IPS ENVIRONMENTAL AND ANALYTICAL SERVICES
Appleton, Wisconsin

LAKE MANAGEMENT PLAN
GRASS LAKE
SHAWANO COUNTY, WISCONSIN

REPORT TO:
CLOVERLEAF LAKES PROTECTIVE ASSOCIATION

June, 1992

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SUMMARY

Grass Lake, Shawano County, is the middle lake of a three lake "chain" known as the Cloverleaf Lakes. The primary source of lake inflow is groundwater. This, combined with a primarily wooded residential or forested watershed, results in a relatively low potential for non-point source inputs of nutrients and sediment from the watershed.

Water quality was fair to good for all parameters measured; transparency, nutrients and **chlorophyll <u>a</u>**[1] indicated a **mesotrophic** status. Grass Lake stratified during summer and exhibited high nutrient levels and near-**anoxic** conditions near bottom in deeper portions of the basin. Higher nutrient levels were observed during a rain event in the small creek inflow on the north shore. This creek receives flow perennially from a spring in a forested area a few hundred meters from the lake and intermittently from roadside and agricultural areas during substantial rain or snowmelt events.

Macrophyte growth in Grass Lake is limited, except on an extensive shallow area along the south shore, to a rather narrow **littoral** zone. Water celery and clasping-leaf pondweed (relatively desireable from the viewpoint of habitat provision), are most common. Water milfoil, which may include Eurasian Milfoil (a nuisance exotic plant) was also relatively common.

The shallow, highly productive south shore area probably provides food, cover and spawning habitat for the fishery. Sediment from this area and particularly in the channel to Pine Lake, contains significant amounts of organic matter. Protection of this area from indiscriminate power boat usage, which may destroy or fragment plants and resuspend sediment, should be considered.

Overall management objectives should emphasize protection and improvement/enhancement of this already high quality resource.

- Regular water quality monitoring should be continued to track water quality trends. Event monitoring should target creek inflows or other sources of overland drainage (parking areas, roads).
- Riparian land owner education and diligence regarding runoff control and yard waste/fertilizer management should be encouraged to minimize sediment and nutrient inputs. Nutrient input from the creek during low flow conditions should be assessed.
- Macrophyte management in near shore areas should be limited to localized manual harvest (if necessary or desired). Water milfoil species should be positively determined; Eurasian Milfoil, if present, should be selectively removed. Plant management should target nuisance species control.

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

INTRODUCTION

Grass Lake is located in the Town of Belle Plaine in south-central Shawano County, Wisconsin. Grass Lake is the middle lake of a three lake "chain" also consisting of Round (upper) and Pine (lower) Lakes. This chain of primarily groundwater fed natural lakes is collectively referred to as the Cloverleaf Lakes.

The Cloverleaf Lakes Protective Association (CLPA) was formed in 1930 to provide leadership and coordination of lake preservation and educational activities pertinent to the Cloverleaf Lakes. Overall objectives of the CLPA, and their major concerns in development of a lake management plan included weed growth, redistribution of sediment, the problem of swimmer's itch and general water quality upkeep. Currently, the CLPA has seven elected officers and about 220 members.

The CLPA, in late-1990, decided to pursue the development of a long range management plan under the Wisconsin Department of Natural Resources (WDNR) Lake Management Planning Grant Program. The CLPA officers selected IPS Environmental & Analytical Services (IPS) of Appleton, Wisconsin as its consultant to develop the plan. A grant application, incorporating required or recommended program components and the following objectives, was prepared, submitted, and approved in April, 1991:

- establishment of a monitoring study designed to track long-term trends,
- acquisition of existing historic data and analysis, along with current data, to assess the present status of the resource,
- location, identification and quantification of aquatic macrophyte concentrations,
- characterization of lake sediments in areas of concern
- determination of event related non-point source runoff from an agricultural ditch,
- development of the awareness of the lake property owners and establishment of a base of support for lake management efforts.

A Planning Advisory Committee, comprised of representatives from CLPA, IPS, WDNR and the Town of Belle Plaine was formed and met initially in May, 1991 to provide program guidance and direction.

DESCRIPTION OF AREA

Grass Lake (T26N R15E S33, 34) is a **drainage lake** located in Shawano County northeast of Clintonville, Wisconsin (Figure 1). The general topography of Shawano County is related to glacial activity. The Cloverleaf Lakes' watershed is predominantly forested with agricultural areas. Topography adjacent to the lakes is level to gently sloping. The major soil types in the Cloverleaf Lakes area are somewhat poorly drained Au Gres loamy sands on 0-3 percent slopes, excessively drained Menahga loamy sands on 2 to 6 percent slopes and moderately well drained Croswell loamy sands on 0 to 3 percent slopes (4). Soil permeability is rapid in all soils.

Grass Lake has a surface area of 87 acres, an average depth of about 14 feet, and a maximum depth of 52 feet (5). The **fetch** is 0.6 miles and lies in a southwest-northeast orientation and the width is 0.4 miles in a north-south orientation. The Grass Lake watershed to lake ratio is 10 to 1 which means that 10 times more land than lake surface area drains to the lake. Lake volume is 1,220 acre feet with a **residence time** of about one year (6).

The **immediately adjacent watershed** of Grass Lake is about 275 acres and is predominantly wooded residential or forested; that of the Cloverleaf Lakes chain, overall, is wooded residential

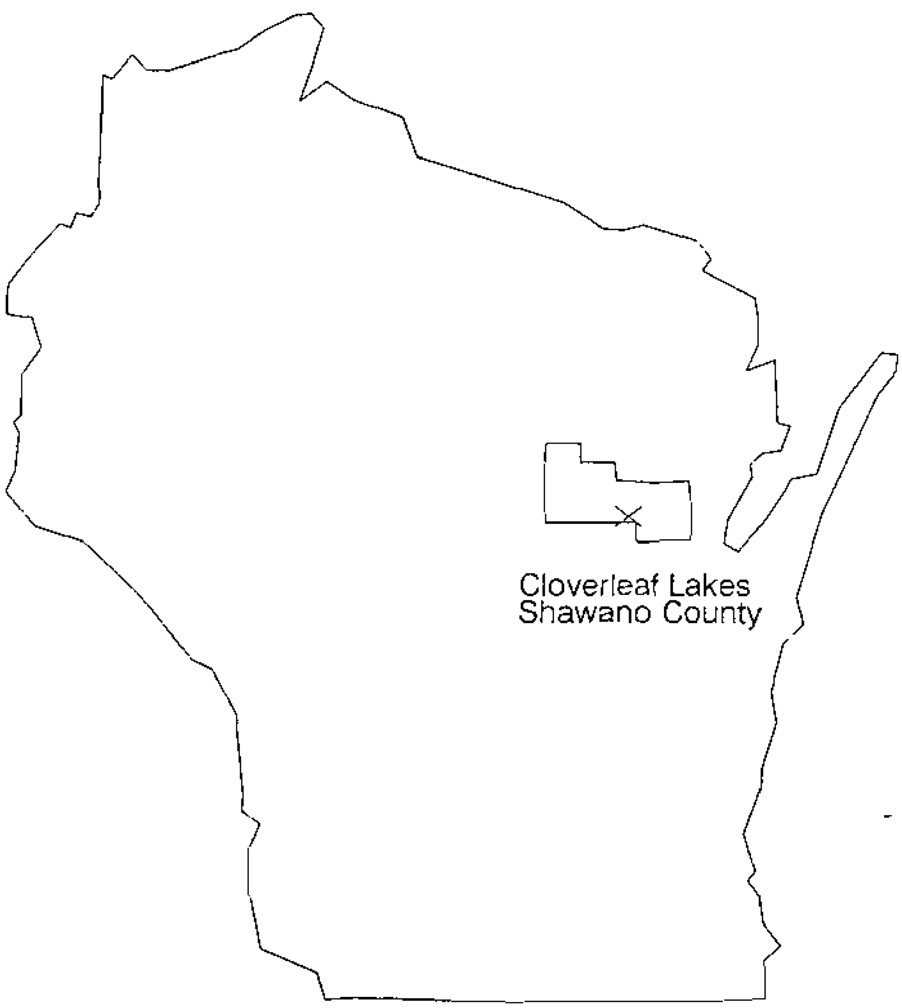

Figure 1. Location Map, Cloverleaf Lakes, Shawano County, WI.

(45%), forested (35%), wetlands (17%) and agricultural (2%) areas. Woodlands are comprised mainly of hardwood forests (maples and oaks) with areas of conifers and pine plantations.

Littoral substrates are primarily sand and muck, but reportedly include some gravel and rock (Personal Communication WDNR). Recently, concern has been expressed about aquatic macrophyte growth, swimmer's itch and sediment resuspension in the shallow southern part of Grass Lake.

Grass Lake supports fish species including largemouth bass (Micropterus salmoides), smallmouth bass (Micropterus dolomieui), rock bass (Ambloplites rupestris), walleye (Stizostedion vitreum), yellow perch (Perca flavescens), black crappie (Pomoxis nigromaculatus), sunfish (Lepomis sp.), northern pike (Esox lucius), muskellunge (Esox masquinongy), black bullhead (Ictalurus melas), longnose gar (Lepisosteus osseus), bowfin (Amia calva), burbot (Lota lota), carp (Cyprinus carpio), white sucker (Catostomus commersoni), buffalo (Ictiobus sp.) and golden shiner (Notemigonus crysoleucas) (6).

