IPS ENVIRONMENTAL AND ANALYTICAL SERVICES
Appleton, Wisconsin

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

REPORT TO:
CHAIN O' LAKES PROPERTY OWNERS ASSOCIATION

December, 1995

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SUMMARY

The Little Chain project group consists of Marl, Pope, Manomin, Knight and Orlando 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 Plan); 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.

Little Chain water quality monitoring during Phases I and II indicated in-lake nutrient levels below those typical of Wisconsin lakes overall and of lakes in the Chain O' Lakes' ecoregion. Hartman's Creek inflow, however, appeared to slightly elevate nutrient levels in the more downstream Little Chain lakes.

The Little Chain is less developed than the other Chain O' Lakes project groups and recreational use survey results suggested that the opinion of the Little Chain user group differ from those of Chain O' Lakes overall and various resident group users. 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. Residents fully agreed there is adequate public boater access, disagreed with the establishment of a public park or restrooms, and were nearly evenly divided on establishment of a public swimming beach. A majority of Little Chain residents agreed additional water use regulations need to be enacted and enforced and also agreed there should be limits set on the number of watercraft on the Chain.

Purple loosestrife, an exotic potentially nuisance plant, was not present in the Little Chain, but is established in nearby Chain O' Lakes project groups.

Water quality protection and water use conflict minimization are priority management objectives for the Little Chain and all Chain O' Lakes residents. Specific recommendations for the Little Chain include private well testing for nitrates and/or pesticides, more event sampling (coordinated with flow and rainfall monitoring) and purple loosestrife surveillance.

Other recommendations are applicable to the Little 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 Little 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 Little Chain consists of Knight, Manomin, Marl, Orlando and Pope Lakes in the southwest portion of the Chain.

Compared to most other Chain O' Lakes project groups, the Little Chain has a relatively more extensive watershed and higher potential for effects associated with nonpoint runoff (2). Flow within the Little Chain is from Marl to Pope Lake (which receives inflow from Hartman's Creek), through Manomin, Knight and Orlando Lakes before draining to Bass Lake of the Lower Chain project group.

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) of the Upper Chain O'Lakes.

Little Chain lakes are small [range: 6 acres (Manomin) to 14 acres (Pope)] and are separated from the other Chain O' Lakes project groups by a shallow (wadable) creek. Little Chain lake

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

maximum depths range from 30 feet (Manomin) to 59 feet (Marl) (3).

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 Little Chain has direct access boat ramps on Marl Lake and the Manomin - Knight Lake Channel.

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 was completed in 1995. Pertinent information from the appraisal as it relates to the Chain O' Lakes is included in the Field Data Discussion section of this report.

Water Quality Monitoring

Water quality samples were taken in July and September, 1992, February, May, August and October, 1993, and February, May, August and September, 1994. Samples were collected three feet below the surface and three feet above bottom for all lakes (Table 2, Fig. 2). 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). The Hartman's Creek site was sampled on October 6, 1993, and February 15, 1994. Event samples were collected on May 3, July 6, and August 1, 1994 (Table 2).

Recreational Use

A recreational use survey of the CLPOA membership was conducted to obtain property and lake use, water use opinions and

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

REGULAR MONITORING

Lake	Site Number	Depth
Manomin (Deepest Point)	1401	30 feet
Pope (Deepest Point)	1402	40 feet
Marl (Deepest Point)	1403	59 feet
Knight (Deepest Point)	1404	42 feet
Orlando (Deepest Point)	1405	39 feet

Event Site	Description
14E1	Hartman's Creek - Rural Road

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

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 0Phase I and II grant periods to document the occurrence 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
Lower Tomorrow	258	168	66	20	6.82
Spring Creek	275	154	39	5	4.71
Chain O' Lakes	389	136	30	2	2.59
Crystal River	266	117	22	5	3.27
Waupaca/ Weyauwega	63	15	11	4	5.31
Total	1,251	590	168	36	4.54
Percent	100%	47%	13%	3%	

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

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

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

Lakes

A computer model applied by WDNR to the western portion of the Chain O' Lakes indicated that the Chain has a natural ability to

remove phosphorus from the water column via marl precipitation. Marl (calcium carbonate) binds with phosphorus and settles to the lake bottom.

