IPS ENVIRONMENTAL AND ANALYTICAL SERVICES
Appleton, Wisconsin

# PHASE I
# LAKE MANAGEMENT PLAN
# MIDDLE 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.

**Drainage Lake** — Generally referred to as natural lakes having permanently inflowing and outflowing streams.

**Eutrophic** — From Greek for "well nourished", describes a lake of high photosynthetic activity and low transparency.

**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.

## GLOSSARY OF TERMS
(Continued)

| | |
|---|---|
| **Mesotrophic** | A lake of intermediate productivity and clarity. |
| **Morphometry** | Pertaining to the shape, depth or structure of a lake. |
| **N/P Ratio** | Total nitrogen divided by the total phosphorus found in a water sample. A value greater than 15 indicates that phosphorus is limiting for primary production. |
| **Oligotrophic** | 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 lakes located in Waupaca County, Wisconsin. 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 Middle Chain consists of Nessling, McCrossen, Round and Limekiln Lakes and comprises about 18% of the total Chain lake surface area. The Middle Chain receives the majority of inflow from the Upper Chain, but also has spring inputs.

Middle Chain lakes water quality is good to excellent and indicative of **oligotrophic** to **mesotrophic** classifications. Highest surface nutrient levels were below levels typical for Wisconsin lakes overall and at or below levels typical for lakes in the Chain O' Lakes' ecoregion. Water quality of the Middle Chain was similar to that of other Chain lakes with similar physical characteristics. Except for somewhat higher phosphorus levels near bottom in McCrossen Lake, no trends were evident from the small amount of data available for the Middle Chain.

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.

Water quality trend monitoring should be continued on a similar schedule to supplement the small amount of historic data available; event samples should be taken as appropriate in areas of concern. 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 and minimization of use conflicts.

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

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

## INTRODUCTION

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

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

The CLPOA, in late 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 Middle Chain application incorporated required or recommended program components including:

- assessment of current water quality in the Middle Chain and implementation of a strategy to track trends,
- increase the awareness of the lake property owners of lake problems and establishment of a base of support for lake management efforts,
- assessment of techniques for swimmer's itch control,
- determination of event-related nonpoint source runoff to Round Lake.

The Middle 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 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. The major soil type near the Middle Chain is well-drained Rosholt sandy loam on 12-20 percent slopes. Erosion potential is moderate on Rosholt soils (6).

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 Middle 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 (Lythrum salicaria), are established in Waupaca County and are capable of spreading to the Chain O' Lakes system.

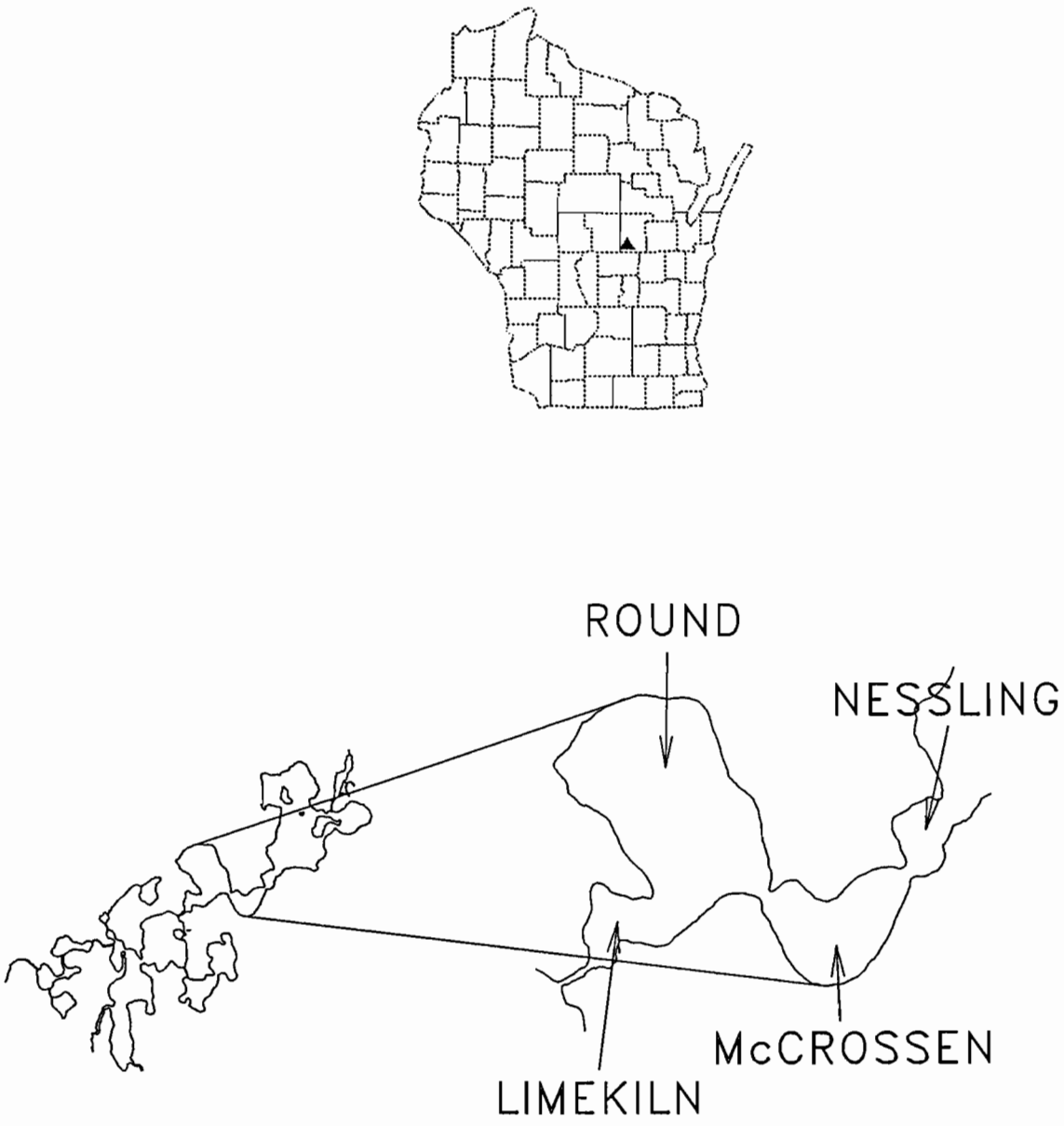



Figure 1. Location Map, Chain O' Lakes, Waupaca County, WI.

The Chain O' Lakes watershed, about 20,000 acres overall, is predominantly forested with open/agricultural areas. Native trees include maple, ash, oak, and pine. Dairy farming represents the chief agricultural activity in the Chain watershed (Pers. comm. WDNR). The only known point source discharge to the Middle Chain is a high water discharge pipe at the northwest corner of Round Lake.

Middle Chain lake area ranges from 9 acres (Nessling) to 80 acres (Round). Volume ranges from 136 (Limekiln) to 2124 acre-feet (Round) (Pers. comm. WDNR). The relatively small (maximum **fetch** 0.54 miles, Round Lake) and deep (46 - 75 feet) basins, combined with adjacent topography inhibits wind driven mixing of the Middle Chain lakes. **Stratification** develops during summer and restricts mixing to spring and fall overturns. The Middle Chain lakes have different **morphometry** and are classified as either spring or **drainage lakes**, even though each lake has a permanent inlet and outlet (Table 2).

The Chain supports warm and cold water 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 also stocked in the Chain from 1979 to 1986. No stocking presently occurs in the Chain (Pers. comm. WDNR). A

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

| Lake Name | NESSLING | McCROSSEN | ROUND | LIMEKILN |
|---|---|---|---|---|
| Location | | | | |
| Township | 22N | 22N | 22N | 22N |
| Range | 11E | 11E | 11E | 11E |
| Section(s) | 34 | 34 | 33,34 | 34 |
| Lake Type | Drainage | Spring | Spring | Drainage |
| Area (acres) | 9 | 30 | 80 | 14 |
| Max. Depth (ft) | 55 | 75 | 67 | 46 |
| Ave. Depth (ft) | 22 | 33 | 30 | 10 |
| Volume (acre-feet) | 200 | 986 | 2124 | 136 |
| Shoreline (miles) | 0.46 | 0.90 | 1.40 | 0.70 |
| Fetch (miles) | 0.16 | 0.33 | 0.54 | 0.21 |
| Fetch Orientation | SW-NE | W-E | NW-SE | SW-NE |
| Width (miles) | 0.15 | 0.19 | 0.35 | 0.19 |
| Lake Shore Soils | | | | |
| Major Type | Rosholt[1] | Rosholt[1] | Rosholt[1] | Rosholt[1] |
| % Slope | 12-20 | 12-20 | 12-20 | 12-20 |

[1] = Rosholt sandy loam

WDNR consumption advisory (for mercury) currently exists for largemouth bass taken from Columbia Lake. Fish from Rainbow Lake have 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 Middle Chain has a boat ramp access at Prell's Marina on the south shore of Limekiln 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, August 7 and September 4, 1991 and January 30 or February 4, and May 6, 1992 at the deepest point of each lake in the Middle Chain (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 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 laboratory included laboratory pH, total alkalinity, total Kjeldahl nitrogen, ammonia nitrogen, nitrate/nitrite nitrogen, total phosphorus and dissolved phosphorus, total solids, and

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

| | | WATER QUALITY | |
|---|---|---|---|
| Lake | Site | Latitude (North) / Longitude (West) | Depth |
| Nessling (Deepest Pt.) | 1104 | 44° 20' 03" / 89° 10' 04" | 55.0 ft. |
| McCrossen (Deepest Pt.) | 1103 | 44° 20' 12" / 89° 09' 59" | 75.0 ft. |
| Round (Deepest Pt.) | 1102 | 44° 20' 03" / 89° 09' 46" | 67.0 ft. |
| Limekiln (Deepest Pt.) | 1101 | 44° 20' 08" / 89° 09' 24" | 46.0 ft. |