One or more species of fish have been sampled containing mercury and currently there is a consumption advisory for fish taken from the chain (7). Fish have been stocked in Grass, Round and Pine Lakes by the WDNR or the CLPA (Pers. Comm. CLPA, Table 1).

Table 1. Stocking Effort, Cloverleaf Lakes.

YEAR	SPECIES (NUMBER:SIZE)					
	WALLEYE	MUSKELLUNGE	LARGEMOUTH BASS	NORTHERN PIKE	YELLOW PERCH	SUNFISH
1939						3,800:Ad./fing.
1940	500,000:fry					
1941	500,000:fry					
1943			300:fingerlings			
1956				2,010:Adult		
1961	16,200					
1962		160:yearlings				
1963		50:yearlings				
1964		1,600:fingerlings				
1965		1,280:fingerlings				
1966		200:fingerlings				
1970		400:fingerlings				
1973		1,300:fingerlings				
1974		1,300:fingerlings				
1976		625:12"				
1977		630:8"				
1978		630:9"				
1979		630:8"				
1980		630:8"				
1982	10,000:fry	315:10"				
1983	17,085:1-5"	455:10"				
1984	1,500					
1985	15,100:2-3"	840:12"				
1986	1,297:2-3"					
1987	11,050:5"	640:10"				
1988	400:4"		1,364:4-5"			
1989	4,500:5"	640:8"		828:9-24"	198:4-6"	
1991	15,000:fingerlings	640:7-9"				

Waterfowl observed nesting in the Cloverleaf lakes include mallards, black ducks and blue-winged teal. Migratory waterfowl that use the Cloverleaf Lakes include other puddle and diving ducks, coots and Canada geese (6).

CLPA has previously tried copper sulfate slow release pellets to control nuisance macrophytes and swimmer's itch in areas along the north (1200 feet long) and south (800 feet long) shores (Pers. Comm. WDNR). These treatments were discontinued so as not to affect monitoring results and because of stricter regulation.

One point of public access is located where County Highway "Y" crosses the channel between Grass and Round Lakes. This ramp allows access to all Cloverleaf Lakes and has parking facilities available. There are public areas owned by the town of Belle Plaine on Round (north shore) and Pine (west shore) Lakes. The Round Lake site is largely undeveloped and the Pine Lake site has park and beach areas.

METHODS

FIELD PROGRAM

Water sampling was conducted May 21, August 1, and August 27, 1991 and January 27, 1992 at two sites (Table 2, Figure 2). Station 0501 (deepest point) was sampled near surface (designated "S") and near bottom (designated "B"); Station 0502 (outlet) was sampled at mid-depth (designated "S").

An event site (05E1) was established at the mouth of a small stream tributary to Grass Lake on the north shore to yield information on possible nutrient input to the lake. This site was designated to be sampled after a major rain event (greater than 1" in a 24 hour period) to evaluate nutrient input at times of increased overland flow. One event sample was collected on August 8, 1991.

Physicochemical parameters measured in the field were **Secchi depth**, water temperature, pH, dissolved oxygen (DO), and conductivity. Field measurements were taken using a standard Secchi disk and either a Hydrolab Surveyor II or 4041 multiparameter meter; Hydrolab units were calibrated prior to and subsequent to daily use.

Table 2. Sampling Station Locations, Grass Lake, 1991 - 1992.

WATER QUALITY

Site	Latitude/Longitude		Depth
0501	44° 41.58'	88° 39.47'	52.0 ft.
0502	44° 41.14'	88° 40.11'	3.0 ft.
05E1			0.5 ft

MACROPHYTE TRANSECTS

Transect	Latitude/Longitude Origin	End	Transect Length (m)	Bearing (Degrees)	Depth Range[1]
A	44° 41.25' 88° 40.24'	44° 41.37' 88° 40.20'	251	14	1/2/3
B	44° 41.40' 88° 40.09'	44° 41.37' 88° 40.20'	38	249	1/2/3
C	44° 41.42' 88° 39.69'	44° 41.37' 88° 40.20'	76	263	1/2/3
D	44° 41.34' 88° 40.41'	44° 41.37' 88° 40.20'	11	196	1/2/3
E	44° 41.33' 88° 40.41'	44° 41.37' 88° 40.20'	46	101	1/2/3

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

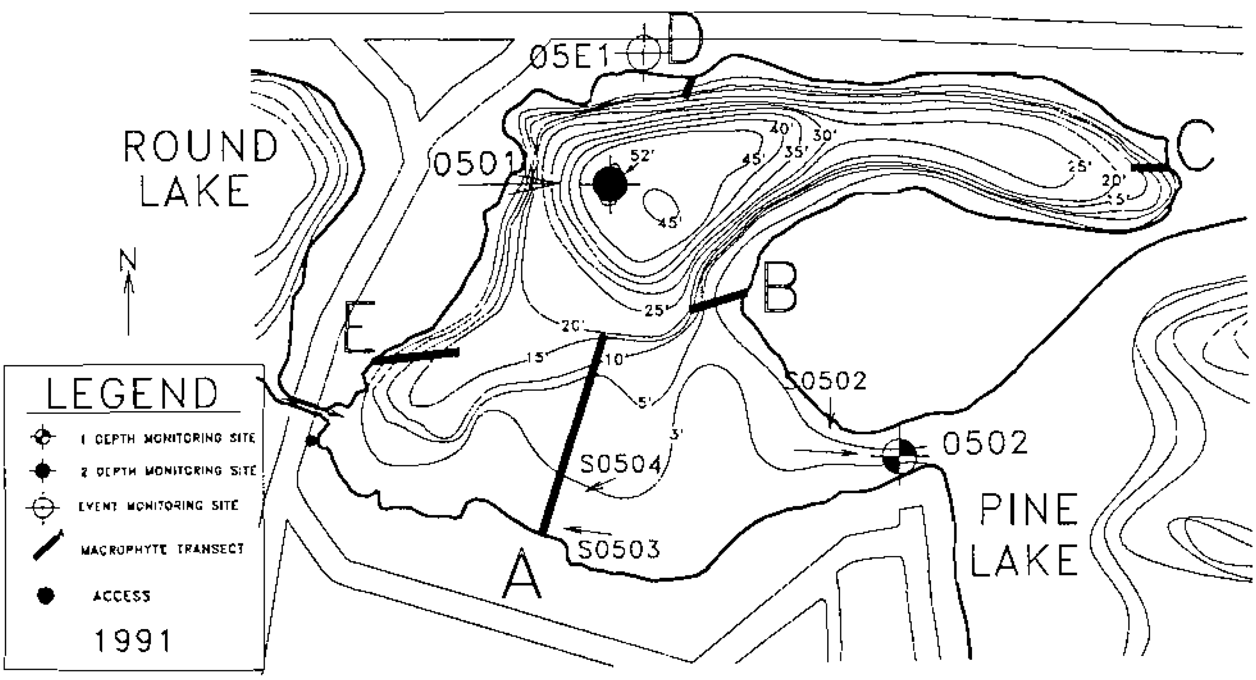

Figure 2. Sampling Sites, Grass Lake, Shawano County, WI, 1991 - 1992.

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, color and chlorophyll a. Summer and late Summer laboratory analyses included total Kjeldahl nitrogen, ammonia nitrogen, nitrate/nitrite nitrogen, total phosphorus, dissolved phosphorus, and chlorophyll a. Winter water quality parameters included total Kjeldahl nitrogen, ammonia nitrogen, nitrate/nitrite nitrogen, total phosphorus and dissolved phosphorus.

Macrophyte surveys were conducted in early Summer (July 19) and again later in the season (September 6) using a method developed by Sorge et al and modified by the WDNR-Lake Michigan District (WDNR-LMD) for use in the Long Term Trend Lake Monitoring Program (9). Transect endpoints were established on and off shore for use as reference from one sampling period to the next. These points were determined using a Loran Voyager Sportnav latitude/longitude locator and recorded with bearing and distance of the transect (line of collection) for future surveys. Five transects sampled in 1991 were chosen to provide information from various habitats and areas of interest.

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

Duplicate sediment samples were taken from each of three sites on August 27, 1991 using an Ekman grab and sediment core tubes. A grab sample of sediment was taken and core tubes (6 in. X 1.5 in.) inserted into the undisturbed grab samples. Analyses included percent organics (weight loss on ignition) and soils separates (% sand, silt and clay) and median particle size (hydrometer method). One core/site was analyzed (top 1 in. and bottom 1 in.) for organic content; the second core/site was analyzed (top half and bottom half) for soil separates.

OTHER

Water Quality Information

Additional lake information was retrieved from the WDNR Surface Water Inventory (6), CLPA water quality data, Wisconsin Self Help Monitoring Program (10) and from the WDNR Wisconsin Lakes publication (5). Historic water quality monitoring was conducted by the University of Wisconsin - Stevens Point Environmental Task Force Laboratory.

Land Use Information

Details of zoning and specific land uses were obtained from the UW-Extension, Shawano County zoning maps, United States Soil Conservation Service soil maps (4), 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 Shawano County Zoning Ordinance, Shawano County Floodplain Zoning Ordinance, and Shawano County Erosion Control and Animal Waste Management Plans which were acquired from the Shawano County Land Conservation Department.

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 card catalogs. Information gathered and results obtained are outlined in the Field Data Discussion section of this report.

