Millecoquin Lake Aquatic Plant Survey 2005

by Tip of the Mitt Watershed Council

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SUMMARY

Aquatic plants provide many benefits to aquatic ecosystems, but become a recreational nuisance when growth is excessive. Non-native aquatic plants potentially impact lake ecosystems by dominating and reducing native plant communities. Responding to concerns expressed by shoreline residents regarding problematic aquatic plant growth and the possibility of non-native species impacting the lake ecosystem, the Hiawatha Sportsman's Club contracted the Tip of the Mitt Watershed Council to conduct an aquatic plant survey on Millecoquin Lake in Mackinac County, Michigan. The aquatic plant survey was conducted during July of 2005. Aquatic plant specimens were collected and documented at 75 sites throughout the lake and major plant communities were also mapped. A total of 20 aquatic plant species were documented, all native to Michigan. The majority of Millecoquin Lake contains aquatic vegetation (~95%). Coontail (*Ceratophyllum demersum*), common watermilfoil (*Myriophyllum sibiricum*), pondweeds (*Potamogeton spp.)* and common waterweed (*Elodea canadensis*) were the most commonly encountered species at sample sites. Aquatic plant density ranged from heavy to very heavy at over 60% of sites. In addition, water quality data was collected from Millecoquin Lake and several tributaries. Physical and chemical water quality data did not expose any water quality problems, though pH was above State standards at a few locations. Due to equipment failure and time constraints, insufficient data was collected to determine relative nutrient loads contributed by individual tributaries. To effectively and safely manage the aquatic plants of Millecoquin Lake, the Hiawatha Sportsman's Club should develop and implement an aquatic plant management plan using information from this study and other relevant sources. Many options for short-term control of aquatic plant growth were researched, though most are not recommended due to applicability, feasibility, or water quality issues. Harvesting aquatic plants in a limited area is the recommended short-term control option as it should improve water recreation with minimal impacts on the aquatic ecosystem. The plan should also include proactive elements that address sedimentation and nutrient pollution in tributaries and along developed shoreline areas. Preventing the introduction of non-native species should also be a priority. The Hiawatha Sportsman's Club now has a good data set to help guide aquatic plant management decisions and to track changes over time. Optimally, aquatic plant surveys should be conducted on Millecoquin Lake every 5-10 years. Future surveys can be improved by tweaking methodologies and reserving additional time and resources for more comprehensive field data collection.

INTRODUCTION

<u>Background:</u>

Aquatic plant communities provide numerous benefits to lake ecosystems. Aquatic plants provide habitat, refuge and act as a food source for a large variety of waterfowl, fish, aquatic insects and other aquatic organisms. Like their terrestrial counterparts, aquatic plants produce oxygen as a by-product of photosynthesis. Aquatic plants utilize nutrients in the water that would otherwise be used by algae and potentially result in nuisance algae blooms. A number of aquatic plants, including bulrush, water lily, cattails, and pickerel weed help prevent shoreline erosion by absorbing wave energy and moderating currents. Soft sediments along the lake bottom are held in place by rooted aquatic plants.

Lake systems with unhealthy or reduced aquatic plant communities will likely experience declining fisheries due to habitat and food source losses. Aquatic plant loss may also cause a drop in daytime dissolved oxygen levels and increased shoreline erosion. If native aquatic plants are removed through harvesting or herbicide application, resistance of the naturally occurring plant community is weakened and can open the door for invasive species such as curly-leaf pondweed or Eurasian watermilfoil.

In spite of all the benefits associated with aquatic plants, some aquatic ecosystems suffer from overabundance, particularly where non-native nuisance species have been introduced. Excessive plant growth tends to create a recreational nuisance, making it difficult or undesirable to boat, fish and swim. In lakes plagued by nuisance plant species, it may be necessary to develop and implement programs to control excessive growth and non-native species. The first step in establishing an aquatic plant management program is to document all plant communities present in the lake to determine if growth is excessive and if there are non-native and other nuisance species that are disrupting natural aquatic plant communities.

Due to concerns expressed by Millecoquin Lake shoreline residents regarding nuisance aquatic plant growth, the Hiawatha Sportsman's Club took this first step and contracted the Tip of the Mitt Watershed Council to conduct a comprehensive aquatic plant survey on the lake. Watershed Council staff collected field data during the summer of 2005. Survey field methods, data management procedures, project results, discussion of results, aquatic plant control options and recommendations are contained in this report.

Study area:

Millecoquin Lake is located in the eastern Upper Peninsula of Michigan; just northeast of Engadine in Garfield Township of Mackinac County. The lake stretches in an oblong shape from north to south with a large central basin and smaller basins on both the north and south ends. According to bathymetric maps from the Michigan Department of Natural Resources (DNR) Institute for Fisheries Research, the entire lake is very shallow with a maximum depth of twelve feet, which is located in the central basin toward the eastern edge. The northern end of the lake is markedly shallower than the central and southern basins. Based upon GIS (Geographical Information System) files generated through on-screen digitization of 1998 aerial photos, the shoreline measures 9.2 miles and lake surface area totals 1,116 acres.

The largest inlet tributary of Millecoquin Lake is the Upper Millecoquins River, which flows into the lake from, at least, three channels on the north end. Several minor tributaries flow into the lake including Cold Creek from the east and four streams from the west, of which Furlong Creek, entering the lake in the southwest corner, is the largest. The Lower Millecoquins River is the only outlet, which exits from the southwest corner of the lake.

Select tributaries of Millecoquin Lake were surveyed by the DNR in 1989 and by the Michigan Department of Environmental Quality (DEQ) in 1999. Physical, chemical and biological data were collected to assess stream water quality. The water quality of Furlong and Doe Creeks, which combine before entering the lake, were surveyed in both studies and found to be negatively impacted by agricultural activity in the watershed. During the 1999 study, the Lower Millecoquins River, Upper Millecoquins River, Milk River, Cold Creek and Three-Mile Creek were also surveyed. Based on results of the survey, the water quality of inlet tributaries was high, though all had excessive sand in the substrate, which may be due to historic logging activities, road construction, beaver activity and trout pond construction. The only outlet, Lower Millecoquins River, was surveyed at US-2 and streambank erosion was noted.

The fisheries of Millecoquin Lake is well documented due to multiple surveys conducted by the DNR. The most recent survey from the DNR (2004), found the fish community to be dominated by rough fish such as carp, bullheads and bowfin. The number of pan fish, such as bluegill and yellow perch has increased, but the average size has decreased. Bass populations are doing well, but pike populations appear to be suffering. Walleye, which were stocked in Millecoquin Lake from 1985 to 2001, are a small part of the fish community and the population appears to be dependent upon stocking efforts. In the DNR report for the 2004 survey, it was speculated that the dense aquatic plant growth may limit the effectiveness of walleye predation on, and thus controlling, the increasing numbers of small bluegill.

Although unable to find the appropriate water quality monitoring data, basin morphology and abundant aquatic plant growth suggest that Millecoquin Lake would be classified as a eutrophic lake. Eutrophic lakes are characteristically shallow, turbid lakes with high biological productivity. Water samples that were collected and analyzed for nutrient concentrations support the speculated trophic status of the lake. Total phosphorus concentrations were 16.2 parts per billion (PPB) at the surface and 24.4 PPB at the bottom. Oligotrophic lakes (deep, clear lakes with low biological productivity) monitored by the Watershed Council typically have total phosphorus concentrations of less than 10 PPB.