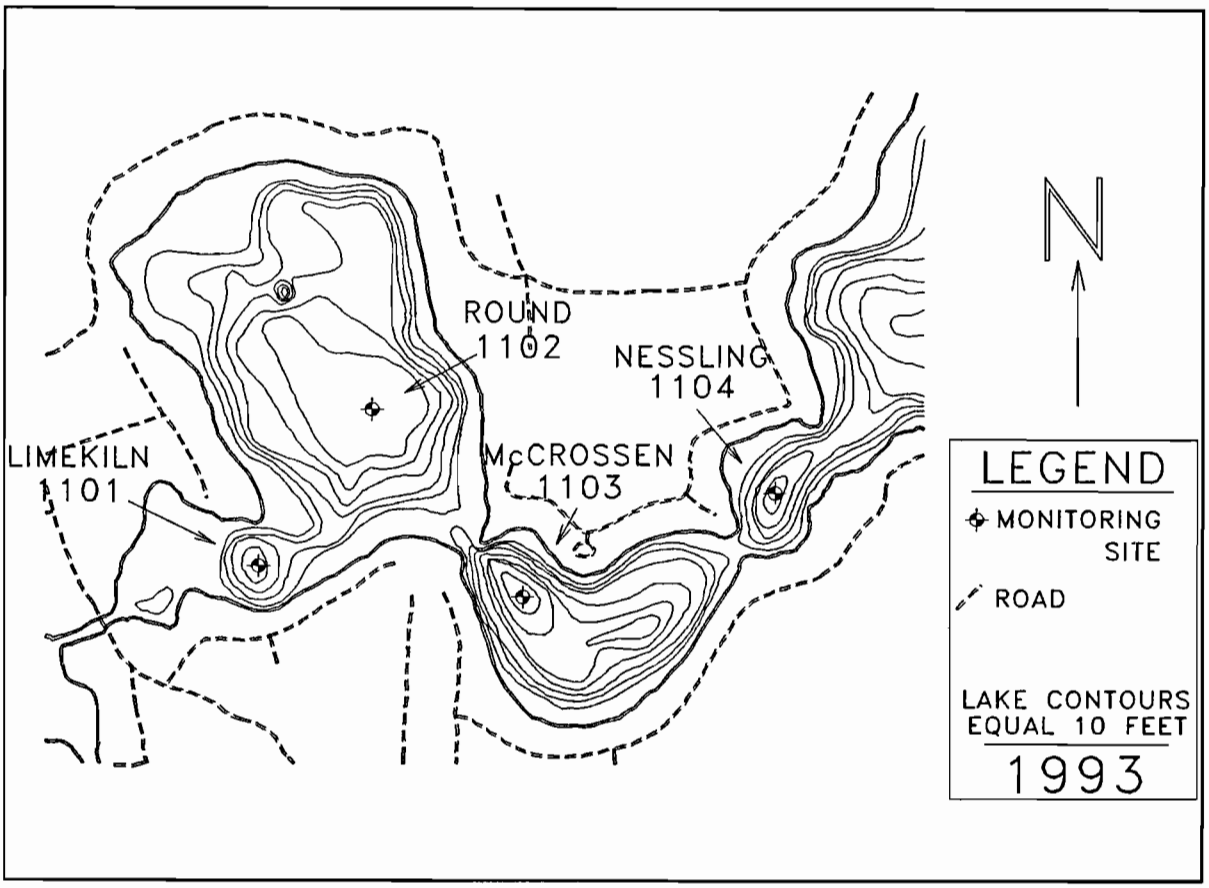



Figure 2. Sample Station Locations, Middle Chain, Chain O' Lakes, Waupaca County, WI

**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 use 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

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

Swimmer's Itch Literature Search

A literature search was conducted through the Dialog network, various environmental computerized bulletin board systems and the Universities of Wisconsin - Madison and Milwaukee library card catalogs. Information gathered and results obtained are outlined in the Field Data Discussion section of this report.

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 Middle Chain is comprised of four natural lakes. Flow for the Middle Chain is from Rainbow Lake (Upper Chain) through Nessling, McCrossen and Round to Limekiln Lake which flows to Columbia Lake (Lower Chain); the Crystal River (originating from Long Lake in the Lower Chain) serves as the outlet stream for the entire Chain O' Lakes.

The Chain O' Lakes watershed consists of wooded/wooded residential, open/agricultural, open/residential and wetland areas; the Middle Chain watershed, exclusive of that associated with the Upper Chain lakes, is about 1000 acres and predominantly open/agricultural. All lakes have bordering wooded/wooded residential areas (not shown) with substantial open/agricultural areas South and East of Nessling and McCrossen Lakes (Figure 3). Round Lake has predominantly wooded/wooded residential areas; Limekiln has relatively larger open/agricultural areas.

The direct watershed to lake ratio for the Middle Chain is about 7.4:1 which means that 7.4 times more land than lake surface area drains to the lakes. This ratio is near the average for seepage (spring) lakes (8:1) and significantly lower than the average for natural drainage lakes (lakes having a permanent inlet and outlet) in Wisconsin (88:1) (9).

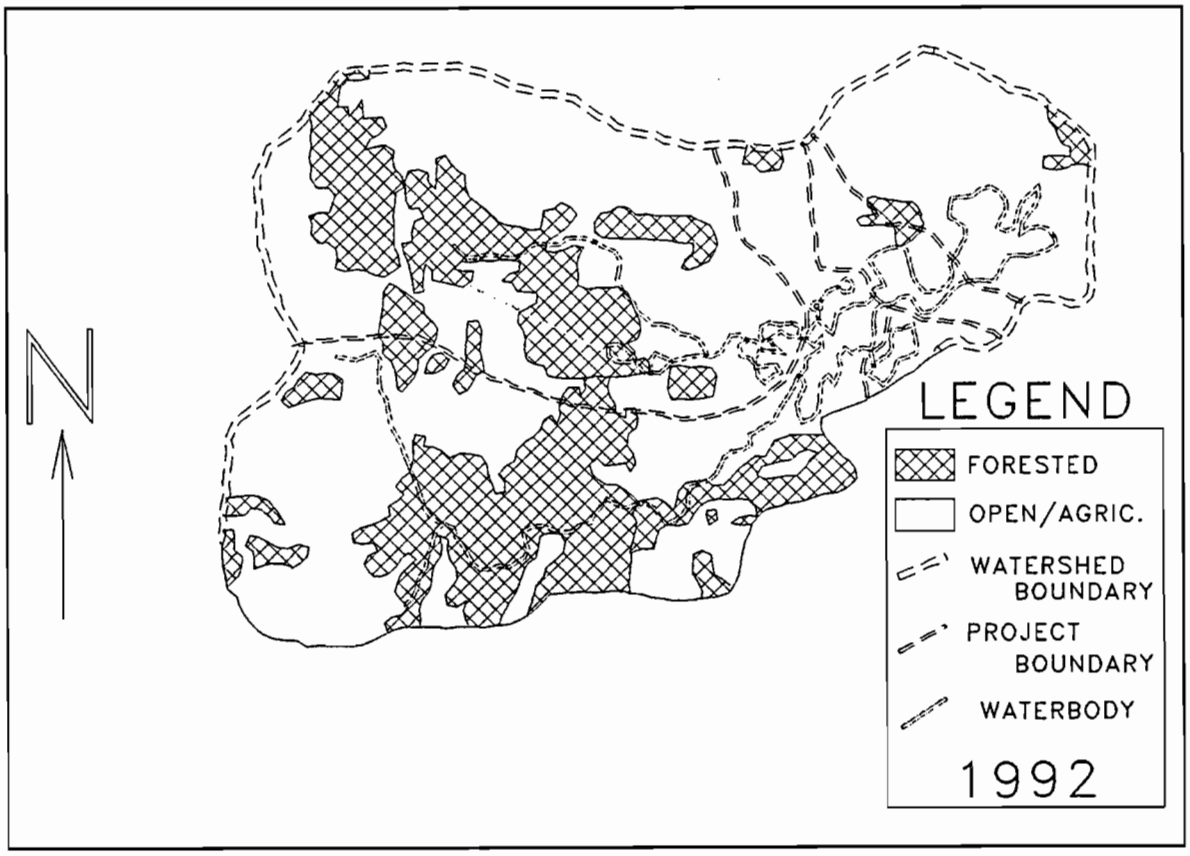



Figure 3. Land Uses in Areas Adjacent to the Middle Chain, Waupaca and Portage Counties, WI.

Monitoring in 1991 - 1992 (Tables 5 - 8), indicated similar water quality among the Middle Chain lakes. Average surface total nitrogen, which can be highly variable among lakes and is best considered on a trend or relative basis, ranged from 1.054 mg/l (milligrams per liter or parts per million) in Nessling to 1.438 mg/l in Limekiln with an average of 1.286 mg/l for all Middle Chain lakes. Surface total nitrogen levels were lowest during summer stratified conditions in all lakes.

Phosphorus is often the limiting nutrient to plant and algal production in lakes. Surface total phosphorus levels for the Middle Chain were similar (range = 0.005 in McCrossen, Round, Limekiln to 0.012 mg/l in Nessling Lake) with an average of 0.009 mg/l. Levels for the Middle Chain were lower than those typical for stratified lakes (0.023 mg/l) and central lakes (0.025 mg/l) in Wisconsin (9); levels were near or below those typical for the ecoregion in which the Chain is located (0.010 - 0.014 mg/l) (10) (Figure 4).

