IPS ENVIRONMENTAL AND ANALYTICAL SERVICES
Appleton, Wisconsin

PHASE I
LAKE MANAGEMENT PLAN
MACHICKANEE FLOWAGE
OCONTO COUNTY, WISCONSIN

REPORT TO:
MACHICKANEE FLOWAGE ADVANCEMENT ASSOCIATION

June, 1993

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ACKNOWLEDGEMENTS

Thanks is extended to the Machickanee Flowage Advancement Association Board for their assistance with this initial phase of management plan development.

Development of this plan was made possible with funds provided by the Wisconsin Department of Natural Resources Lake Management Planning Grant Program, the Machickanee Flowage Advancement Association, the Town of Stiles, the Oconto County Land Conservation Department and the Oconto Electric Cooperative.

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GLOSSARY OF TERMS (1, 2, 3)

Best Management Practices (BMP's) — Land use practices to control the interactive processes of erosion, runoff and nutrient or pesticide inflows.

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 those natural lakes having inflowing and outflowing streams.

Edge — A biologically diverse area located at the interface of differing habitat types.

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.

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.

Mesotrophic — A lake of intermediate photosynthetic activity and transparency.

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.

GLOSSARY OF TERMS
(Continued)

Physicochemical	Pertaining to physical and/or chemical characteristics.
Residence Time	Commonly called the hydraulic residence time. The amount of time required to completely replace the lake's current volume of water with an equal volume of "new" water.
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.
Watershed to Lake Ratio (W/L Ratio)	The area of the watershed divided by the lake surface area.

SUMMARY

The Machickanee Flowage is an impoundment of the Oconto River located in southeast Oconto County, Wisconsin. The 463 acre pool is maintained by a dam owned by the Oconto Electric Cooperative. Prior to February, 1978, Scott Paper Company had operated an ammonia based sulfite paper mill on the Oconto River about six miles upstream from the Flowage. Organic loading from the mill created unsuitable instream conditions for most fish species; low dissolved oxygen (DO) and subsequent fish kills were common.

The mill was cited for wastewater discharge permit noncompliance in 1977 and later agreed to a settlement of which $600,000 was allocated to the Wisconsin Department of Natural Resources (WDNR) to restore the health of the Oconto River. The restoration program began in 1981 and included a three month drawdown of the Machickanee Flowage, chemical treatment for rough fish control, repopulation of fish in the flowage and the Oconto River below the dam, access development and monitoring.

The River, and subsequently the Flowage, have since made dramatic improvements. DO was above fish sustainable levels throughout 1992 monitoring and in-lake nutrients were lower than typical for impoundments. Nutrient inflow observed during runoff events was variable but not exceptionally high. Sedimentation estimates varied from near to higher than that typical for impoundments. Sedimentation potential is high (watershed about 1,000 sq mi) but apparently moderated by a largely forested watershed and overall basin morphometry. Plant populations which were once scarce, now grow abundantly and are apparently dominated by Eurasian Milfoil. Recent fish surveys have indicated exceptional growth.

Management of the Machickanee Flowage should target continued monitoring, improved recreational access (through aquatic plant harvest/control), reduction of nutrient and sediment inflows to the system and exotic species control and prevention.

- Monitoring should be continued to track trends. Event monitoring provided highly variable data and should be continued. Self-Help monitoring should be implemented.
- While plant growth provides benefits such as shoreline stabilization, nutrient uptake and fish food and habitat production, populations consist of nuisance levels of few species. Steps need to be taken to create access and **edge**[1] through plant cover. Plant management should include and emphasize steps to prevent transfer of Eurasian Milfoil from the system and introduction of new exotics to the system.
- Watershed wide **Best Management Practices (BMP's)** should be implemented to control nutrient and sediment inputs, but riparian management practices should also be encouraged.

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

INTRODUCTION

Machickanee Flowage is an impoundment of the Oconto River located in southeast Oconto County, Wisconsin. The impoundment was created by construction of a dam in 1851; the existing dam (known as the Stiles Dam) was built in 1949 and is owned by the Oconto Electric Cooperative. The dam has a head of about 19 feet and is used for hydroelectric power generation.

The Machickanee Flowage Advancement Association (MFAA) was formed to help provide leadership and coordination of resource preservation efforts. The MFAA currently has approximately 90 paid members and is governed by an elected, three person, Board.

The MFAA, in October 1991, decided to pursue development of a management plan under the Wisconsin Department of Natural Resources (WDNR) Lake Management Planning Grant Program. The MFAA Board selected IPS Environmental & Analytical Services (IPS) of Appleton, Wisconsin as its consultant to assist with development of the plan. A grant application, incorporating required or recommended program components and the objectives below, was prepared, submitted, and approved in October, 1991:

- determine flowage water quality and track trends,
- locate, quantify and identify aquatic plant (weed) populations,

- determine potential impacts of upstream dischargers on water quality,
- increase the awareness of property owners of flowage's problems and establish continuing support for rehabilitation and maintenance efforts.

DESCRIPTION OF AREA

Machickanee Flowage (T27N R20E S4, T28N R20E, S32, 33, 34) is a **drainage lake** (i.e., with a permanent inlet and outlet) located in the Towns of Stiles (North) and Abrams (South), in Oconto County, Wisconsin (Figure 1). The lake is actually an impoundment of the Oconto River created by a dam with a 19 foot head. Impoundments in general, have extensive shallow shelf areas, experience periodic flushing and continuous "filling in" and are often more prone, than natural lakes, to non-point source nutrient and sediment inputs. Basin morphometry and chemical and biological dynamics are often directly related to the relatively extensive watersheds and effects of changing flow conditions in the parent river.

The general topography of Oconto County is related to glacial activity; topography adjacent to the lake is nearly level to steep. Major soil types on the lake perimeter are excessively drained Shawano fine sands on 2 - 30 percent slopes, Oconto fine sandy loam on 2 - 30 percent slopes, and poorly drained Cormant loamy fine sands on 0 - 1 percent slopes. Soil permeability is moderate (Oconto) to rapid (Shawano and Cormant). The three major soil types are generally unsuited for septic systems because of ponding (Cormant), steep slope (Shawano, Oconto) or inability to filter septate (Shawano, Oconto)(4).

