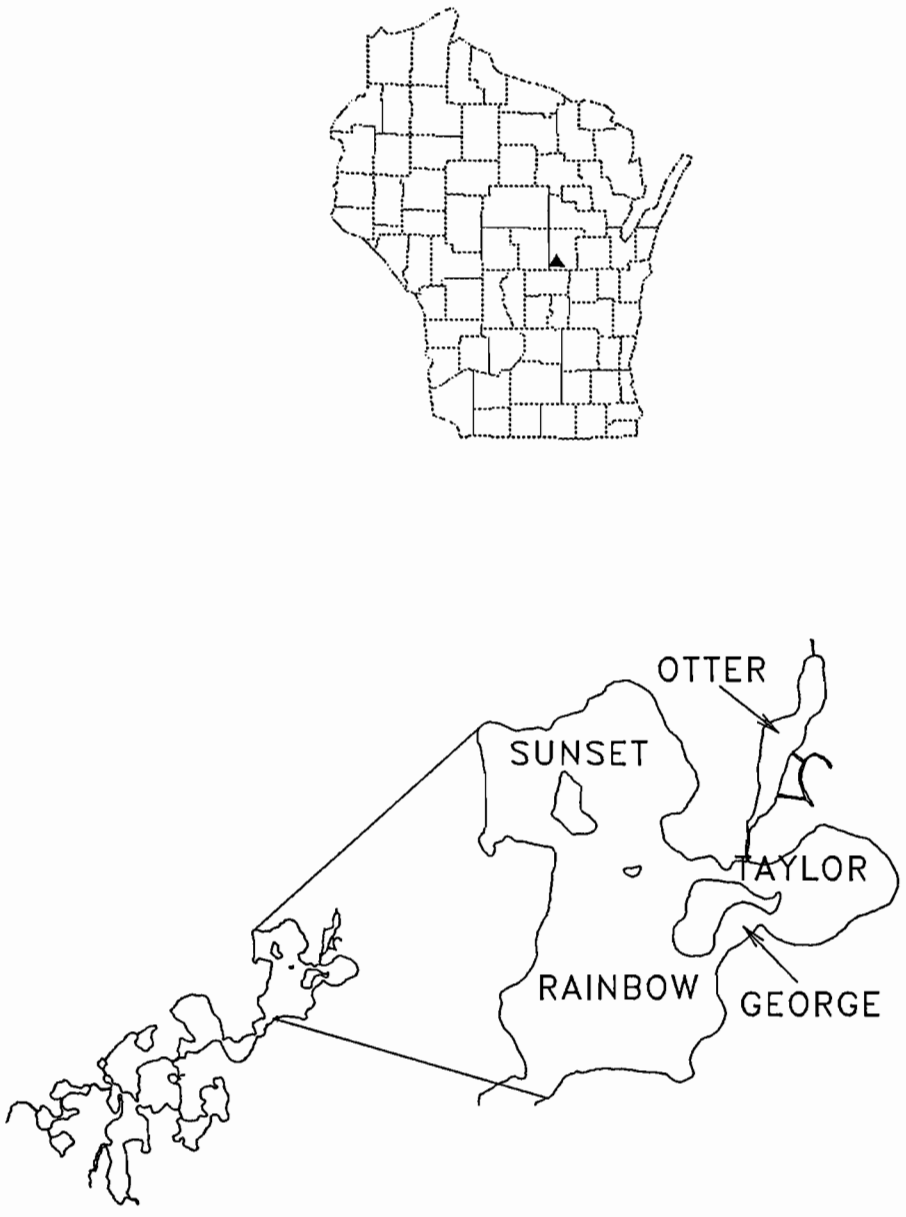


Figure 1. Location Map, Chain O' Lakes, Waupaca County, WI.

predominantly forested with open/agricultural areas. Native trees include maple, ash, oak, and pine. Dairy farming represents the chief agricultural activity in the Chain watershed (Pers. comm. WDNR). The only known point source discharge to the Upper Chain is a Village of King storm sewer to George Lake.

The lakes are spring-fed but vary with respect to basin morphometry (Table 2). Upper Chain lake area ranges from 5 acres (George) to 116 acres (Rainbow); volume ranges from 50 (George)

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

Lake Name	OTTER	TAYLOR	GEORGE	SUNSET	RAINBOW
Location					
Township	22N	22N	22N	22N	22N
Range	11E	11E	11E	11E	11E
Section(s)	26	34,35	34	27,34	34
Lake Type	Spring	Spring	Spring	Spring	Spring
Area (acres)	14	35	5	89	116
Max. Depth (ft)	40	58	30	63	95
Ave. Depth (ft)	14	14	10	26	37
Volume (acre-feet)	193	504	50	2124	4280
Shoreline (miles)	1.1	1.1	0.4	1.7	2.0
Fetch (miles)	0.43	0.37	0.13	0.55	0.64
Fetch Orientation	SW-NE	NW-SE	SW-NE	SW-NE	SW-NE
Width (miles)	0.11	0.31	0.08	0.47	0.64
Lake Shore Soils					
Major Type	Rosholt[1]	Richford[2]	Rosholt[1]	Rosholt[1]	Rosholt[1]
% Slope	12-20	2-6	12-20	12-20	12-20

[1] = Rosholt sandy loam
[2] = Richford loamy sand

to 4300 acre-feet (Rainbow) (Pers. comm. WDNR). The relatively small (maximum **fetch** 0.64 miles) and deep (30 - 95 feet) lake basins, combined with adjacent topography, inhibits wind driven mixing of the Upper Chain lakes and promotes **stratification** during open water seasons and restricts mixing to spring and fall overturns.

The Chain supports warmwater and coldwater fisheries (Table 3). At least 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).

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 Upper Chain has boat ramp access points at Clearwater Harbor and off Pine Ridge Lane on the north shore of Taylor Lake (Pers. comm. WDNR).

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*

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

Water sampling was conducted May 30 or June 5, August 7, and September 5, 1991 and January 30 or February 4 and May 6, 1992 at the deepest point of each lake in the Upper Chain; two distinct basins (i.e., east and west of Onaway Island) of Sunset Lake were sampled (Table 4, Figure 2). All sites were sampled three feet below the surface (designated "S") and three feet above bottom (designated "B").

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 unit 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. All laboratory analyses were conducted at the State Laboratory of Hygiene (Madison, WI) using WDNR or APHA (8) methods. Spring parameters determined by the

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

		WATER QUALITY	
Lake	Site	Latitude (North) / Longitude (West)	Depth
Otter (Deepest Pt.)	1004	44° 20' 57" / 89° 08' 22"	40.0 ft.
Taylor (Deepest Pt.)	1003	44° 20' 30" / 89° 08' 25"	58.0 ft.
George (Deepest Pt.)	1002	44° 20' 28" / 89° 08' 41"	30.0 ft.
Sunset (Deepest Pt.)	1005	44° 20' 43" / 89° 08' 58"	63.0 ft.
Sunset (W. of Onaway)	1006	44° 20' 47" / 89° 09' 15"	59.0 ft.
Rainbow (Deepest Pt.)	1001	44° 20' 17" / 89° 09' 05"	95.0 ft.

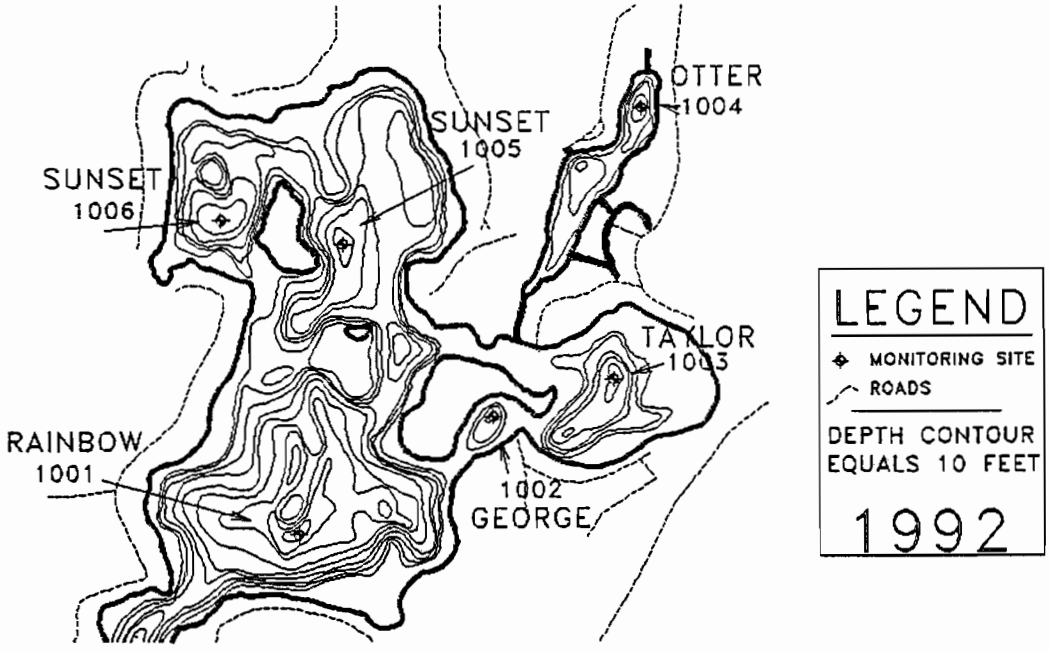


Figure 2. Sample Station Locations, Upper Chain, Chain O' Lakes, Waupaca County, WI

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.

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 out-dated, was confirmed by field reconnaissance.

Ordinance information was taken from the 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

A summary of public involvement activities coordinated with the lake management planning process is outlined 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 Upper Chain is comprised of 5 natural lakes. Otter Lake has a comparatively larger littoral zone (primarily muck) than other lakes of the Upper Chain which are relatively deeper with primarily sandy substrates. Flow in the Upper Chain is to Rainbow Lake and then to Nessling Lake (Middle Chain); the Crystal River (originating from Long Lake in the Lower Chain) serves as the outlet for the entire Chain O' Lakes.

The Chain O' Lakes watershed consists of wooded/wooded residential, open/agricultural, open/residential and wetland areas; the watershed of the Upper Chain is about 2,400 acres and has more extensive open areas compared to other Chain project groups. Shoreline areas immediately adjacent to all Upper Chain lakes are predominantly wooded/wooded residential with low potential for surface runoff (Figure 3). The Village of King occupies a large portion of the Rainbow, George, and Taylor Lakes shorelines; Otter Lake shoreline areas are heavily wooded.

The Upper Chain has a watershed to lake ratio of 9.2:1 which means that 9.2 times more land than lake surface area drains to the lakes. This value is only slightly higher the 8:1 ratio for seepage lakes (lakes without inlets) in Wisconsin (9).

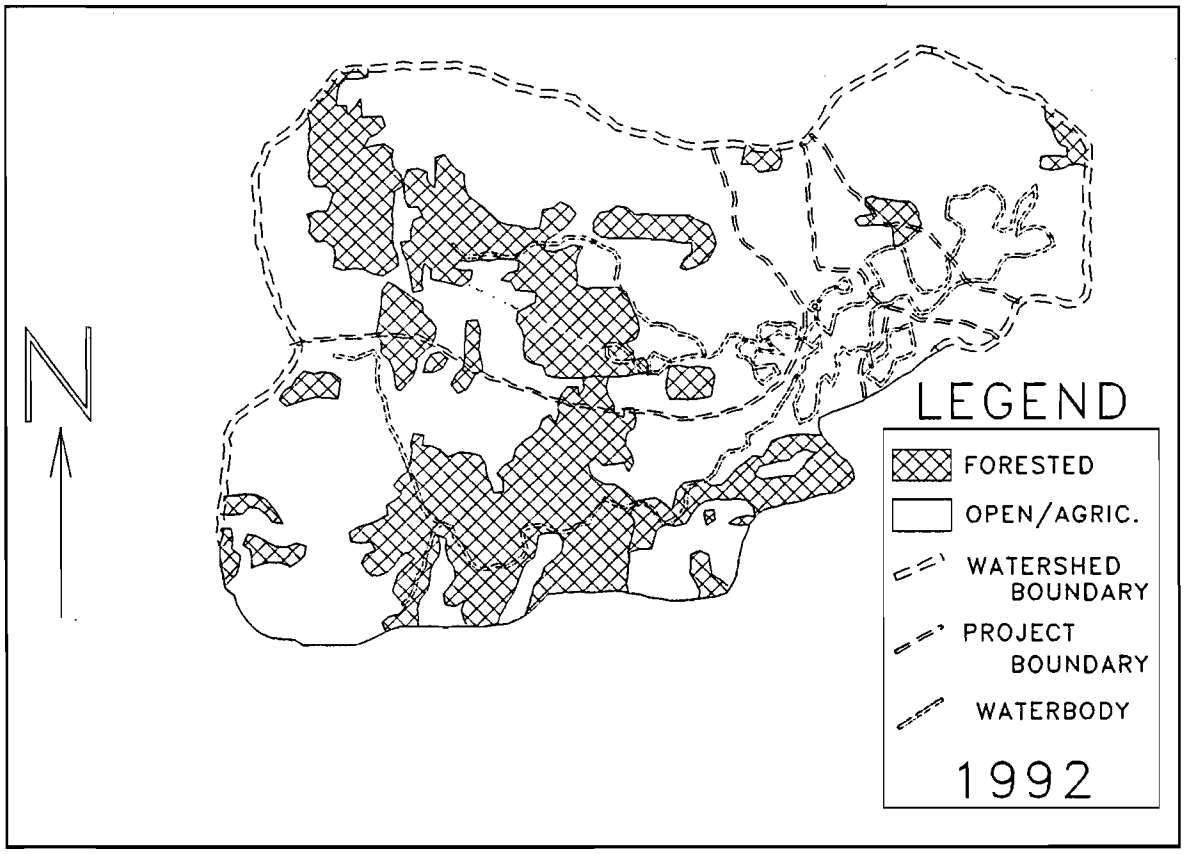


Figure 3. Land Uses in the Chain O' Lakes Watershed, Waupaca and Portage Counties, WI.