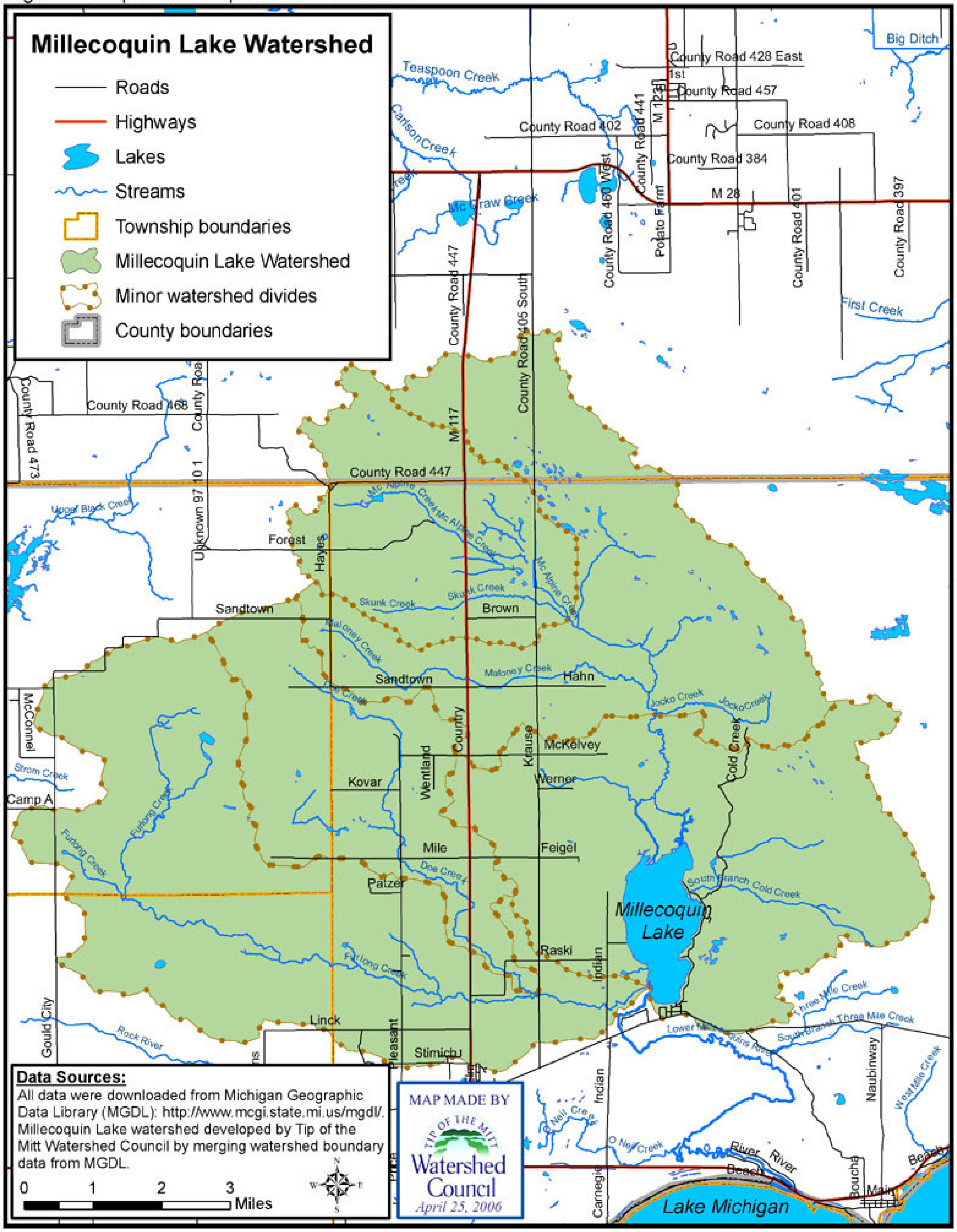
Using watershed boundary data acquired from the State of Michigan, the Millecoquin Lake watershed area was determined to encompass approximately 56,503 acres, which includes the lake area (Figure 1). By dividing the lake surface area into the watershed area (not including the lake), a watershed area to lake area ratio of 49.63 was calculated. The ratio provides a statistic for gauging susceptibility of lake water quality to changes in watershed land cover. There are nearly 50 acres of land in the watershed for each acre of Millecoquin Lake water surface, which, compared to other lakes in Michigan, is quite high. Essentially, the statistic indicates that the large size of the Millecoquin Lake watershed provides a protective buffer for lake water quality; i.e., it would require considerable landscape development (in terms of area) to negatively impact water quality.

Land cover statistics were generated for the watershed using remotely sensed data from the year 2000, which was produced as part of the Coastal Great Lakes Land Cover project (Table 1). Based upon these statistics, it appears that the watershed is relatively pristine; with very little development. Nearly 40% of the watershed is forested and more than 30% is covered with wetlands. A very small percentage of land is being used for agriculture (~6%) and even less is developed for residential and commercial use (~1%).

Table 1. Millecoquin Lake watershed land cover data 2000.

Land Cover Type	Acreage	Percent
Agriculture	3493.23	6.18
Barren	199.78	0.35
Developed	659.46	1.17
Forest	22197.74	39.29
Grassland	9754.66	17.26
Scrub/Shrub	460.89	0.82
Water	1310.21	2.32
Wetlands	18427.52	32.61
TOTAL	56503.50	100.00

Figure 1. Map of Millecoquin Lake watershed.