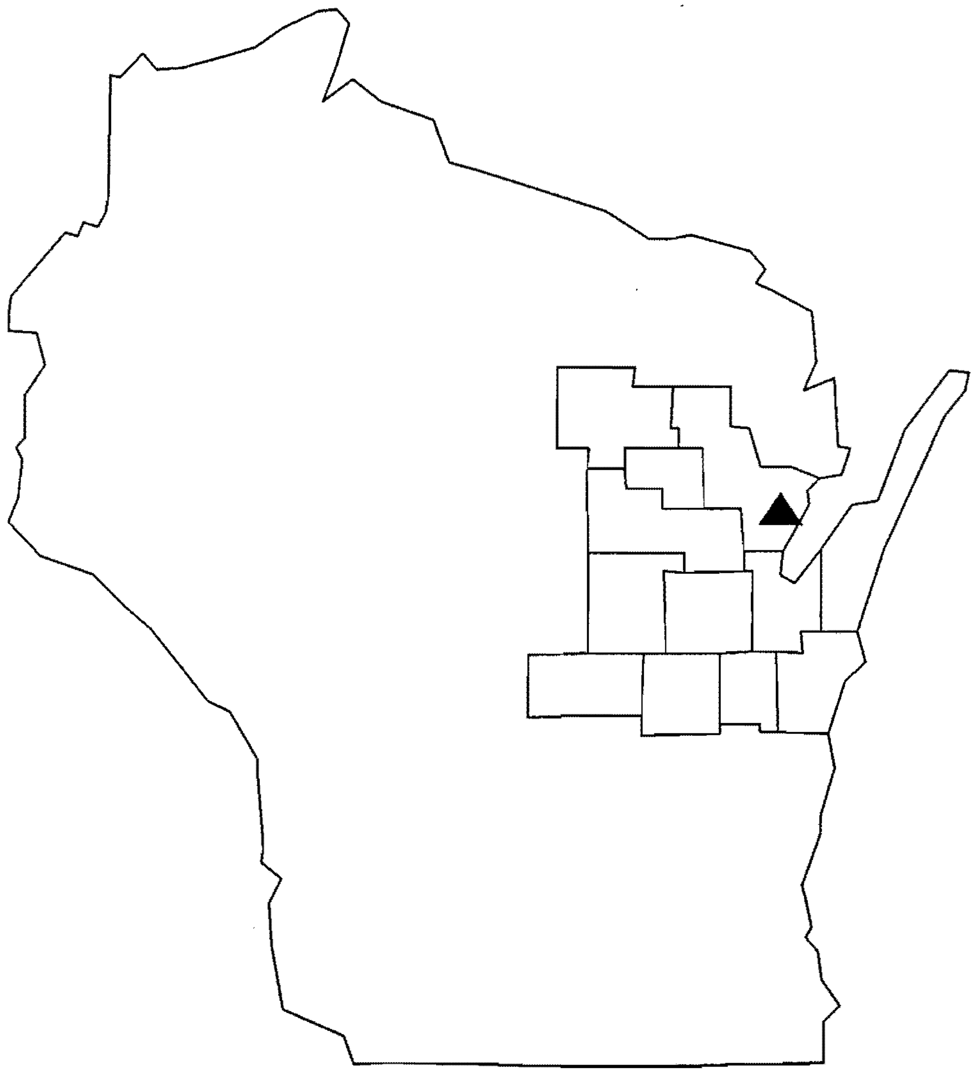

Figure 1. Location Map, Machickanee Flowage, Oconto County, WI.

Machickanee Flowage has a surface area of 463 acres, an average depth of 6 feet, a maximum depth of 21 feet and a lake volume of approximately 2,778 acre-feet (5). The **fetch** is 1.7 miles in a southwest-northeast orientation and the width is 0.7 miles in a northwest-southeast orientation. The **residence time** for the impoundment was estimated to be 2.6 days at a flow of 16.4 cubic meters per second. Predominant **littoral** substrates include sand (80%) and muck (20%) (6).

The Machickanee Flowage watershed is nearly 1,000 square miles and predominantly forested (about 75%) with open/agricultural influence near the impoundment. The **watershed to lake ratio (W/L ratio)** is about 1400, meaning 1400 times more land than lake surface area drains to the lake. This value is very high given the average for impoundments in Wisconsin (676). The average for natural drainage lakes (those having a permanent inlet and outlet) is 88. This high number indicates an increased potential for flow variations, flushing and non-point source nutrient input effects compared to other impoundments and natural lakes.

Pollution of the Oconto River dates back to the 1800's. Low dissolved oxygen (DO) and fish kills were not uncommon and were caused by an ammonia based sulfite paper mill in Oconto Falls (about 6 miles upstream). The mill was cited in 1977 for noncompliance with its wastewater discharge permit and later agreed to a $1 million settlement for damages to the Oconto River. Of that amount, $600,000 was allocated to the Wisconsin Department of Natural Resources (WDNR) to restore the health of the Oconto River. The restoration program began in 1981 and included a three month drawdown of the Machickanee Flowage (to chemically treat for rough fish), repopulation of sport fish in the flowage and the Oconto River below the dam, access development and continued monitoring.

The latest fish survey (April - October, 1988) indicated the following fish species to be present: northern pike (Esox lucius), largemouth bass (Micropterus salmoides), yellow perch (Perca flavescens), walleye (Stizostedion vitreum vitreum), black crappie (Pomoxis nigromaculatus), pumpkinseed (Lepomis gibbosus), bluegill (Lepomis macrochirus), bullhead (Ictalurus spp.), white sucker (Catostomus commersoni), and carp (Cyprinus carpio) (7). Recent management and stocking efforts have been directed toward the largemouth bass, northern pike, and panfish fisheries. Surveys also indicated exceptional growth which is typical of a recently reclaimed or rejuvenated resource.

Public access is available at three locations. A paved boat ramp is maintained by Oconto County on the south shore near the Stiles Dam, and carry on/walk-in access sites are located off Machickanee Lane and Birchwood Shores on the north shore.

METHODS

FIELD PROGRAM

Machickanee Flowage water sampling was conducted January 29, April 30, July 6, and September 30, 1992, at Stations 1901 (Oconto River inlet), 1902 (mid-lake) and 1903 (deepest point) (Table 1, Figure 2). Stations 1901 and 1902 were sampled mid-depth (designated "M") and 1903 was sampled three feet below the surface ("S") and three feet above the bottom ("B").

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

Samples were taken for laboratory analyses with a Kemmerer water bottle. Samples were labelled, preserved if necessary, and packed on ice in the field; delivery to the laboratory was made via overnight carrier. All laboratory analyses were conducted at the State Laboratory of Hygiene (Madison, WI) using WDNR or APHA (8) methods. Winter parameters determined by the laboratory included laboratory pH, total alkalinity, total Kjeldahl

Table 1. Sampling Station Descriptions, Machickanee Flowage, 1992.

WATER QUALITY

Regular Monitoring

Site	Latitude/Longitude		Depth
1901	44° 51' 16"	88° 06' 06"	6.0 feet
1902	44° 51' 19"	88° 04' 02"	7.0 feet
1903	44° 51' 26"	88° 04' 22"	21.0 feet

Event Monitoring

Site	Description
19E1	Brehmer Creek inlet (perennial) draining forested land and entering near Station 1901
19E2	Intermittent inlet draining forested land North of the flowage
19E3	Intermittent inlet draining forested land South of the flowage
19E4	Splinter Creek entering on the north shore
19E5	Intermittent inlet 100 yards East of Machickanee Lane

MACROPHYTE TRANSECTS

Transect	Origin Latitude/Longitude		Transect Length(m)	Bearing (Degrees)	Depth Range[1]
A	44° 51' 18"	88° 06' 03"	6	190	1/2
B	44° 51' 13"	88° 06' 04"	4	10	1/2
C	44° 51' 06"	88° 04' 58"	6	245	1/2/3
D	44° 51' 03"	88° 05' 06"	90	65	1/2/3
E	44° 51' 07"	88° 04' 27"	350	110	1/2/3
F	44° 51' 43"	88° 03' 31"	12	60	1/2/3
G	44° 51' 45"	88° 03' 24"	30	240	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)