Public Involvement Program

A summary of public involvement activities coordinated with the lake management planning process is outlined in Appendix I.

FIELD DATA DISCUSSION

A precise or universally applicable definition of "lake" is rather difficult given the wide size range and differences of origin of basins with standing water. The term is further complicated by the common usage of "lake" in reference to dammed reaches of flowing water (riverine) systems.

Grass Lake is a natural lake, as opposed to an artificial lake, i.e., dammed riverine system. Physicochemical characteristics of natural lakes tend toward a state of dynamic equilibrium (e.g., seasonally variable but relatively consistent within that framework over the long-term) as defined by basin morphometry and watershed characteristics.

Grass Lake is, by definition, a drainage lake since it has a definite inlet and outlet stream; the Cloverleaf Lakes overall, however, receive major inflow from groundwater. It is a moderately deep lake with a water residence time of about one year. Land use in the immediately adjacent Grass Lake watershed is primarily wooded residential or forested (Figure 3).

Phosphorus is often the limiting major nutrient in algal and plant production in lakes. Surface total phosphorus during 1991 monitoring ranged from .009 to .023 mg/l (parts per million) with

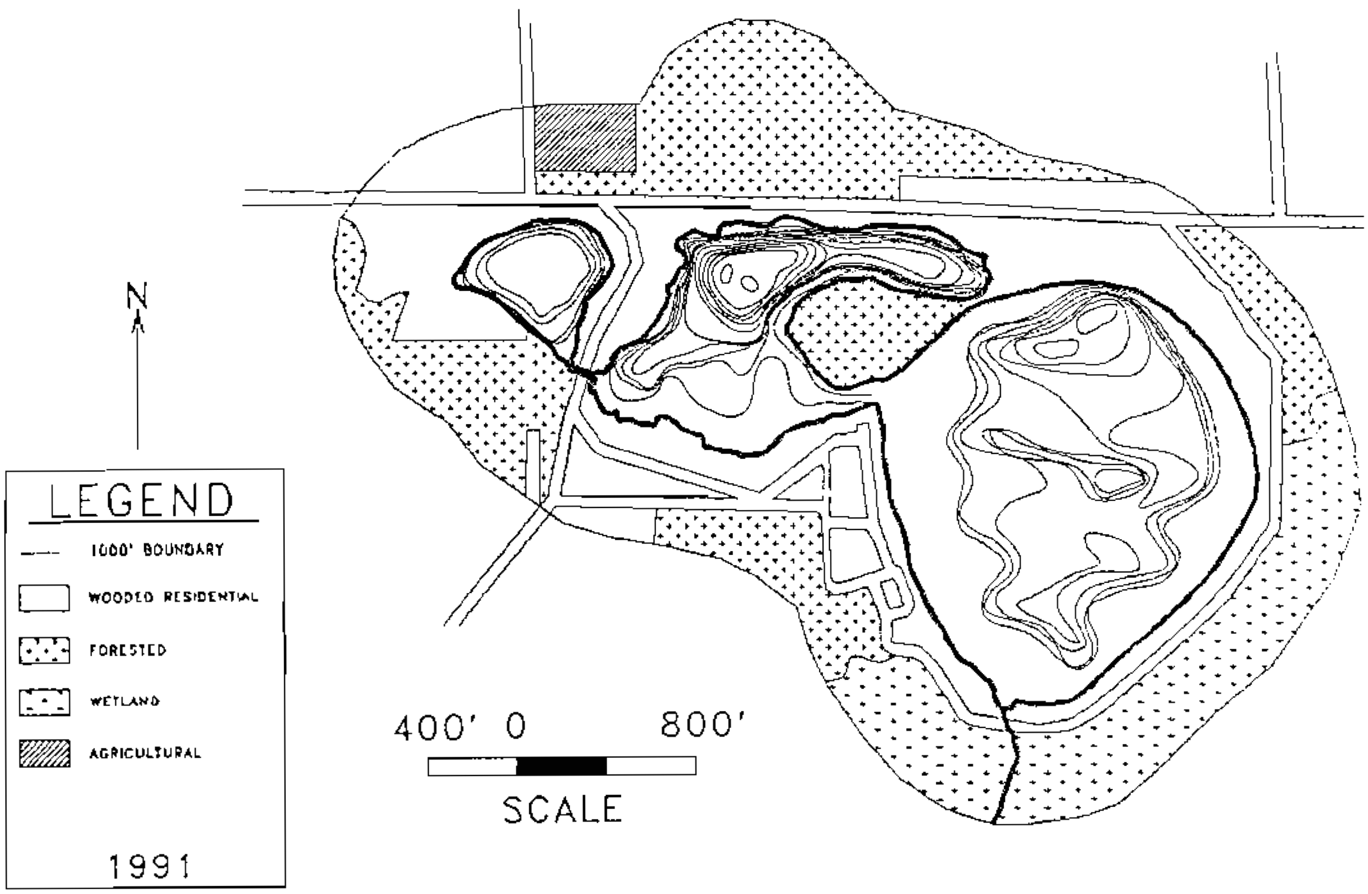

Figure 3. Land Uses in the Immediately Adjacent Watershed, Cloverleaf Lakes, 1991 - 1992.

a mean value of .014 mg/l (Tables 3-4). During available past monitoring data (1986-1990), in-lake surface total phosphorus ranged from .005 to .042 mg/l with a mean value of .019 mg/l (Appendix II). Nitrogen to phosphorus ratios (**N/P ratio**) consistently greater than 15 also indicate Grass Lake to be phosphorus limited.

Summer surface phosphorus levels in 1991 (.012 to .015 mg/l) were, according to a recent compilation of summer total phosphorus levels in upper midwestern lakes (11), much lower than typical (.030 to .050 mg/l) for the transitional region in which Grass Lake is located. Much higher values for total phosphorous and other nutrient parameters were observed near bottom at Station 0501 and were attributable to release from the sediments, which likely occurred under anoxic or near-anoxic conditions in the **hypolimnion** during summer **stratification** at this relatively deep point (Figure 4).

Grass Lake monitoring suggested that nutrient levels are relatively low in comparison to those observed entering the lake from the immediately adjacent watershed, which, may be significant at times. Event sampling on Grass Lake showed higher values of nutrients, particularly nitrate and nitrite, entering the lake via surface runoff from the small spring creek on the north shore (Table 5).

Table 3. Water Quality Parameters, Station 0501, Grass Lake, 1991 - 1992.

PARAMETER	SAMPLE[1]	05/21	08/01	08/27	01/27
Secchi (feet)		11.7	12.0	8.0	NR[2]
Temperature (°C)	S	24.07	22.92	24.62	2.99
	B	4.94	5.63	6.78	3.70
pH (S.U.)	S	8.24	8.53	8.57	8.22
	B	7.30	6.39	7.10	7.37
D.O. (mg/l)	S	8.54	8.84	8.69	8.26
	B	0.83	0.14	0.33	3.75
Conductivity (μmhos/cm)	S	349	316	305	347
	B	457	434	413	399
Laboratory pH (S.U.)	S	8.4	NR	NR	NR
	B	7.6	NR	NR	NR
Total Alkalinity (mg/l)	S	152	NR	NR	NR
	B	195	NR	NR	NR
Color (Pt-Co Units)	S	15	NR	NR	NR
	B	15	NR	NR	NR
Total Solids (mg/l)	S	228	NR	NR	NR
	B	290	NR	NR	NR
Total Kjeldahl N (mg/l)	S	0.5	0.6	0.5	0.7
	B	2.3	4.1	1.8	0.9
Ammonia Nitrogen (mg/l)	S	0.044	0.017	0.005	0.160
	B	1.43	2.72	1.12	0.485
$NO_2 + NO_3$ Nitrogen (mg/l)	S	0.033	<0.007	<0.007	0.219
	B	<0.015	0.012	<0.007	0.189
Total Nitrogen (mg/l)	S	0.533	0.6	0.5	0.919
	B	2.3	4.112	1.8	1.089
Total Phosphorus (mg/l)	S	0.009	0.013	0.012	0.023
	B	0.21	0.41	0.050	0.022
Diss. Phosphorus (mg/l)	S	0.008	0.004	<0.002	0.002
	B	0.090	0.230	0.002	0.007
N/P Ratio	S	59.2	46.2	41.7	40.0
	B	11.0	10.0	36.0	49.5
Chlorophyll a (μg/l)	S	4	4	4	NR

[1] S = Near Surface; B = Near Bottom
[2] NR = No Reading

Table 4. Water Quality Parameters, Station 0502, Grass Lake, 1991 - 1992.