METHODS

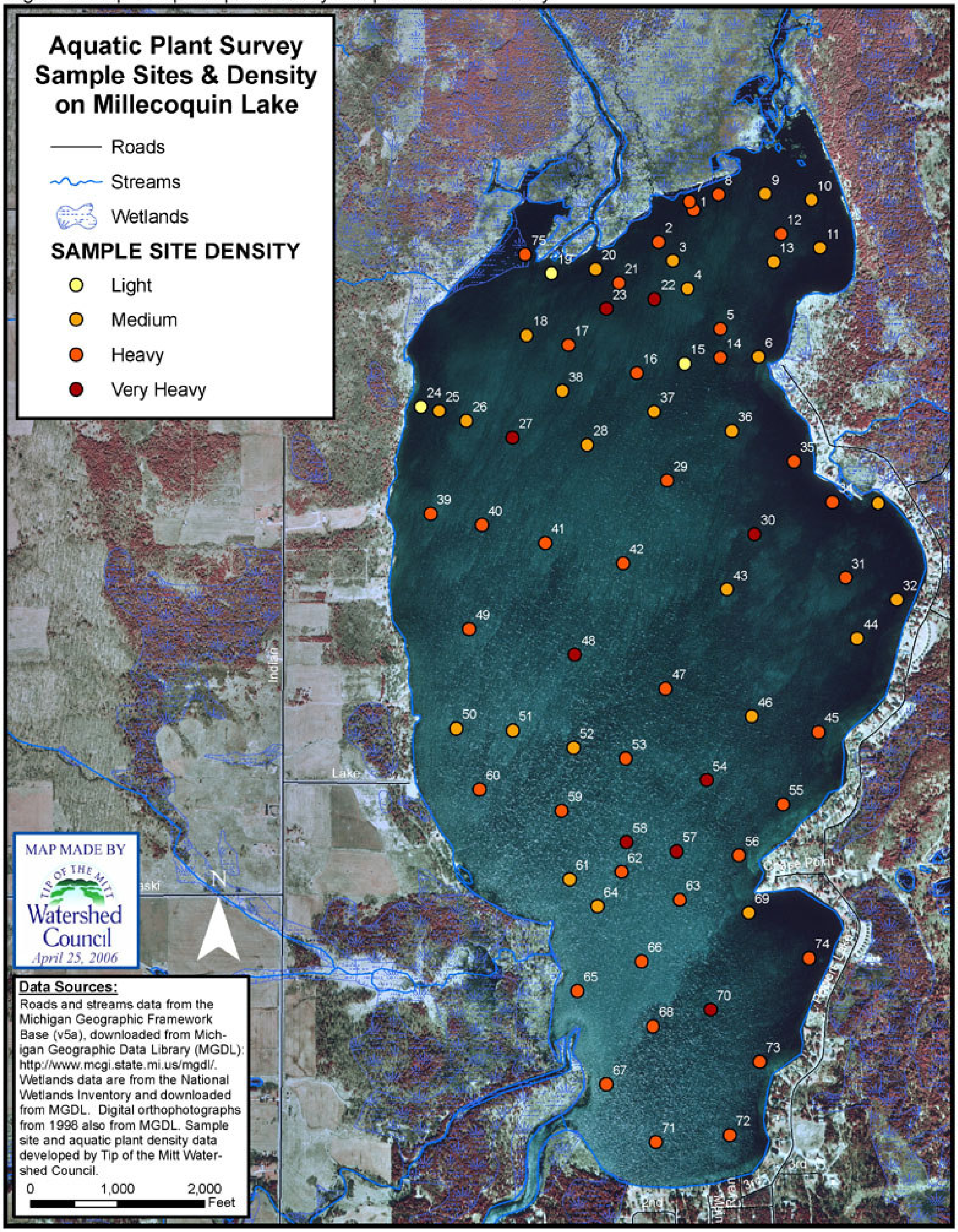
Watershed Council staff conducted the field data collection component of the Millecoquin Lake aquatic plant survey during the week of July 5-8, 2005. The aquatic plant communities of Millecoquin Lake were documented using two primary methods: 1) aquatic plant sampling at specific locations, and 2) generalized aquatic plant community mapping. Both methods were employed from a motorized boat using a mapping grade GPS (global positioning system). In addition, physico-chemical water quality data were collected from Millecoquin Lake and its tributaries. After performing surveys, data collected in the field was processed, entered into databases, and reviewed for quality assurance. Data was used for generating statistics and producing maps.

Aquatic plant sampling at specific sites:

To gather specific information about aquatic plant community composition, specimens were collected, identified, photographed and recorded in a notebook at 75 sample sites throughout the lake. Samples were collected at intervals along transects followed across the lake. Sampling site locations (Figure 2) were selected at somewhat regular intervals along the transect, but varied depending upon plant community changes that were observable from the surface. In general, transects crossed the lake in an east-west direction, but varied more in the northern and southern ends due to basin shape. The precise location of each sampling station was determined using a Trimble GeoExplorer3 GPS unit with a reported accuracy of 1-3 meters.

At each sample site, the boat was anchored, water depth measured and GPS data recorded. Plant specimens were collected using a sampling device consisting of two garden rake heads fastened together back to back with a length of rope attached. A minimum of three throws (using the sampling device) were made at each site, collecting from both sides of the boat. Sampling continued until the collector was satisfied that all plant species present at the site were represented in the sample.

Figure 2. Map of aquatic plant survey sample sites and density.



All specimens were identified to the species level. If a specimen could not be identified immediately, it was stored in a sealed bag and identified later with the aid of taxonomic keys, mounted herbarium specimens, and, if necessary, other aquatic plant experts. Representative samples of each species were laid out, accompanied with a site identification number, and photographed. Species density was subjectively determined and recorded as light (L), medium (M), or heavy (H), but also included the sub-categories of very light (VL), medium-light (ML), medium-heavy (MH) and very heavy (VH) (Appendix A). The site number, water depth, species names, species density, and comments were recorded in a field notebook.

Aquatic plant community mapping:

To supplement aquatic plant species data collected at sample sites and improve the accuracy of delineations between plant communities, additional notes and GPS data were recorded for large aquatic plant communities that were visible from the water surface. Neither plant specimens nor photographs were collected for this portion of the field work. Although a few submerged plant beds were documented in this way, the majority of generalized aquatic plant community mapping was performed in areas of emergent vegetation and no vegetation.

Areas with emergent vegetation and no vegetation were mapped directly by navigating around the feature being surveyed or indirectly at an offset distance. Where depth allowed, the perimeter of the feature being surveyed was followed as closely as possible in the boat, collecting GPS data at major vertices. In shallow, shoreline areas, GPS data were collected along the length of shoreline containing the feature and an offset distance from the shoreline was estimated (and recorded). In a few instances, plant communities were mapped in shallow areas by wading.

Water quality data collection and analyses:

Water quality data were collected from Millecoquin Lake and three of its tributaries, Upper Millecoquins River, the Lower Millecoquins River and Cold Creek, on July 8, 2005 in the late afternoon (from 4 p.m. to 9 p.m.). In the lake, data were collected at the deep point on the east side of the central basin. Data from the Upper Millecoquins

River were collected at the mouth of two main channels flowing into the lake toward the center of the north end, while those collected from the Lower Millecoquins River were collected immediately downstream of the bridge at Highway H40. At Cold Creek, water quality was monitored at the mouth.

Water quality data collection consisted of physical measurements in the field and water sample collection for chemical analyses in the laboratory. Physical parameters included water temperature, dissolved oxygen, temperature and conductivity. Water samples were delivered to the University of Michigan Bio-station and analyzed for soluble reactive phosphorus ($PO4^-$), total phosphorus (TP), nitrate-nitrogen ($NO3^-$), ammonia-nitrogen ($NH4^-$), total nitrogen (TN), and chloride (CL^-). In addition, water discharge data were collected from the tributaries.

Upon arriving at a sample site, water samples were collected first. In the lake, samples were collected from both the surface and the bottom, and in the tributaries, samples were collected in the middle of the stream and at approximately mid-depth. Acid-rinsed containers used to collect samples for chemical analysis were rinsed three times with lake or stream water (both bottle and cap) prior to collecting the final water sample. All water samples were immediately placed in a cooler containing ice. As water samples could not be analyzed immediately, they were frozen and delivered to the University of Michigan Bio-station for analyses at a later date.

Following water sample collection, physical water quality data was collected using a Hydrolab MiniSonde®. The MiniSonde® was calibrated prior to field work, using methods detailed in the Hydrolab manual. Dissolved oxygen was calibrated with the percent saturation method, using actual barometric pressure as measured by a sensor contained in the Surveyor4a Data Display unit. Conductivity was calibrated using a standard solution of 447 microSiemens/cm and pH was calibrated using standard buffer solutions of 7 and 10 units pH.