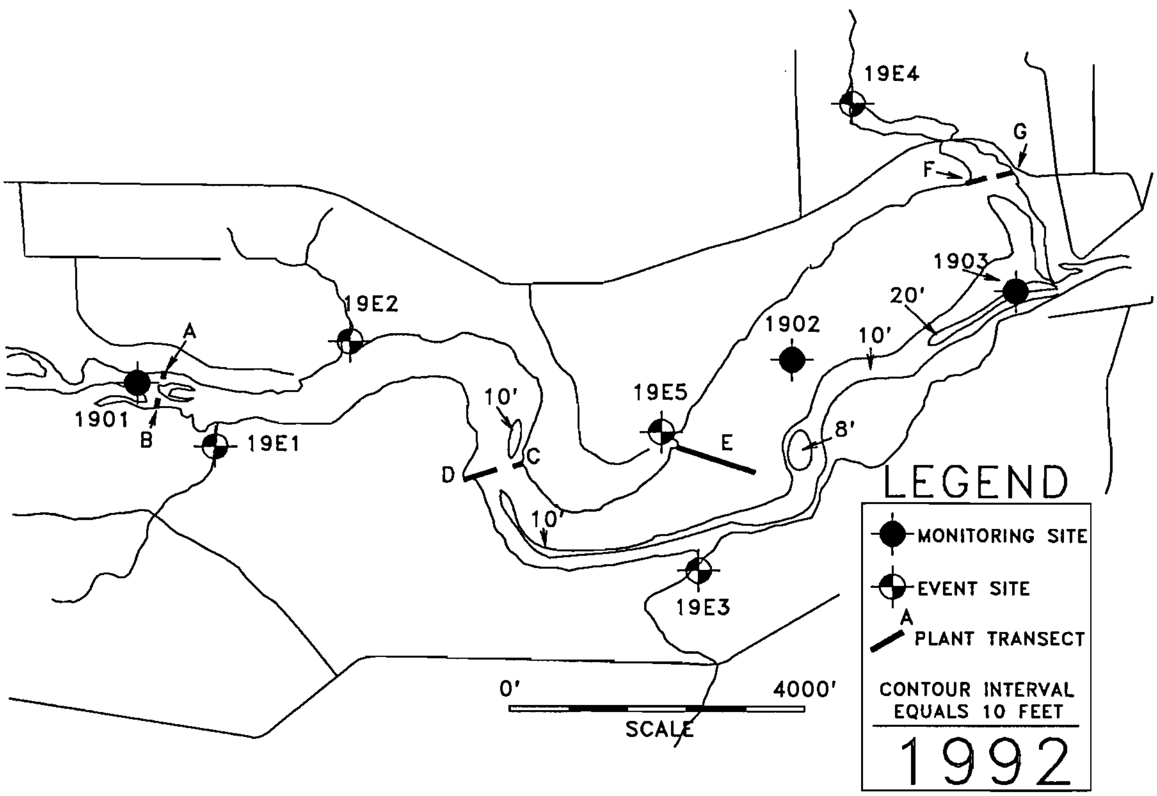

Figure 2. Sampling Station Locations, Machickanee Flowage, Oconto County, WI, 1992.

nitrogen, ammonia nitrogen, nitrate/nitrite nitrogen, total phosphorus, and dissolved phosphorus. Spring water quality parameters included laboratory pH, total alkalinity, total Kjeldahl nitrogen, ammonia nitrogen, nitrate/nitrite nitrogen, total phosphorus, dissolved phosphorus, 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.

In addition to regular monitoring sites, event sampling sites were located at five inlets to the impoundment (Table 1, Figure 2). Runoff samples were collected from each site on August 26 and November 11, 1992 to characterize nutrient inputs to the lake. Event sample laboratory analyses included total Kjeldahl nitrogen, ammonia nitrogen, nitrate/nitrite nitrogen, total phosphorus and dissolved phosphorus.

Macrophyte surveys were conducted July 6 and September 30, 1992 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-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. Seven transects were sampled to provide information from various habitats and areas of interest (Table 1, Figure 2).

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.

OTHER

Water Quality Information

Additional lake information was retrieved from the WDNR Surface Water Inventory (6), Wisconsin Self Help Monitoring Program (10), the WDNR Wisconsin Lakes publication (5) and the WDNR WI LAKES Bulletin Board System.

Land Use Information

Details of zoning and specific land uses were obtained from the Oconto County UW-Extension, Oconto 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 outdated, was confirmed by field reconnaissance.

Ordinance information was taken from the Oconto County Zoning Ordinance, and Oconto County Erosion Control and Animal Waste Management Plans which were acquired from the Oconto County Land Conservation Department.

Public Involvement Program

Various public involvement activities were coordinated with the planning process; these activities are summarized in Appendix I.

FIELD DATA DISCUSSION

Impoundments differ from natural lakes in that they characteristically have much larger watersheds, exhibit periodic flushing, and "fill-in". While the physical, chemical and biological characteristics natural lakes tend more toward a seasonally variable state of equilibrium, those of impoundments are typically more variable as they are continuously affected by the parent river. Physicochemical parameters and biological communities in reservoirs are longitudinally and transectionally related to basin morphometry, are temporally affected by flow conditions (in the upstream reach) and water mass retention time (in the lower reach), and are influenced by flow release operations at the dam.

Machickanee Flowage, by general definition, is a drainage lake because it has a permanent inlet and outlet stream. Due to shallow shelf areas and the organic nature of deposited sediments, Machickanee Flowage provides habitat very conducive to aquatic plant growth.

The Machickanee Flowage watershed is primarily forested, especially in northern areas, with more open/agricultural land in the lower watershed. Land use adjacent to the flowage is predominantly forested/forested residential (Figure 3).