PARAMETER	SAMPLE[1]	05/21	08/01	08/27	01/27
Secchi (feet)		b[2]	b	b	b
Temperature (°C)	S	23.60	22.73	24.81	2.61
pH (S.U.)	S	8.24	8.46	8.49	7.73
D.O. (mg/l)	S	7.75	8.50	8.10	8.54
Conductivity (µmhos/cm)	S	335	308	305	420
Laboratory pH (S.U.)	S	8.4	NR[3]	NR	NR
Total Alkalinity (mg/l)	S	151	NR	NR	NR
Color (Pt-Co Units)	S	15	NR	NR	NR
Total Solids (mg/l)	S	222	NR	NR	NR
Total Kjeldahl N (mg/l)	S	0.6	0.6	0.5	0.7
Ammonia Nitrogen (mg/l)	S	0.049	0.007	0.006	0.188
NO_2+NO_3 Nitrogen (mg/l)	S	0.023	<0.007	<0.007	0.200
Total Nitrogen (mg/l)	S	0.623	0.6	0.5	0.900
Total Phosphorus (mg/l)	S	0.018	0.015	0.012	0.011
Diss. Phosphorus (mg/l)	S	0.007	0.005	<0.002	<0.002
N/P Ratio	S	34.6	40.0	41.7	81.8
Chlorophyll a (µg/l)	S	4	5	5	NR

[1] S = Near Surface;
[2] b = Secchi disk visible to bottom
[3] NR = No Reading

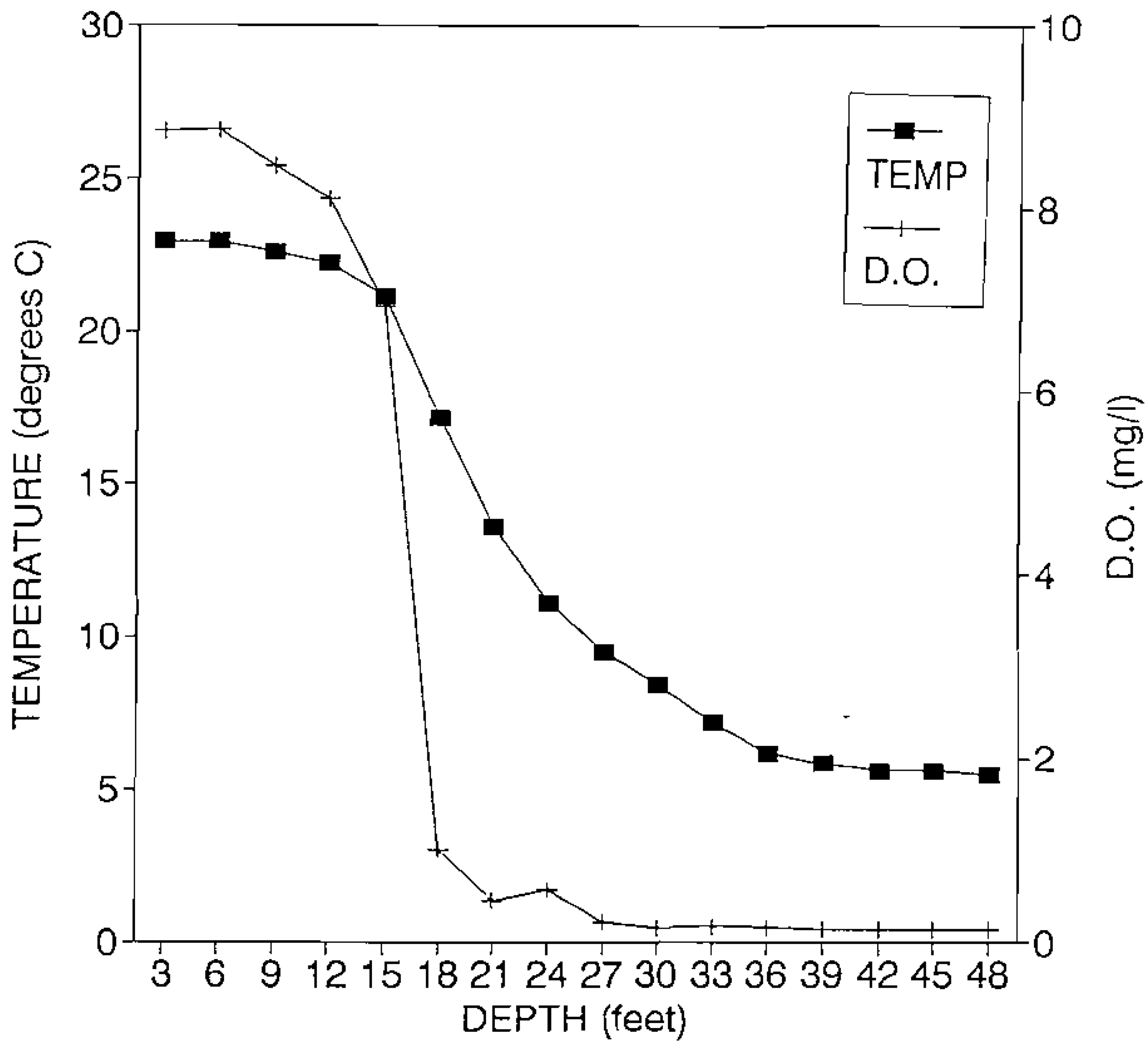

Figure 4. Temperature/DO Profile, Grass Lake, August 1, 1991.

Table 5. Event Water Quality Parameters, Grass Lake, August 8, 1991.

		STATION
PARAMETER	UNITS	05E1
Total Kjeldahl N	mg/l	0.8
Ammonia Nitrogen	mg/l	0.049
NO_2+NO_3 Nitrogen	mg/l	1.91
Total Phosphorus	mg/l	0.060
Diss. Phosphorus	mg/l	NR[1]
Total Nitrogen	mg/l	2.71
N/P Ratio		45.2

[1] NR = No Reading

Other indicators of lake **eutrophication** status include light penetration and algal production. Numerous summarative indices have been developed, based on a combination of these and other parameters, to assess or monitor lake eutrophication or aging. The Trophic State Index (TSI) developed by Carlson (12) utilizes Secchi transparency, chlorophyll a, and total phosphorus. As with most indices, application is generally most appropriate on a relative and trend monitoring basis. This particular index does not account for natural, regional variability in total phosphorus levels nor in Secchi transparency reduction unrelated to algal growth (e.g. that associated with color). TSI numbers for Grass Lake, in general, indicated a mesotrophic classification; values for total phosphorus were most variable and ranged from those indicative of **oligotrophic** to **eutrophic** classifications (Figures 5-7).

During recent macrophyte surveys (Appendix III), macrophytes (Table 6) were found at all 30 sample sites (sample sites = number of depth ranges sampled). Water celery (Vallisneria americana), an abundant Wisconsin macrophyte, was widely distributed (at 22 of 30 sites), and overall the most abundant macrophyte (Tables 7-10). Water celery (also known as eel grass), has long tape-like leaves, grows completely submerged and is typically found on hard substrates; growth can increase with turbidity. It is rated as excellent waterfowl food and provides fish with forage, cover and spawning habitat but has been known to reach nuisance levels (14). Water celery produces seeds, but spreads mainly from rhizome growth and reproduces mainly by tubers from one year to the next (13).

Clasping-leaf pondweed (Potamogeton richardsoni) was the second most common macrophyte (at 22 of 30 sites). It is a common Wisconsin macrophyte, grows completely submerged and is rated as good waterfowl food and also provides fish forage and cover (13).

Flatstem pondweed (Potamogeton zosteriformis), bushy pondweed (Najas sp.) and water milfoil (Myriophyllum sp.) were also

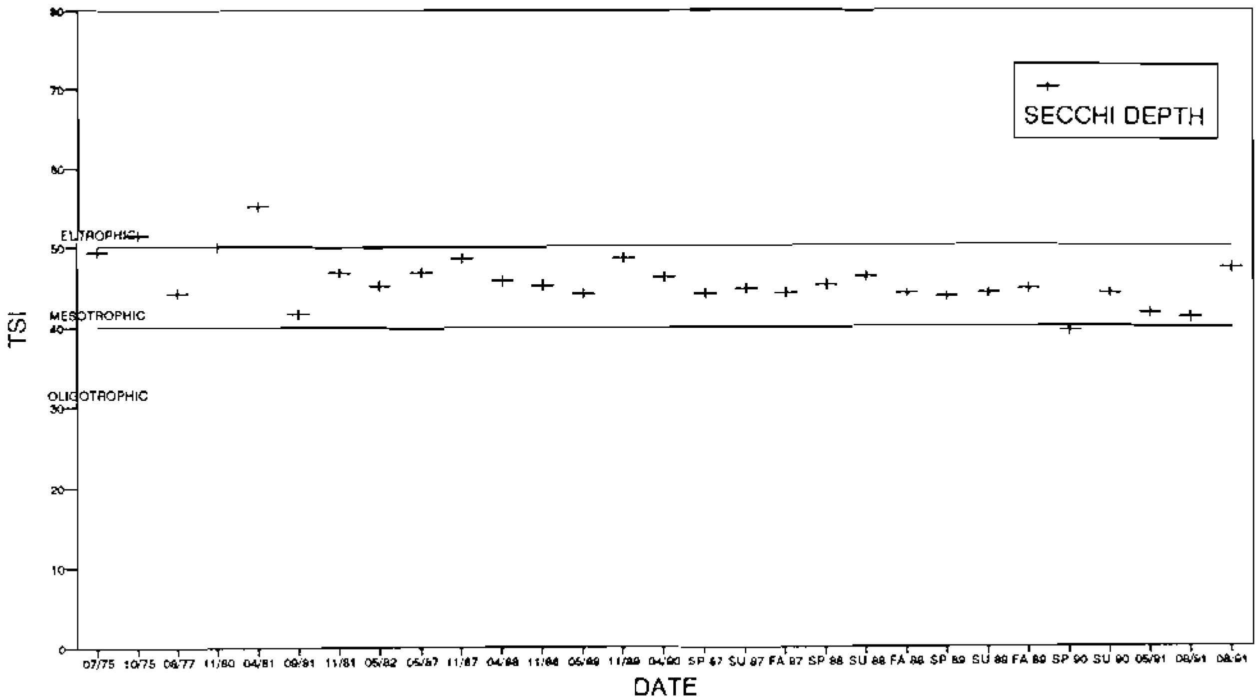

Figure 5. Trophic State Index for Secchi Depth, Grass Lake.