Substantially higher values for total phosphorous and other nutrient parameters were observed near bottom during all seasons. These data suggested nutrient release from sediments under **anoxic** or near-anoxic conditions which occurred in the **hypolimnion** during summer stratification and during winter at these relatively deep points. Near bottom phosphorus in McCrossen Lake

Table 5. Water Quality Parameters, Station 1104, Nessling Lake, Waupaca County, WI.

| PARAMETER | SAMPLE[1] | 05/30/91 | 08/07/91 | 09/04/91 | 01/30/92 | 05/06/92 |
|---|---|---|---|---|---|---|
| Secchi (feet) | | 8.0 | 8.0 | 8.0 | NR[2] | 7.0 |
| Cloud Cover (%) | | 70 | 100 | 0 | 100 | 0 |
| Temperature (°C) | S | 22.83 | 21.82 | 22.74 | 2.67 | 11.63 |
| | B | 6.02 | 7.35 | 8.20 | 3.53 | 5.39 |
| pH (S.U.) | S | 8.49 | 8.60 | 8.60 | 7.55 | 8.29 |
| | B | 7.68 | 7.00 | 7.38 | 7.09 | 7.43 |
| D.O. (mg/l) | S | 9.32 | 9.07 | 8.80 | 9.60 | 11.77 |
| | B | 2.52 | 0.13 | 0.30 | 0.41 | 5.50 |
| Conductivity (µmhos/cm) | S | 313 | 306 | 290 | 334 | 316 |
| | B | 349 | 371 | 352 | 352 | 324 |
| Laboratory pH (S.U.) | S | 8.5 | NR | NR | NR | NR |
| | B | 7.7 | NR | NR | NR | NR |
| Total Alkalinity (mg/l) | S | 152 | NR | NR | NR | NR |
| | B | 170 | NR | NR | NR | NR |
| Total Solids (mg/l) | S | 234 | NR | NR | NR | NR |
| | B | 250 | NR | NR | NR | NR |
| Total Kjeldahl N (mg/l) | S | 0.6 | 0.5 | 0.6 | 1.0 | 0.6 |
| | B | 1.0 | 1.5 | 0.6 | 1.6 | 1.0 |
| Ammonia Nitrogen (mg/l) | S | 0.047 | 0.022 | 0.019 | 0.518 | 0.118 |
| | B | 0.430 | 0.877 | 0.089 | 0.933 | 0.379 |
| $NO_2$ + $NO_3$ Nitrogen(mg/l) | S | 0.492 | 0.258 | 0.212 | 0.318 | 0.690 |
| | B | 0.448 | ND[3] | 0.195 | 0.068 | 0.547 |
| Total Nitrogen (mg/l) | S | 1.092 | 0.758 | 0.812 | 1.318 | 1.29 |
| | B | 1.448 | <1.500 | 0.789 | 1.668 | 1.547 |
| Total Phosphorus (mg/l) | S | 0.009 | 0.010 | 0.007 | 0.010 | 0.012 |
| | B | 0.028 | 0.025 | 0.008 | 0.032 | 0.021 |
| Diss. Phosphorus (mg/l) | S | ND | ND | ND | 0.003 | ND |
| | B | 0.002 | 0.002 | 0.002 | 0.002 | ND |
| N/P Ratio | S | 121.3 | 75.8 | 116.0 | 131.8 | 107.5 |
| | B | 51.7 | <60.3 | 98.6 | 52.1 | 73.7 |
| Chlorophyll *a* (µg/l) | S | 4 | 6 | 4 | NR | 10 |

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

Table 6. Water Quality Parameters, Station 1103, McCrossen Lake, Waupaca County, WI.

| PARAMETER | SAMPLE[1] | 05/30/91 | 08/07/91 | 09/04/91 | 02/04/92 | 05/06/92 |
|---|---|---|---|---|---|---|
| Secchi (feet) | | 8.0 | 9.0 | 8.0 | NR[2] | 8.0 |
| Cloud Cover (%) | | 100 | 100 | 0 | 30 | 0 |
| Temperature (°C) | S | 22.89 | 22.17 | 22.85 | 3.43 | 11.66 |
| | B | 4.45 | 4.69 | 5.40 | 4.39 | 4.50 |
| pH (S.U.) | S | 8.48 | 8.59 | 8.57 | 12.15 | 8.32 |
| | B | 7.32 | 6.46 | 7.06 | 7.99 | 7.00 |
| D.O. (mg/l) | S | 9.58 | 9.19 | 8.95 | 9.01 | 12.02 |
| | B | 0.99 | 0.10 | 0.36 | 0.05 | 0.38 |
| Conductivity (μmhos/cm) | S | 315 | 311 | 292 | 336 | 315 |
| | B | 393 | 433 | 410 | 461 | 370 |
| Laboratory pH (S.U.) | S | 8.5 | NR | NR | NR | NR |
| | B | 7.5 | NR | NR | NR | NR |
| Total Alkalinity (mg/l) | S | 150 | NR | NR | NR | NR |
| | B | 198 | NR | NR | NR | NR |
| Total Solids (mg/l) | S | 226 | NR | NR | NR | NR |
| | B | 280 | NR | NR | NR | NR |
| Total Kjeldahl N (mg/l) | S | 0.6 | 0.5 | 0.6 | 1.0 | 0.7 |
| | B | 3.7 | 5.5 | 5.6 | 10.0 | 3.5 |
| Ammonia Nitrogen (mg/l) | S | 0.059 | 0.038 | 0.021 | 0.492 | 0.139 |
| | B | 2.62 | 4.26 | 4.01 | 7.82 | 2.76 |
| $NO_3$ + $NO_2$ Nitrogen(mg/l) | S | 0.623 | 0.425 | 0.326 | 0.406 | 1.03 |
| | B | <0.015 | ND[3] | ND | 0.030 | ND |
| Total Nitrogen (mg/l) | S | 1.223 | 0.925 | 0.926 | 1.406 | 1.73 |
| | B | <3.715 | <5.500 | <5.600 | 10.03 | <3.500 |
| Total Phosphorus (mg/l) | S | 0.011 | 0.009 | 0.005 | 0.011 | 0.010 |
| | B | 0.110 | 0.132 | 0.107 | 0.67 | 0.150 |
| Diss. Phosphorus (mg/l) | S | ND | 0.002 | ND | 0.002 | ND |
| | B | 0.026 | 0.084 | 0.042 | 0.47 | 0.069 |
| N/P Ratio | S | 111.2 | 102.8 | 185.2 | 127.8 | 173.0 |
| | B | <33.8 | <41.7 | <52.4 | 15.0 | <23.4 |
| Chlorophyll *a* (μg/l) | S | 5 | 4 | 4 | NR | 8 |

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

Table 7. Water Quality Parameters, Station 1102, Round Lake, Waupaca County, WI.

| PARAMETER | SAMPLE[1] | 05/30/91 | 08/07/91 | 09/04/91 | 02/04/92 | 05/06/92 |
|---|---|---|---|---|---|---|
| Secchi (feet) | | 8.0 | 9.0 | 9.0 | NR[2] | 9.0 |
| Cloud Cover (%) | | 100 | 100 | 0 | NR | 0 |
| Temperature (°C) | S | 23.14 | 22.07 | 22.71 | 3.50 | 11.29 |
| | B | 5.26 | 5.66 | 6.21 | 4.11 | 5.16 |
| pH (S.U.) | S | 8.44 | 8.46 | 8.49 | 8.46 | 8.29 |
| | B | 7.56 | 6.64 | 7.01 | 7.50 | 7.23 |
| D.O. (mg/l) | S | 9.19 | 8.95 | 8.98 | 10.98 | 11.88 |
| | B | 0.87 | 0.10 | 0.29 | 0.17 | 0.37 |
| Conductivity (µmhos/cm) | S | 317 | 320 | 301 | 341 | 318 |
| | B | 383 | 412 | 411 | 369 | 348 |
| Laboratory pH (S.U.) | S | 8.5 | NR | NR | NR | NR |
| | B | 7.7 | NR | NR | NR | NR |
| Total Alkalinity (mg/l) | S | 151 | NR | NR | NR | NR |
| | B | 179 | NR | NR | NR | NR |
| Total Solids (mg/l) | S | 236 | NR | NR | NR | NR |
| | B | 282 | NR | NR | NR | NR |
| Total Kjeldahl N (mg/l) | S | 0.6 | 0.5 | 0.4 | 0.9 | 0.7 |
| | B | 1.3 | 3.5 | 4.5 | 1.4 | 1.3 |
| Ammonia Nitrogen (mg/l) | S | 0.054 | 0.038 | 0.019 | 0.481 | 0.157 |
| | B | 0.636 | 2.77 | 3.01 | 0.944 | 0.615 |
| $NO_2$ + $NO_3$ Nitrogen(mg/l) | S | 0.875 | 0.594 | 0.516 | 0.705 | 1.25 |
| | B | 1.38 | 0.018 | ND[3] | 1.90 | 1.70 |
| Total Nitrogen (mg/l) | S | 1.475 | 1.094 | 0.916 | 1.605 | 1.95 |
| | B | 2.68 | 3.518 | <4.500 | 3.3 | 3.0 |
| Total Phosphorus (mg/l) | S | 0.010 | 0.007 | 0.005 | 0.009 | 0.009 |
| | B | 0.020 | 0.060 | 0.049 | 0.048 | 0.035 |
| Diss. Phosphorus (mg/l) | S | ND | 0.002 | 0.006 | 0.003 | ND |
| | B | ND | 0.003 | 0.003 | 0.009 | ND |
| N/P Ratio | S | 147.5 | 156.3 | 183.2 | 178.3 | 216.7 |
| | B | 134.0 | 58.6 | <92.0 | 68.8 | 85.7 |
| Chlorophyll a (µg/l) | S | 4 | 4 | 4 | NR | 8 |