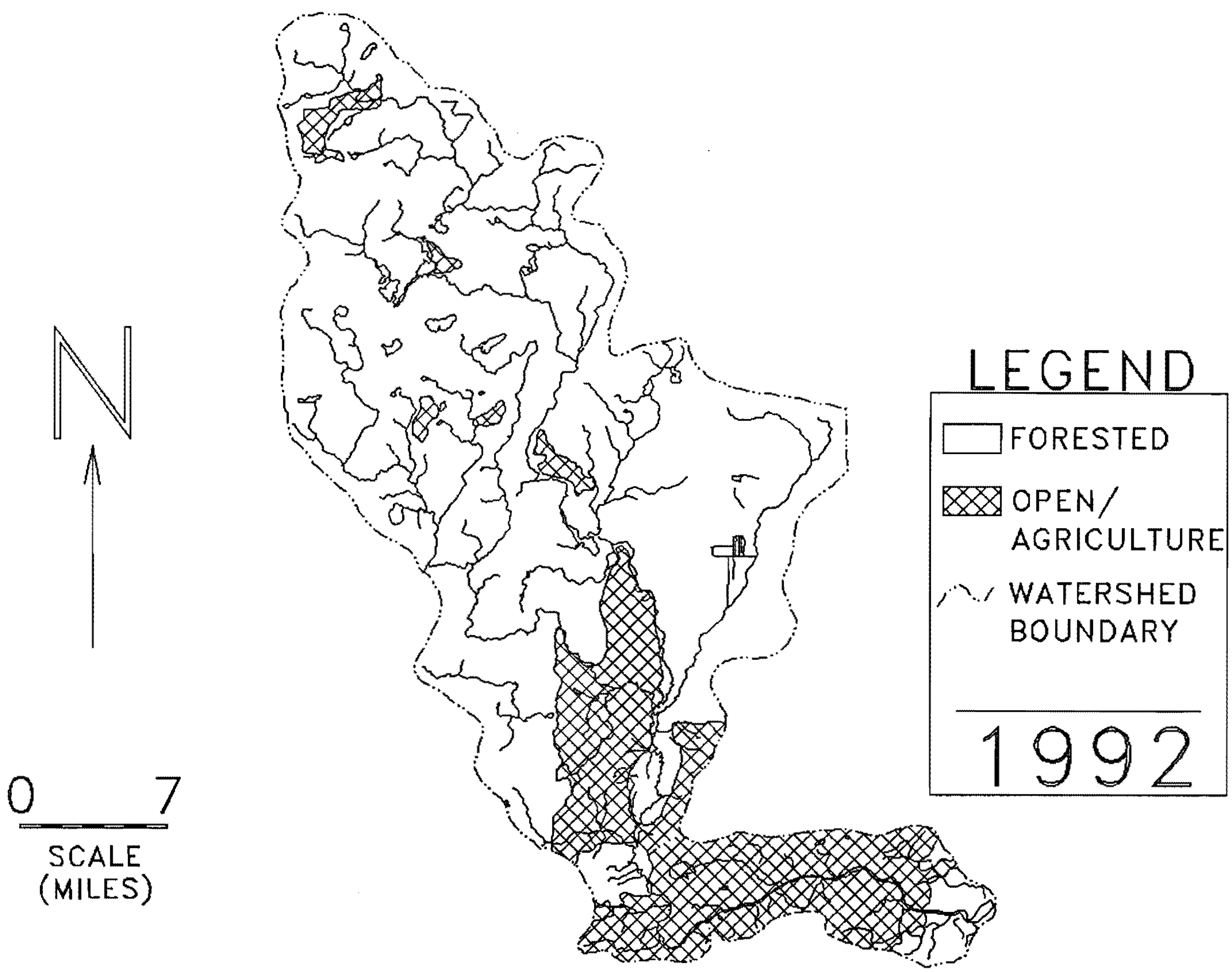

Figure 3. Land Uses in the Machickanee Flowage Watershed, 1992.

Phosphorus is often the limiting major nutrient in algal and plant production. Total phosphorus levels (for the three sampling stations) during the 1992 monitoring period ranged from 0.013 to 0.032 mg/l (parts per million) with an average value of 0.025 mg/l [median = 0.026, standard deviation (σ) = 0.006 mg/l] (Tables 2-4). Nitrogen to phosphorus ratios (**N/P ratio**) greater than 15 indicated Machickanee Flowage to be phosphorus limited for all samples. Similar results from surface and bottom samples from the deepest point indicated that Machickanee Flowage is a well mixed impoundment. Very similar water quality was observed for the three sample sites.

Surface summer total phosphorus levels in 1992 (range 0.026 - 0.032 mg/l, ave = 0.029, median = 0.029, σ = 0.003 mg/l) were, according to a recent compilation of summer total phosphorus levels in upper midwestern lakes (11), slightly lower than typical (0.030 to 0.050 mg/l) for natural lakes in the region in which Machickanee Flowage is located. Characteristically, impoundments would have higher total phosphorus averages than natural lakes; Machickanee Flowage total phosphorus is considerably lower than an average for 100 Wisconsin impoundments (ave. = 0.064, median = 0.035, σ = 0.100 mg/l). Average summer total phosphorus was also lower than that for waterbodies (79 lakes and impoundments) with similar retention times (average = 0.094, median = 0.075, σ = 0.079 mg/l) (Figure 4) (12).

Table 2. Water Quality Parameters, Station 1901 (Oconto River Inlet), Machickanee Flowage, 1992.

Parameter (Units)	Sample[1]	Date			
		01/29/92	04/30/92	07/06/92	09/30/92
Secchi (feet)		NR[2]	4.4	4.1	2.7
Cloud Cover (%)		NR	100	30	30
Temperature (°C)	M	NR	11.00	21.29	11.85
pH (S.U.)	M	NR	6.82	8.56	7.74
D.O. (mg/l)	M	NR	10.80	12.10	10.20
Conductivity (µmhos/cm)	M	NR	187	258	233
Laboratory pH (S.U.)	M	NR	8.05	NR	NR
Total Alkalinity (mg/l)	M	NR	85	NR	NR
Total Kjeldahl N (mg/l)	M	NR	0.5	0.4	0.7
Ammonia Nitrogen (mg/l)	M	NR	0.029	0.026	0.026
NO_2 + NO_3 Nitrogen (mg/l)	M	NR	0.095	0.095	0.160
Total Nitrogen (mg/l)	M	NR	0.595	0.495	0.860
Total Phosphorus (mg/l)	M	NR	0.02	0.026	0.032
Diss. Phosphorus (mg/l)	M	NR	0.003	0.004	0.005
N/P Ratio	M	NR	29.8	19.0	26.9
Chlorophyll *a* (µg/l)	M	NR	6	9	2.86

[1] M = Mid Depth
[2] NR = No Reading

Table 3. Water Quality Parameters, Station 1902 (Mid-Lake), Machickanee Flowage, 1992.

Parameter (Units)	Sample[1]	Date			
		01/29/92	04/30/92	07/06/92	09/30/92
Secchi (feet)		NR[2]	4.9	6.0	4.2
Cloud Cover (%)		100	100	40	30
Temperature (°C)	M	0.20	10.48	19.92	13.01
pH (S.U.)	M	7.37	7.72	8.40	7.96
D.O. (mg/l)	M	12.80	11.10	9.58	10.10
Conductivity (μmhos/cm)	M	323	184	252	244
Laboratory pH (S.U.)	M	8.10	8.05	NR	NR
Total Alkalinity (mg/l)	M	156	84	NR	NR
Total Kjeldahl N (mg/l)	M	0.3	0.5	0.5	0.6
Ammonia Nitrogen (mg/l)	M	0.076	0.030	0.024	0.026
NO_2 + NO_3 Nitrogen (mg/l)	M	0.417	0.099	0.059	0.150
Total Nitrogen (mg/l)	M	0.717	0.599	0.559	0.750
Total Phosphorus (mg/l)	M	0.013	0.02	0.030	0.028
Diss. Phosphorus (mg/l)	M	0.004	0.005	0.008	0.011
N/P Ratio	M	55.2	30.0	18.6	26.8
Chlorophyll a (μg/l)	M	NR	5	6	3.15

[1] M = Mid Depth
[2] NR = No Reading

Table 4. Water Quality Parameters, Station 1903 (Deepest Point), Machickanee Flowage, 1992.

Parameter (Units)	Sample[1]	Date			
		01/29/92	04/30/92	07/06/92	09/30/92
Secchi (feet)		NR[2]	4.9	4.9	4.1
Cloud Cover (%)		100	100	45	30
Temperature (°C)	S	0.32	10.38	20.46	12.84
	B	0.42	9.90	18.91	12.55
pH (S.U.)	S	7.15	7.86	9.13	7.78
	B	7.31	7.65	8.56	7.70
D.O. (mg/l)	S	13.40	10.80	10.50	9.73
	B	11.80	10.40	7.06	9.54
Conductivity (µmhos/cm)	S	329	185	261	244
	B	325	183	258	244
Laboratory pH (S.U.)	S	8.10	7.95	NR	NR
	B	8.00	7.99	NR	NR
Total Alkalinity (mg/l)	S	159	84	NR	NR
	B	157	83	NR	NR
Total Kjeldahl N (mg/l)	S	0.6	0.6	0.4	0.6
	B	0.4	0.6	0.4	0.6
Ammonia Nitrogen (mg/l)	S	0.064	0.026	0.020	0.029
	B	0.071	0.030	0.062	0.032
NO_2 + NO_3 Nitrogen (mg/l)	S	0.422	0.099	0.065	0.165
	B	0.411	0.102	0.055	0.161
Total Nitrogen (mg/l)	S	1.022	0.699	0.465	0.765
	B	0.811	0.702	0.455	0.761
Total Phosphorus (mg/l)	S	0.031	0.02	0.026	0.032
	B	0.015	0.02	0.024	0.031
Diss. Phosphorus (mg/l)	S	0.006	0.005	0.002	0.012
	B	0.005	0.004	0.005	0.013
N/P Ratio	S	33.0	35.0	19.9	23.9
	B	54.1	35.1	19.0	24.5
Chlorophyll *a* (µg/l)	S	NR	5	14	3.86