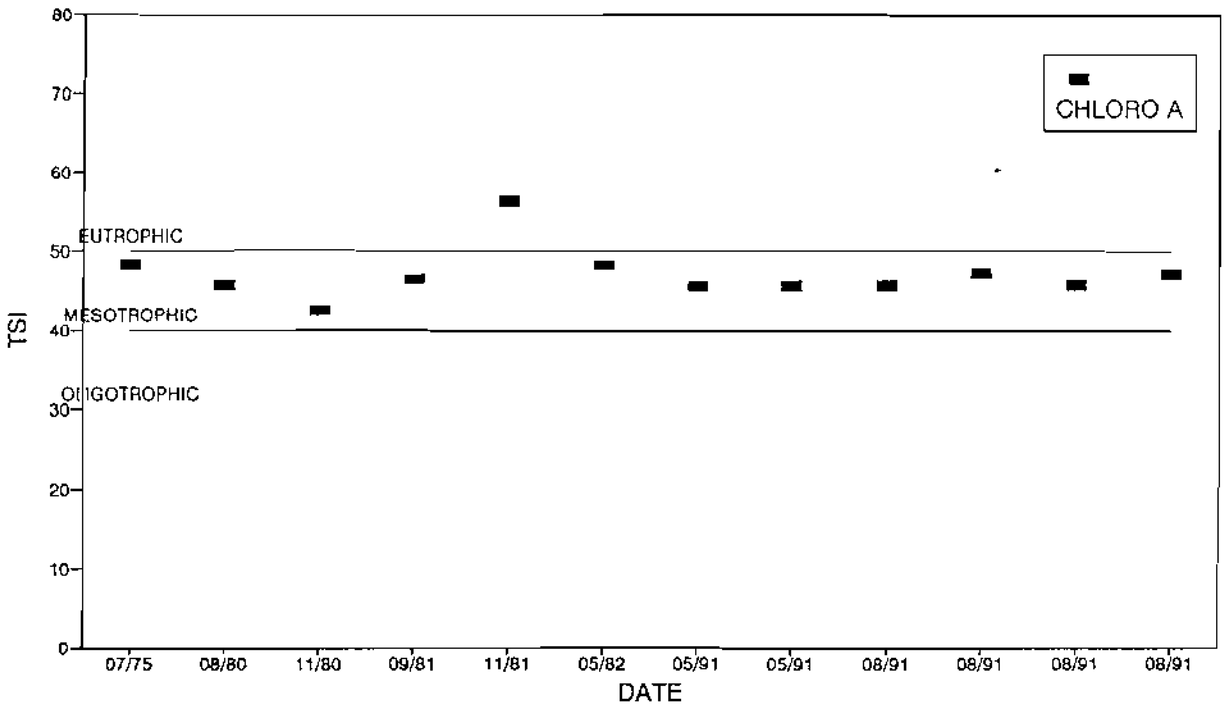

Figure 6. Trophic State Index for Chlorophyll a, Grass Lake.

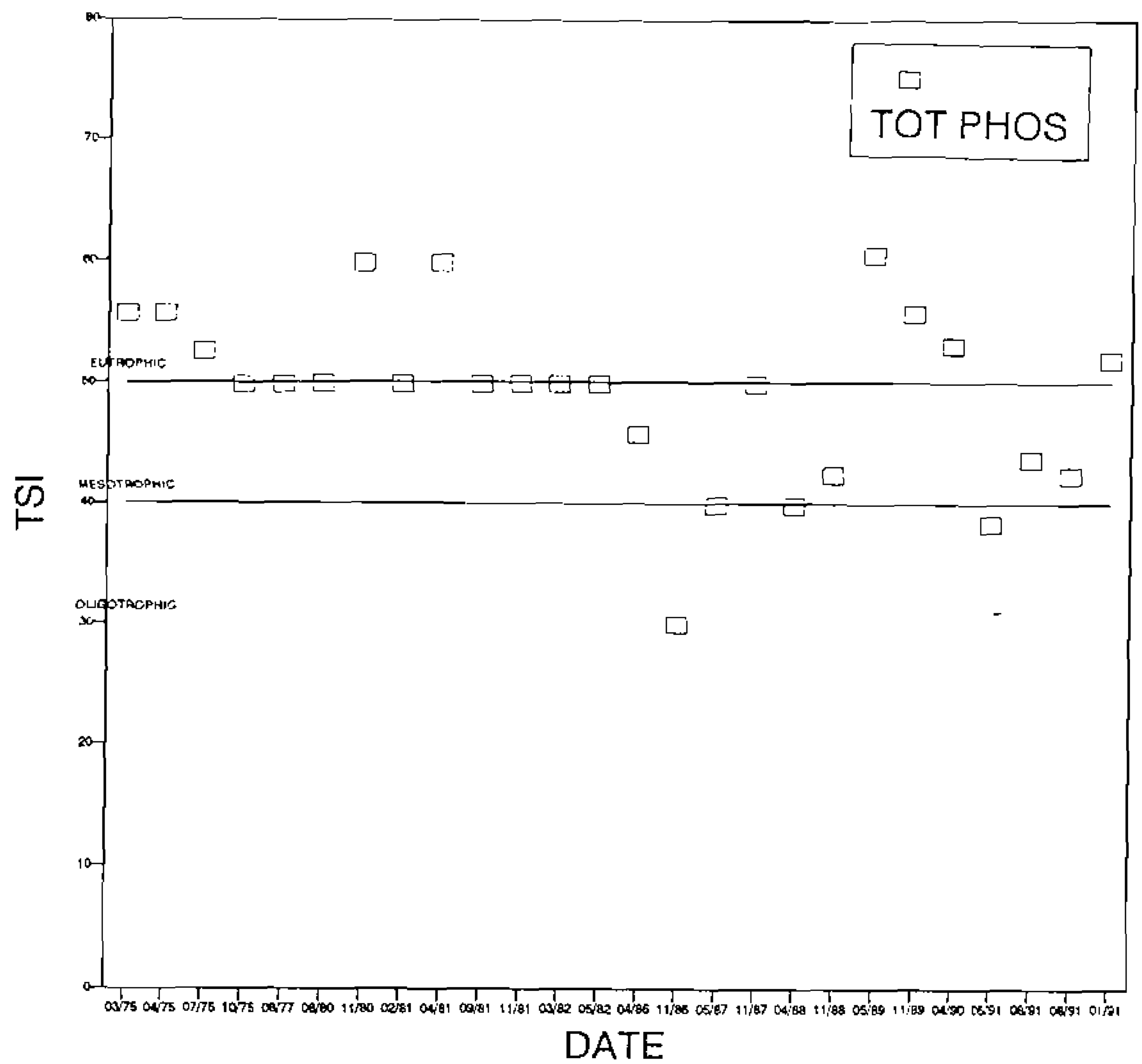

Figure 7. Trophic State Index for Total Phosphorus, Grass Lake.

Table 6. Macrophyte Species Observed, Grass Lake, 1991 (13).

Taxa	Code
Watershield (*Brasenia schreberi*)	BRASC
Water arum (*Calla palustris*)	CALPA
Coontail (*Ceratophyllum demersum*)	CERDE
Common waterweed (*Elodea canadensis*)	ELOCA
Filamentous algae	FILAL
Small duckweed (*Lemna minor*)	LEMMI
Forked duckweed (*Lemna trisulca*)	LEMTR
Water milfoil (*Myriophyllum* sp.)	MYRSPE
Bushy pondweed (*Najas* sp.)	NAJSP
Nitella (*Nitella* sp.)	NITSP
Yellow pond lily (*Nuphar* sp.)	NUPSP
White water lily (*Nymphaea* sp.)	NYMSP
Pickerel-weed (*Pontedaria cordata*)	PONCO
Large-leaf pondweed (*Potamogeton amplifolious*)	POTAM
Curly-leaf pondweed (*Potamogeton crispus*)	POTCR
Illinois pondweed (*Potamogeton illinoensis*)	POTIL
Sago pondweed (*Potamogeton pectinatus*)	POTPE
White-stem pondweed (*Potamogeton praelongus*)	POTPR
Small pondweed (*Potamogeton pusillus*)	POTPU
Clasping-leaf pondweed (*Potamogeton richardsonii*)	POTRI
Fern pondweed (*Potamogeton robbinsii*)	POTRO
Flat-stem pondweed (*Potamogeton zosteriformis*)	POTZO

Table 6 (continued)

Water crowfoot (*Ranunculus* sp.)	RANSP
Rush (*Scirpus* sp.)	SCISP
Broad-leaf cattail (*Typha latifolia*)	TYPLA
Eel grass (water celery) (*Vallisneria americana*)	VALAM

Table 7. Occurrence and Abundance of Macrophytes by Depth, Grass Lake, July, 1991.