Overall, the lakes modeled (Marl, Pope, Manomin, Orlando, Knight, Ottman, Youngs, Bass, Beasley and Long) showed a 36% reduction 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 Little Chain lakes and trends similar to those observed during Phase I. Pope and Orlando Lakes exhibited somewhat higher nutrients than the other Little Chain lakes and all nutrient data

reflected seasonal influence of stratification/mixing and surface or groundwater inflows (Tables 5-9, Figs. 4 and 5).

Surface total nitrogen ranged from 0.339 mg/l (Marl) to 1.88 mg/l (Manomin) with an average of 1.07 mg/l for all Little Chain Lakes (Tables 5-9). Total nitrogen levels were relatively lower in Marl Lake than in the more downstream Lower Chain lakes. Lowest surface total nitrogen levels were observed during stratified conditions (Summer); highest levels were during periods of highest groundwater input (Winter) (Fig. 5).

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

Surface phosphorus levels for the Little 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 typically at or below those typical for the ecoregion in which the Chain is located (0.010 - 0.014 mg/l) (7). NOTE: Some samples 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 1401, Manomin Lake, Chain O' Lakes, July 1992 - September 1994.

PARAMETER	SAMPLE[1]	DATE									
		07/14/92	09/23/92	02/03/93	05/18/93	08/17/93	10/06/93	02/15/94	05/02/94	08/02/94	09/21/94
Secchi (feet)		23.5	16.4	NR[2]	8.5	14.0	8.7	NR	9.4	19.0	9.5
Cloud Cover (percent)		100	0	10	100	100	0	0	10	10	100
Temperature (degrees Celcius)	S	19.26	15.06	2.47	14.16	22.05	12.48	2.09	9.91	21.69	19.92
	B	10.50	12.61	3.18	6.24	8.88	5.10	2.50	6.24	10.37	11.54
pH (surface units)	S	7.94	8.25	7.30	7.67	7.49	7.60	6.95	NR	7.79	8.90
	B	7.01	7.38	7.01	6.10	6.50	6.40	6.88	NR	6.58	7.20
D.O. (mg/l)	S	8.43	7.97	9.33	11.70	7.34	9.26	9.43	11.24	8.49	9.43
	B	0.15	0.50	4.00	0.19	0.65	0.67	8.44	0.61	0.34	0.99
Conductivity (umhos/cm)	S	294	303	341	305	299	326	344	300	306	292
	B	372	394	357	361	357	392	351	336	399	392
Laboratory pH (surface units)	S	NR	NR	NR	8.46	NR	NR	NR	8.24	NR	NR
	B	NR	NR	NR	8.04	NR	NR	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	NR	NR	NR	162	NR	NR	NR	161	NR	NR
	B	NR	NR	NR	196	NR	NR	NR	NR	NR	NR
Total Solids (mg/l)	S	NR	NR	NR	200	NR	NR	NR	198	NR	NR
	B	NR	NR	NR	234	NR	NR	NR	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	S	0.3	0.4	0.3	0.4	0.4	0.5	0.5	0.4	0.46[4]	0.37[4]
	B	1.6	1.6	0.4	1.0	2.0	2.6	0.5	0.8	NR	1.34
Ammonia Nitrogen (mg/l)	S	0.051	0.078	0.150	0.021	0.042	0.109	0.194	0.024	0.43	0.027
	B	0.766	0.638	0.268	0.417	0.767	2.02	0.256	0.440	NR	0.434
NO_2 + NO_3 Nit. (mg/l)	S	0.811	0.699	1.54	0.675	0.739	0.457	1.38	0.926	0.629	0.714
	B	ND[3]	0.124	1.24	0.123	0.010	ND	1.30	0.509	NR	0.099
Total Nitrogen (mg/l)	S	1.111	1.099	1.84	1.075	1.139	0.957	1.88	1.326	1.089	1.084
	B	1.6	1.724	1.64	1.123	2.010	2.6	1.80	1.309	--	1.439
Total Phosphorus (mg/l)	S	0.010	0.009	0.004	<0.02	0.011	0.008	0.010	0.019	0.010	0.011
	B	0.153	0.125	0.008	0.05	0.23	0.048	0.012	0.038	NR	0.269
Dissolved Phos. (mg/l)	S	0.006	0.002	0.004	ND	ND	0.004	0.002	NR	ND	ND
	B	0.056	0.002	0.006	ND	0.026	0.013	0.007	NR	NR	0.187
Nit./Phos Ratio	S	111.1	122.1	460.0	--	103.5	119.6	188.0	69.8	108.9	98.5
	B	10.5	13.8	205.0	22.5	8.7	54.2	150.0	34.4	--	5.35
Chlorophyll a (ug/l)	S	2.0	3.11	NR	8.85	2.07	6.89	NR	11.6	1.67	1.65

