IPS ENVIRONMENTAL AND ANALYTICAL SERVICES
Appleton, Wisconsin

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

REPORT TO:
CHAIN O' LAKES PROPERTY OWNERS ASSOCIATION

December, 1995

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SUMMARY

The Middle Chain project group consists of Nessling, McCrossen, Round and Limekiln 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.

Middle Chain water quality monitoring during Phases I and II indicated in-lake nutrient levels below those expected for the region. Round and Limekiln Lakes continued to have relatively higher total nitrogen than other Middle and most (except for Otter Lake) Upper Chain lakes. Total nitrogen and phosphorus for Middle Chain lakes during winter or spring, 1994, were somewhat higher than observed previously.

Middle Chain recreational use survey results were generally 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 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 slightly in favor of more water accessible public restrooms.

Purple loosestrife, an exotic potentially nuisance plant, was present in the Middle Chain.

Water quality protection and water use conflict minimization are priority management objectives for the Middle Chain and all Chain O' Lakes residents. Specific recommendations for the Middle Chain include private well testing for nitrates and/or pesticides, more event sampling (coordinated with flow and rainfall monitoring) in Round and McCrossen Lakes inflow, and removal or management of the purple loosestife beds. Other recommendations are applicable to the Middle 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 Middle Chain O' Lakes.

DESCRIPTION OF AREA

The Chain O' Lakes are a group of "kettle" lakes in the southwest corner of Waupaca County, Wisconsin (Fig. 1). Kettle lakes are formed when ice is pushed into the soil by retreating glaciers; the depressions subsequently filled with water when the ice blocks melted. The Middle Chain consists of Limekiln, Round, McCrossen and Nessling Lakes in the north-central portion of the Chain.

Predominant shoreline area substrates for the Middle 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 and minimal littoral zones.

Generally, groundwater inflow to the Chain O' Lakes is from the northwest. Groundwater input to the Middle Chain was most visible and documented in Round Lake (north and west shores). The Middle Chain, via Nessling Lake, receives inflow from the Upper Chain lakes.

Round Lake is the largest lake (80 acres, 60% of the total surface area) in the Middle Chain; McCrossen Lake is the deepest (75 feet). Other lake areas include Limekiln (14 acres, 11%), Nessling (9 acres, 6%) and McCrossen (30 acres, 23%) (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 Middle Chain has boat ramp access at Becker's Marina on Limekiln 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 collected 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 22, 1992; February 2, May 20, August 16 and October 4, 1993; February 15, 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, the Phase I monitoring site at McCrossen Lake (Site 1103) was discontinued 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 11E1, a wetland drainage pipe near the northwest shore of Round Lake (Table 2) and at Site 11E2, a roadside drainage pipe on the south shore of

McCrossen Lake. Samples were collected by IPS or members of the CLPOA (with IPS instruction) on August 17 and October 6, 1993 and May 3 and July 6, 1994.

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

REGULAR MONITORING

Lake	Site Number	Depth
Limekiln (Deepest Point)	1101	46 feet
Round (Deepest Point)	1102	67 feet
McCrossen (Deepest Point)	1103[1]	75 feet
Nessling (Deepest Point)	1104	55 feet

EVENT MONITORING

Site	Description
11E1	Wetland drainage pipe on the northwest shore of Round Lake
11E2	Roadside drainage pipe on the south shore of McCrossen Lake

[1] site discontinued after 05/93 sample date

Figure 2. Sample Station Locations, Middle 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 generally similar water quality among the Middle Chain lakes and trends similar to those observed during Phase I. Limekiln and Round Lakes continued to exhibit somewhat

higher total nitrogen than the other Middle Chain lakes and total nitrogen and total phosphorus levels throughout the Middle Chain during winter or spring, 1994, were higher than observed since the spring of 1991. All nutrient data reflected seasonal influences of stratification/mixing and surface or goundwater inflows.

Average surface total nitrogen was highest in Limekiln (1.536 mg/L) and Round (1.544 mg/L) Lakes and lowest (for continuously sampled lakes, 1.039 mg/l) in Nessling (Tables 5-8). Average surface total phosphorus, excluding a suspected outlier data point for Nessling Lake on 09/22/92, was similar (0.007 - 0.009 mg/l) among the Middle Chain lakes. Lowest surface total nitrogen or phosphorus levels were generally observed during Summer stratification (Figs. 4 and 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 Middle 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

Table 5. Water Quality Parameters, Station 1101, Limekiln Lake, Chain O' Lakes, July 1992 - September 1994.