	Depth Ranges					
CODE	1 (N=5)		2 (N=5)		3 (N=5)	
	% of Sites	Σ Abundance (range)	% of Sites	Σ Abundance (range)	% of Sites	Σ Abundance (range)
BRASC	0	0	20	3(3)	0	0
CALPA	20	1(1)	0	0	0	0
CERDE	60	6(1-3)	20	3(3)	60	8(2-3)
ELOCA	40	4(2)	40	3(1-2)	60	6(1-3)
FILAL	80	9(1-3)	40	4(1-3)	0	0
LEMMI	20	2(2)	0	0	0	0
LEMTR	20	3(3)	0	0	0	0
MYRSPE	0	0	40	3(1-2)	60	9(2-4)
NAJSP	40	5(2-3)	60	7(1-3)	80	9(1-4)
NUPSP	40	5(2-3)	60	7(1-4)	0	0
NYMSP	60	9(2-4)	40	5(2-3)	0	0
PONCO	20	1(1)	20	2(2)	0	0
POTAM	0	0	0	0	0	0
POTCR	20	1(1)	0	0	0	0
POTIL	0	0	40	2(1)	0	0
POTPE	60	5(1-3)	60	4(1-2)	20	2(2)
POTPR	0	0	0	0	0	0
POTPU	0	0	20	3(3)	0	0
POTRI	0	0	100	9(1-3)	100	9(1-2)
POTRO	0	0	20	3(3)	0	0
POTZO	20	1(1)	60	7(2-3)	80	11(2-3)
RANSP	20	1(1)	60	5(1-2)	60	5(1-3)
SCISP	60	7(2-3)	40	4(1-3)	0	0
TYPLA	40	2(1)	0	0	0	0
VALAM	60	5(1-2)	100	10(2)	40	5(2-3)

Table 8. Occurrence and Abundance of Macrophytes by Depth, Grass Lake, September, 1991.

Depth Ranges

CODE	1 (N=5)		2 (N=5)		3 (N=5)	
	% of Sites	Σ Abundance (range)	% of Sites	Σ Abundance (range)	% of Sites	Σ Abundance (range)
BRASC	20	2(2)	20	2(2)	0	0
CALPA	0	0	0	0	0	0
CERDE	0	0	0	0	60	6(1-3)
ELOCA	20	2(2)	20	2(2)	20	1(1)
FILAL	0	0	0	0	0	0
LEMMI	20	3(3)	0	0	0	0
LEMTR	20	3(3)	0	0	0	0
MYRSPE	40	3(1-2)	60	6(1-3)	80	12(2-4)
NAJSP	20	2(2)	40	4(2)	60	9(2-4)
NUPSP	20	1(1)	20	2(2)	0	0
NYMSP	60	10(3-4)	40	6(2-4)	0	0
PONCO	0	0	20	2(2)	0	0
POTAM	0	0	20	3(3)	0	0
POTCR	0	0	0	0	0	0
POTIL	0	0	60	5(1-2)	0	0
POTPE	40	3(1-2)	60	5(1-2)	20	2(2)
POTPR	0	0	20	2(2)	20	2(2)
POTPU	0	0	0	0	0	0
POTRI	40	4(1-2)	100	11(2-3)	100	12(2-3)
POTRO	0	0	0	0	0	0
POTZO	20	1(1)	60	6(2)	100	11(2-3)
RANSP	0	0	20	2(2)	0	0
SCISP	40	4(1-3)	40	4(1-3)	0	0
TYPLA	0	0	0	0	0	0
VALAM	60	7(1-3)	100	14(2-3)	80	11(2-3)

Table 9. Comparison of Occurrence as Percent of Total Abundance for Selected Macrophytes by Depth, Grass Lake, 1991.

Species Code	Depth Range 1		2		3	
	JULY	SEP	JULY	SEP	JULY	SEP
VALAM	7	14	11	18	8	17
POTRI	0	8	10	14	14	18
POTZO	1	2	8	8	17	17
NAJSP	7	4	8	5	14	11
NYMSP	12	20	5	8	0	0
CERDE	8	0	3	0	13	9
MYRSPE	0	6	3	8	14	18
POTPE	7	6	4	6	3	3
SCISP	10	8	4	5	0	0
ELOCA	5	4	3	3	9	2

widespread and relatively abundant. Flatstem and bushy pondweed are most commonly found completely submerged in water with low turbidity. Flatstem pondweed prefers soft substrates while bushy pondweed prefers hard substrates; both are a source of waterfowl food and provide fish with forage food and cover. Bushy pondweed is known to reach nuisance levels.

Species for water milfoil was not determinable because of lack of distinguishing flower parts (bracts) during the time of the surveys, but Eurasian Milfoil (Myriophyllum spicatum) may be present in Grass Lake. This species is an exotic (not native to Wisconsin) and has shown the capability to outcompete native vegetation and reach nuisance levels quickly.

Table 10. Abundance Distribution and Substrate Relations for Selected Macrophytes, Grass Lake, 1991.

Transect	Substrate	Species Code																			
		VALAM		POTRI		POTZO		NAJSP		NYMSP		CERDE		MYRSPE		POTPE		SCISP		ELOCA	
		J[1]	S	J	S	J	S	J	S	J	S	J	S	J	S	J	S	J	S	J	S
A1	SAND/GRAV	2	3	0	2	0	0	3	2	3	4	2	0	0	2	3	1	2	0	0	2
A2	SAND/GRAV	2	3	2	2	2	0	3	2	2	4	0	0	2	2	2	1	3	3	0	2
A3	SAND	0	3	2	3	3	3	0	0	0	0	3	1	2	3	0	0	0	0	3	0
B1	SAND	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0
B2	SA/GRAV/MK	2	3	3	3	0	0	0	0	0	0	0	0	0	3	1	2	0	0	0	0
B3	SILT/MUCK	2	2	2	2	3	2	4	4	0	0	0	0	0	3	2	2	0	0	1	0
C1	ROCK	2	0	0	0	1	1	2	0	2	3	1	0	0	0	1	0	3	3	2	0
C2	ROCK/MUCK	2	3	2	2	3	2	3	2	0	2	0	0	0	1	0	2	1	1	1	0
C3	SAND	0	3	2	2	3	2	2	2	0	0	3	3	3	4	0	0	0	0	2	0
D1	SAND	1	3	0	1	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0
D2	SAND	2	3	1	2	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0
D3	SILT/MUCK	3	3	2	2	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
E1	RK/GRAV/SA	0	0	0	1	0	0	0	0	4	3	3	0	0	1	0	0	0	0	2	0
E2	RK/GRAV/SA	2	2	1	2	2	2	1	0	3	0	3	0	1	0	0	0	0	0	2	0
E3	SILT/MUCK	0	0	1	3	2	2	2	3	0	0	2	2	4	2	0	0	0	0	0	1

[1] J = July survey; S = September survey

Sediment analyses showed relatively high amounts of organics. Organic content (by weight) ranged from 14.8% (Site S0504) to 58% (Site S0502). Sediment textures observed included clay loam (Site S0502), silty clay loam (Site S0503) and silt loam (Site S0504). Median particle size ranged from 9.0μ (Site S0503) to 14.0μ (Site S0504) (Table 11).

Table 11. Sediment Sample Results, Grass Lake, 1991.

Sample Site	Soil Class	% Sand/ Silt/Clay	Median Particle Dia.	% Organics
S0502	Clay Loam	40/29/31	2.5μ	58.0
S0503T[1]	Silty Clay Loam	20/49/31	9.0μ	15.9
S0503B[2]	Silty Clay Loam	16/56/28	10.5μ	16.1
S0504T	Silt Loam	25/57/18	14.0μ	14.8
S0504B	Silt Loam/Loam	31/51/18	14.0μ	15.1

[1] T denotes top of core
[2] B denotes bottom of core

Swimmer's itch (schistosome dermatitis) has been a recurrent problem in the Cloverleaf Lakes. 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 increase (especially when scratched) and persist for several days (usually less than a week).

Adult flatworms are carried by birds and rodents in blood vessels where the females 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 undesirable because they cannot ensure eradication of cercaria and snails and can cause native mollusk and vegetation die-off, reduced DO levels and fishkills (15). Infestation of snails is most common during dry and hot Summer months (16) and the swimmer's itch problem can persist longer than a month.

Suggestions to prevent swimmer's itch are designed to minimize contact with cercaria (17). 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 (18)], 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

- Grass Lake water quality is fair to good with respect to all parameters measured and has not exhibited any readily discernible trends since the mid 1970's. Summer total phosphorus was variable but much lower than that typically found in lakes in this region. Overall good water quality and a mesotrophic status appears related to substantial groundwater inflow (low surface runoff) and a primarily wooded watershed. Higher phosphorus levels near bottom, at the stratified deepest point, appear related to sediment release under near-anoxic conditions. Surface runoff from the immediate watershed (e.g., high nitrate/nitrate nitrogen and total phosphorous input observed at the spring-fed creek on the north shore shortly after a rain event) may introduce a significant amount of nutrients. Water chemistry parameters were similar to those observed in the other Cloverleaf Lakes.

- Macrophytes, around much of Grass Lake, are limited to relatively narrow littoral near-shore areas; an exception is the shallow shelf area along the south shore where sediment is primarily silty loam with high organic content.

MANAGEMENT ALTERNATIVES DISCUSSION

WATER QUALITY

Grass Lake is a natural lake which benefits from high groundwater inflow and relatively low surface runoff from a predominantly forested watershed. Water quality relative to transparency, productivity and nutrients is fair to good. Net nutrient input from the immediately adjacent watershed, however, may be substantial during storm or other (e.g., snow-melt) surface runoff events.