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

Table 6. Water Quality Parameters, Station 1402, Pope Lake,

Chain O' Lakes, July 1992 - September 1994.

PARAMETER	SAMPLE[1]	DATE									
		07/14/92	09/23/92	02/03/93	05/18/93	08/17/93	10/06/93	02/15/94	05/02/94	08/02/94	09/21/94
Secchi (feet)		17.0	16.2	NR[2]	7.9	13.1	9.8	NR	10.0	14.5	12.0
Cloud Cover (percent)		100	0	10	100	100	0	0	0	10	100
Temperature (degrees Celcius)	S	17.67	14.34	3.28	13.24	19.95	12.28	0.27	9.69	19.54	18.89
	B	9.07	10.14	4.01	6.40	8.97	9.53	4.17	7.02	9.30	9.83
pH (surface units)	S	8.01	8.05	7.77	7.74	7.41	NR	7.05	NR	7.66	8.95
	B	6.89	7.28	7.27	6.34	6.21	NR	6.80	NR	6.34	7.49
D.O. (mg/l)	S	8.57	8.30	9.98	12.10	6.92	9.72	12.10	11.64	8.70	9.61
	B	0.08	0.58	5.44	2.61	0.16	0.39	5.52	0.63	0.36	0.53
Conductivity (umhos/cm)	S	293	307	348	309	304	330	342	298	316	293
	B	348	357	358	336	337	372	363	344	365	338
Laboratory pH (surface units)	S	NR	NR	NR	8.47	NR	NR	NR	8.29	NR	NR
	B	NR	NR	NR	8.05	NR	NR	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	NR	NR	NR	164	NR	NR	NR	161	NR	NR
	B	NR	NR	NR	180	NR	NR	NR	NR	NR	NR
Total Solids (mg/l)	S	NR	NR	NR	202	NR	NR	NR	198	NR	NR
	B	NR	NR	NR	216	NR	NR	NR	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	S	0.3	0.4	0.3	0.4	0.4	0.3	0.4	0.3	0.35[4]	0.42[4]
	B	1.2	1.8	0.4	0.5	1.1	1.5	0.4	0.5	1.41[4]	NR
Ammonia Nitrogen (mg/l)	S	0.050	0.045	0.144	0.014	0.036	0.029	0.157	0.014	0.038	0.033
	B	0.762	1.19	0.266	0.256	0.767	1.10	0.192	0.295	0.901	NR
NO_2 + NO_3 Nit. (mg/l)	S	0.908	0.804	1.33	0.776	0.842	0.877	1.42	0.960	0.830	0.797
	B	ND[3]	0.011	1.39	0.820	ND	0.009	1.25	0.677	0.010	NR
Total Nitrogen (mg/l)	S	1.208	1.204	1.63	1.176	1.242	1.177	1.82	1.26	1.18	1.217
	B	1.2	1.811	1.79	1.320	1.1	1.509	1.65	1.18	1.42	--
Total Phosphorus (mg/l)	S	0.011	0.009	0.004	<0.02	0.011	0.011	0.009	0.011	0.011	0.009
	B	0.176	0.178	0.010	0.02	0.102	0.180	0.007	0.021	0.159	NR
Dissolved Phos. (mg/l)	S	0.004	0.003	0.004	0.002	ND	0.004	0.003	NR	ND	ND
	B	0.014	0.009	0.008	0.002	0.010	0.012	0.005	NR	0.004	NR
Nit./Phos Ratio	S	109.8	133.8	407.5	--	112.9	107.0	202.2	114.5	107.3	135.2
	B	6.8	10.2	179.0	66.0	10.8	13.97	235.7	56.0	8.93	--
Chlorophyll a (ug/l)	S	2	4.44	NR	8.45	1.70	4.09	NR	9.00	1.80	1.79