Monitoring in 1991-1992 (Tables 5-10), indicated similar water quality among the Upper Chain lakes. Surface total nitrogen, which is highly variable among lakes and best considered on a trend or relative basis, ranged from 0.677 in Taylor Lake to 2.09 mg/l in Otter Lake with an average of 1.07 mg/l for all Upper Chain lakes. Highest average surface total nitrogen (1.25 mg/l) was observed in Otter Lake while Taylor Lake exhibited the lowest (0.999 mg/l). Lowest levels were typically observed during stratified conditions in Summer.

Phosphorus is often the limiting nutrient to plant and algal production in lakes. Surface total phosphorus levels were similar among Upper Chain lakes (range: 0.005 in Sunset Lake at Station 1006 to 0.017 mg/l in Otter Lake) with an average of 0.010 mg/l (Tables 5-10). Average surface total phosphorus in Otter Lake (0.014 mg/l) was somewhat higher than elsewhere in the Upper Chain and was probably related to the relatively greater amount of littoral area in the lake. Lowest average surface total phosphorus levels were observed in Rainbow and Sunset Lakes (0.009 mg/l). Phosphorus levels for the Upper Chain were lower than those typical for stratified lakes (0.023 mg/l) and for lakes in the central region in Wisconsin (0.020 mg/l) (9); levels were at or slightly below those typical for the ecoregion in which the Chain is located (0.010-0.014 mg/l) (10) (Figure 4).

Table 5. Water Quality Parameters, Station 1004, Otter Lake, Waupaca County, WI.

PARAMETER	SAMPLE[1]	05/30/91	08/07/91	09/05/91	02/04/92	05/06/92
Secchi (feet)		6.0	12.0	13.0	NR[2]	14.0
Cloud Cover (%)		100	70	70	50	0
Temperature (°C)	S	24.26	21.23	21.55	3.62	13.02
	B	7.21	8.87	9.38	4.36	6.51
pH (S.U.)	S	8.16	8.09	8.17	11.11	8.06
	B	7.48	6.91	7.25	8.62	7.10
D.O. (mg/l)	S	8.05	8.91	8.82	4.41	11.38
	B	0.80	0.33	0.36	0.78	0.36
Conductivity (µmhos/cm)	S	351	377	362	419	369
	B	444	435	416	430	414
Laboratory pH (S.U.)	S	8.3	NR	NR	NR	NR
	B	7.7	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	180	NR	NR	NR	NR
	B	239	NR	NR	NR	NR
Total Solids (mg/l)	S	252	NR	NR	NR	NR
	B	318	NR	NR	NR	NR
Total Kjeldahl N (mg/l)	S	0.4	0.5	0.5	0.7	0.6
	B	1.2	0.9	0.5	0.8	0.8
Ammonia Nitrogen (mg/l)	S	0.082	0.028	0.044	0.321	0.034
	B	0.437	0.402	0.112	0.423	0.318
NO_2 + NO_3 Nitrogen(mg/l)	S	0.492	0.325	0.277	1.39	1.08
	B	<0.015	0.254	0.247	1.32	0.635
Total Nitrogen (mg/l)	S	0.892	0.825	0.777	2.09	1.68
	B	<1.215	1.154	0.747	2.12	1.435
Total Phosphorus (mg/l)	S	0.010	0.016	0.017	0.017	0.008
	B	0.050	0.080	0.016	0.032	0.027
Diss. Phosphorus (mg/l)	S	ND[3]	0.002	ND	0.007	ND
	B	ND	0.020	0.002	0.014	ND
N/P Ratio	S	89.2	51.6	45.7	122.9	210.0
	B	<24.3	14.4	46.7	66.2	53.1
Chlorophyll a (µg/l)	S	NR	5	4	NR	NR

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

Table 6. Water Quality Parameters, Station 1003, Taylor Lake, Waupaca County, WI.

PARAMETER	SAMPLE[1]	05/30/91	08/07/91	09/05/91	01/30/92	05/06/92
Secchi (feet)		6.0	12.0	8.0	NR[2]	8.0
Cloud Cover (%)		100	40	60	100	0
Temperature (°C)	S	24.53	21.97	21.83	3.22	12.38
	B	4.92	5.44	6.20	3.81	4.76
pH (S.U.)	S	8.39	8.56	8.62	7.83	8.85
	B	7.50	6.60	7.18	7.16	7.60
D.O. (mg/l)	S	8.76	8.65	8.60	10.54	11.98
	B	1.14	0.10	0.33	0.87	0.36
Conductivity (µmhos/cm)	S	307	301	286	344	326
	B	404	419	401	389	372
Laboratory pH (S.U.)	S	8.4	NR	NR	NR	NR
	B	7.6	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	148	NR	NR	NR	NR
	B	196	NR	NR	NR	NR
Total Solids (mg/l)	S	238	NR	NR	NR	NR
	B	294	NR	NR	NR	NR
Total Kjeldahl N (mg/l)	S	0.7	0.6	0.6	1.0	0.7
	B	2.3	3.4	3.0	1.8	2.0
Ammonia Nitrogen (mg/l)	S	0.090	0.045	0.047	0.488	0.104
	B	1.48	2.38	2.31	1.04	1.41
NO$_2$ + NO$_3$ Nitrogen(mg/l)	S	0.346	0.125	0.077	0.250	0.597
	B	<0.015	ND[3]	ND	0.185	ND
Total Nitrogen (mg/l)	S	1.046	0.725	0.677	1.25	1.297
	B	<2.315	<3.400	<3.000	1.985	<2.000
Total Phosphorus (mg/l)	S	0.010	0.010	0.007	0.015	0.012
	B	0.045	0.053	0.057	0.057	0.048
Diss. Phosphorus (mg/l)	S	ND	0.003	ND	0.003	ND
	B	ND	0.002	ND	0.003	ND
N/P Ratio	S	104.6	72.5	96.7	83.3	108.1
	B	<51.4	<64.3	<52.8	34.8	<41.8
Chlorophyll *a* (µg/l)	S	2	3	4	NR	9

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

Table 7. Water Quality Parameters, Station 1002, George Lake, Waupaca County, WI.

PARAMETER	SAMPLE[1]	05/30/91	08/07/91	09/05/91	01/30/92	05/06/92
Secchi (feet)		7.0	14.0	9.0	NR[2]	7.0
Cloud Cover (%)		100	70	50	100	0
Temperature (°C)	S	23.97	21.66	21.86	3.03	12.25
	B	9.46	12.49	14.23	4.06	5.91
pH (S.U.)	S	8.31	8.44	8.53	7.66	8.67
	B	7.72	7.03	7.02	7.22	7.50
D.O. (mg/l)	S	8.21	8.09	7.90	8.91	12.16
	B	1.40	0.13	0.21	0.74	0.36
Conductivity (µmhos/cm)	S	308	306	289	352	326
	B	365	417	422	367	336
Laboratory pH (S.U.)	S	8.3	NR	NR	NR	NR
	B	7.8	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	148	NR	NR	NR	NR
	B	173	NR	NR	NR	NR
Total Solids (mg/l)	S	238	NR	NR	NR	NR
	B	266	NR	NR	NR	NR
Total Kjeldahl N (mg/l)	S	0.7	0.6	0.6	1.1	0.6
	B	1.6	2.6	3.1	1.5	1.6
Ammonia Nitrogen (mg/l)	S	0.084	0.046	0.043	0.514	0.101
	B	0.794	0.851	1.34	0.921	0.838
NO_3 + NO_2 Nitrogen(mg/l)	S	0.362	0.155	0.087	0.241	0.588
	B	0.018	0.011	ND[2]	0.095	0.137
Total Nitrogen (mg/l)	S	1.062	0.755	0.687	1.341	1.188
	B	1.618	2.611	<3.100	1.595	1.737
Total Phosphorus (mg/l)	S	0.012	0.010	0.008	0.011	0.011
	B	0.054	0.091	0.106	0.016	0.054
Diss. Phosphorus (mg/l)	S	ND	ND	ND	0.002	ND
	B	ND	0.002	ND	0.003	ND
N/P Ratio	S	88.5	75.5	85.9	121.9	108.0
	B	30.0	28.7	<29.3	99.7	32.2
Chlorophyll a (µg/l)	S	NR	4	NR	NR	9

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

Table 8. Water Quality Parameters, Station 1005, Sunset Lake (Deepest Point), Waupaca County, WI.

PARAMETER	SAMPLE[1]	06/05/91	08/07/91	09/05/91	01/30/92	05/06/92
Secchi (feet)		12.0	10.0	8.0	NR[2]	7.0
Cloud Cover (%)		NR	50	80	100	0
Temperature (°C)	S	23.24	22.32	22.46	2.44	11.81
	B	5.95	6.37	6.95	3.53	5.60
pH (S.U.)	S	8.35	8.59	8.64	7.77	8.90
	B	7.39	6.70	7.13	7.11	8.00
D.O. (mg/l)	S	9.01	9.08	9.10	10.76	11.86
	B	0.71	0.09	0.27	1.06	4.54
Conductivity (µmhos/cm)	S	355	306	288	339	314
	B	408	383	385	366	326
Laboratory pH (S.U.)	S	8.5	NR	NR	NR	NR
	B	7.6	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	153	NR	NR	NR	NR
	B	178	NR	NR	NR	NR
Total Solids (mg/l)	S	224	NR	NR	NR	NR
	B	254	NR	NR	NR	NR
Total Kjeldahl N (mg/l)	S	0.6	0.5	0.5	0.9	0.8
	B	1.5	2.7	3.1	1.5	1.1
Ammonia Nitrogen (mg/l)	S	0.046	0.038	0.025	0.452	0.116
	B	0.933	1.90	2.46	0.881	0.493
NO_3 + NO_2 Nitrogen(mg/l)	S	0.524	0.291	0.217	0.322	0.652
	B	<0.015	ND[3]	ND	0.574	0.552
Total Nitrogen (mg/l)	S	1.124	0.791	0.717	1.222	1.452
	B	<1.515	<2.700	<3.100	2.074	1.652
Total Phosphorus (mg/l)	S	0.008	0.008	0.006	0.010	0.013
	B	0.040	0.051	0.049	0.047	0.025
Diss. Phosphorus (mg/l)	S	ND	ND	ND	0.002	ND
	B	ND	ND	ND	0.003	ND
N/P Ratio	S	140.5	98.9	119.5	122.2	111.7
	B	<37.9	<53.1	<63.4	44.1	66.1
Chlorophyll a (µg/l)	S	NR	4	4	NR	10

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

Table 9. Water Quality Parameters, Station 1006, Sunset Lake (W. of Onaway Island), Waupaca County, WI.

PARAMETER	SAMPLE[1]	06/05/91	08/07/91	09/05/91	01/30/92	05/06/92
Secchi (feet)		11.0	10.0	8.0	NR[2]	6.0
Cloud Cover (%)		40	50	80	100	0
Temperature (°C)	S	23.48	22.23	22.32	2.78	11.77
	B	6.03	6.79	7.34	4.23	5.83
pH (S.U.)	S	8.43	8.66	8.63	7.87	8.50
	B	7.35	7.17	7.24	7.17	NR
D.O. (mg/l)	S	9.52	9.60	9.25	11.60	11.97
	B	0.79	0.28	0.33	0.39	0.39
Conductivity (µmhos/cm)	S	353	305	289	337	316
	B	512	460	455	394	446
Laboratory pH (S.U.)	S	8.6	NR	NR	NR	NR
	B	7.6	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	152	NR	NR	NR	NR
	B	225	NR	NR	NR	NR
Total Solids (mg/l)	S	222	NR	NR	NR	NR
	B	312	NR	NR	NR	NR
Total Kjeldahl N (mg/l)	S	0.6	0.5	0.6	0.9	0.7
	B	2.6	1.6	2.4	1.3	2.2
Ammonia Nitrogen (mg/l)	S	0.043	0.021	0.029	0.410	0.118
	B	1.77	1.19	2.04	0.848	1.61
NO$_2$ + NO$_3$ Nitrogen(mg/l)	S	0.545	0.316	0.227	0.354	0.719
	B	0.467	0.337	ND[3]	1.33	1.52
Total Nitrogen (mg/l)	S	1.145	0.816	0.827	1.254	1.419
	B	3.067	1.937	<2.400	2.63	3.72
Total Phosphorus (mg/l)	S	0.009	0.009	0.005	0.011	0.015
	B	0.072	0.026	0.031	0.030	0.040
Diss. Phosphorus (mg/l)	S	0.002	ND	ND	0.003	ND
	B	0.008	ND	ND	0.003	ND
N/P Ratio	S	127.2	90.7	165.4	114.0	94.6
	B	42.6	74.5	<77.6	87.7	93.0
Chlorophyll a (µg/l)	S	NR	4	4	NR	10

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

Table 10. Water Quality Parameters, Station 1001, Rainbow Lake, Waupaca County, WI.