PARAMETER	SAMPLE[1]	DATE									
		07/15/92	09/22/92	02/02/93	05/20/93	08/16/93	10/04/93	01/15/94	05/03/94	08/03/94	9/21/94
Secchi (feet)		12.0	9.8	NR[2]	9.9	10.0	10.3	NR	11.0	9.0	8.0
Cloud Cover (percent)		0	0	10	10	30	0	0	60	100	100
Temperature (degrees Celsius)	S	20.80	16.68	2.64	14.51	24.46	12.22	0.18	10.22	23.84	21.33
	B	6.40	6.85	3.73	5.76	7.22	6.90	3.20	6.29	8.39	8.66
pH (std units)	S	8.42	8.84	7.31	NR	8.01	NR	7.00	7.58	8.07	NR
	B	6.66	7.20	6.77	NR	6.16	NR	NR	6.79	6.46	NR
D.O. (mg/l)	S	9.16	9.72	9.95	10.98	8.12	9.50	12.36	12.06	8.79	8.39
	B	0.19	0.66	0.67	2.11	0.27	0.51	7.78	3.09	0.46	0.56
Conductivity (umhos/cm)	S	308	293	336	325	301	328	342	346	327	289
	B	392	455	367	343	350	426	NR	363	404	415
Laboratory pH (surface units)	S	NR	NR	NR	8.31	NR	NR	NR	NR	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	NR	NR	NR
	B	NR	NR	NR	164	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	224	NR	NR	NR	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	S	0.5	0.5	0.8	0.6	0.4	0.5	1.0	0.6	0.63[3]	0.54[3]
	B	3.1	6.1	1.2	1.3	2.1	4.3	1.1	0.6	0.58[3]	4.77[3]
Ammonia Nitrogen (mg/l)	S	0.042	0.030	0.454	0.075	0.035	0.047	0.396	0.203	0.038	0.065
	B	2.201	5.15	0.916	0.640	1.39	3.20	0.416	0.220	0.034	3.64
NO_2 + NO_3 Nit. (mg/l)	S	0.892	0.661	0.948	1.08	0.662	1.01	1.05	1.60	0.715	0.674
	B	ND[4]	ND	0.648	0.708	0.054	ND	1.36	1.81	0.760	ND
Total Nitrogen (mg/l)	S	1.392	1.161	1.748	1.68	1.062	1.51	2.05	2.20	1.345	1.214
	B	3.1	6.1	1.848	2.008	2.154	4.3	2.46	2.41	1.34	4.77
Total Phosphorus (mg/l)	S	0.008	ND	0.007	ND	0.006	0.006	0.014	0.013	0.004[3]	0.007[3]
	B	0.062	0.104	0.014	0.04	0.061	0.061	0.012	0.013	0.005[3]	0.060[3]
Dissolved Phos. (mg/l)	S	0.002	0.001[3]	0.001[3]	ND	ND	ND	0.002	NR	ND	ND
	B	0.003	0.004[3]	0.002[3]	0.002	ND	ND	0.002	NR	ND	ND
Nit./Phos Ratio	S	174.0	--	249.7	--	177.0	251.7	146.4	169.2	336.2	173.4
	B	50.0	58.7	132.0	50.2	35.3	70.5	205.0	185.4	268.0	79.5
Chlorophyll a (ug/l)	S	3	6.32	NR	4.04	3.01	5.16	NR	3.91	3.46	3.56

[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 1102, Round Lake, Chain O' Lakes, July 1992 - September, 1994.