In Millecoquin Lake, the MiniSonde® probe was lowered through the water column to collect data from the surface and bottom, whereas in the streams, the probe was placed on the stream bottom at mid-channel. Measurements were saved to memory in the Surveyor4a and also written on a paper field data collection sheet. Upon returning to the office, data was transferred from the Surveyor4a to a computer and all data consolidated in a Microsoft Excel workbook.

In the tributaries, discharge data were collected at each site following physical and chemical data collection. A nylon measuring tape was tied across the stream channel perpendicular to flow. Water depth and stream width (location along the transect) were recorded at irregular intervals across the transect. Positions along the transect for data collection were selected based upon changes in depth. Due to equipment failure, current velocity was measured by timing multiple runs of a mostly submerged container down a known channel length distance. Current velocity was measured in this manner in two to three locations along the transect. All data, including total channel width, were recorded on a field data sheet and later inputted into a Microsoft Excel workbook.

Data processing and map development:

GPS data collected in the field was post-processed and exported into a GIS (Geographical Information System) file format using GPS Pathfinder Office 2.90 software. Polygons depicting distinct plant communities were created using the ESRI GIS software package: ArcView 9.1. Where possible, polygons were developed directly from line or area features mapped with GPS in the field. Otherwise, polygons were created indirectly by extrapolating from or interpolating between sample sites.

Data collected at sample sites and recorded in the field notebook (species names, species density, overall community density, water depth and comments) were entered into a spreadsheet organized by site number. Columns were added to the spreadsheet to include number of taxa (i.e., species), overall site density, dominant taxa, and community at each site (Appendix A). The overall site density was calculated by assigning a value of 1 to species collected at the site in the heavy density category, 2 to species in the very heavy category, 0 to all others, and then summing values for each site. Overall site density scores of 0 were put in the “light” category, 1-2 in the “medium” category, 3-4 in the “heavy” category, and 5-7 in the “very heavy” category. The dominant taxa include species found to occur at the heaviest density at a site. If a single species was found at a greater density than all others, then it was listed as the only dominant taxon, but in most cases, several species were listed as dominant taxa as they occurred at equal density. The community at each site was determined from the dominant taxa, using common names and grouping species by family.

Upon completing data entry and calculations, the spreadsheet was saved to a *.dbf format. The *.dbf file was joined to the point GIS data layer and exported to a new GIS data layer containing all attribute information collected in the field. Digital photographs were renamed to match sample site numbers and linked to corresponding GPS points in ArcView.

The final products include both maps and statistics generated from digital map layers. All GPS, tabular and photographic data were combined in an ArcView project to develop a sample site map that includes overall plant density and a map depicting major plant communities. In addition, an interactive map was developed that allows users to view photographs of specimens collected in the field as well as all tabular data associated with the site (by clicking on the point representing the sample site). The interactive map requires GIS software, but can be converted to a web-based format, so that anyone with internet browsing software (e.g., Internet Explorer, Netscape, Mozilla) could use the map. Upon completing GIS work to develop polygons representing plant communities and vegetation types, area statistics for specific plant communities and vegetation types were calculated.

RESULTS

<u>Sample site data:</u>

Aquatic plants were collected at all 75 sites that were sampled on Millecoquin Lake (Figure 2). A total of 20 different aquatic plant species were documented. All species found were native to Michigan. The number of species encountered at a site ranged from 1 to 10, with an average of 6.0 species per site.

Table 2. Number and percentage of sample sites where specific species were found.

Genus and species	Common Name	# of sites	% of sites	Occurrence*
Ceratophyllum demersum	Coontail	64	85.3	very common
Myriophyllum sibiricum	Common watermilfoil	62	82.7	very common
Potamogeton robbinsii	Robbins' pondweed	60	80.0	very common
Potamogeton zosteriformis	Flat-stem pondweed	54	72.0	very common
Elodea canadensis	Common waterweed	53	70.7	very common
Potamogeton amplifolius	Large-leaf pondweed	33	44.0	common
Potamogeton friesii	Fries' pondweed	29	38.7	common
Potamogeton richardsonii	Richardson's pondweed	24	32.0	common
Vallisneria americana	American eelgrass	19	25.3	common
Megalodonta beckii	Water marigold	11	14.7	uncommon
Potamogeton praelongus	White-stem pondweed	10	13.3	uncommon
Stuckenia pectinata	Sago pondweed	10	13.3	uncommon
Heteranthera dubia	Water stargrass	7	9.3	uncommon
Potamogeton natans	Floating-leaf pondweed	4	5.3	uncommon
Chara spp.	Muskgrass	3	4.0	rare
Myriophyllum heterophyllum	Variable-leaf watermilfoil	1	1.3	rare
Najas flexilis	Slender naiad	1	1.3	rare
Nuphar variegata	Yellow pond-lily	1	1.3	rare
Ranunculus spp.	Water buttercup	1	1.3	rare
Schoenoplectus acutus	Hard-stem bulrush	1	1.3	rare

*Occurrence categories determined by Watershed Council staff based on natural breaks: 1-3 = rare, 4-15 = uncommon, 16-30 = common, and 31+ = very common.

Coontail and common watermilfoil were the most commonly encountered species; collected at 64 and 62 sites respectively (Table 2). Three other species, Robbins' pondweed, flat-stem pondweed and common waterweed, were also very common and collected at more than 40 sites. The pondweed family dominated the common and very common categories, representing six of the nine total species. Emergent plant species, such as yellow pond-lily and hard-stem bulrush, inhabit shallow areas and were thus, rarely encountered at sample sites. However, the emergent plant communities were well documented during the plant community mapping component of field data collection.

Aquatic plant communities at the sample sites were dominated by members of the pondweed family (Table 3). Nearly 70% of sites were dominated or co-dominated by pondweeds. Coontail dominated or co-dominated 48% of sites and watermilfoil followed at ~23%. Although elodea was in the "very common" category at sample sites it only dominated and co-dominated less than 10% of the sites.

Table 3. Dominant aquatic plants at sample sites.

Dominant Plants	Number of sites	Percent of sites
Pondweeds	25	33.33
Coontail, Pondweeds	15	20.00
Coontail	13	17.33
Watermilfoil	5	6.67
Coontail, Pondweeds, Watermilfoil	4	5.33
Pondweeds, Watermilfoil	3	4.00
Coontail, Elodea, Pondweeds	2	2.67
Coontail, Watermilfoil	2	2.67
Coontail, Elodea, Pondweeds, Watermilfoil	1	1.33
Elodea	1	1.33
Elodea, Pondweeds	1	1.33
Elodea, Watermilfoil	1	1.33
Elodea, Watermilfoil, Pondweeds	1	1.33
Hard-stem bulrush	1	1.33

Aquatic vegetation was quite dense at most sample sites. Over 60% of sites were characterized as having aquatic plant densities in the heavy or very heavy categories. Of the remainder, plant density at 26 sites (~35%) was classified as medium and only 3 sites (4%) were considered to have light growth. Although aquatic plant density at sample sites was subjectively determined, overall aquatic plants density on Millecoquin Lake was observed to be far greater than any other lake that has been surveyed for aquatic plants by this author.