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

Table 7. Water Quality Parameters, Station 1403, Marl Lake, Chain O' Lakes, July 1992 - September 1994.

PARAMETER	SAMPLE[1]	DATE									
		07/14/92	09/23/92	02/03/93	05/18/93	08/17/93	10/06/93	02/15/94	05/02/94	08/02/94	09/21/94
Secchi (feet)		11.5	13.7	NR[2]	13.9	6.0	14.0	NR	13.0	11.0	13.0
Cloud Cover (percent)		100	0	10	80	100	0	0	0	0	100
Temperature (degrees Celcius)	S	19.61	16.28	3.95	14.28	23.53	13.00	3.88	10.82	22.87	20.34
	B	8.27	9.34	4.06	6.60	8.65	8.99	4.14	6.90	8.64	9.33
pH (surface units)	S	8.36	8.37	7.27	7.77	8.15	NR	6.95	7.10	8.17	NR
	B	6.99	7.05	7.20	6.60	6.35	NR	6.87	6.48	6.43	NR
D.O. (mg/l)	S	10.80	11.15	6.40	11.50	9.98	10.56	6.84	12.20	9.89	9.46
	B	0.30	0.49	5.42	4.04	0.12	0.32	6.08	6.13	0.41	0.98
Conductivity (umhos/cm)	S	280	274	326	310	271	313	340	305	286	265
	B	348	371	328	349	347	390	341	337	368	341
Laboratory pH (surface units)	S	NR	NR	NR	8.51	NR	NR	NR	8.38	NR	NR
	B	NR	NR	NR	8.21	NR	NR	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	NR	NR	NR	167	NR	NR	NR	175	NR	NR
	B	NR	NR	NR	191	NR	NR	NR	NR	NR	NR
Total Solids (mg/l)	S	NR	NR	NR	198	NR	NR	NR	208	NR	NR
	B	NR	NR	NR	226	NR	NR	NR	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	S	0.2	0.3	0.4	0.3	0.3	0.2	0.4	0.2	0.36[3]	0.39[3]
	B	0.6	2.1	0.4	0.5	0.3	0.9	0.4	0.4	0.79[3]	NR
Ammonia Nitrogen (mg/l)	S	0.025	0.015	0.237	0.032	0.017	0.025	0.178	0.024	0.015	0.012
	B	0.251	0.823	0.275	0.175	0.030	0.603	0.226	0.082	0.508	NR
NO_2 + NO_3 Nit. (mg/l)	S	0.139	0.145	0.357	0.392	0.054	0.212	0.372	0.339	0.093	0.081
	B	0.345	ND[4]	0.329	0.371	0.101	ND	0.331	0.416	ND	NR
Total Nitrogen (mg/l)	S	0.339	0.445	0.757	0.692	0.354	0.412	0.772	0.539	0.883	0.471
	B	0.945	2.1	0.729	0.871	0.401	0.9	0.731	0.816	0.79	--
Total Phosphorus (mg/l)	S	0.007	0.006	0.008	<0.02	0.008	0.005	0.017	0.005	0.011	ND
	B	0.018	0.033	0.008	<0.02	0.008	0.018	0.004	0.015	0.021	NR
Dissolved Phos. (mg/l)	S	0.002	ND	0.003	ND	ND	0.003	ND	NR	ND	ND
	B	ND	ND	0.003	ND	ND	ND	ND	NR	ND	NR
Nit./Phos Ratio	S	48.4	74.2	94.6	--	44.3	82.4	45.4	107.8	80.3	--
	B	52.5	63.6	91.1	--	50.1	50.0	182.8	54.4	37.6	--
Chlorophyll a (ug/l)	S	3	2.47	NR	2.59	2.63	2.19	NR	2.79	2.41	1.69

[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 1404, Knight Lake, Chain O' Lakes, July 1992 - May 1993.