Efforts should be made to identify and control localized non-point sources of nutrients entering Grass Lake (investigation of the creek or other identified inflows at low and high flows may be warranted). Riparian land use practices can have a significant influence and land owner diligence should be strongly emphasized and encouraged to prevent (to the extent practical) nutrient and sediment inflows. A major concern is nutrient inputs; common sense approaches are relatively easy and can be very effective in minimizing these inputs.

Yard practices can minimize both nutrient and sediment inputs. Lawn 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 (19).

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 (19).

There are a number of informational sources for land owners with questions regarding land management practices. Some sources are outlined in Appendix IV.

MACROPHYTES

Management of localized nuisance macrophyte populations may be a management objective on Grass Lake. Existing macrophytic growth appears to positively affect the resource in some places through forage fish production, shoreline stabilization and negatively in others (reduced access, sediment build-up, aesthetics). A macrophyte management plan should be carefully thought out by prioritizing differing use areas in the lake. Numerous methods of macrophyte control and management are available ranging from radical habitat alteration to more subtle habitat manipulation and are discussed below relative to Grass Lake applicability.

Dredging is a drastic form of habitat alteration. Dredging could entail massive lake-wide sediment removal (to a depth at which macrophyte growth would be retarded due to reduced sunlight) or spot dredging of limited (high priority) areas. Large scale sediment removal is very costly. Spot dredging, because of lower cost may be a reasonable alternative in some cases. Spot dredging may be a viable alternative in Grass Lake in the near future since there is a low potential for sediment transport into the lake and it may reduce sediment redistribution/resuspension in high power boat use areas.

Chemical treatment has been shown to eradicate some undesirable species and leave others intact. The WDNR strongly discourages the use of chemicals because of nutrient release, oxygen depletion, sediment accumulation, bioaccumulation and other unknown environmental hazards including invasion potential from nuisance exotics. Chemical effects are nondiscriminate and may harm desireable or beneficial plant populations. Therefore, chemical treatment should not be considered for Grass Lake at this time.

Aquatic plant screens have been shown to reduce plant densities in other lakes and may be applicable here. A fiberglass screen or plastic sheet is placed and anchored on the sediment to prevent plants from growing. This may also make some sediment nutrients unavailable for algal growth. Screens should be removed each fall and cleaned in order to last a number of years.

A newer technique of rototilling sediments to destroy plant roots appears to be effective in controlling plant growth for a relatively longer period than harvesting. The process is about the same cost per hour as a contracted macrophyte harvester (20). A potential problem is disturbance of the sediments and resuspension of nutrients or toxics.

Installation of floating platforms (black plastic attached to wooden frames) just before or after ice-out can shade the sediments, restrict plant growth and help to open corridors for swimming or boat navigation. Shading is usually required for three weeks to two months to significantly impact nuisance plant growth (21). A potential drawback is that the area cannot be used while the platform is in place.

Remaining control methods consist, in one form or another, of macrophyte harvest. It is a commonly used technique which can be applied on a widespread or localized basis. Its efficiency, based on method of cut/harvest, can vary substantially with depth.

Several conditions should be considered with respect to macrophyte harvest in Grass Lake. Nuisance macrophyte growth on Grass Lake is sporadic and manipulation methods should be species selective. The exotic Eurasian Milfoil, which spreads easily by fragmentation, may be present in Grass Lake; strong consideration should also be given to the potential of this species to invade areas where competing macrophytes have been removed.

Macrophyte harvesting is typically conducted with a mechanical harvester which cuts the vegetation and removes (harvests) it onto a platform for out-lake disposal. Given the previously mentioned precautions regarding potential Eurasian Milfoil dispersal and the ability of some plants to survive and spread when detached from the substrate, harvest practices may even enhance the nuisance macrophyte problem through seed dispersal, fragmentation or incomplete removal. Indiscriminate power boat usage, through formation of "prop cut" floating weed masses, may also contribute to this problem.

Selective SCUBA assisted harvest has been shown to selectively manage macrophytes. It can be used in deeper areas and to target only desired species (i.e. water milfoil) or nuisance growth areas. This method is labor intensive, but has proved to effectively reduce nuisance plant levels for up to two years (20). With the limited areas of potential macrophyte management in Grass Lake, SCUBA assisted harvest may be a viable option.

Raking weeds (using an ordinary garden rake) in the frontage area can be a very effective localized plant control method when done on a regular basis. Such concentration on the problem shallow water areas would reduce efforts expended on other control methods. Harvested plants should be removed from the lakeshore area to prevent nutrients from re-entering the lake.

MANAGEMENT RECOMMENDATIONS

CLPA management objectives for Grass Lake should include continued monitoring, further assessment of runoff input and localized macrophyte management (where necessary or desired) to protect or improve aesthetics/recreational use of the resource. The CLPA may also consider conducting a user or landowner survey to better define desired uses of, and minimize potential user conflicts in, the Cloverleaf Lakes chain. CLPA should also strongly encourage riparian land owner education and diligence with respect to nutrient input and erosion control to maintain or enhance water quality.

- Water quality monitoring should be continued to track long-term water quality trends. Self-Help Monitoring as well as regular monitoring by a similar protocol should be continued. Event monitoring should be undertaken to provide additional information in areas of concern (i.e., roadside and agricultural areas). Low flow nutrient sampling from the north shore inlet may help to assess continual versus event related input to the lake system.
- There is the potential of nutrient runoff or infiltration to surface or groundwater because soils in the immediate Grass Lake watershed may not filter

runoff adequately. Residential input is relatively less substantial on an individual basis, but, cumulatively can have a large impact. Fertilizer management, nuisance macrophyte raking and buffer stripping can all have positive effects, especially in near-shore areas.

- Input of nutrients from the watershed appears to be significant compared to that observed in-lake. An investigation should be made as to the source of the relatively high nutrient content in the identified inflow, and efforts should be made to identify other areas.

- Localized and selective macrophyte manipulation may be implemented to improve desireable plant diversity and to reduce numbers of nuisance species. Management should emphasize creation and protection of habitat, access improvement, and minimization of the build-up of in-lake organic sediments. Eurasian Milfoil beds (if present) should be identified and selective SCUBA aided removal implemented.

IMPLEMENTATION

The success of any lake management plan relates directly to the ability of the association/district to obtain funds and regulatory approval necessary to implement the plan. The CLPA is a voluntary association that does not have a lake district's specific legal or financial powers (to adopt ordinances or levy taxes or special assessments) to meet plan objectives.

The Grass Lake watershed is located within the political jurisdictions of the Town of Belle Plaine, County of Shawano and the State of Wisconsin. These units have the power to regulate land uses and land use practices. Shawano County ordinances and plans possibly pertinent to the Grass Lake plan are summarized in Appendix V.

Potential sources of funding are listed in Appendix VI.

APPENDIX II
HISTORIC WATER QUALITY DATA
Grass Lake, Shawano County, WI
Water Chemistry: 04/86 - 04/90
Lake Center - Surface
(Source: UW-Stevens Point Environmental Task Force)

Parameter (Units)	Date								
	04/86	11/86	05/87	11/87	04/88	11/88	05/89	11/89	04/90
Water Temperature (°F)	NR[1]	36	64	41	56	40	60	42	56
Air Temperature (°F)	NR	NR	70	50	72	45	64	50	65
Cloud Cover (%)	NR	NR	50	50	10	60	40	10	15
Lake Level (inches)	NR	NR	72	74	70	72	66	69	65
Secchi Depth (feet)	NR	NR	8.2	7.3	8.7	9.2	10.0	7.3	8.5
pH (SU)	8.13	8.19	8.42	7.74	8.22	7.84	8.08	7.83	8.08
Conductivity (umhos/cm)	328	291	323	375	340	355	322	332	307
Alkalinity (mg/l $CaCO_3$)	150	136	152	152	150	152	152	152	160
Magnesium (mg/l)	74.1	69.5	72.0	64.0	76.0	72.0	64.0	88.0	80.0
Calcium (mg/l)	89.8	62.9	88.0	108.0	92.0	108.0	92.0	80.0	84.0
Color (Pt/Co Units)	15.0	4.0	9.0	9.0	7.0	0.5	7.5	2.0	5.0
Turbidity (NTU's)	1.5	1.0	1.2	1.2	0.8	0.9	1.0	0.7	3.6
Total Hardness (mg/l $CaCO_3$)	163.9	132.4	160.0	172.0	168.0	180.0	156.0	168.0	164.0
Reactive Phosphorous (mg/l)	<0.002	0.002	<0.005	<0.002	<0.002	0.005	0.010	0.012	0.005
Total Phosphorous (mg/l)	0.015	0.005	0.010	0.020	0.010	0.012	0.042	0.030	0.025
NH_4-Nitrogen (mg/l)	0.06	0.06	0.11	0.18	<0.01	0.18	0.04	0.20	0.10
NO_2/NO_3-Nitrogen (mg/l)	0.32	<0.01	<0.05	0.02	<0.01	0.06	<0.20	0.01	<0.02
Total Kjeldahl Nitrogen (mg/l)	0.46	0.35	0.50	0.85	0.28	0.73	0.65	0.80	0.58
Total Nitrogen	0.78	0.35	0.50	0.87	>0.28	0.79	>0.65	0.81	>0.58
N/P Ratio	52.0	70.0	50.0	43.5	<28.0	65.8	<15.5	27.0	23.2
Chloride (mg/l)	16.6	14.0	18.0	19.0	24.0	17.0	15.0	13.0	17.0
Sulfate (mg/l)	12.0	8.0	9.0	7.5	8.5	9.0	9.0	8.0	7.5
Sodium (mg/l)	7.9	6.5	6.3	7.9	7.6	4.8	7.6	7.9	7.5
Potassium (mg/l)	1.6	1.5	1.0	1.4	1.4	1.3	1.6	1.5	1.4