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

Table 8. Water Quality Parameters, Station 1101, Limekiln Lake, Waupaca County, WI.

| PARAMETER | SAMPLE[1] | 05/30/91 | 08/07/91 | 09/04/91 | 02/04/92 | 05/06/92 |
|---|---|---|---|---|---|---|
| Secchi (feet) | | 7.0 | 9.0 | 8.0 | NR[2] | 9.0 |
| Cloud Cover (%) | | 70 | 100 | 0 | 10 | 0 |
| Temperature (°C) | S | 22.98 | 21.96 | 22.39 | 3.62 | 11.51 |
| | B | 5.45 | 6.51 | 7.29 | 3.86 | 5.04 |
| pH (S.U.) | S | 8.27 | 8.49 | 8.42 | 8.16 | 8.78 |
| | B | 7.41 | 6.74 | 6.83 | 7.40 | 7.40 |
| D.O. (mg/l) | S | 8.96 | 8.59 | 8.40 | 11.33 | 11.79 |
| | B | 1.05 | 0.14 | 0.13 | 0.75 | 0.32 |
| Conductivity (µmhos/cm) | S | 316 | 317 | 302 | 340 | 317 |
| | B | 405 | 446 | 440 | 370 | 359 |
| Laboratory pH (S.U.) | S | 8.4 | NR | NR | NR | NR |
| | B | 7.6 | NR | NR | NR | NR |
| Total Alkalinity (mg/l) | S | 151 | NR | NR | NR | NR |
| | B | 205 | NR | NR | NR | NR |
| Total Solids (mg/l) | S | 244 | NR | NR | NR | NR |
| | B | 302 | NR | NR | NR | NR |
| Total Kjeldahl N (mg/l) | S | 0.6 | 0.5 | 0.5 | 0.8 | 0.700 |
| | B | 3.2 | 4.6 | 5.4 | 1.6 | 2.7 |
| Ammonia Nitrogen (mg/l) | S | 0.073 | 0.049 | 0.035 | 0.464 | 0.156 |
| | B | 2.16 | 3.55 | 3.74 | 0.962 | 1.63 |
| $NO_2$ + $NO_3$ Nitrogen(mg/l) | S | 0.848 | 0.522 | 0.478 | 1.04 | 1.2 |
| | B | <0.015 | ND[3] | ND | 0.530 | ND |
| Total Nitrogen (mg/l) | S | 1.448 | 1.022 | 0.978 | 1.84 | 1.9 |
| | B | <3.215 | <4.600 | <5.400 | 2.13 | <2.700 |
| Total Phosphorus (mg/l) | S | 0.009 | 0.008 | 0.005 | 0.011 | 0.010 |
| | B | 0.071 | 0.084 | 0.075 | 0.048 | 0.085 |
| Diss. Phosphorus (mg/l) | S | ND | 0.003 | 0.003 | 0.002 | ND |
| | B | ND | 0.003 | 0.003 | 0.003 | ND |
| N/P Ratio | S | 160.9 | 127.8 | 195.6 | 167.3 | 190.0 |
| | B | <45.3 | <54.8 | <72.1 | 44.4 | <31.8 |
| Chlorophyll *a* (µg/l) | S | 4 | 4 | 4 | NR | 7.0 |

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

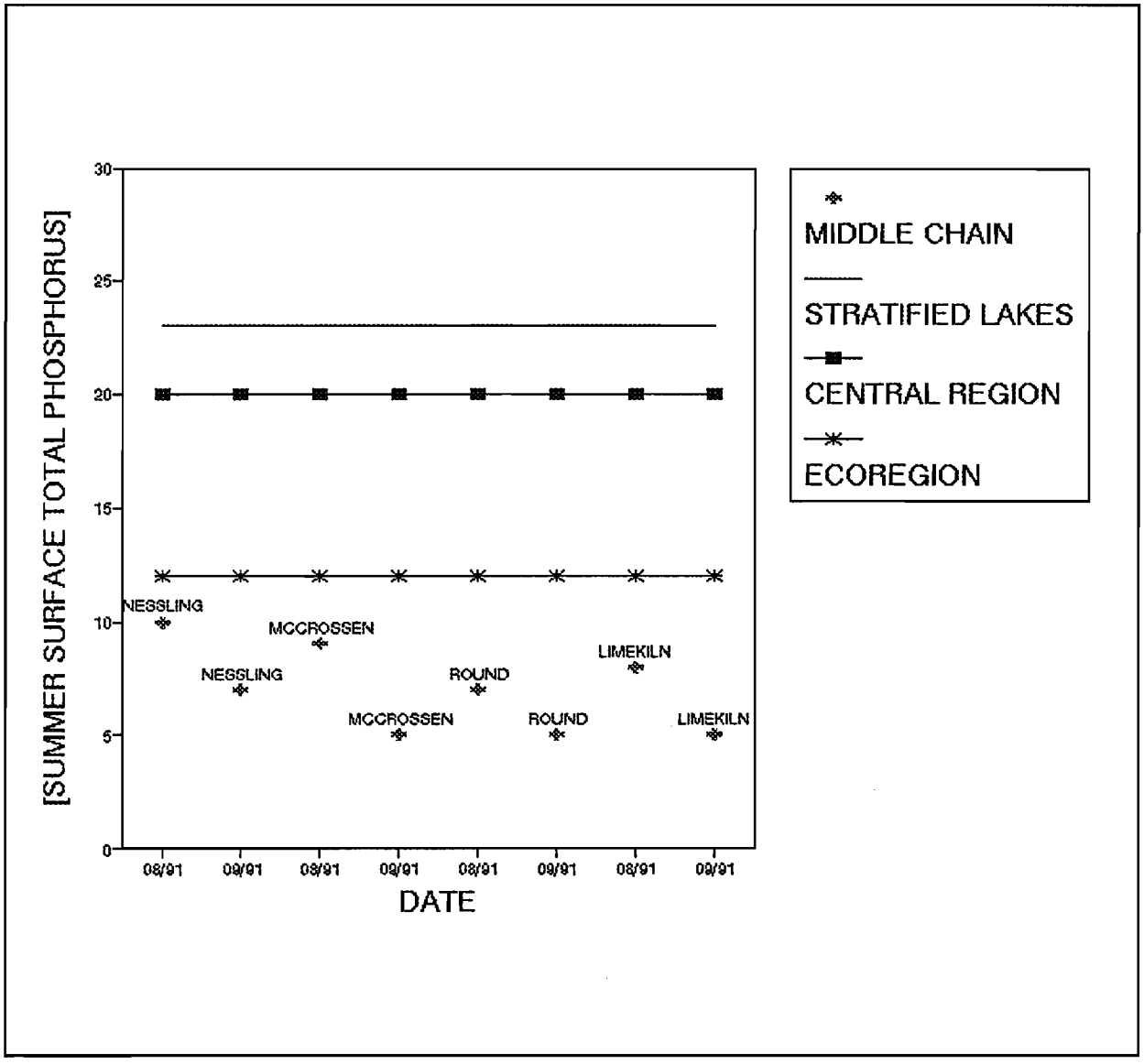
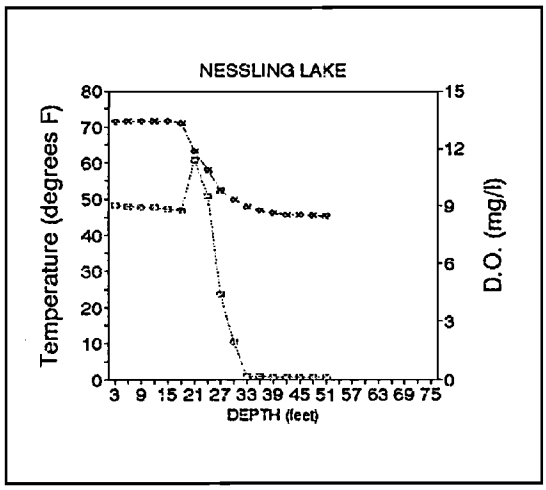


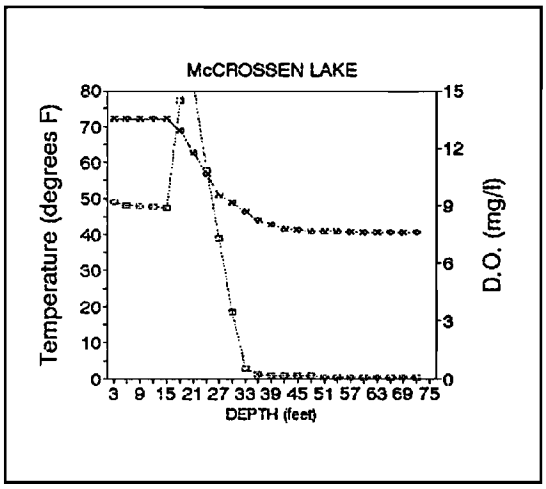

Figure 4. Comparison of Total Phosphorus Levels, Middle Chain, Chain O' Lakes, 1991.