PARAMETER	SAMPLE[1]	DATE			
		07/14/92	09/23/92	02/03/93	05/18/93
Secchi (feet)		27.5	14.1	NR[2]	11.9
Cloud Cover (percent)		90	0	10	80
Temperature (degrees Celcius)	S	19.25	15.36	1.88	NR
	B	9.03	9.33	4.79	NR
pH (surface units)	S	8.18	8.58	7.25	NR
	B	6.86	7.68	6.75	NR
D.O. (mg/l)	S	9.15	7.87	9.33	NR
	B	0.16	0.57	0.88	NR
Conductivity (umhos/cm)	S	292	307	344	NR
	B	394	406	381	NR
Laboratory pH (surface units)	S	NR	NR	NR	8.42
	B	NR	NR	NR	7.74
Total Alkalinity (mg/l)	S	NR	NR	NR	163
	B	NR	NR	NR	208
Total Solids (mg/l)	S	NR	NR	NR	200
	B	NR	NR	NR	246
Tot. Kjeld. Nitrogen (mg/l)	S	0.3	0.4	0.2	0.4
	B	0.5	1.0	0.4	0.4
Ammonia Nitrogen (mg/l)	S	0.045	0.079	0.124	0.055
	B	0.221	0.773	0.232	0.219
NO_2 + NO_3 Nit. (mg/l)	S	0.669	0.596	1.49	0.662
	B	0.262	0.018	0.864	0.557
Total Nitrogen (mg/l)	S	0.969	0.996	1.69	1.062
	B	0.762	1.018	1.264	0.957
Total Phosphorus (mg/l)	S	0.010	0.014	0.005	<0.02
	B	0.061	0.106	0.024	0.02
Dissolved Phos. (mg/l)	S	0.002	0.002	0.003	ND[3]
	B	0.023	0.028	0.020	0.002
Nit./Phos Ratio	S	96.9	71.1	338.0	--
	B	12.5	9.6	52.7	47.9
Chlorophyll a (ug/l)	S	2	2.94	NR	2.91

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

Table 9. Water Quality Parameters, Station 1405, Orlando Lake, Chain O' Lakes, July 1992 - September 1994.