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

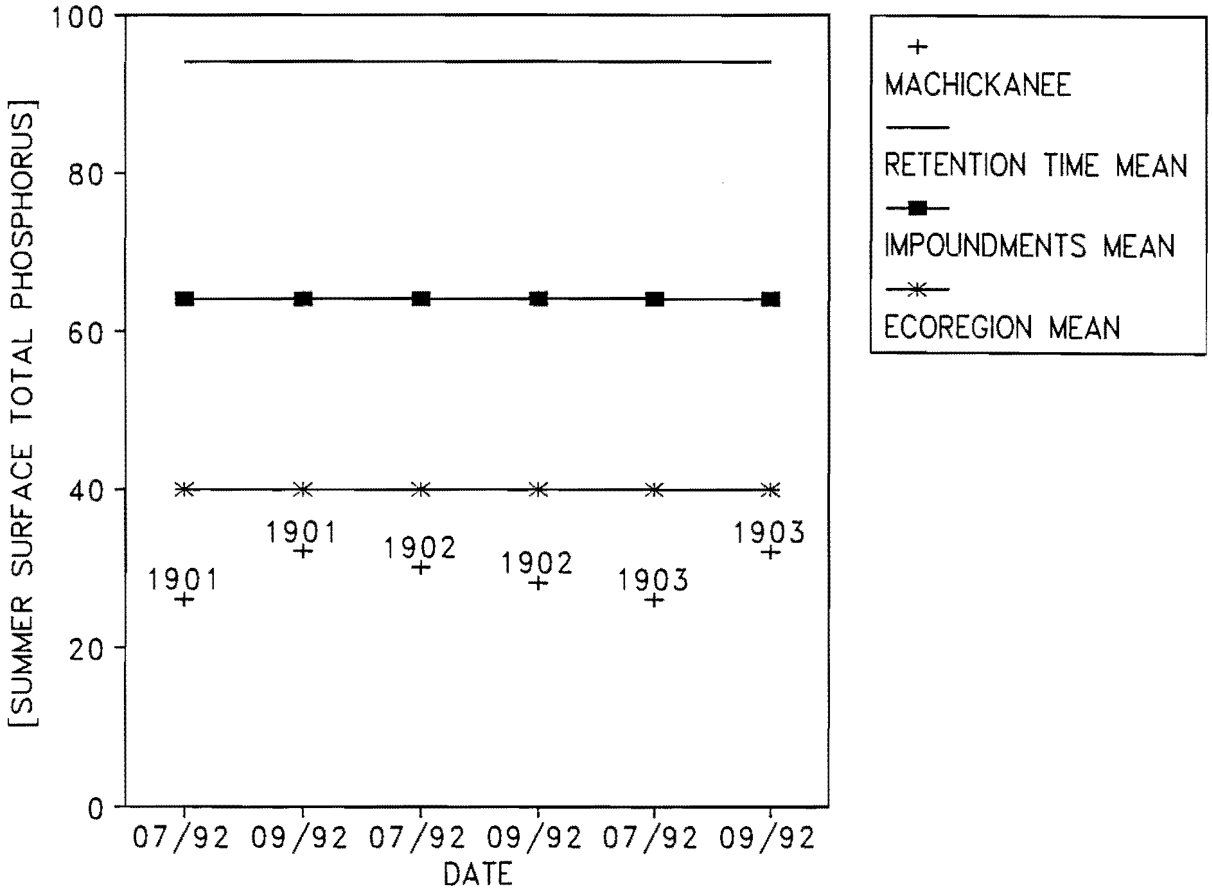

Figure 4. Comparison of Total Phosphorus Levels, Machickanee Flowage, Oconto County, WI.

Event monitoring total phosphorus levels varied between sites and dates and were somewhat higher than levels observed in-lake. Event total phosphorus ranged from 0.021 to 0.103 mg/l (ave. = 0.049, median = 0.033, σ = 0.030 mg/l) on August 26, 1992, and from 0.031 to 0.108 mg/l (ave = 0.061, median = 0.060, σ = 0.027 mg/l) on November 11, 1992 (Tables 5 and 6).

Nitrogen can be highly variable between lakes and should only be analyzed on a relative or trend basis within the same lake. Total in-lake nitrogen for 1992 monitoring ranged from 0.465 to 1.022 mg/L. Generally, highest total nitrogen readings occurred under ice cover. Event monitoring total nitrogen ranged from 0.433 to 1.015 mg/l for August samples, and 0.560 to 2.017 mg/l for November samples. Significantly higher levels of nitrogen and phosphorus were detected at Station 19E3 during November event sampling, August samples, however, indicated the lowest readings (of the five samples) for the same station.

Other indicators of lake **eutrophication** status, in addition to nutrients, 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 (13) utilizes Secchi transparency, chlorophyll a, and total phosphorus. As with most indices,

Table 5. Event Water Quality Parameters, August 26, 1992, Machickanee Flowage.

Parameter (Units)	19E1	19E2	19E3	19E4	19E5
Total Kjeldahl N (mg/l)	0.5	0.6	0.3	1.0	0.7
Ammonia Nitrogen (mg/l)	0.015	0.100	0.023	0.025	0.032
NO_2 + NO_3 Nitrogen (mg/l)	0.505	0.088	0.133	0.015	0.306
Total Nitrogen (mg/l)	1.005	0.688	0.433	1.015	1.006
Total Phosphorus (mg/l)	0.030	0.033	0.021	0.103	0.057
Diss. Phosphorus (mg/l)	0.004	0.008	0.005	0.020	0.011
N/P Ratio	33.5	20.8	20.6	9.9	17.6

Table 6. Event Water Quality Parameters, November 11, 1992, Machickanee Flowage.

Parameter (Units)	19E1	19E2	19E3	19E4	19E5
Total Kjeldahl N (mg/l)	0.8	0.6	1.6	0.5	1.1
Ammonia Nitrogen (mg/l)	0.031	0.020	0.029	0.032	0.017
NO_2 + NO_3 Nitrogen (mg/l)	0.048	0.041	0.417	0.060	0.103
Total Nitrogen (mg/l)	0.848	0.641	2.017	0.560	1.203
Total Phosphorus (mg/l)	0.060	0.038	0.108	0.031	0.070
Diss. Phosphorus (mg/l)	ND[1]	0.002	0.004	0.005	0.003
N/P Ratio	14.1	16.9	18.7	18.1	17.2

[1] ND = Not Detectable

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 Machickanee Flowage, in general, indicated a primarily late **mesotrophic** to **eutrophic** status (Figure 5). Historic data (1977 - 1989, Appendix II) was highly variable, probably as a result of changing flow conditions of the Oconto river. Recent data appear to be less variable than in the past.