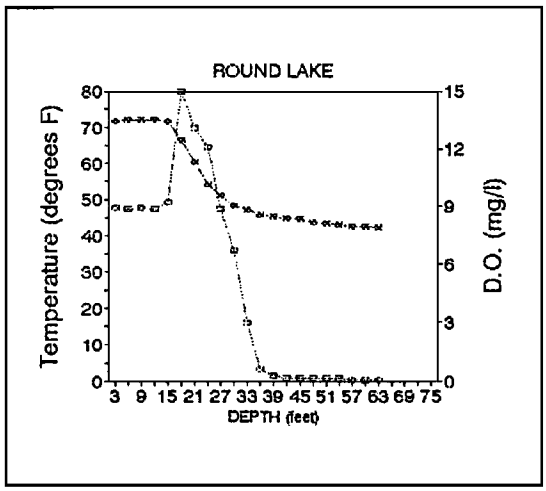
(deepest of the Middle Chain lakes) was somewhat higher than elsewhere in the Middle Chain. Nitrogen to phosphorus ratios (**N/P ratio**) for surface samples were greater than 15 and indicated all Middle Chain lakes to be phosphorus limited during the 1991 - 1992 monitoring period.

All Middle Chain lakes were thermally stratified during summer (Figure 5, Appendix II). Depth to the thermocline varied from 18 ft (McCrossen Lake) to 21 ft (all other Middle Chain lakes). Hypolimnetic dissolved oxygen levels fell below those generally considered necessary to sustain most aquatic life. Winter water column readings indicated typical thermally 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 levels nor in Secchi transparency reduction unrelated to algal growth (e.g. that associated with color). TSI numbers for recent Middle Chain data generally indicated oligotrophic (total



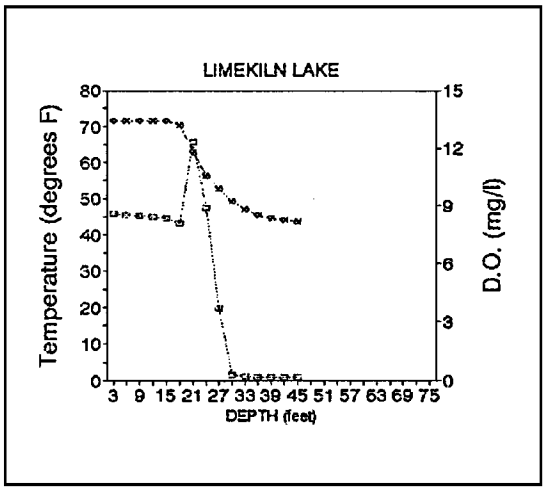




Figure 5. Temperature/DO Profiles, Middle Chain, Chain O' Lakes, Summer, 1991.

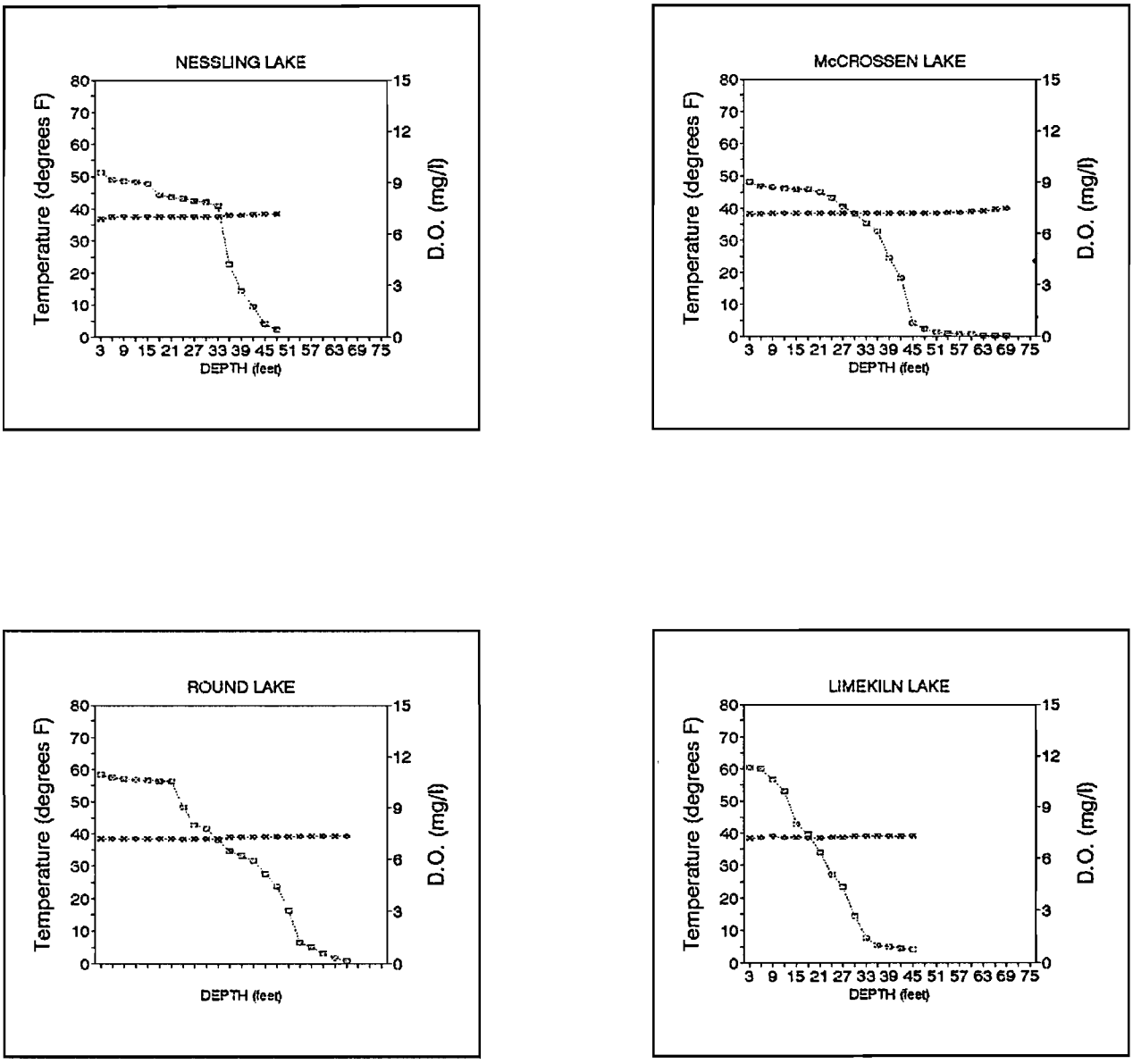


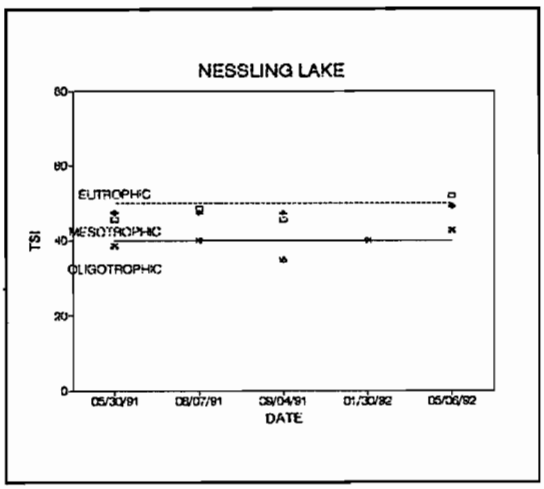

Figure 6. Temperature/DO Profiles, Middle Chain, Chain O' Lakes, Winter, 1992.

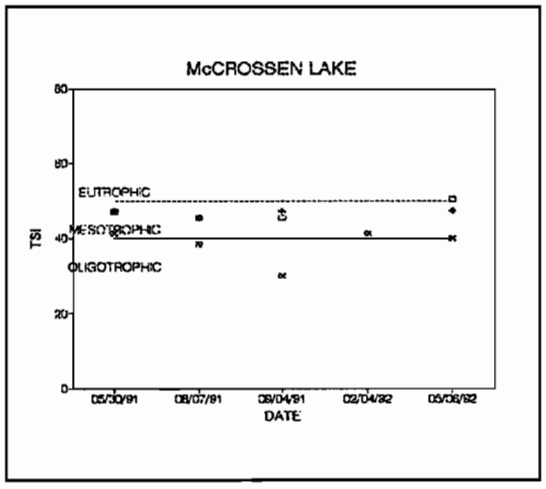
phosphorus) to mesotrophic (chlorophyll and transparency) conditions (Figure 7). No readily discernable trends were evident for the very limited amount of historic data available (Appendix III).

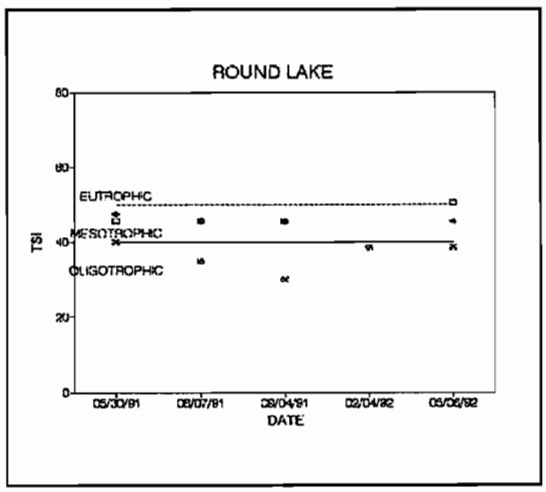
Swimmer's itch (schistosome dermatitis) has been a problem in the Chain O' Lakes (primarily the Middle Chain). It is caused by penetration of the skin by an intermediate life cycle stage of the flatworm known as cercaria larvae. The cercaria die shortly after penetration (in humans) but swelling and redness can persist for several days (usually less than one week) and can increase (especially when scratched).

Adult flatworms are carried by birds and rodents in blood vessels where the female flatworms lay eggs which travel to the intestine and are expelled in feces. The eggs hatch into miracidia larvae that are taken up in snails where they develop into cercaria; cercaria then penetrate rodents and birds to complete the cycle.