PARAMETER	SAMPLE[1]	DATE									
		07/14/92	09/23/92	02/03/93	05/20/93	08/17/93	10/06/93	02/15/94	05/02/94	08/02/94	09/21/94
Secchi (feet)		24.5	14.6	NR[2]	17.2	16.0	12.2	NR	17.5	12.6	14.5
Cloud Cover (percent)		80	0	10	90	100	0	0	10	0	100
Temperature (degrees Celcius)	S	19.84	15.55	2.22	14.53	22.50	13.00	2.33	10.17	22.73	20.29
	B	8.11	8.91	4.33	5.72	6.93	7.23	4.19	6.28	8.63	9.06
pH (surface units)	S	8.35	7.97	7.41	NR	7.67	NR	6.70	NR	8.09	NR
	B	6.97	7.04	6.82	NR	6.09	NR	6.38	NR	6.33	NR
D.O. (mg/l)	S	9.31	7.96	9.37	10.43	8.16	10.01	8.35	10.96	9.84	9.13
	B	0.13	0.58	0.32	0.35	0.18	0.59	0.38	0.72	0.34	0.95
Conductivity (umhos/cm)	S	287	300	341	311	300	336	350	303	298	289
	B	376	407	372	403	392	441	369	374	403	399
Laboratory pH (surface units)	S	NR	NR	NR	8.29	NR	NR	NR	NR	NR	NR
	B	NR	NR	NR	7.49	NR	NR	NR	NR	NR	NR
Total Alkalinity (mg/l)	S	NR	NR	NR	161	NR	NR	NR	NR	NR	NR
	B	NR	NR	NR	217	NR	NR	NR	NR	NR	NR
Total Solids (mg/l)	S	NR	NR	NR	200	NR	NR	NR	NR	NR	NR
	B	NR	NR	NR	262	NR	NR	NR	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	S	0.3	0.4	0.3	2.6[3]	0.4	0.4	0.3	NR	0.48	0.40
	B	3.4	3.9	1.2	0.3[3]	2.5	4.8	1.1	1.1	4.06	NR
Ammonia Nitrogen (mg/l)	S	0.059	0.102	0.117	1.83[3]	0.045	0.043	0.153	NR	0.024	0.050
	B	1.68	2.58	0.919	0.087[3]	1.58	3.50	0.709	0.702	0.941	NR
$NO_2 + NO_3$ Nit. (mg/l)	S	0.645	0.561	1.56	0.036[3]	0.602	0.722	1.44	NR	0.454	0.580
	B	ND[4]	ND	0.241	0.645[3]	ND	ND	0.465	0.204	ND	NR
Total Nitrogen (mg/l)	S	0.945	0.961	1.86	2.636[3]	1.002	1.122	1.74	NR	0.934	0.45
	B	3.4	3.9	1.441	0.945[3]	2.5	4.80	1.565	NR	4.06	--
Total Phosphorus (mg/l)	S	0.006	0.009	0.004	0.21[3]	0.007	0.009	0.014	NR	0.015	0.010
	B	0.49	0.39	0.070	<0.02[3]	0.26	0.58	0.050	0.057	0.091	NR
Dissolved Phos. (mg/l)	S	0.002	0.002	0.003	ND	ND	0.002	ND	NR	0.002	ND
	B	0.25	0.19	0.043	0.075	0.153	0.340	0.026	NR	ND	NR
Nit./Phos Ratio	S	157.5	106.8	465.0	12.6	143.1	124.7	124.3	NR	62.3	--
	B	6.9	10.0	20.6	--	9.6	8.3	31.3	NR	44.6	--
Chlorophyll a (ug/l)	S	2	3.01	NR	0.96	1.62	3.73	NR	NR	3.21	3.46

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[1] S = surface, B = bottom; [2] NR = no reading; [3] Probable labeling error; [4] ND = not detectable

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

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

Average total nitrogen for site 14E1 (Hartman's Creek) for regular and event monitoring was 0.76 mg/l; average total phosphorus was 0.020 mg/l (Table 10).

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 10. Event and Regular Water Quality Parameters, Station 14E1, Hartman's Creek at Rural Road, Chain O' Lakes, October 1993 - August 1994

PARAMETER	SAMPLE[1]	DATE				
		10/06/93	02/15/94	05/03/94[2]	07/06/94[2]	08/01/94[2]
Temperature (degrees Celcius)	M	13.89	2.69	NR[3]	NR	NR
pH (surface units)	M	7.49	6.74	NR	NR	NR
D.O. (mg/l)	M	5.94	15.50	NR	NR	NR
Conductivity (umhos/cm)	M	203	351	NR	NR	NR
Tot. Kjeld. Nitrogen (mg/l)	M	0.4	0.3	0.3	0.4	0.45[4]
Ammonia Nitrogen (mg/l)	M	0.039	0.241	0.035	0.062	0.058
NO_2 + NO_3 Nit. (mg/l)	M	0.423	1.07	0.199	0.099	0.163
Total Nitrogen (mg/l)	M	0.823	1.37	0.499	0.499	0.613
Total Phosphorus (mg/l)	M	0.014	0.007	0.017	0.039	0.021
Dissolved Phos. (mg/l)	M	ND[5]	0.002	NR	0.003	ND
Nit./Phos Ratio	M	58.8	195.7	29.4	12.8	29.2

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

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

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

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

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 11); seasonal residents averaged 4.7 months.

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

Parameter	User Group			
	Little Chain	Fast Lakes	Slow Lakes	Entire Chain
Average monthly occupancy	8.6	7.5	8.1	7.8
Average number of watercraft (per response)	2.6	3.1	2.7	2.9
Average number of adults (per respondent household)	2.5	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)	0.6	0.5	0.5	0.5
Average respondent age	57.6	59.1	57.7	58.3
Percent of respondents leaving comments	71.0	51.9	44.9	48.0

Respondents indicated a total of 1222 watercraft with an average of 2.9 per household (Table 11). 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.