During recent macrophyte surveys, macrophytes (Table 7) were found at all 38 sample sites (sample sites = number of depth ranges sampled on both dates) and often at nuisance levels (Tables 8-10, Appendix III). Water milfoil (Myriophyllum spp.) was widespread and most abundant (observed at 25 sites) and appears to include Eurasian Milfoil (Myriophyllum spicatum). Species determination was not verifiable because the plants lacked necessary flower parts; plants did possess, however, leaves with 12-15 pairs of leaflets and red tinged stems and shoots (characteristics normally associated with Eurasian Milfoil). Eurasian Milfoil spreads quickly, often occurs at nuisance levels (14), displaces more desirable native vegetation and can alter plant and animal assemblages within a lake. Milfoils are able to reproduce by seeds, winter buds, and by

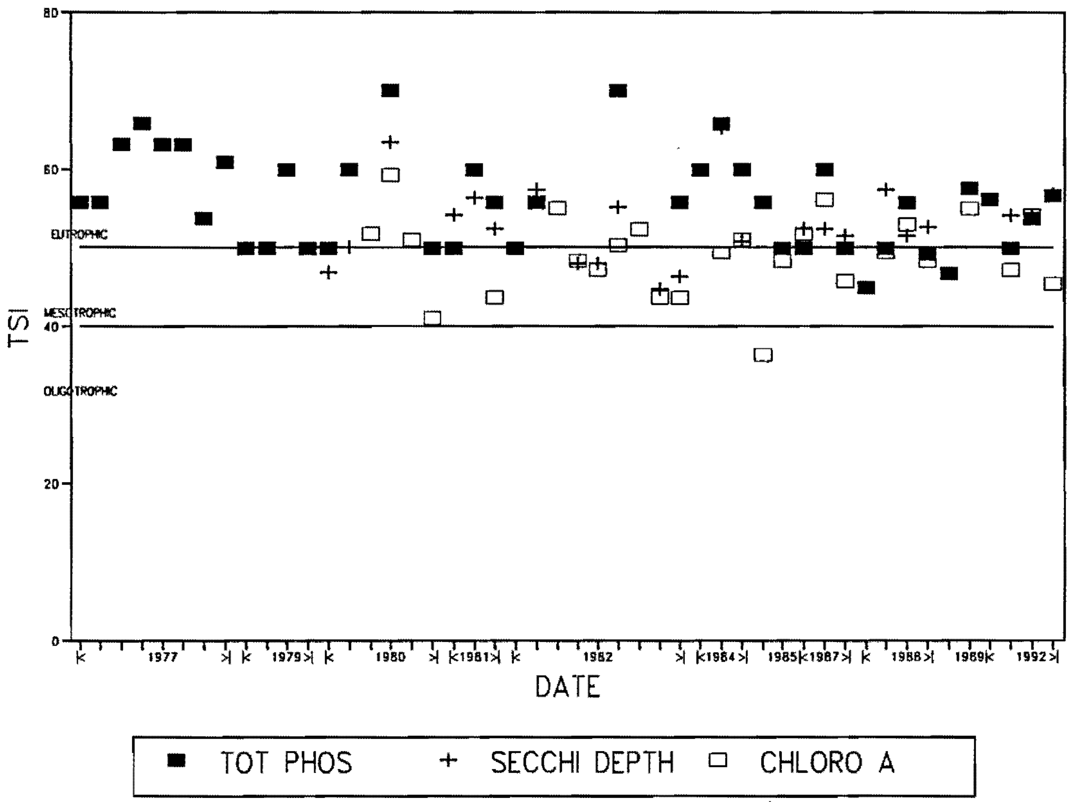

Figure 5. Trophic State Index for Chlorophyll a, Total Phosphorus and Secchi Depth, Machickanee Flowage.

Table 7. Macrophyte Species Observed, Machickanee Flowage, 1992 (14).

Taxa	Code
Coontail (*Ceratophyllum demersum*)	CERDE
Muskgrass (*Chara* sp.)	CHASP
Common waterweed (*Elodea canadensis*)	ELOCA
Filamentous algae	FILAL
Small duckweed (*Lemna minor*)	LEMMI
Water milfoil (other than Eurasian) (*Myriophyllum* spp.)	MYRSPE
Eurasian water milfoil (*Myriophyllum spicatum*)	MYRSPI
Bushy pondweed (*Najas* sp.)	NAJSP
Nitella (*Nitella* sp.)	NITSP
White water lily (*Nymphaea* sp.)	NYMSP
Large-leaf pondweed (*Potamogeton amplifolious*)	POTAM
Leafy pondweed (*Potamogeton foliosus*)	POTFO
Illinois pondweed (*Potamogeton illinoensis*)	POTIL
Sago pondweed (*Potamogeton pectinatus*)	POTPE
Flat-stem pondweed (*Potamogeton zosteriformis*)	POTZO
Water crowfoot (*Ranunculus* spp.)	RANSP
Arrowhead (*Sagittaria* sp)	SAGSP
Rush (*Scirpus* sp.)	SCISP
Broad-leaf cattail (*Typha latifolia*)	TYPLA
Eel grass (water celery) (*Vallisneria americana*)	VALAM
Watermeal (*Wolffia columbiana*)	WOLCO

Table 8. Occurrence and Abundance of Macrophytes by Depth, Machickanee Flowage, July, 1992.

CODE	Depth Ranges 1 (N=7) % of Sites	1 (N=7) Σ Abundance (range)	2 (N=7) % of Sites	2 (N=7) Σ Abundance (range)	3 (N=5) % of Sites	3 (N=5) Σ Abundance (range)
MYRSPI	43	3(1)	57	14(3-4)	40	6(2-4)
CERDE	29	3(1-2)	86	14(1-4)	80	6(1-3)
FILAL	43	7(1-3)	57	12(2-4)	0	0
VALAM	57	7(1-3)	57	7(1-2)	40	4(2)
POTFO	43	8(2-3)	43	6(2)	0	0
SCISP	57	4(1)	57	8(1-3)	40	2(1)
MYRSPE	14	1(1)	57	12(2-4)	0	0
POTZO	57	4(1)	57	7(1-2)	0	0
NYMSP	29	4(2)	71	7(1-2)	0	0
POTAM	43	7(1-4)	29	3(1-2)	0	0
WOLCO	43	5(1-2)	29	4(1-3)	0	0
LEMMI	43	6(2)	14	2(2)	0	0
ELOCA	29	4(2)	29	3(1-2)	0	0
NAJSP	43	5(1-2)	0	0	0	0
RANSP	14	1(1)	0	0	0	0
POTIL	0	0	14	1(1)	0	0
SAGSP	14	1(1)	0	0	0	0
CHASP	14	1(1)	0	0	0	0
TYPLA	0	0	0	0	0	0
POTPE	0	0	0	0	0	0

fragmentation (15), though fragmentation accounts for most of its spread. When harvesting, care must be taken to avoid introduction, via fragments, into previously unpopulated areas.

Coontail (*Ceratophyllum demersum*, observed at 22 sites) was also common and relatively abundant. Coontail has worldwide range, is a submergent plant typically found on soft substrates, and often grows abundantly in turbid water where many plants do not. It is

Table 9. Occurrence and Abundance of Macrophytes by Depth, Machickanee Flowage, September, 1992.