Attempts to control swimmer's itch have largely been through snail or cercaria control. Biological and chemical controls have met only with limited success and introduction of exotic snail species (resistant to larvae) can lead to displacement of native populations and change animal and plant assemblages. Chemical controls (usually copper sulfate or copper carbonate) are often



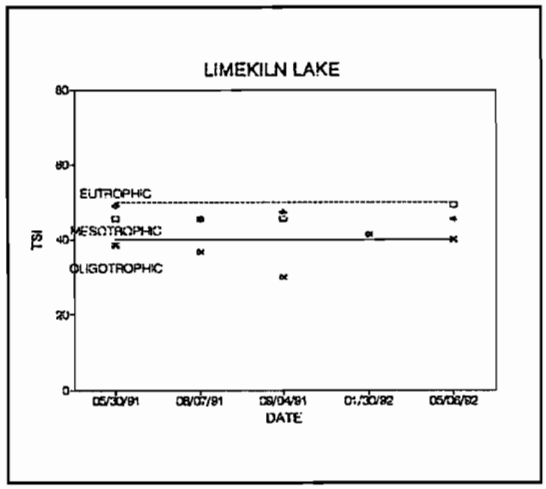




Figure 7. Trophic State Index for Secchi Depth, Total Phosphorus and Chlorophyll a, Middle Chain, Chain O' Lakes.

undesirable because they cannot ensure eradication of cercaria and snails and can cause native mollusk and vegetation die-off, reduced DO levels and fishkills (12). Infestation of snails is most common during dry and hot summer months (13) and the swimmer's itch problem can persist longer than a month.

The most practical suggestions to prevent swimmer's itch are designed to minimize contact with cercaria (14). These include avoid swimming when an onshore wind is present and swim away from shore [cercaria move in the top 1 mm of water and often near shores (15)], towel down or shower immediately after swimming to prevent penetration of the cercaria, discourage birds from staying near swimming areas, and avoid swimming in areas with large accumulations of snails.

## BASELINE CONCLUSIONS

The Middle Chain is a group of four interconnected lakes which accounts for about 18 percent of the total surface area of the Chain O' Lakes. Though McCrossen and Round Lakes are listed as spring lakes, inflow from the Upper Chain is probably the predominant source of water for the Middle Chain.

Overall, water quality is good to excellent for all parameters measured and generally indicated oligotrophic to mesotrophic classification. Water quality was similar among Middle Chain lakes and also similar to that observed in similar lake types throughout the Chain. Nutrient levels were generally low and typical of lake type and regional location. Except for somewhat higher phosphorus near bottom in McCrossen Lake, no spatial or temporal trends were evident from the relatively limited amount of historical data available. Excellent water quality is attributable to low overland inflow to the system, a relatively small, forested watershed, substantial flushing from groundwater inflow and nutrient tie up in marl precipitation.

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

## MANAGEMENT RECOMMENDATIONS

Management recommendations for the Middle Chain are targeted at maintenance of good to excellent water quality by 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.

Relatively little is known about historic water quality on the Middle Chain. Water quality should be continued and should include event testing of areas of concern. Regular monitoring should be conducted on a similar schedule; event testing should be conducted after major rain or snowmelt runoff events. Self-Help Secchi readings should also be taken on a regular basis in each lake of the Middle Chain by volunteers.

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 Plans**

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

**Planning Advisory Committee**

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

**Brochures**

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

**Meetings**

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

**Print Media**

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

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

### NESSLING LAKE

| 08/07/91 | | | 01/30/92 | | |
|---|---|---|---|---|---|
| Depth (ft) (mg/l) | Temp. °C | DO (mg/l) | Depth (ft) | Temp. °C | DO |
| 3 | 21.82 | 9.07 | 3 | 2.67 | 9.60 |
| 6 | 21.89 | 8.98 | 6 | 3.01 | 9.18 |
| 9 | 21.95 | 8.92 | 9 | 3.05 | 9.10 |
| 12 | 22.00 | 8.94 | 12 | 3.06 | 9.04 |
| 15 | 21.97 | 8.85 | 15 | 3.07 | 8.91 |
| 18 | 21.65 | 8.79 | 18 | 3.08 | 8.29 |
| 21 | **17.25** | **11.40** | 21 | 3.09 | 8.17 |
| 24 | **14.44** | **9.50** | 24 | 3.09 | 8.11 |
| 27 | **11.33** | **4.45** | 27 | 3.09 | 7.98 |
| **30** | **9.98** | **1.94** | 30 | 3.10 | 7.86 |
| **33** | **8.79** | **0.16** | 33 | 3.12 | 7.65 |
| 36 | 8.22 | 0.17 | 36 | 3.29 | 4.26 |
| 39 | 7.80 | 0.13 | 39 | 3.38 | 2.69 |
| 42 | 7.63 | 0.13 | 42 | 3.42 | 1.78 |
| 45 | 7.49 | 0.13 | 45 | 3.50 | 0.77 |
| 48 | 7.41 | 0.13 | 48 | 3.53 | 0.41 |
| 51 | 7.35 | 0.13 | | | |

### McCROSSEN LAKE

| 08/07/91 | | | 02/04/92 | | |
|---|---|---|---|---|---|
| Depth (ft) (mg/l) | Temp. °C | DO (mg/l) | Depth (ft) | Temp. °C | DO |
| 3 | 22.17 | 9.19 | 3 | 3.43 | 9.01 |
| 6 | 22.19 | 9.00 | 6 | 3.48 | 8.78 |
| 9 | 22.23 | 8.97 | 9 | 3.50 | 8.72 |
| 12 | 22.26 | 8.92 | 12 | 3.50 | 8.66 |
| 15 | 22.23 | 8.89 | 15 | 3.50 | 8.60 |
| **18** | **20.40** | **14.47** | 18 | 3.50 | 8.60 |
| **21** | **17.06** | **15.55** | 21 | 3.50 | 8.42 |
| **24** | **13.65** | **10.82** | 24 | 3.50 | **8.12** |
| **27** | **10.51** | **7.28** | 27 | 3.50 | 7.59 |
| **30** | **9.26** | **3.45** | 30 | 3.50 | 7.17 |
| **33** | **7.92** | **0.53** | 33 | 3.51 | 6.63 |
| **36** | **6.56** | **0.23** | 36 | 3.53 | 6.15 |
| 39 | 5.95 | 0.14 | 39 | 3.57 | 4.60 |
| 42 | 5.34 | 0.15 | 42 | 3.56 | 3.42 |
| 45 | 5.08 | 0.15 | 45 | 3.62 | 0.76 |
| 48 | 4.90 | 0.15 | 48 | 3.64 | 0.41 |
| 51 | 4.86 | 0.10 | 51 | 3.64 | 0.23 |
| 54 | 4.85 | 0.10 | 54 | 3.65 | 0.17 |
| 57 | 4.79 | 0.10 | 57 | 3.72 | 0.11 |
| 60 | 4.75 | 0.10 | 60 | 3.78 | 0.11 |
| 63 | 4.72 | 0.10 | 63 | 3.95 | 0.05 |
| 66 | NR[1] | NR | 66 | 4.13 | 0.05 |
| 69 | 4.70 | 0.10 | 69 | 4.39 | 0.05 |
| 72 | 4.71 | 0.10 | | | |
| 75 | 4.69 | 0.10 | | | |

NR[1] = NO READING

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

## ROUND LAKE

| 08/07/91 | | | 02/04/92 | | |
|---|---|---|---|---|---|
| Depth (ft) | Temp. °C | DO (mg/l) | Depth (ft) | Temp. °C | DO (mg/l) |
| 3 | 22.07 | 8.95 | 3 | 3.50 | 10.98 |
| 6 | 22.16 | 8.89 | 6 | 3.51 | 10.78 |
| 9 | 22.18 | 8.91 | 9 | 3.51 | 10.73 |
| 12 | 22.17 | 8.89 | 12 | 3.50 | 10.67 |
| 15 | 22.04 | 9.21 | 15 | 3.50 | 10.61 |
| 18 | **19.07** | **15.00** | 18 | 3.50 | 10.56 |
| 21 | **15.73** | **15.06** | 21 | 3.50 | 10.56 |
| 24 | **12.29** | **12.10** | 24 | 3.48 | 9.07 |
| 27 | **10.55** | **8.90** | 27 | 3.52 | 7.99 |
| 30 | **9.06** | **6.75** | 30 | 3.56 | 7.80 |
| 33 | 8.38 | 2.97 | 33 | 3.58 | 7.13 |
| 36 | 7.68 | 0.62 | 36 | 3.74 | 6.48 |
| 39 | 7.40 | 0.27 | 39 | 3.82 | 6.21 |
| 42 | 7.15 | 0.18 | 42 | 3.91 | 5.94 |
| 45 | 6.85 | 0.18 | 45 | 3.98 | 5.17 |
| 48 | 6.48 | 0.14 | 48 | 3.98 | 4.47 |
| 51 | 6.30 | 0.14 | 51 | 4.04 | 3.08 |
| 54 | 6.07 | 0.14 | 54 | 4.07 | 1.20 |
| 57 | 5.85 | 0.10 | 57 | 4.07 | 0.97 |
| 60 | 5.74 | 0.10 | 60 | 4.07 | 0.57 |
| 63 | 5.66 | 0.10 | 63 | 4.08 | 0.34 |
| | | | 66 | 4.11 | 0.17 |