Interpreted data:

Statistics generated from spatial analyses of GIS data reveal that ~95% of Millecoquin Lake's 1,116 acres contains aquatic vegetation (Table 4). Vegetated areas were divided into two categories: emergent vegetation (bulrush, pond-lillies, etc.) and submergent vegetation (pondweeds, coontail, etc.). Of the ~1060 acres of Millecoquin Lake that possess aquatic vegetation, approximately 14% (~153 acres) include emergent vegetation while the other 86% (~907 acres) contains submergent vegetation only. Areas with no aquatic vegetation primarily occurred along developed shoreline areas (Figure 3).

Table 4. Lake aquatic vegetation statistics.

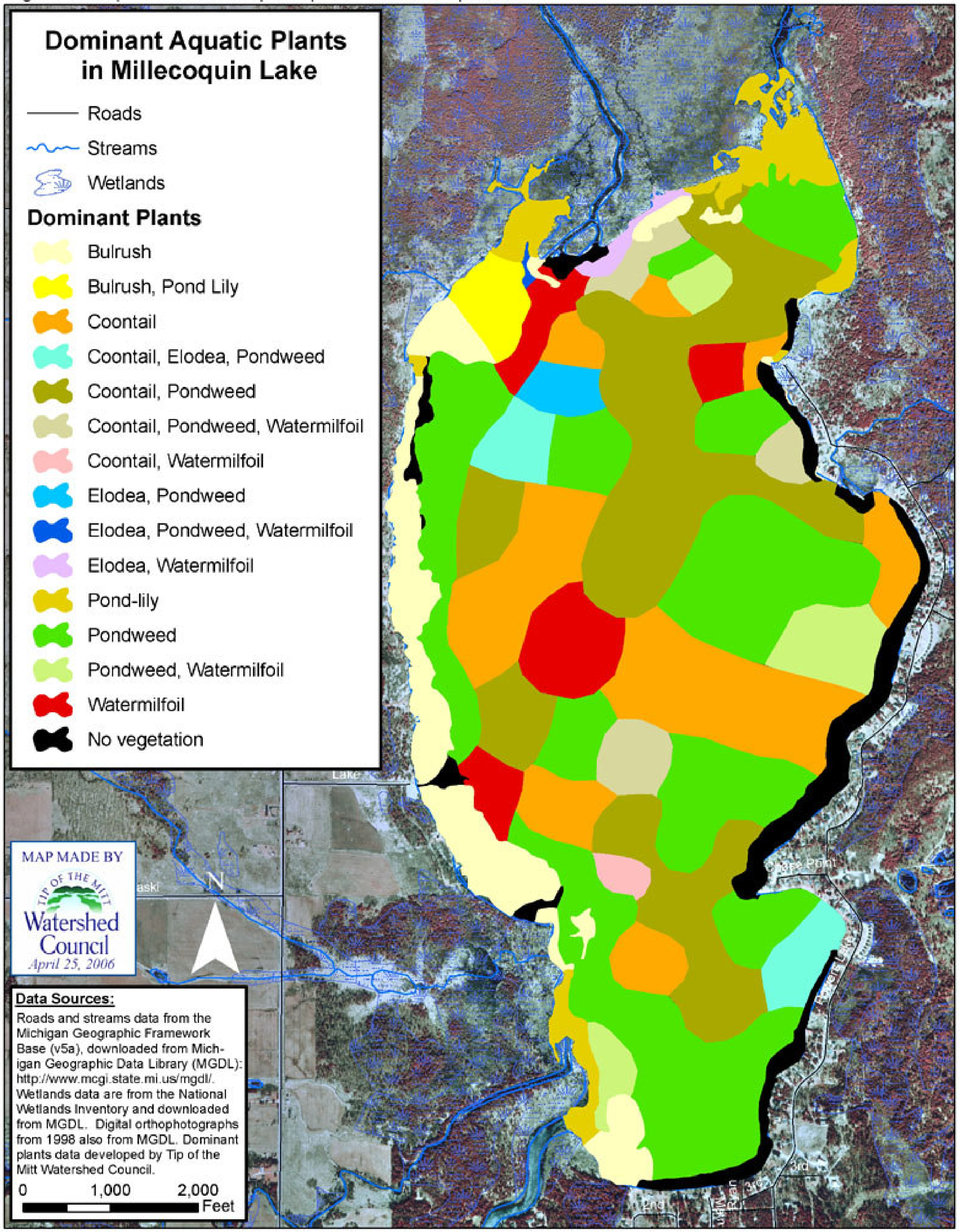
Lake & Vegetation	Surface Area (acres)	% of Total Surface Area
Millecoquin Lake	1115.81	100.00
Aquatic vegetation	1059.53	94.96
Little or no vegetation	56.28	5.04
Emergent vegetation	152.55	13.67
Submergent vegetation	906.98	81.28

The areal extent of dominant submergent plants was determined largely based upon sample site data and thus, it comes as no surprise that pondweeds and coontail were the dominant plants in terms of the lake's surface area. Together, they dominated over 65% of the lake's surface area (Table 5). Bulrush dominated approximately 8% of the lake area, watermilfoil dominated just over 5%, pond-lily dominated ~4% and the remaining ~12% were dominated by a mix of plant types.

Table 5. Areal extent of dominant aquatic plants.

Dominant aquatic plants	Lake surface area (acres)	Percent of surface area
Pondweed	333.78	29.91
Coontail, Pondweed	224.93	20.16
Coontail	169.73	15.21
Bulrush	89.16	7.99
Watermilfoil	58.10	5.21
No vegetation	56.28	5.04
Pond-lily	46.89	4.20
Pondweed, Watermilfoil	38.01	3.41
Coontail, Elodea, Pondweed	30.23	2.71
Coontail, Pondweed, Watermilfoil	29.78	2.67
Bulrush, Pond Lily	16.50	1.48
Elodea, Pondweed	10.91	0.98
Coontail, Watermilfoil	5.58	0.50
Elodea, Watermilfoil	5.16	0.46
Elodea, Pondweed, Watermilfoil	0.77	0.07

Figure 3. Map of dominant aquatic plants in Millecoquin Lake.



Water quality data:

Results from physical measurements of temperature and oxygen show largely what would be expected. Water temperatures were highest in the lake and the outlet tributary (Lower Millecoquins River) and lowest in the inlet tributaries (Table 6). Dissolved oxygen levels, which generally peak in the afternoon due to photosynthetic activity of plants, was above the State of Michigan water quality standard minimum of 7 parts per million (PPM) at every site.

Table 6. Results of physical water quality measurements.

Site*	Date	Time	Depth†	Temp†	DO†	SpCond†	pH
A	7/8/2005	15:57:05	0.2	18.40	10.97	146.7	8.41
B	7/8/2005	16:15:27	0.3	18.30	10.70	226.9	8.54
C	7/8/2005	19:03:57	0.4	16.35	8.91	74.8	8.14
D	7/8/2005	20:49:36	0.8	24.97	11.16	151.5	9.40
E	7/8/2005	18:43:09	0.3	23.48	9.98	164.9	8.95
F	7/8/2005	18:46:47	2.6	22.29	12.19	163.6	9.08

*Site A = Upper Millecoquins River – East, Site B = Upper Millecoquins River – West, Site C = Cold Creek, Site D = Lower Millecoquins River, Site E = Millecoquin Lake – Surface, Site F = Millecoquin Lake – Bottom.

†Depth measured in meters, temp = temperature and measured in degrees Celsius, DO = dissolved oxygen and measured in parts per million, SpCond = specific conductivity and measured in microSiemens/cm.