CODE	1 (N=7)		2 (N=7)		3 (N=5)	
	% of Sites	Σ Abundance (range)	% of Sites	Σ Abundance (range)	% of Sites	Σ Abundance (range)
MYRSPI	57	7(1-4)	100	25(1-5)	100	18(2-5)
CERDE	57	6(1-3)	29	5(2-3)	80	10(2-3)
ELOCA	43	4(1-2)	29	7(3-4)	80	4(1)
VALAM	43	4(1-2)	29	4(1-3)	80	6(1-2)
NYMSP	29	6(3)	57	8(1-3)	0	0
LEMMI	43	9(1-5)	43	4(1-2)	0	0
FILAL	43	4(1-2)	43	4(1-2)	20	1(1)
MYRSPE	0	0	29	4(2)	60	5(1-2)
POTZO	0	0	57	7(1-2)	20	1(1)
CHASP	29	8(4)	0	0	0	0
WOLCO	14	4(4)	14	2(2)	0	0
POTFO	14	1(1)	43	3(1)	0	0
POTAM	29	3(1-2)	14	1(1)	0	0
NAJSP	29	4(2)	0	0	0	0
POTPE	14	4(4)	0	0	0	0
RANSP	0	0	14	3(3)	0	0
POTIL	0	0	14	1(1)	0	0
TYPLA	14	1(1)	0	0	0	0
SCISP	0	0	0	0	0	0
SAGSP	0	0	0	0	0	0

Depth Ranges

rated as a fair waterfowl food and provides fish with both forage and spawning habitat. The plant develops roots but does not need them as it can often be found free-floating. Coontail has been known to reach nuisance levels and does so in part because the plant can grow to over six feet long with numerous branches (14). Thorny seeds are produced underwater during the growing season but coontail reproduces primarily by the formation of winter buds which grow into new plants in Spring (15).

Table 10. Abundance Distribution and Substrate Relations for Selected Macrophytes, Machickanee Flowage, 1992.

Transect	Substrate	Species Code MYRSPI J S	CERDE J S	VALAM J S	FILAL J S	NYMSP J S	ELOCA J S	MYRSPE J S	LEMMI J S	POTZO J S	POTFO J S
A1	MUCK	0 0	0 0	1 0	0 0	0 0	0 0	0 0	0 0	1 0	0 0
A2	MUCK	0 1	0 0	0 0	0 0	0 3	0 0	0 0	0 0	2 1	2 0
B1	SAND/MUCK/ROCK	0 0	0 1	3 1	0 1	0 0	0 1	0 0	0 0	0 0	0 0
B2	GRAVEL/MUCK	0 2	2 0	2 0	0 1	2 0	0 0	0 0	0 0	1 2	2 1
C1	SAND/GRAV/RK	0 0	0 1	1 2	0 1	0 0	0 0	0 0	0 0	0 0	0 0
C2	SAND/GRAV/MUCK	0 3	1 0	2 3	0 0	0 0	0 0	0 0	0 0	0 2	0 0
C3	SAND/GRAVEL	0 2	1 0	2 2	0 0	0 0	0 1	0 0	0 0	0 1	0 0
D1	MUCK	1 1	2 3	0 0	3 2	2 3	2 1	0 0	2 1	1 0	3 0
D2	MUCK/DETRITUS	4 5	2 3	2 0	3 2	1 2	1 4	2 2	2 1	2 0	2 1
D3	SAND/GRAVEL	0 3	1 2	2 2	0 0	0 0	0 1	0 1	0 0	0 0	0 0
E1	SAND	1 1	1 1	2 0	3 0	2 3	2 2	0 0	2 3	1 0	0 0
E2	SAND	4 5	4 0	0 0	4 0	1 2	2 3	4 2	0 1	2 2	0 1
E3	SAND	4 5	1 3	0 1	0 1	0 0	0 0	0 2	0 0	0 0	0 0
F1	SAND	1 1	0 0	0 0	1 0	0 0	0 0	1 0	0 0	0 0	3 1
F2	SAND/MUCK	3 4	2 2	0 0	2 0	2 0	0 0	3 0	0 2	0 0	0 0
F3	SILT/MUCK	2 4	3 2	0 1	0 0	0 0	0 1	0 0	0 0	0 0	0 0
G1	SAND	0 4	0 0	0 1	0 0	0 0	0 0	0 0	2 5	1 0	2 0
G2	SAND/MUCK	3 5	3 0	1 1	3 1	1 1	0 0	3 0	0 0	0 0	0 0
G3	SILT/MUCK	0 4	0 3	0 0	0 0	0 0	0 1	0 2	0 0	0 0	0 0

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

Mathematical formulas for estimating sedimentation suggested significant sedimentation taking place in Machickanee Flowage. One formula (probably the most accurate of the three to be discussed), is based on inflowing and in-lake average annual total phosphorus levels and indicated a sedimentation rate (unitless number) of 20.1 (Table 11). Another estimate of sedimentation rate (FR) was derived using the square root of the flushing rate (which equals the inverse of the retention time). This estimate for Machickanee Flowage is probably low because retention time, based on lake volume, has not recently been determined, e.g., after further filling in of the basin. The FR

Table 11. Sedimentation Rates for Wisconsin Impoundments, Natural Lakes and Machickanee Flowage as Determined by Three Estimates.[1]

Sedimentation Rate Based on:	Impoundments	Natural Lakes	Machickanee Flowage
Phosphorus	-	-	20.1
FR	5.8	1.1	11.8
10/mean depth (m)	5.4	2.4	5.5

[1] Adapted from "Limnological Characteristics of Wisconsin Lakes" (12)

estimate indicated Machickanee Flowage to have a sedimentation rate about double that expected for impoundments. The third estimate equates sedimentation rate with 10 divided by the lake's mean depth (in meters). This estimate may also be in error since the average depth may have changed since last determined. This estimate indicated Machickanee Flowage to have a sedimentation rate about that expected for impoundments. If data for the last two estimates were modified to account for filling in, the estimates would increase because flushing rate would be higher (decreased lake volume) and the mean depth would be lower; it may then be assumed that these methods underestimated sedimentation.

Lakes are estimated to fill in from 0.10 to 0.50 inches per year (1). Using this estimate, combined with the sedimentation factors in Table 11, sedimentation for impoundments would range from 0.2 inches to 2.6 inches per year; Machickanee Flowage sedimentation rates would be estimated between 0.2 and 5.4 inches per year (12).

BASELINE CONCLUSIONS

Machickanee Flowage is an impoundment of the Oconto River located in the Towns of Abrams and Stiles, Oconto County. Physical characteristics of the impoundment make Machickanee Flowage prone to sedimentation, prolific macrophyte growth, non-point source nutrient inflows, and variable water quality as affected by parent river watershed and flow conditions.

- In-lake nutrient levels, despite the large size of the watershed, were slightly less than expected for natural lakes in the region and less than an average for impoundments. Event samples showed somewhat higher (but variable) levels of nutrients entering the system during/after major runoff events. Water clarity was poor to very poor which is attributable to the dark color of the Oconto River and turbidity from relatively high flushing. These conditions of reduced water clarity appear to enhance the growth potential for milfoil and coontail.

- Recreational use of the resource is restricted by widespread and abundant macrophytic growth throughout much of the open-water season. Macrophyte growth is typical of a recently reclaimed resource in that it is dense and dominated by few species, primarily milfoils and coontail. These species are able to grow great vertical lengths to reach adequate sunlight (water milfoil), or survive unrooted and floating on the surface (coontail) and thus can occupy a large portion of the surface area even with conditions of reduced sunlight penetration. Rejuvenation of the resource, abundant nutrients and predominantly soft, shallow shelf areas make conditions in Machickanee Flowage conducive to nuisance aquatic plant growth.