PARAMETER	SAMPLE[1]	DATE									
		07/15/92	09/22/92	02/02/93	05/20/93	08/17/93	10/04/93	01/24/94	05/03/94	08/03/94	9/21/94
Secchi (feet)		12.1	9.5	NR[2]	9.9	9.5	9.8	NR	10.5	10.5	8.0
Cloud Cover (percent)		0	0	10	10	100	0	0	60	80	100
Temperature (degrees Celsius)	S	20.74	16.95	2.28	14.63	24.61	12.35	1.82	10.25	23.85	21.41
	B	5.56	6.16	4.01	5.09	5.84	5.84	3.83	6.76	7.43	7.99
pH (std units)	S	8.38	8.89	7.33	NR	8.01	NR	6.94	7.48	8.11	NR
	B	6.55	7.20	6.70	NR	5.76	NR	6.41	6.78	6.08	NR
D.O. (mg/l)	S	9.63	9.80	9.98	11.09	8.30	9.80	10.98	11.79	9.04	8.60
	B	0.10	0.49	0.44	0.26	0.15	0.74	2.41	5.43	0.36	0.80
Conductivity (umhos/cm)	S	310	293	332	325	301	331	354	345	326	287
	B	384	426	375	386	387	447	390	358	398	374
Laboratory pH (surface units)	S	NR	NR	NR	8.38	NR	NR	NR	8.25	NR	NR
	B	NR	NR	NR	7.91	NR	NR	NR		NR	NR
Total Alkalinity (mg/l)	S	NR	NR	NR	151	NR	NR	NR	165	NR	NR
	B	NR	NR	NR	180	NR	NR	NR		NR	NR
Total Solids (mg/l)	S	NR	NR	NR	212	NR	NR	NR	228	NR	NR
	B	NR	NR	NR	248	NR	NR	NR		NR	NR
Tot. Kjeld. Nitrogen (mg/l)	S	0.5	0.6	0.8	0.5	0.4	0.4	0.9	0.6	0.55[3]	0.48[3]
	B	4.1	4.8	1.1	1.3	0.6	4.2	1.3	1.0	0.65[3]	0.70[3]
Ammonia Nitrogen (mg/l)	S	0.040	0.019	0.447	0.078	0.031	0.026	0.420	0.229	0.021	0.062
	B	2.929	4.04	0.805	0.937	0.070	3.31	0.771	0.519	0.077	0.177
NO_2 + NO_3 Nit. (mg/l)	S	0.835	0.675	0.979	1.08	0.671	1.15	1.25	1.54	0.816	0.714
	B	ND[4]	ND	2.19	1.62	0.968	ND	2.74	1.59	1.0	1.92
Total Nitrogen (mg/l)	S	1.335	1.275	1.779	1.58	1.071	1.55	2.15	2.14	1.366	1.194
	B	4.1	4.8	3.29	2.92	1.568	4.2	4.04	2.59	1.65	2.62
Total Phosphorus (mg/l)	S	0.006	0.004	0.007	ND	0.007	0.004	0.022	0.007	0.004[3]	0.007[3]
	B	0.093	0.082	0.022	0.04	0.010	0.047	0.039	0.028	0.005[3]	0.010[3]
Dissolved Phos. (mg/l)	S	0.003	0.002[3]	0.002[3]	ND	ND	ND	0.001[3]	NR	ND	ND
	B	0.003	0.024[3]	0.004[3]	0.002	ND	ND	0.002[3]	NR	ND	ND
Nit./Phos Ratio	S	222.5	318.8	254.1	--	153.0	387.5	97.7	305.7	341.5	170.6
	B	44.1	58.5	149.5	73.0	156.8	89.4	103.6	92.5	330.0	262.0
Chlorophyll a (ug/l)	S	2	7.03	NR	3.94	3	5.99	NR	4.21	3.66	3.21

[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 1103, McCrossen Lake, Chain O' Lakes, July 1992 - August, 1993.