The number of Little Chain resident responses, compared to the number of responses for other user groups, was relatively small. Their opinion, however, differed somewhat 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)] lake user groups (Table 12).

Little Chain respondents agreed (88% "strongly agree" or "agree" responses) there are too many watercraft on the Chain [primarily on weekends and holidays (App. II)] and that the number of watercraft cause safety problems (82%) (primary causes identified as non-resident and commercial watercraft) and diminish user enjoyment. They were rather evenly split on the issue of adequate water safety enforcement on weekdays (57%), weekends (57%) and holidays (50%). Concensus was in favor of enactment of more ordinances and limiting boat numbers.

Respondents fully agreed that there was adequate public boater access to the Chain (100%). Most disagreed ("strongly disagree" or "disagree" responses) with establishment of a park

(62%) or public restrooms (62%) on the Chain, and they were nearly evenly split on the establishment of a public beach.

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

Opinion	User Group			
	Little Chain	Fast Lakes	Slow Lakes	Entire Chain
There are too many watercraft on the Chain	88	79	77	77
The current number of watercraft causes safety problems	82	77	75	76
There is adequate water safety enforcement:				
weekdays	57	82	85	84
weekends	57	60	69	65
holidays	50	58	62	60
Additional water use regulations need to be enacted and enforced	76	62	61	61
There should be limits set on the number of watercraft	71	54	54	54
There is adequate public boater access to the Chain	100	92	90	91
There should be more public restrooms on the Chain	38	52	47	50
There should be a public swimming beach on the Chain	47	36	34	35
There should be a public park on the shoreline of the Chain	38	29	29	29

Exotic Species

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

Purple Loosestrife was not present in the Little Chain, but is established in nearby Chain O' Lakes project groups. Purple Loosestrife is an exotic plant with a bright purple flower, originally propagated in the United States by the horticulture industry for flower gardens. It blooms late June to July and produces seeds soon after. The plant is able to outcompete native wetland vegetation and modify entire plant (and thus animal) assemblages.

BASELINE CONCLUSIONS

Watershed Characteristics

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

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

Water Quality

Regular water quality monitoring in the Little Chain during Phase II, as during Phase I, indicated good to very good water quality. Hartman's Creek inflow appeared to slightly elevate nutrient levels in the more downstream Little Chain lakes. Surface total phosphorus levels were generally similar to that in the other Chain lakes and exhibited, as a whole, weak to variable seasonal trends. Total nitrogen was highest during periods when

groundwater input was of the greatest influence (Winter) and lowest during summer stratification. 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 Hartman's Creek, according to the TWRPW Project, is relatively small compared to other overland sources to the Chain (Fig. 6-8). These 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

Little Chain resident responses to the recreational use survey differed from those of 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 and diminished recreational enjoyment. Little Chain Residents were evenly divided regarding adequate water safety enforcement on weekdays, weekends and during holiday periods of heavy recreational use and were more agreeable (than other Chain user groups) towards additional use

regulations and limiting the number of watercraft on the Chain. There was relatively low interest in establishment of public restrooms on the Chain, but respondents were more agreeable as to the need for a public swimming beach or park when compared to other Chain user groups.

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, Lower, and Middle Chains and the potential for colonization of the Little Chain should be considered high.

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 Little 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 Little 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.

- Marl, Pope, and Orlando Lake sites should be considered "indicator lakes" for Little 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 14E1; 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. Survey results also suggest that the opinions of the Little Chain user group differ from those of other user groups. 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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APPENDIX I
RECREATIONAL USE SURVEY RESULTS
Little Chain O' Lakes Management Plan

APPENDIX I
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APPENDIX II
SUMMARY OF PUBLIC INVOLVEMENT ACTIVITIES
Little 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" 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
LITTLE CHAIN O' LAKES
WAUPACA COUNTY, WISCONSIN

Prepared for

Chain O' Lakes Property Owners Association

by

December, 1995