Results from the remaining physical parameters, conductivity and pH, revealed some differences between sites. Conductivity, which measures the water's ability to carry an electric current, was found to range from 74.8 to 226.9 microSiemens (Table 6). While there is a great deal of natural variability in conductivity, Cold Creek displayed much lower levels than the other tributaries. In addition, there was an unexpected large difference in conductivity between adjacent stream channels in the Upper Millecoquins River (sites A and B).

Expressed as pH, the hydrogen ion concentration measures the acidity (low pH) or alkalinity (high pH) of water, ranging from 0-14 with 7 being neutral. Results from Millecoquin Lake and its tributaries ranged from 8.14 to 9.4 (Table 6). According to DEQ Part 4 Water Quality Standards, Rule 53 (323.1053), a pH range of 6.5 to 9.0 must be maintained in all Michigan surface waters. The pH reading was barely above the standard maximum of 9.0 at the lake bottom and plainly exceeded the maximum in the outlet river channel.

Nutrient concentrations for the different forms of nitrogen and phosphorus were similar to water bodies regularly monitored by the Watershed Council. As expected, total phosphorus levels were higher in Millecoquin Lake than those in deep, clear, nutrient-poor, oligotrophic lakes. Most oligotrophic lakes monitored by the Watershed Council have total phosphorus values of less than 10 parts per billion (PPB), so the phosphorus concentrations of 16.2 PPB and 24.4 PPB in Millecoquin Lake do not appear to be excessive (Table 7). By comparing nitrogen to phosphorus ratios, it was determined that all aquatic ecosystems except Cold Creek are phosphorus limited. Chloride concentrations, which often increase as a result of increased human activity and development in the watershed, were very low.

Table 7. Results of chemical analyses of water samples.

Site	Date	Time	PO4-P	TP	NO3-N	NH4-N	TN	Cl
A	7/8/2005	15:57:05	2.4	7.4	39.8	0.2	0.3	1.7
B	7/8/2005	16:15:27	2.7	10.2	38.8	1.0	0.2	1.7
C	7/8/2005	19:03:57	7.8	14.2	7.9	4.2	0.1	0.3
D	7/8/2005	20:49:36	3.2	13.3	1.8	7.1	0.3	1.9
E	7/8/2005	18:43:09	2.9	16.2	0.6	1.8	0.4	1.8
F	7/8/2005	18:46:47	7.1	24.4	0.4	7.0	0.8	1.7

*Site A = Upper Millecoquins River – East, Site B = Upper Millecoquins River – West, Site C = Cold Creek, Site D = Lower Millecoquins River, Site E = Millecoquin Lake – Surface, Site F = Millecoquin Lake – Bottom.

†PO4-P = soluble reactive phosphorus, units = PPB; TP = total phosphorus, units = PPB; NO3-N = nitrate-nitrogen, units = PPB; NH4-N = ammonia-nitrogen, units= PPB; TN = total nitrogen, units = PPM; Cl = chloride, units = PPM.

The purpose of collecting water samples for nutrient analysis and measuring stream discharge was to calculate the relative nutrient load from each tributary. Due to time constraints, difficulty in locating and accessing all tributaries of Millecoquin Lake, and equipment failure, this portion of the project was not completed. Stream discharge calculations were performed where data were collected, but are not presented due to unreliability of current velocity measurements.

DISCUSSION

General:

Millecoquin Lake abounds with plant life as approximately 95% of the lake is filled with aquatic vegetation. Not only is there plant growth throughout most of the lake, but the growth is very dense (60% of sample sites). A relatively small portion of the lake contains no vegetation (~5%). Lake depth and human activity are probably the key factors that determine the distribution and density of the aquatic plant community in Millecoquin Lake. However, other factors, ranging from nutrient loading to global warming may also be responsible for aquatic plant growth in the lake.

Water depth is an extremely important variable for determining the extent of plant growth in a lake. Based upon data collected during aquatic plant surveys conducted by the Watershed Council on other lakes, the majority of aquatic plant life is found in areas of 20 feet of depth or less. As all of Millecoquin Lake is shallower than the 20-foot threshold, water depth is probably the variable that is most responsible for the abundant aquatic plant life in Millecoquin Lake.

Human activity impacts all aspects of the lake ecosystem, from fisheries to phytoplanktonic algae blooms to aquatic plant growth. Recreational activities, such as boating and swimming damage aquatic plants and plants are often removed or smothered intentionally for these activities. However, human activity can also augment plant growth by adding excess nutrients to the water as a result of lawn fertilization and improper septic system maintenance.

Results from field data collection show that lake areas without vegetation primarily occur along developed shoreline areas on the east side of the lake (Figure 3). Records from the Michigan Department of Environmental Quality (DEQ) indicate that permits have been requested by individuals on Millecoquin Lake during the last few years to use chemical treatment to control aquatic plant growth. In addition, according to personal communications with members of the Hiawatha Sportsman's Club, some lakeshore residents practice manual removal of aquatic plants in front of their lots. Thus, it follows that the lack of aquatic vegetation in developed shoreline areas is not a natural phenomenon, but rather due to human aquatic plant management efforts.

The aquatic plant growth in Millecoquin Lake may be partially attributed to excess nutrients in the ecosystem. Nutrients, such as phosphorus and nitrogen, are essential for plant growth. Although there are many natural nutrient sources, ranging from decaying shoreline vegetation to atmospheric deposition, human activity often contributes extra nutrients that, when reaching problematic levels, is termed 'nutrient pollution.' Nutrient pollution directly impacts an aquatic ecosystem by causing excessive and nuisance aquatic plant growth. However, indirect impacts of nutrient pollution may have more dire consequences. Aquatic plants release oxygen into the water during the day due to photosynthetic activity, but consume oxygen while respiring at night. Therefore, excessive aquatic plant growth has the potential to diminish and even exhaust dissolved oxygen levels in the water, which would have serious negative impacts on fish, aquatic macroinvertebrates, and all aquatic organisms dependent upon oxygen to survive.

Nitrogen and phosphorus are key nutrients that control plant growth in aquatic environments. Based on extensive water quality data collected by the Watershed Council in lakes of the northern Lower Peninsula of Michigan, phosphorus is typically the limiting nutrient. This means that the ratio of nitrogen to phosphorus is such that additional nitrogen in the system will not stimulate plant growth whereas additional phosphorus will. Water samples collected and analyzed for nutrient concentrations from Millecoquin Lake and its tributaries showed phosphorus to be the limiting nutrient at all sites except for Cold Creek. Thus, as far as nutrients are concerned, limiting or reducing phosphorus inputs into the lake ecosystem will have the greatest effect on controlling aquatic plant growth.

Nutrient contributions by shoreline property owners were assessed during a previous study performed by the Watershed Council in 2002-2003. The developed shoreline of Millecoquin Lake was surveyed to document any potential sources of nutrient pollution. Results of this survey showed that there were signs of nutrient pollution at 35 locations throughout the lake. Most of these were documented as light nutrient pollution and were usually associated with human activity. No areas were documented with severe nutrient pollution.