PARAMETER	SAMPLE[1]	DATE				
		07/15/92	09/22/92	02/02/93	05/20/93	08/17/93
Secchi (feet)		12.0	8.7	NR[2]	8.2	8.0
Cloud Cover (percent)		0	0	10	10	100
Temperature (degrees Celsius)	S	20.90	17.12	2.50	14.85	24.59
	B	4.75	5.12	4.49	4.57	4.88
pH (std units)	S	8.45	8.90	7.11	NR	8.21
	B	6.38	7.33	6.12	NR	5.66
D.O. (mg/l)	S	9.68	9.86	8.46	11.18	8.91
	B	0.10	0.68	0.31	0.27	0.10
Conductivity (umhos/cm)	S	306	290	332	326	296
	B	393	417	485	438	404
Laboratory pH (surface units)	S	NR	NR	NR	8.40	NR
	B	NR	NR	NR	7.23	NR
Total Alkalinity (mg/l)	S	NR	NR	NR	153	NR
	B	NR	NR	NR	215	NR
Total Solids (mg/l)	S	NR	NR	NR	216	NR
	B	NR	NR	NR	278	NR
Tot. Kjeld. Nitrogen (mg/l)	S	0.5	0.5	0.9	0.5	0.4
	B	5.2	4.8	7.4	5.2	0.8
Ammonia Nitrogen (mg/l)	S	0.027	0.013	0.529	0.077	0.023
	B	3.941	3.83	6.74	4.48	0.208
NO_2 + NO_3 Nit. (mg/l)	S	0.672	0.429	0.381	0.796	0.4
	B	ND[3]	ND	ND	ND	0.376
Total Nitrogen (mg/l)	S	1.172	0.929	1.281	1.296	0.8
	B	5.2	4.8	7.4	5.2	1.176
Total Phosphorus (mg/l)	S	0.007	0.004	0.009	ND	0.009
	B	0.186	0.071	0.27	0.26	0.012
Dissolved Phos. (mg/l)	S	ND	0.002	0.001[3]	ND	0.002
	B	0.113	0.025	0.075[3]	0.16	0.002
Nit./Phos Ratio	S	167.4	232.2	142.3	--	88.9
	B	28.0	67.6	27.4	20.0	98.0
Chlorophyll a (ug/l)	S	3	5.84	NR	4.18	3.69

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[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 1104, Nessling Lake, Chain O' Lakes, July 1992 - September 1994.

PARAMETER	SAMPLE[1]	DATE									
		07/15/92	09/22/92	02/02/93	05/20/93	08/17/93	10/06/93	01/24/94	05/03/94	08/03/94	9/21/94
Secchi (feet)		11.2	7.4	NR[2]	8.0	8.0	8.9	NR	8.5	8.0	7.0
Cloud Cover (percent)		0	0	10	10	100	0	0	60	80	100
Temperature (degrees Celsius)	S	20.86	17.00	2.18	14.75	24.43	12.49	1.25	9.75	23.65	21.30
	B	6.66	7.58	3.23	5.27	6.65	6.98	2.86	6.88	8.89	9.90
pH (std units)	S	8.46	8.80	7.17	NR	8.23	NR	6.90	7.62	8.24	NR
	B	6.86	7.30	6.63	NR	6.21	NR	6.76	6.93	6.29	NR
D.O. (mg/l)	S	9.66	9.47	9.33	11.12	9.60	9.80	11.47	12.18	9.42	8.69
	B	0.09	0.59	0.33	2.96	0.14	0.69	9.19	6.78	0.33	0.49
Conductivity (umhos/cm)	S	305	290	331	331	295	327	351	341	310	279
	B	345	367	372	346	344	385	352	350	380	361
Laboratory pH (surface units)	S	NR	NR	NR	8.31	NR	NR	NR	8.27	NR	NR
	B	NR	NR	NR	7.71	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	210	NR	NR	NR	226	NR	NR
	B	NR	NR	NR	226	NR	NR	NR	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	S	0.5	0.5	0.9	0.6	0.5	0.5	0.9	0.6	0.59[3]	0.49[3]
	B	1.6	2.1	1.5	1.2	1.6	1.6	1.1	0.9	0.62[3]	0.61[3]
Ammonia Nitrogen (mg/l)	S	0.027	0.030	0.484	0.073	0.023	0.103	0.441	0.208	0.019	0.038
	B	0.788	1.43	1.06	0.515	1.02	1.24	0.490	0.470	0.020	NR
NO_2 + NO_3 Nit. (mg/l)	S	0.418	0.245	0.284	0.636	0.386	0.456	0.460	0.764	0.364	0.301
	B	0.043	ND[4]	0.009	0.463	ND	ND	0.477	0.591	0.382	0.111
Total Nitrogen (mg/l)	S	0.918	0.745	1.184	1.236	0.886	0.956	1.360	1.364	0.954	0.791
	B	1.643	2.1	1.509	1.663	1.6	1.6	1.577	1.491	1.002	0.721
Total Phosphorus (mg/l)	S	0.009	0.070	0.008	ND	0.009	0.008	0.018	0.012	0.006[3]	0.006[3]
	B	0.031	0.032	0.040	0.04	0.022	0.020	0.012	0.031	0.008[3]	0.008[3]
Dissolved Phos. (mg/l)	S	0.002	0.002[3]	0.002[3]	0.002	ND	ND	0.001[3]	NR	ND	ND
	B	ND	0.002[3]	0.002[3]	0.003	ND	ND	0.002[3]	NR	ND	0.002
Nit./Phos Ratio	S	102.0	10.6	148.0	--	98.4	119.5	75.6	113.7	159.0	131.8
	B	53.0	65.6	37.7	41.6	72.7	80.0	131.4	48.1	125.2	90.1
Chlorophyll a (ug/l)	S	4	4.81	NR	4.70	5	6.91	NR	6.79	4.78	3.62