## LIMEKILN LAKE

| 08/07/91 | | | 02/04/92 | | |
|---|---|---|---|---|---|
| Depth (ft) | Temp. °C | DO (mg/l) | Depth (ft) | Temp. °C | DO (mg/l) |
| 3 | 21.96 | 8.59 | 3 | 3.62 | 11.33 |
| 6 | 21.99 | 8.50 | 6 | 3.69 | 11.24 |
| 9 | 22.00 | 8.45 | 9 | 3.75 | 10.62 |
| 12 | 21.98 | 8.42 | 12 | 3.72 | 9.93 |
| 15 | 21.88 | 8.31 | 15 | 3.65 | 8.03 |
| 18 | 21.30 | 8.08 | 18 | 3.64 | 7.40 |
| 21 | **17.20** | **12.30** | 21 | 3.63 | 6.35 |
| 24 | **13.60** | **8.90** | 24 | 3.67 | 5.10 |
| 27 | **11.50** | **3.69** | 27 | 3.69 | 4.39 |
| 30 | **9.62** | **0.27** | 30 | 3.73 | 2.68 |
| 33 | **8.34** | **0.21** | 33 | 3.79 | 1.45 |
| 36 | 7.41 | 0.18 | 36 | 3.81 | 0.98 |
| 39 | 6.95 | 0.14 | 39 | 3.83 | 0.92 |
| 42 | 6.65 | 0.14 | 42 | 3.85 | 0.86 |
| 45 | 6.51 | 0.14 | 45 | 3.86 | 0.75 |

# APPENDIX III
## HISTORIC WATER QUALITY DATA
McCrossen Lake, Waupaca County, WI
Water Chemistry: 08/17 - 09/69; Deepest Site
Source: WDNR

| PARAMETER | Sample Dates 08/10/17 | 09/07/67 | 09/07/67 | 09/16/69 |
|---|---|---|---|---|
| Depth (feet) | - | 5 | 54 | - |
| Secchi (meters) | 2.1 | NR[1] | - | 1.8 |
| pH (S.U.) | NR | 8.5 | 7.1 | NR |
| Conductivity ($\mu$mhos/cm) | NR | 270 | 385 | NR |
| Total Alkalinity (mg/l $CaCO_3$) | NR | 129 | 192 | NR |
| Calcium (mg/l $CaCO_3$) | NR | 49.2 | 69.9 | NR |
| Magnesium (mg/l Ca $CO_3$) | NR | 91.0 | 97.2 | NR |
| Hardness (mg/l $CaCO_3$) | - | 140.2 | 167.1 | - |
| Sodium (mg/l) | NR | 2.96 | 3.04 | NR |
| Sulfate (mg/l) | NR | 15.0 | 15.0 | NR |
| Potassium (mg/l) | NR | 0.88 | 1.20 | NR |
| Iron (mg/l) | NR | 0.03 | 0.03 | NR |
| Chloride (mg/l) | NR | 5.00 | 6.40 | NR |
| $NO_3$ Nitrogen(mg/l) | NR | 0.04 | 0.01 | NR |
| Total Phosphorus (mg/l) | NR | 0.05 | 0.14 | NR |
| Phosphate Phos. (mg/l) | NR | 0.05 | 0.02 | NR |

NR[1] = No Reading

# APPENDIX III
## HISTORIC WATER QUALITY DATA
Round Lake, Waupaca County, WI
Water Chemistry: 07/13 - 10/86; Deepest Site
Source: WDNR and UW-Stevens Point Environmental Task Force

| PARAMETER | Sample Dates 07/21/13 | 08/24/18 | 09/07/67 | 09/07/67 | 09/16/69 | 10/20/86 |
|---|---|---|---|---|---|---|
| Depth (feet) | - | - | 10 | 54 | - | 0 |
| Secchi (meters) | 1.9 | 2.1 | NR[1] | NR | 1.5 | NR |
| pH (S.U.) | NR | NR | 8.5 | 7.3 | NR | 8.39 |
| Conductivity ($\mu$mhos/cm) | NR | NR | 285 | 354 | NR | 318 |
| Total Alkalinity (mg/l $CaCO_3$) | NR | NR | 135 | 175 | NR | 136 |
| Calcium (mg/l $CaCO_3$) | NR | NR | 47.4 | 62.4 | NR | NR |
| Magnesium (mg/l Ca $CO_3$) | NR | NR | 88.9 | 92.6 | NR | NR |
| Hardness (mg/l $CaCO_3$) | - | - | 136.3 | 155.0 | - | - |
| Sodium (mg/l) | NR | NR | 3.44 | 2.72 | NR | NR |
| Sulfate (mg/l) | NR | NR | 21.0 | 11.3 | NR | NR |
| Potassium (mg/l) | NR | NR | 1.52 | 0.96 | NR | NR |
| Iron (mg/l) | NR | NR | 0.02 | 0.06 | NR | NR |
| Chloride (mg/l) | NR | NR | 5.35 | 5.40 | NR | 7.8 |
| Total Kjeldahl N (mg/l) | NR | NR | NR | NR | NR | 0.45 |
| $NO_3$ Nitrogen(mg/l) | NR | NR | 0.12 | 0.01 | NR | NR |
| $NO_2$ + $NO_3$ Nitrogen (mg/l) | NR | NR | NR | NR | NR | 0.43 |
| Total Nitrogen (mg/l) | - | - | - | - | - | 0.88 |
| Total Phosphorus (mg/l) 0.015 | NR | NR | 0.18 | 0.12 | NR | |
| Phosphate Phos. (mg/l) <0.002 | NR | NR | 0.01 | 0.02 | NR | |
| N/P Ratio | - | - | - | - | - | 58.7 |

NR[1] = No Reading

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).

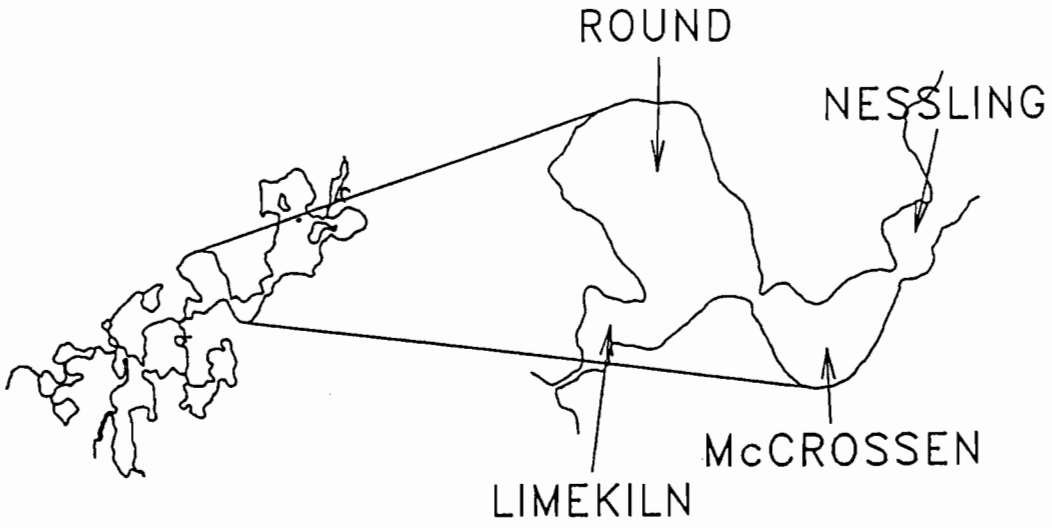


Figure 1. Location Map, Chain O' Lakes, Waupaca County, Wisconsin.

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

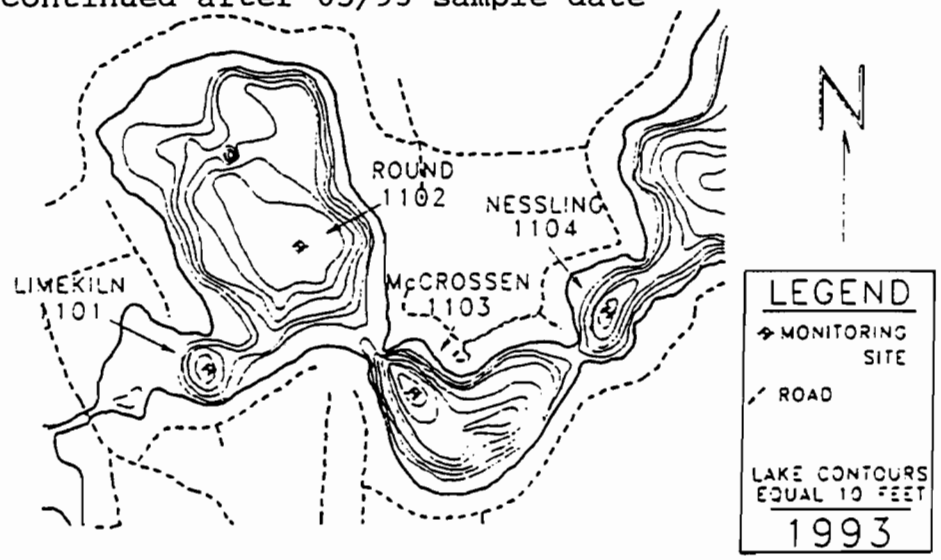


Figure 2. Sample Station Locations, Middle Chain, 1992 - 1994.

**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).

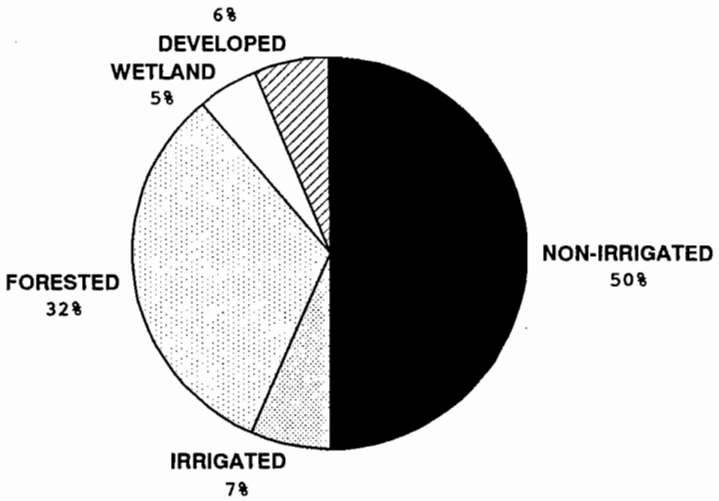


Figure 3. Land Uses in the Chain O' Lakes Subwatershed, 1994.