PARAMETER	SAMPLE[1]	05/30/91	08/07/91	09/05/91	01/30/92	05/06/92
Secchi (feet)		8.0	8.0	8.0	NR[2]	8.0
Cloud Cover (%)		70	100	40	100	0
Temperature (°C)	S	23.14	21.92	21.73	2.77	11.84
	B	8.3	NR	4.95	3.22	4.37
pH (S.U.)	S	8.50	8.57	8.18	7.70	8.78
	B	7.72	6.78	6.73	NR	7.50
D.O. (mg/l)	S	9.34	8.95	8.98	9.58	11.89
	B	2.60	0.10	0.16	0.78	0.33
Conductivity (µmhos/cm)	S	312	305	289	337	317
	B	370	410	367	347	338
Laboratory pH (S.U.)	S	8.5	NR	NR	NR	NR
	B	7.7	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	150	NR	NR	NR	NR
	B	180	NR	NR	NR	NR
Total Solids (mg/l)	S	240	NR	NR	NR	NR
	B	264	NR	NR	NR	NR
Total Kjeldahl N (mg/l)	S	0.6	0.5	0.6	1.0	0.6
	B	1.8	3.3	3.4	2.4	1.6
Ammonia Nitrogen (mg/l)	S	0.052	0.013	0.044	0.489	0.146
	B	1.01	2.44	2.69	1.20	0.659
NO_2 + NO_3 Nitrogen(mg/l)	S	0.471	0.258	0.200	0.250	0.641
	B	<0.015	ND[2]	ND	ND	0.380
Total Nitrogen (mg/l)	S	1.071	0.758	0.8	1.25	1.241
	B	<1.815	<3.300	<3.400	<2.400	1.98
Total Phosphorus (mg/l)	S	0.008	0.008	0.006	0.012	0.011
	B	0.050	0.146	0.107	0.139	0.053
Diss. Phosphorus (mg/l)	S	ND	ND	ND	0.003	ND
	B	ND	0.089	0.044	0.026	ND
N/P Ratio	S	133.9	94.8	133.3	104.2	112.8
	B	<36.3	<22.6	<31.8	<17.3	37.4
Chlorophyll a (µg/l)	S	4	4	4	NR	9

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

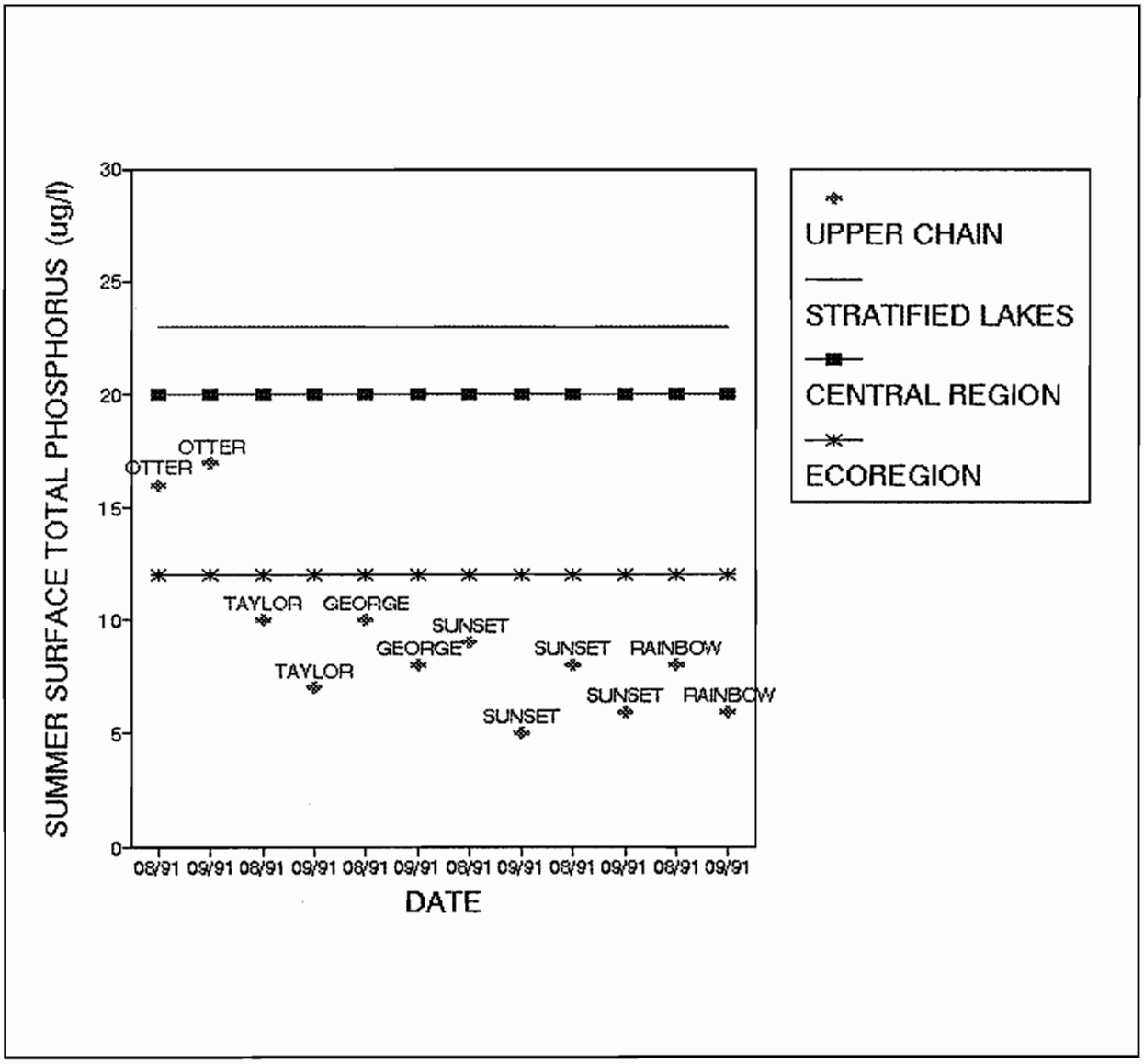


Figure 4. Comparison of Total Phosphorus Levels, Upper Chain, Chain O' Lakes, 1991.

Substantially higher values for total phosphorous and other nutrient parameters were observed near bottom 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 samples were greater than 15 and indicated all Upper Chain lakes to be phosphorus limited during the 1991 - 1992 monitoring period.

All Upper Chain lakes were thermally stratified during open-water monitoring (Figure 5, Appendix II). Depth to the thermocline was variable among lakes [minimum 12 feet (Otter Lake), maximum 21 feet (Sunset and Rainbow Lakes)]. Hypolimnetic oxygen levels were below those 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 (11) 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

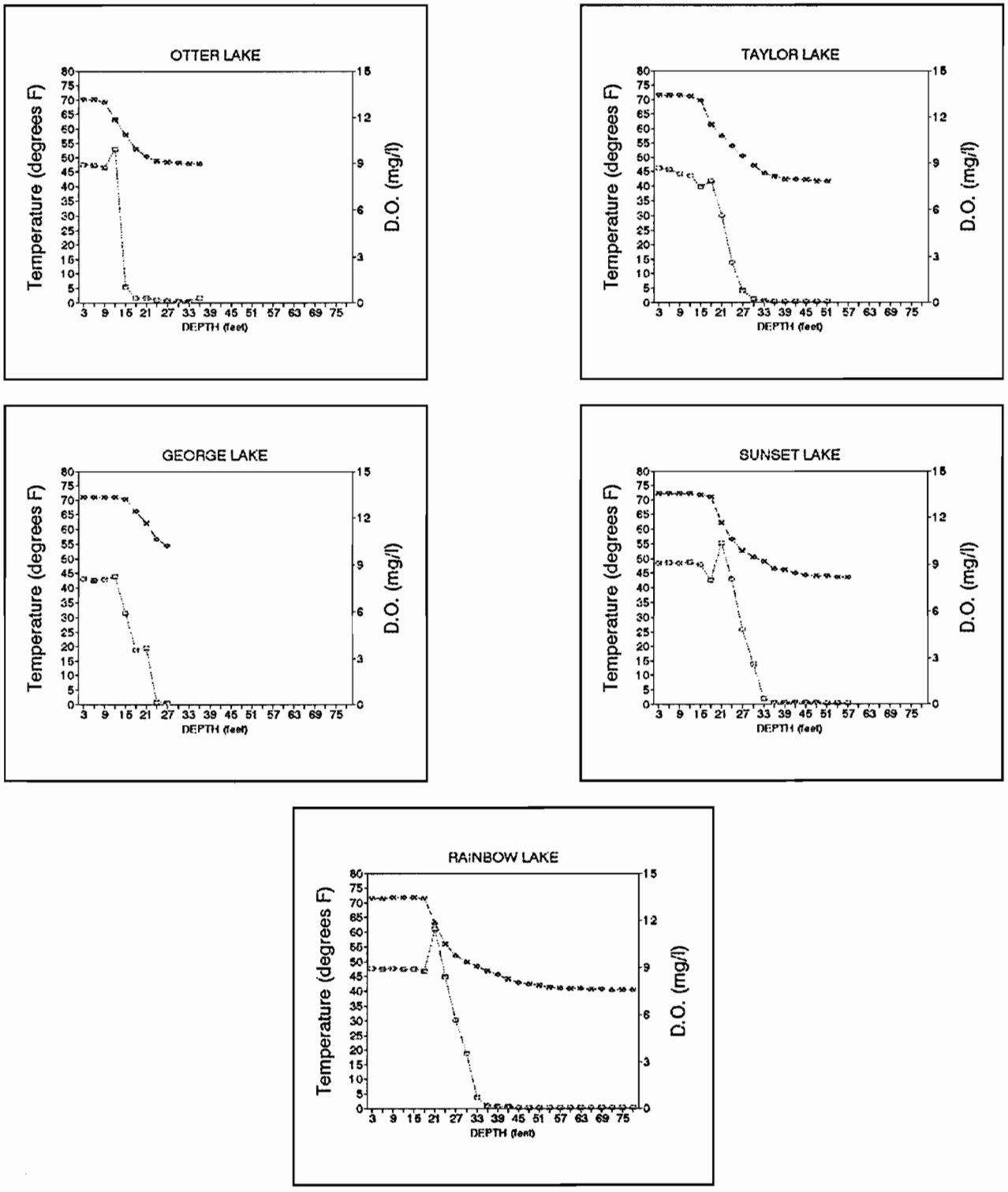


Figure 5. Temperature/DO Profiles, Upper Chain, Chain O' Lakes, Summer, 1991.

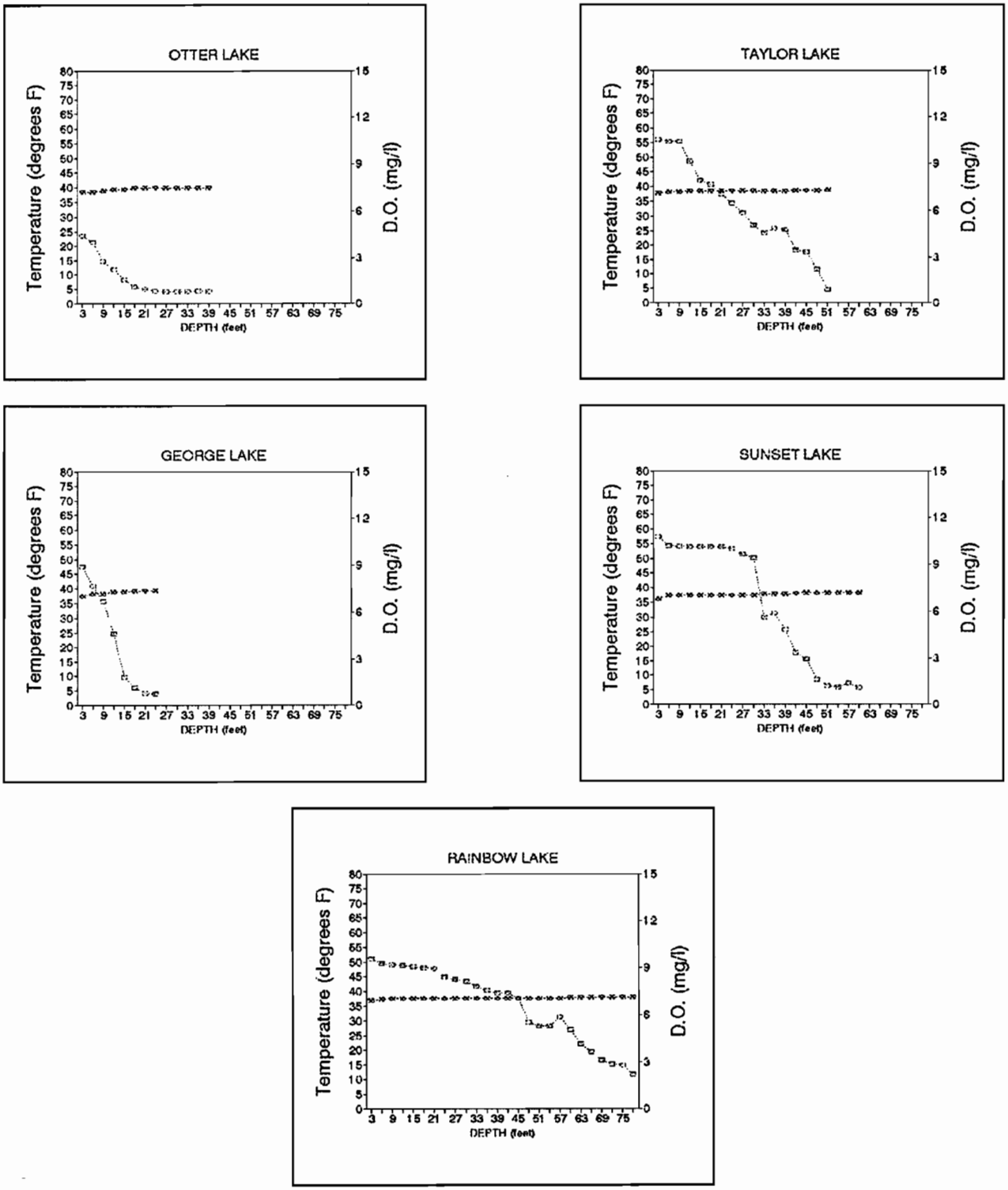
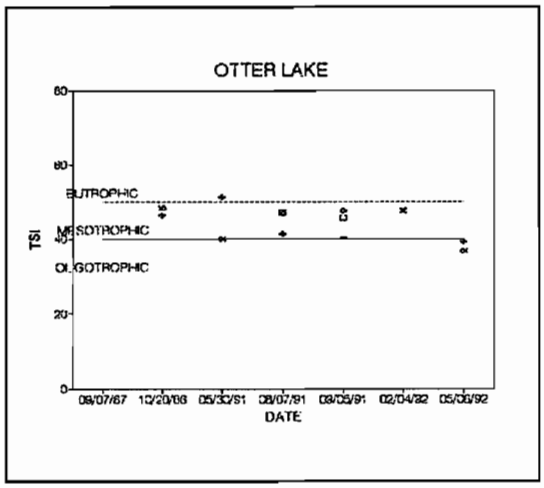
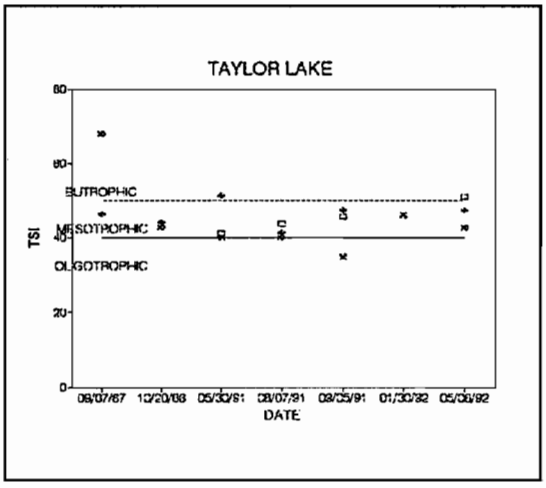