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

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

Figure 5. Surface Total Phosphorus Trends for the Middle Chain,

1991 - 1994. [*9/92 Nessling Lake value (0.07) considered outlier].

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).

Event monitoring at Sites 11E1 and 11E2 (Tables 9 & 10) indicated total nitrogen levels similar to that observed near bottom in-lake and in creek inflows to the Chain (Table 4). Total phosphorus levels in the event samples were substantially higher than observed in-lake. On dates when both event sites were sampled, total phosphorus and total nitrogen levels were greater in Site 11E1 than in Site 11E2 samples.

Recreational Use

About 43% of the Chain O' Lakes respondents indicated they were permanent residents. Average occupancy for all respondents was 7.8 months (Table 11); seasonal residents averaged 4.7 months.

Respondents indicated a total of 1222 watercraft with an average of 2.9 per household (Table 11). Pro-rated results (to include all landowners) 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.

Table 9. Event Water Quality Parameters, Station 11E1 (Wetland Drainage Pipe to Round Lake), Chain O' Lakes, August 1993 - July 1994.

PARAMETER	SAMPLE[1]	DATE			
		08/17/93	10/06/93	05/03/94	07/06/94
Temperature (degrees Celsius)	M	NR[2]	13.97	NR	NR
pH (surface units)	M	NR	5.80	NR	NR
D.O. (mg/l)	M	NR	NR	NR	NR
Conductivity (umhos/cm)	M	NR	147	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	M	1.0	2.2	4.8	2.8
Ammonia Nitrogen (mg/l)	M	0.031	0.185	1.35	0.216
NO_2 + NO_3 Nit. (mg/l)	M	0.832	0.243	ND[3]	0.201
Total Nitrogen (mg/l)	M	1.832	2.443	4.8	3.001
Total Phosphorus (mg/l)	M	0.024	0.22	0.51	1.23
Dissolved Phos. (mg/l)	M	ND	0.122	NR	0.144
Nit./Phos Ratio	M	76.3	11.1	9.41	2.44

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

Table 10. Event Water Quality Parameters, Station 11E2 (Roadside Drainage Pipe to McCrossen Lake), Chain O' Lakes, May - July 1994.

PARAMETER	SAMPLE[1]	DATE	
		05/03/94	07/06/94
Temperature (degrees Celsius)	M	NR[2]	NR
pH (surface units)	M	NR	NR
D.O. (mg/l)	M	NR	NR
Conductivity (umhos/cm)	M	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	M	1.2	1.7
Ammonia Nitrogen (mg/l)	M	0.118	0.192
NO_2 + NO_3 Nit. (mg/l)	M	ND[3]	0.018
Total Nitrogen (mg/l)	M	1.318	1.718
Total Phosphorus (mg/l)	M	0.170	0.240
Dissolved Phos. (mg/l)	M	NR	0.079
Nit./Phos Ratio	M	7.8	7.2

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

Table 11. Comparison of Recreational Use Parameters for Various User Groups, Chain O' Lakes, Waupaca County, Wisconsin.

Parameter	User Group			
	Middle Chain	Fast Lakes	Slow Lakes	Entire Chain
Average monthly occupancy	7.4	7.5	8.1	7.8
Average number of watercraft (per response)	2.9	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)	0.2	0.6	0.3	0.4
Average number of children less than 12 years old (per respondent household)	0.3	0.5	0.5	0.5
Average respondent age	58.1	59.1	57.7	58.3
Percent of respondents leaving comments	44.0	51.9	44.9	48.0

Middle Chain respondents agreed (73% "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 (78%) (primary cause identified as non-resident watercraft) and diminish user enjoyment. They agreed there was adequate water safety enforcement on weekdays (89%); fewer agreed for weekends (70%) and holidays (60%) (Table 12). Concensus was only somewhat in favor of enactment of more ordinances and

limiting boat numbers.