[1] NR denotes no reading given

APPENDIX II
HISTORIC WATER QUALITY DATA
Grass Lake, Shawano County, WI
Water Chemistry: 03/75 - 04/81
Lake Center
(Source: WDNR)

Parameter (Units)	Date														
	03/75	04/75	07/75	10/75	08/77	08/77	08/77	08/80	08/80	11/80	11/80	02/81	02/81	04/81	04/81
Depth (feet)	0	0	0	0	0	25	50	3	33	3	26	3	43	3	40
Water Temperature (°F)	36	NR[1]	81	52	70	47	40	NR	NR	37	39	41	42	46	39
Air Temperature (°F)	NR	NR	NR	NR	70	–	–	NR	–	25	–	50	–	45	–
Cloud Cover (%)	NR	NR	NR	NR	100	–	–	NR	–	0	–	10	–	100	–
Dissolved Oxygen (mg/L)	6.0	NR	8 4	9 0	8 4	0 5	0.5	NR	NR	11 3	11 3	5.9	1 4	11 2	0 0
Secchi Depth (feet)	NR	NR	7 0	6 0	10 0	–	–	NR	–	6 6	–	NR	–	4 6	–
pH (SU)	7 3	7 4	8.4	7 8	7 8	7 5	7 3	8 4	7 3	NR	NR	7 5	7 8	7.8	8 0
Conductivity (umhos/cm)	200	NR	265	291	304	350	368	NR	NR	NR	NR	NR	NR	NR	NR
Alkalinity (mg/l $CaCO_3$)	160	71	124	138	118	170	166	130	194	156	156	86	168	150	150
Magnesium (mg/l)	NR	NR	NR	NR	22	22	24	NR	NR	NR	NR	NR	NR	NR	NR
Calcium (mg/l)	NR	NR	NR	NR	28	29	31	NR	NR	NR	NR	NR	NR	NR	NR
Turbidity (NTU's)	NR	NR	NR	NR	1 2	2 0	4 2	NR	NR	NR	NR	NR	NR	NR	NR
Reactive Phosphorous (mg/l)	0 07	0 03	0 013	0 002	0.007	0.031	0 176	<0.004	0 42	<0 004	<0 004	0.014	0.013	<0.04	<0.004
Total Phosphorous (mg/l)	0 03	0 03	0 024	0 02	0.02	0 06	0 31	0.02	0 58	0 04	0 03	0.02	0.02	0.04	0 07
NO_3-Nitrogen (mg/L)	NR	NR	NR	NR	0 13	0 06	1 75	NR	NR	NR	NR	NR	NR	NR	NR
NH_4-Nitrogen (mg/l)	0 15	0 13	0 04	0 15	<0.03	0 13	<0 03	<0 02	2 2	0.07	0 11	0.35	0 03	<0 02	0 02
NO_2/NO_3-Nitrogen (mg/l)	0 56	0 20	0 01	0.01	0 13	0 164	1 761	<0.02	<0 02	0 06	0 06	0 66	0 42	<0 02	0 03
Organic Nitrogen (mg/l)	0 30	0 25	0 70	0.39	0 42	0.59	0 58	0 6	0.8	0 8	0 7	0.4	0 6	<0 8	0 58
Total Nitrogen (mg/L)	1 01	0 58	0 75	0.55	<0 58	0 904	<2 371	<0 64	<3.02	0 93	0 87	1 41	1 05	<0 82	0 63
N/P Ratio	33 7	19 3	31 3	27 5	<29 0	15 1	<7 6	<32 0	<5 2	23.2	29 0	70 5	52 5	<20 5	21 0
Chloride (mg/l)	NR	NR	NR	NR	11	11	11	NR	NR	NR	NR	NR	NR	NR	NR
Sulfate (mg/l)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Sodium (mg/l)	NR	NR	NR	NR	5	5	6	NR	NR	NR	NR	NR	NR	NR	NR
Potassium (mg/l)	NR	NR	NR	NR	1 7	1 8	1 0	NR	NR	NR	NR	NR	NR	NR	NR
Iron (mg/l)	NR	NR	NR	NR	<0 06	0 32	0 17	NR	NR	NR	NR	NR	NR	NR	NR
Manganese (mg/L)	NR	NR	NR	NR	<0 03	0 20	0 53	NR	NR	NR	NR	NR	NR	NR	NR
Chlorophyll a (mg/l)	NR	NR	0.006	NR	NR	NR	NR	0 004	NR	0 0025	NR	NR	NR	NR	NR

[1] NR [illegible]

APPENDIX II
HISTORIC WATER QUALITY DATA
Grass Lake, Shawano County, WI
Water Chemistry: 09/81 - 05/82
Lake Center
(Source: WDNR)

Parameter (Units)	Date							
	09/81	09/81	11/81	11/81	03/82	03/82	05/82	05/82
Depth (feet)	3	30	0	46	3	33	0	46
Water Temperature (°F)	68	48	50	43	NR	NR	60	40
Air Temperature (°F)	60	–	60	–	NR	–	75	–
Cloud Cover (%)	95	–	0	–	NR	–	30	–
Dissolved Oxygen (mg/L)	7.8	0.0	10.9	0.0	NR	NR	11.6	0.0
Secchi Depth (feet)	11.9	–	8.2	–	NR	–	9.2	–
pH (SU)	8.0	7.5	7.9	6.9	NR	NR	8.4	7.7
Conductivity (umhos/cm)	NR	NR	NR	NR	NR	NR	NR	NR
Alkalinity (mg/l $CaCO_3$)	130	162	142	170	166	168	150	182
Magnesium (mg/l)	NR	NR	NR	NR	NR	NR	NR	NR
Calcium (mg/l)	NR	NR	NR	NR	NR	NR	NR	NR
Turbidity (NTU's)	NR	NR	NR	NR	NR	NR	NR	NR
Reactive Phosphorous (mg/l)	<0.004	<0.004	<0.004	0.31	0.007	0.014	<0.004	0.043
Total Phosphorous (mg/l)	0.02	0.04	<0.02	0.38	0.02	0.04	0.02	0.14
NO_2-Nitrogen (mg/L)	NR	NR	NR	NR	NR	NR	NR	NR
NH_4-Nitrogen (mg/l)	<0.02	0.02	0.04	3.8	<0.02	0.08	<0.02	1.6
NO_2/NO_3-Nitrogen (mg/l)	<0.02	<0.02	0.03	<0.02	0.46	0.48	<0.02	<0.02
Organic Nitrogen (mg/l)	<0.6	0.78	0.6	4.4	<0.6	0.52	<0.6	0.2
Total Nitrogen (mg/L)	<0.64	<0.82	0.67	<8.22	<1.08	1.08	>0.64	<1.82
N/P Ratio	<32.0	<20.5	>33.5	<21.6	<53.0	27.0	<30.0	>12.9
Chloride (mg/l)	NR	NR	NR	NR	NR	NR	NR	NR
Sulfate (mg/l)	NR	NR	NR	NR	NR	NR	NR	NR
Sodium (mg/l)	NR	NR	NR	NR	NR	NR	NR	NR
Potassium (mg/l)	NR	NR	NR	NR	NR	NR	NR	NR
Iron (mg/L)	NR	NR	NR	NR	NR	NR	NR	NR
Manganese (mg/L)	NR	NR	NR	NR	NR	NR	NR	NR
Chlorophyll "a"(mg/L)	0.0046	NR	0.020	NR	NR	NR	0.006	NR

[1] NR denotes no reading given

APPENDIX II

HISTORIC WATER QUALITY DATA

Grass Lake, Shawano County, WI

Secchi Readings: 05/87 - 07/90

Lake Center

(Source: CLPA Water Quality Files)

DATE	SECCHI DEPTH (ft)	DATE	SECCHI DEPTH (ft)
05-10-87	8.2	10-01-88	10.0
05-25-87	11.7	10-22-88	9.8
06-07-87	9.0	11-16-88	9.2
06-27-87	9.2	05-14-89	10.0
07-12-87	8.5	06-03-89	9.3
07-25-87	8.5	06-11-89	10.9
08-09-87	10.7	06-17-89	10.8
08-22-87	9.7	06-25-89	10.5
09-07-87	10.0	07-09-89	8.2
09-19-87	10.7	07-30-89	8.8
09-26-87	12.2	08-20-89	9.8
10-24-87	9.9	09-02-89	9.8
11-14-87	7.3	09-17-89	11.3
04-17-88	7.0	10-08-89	12.8
04-30-88	8.7	10-22-89	8.2
05-14-88	11.5	11-11-89	7.3
05-30-88	8.0	04-21-90	8.5
06-12-88	10.6	05-13-90	18.0
06-19-88	8.7	05-28-90	15.2
06-26-88	7.8	06-09-90	13.7
07-09-88	8.5	06-29-90	12.1
07-24-88	9.0	07-09-90	7.3
08-07-88	8.0	07-20-90	9.7
08-20-88	7.6		
09-05-88	9.5		
09-18-88	9.4		