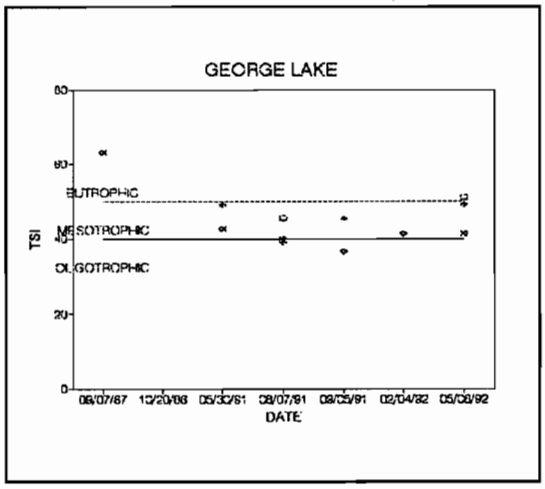
Figure 6. Temperature/DO Profiles, Upper Chain, Chain O' Lakes, Winter, 1992.

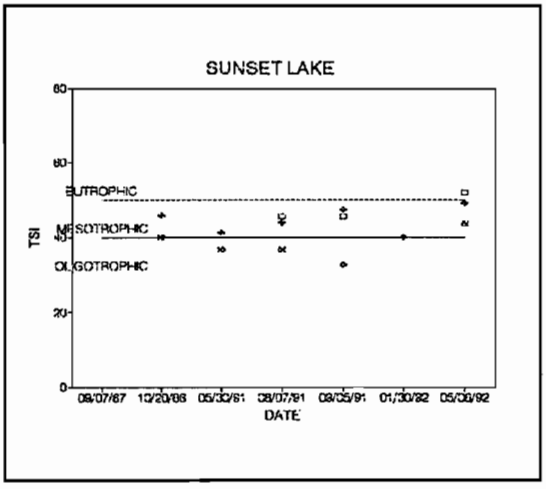
levels nor in Secchi transparency reduction unrelated to algal growth (e.g. that associated with color). TSI numbers for the Upper Chain sampling sites generally indicated oligotrophic to mesotrophic conditions (Figure 7). No readily discernable trend was evident from the limited amount of historical data available (Appendix III).

A stand of purple loosestrife was noted at the outlet from Otter Lake (i.e., to Taylor Lake). Dense growth on both sides of the channel occurred in 1992. Purple loosestrife is an exotic plant that is known to displace native (more beneficial) wetland plant stands and alter plant and animal assemblages.









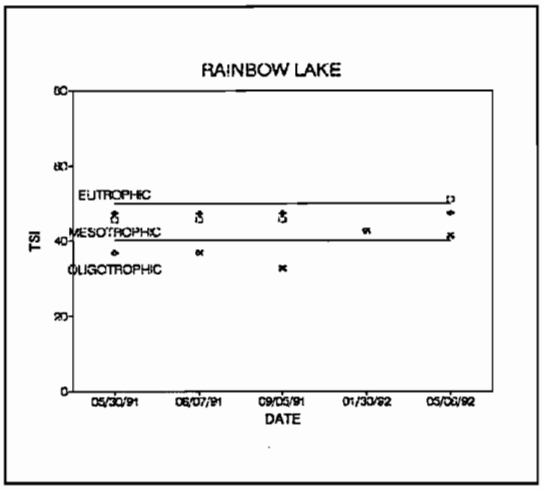


Figure 7. Trophic State Index for Secchi Depth, Total Phosphorus and Chlorophyll a, Upper Chain, Chain O' Lakes.

BASELINE CONCLUSIONS

The Upper Chain is a group of five spring-fed lakes that accounts for about 36 percent of the total surface area of the Chain O' Lakes. Flow for the Upper Chain is to Rainbow Lake and then to Nessling Lake of the Middle Chain project group. The Chain O' Lakes (overall) is eventually drained via the Crystal River at the south end of Long Lake (Lower Chain).

Overall, water quality is good to excellent for all parameters measured and generally indicated oligotrophic to mesotrophic classifications. Otter Lake exhibited higher nutrient readings, but these levels were considered typical of the lake type and regional location. No trends were evident from the relatively limited amount of historical data available. Good water quality is attributable to minimal overland inflow to the system, a relatively small forested watershed, flushing from groundwater flow, and phosphorus binding from marl precipitation.

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 in attempt to identify and quantify the use of the Chain O' Lakes. Tabulation and analysis of survey results will be completed during Phase II activities for the Chain O' Lakes.

Purple loosestrife, an exotic nuisance plant, has colonized the outlet channel from Otter Lake. Waupaca County has well established areas of Eurasian milfoil and the potential also exists for invasion of this exotic and potentially harmful species.

MANAGEMENT RECOMMENDATIONS

Management recommendations for the Upper Chain are targeted at maintenance of existing good to excellent water quality through continued monitoring, reduction of nutrient inflow to the system (where possible and practical), and assessment of the need for further regulation on the Chain to maximize enjoyment of the resource by all.

Relatively little is known about historic water quality on the Upper Chain; efforts should be made to continue regular water quality testing. Testing should also include event testing of areas of concern (e.g., the Village of King storm sewer). Regular monitoring should be conducted in a similar schedule; event testing should be conducted after major rain or snowmelt runoff events. Self-Help secchi disk monitoring should be conducted by volunteers on each lake.

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. Fertilizer and compost management, buffer stripping 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, increase infiltration (to filter nutrients and soil particles), and 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 of the buffer strip 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 IV. Information on pertinent ordinances and plans are presented in Appendix V.

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 Plan

The Chain O' Lakes Property Owners Association (CLPOA) initiated steps to develop a comprehensive lake management plan under the Wisconsin Department of Natural Resources (WDNR) Lake Management Planning Grant Program in the fall of 1990. The grant was 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 document.

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

OTTER LAKE

08/07/91			02/04/92		
Depth (ft)	Temp. °C	DO (mg/l)	Depth (ft)	Temp. °C	DO (mg/l)
3	21.23	8.91	3	3.62	4.41
6	21.22	8.88	6	3.69	3.99
9	20.67	8.75	9	3.88	2.77
12	**17.44**	**9.94**	12	4.04	2.23
15	**14.49**	**1.03**	15	4.15	1.58
18	**11.66**	**0.34**	18	4.30	1.12
21	**10.22**	**0.32**	21	4.34	0.95
24	**9.34**	**0.20**	24	4.35	0.84
27	9.09	0.16	27	4.35	0.78
30	9.00	0.12	30	4.35	0.78
33	8.93	0.12	33	4.36	0.78
36	8.87	0.33	36	4.36	0.83
			39	4.36	0.78

TAYLOR LAKE

08/07/91			01/30/92		
Depth (ft)	Temp. °C	DO (mg/l)	Depth (ft)	Temp. °C	DO (mg/l)
3	21.97	8.65	3	3.22	10.54
6	21.98	8.58	6	3.41	10.38
9	21.91	8.28	9	3.47	10.40
12	21.81	8.16	12	3.57	9.10
15	**20.89**	**7.47**	15	3.61	7.89
18	**16.29**	**7.83**	18	3.63	7.64
21	**14.23**	**5.63**	21	3.64	6.99
24	**12.19**	**2.60**	24	3.66	6.45
27	**10.23**	**0.80**	27	3.67	5.80
30	**8.46**	**0.25**	30	3.69	5.03
33	**6.87**	**0.13**	33	3.69	4.56
36	6.32	0.09	36	3.70	4.85
39	5.87	0.10	39	3.70	4.73
42	5.76	0.10	42	3.72	3.44
45	5.68	0.10	45	3.75	3.32
48	5.49	0.10	48	3.75	2.21
51	5.44	0.10	51	3.81	0.87

GEORGE LAKE

08/07/91			01/30/92		
Depth (ft)	Temp. °C	DO (mg/l)	Depth (ft)	Temp. °C	DO (mg/l)
3	21.66	8.09	3	3.03	8.91
6	21.67	7.99	6	3.44	7.68
9	21.71	8.04	9	3.51	6.68
12	21.74	8.26	12	3.80	4.63
15	21.32	5.92	15	3.92	1.84
18	**19.00**	**3.54**	18	3.99	1.14
21	**16.77**	**3.68**	21	4.01	0.80
24	**13.75**	**0.18**	24	4.06	0.74
27	**12.49**	**0.13**			

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

SUNSET LAKE

08/07/91			01/30/92		
Depth (ft)	Temp. °C	DO (mg/l)	Depth (ft)	Temp. °C	DO (mg/l)
3	22.32	9.08	3	2.44	10.76
6	22.26	9.11	6	2.97	10.20
9	22.25	9.05	9	3.01	10.17
12	22.23	9.15	12	3.01	10.11
15	22.11	8.98	15	3.01	10.11
18	21.66	8.01	18	3.01	10.11
21	**16.81**	**10.35**	21	3.01	10.11
24	**13.55**	**8.02**	24	3.01	9.98
27	**11.56**	**4.80**	27	3.04	9.66
30	**10.31**	**2.59**	30	3.07	9.40
33	9.51	0.36	33	3.22	5.61
36	8.11	0.13	36	3.26	5.85
39	7.70	0.13	39	3.29	4.81
42	7.22	0.13	42	3.36	3.35
45	6.89	0.14	45	3.40	2.92
48	6.70	0.14	48	3.43	1.60
51	6.62	0.09	51	3.44	1.19
54	6.48	0.09	54	3.47	1.12
57	6.37	0.09	57	3.48	1.36
			60	3.53	1.06

RAINBOW LAKE

08/07/91			01/30/92		
Depth (ft)	Temp. °C	DO (mg/l)	Depth (ft)	Temp. °C	DO (mg/l)
3	21.92	8.95	3	2.77	9.58
6	21.97	8.92	6	3.06	9.27
9	22.00	8.94	9	3.12	9.19
12	21.99	8.92	12	3.12	9.13
15	21.99	8.90	15	3.12	9.07
18	21.94	8.76	18	3.12	9.00
21	**17.33**	**11.46**	21	3.10	8.95
24	**13.26**	**8.40**	24	3.09	8.41
27	**11.13**	**5.65**	27	3.09	8.23
30	**10.00**	**3.50**	30	3.09	8.10
33	9.10	0.69	33	3.09	7.79
36	8.20	0.21	36	3.12	7.54
39	7.55	0.13	39	3.12	7.36
42	6.74	0.13	42	3.12	7.36
45	6.12	0.09	45	3.12	7.06
48	5.81	0.10	48	3.13	5.53
51	5.53	0.10	51	3.13	5.29
54	5.21	0.10	54	3.14	5.28
57	5.05	0.10	57	3.14	5.83
60	4.90	0.10	60	3.16	5.03
63	4.88	0.10	63	3.16	4.12
66	4.83	0.10	66	3.17	3.63
69	4.82	0.10	69	3.18	3.09
72	4.77	0.10	72	3.19	2.84
75	4.67	0.10	75	3.19	2.78
78	4.70	0.10	78	3.22	2.17

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

PARAMETER	Sample Dates 09/07/67	09/07/67	10/20/86
Depth (feet)	13	33	0
Secchi (meters)	NR[1]	NR	2.6
pH (S.U.)	7.9	7.0	8.65
Conductivity (μmhos/cm)	389	477	360
Total Alkalinity (mg/l $CaCO_3$)	190	248	162
Calcium (mg/l $CaCO_3$)	69.9	52.4	NR
Magnesium (mg/l $CaCO_3$)	109.5	120.7	NR
Hardness (mg/l $CaCO_3$)	179.4	173.1	NR
Sodium (mg/l)	3.60	3.60	NR
Sulfate (mg/l)	17.7	18.3	NR
Potassium (mg/l)	1.20	1.28	NR
Iron (mg/l)	0.05	0.02	NR
Chloride (mg/l)	5.00	3.55	5.9
Total Kjeldahl N (mg/l)	NR	NR	0.49
NO_3 Nitrogen (mg/l)	0.69	0.05	-
NO_2 + NO_3 Nitrogen(mg/l)	-	-	0.30
Total Nitrogen (mg/l)	-	-	0.79
Total Phosphorus (mg/l)	0.10	0.25	0.018
Phosphate Phos. (mg/l)	0.04	0.04	<0.002
N/P Ratio	-	-	43.9

NR[1] = No Reading

APPENDIX III
HISTORIC WATER QUALITY DATA
Taylor Lake, Waupaca County, WI
Water Chemistry: 09/62 - 10/86; Deepest Site
Source: WDNR and UW-Stevens Point Environmental Task Force