To better understand nutrient inputs and outputs in the Millecoquin Lake ecosystem and to determine if excessive nutrient loading was occurring in inlet tributaries, a water quality monitoring component was added to this study. Water samples were collected and analyzed for nutrients from the lake and three tributaries, but the data set was not complete due to difficulties in locating and accessing the remaining tributaries. In addition, not all necessary data were collected due to equipment failure. Although the data set was incomplete, no serious water quality problems were documented.

Water quality data did provide some interesting numbers, particularly for Cold Creek. Cold Creek had the lower readings than any other site tested for water temperature, specific conductivity, dissolved oxygen levels, pH, total nitrogen and chloride. In addition, it was the only site that was not phosphorus limited. Time was not taken to research the origins of Cold Creek, but it is likely that surficial geology and land cover would help explain its distinct water quality characteristics.

Also surfacing in the water quality data were a few high pH readings. The pH exceeded the State of Michigan water quality standard maximum of 9.0 at two sites, which measured 9.08 and 9.4. Lakes frequently monitored by the Watershed Council during the spring for the last 17 years have had an average pH of 7.97. Considering that photosynthetic activity causes elevated pH levels during the daytime, and that data was collected in mid-summer in a heavily vegetated lake, it is likely that the high pH was a naturally occurring phenomenon. However, additional pH monitoring could be accomplished at little expense to rule out the possibility of contamination by alkaline substances.

Another water quality parameter that merits discussion is chloride. Chloride is a component of salt that occurs naturally in Michigan waters at low levels. People use salt in daily activities such as cooking, water softening, and road de-icing, which inevitably finds its way to our surface waters. Chloride is a useful indicator of human activity and landscape development in a watershed because it is a mobile ion and is not used in physical or biological processes and thus, tends to accumulate. In most lakes monitored by the Watershed Council, chloride concentrations have increased. Chloride levels in Millecoquin Lake and its tributaries, however, are extremely low, which is a good sign, indicating that the watershed is still minimally impacted by human activity.

Near the top of the long list of potential human impacts to aquatic ecosystems is the introduction of non-native (also referred to as invasive or exotic) species. Non-native species impact aquatic ecosystems through predation on or displacement of native species, but also cause ecosystem wide changes by disrupting the natural food-web cycle. In the Midwest, examples of problematic non-native aquatic plant species include Eurasian watermilfoil (*Myriophyllum heterophyllum*) and curly-leaf pondweed (*Potamogeton crispus*). Fortunately, no non-native aquatic plant species were encountered during this survey.

Even though Millecoquin Lake has not suffered the effects of the introduction of a non-native species, aquatic plant growth has nevertheless become problematic. According to lake residents, excessive aquatic plant growth has become a nuisance to recreational activities such as swimming, fishing and boating. The results of this study, documenting areal extent and density of aquatic plants, support the residents' comments. However, recreational activities should not be the only consideration. In spite of the problematic plant growth, available information does not indicate that there are water quality problems or impacts on the lake's fisheries. To the contrary, the abundance of aquatic plants could potentially be augmenting the lake's fisheries by providing habitat, food and refuge to aquatic organisms throughout the food chain. The solution to aquatic plant management in Millecoquin Lake will not necessarily be simple or straightforward. Aquatic plants cannot be managed simply for recreational activities, but rather by finding an acceptable and sustainable balance between recreational lake use and a healthy ecosystem upon which recreation depends.

To achieve the balance between recreational activities and a healthy ecosystem, some type of aquatic plant control will probably be needed. Areas of no vegetation in front of shoreline residences are evidence that aquatic plant control is already occurring to some degree. To assist the Hiawatha Sportsman's Club in making informed decisions regarding aquatic plant control, a variety of options are presented in detail in the next section and also included at the end of the report in the form of a quick-reference matrix (Appendix B).

<u>Aquatic plant control options:</u>

In general, there are four major approaches to aquatic plant management as well as combinations of these. The first and often overlooked option is to do nothing and let nature take its course. Otherwise, options for controlling problematic aquatic plant growth consist of chemical, physical or biological treatment. Chemical control would entail the application of herbicide to kill or suppress growth of aquatic plants. Physical control involves plant removal, dredging, lake drawdown or barrier installation. Biological control is accomplished by introducing another living organism that feeds upon or by some other means, disrupts the life cycle of the target species.

Natural control

Aquatic plant communities and growth or density within these communities fluctuates naturally over time. There may be periods of heavy nuisance growth in a given area that are followed by periods of little to no growth. Sometimes, simply being patient and letting nature take its course is the best option.

There are a variety of resources for determining natural fluctuations in the aquatic plant community on a given lake. One of the best resources may be your neighbor; particularly somebody who have lived on or near the lake for a long period of time and can provide the 'big picture.' Other resources include: surveys and reports from regulatory agencies such as the DNR, research reports from universities, and surveys and reports from other organizations or companies working in water resource management. Even archive newspapers and other forms of media may provide clues to historical trends in aquatic plant growth in the lake. Unfortunately, conducting background research takes a lot of time and effort and may not provide substantive or reliable information.

Natural control may not be appropriate for lakes that are or have become 'unnatural.' Human-made lakes, lakes being polluted from excessive urban or agricultural runoff, and lakes suffering from the introduction of invasive species are all examples of unnatural lakes. In instances like these, not taking action to control aquatic plant growth could result in further problems. However, solutions may consist of indirect methods, such as changing human behavior and practices (e.g., reducing fertilizer application or properly maintaining septic systems), as opposed to direct control of plant growth.

Chemical control

Chemical control, the application of herbicides, is the easiest, fastest and often cheapest (in the short-term) method for controlling an aquatic nuisance plant species. There are many chemicals on the market that are used to control aquatic plants. Some of the most commonly used include endothall, glyphosate, copper-sulfate and diquat. Some herbicides, such as fluridone and 2-4.D, selectively control watermilfoils and a limited number of other species when applied at proper rates. All chemical applications in water require a permit from the DEQ.

If it seems too good to be true, then it probably is; i.e., there are a number of downsides to chemical application. A variety of human and animal health problems, ranging from cancer to infertility, are associated with chemicals in the environment and herbicide application is doing just that, introducing chemicals into your environment. Even though companies producing herbicides to treat aquatic plant growth consistently guarantee the safety of their products and even if the Michigan Department of Environmental Quality gives its stamp of approval (approved herbicides and target species - Appendix C), you may want to think twice about adding chemicals to the water that you swim and fish in. Beyond surface water contamination, groundwater contamination should also be considered as chemicals in surface water have been shown to migrate into groundwater (Lovato et al. 1996).

Chemical application, in the case of rapid-acting herbicides, also has the potential to cause problems in the aquatic ecosystem that lead to fish kills. A large amount of dead and decaying plant material as the result of herbicide treatment may lead to dissolved oxygen depletion as these materials are consumed by aerobic decomposers. Depleted or low dissolved oxygen levels will kill or stress fish and many other organisms as almost all life needs oxygen to survive.

Another consideration regarding chemical control is the distinct possibility of long-term application; year after year, perhaps indefinitely into the future. Although often less expensive than physical or biological control in the short-term, long-term chemical control costs may reach or surpass that of other methods. More alarming still is that some chemicals, particularly copper from copper-sulfate, build up in the environment with continual application and can reach levels that are toxic for aquatic organisms (Oleskiewicz 2002).