Table 12. Percentage of "Strongly Agree" and "Agree" Responses for Various User Groups, Chain O' Lakes, Waupaca County, Wisconsin.

Opinion	User Group			
	Middle Chain	Fast Lakes	Slow Lakes	Entire Chain
There are too many watercraft on the Chain	73	79	77	77
The current number of watercraft causes safety problems	78	77	75	76
There is adequate water safety enforcement:				
weekdays	89	82	85	84
weekends	70	60	69	65
holidays	60	58	62	60
Additional water use regulations need to be enacted and enforced	65	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	87	92	90	91
There should be more public restrooms on the Chain	62	52	47	50
There should be a public swimming beach on the Chain	40	36	34	35
There should be a public park on the shoreline of the Chain	35	29	29	29

Respondents agreed that there was adequate public boater access to the Chain (87%). Most disagreed ("strongly disagree" or "disagree" responses) with establishment of a park (65%) or beach

(60%) on the Chain, but agreed (62%) with the need for more public restrooms.

Exotic Species

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

Purple Loosestrife, however, was present in a several areas of the Middle Chain. Growth areas were located on the north shore of Nessling Lake, the south shore of McCrossen Lake and the north and south shores of Limekiln Lake (Fig. 6).

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. Middle Chain growth areas are not as dense as in the Upper Chain, but the plant is able to outcompete native wetland vegetation, spread quickly and modify entire plant (and thus animal) assemblages.

Figure 6. 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 Middle 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. 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.

Limekiln and Round Lakes exhibited higher total nitrogen than the other Middle Chain lakes. All Middle Chain lakes exhibited relatively higher total nitrogen and total phosphorus during winter or spring, 1994, than were observed since 1991.

Rain event monitoring at sites on Round and McCrossen Lakes indicated relatively low total nitrogen levels but total phosphorus levels substantially higher than observed in-lake. Levels at the Round Lake site were higher than at the McCrossen Lake site but flow and nutrient contribution via the two event sampling sites 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 (see Upper Chain Phase II report).

Recreational Use

Middle 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 somewhat agreeable to, but rather evenly split, regarding 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 Middle Chain respondents were more agreeable 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" and activities on shorelines immediately adjacent, or directly draining, to the lakes, they should be strongly encouraged to keep abreast of and support the TWRPW Project.

- Residents in the Middle 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 Middle 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.

- Round (the largest basin), Nessling and Limekiln Lakes should be considered "indicator lakes" for Middle 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 Sites 11E1 and 11E2; flow determination and rainfall monitoring would enhance the value of this information relative to alternatives.

- 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 an 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 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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APPENDIX I
SAMPLE RECREATIONAL USE SURVEY
Middle Chain O' Lakes Management Plan

APPENDIX I
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APPENDIX II
SUMMARY OF PUBLIC INVOLVEMENT ACTIVITIES
Middle 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. A public involvement program was immediately initiated as part of the planning process. The following is a summary of Phase I and Phase II major public involvement efforts.

Planning Advisory Committee

A working group comprised of the CLPOA officers, IPS and WDNR was established at the start of the program. The group provided planning direction and served as main reviewer of the draft plan document.

Brochures

A informational brochure titled "Chain O' Lakes Management Planning Program" was developed and distributed which outlined objectives, elements and ways for CLPOA members to get involved in the planning process.

A Phase I plan summary brochure was also produced. It was made available for CLPOA use and distribution when the plan document was approved by WDNR. The brochure described the main features of plan development, plan recommendations and other pertinent information. Another plan brochure will be produced upon conclusion of Phase II.

Meetings

IPS presented progress reports, provided information about the resource and interpretations of these results periodically and at CLPOA member meetings.

Print Media

After receipt of the grant award, a news release was issued to the Waupaca Post. The release highlighted information about the length and scope of the project and persons to contact for additional information.

A quarterly IPS newsletter entitled "Lake Management News" was developed and distributed to the CLPOA for the officers' 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. Information was also prepared for inclusion into the CLPOA newsletter.

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

Prepared for

Chain O' Lakes Property Owners Association

by

December, 1995