PARAMETER	Sample Dates 09/06/62	09/06/62	09/07/67	09/07/67	10/20/86
Depth (feet)	0	50	2	21	0
Secchi (meters)	2.6	-	NR[1]	-	3.0
pH (S.U.)	8.7	7.2	8.5	7.6	8.29
Conductivity (μmhos/cm)	NR	NR	273	351	302
Dissolved Oxygen (mg/l)	8.6	0.0	NR	NR	NR
Total Alkalinity (mg/l $CaCO_3$)	131	NR	131	169	146
Calcium (mg/l $CaCO_3$)	NR	NR	40.0	67.9	77.8
Magnesium (mg/l $CaCO_3$)	NR	NR	92.6	92.6	86.4
Hardness (mg/l $CaCO_3$)	NR	NR	132.6	160.5	164.2
Sodium (mg/l)	NR	NR	3.44	3.20	3.5
Sulfate (mg/l)	NR	NR	17.0	16.5	13.2
Potassium (mg/l)	NR	NR	1.28	1.12	1.4
Iron (mg/l)	NR	NR	0.03	0.03	NR
Chloride (mg/l)	NR	NR	4.95	5.00	8.0
Turbidity (NTU's)	NR	NR	NR	NR	0.61
Total Kjeldahl N (mg/l)	NR	NR	NR	NR	0.72
Ammonia Nitrogen (mg/l)	NR	NR	NR	NR	0.16
NO_3 Nitrogen (mg/l)	NR	NR	0.01	0.03	-
NO_2 + NO_3 Nitrogen(mg/l)	NR	NR	-	-	0.13
Total Nitrogen (mg/l)	-	-	-	-	0.85
Total Phosphorus (mg/l)	NR	NR	0.07	0.10	0.012
Phosphate Phos. (mg/l)	NR	NR	0.02	0.05	0.005
N/P Ratio	-	-	-	-	70.8
Color (SU)	NR	NR	NR	NR	<5.0

NR[1] = No Reading

APPENDIX III
HISTORIC WATER QUALITY DATA
George Lake, Waupaca County, WI
Water Chemistry: 09/67; Deepest Site
Source: WDNR

PARAMETER	Sample Dates 09/07/67
Depth (feet)	6
pH (S.U.)	8.5
Conductivity (μmhos/cm)	270
Total Alkalinity (mg/l $CaCO_3$)	131
Calcium (mg/l $CaCO_3$)	37.4
Magnesium (mg/l $CaCO_3$)	93.1
Hardness (mg/l $CaCO_3$)	130.5
Sodium (mg/l)	3.12
Sulfate (mg/l)	16.8
Potassium (mg/l)	0.80
Iron (mg/l)	0.02
Chloride (mg/l)	5.50
NO_3 Nitrogen (mg/l)	0.01
Total Phosphorus (mg/l)	0.05
Phosphate Phos. (mg/l)	0.01

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

PARAMETER	Sample Dates 09/07/67	09/07/67	10/20/86
Depth (feet)	9	45	0
Secchi (meters)	NR	-	2.7
pH (S.U.)	8.6	7.2	8.42
Conductivity (μmhos/cm)	270	421	300
Total Alkalinity (mg/l $CaCO_3$)	128	206	144
Calcium (mg/l $CaCO_3$)	38.7	72.4	75.6
Magnesium (mg/l $CaCO_3$)	91.0	100.1	87.2
Hardness (mg/l $CaCO_3$)	129.7	172.5	162.8
Sodium (mg/l)	3.08	3.04	3.4
Sulfate (mg/l)	16.5	16.4	14.0
Potassium (mg/l)	0.96	1.08	1.3
Iron (mg/l)	0.03	0.03	NR[1]
Chloride (mg/l)	5.35	5.40	8.0
Turbidity (NTU's)	NR	NR	0.6
Total Kjeldahl N (mg/l)	NR	NR	0.64
Ammonia Nitrogen (mg/l)	NR	NR	0.11
NO_3 Nitrogen (mg/l)	0.02	0.01	-
NO_2 + NO_3 Nitrogen(mg/l)	-	-	0.18
Total Nitrogen (mg/l)	-	-	0.82
Total Phosphorus (mg/l)	0.07	0.08	0.010
Phosphate Phos. (mg/l)	0.07	0.05	<0.002
N/P Ratio	-	-	82.0
Color (SU)	NR	NR	<5.0

NR[1] = No Reading

APPENDIX III
HISTORIC WATER QUALITY DATA
Rainbow Lake, Waupaca County, WI
Water Chemistry: 08/62 - 10/86; Deepest Site
Source: WDNR

PARAMETER	Sample Dates 08/31/62	08/31/62	09/07/67	09/07/67	10/20/86
Depth (feet)	0	88	21	60	0
Secchi (meters)	3.0	-	2.9	-	2.6
pH (S.U.)	8.9	7.3	8.4	7.3	8.42
Conductivity (μmhos/cm)	NR[1]	NR	293	354	302
Total Alkalinity (mg/l)	123	NR	131	169	144
Dissolved Oxygen (mg/l)	8.4	0.0	NR	NR	NR
Calcium (mg/l)	NR	NR	18.0	26.5	29.6
Magnesium (mg/l)	NR	NR	23.0	22.0	21.3
Sodium (mg/l)	NR	NR	3.44	3.12	3.5
Sulfate (mg/l)	NR	NR	16.5	16.3	14.0
Potassium (mg/l)	NR	NR	1.04	1.20	1.3
Iron (mg/l)	NR	NR	0.03	0.03	NR
Chloride (mg/l)	NR	NR	4.95	5.00	8
Turbidity (NTU's)	NR	NR	NR	NR	0.63
Total Kjeldahl N (mg/l)	NR	NR	NR	NR	0.63
Ammonia Nitrogen (mg/l)	NR	NR	NR	NR	0.10
NO_3 Nitrogen (mg/l)	NR	NR	0.03	0.01	-
NO_2 + NO_3 Nitrogen(mg/l)	NR	NR	-	-	0.18
Total Nitrogen (mg/l)	-	-	-	-	0.81
Total Phosphorus (mg/l)	NR	NR	0.05	0.12	0.008
Phosphate Phos. (mg/l)	NR	NR	<0.01	0.01	<0.002
N/P Ratio	-	-	-	-	101.2
Color (Pt-Co Units)	NR	NR	NR	NR	<5

NR[1] = No Reading

IPS ENVIRONMENTAL AND ANALYTICAL SERVICES
Appleton, Wisconsin

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

REPORT TO:
CHAIN O' LAKES PROPERTY OWNERS ASSOCIATION

December, 1995

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SUMMARY

The Upper Chain project group consists of Otter, Taylor, George, Sunset and Rainbow 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.

Upper Chain water quality monitoring during Phases I and II indicated in-lake nutrient levels below those expected for the region. Otter Lake continued to have relatively higher nutrients, which may reflect basin differences between it and other Upper Chain lakes. The King storm sewer was estimated to contribute a relatively small amount of nutrients.

Upper 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 swimming beach, and were evenly divided regarding the need for more water accessible public restrooms.

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

Water quality protection and water use conflict minimization are priority management objectives for the Upper Chain and all Chain O 'Lakes residents. Specific recommendations for the Upper Chain include private well testing for nitrates and/or pesticides, more event sampling (coordinated with flow and rainfall monitoring) at the storm sewer inflow, and removal or management of the purple loosestife beds. Other recommendations are applicable to the Upper 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, which include trend monitoring for water quality, are designed to identify potential problem areas or conflicts before they become widespread or severe.

INTRODUCTION

The Chain O' Lakes is a group of 22 mostly interconnected lakes in the Towns of Dayton and Farmington, Waupaca County, Wisconsin. The lakes are, in general, relatively small, highly developed, groundwater fed and located in a sandy, mostly level watershed. The lakes are a major tourist attraction for Waupaca County and occasionally receive excessive recreational use.

The Chain O' Lakes Property Owners Association (CLPOA), which serves as the main steward for the resource, was formed in the 1960's and currently has about 800 voting members (1). The CLPOA received its first Wisconsin Department of Natural Resources (WDNR) Lake Management Planning Grant in April, 1991. IPS Environmental & Analytical Services (IPS) of Appleton, Wisconsin was selected as their consultant for management plan development.

The Chain O' Lakes was delineated into five Project Groups (Table 1) for management planning purposes. Phase I efforts included baseline assessment activities (for water quality and aquatic plants) and a public involvement program. Specific physical properties, preliminary methods, and other introductory and technical information for the Chain O' Lakes and the respective Project Groups were presented in the Phase I reports (printed 1993).

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

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

A Phase II grant was received in August, 1993; Phase II efforts included continuation of the water quality monitoring and public involvement programs, analysis of a recreational use questionnaire (circulated under Phase I) and more intensive assessment of areas of concern in the watershed. This report presents the results of these Phase II lake management planning efforts for the Upper Chain O' Lakes.

DESCRIPTION OF AREA

The Chain O' Lakes is a group of "kettle" lakes in the southwest corner of Waupaca County, Wisconsin (Fig. 1). Kettle lakes were formed when ice was pushed into the soil by retreating glaciers; the depressions subsequently filled with water when the ice blocks melted. The Upper Chain consists of Otter, Taylor, George, Sunset and Rainbow Lakes in the northeast portion of the Chain.

Predominant shoreline area substrates for the Upper Chain are sand and marl with localized areas of muck and detritus. Aquatic plants are present but exhibit limited growth because of sandy bottom material. Otter Lake, with the shallowest average depth and relatively high organic bottom type, has the most aquatic plant growth of the Upper Chain.

Generally, groundwater inflow to the Chain O' Lakes is from the northwest. Groundwater input was most visible and documented in Sunset Lake (south and west shores), Otter Lake (northwest shore) and George Lake (north shore).

Rainbow Lake is the largest (166 acres, 45% of the total surface area) and deepest (95 feet) lake in the Upper Chain. Other lake areas include George (5 acres, 2%), Taylor (35 acres, 14%), Otter (14 acres, 5%) and Sunset (89 acres, 34%) (2).

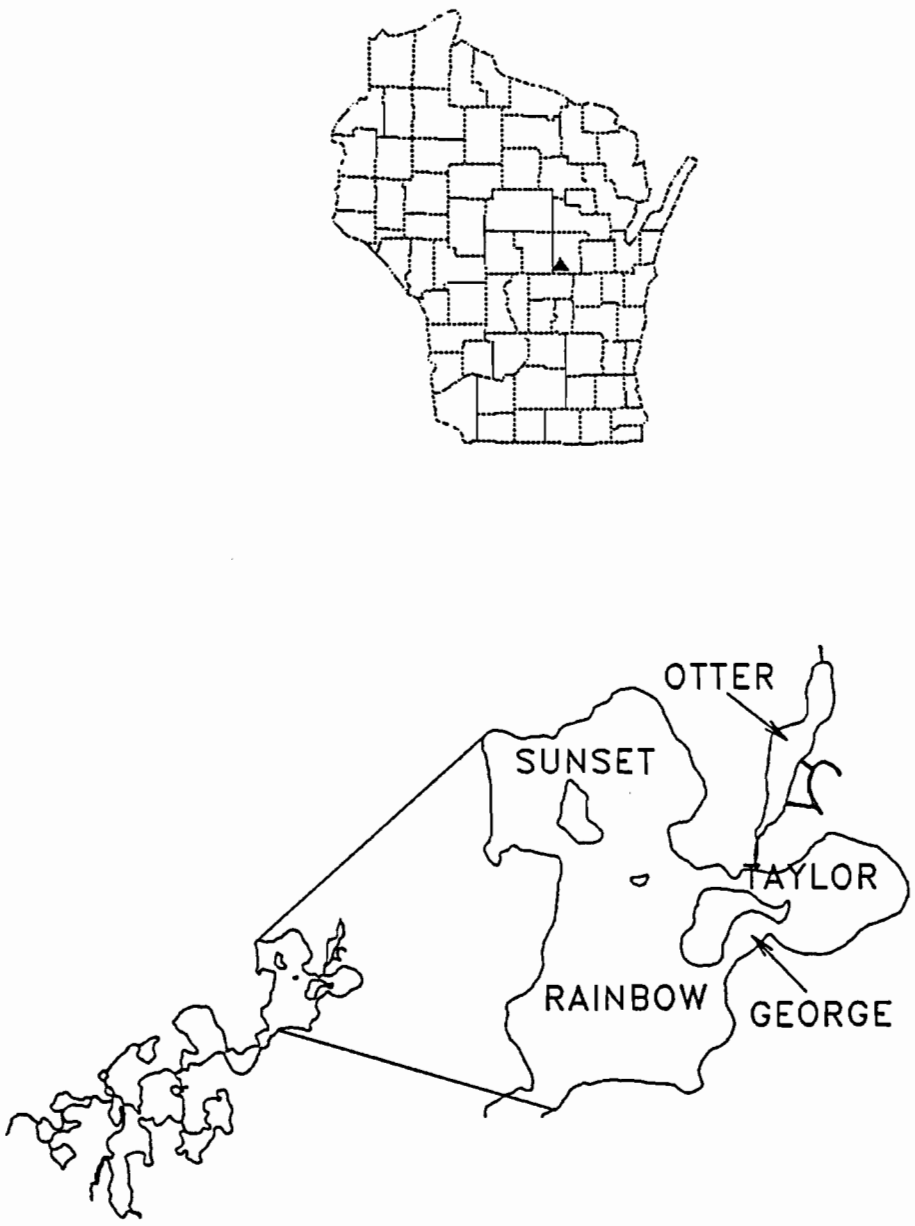

Figure 1. Location Map, Chain O' Lakes, Waupaca County, Wisconsin.

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 Upper Chain has boat ramp access

points at Clearwater Harbor and off Pine Ridge Lane on the north shore of Taylor Lake.