- Sedimentation estimates for the Machickanee Flowage (some probably biased low given old data for use in the calculations) were variable and ranged from near that expected to considerably higher than that expected for impoundments. Except for a well defined river channel through the impoundment, a high flushing rate from the Oconto River, and a largely forested/undisturbed watershed, sedimentation from the large watershed could be considerably greater than it is.

MANAGEMENT ALTERNATIVES DISCUSSION

WATER QUALITY AND SEDIMENTATION

Machickanee Flowage is an impoundment with basin characteristics prone to sedimentation, non-point source runoff and variable water quality. Water quality is good but macrophyte growth is dominated by a few species at nuisance levels. Recreational use of the impoundment is currently impaired by macrophyte growth throughout open-water periods as portions of the lake become largely is impassible shortly after ice-out. Sedimentation may be significant in some areas of the impoundment.

Before drastic management measures are taken to further reclaim or "rejuvenate" the resource, steps should be taken to reduce sediment and nutrient inputs to the extent possible and/or practical. Efforts should be made to identify runoff or erosion prone areas and control nutrient and sediment inflows on a watershed-wide basis. Major emphasis should be given to implementation of BMP's to reduce nutrient and sediment inputs to the drainage basin. Some BMP's pertinent to Machickanee Flowage are outlined in Appendix IV.

While inflows from the upstream watershed are probably of greatest significance, riparian land use practices can, cumulatively, have a significant influence on water quality and landowner diligence should, in any case, be strongly emphasized and encouraged. Common sense approaches are relatively easy and can be very effective in minimizing 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 (16), 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), 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 (16). A number of informational sources for people with questions regarding land management are outlined in Appendix V.

MACROPHYTES

Management of macrophyte populations is often a major objective for lakes and particularly for shallow impoundments. Macrophytic growth can positively affect the resource through forage fish and wildlife production/protection, shoreline stabilization and nutrient uptake. Nuisance levels of macrophytes, however, can cause organic sediment build-up, preclude development of more desirable diverse plant populations, reduce aesthetics, reduce DO (potential fish kills), impair recreational use and contribute to the development of stunted fish populations. Macrophyte management should be carefully implemented and consider different use areas of 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 Machickanee Flowage applicability.

Dredging is a drastic and costly form of habitat alteration. Before any dredge plan is developed or implemented on Machickanee Flowage, steps should be taken to ensure dredging results will be most cost-effective (e.g., last as long as possible). Only when erosion and nutrient control measures are implemented (to the extent practical) on a watershed-wide basis, should a dredging plan be considered feasible. A dredge plan should involve as little sediment removal as possible (be cost effective) to create access and edge (removal to a depth at which macrophyte growth would be retarded due to reduced sunlight). Emphasis should also be given to the potential for redistribution of existing unconsolidated sediment beds in the feasibility/design stage.

Chemical treatment for macrophyte control 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. Chemical use has shown no lasting effect on controlling plant populations and should not be considered for Machickanee Flowage at this time.

Aquatic plant screens have been shown to reduce plant densities in other lakes and may be applicable in near-shore areas 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. Screens are generally used in small areas of concern, e.g., around beaches, landings or piers.

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 (17). 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 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 impact nuisance plant growth (18). A 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 harvest, can vary substantially with depth.

Several conditions should be considered with respect to continued macrophyte harvest. Macrophyte growth on Machickanee Flowage is dense and widespread; even intense harvest efforts will probably not manage all areas of concern in the impoundment. Milfoils, coontail and common waterweed all spread easily by fragmentation; strong consideration should be given to the potential of these species to become even more dominant by becoming better established 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 precautions regarding potential nuisance species 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. Harvest is, however, area selective, relatively inexpensive and removes nutrients from the lake system. Continued harvest should play a major role in the future management of Machickanee Flowage macrophytes.

Selective SCUBA assisted harvest has been shown to selectively manage macrophytes. It can be used in deeper areas and to target only desired species (e.g., Eurasian milfoil) or nuisance growth areas. This method is labor intensive, but has proved to effectively reduce nuisance plant levels for up to two years (17). With the large area of potential macrophyte management in Machickanee Flowage, SCUBA assisted harvest as a widespread application is probably not applicable, but may be implemented on small, localized populations of Eurasian Milfoil or other nuisance macrophytes.

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.

MANAGEMENT RECOMMENDATIONS

Management of the Machickanee Flowage resource should include continued monitoring (to track trends of the resource through management and BMP implementation), improved recreational access (through nuisance aquatic plant harvest/control), exotic species control and prevention, and reduction of nutrients and sediment entering the system (through riparian and watershed wide adoption of BMP's).

Water quality monitoring should include regular, in-lake sampling of similar parameters on a similar schedule. Event monitoring provided highly variable results and should be continued as well. Self-Help Secchi monitoring should be undertaken by a volunteer (preferably a permanent resident) on the flowage. Consideration should be given to taking Secchi readings at the inlet and at the deepest point of the flowage.

The Machickanee Flowage currently has nuisance levels of relatively few species (especially in areas deeper than five feet). Eurasian Milfoil typically moves into areas of disturbance within a waterbody; pollution, lengthy drawdown of the flowage and chemical treatments may have provided that disturbance.

Management of nuisance areas is probably best accomplished through macrophyte harvest. Harvest should be conducted to increase access and maximize the creation of edge habitat. Because of milfoil and coontail growth, the bulk of the plant matter is at the surface of the flowage. Macrophyte harvest could "skim" the plants off the surface and create openings for recreational and predator fish access and, in shallower depths, for increased growth of more beneficial species. Harvest should be conducted by cutting corridors off of existing open areas (the river channel) to maximize edge effects. Harvest provides immediate openings, removes nutrients from the system, and is relatively inexpensive compared to other means of plant control. Shoreline raking, bottom screening or other methods of plant control should be limited to individual landowner application in localized areas. Such concentration on near-shore areas would reduce harvesting efforts.

Exotic species prevention/containment should be a major emphasis for near-term and future management of the flowage. Eurasian Milfoil should be positively identified and if present, signs should be posted at access points to prevent its spread to other lakes. Educational signs concerning other exotic and potentially harmful species should also be posted and information circulated to raise awareness of lake users of these species.

Near- and long-term goals should be adopted for nutrient and sediment reduction in the Machickanee Flowage. Near-term measures should concentrate on riparian land management practices such as runoff control, buffer stripping, sanitary system upkeep, and fertilizer and yard waste management. Collectively, riparian management can have a significant effect on nutrient and sediment reduction.

Long-term goals should target adoption of BMP's on a watershed wide basis. While a 1,000 square mile watershed would appear to be unmanageable, much of the watershed (about 75%) is relatively undisturbed and forested; open/agricultural areas are located primarily in the more downstream reach of the watershed. Steps should be taken to further delineate the land use types in the watershed and pinpoint areas of concern (i.e. erodible soils, steep slopes, detrimental land uses). Steps may then be taken to obtain cost-share funding on a local, state or federal level.

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 MFAA does not have specific legal or financial powers (to adopt ordinances or levy taxes or special assessments) to meet plan objectives, if necessary.

The Machickanee Flowage is located within the political jurisdictions of the Towns of Abrams and Stiles, County of Oconto and the State of Wisconsin. These units have the power to regulate land uses and land use practices. Oconto County ordinances and plans possibly pertinent to the Machickanee Flowage plan are summarized in Appendix VI.

Potential sources of funding are listed in Appendix VII.

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