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 |

[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

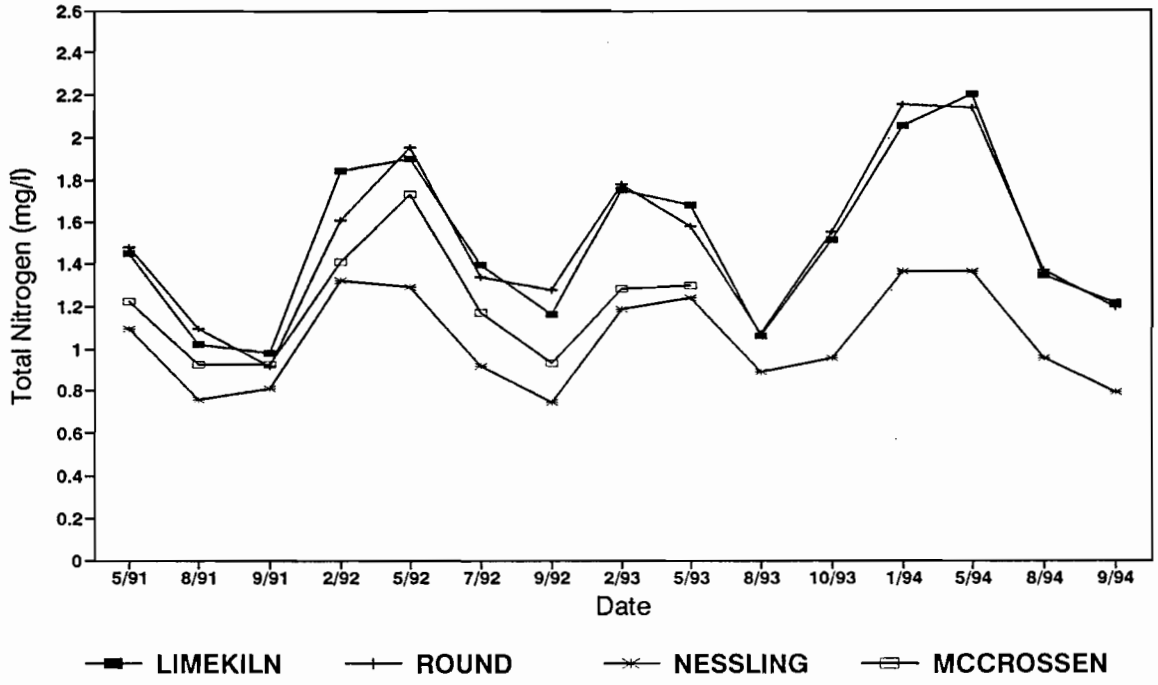


Figure 4. Surface Total Nitrogen Trends for the Middle Chain, 1991 - 1994.

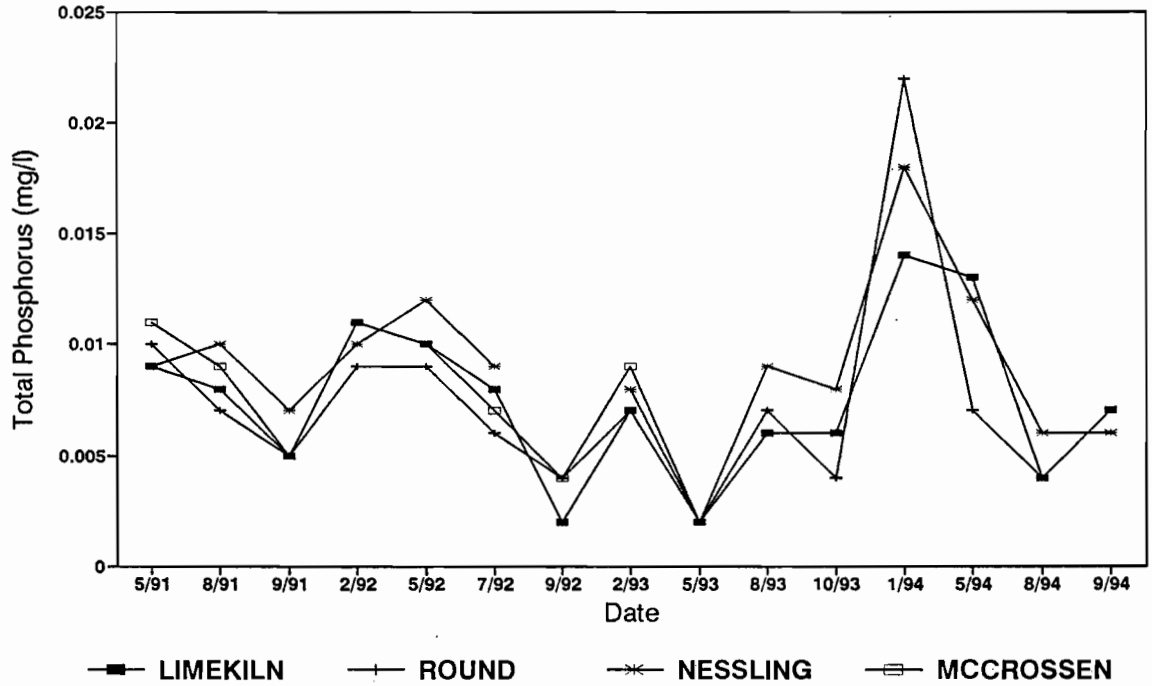


Figure 5. Surface Total Phosphorus Trends for the Middle Chain, 1991 - 1994. [ *9/92 Nessling Lake value (0.07) considered outlier].

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.

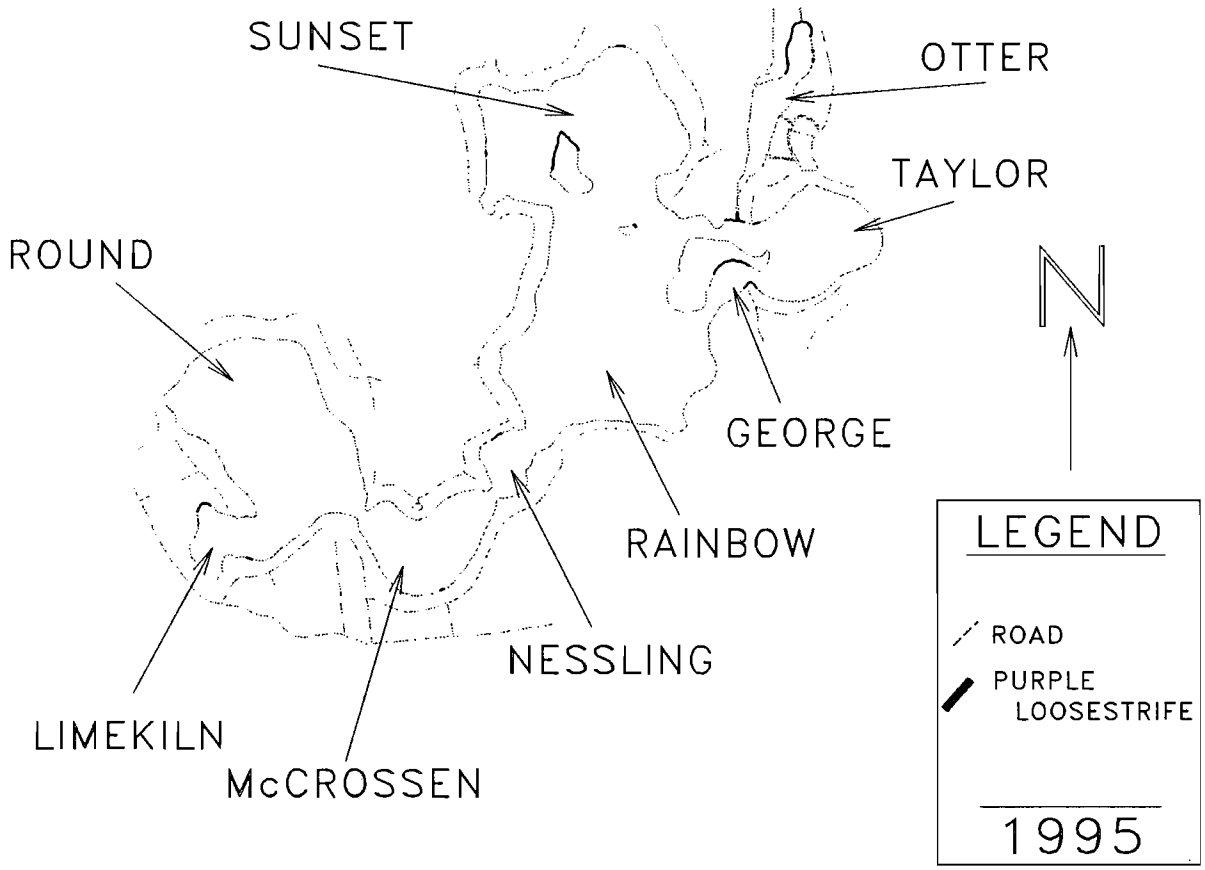


Figure 6. Purple Loosestrife Growth Areas, Upper and Middle Chain, 1994.

## 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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