Because of intensive recreational use, the Towns of Dayton and Farmington and the CLPOA adopted ordinances to regulate boat speeds on the Chain. Except for the largest lakes (Columbia, Long, Rainbow and Round), all lakes on the Chain have a "no wake" speed limit. 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

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 is scheduled to be 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 on July 15 and September 23, 1992, February 2, May 20, August 17 and October 10, 1993, and January 24, May 3, August 3 and September 22, 1994. Samples were collected three feet below the surface and three feet above bottom for all lakes (Table 2, Fig. 2); because of budget constraints and similarity of data, sampling at Site 1002 (George Lake) and Site 1006 (Sunset Lake - West of Onaway Island) was discontinued (after May, 1993) during Phase II. Parameters measured in the field were Secchi depth, water temperature, pH, dissolved oxygen (DO), and conductivity (see the Phase I document for specific equipment and methods information).

Water samples were also collected at Site 10E1, the storm sewer outfall to George Lake (Table 2). Samples were collected by IPS

or members of the CLPOA (with IPS instruction) on May 20, August 17 and October 6, 1993 and May 3, July 6 (surface runoff event), and August 3, 1994.

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

REGULAR MONITORING

Lake	Site Number	Depth
Rainbow (Deepest Point)	1001	95 feet
George (Deepest Point)	1002[1]	30 feet
Taylor (Deepest Point)	1003	58 feet
Otter (Deepest Point)	1004	40 feet
Sunset (Deepest Point)	1005	63 feet
Sunset (West of Onaway)	1006[1]	59 feet

Event Site	Description
10E1	Storm sewer outfall near the Wisconsin Veterans Home at George Lake

[1] site discontinued after 05/93 sample date

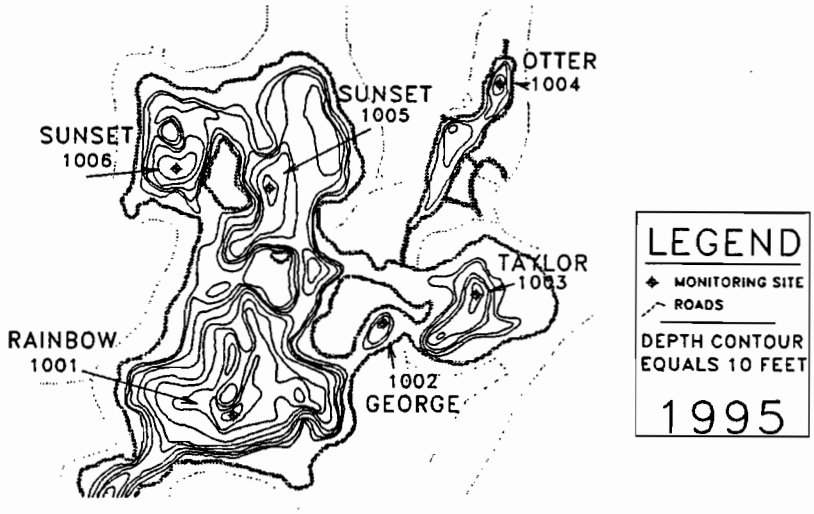

Figure 2. Sample Station Locations, Upper Chain, 1992 - 1994.

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.

Exotic Species

Visual observations [including a full shoreline cruise and in-lake observations (raking and SCUBA)] were made throughout the Phase I and II grant periods to document the occurrence of exotic species. Target species included Eurasian Water Milfoil (*Myriophyllum spicatum*), Purple Loosestrife (*Lythrum salicaria*) and Zebra Mussels (*Dreissena polymorpha*).

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).

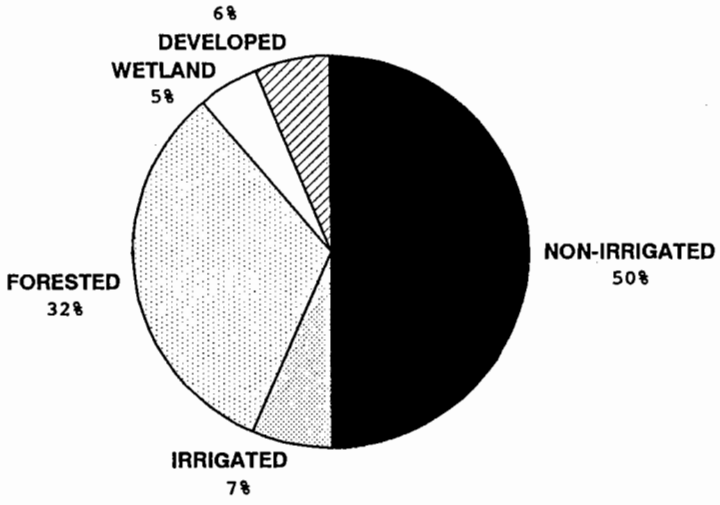

Figure 3. Land Uses in the Chain O' Lakes Subwatershed, 1994.

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
Upper 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 of (outflowing versus inflowing) 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 similar water quality among the Upper Chain lakes and trends similar to those observed during Phase I. Otter Lake continued to exhibit higher nutrients than the other

Upper Chain lakes. All nutrient data reflected seasonal influences of stratification/mixing and surface or goundwater inflows.

Average surface total nitrogen (1.46 mg/l) was highest in Otter Lake and lowest (for continuously sampled lakes, 1.03 mg/l) in Taylor Lake (Tables 5 - 10). Average surface total phosphorus was also highest in Otter Lake (0.015 mg/l); lowest levels were observed in Sunset Lake (0.009 mg/l). Lowest surface total nitrogen or phosphorus levels were generally observed during Summer stratification (Figs. 4 & 5). Higher 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).

Phosphorus levels for the Upper Chain were 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 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).

Table 5. Water Quality Parameters, Station 1001, Rainbow Lake, Chain O' Lakes, July 1992 - September 1994.

PARAMETER	SAMPLE[1]	DATE									
		7/15/92	9/23/92	2/02/93	5/20/93	8/17/93	10/06/93	1/24/94	5/03/94	8/03/94	9/22/94
Secchi (feet)		11.0	8.4	NR[2]	7.9	8.0	8.7	NR	8.5	8.0	7.0
Cloud Cover (percent)		10	0	10	10	100	0	0	60	80	100
Temperature (degrees Celsius)	S	21.14	17.05	2.42	14.94	24.51	12.48	2.03	9.94	23.83	21.51
	B	4.63	5.01	3.16	4.40	5.06	5.10	3.03	5.14	5.76	6.07
pH (std units)	S	8.46	8.86	7.26	NR	8.20	7.60	6.88	7.61	8.25	NR
	B	6.47	7.19	6.75	NR	5.95	6.40	6.54	6.72	6.11	NR
D.O. (mg/l)	S	9.44	9.36	8.87	10.93	8.99	9.26	11.06	12.16	9.52	8.69
	B	0.11	0.48	1.33	0.22	0.15	0.67	6.67	3.75	0.45	0.43
Conductivity (umhos/cm)	S	304	287	330	331	294	326	346	341	310	277
	B	364	377	348	355	360	392	362	355	385	360
Laboratory pH (surface units)	S	NR	NR	NR	8.41	NR	NR	NR	8.27	NR	NR
	B	NR	NR	NR	7.65	NR	NR	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	NR	NR	NR	156	NR	NR	NR	169	NR	NR
	B	NR	NR	NR	175	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	236	NR	NR	NR	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	S	0.6	0.4	0.9	0.6	0.5	0.5	0.9	0.7	0.6[3]	0.48[3]
	B	3.8	2.8	1.4	1.5	0.5	2.6	1.0	0.8	0.54[3]	0.55[3]
Ammonia Nitrogen (mg/l)	S	0.026	0.028	0.497	0.061	0.022	0.109	0.422	0.199	0.016	0.048
	B	2.586	2.07	0.928	0.898	0.024	2.02	0.583	0.377	0.029	0.039
NO_2 + NO_3 Nit. (mg/l)	S	0.418	0.242	0.280	0.658	0.405	0.457	0.473	0.730	0.379	0.328
	B	ND[4]	ND	0.221	0.306	0.407	ND	0.533	0.685	0.401	0.310
Total Nitrogen (mg/l)	S	1.018	0.642	1.180	1.258	0.905	0.957	1.373	1.430	0.979	0.808
	B	3.8	2.8	1.621	1.806	0.907	2.6	1.533	1.485	0.941	0.860
Total Phosphorus (mg/l)	S	0.008	0.005	0.008	ND	0.009	0.008	0.019	0.011	0.007	0.034[3]
	B	0.26	0.068	0.042	0.04	0.008	0.048	0.018	0.016	0.009	0.008[3]
Dissolved Phos. (mg/l)	S	0.002	ND	NR	ND	ND	0.004	0.002	NR	ND	ND
	B	0.186	0.035	0.019	ND	ND	0.013	0.001	NR	0.002	ND
Nit./Phos Ratio	S	127.3	128.4	147.5	--	100.6	119.6	72.3	130.0	139.9	23.8
	B	14.6	41.2	38.6	45.2	113.4	54.2	85.2	92.8	104.6	107.5
Chlorophyll a (ug/l)	S	4	4.47	NR	4.76	5	6.89	NR	6.31	4.35	2.89

[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 1002, George Lake, Chain O' Lakes, July 1992 - May 1993.

PARAMETER	SAMPLE[1]	DATE			
		7/15/92	9/23/92	2/02/93	5/20/93
Secchi (feet)		13.6	9.4	NR[2]	9.1
Cloud Cover (percent)		10	0	10	70
Temperature (degrees Celsius)	S	20.94	16.55	2.06	15.15
	B	11.07	15.69	4.47	7.01
pH (std units)	S	8.43	8.60	7.38	NR
	B	7.38	8.62	6.85	NR
D.O. (mg/l)	S	10.38	8.65	10.05	10.89
	B	0.51	7.85	0.58	0.69
Conductivity (umhos/cm)	S	297	290	347	329
	B	368	293	390	368
Laboratory pH (surface units)	S	NR	NR	NR	8.38
	B	NR	NR	NR	7.76
Total Alkalinity (mg/l)	S	NR	NR	NR	155
	B	NR	NR	NR	178
Total Solids (mg/l)	S	NR	NR	NR	214
	B	NR	NR	NR	238
Tot. Kjeld. Nitrogen (mg/l)	S	0.6	0.5	1.0	0.6
	B	3.1	0.6	1.6	1.6
Ammonia Nitrogen (mg/l)	S	0.085	0.096	0.515	0.059
	B	1.101	0.171	1.18	0.654
NO2 + NO3 Nit. (mg/l)	S	0.297	0.138	0.277	0.562
	B	0.016	0.130	0.018	0.182
Total Nitrogen (mg/l)	S	0.897	0.638	1.277	1.162
	B	3.116	0.730	1.618	1.782
Total Phosphorus (mg/l)	S	0.009	0.010	0.014	ND[3]
	B	0.131	0.013	0.044	0.05
Dissolved Phos. (mg/l)	S	0.002	0.005	NR	ND
	B	0.002	0.004	NR	ND
Nit./Phos Ratio	S	99.7	63.8	91.2	-
	B	23.8	56.2	36.8	35.6
Chlorophyll a (ug/l)	S	3	3.71	NR	3.75

[1] S = surface, B = bottom; [2] NR = no reading; [3] ND = not detectable;

Table 7. Water Quality Parameters, Station 1003, Taylor Lake, Chain O' Lakes, July 1992 - September 1994.

PARAMETER	SAMPLE[1]	DATE									
		7/15/92	9/23/92	2/02/93	5/20/93	8/17/93	10/06/93	1/24/94	5/03/94	8/03/94	9/22/94
Secchi (feet)		12.2	9.3	NR[2]	9.1	NR	8.2	NR	9.0	9.0	8.0
Cloud Cover (percent)		10	0	10	100	50	0	0	90	80	100
Temperature (degrees Celsius)	S	20.99	16.23	3.97	14.54	25.10	12.78	3.18	11.57	24.46	21.44
	B	5.33	5.91	4.27	4.66	5.47	5.95	3.73	6.22	7.21	7.76
pH (std units)	S	8.55	8.38	7.10	NR	8.23	NR	6.97	7.63	8.26	NR
	B	6.63	6.94	6.57	NR	5.87	NR	6.61	6.65	5.95	NR
D.O. (mg/l)	S	9.97	9.29	8.38	11.10	8.99	9.85	11.68	12.18	9.38	8.34
	B	0.15	0.76	0.37	0.48	0.10	0.78	6.41	0.99	0.45	0.43
Conductivity (umhos/cm)	S	289	287	336	329	289	323	359	336	300	219
	B	394	411	393	410	395	428	382	370	394	370
Laboratory pH (surface units)	S	NR	NR	NR	8.32	NR	NR	NR	NR	NR	NR
	B	NR	NR	NR	8.02	NR	NR	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	NR	NR	NR	155	NR	NR	NR	NR	NR	NR
	B	NR	NR	NR	190	NR	NR	NR	NR	NR	NR
Total Solids (mg/l)	S	NR	NR	NR	214	NR	NR	NR	NR	NR	NR
	B	NR	NR	NR	262	NR	NR	NR	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	S	0.5	0.5	0.9	0.6	0.6	0.8	1.1	0.7	0.66[3]	0.61[3]
	B	3.5	3.9	1.8	1.8	2.8	3.2	1.1	1.4	3.09[3]	2.95[3]
Ammonia Nitrogen (mg/l)	S	0.042	0.057	0.495	0.053	0.037	0.129	0.420	0.160	0.056	0.069
	B	2.405	2.87	1.03	1.19	2.04	2.59	0.586	0.845	1.80	2.100
NO_2 + NO_3 Nit. (mg/l)	S	0.241	0.170	0.271	0.587	0.303	0.401	0.472	0.646	0.251	0.192
	B	ND[4]	ND	0.055	ND	ND	ND	0.419	0.196	ND	ND
Total Nitrogen (mg/l)	S	0.741	0.670	1.171	1.187	0.903	1.201	1.572	1.346	0.911	0.802
	B	3.5	3.9	1.855	1.8	2.8	3.2	1.519	1.596	3.09	2.95
Total Phosphorus (mg/l)	S	0.008	0.009	0.009	ND	0.011	0.016	0.014	0.012	0.011	0.008[3]
	B	0.072	0.064	0.105	0.07	0.037	0.039	0.011	0.031	0.046	0.031[3]
Dissolved Phos. (mg/l)	S	0.005	0.002	0.036[3]	ND	0.002	ND	0.003	NR	ND	0.002
	B	0.005	0.015	0.001[3]	ND	ND	ND	0.001	NR	ND	ND
Nit./Phos Ratio	S	92.6	74.4	130.1	–	82.1	75.1	112.3	112.2	82.8	100.3
	B	48.6	60.9	17.7	25.7	75.7	82.1	138.1	51.5	67.2	–
Chlorophyll a (ug/l)	S	3	3.91	NR	4.25	4	6.85	NR	5.29	5.40	3.65

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

Table 8. Water Quality Parameters, Station 1004, Otter Lake, Chain O' Lakes, July 1992 - September 1994.

PARAMETER	SAMPLE[1]	DATE									
		7/15/92	9/23/92	2/02/93	5/20/93	8/17/93	10/06/93	1/24/94	5/03/94	8/03/94	9/22/94
Secchi (feet)		13.1	12.1	NR[2]	15.5	7.0	9.4	NR	11.5	11.0	12.0
Cloud Cover (percent)		30	0	10	100	100	0	0	90	80	100
Temperature (degrees Celsius)	S	21.21	16.71	3.55	13.99	23.31	12.34	2.50	11.79	23.42	20.78
	B	8.83	9.16	4.54	6.60	8.58	8.85	4.28	7.32	9.32	9.51
pH (std units)	S	8.33	NR	6.89	NR	7.62	NR	6.45	7.50	7.85	NR
	B	6.71	NR	6.72	NR	6.19	NR	6.32	6.50	6.36	NR
D.O. (mg/l)	S	10.75	7.58	5.38	10.23	9.61	9.89	7.98	11.69	9.26	7.68
	B	0.12	0.61	1.27	0.49	0.16	0.89	3.28	0.87	0.47	0.31
Conductivity (umhos/cm)	S	339	354	410	392	376	425	439	395	366	363
	B	420	420	427	439	418	451	454	444	438	396
Laboratory pH (surface units)	S	NR	NR	NR	8.14	NR	NR	NR	8.25	NR	NR
	B	NR	NR	NR	7.77	NR	NR	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	NR	NR	NR	193	NR	NR	NR	204	NR	NR
	B	NR	NR	NR	223	NR	NR	NR	NR	NR	NR
Total Solids (mg/l)	S	NR	NR	NR	254	NR	NR	NR	264	NR	NR
	B	NR	NR	NR	286	NR	NR	NR	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	S	0.6	0.6	0.4	0.5	0.6	0.5	0.4	0.6	0.50[3]	0.55[3]
	B	0.7	1.2	0.6	0.6	0.5	1.5	0.7	0.8	0.91[3]	1.25[3]
Ammonia Nitrogen (mg/l)	S	0.048	0.115	0.123	0.088	0.029	0.113	0.167	0.038	0.041	0.099
	B	0.304	0.758	0.288	0.266	0.015	0.894	0.350	0.405	0.424	0.927
NO_2 + NO_3 Nit. (mg/l)	S	0.321	0.280	1.56	1.01	0.629	1.35	1.81	1.33	0.487	0.597
	B	0.623	0.129	1.37	0.817	1.33	0.040	1.71	0.905	0.777	0.100
Total Nitrogen (mg/l)	S	0.921	0.880	1.96	1.51	1.229	1.85	2.21	1.93	0.987	1.147
	B	1.323	1.329	1.97	1.417	1.83	1.540	2.41	1.705	1.687	1.35
Total Phosphorus (mg/l)	S	0.013	0.017	0.007	0.02	0.014	0.015	0.018	0.026	0.0110[3]	0.010[3]
	B	0.027	0.046	0.022	0.03	0.015	0.079	0.026	0.034	0.1280[3]	0.171[3]
Dissolved Phos. (mg/l)	S	0.004	0.003	0.001[3]	ND	ND	ND	0.007	NR	ND	ND
	B	0.002	0.002	0.008[3]	0.002	ND	0.012	0.013	NR	0.091	0.132
Nit./Phos Ratio	S	70.8	51.8	280.0	75.5	87.8	123.3	122.8	74.2	89.7	114.7
	B	49.0	28.9	89.5	47.2	122.0	19.5	92.7	50.1	13.2	--
Chlorophyll a (ug/l)	S	5	4.97	NR	3.95	12	13.3	NR	4.69	6.39	3.26

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

Table 9. Water Quality Parameters, Station 1005, Sunset Lake (Deep Pt.), Chain O' Lakes, July 1992 - September 1994.

PARAMETER	SAMPLE[1]	DATE									
		7/15/92	9/23/92	2/02/93	5/20/93	8/17/93	10/06/93	1/24/94	5/03/94	8/03/94	9/22/94
Secchi (feet)		10.2	9.8	NR[2]	8.2	8.0	8.5	NR	9.0	8.5	7.0
Cloud Cover (percent)		30	0	10	70	100	0	0	60	80	100
Temperature (degrees Celsius)	S	21.56	16.97	1.66	14.69	24.40	12.74	1.83	10.89	24.12	21.46
	B	6.26	6.57	3.35	5.52	6.34	6.47	3.39	7.22	8.16	9.77
pH (std units)	S	8.50	8.60	7.33	NR	8.27	NR	6.90	7.65	8.24	NR
	B	6.57	7.20	6.80	NR	5.99	NR	6.38	6.94	6.05	NR
D.O. (mg/l)	S	9.67	9.45	10.05	11.13	9.53	9.74	11.07	11.66	9.57	8.65
	B	0.14	0.72	1.26	3.17	0.14	0.73	2.04	6.79	0.46	0.45
Conductivity (umhos/cm)	S	304	290	333	332	295	327	345	342	310	279
	B	362	395	364	349	357	405	375	347	388	378
Laboratory pH (surface units)	S	NR	NR	NR	8.33	NR	NR	NR	8.22	NR	NR
	B	NR	NR	NR	7.77	NR	NR	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	NR	NR	NR	156	NR	NR	NR	169	NR	NR
	B	NR	NR	NR	168	NR	NR	NR	NR	NR	NR
Total Solids (mg/l)	S	NR	NR	NR	216	NR	NR	NR	224	NR	NR
	B	NR	NR	NR	228	NR	NR	NR	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	S	0.5	0.5	0.9	0.6	0.4	0.6	0.9	0.6	0.64[3]	0.51[3]
	B	2.7	3.2	1.3	1.1	2.2	2.7	1.3	1.0	0.64[3]	3.63[3]
Ammonia Nitrogen (mg/l)	S	0.038	0.034	0.465	0.060	0.021	0.103	0.431	0.189	0.019	0.039
	B	1.714	2.56	0.904	0.549	1.58	2.05	0.697	0.442	0.051	2.66
NO_2 + NO_3 Nit. (mg/l)	S	0.435	0.247	0.383	0.677	0.465	0.487	0.469	0.769	0.406	0.335
	B	ND[3]	ND	0.703	0.497	ND	ND	0.690	0.599	0.418	ND
Total Nitrogen (mg/l)	S	0.935	0.747	1.283	1.277	0.865	1.087	1.369	1.369	1.046	0.845
	B	2.7	3.2	2.003	1.597	2.2	2.7	1.990	1.599	1.058	3.630
Total Phosphorus (mg/l)	S	0.009	0.009	0.009	ND	0.006	0.008	0.015	0.013	0.0050[3]	0.005[3]
	B	0.058	0.048	0.029	0.040	0.038	0.035	0.016	0.026	0.009	0.031[3]
Dissolved Phos. (mg/l)	S	0.003	0.004	ND[3]	ND	ND	0.003	0.001	NR	ND	ND
	B	0.003	0.002	0.003[3]	0.002	ND	0.003	0.001	NR	ND	ND
Nit./Phos Ratio	S	103.9	83.0	142.6	--	144.2	135.9	91.3	105.3	209.2	169.0
	B	46.6	66.7	69.1	39.9	57.9	77.1	124.4	61.5	117.6	--
Chlorophyll a (ug/l)	S	4	4.12	NR	4.83	4	7.23	NR	5.35	3.89	3.57

[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 1006, Sunset Lake (West of Onaway Island), Chain O' Lakes, July 1992 - May 1993.

PARAMETER	SAMPLE[1]	DATE			
		7/15/92	9/23/92	2/02/93	5/20/93
Secchi (feet)		9.3	9.6	NR[2]	8.0
Cloud Cover (percent)		30	0	10	60
Temperature (degrees Celsius)	S	21.64	16.92	1.95	14.45
	B	6.95	7.03	4.05	5.49
pH (std units)	S	8.54	8.51	7.41	NR
	B	7.14	7.01	6.75	NR
D.O. (mg/l)	S	10.30	9.65	10.68	11.19
	B	0.47	0.70	0.60	0.41
Conductivity (umhos/cm)	S	303	291	336	333
	B	470	495	392	401
Laboratory pH (surface units)	S	NR	NR	NR	8.37
	B	NR	NR	NR	7.65
Total Alkalinity (mg/l)	S	NR	NR	NR	156
	B	NR	NR	NR	186
Total Solids (mg/l)	S	NR	NR	NR	214
	B	NR	NR	NR	258
Tot. Kjeld. Nitrogen (mg/l)	S	0.7	0.6	0.8	0.6
	B	0.9	4.2	1.5	1.2
Ammonia Nitrogen (mg/l)	S	0.032	0.032	0.433	0.066
	B	0.235	3.27	1.01	0.834
NO_2 + NO_3 Nit. (mg/l)	S	0.439	0.274	0.364	0.729
	B	0.584	ND[2]	1.35	1.16
Total Nitrogen (mg/l)	S	1.139	0.874	1.164	1.329
	B	1.484	4.2	2.85	2.36
Total Phosphorus (mg/l)	S	0.008	0.006	0.011	ND
	B	0.024	0.039	0.050	0.03
Dissolved Phos. (mg/l)	S	0.002	0.002	0.001[3]	0.002
	B	0.003	0.002	0.005[3]	0.002
Nit./Phos Ratio	S	142.4	145.7	105.8	-
	B	61.8	107.7	57.0	78.7
Chlorophyll a (ug/l)	S	5	4.23	NR	4.83

[1] S = surface, B = bottom; [2] NR = no reading; [3] ND = not detectable;

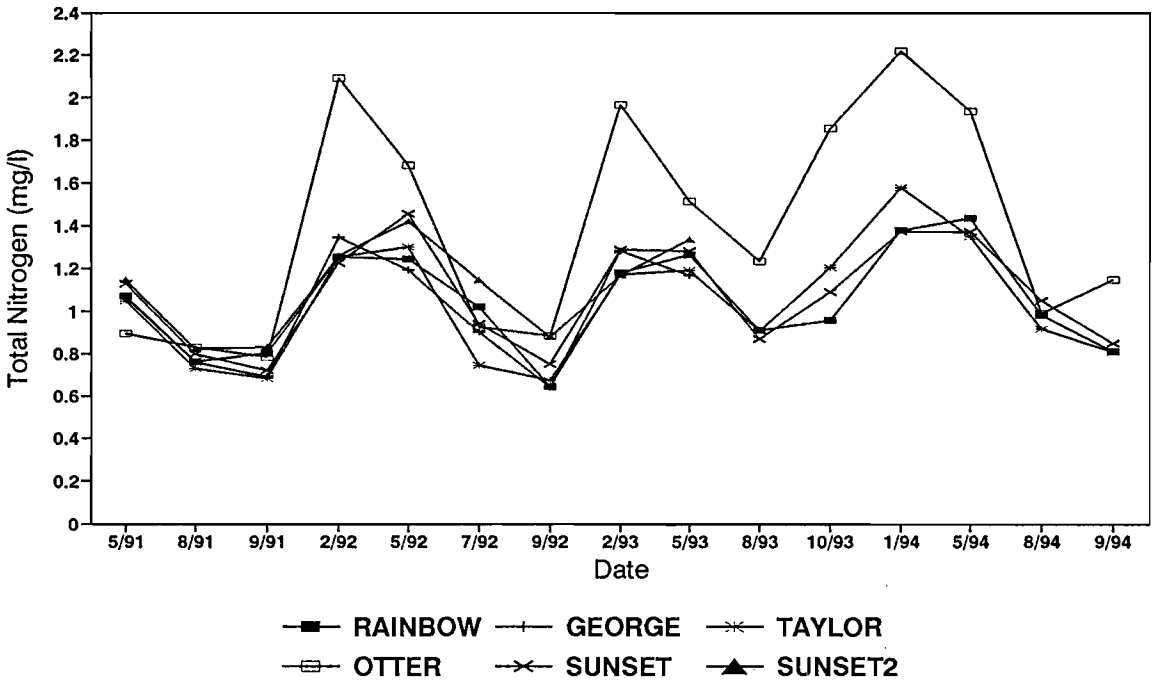

Figure 4. Surface Total Nitrogen Trends for the Upper Chain, 1991 - 1994.

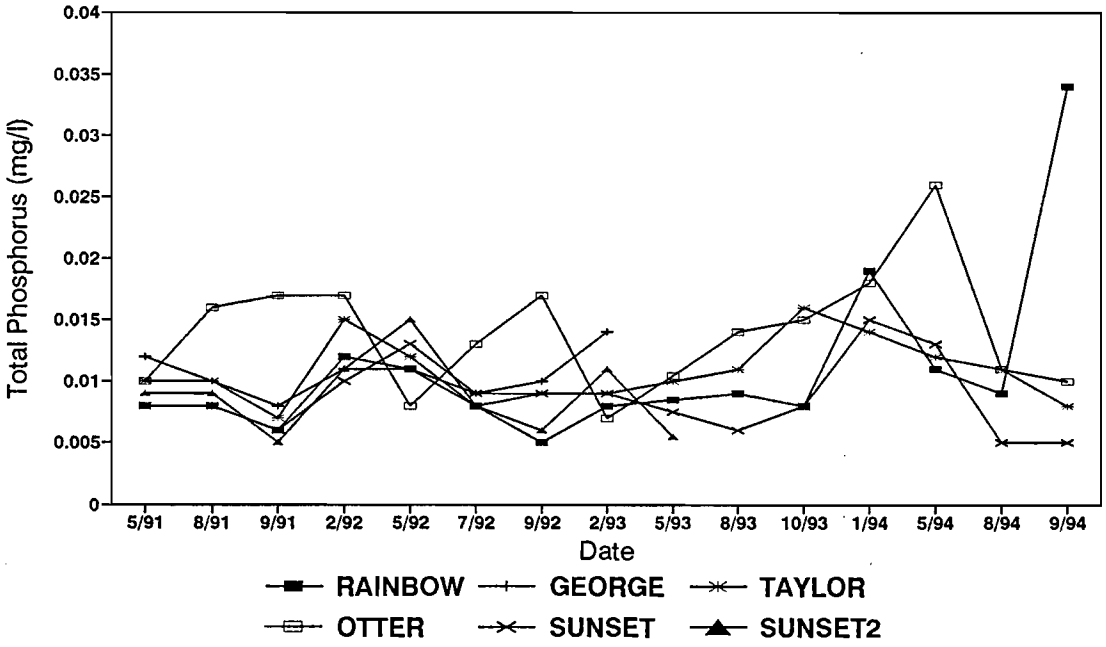

Figure 5. Surface Total Phosphorus Trends for the Upper Chain, 1991 - 1994.

Monitoring at Site 10E1 indicated similar readings for the single runoff event (July 6, 1994) and regular monitoring (all other dates) (Table 11). Average total nitrogen for all dates was 1.15 mg/l; average total phosphorus was 0.031 mg/l.

Flow was measured on May 3, 1994 at Site 10E1 and from visual observations was considered average. Flow was 0.12 cubic feet per second [(cfs) or 0.080 million gallons per day (mgd)]. This rate combined with nutrient levels above, resulted in an estimated annual discharge of 3.43 kilograms (7.55 pounds) of phosphorus and 127.1 kilograms (280.2 pounds) of nitrogen to George Lake (Fig. 6 - 8).

Hartman's Creek flow was estimated (9) at 5.90 cfs (3.81 mgd); this flow, when combined with field instantaneous measurements of total phosphorus and nitrogen, yielded loading rates of 15.0 kilograms (33.0 pounds) phosphorus and 330.9 kilograms (729.4 pounds) nitrogen per year to Pope Lake. Similarly, Emmon's Creek inputs to Long Lake of the Lower Chain 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.

Table 11. Event Water Quality Parameters, Station 10E1, King Storm Sewer (Near Veterans Home), Chain O' Lakes, May 1993 - August 1994.

PARAMETER	SAMPLE[1]	DATE					
		5/20/93	8/17/93	10/06/93	5/03/94	7/06/94[2]	8/03/94
Temperature (degrees Celsius)	M	NR[3]	NR	15.64	13.84	NR	NR
pH (surface units)	M	NR	NR	7.30	7.53	NR	NR
D.O. (mg/l)	M	NR	NR	7.08	9.78	NR	NR
Conductivity (umhos/cm)	M	544	NR	457	422	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	M	ND[4]	ND	0.2	ND	ND	0.32[5]
Ammonia Nitrogen (mg/l)	M	0.013	0.026	0.021	0.018	0.055	0.029
NO_2 + NO_3 Nit. (mg/l)	M	0.810	1.07	1.44	1.46	1.01	0.613
Total Nitrogen (mg/l)	M	0.810	1.07	1.64	1.46	1.01	0.933
Total Phosphorus (mg/l)	M	0.08	0.045	0.022	0.019	0.016	0.004
Dissolved Phos. (mg/l)	M	0.056	0.044	0.021	NR	0.013	ND
Nit./Phos Ratio	M	10.1	23.8	74.5	76.8	63.1	233.3

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

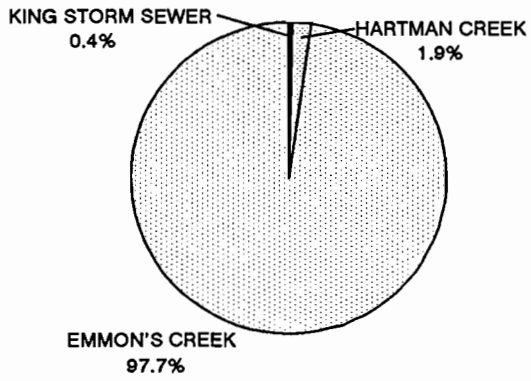

Figure 6. Average Flow Contribution from Overland Sources, Chain O' Lakes, 1994.

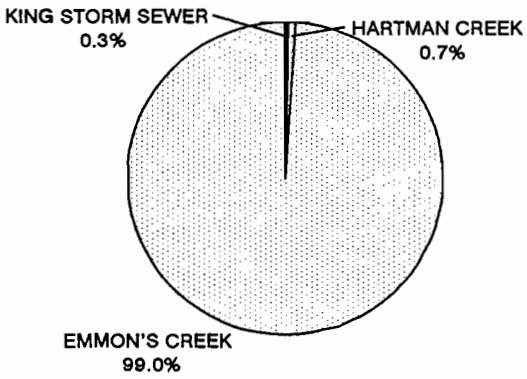

Figure 7. Average Nitrogen Contribution from Overland Sources, Chain O' Lakes, 1994.

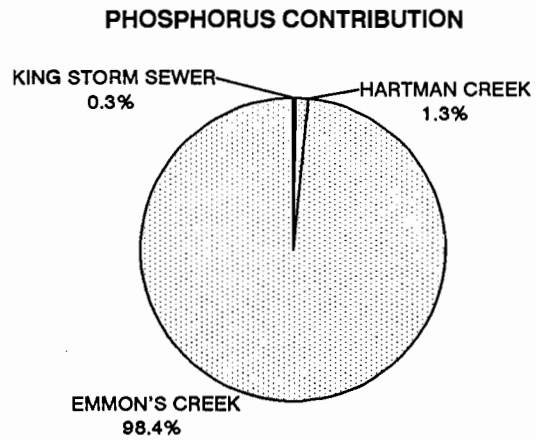

Figure 8. Average Phosphorus Contribution from Overland Sources, Chain O' Lakes, 1994.

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 12); seasonal residents averaged 4.7 months.

Table 12. Comparison of Recreational Use Parameters for Various User Groups, Chain O' Lakes, Waupaca County, Wisconsin.

Parameter	User Group			
	Upper Chain	Fast Lakes	Slow Lakes	Entire Chain
Average monthly occupancy	7.4	7.5	8.1	7.8
Average number of watercraft (per response)	3.1	3.1	2.7	2.9
Average number of adults (per respondent household)	2.8	2.4	2.4	2.4
Average number of children 12 - 18 years old (per respondent household)	0.5	0.6	0.3	0.4
Average number of children less than 12 years old (per respondent household)	0.7	0.5	0.5	0.5
Average respondent age	57.6	59.1	57.7	58.3
Percent of respondents leaving comments	53.5	51.9	44.9	48.0

Respondents indicated a total of 1222 watercraft with an average of 2.9 per household (Table 12). Pro-rated (to include all landowners) 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.

Upper 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)]. The Upper Chain user group appeared to be slightly more against establishment of a park or beach on the Chain when compared to respondents from the Chain overall or from the fast or slow lake groups.

Upper Chain respondents agreed (76% "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 (75%) (primary causes identified as non-resident and commercial watercraft) and diminish user enjoyment. They agreed there was adequate water safety enforcement on weekdays (79%); fewer agreed for weekends (68%) and holidays (60%) (Table 13). 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 (86%) and most disagreed ("strongly disagree" or

"disagree" responses) with establishment of a park (75%) or beach (70%) on the Chain. Upper Chain respondents, however, were quite evenly split on the need for more public restrooms.

Table 13. Percentage of "Strongly Agree" and "Agree" Responses for Various User Groups, Chain O' Lakes, Waupaca County, Wisconsin.

Opinion	User Group			
	Upper Chain	Fast Lakes	Slow Lakes	Entire Chain
There are too many watercraft on the Chain	76	79	77	77
The current number of watercraft causes safety problems	75	77	75	76
There is adequate water safety enforcement:				
weekdays	79	82	85	84
weekends	68	60	69	65
holidays	60	58	62	60
Additional water use regulations need to be enacted and enforced	64	62	61	61
There should be limits set on the number of watercraft	56	54	54	54
There is adequate public boater access to the Chain	86	92	90	91
There should be more public restrooms on the Chain	48	52	47	50
There should be a public swimming beach on the Chain	30	36	34	35
There should be a public park on the shoreline of the Chain	25	29	29	29

Exotic Species

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

Purple Loosestrife, however, was present and locally abundant in a several areas of the Upper Chain. Major populations are at the channel to/from Otter Lake, the north and west shores of Otter Lake, north Onaway Island, and the north and south shores of George Lake (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.

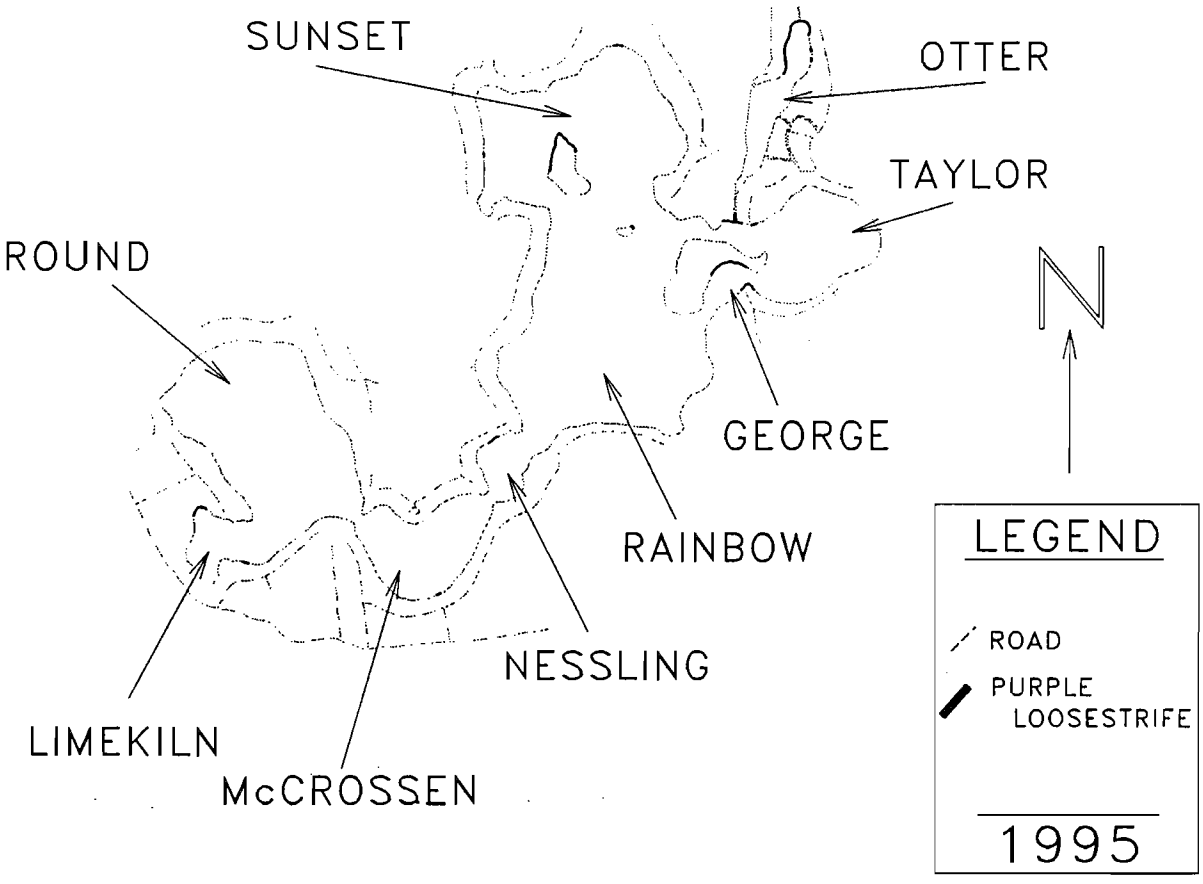

Figure 9. Purple Loosestrife Growth Areas. Upper and Middle Chain, 1994.

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 Upper Chain during Phase II, as during Phase I, indicated good to very good water quality. Surface total phosphorus and total nitrogen levels were lowest during Summer when the water columns were stratified. Higher total phosphorus and total nitrogen levels were observed during Winter or Spring when surface or groundwater influences were greater and the water columns were mixed or, at most, weakly

stratified. Otter Lake continued to have the highest overall nutrients, as would be expected given its relatively more productive habitat. In-lake nutrients 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 the storm sewer is relatively small compared to other overland sources to the Chain. 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

Upper 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 only somewhat agreeable to additional use regulations or limiting the number of watercraft. There was

relatively low interest in establishment of a public park or beach on the Chain but 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 Upper 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 Upper 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.

- Otter, Taylor, Sunset (deepest point) and Rainbow Lake sites should be considered "indicator lakes" for Upper 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 10E1; 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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