Physical control

Physical aquatic plant control can be accomplished through various means including: manual cutting/removal, mechanical cutting/removal, dredging, lake drawdown, and barrier installation. Manual removal is performed by getting into the water and pulling or cutting aquatic plants by hand or with hand tools. Mechanical cutting/removal uses machines to cut and remove aquatic plants. Dredging deepens an area by removing soft bottom sediments, essentially reducing habitat for aquatic plants by reducing the lake bottom area that receives sunlight. Lake drawdown consists of lowering the water level of the lake and eliminating plants from the shallow (dry) areas. The remaining option is to install fabric barriers along the lake bottom, which blocks sunlight and prevents plant growth. Most of these methods require a permit from DEQ. The following paragraphs discuss each physical method in greater detail, including advantages and disadvantages.

Manual aquatic plant removal is an age-old technique that is commonly applied in small areas. You simply get into the water and pull plants (and roots) out by hand or use a tool, such as a scythe to cut plants or a rake to remove plants. Advantages of this method include low costs, the ability to remove specific species, and long duration of control if the entire plant is removed. The disadvantages for manual removal are that it is labor intensive, time consuming, creates some localized turbidity, and requires diving equipment in deep areas. In general, this method is only feasible for a small area.

Mechanical cutting and removal is a method commonly applied in large areas, using equipment that functions like a lawn mower. Like lawn mowers, some systems simply cut the plants while others cut and collect. Aquatic plant cutters range from simple systems that can be attached to a small boats (14'+ of length) to specialized cutting boats. The cutters typically cut to a depth of 4-7 feet. Aquatic plant harvesters are large machines that cut and collect aquatic plants. Harvesters typically cut a swath 6 to

20 feet wide and 5 to 10 feet deep, removing the plants from the water and storing them for later disposal.

Advantages of both cutters and harvesters are that large areas of open water are immediately opened and, because the entire plant is not removed, habitat for fish and other aquatic organisms are preserved. One of the biggest disadvantages of both is the costs for purchasing/renting equipment or contracting the work to be performed. Cutters are less expensive than harvesters, but do not remove the plant material and thus, require extra work to gather cut plant material (to prevent dissolved oxygen loss due to decomposing plant matter).

Whether collecting plants immediately with a harvester or after the fact when using a cutter, some plant cuttings are missed and will accumulate on shore or decompose in the water. By removing plant material, harvesters have the added benefit of removing nutrients, such as phosphorus and nitrogen, from the ecosystem (providing that materials are disposed of in such a manner that the nutrients are not re-introduced to the lake). The downside of removing plant material is that fish, aquatic insects and other invertebrates are inevitably removed along with the plants.

There are a number of other considerations pertaining to cutters and harvesters. As with mowing a lawn, aquatic plants may need to be cut several times per season. Some species are difficult to cut, while others, such as watermilfoils, fragment when cut and spread to (and colonize) other parts of the lake. Sediments may be loosened when using cutters and harvesters in shallow areas of lakes with soft sediments. Loosened sediments that become suspended in the water column will clog fish and invertebrate gills as well as smother and reduce habitat of small aquatic organisms when resettling.

Aquatic plant control using cutters and harvesters in lakes containing many obstructions in the cutting zone, such as logs, may be difficult. Besides the possibility of hitting obstacles and damaging equipment, the poor maneuverability of harvesters for moving around obstructions (including docks) and operating in shallow water should be considered.

Specific to harvesters, plant material disposal needs to be considered and planned for. On large lakes, multiple sites may be needed for off-loading spoils in order to reduce harvester travel time. Collected plants will need to be properly disposed of, such that decaying plant material and nutrients are not re-introduced to the lake.

Any cutting or harvesting equipment brought in from another lake must be carefully inspected to ensure that no invasive species are on it. A final consideration is maintenance; cutters and harvesters will eventually require maintenance and therefore, these costs will need to be accounted for.

Dredging is sometimes used as a method for aquatic plant control, but has many drawbacks. Plant removal as a result of dredging has the potential to destabilize lake bottoms and even cause shoreline erosion as roots hold sediments in place and plant stems/leaves absorb wave energy and currents. Furthermore, dredging stirs up sediments and may cause nutrients and other contaminants to be released into the water column. Loosening sediments has the same biological consequences as described above for harvesters.

Diver dredging is an aquatic plant control technique that utilizes SCUBA divers to remove plants using hoses and suction. This method is particularly useful for removing aquatic plants from around docks and other areas that are difficult to access. Diver dredging also allows for selective removal of target species. However, the procedure is not 100% effective as root masses are not always removed. As with other forms of dredging, diver dredging is expensive and has the same negative impacts on lake ecosystems, though to a lesser degree as mostly plant material and little sediment is removed.

Lake drawdown is a cost-effective method used for aquatic plant control where lake-level control structures are in place. For species that do not have overwintering structures (seeds, winter buds, etc.) such as milfoil or elodea, exposure to freezing temperatures during lake drawdown is fatal. Lake drawdown during hot, dry summer months will kill some aquatic plants due to desiccation and high temperatures. To be effective, lake water levels need to be lowered to the extent that sediments containing nuisance plant areas are exposed for a long period of time (one month or more is recommended).

Lowering lake levels also impacts other denizens of the aquatic community, such as turtles, frogs and macroinvertebrates that reside or overwinter in shallow areas. If drawdowns are not performed on a regular basis, aquatic plants will simply recolonize affected areas. Some aquatic plants thrive under drawdown conditions and there may be long-lasting or even permanent changes in the aquatic plant community. Other considerations for shoreline residents include: boats may not be able to be launched, docks and water intakes may be left high and dry, and lakeside well water-levels may lower.

Benthic barriers are installed in limited areas to control patches of aquatic nuisance plant growth or to eliminate plants from swimming areas. Benthic barriers reduce or eliminate aquatic plant growth due to compression and lack of sunlight. Materials ranging from burlap to synthetics have been used as benthic barriers. Barrier installation is accomplished more easily in late fall, winter, or early spring, when plant growth is minimal. It is extremely important to securely fasten barriers to the lake bottom as gases building up underneath will cause the barrier to bulge and rise. Aquatic plant control will only last as long as the barrier remains intact or until enough sediments have been deposited on top of the barrier to allow for plant growth.

Free-floating aquatic plant species, such as coontail, are not controlled by barriers. Other plants growing near the barriers, such as watermilfoils, are able to send out lateral shoots and inhabit areas where barriers have been installed. Spawning fish and other aquatic organisms inhabiting lake-bottom areas covered by barriers may be affected. Benthic barriers are susceptible to damage by anchors, fishing gear, harvesters, weather and other factors and must be inspected regularly as they can create safety hazards for navigation and swimming.

Biological control

Biological control of a nuisance, and usually invasive, species is accomplished by introducing an organism that is known to control or reduce the population of the target species. Millecoquin Lake is currently not infested with any invasive aquatic plant species nor is there a particular aquatic plant species that is dominating the ecosystem. Therefore, biological control is presented as additional information and to encourage lake users to do all they can to prevent the introduction of non-native species.

Biological control has primarily been used in Michigan to control the growth of two non-native species: Eurasian watermilfoil (*Myriophyllum spicatum*) and purple loosestrife (*Lythrum salicaria*). In both cases, a specific aquatic beetle known to feed upon the invasive plant is stocked in infested areas. The beetle (*Galerucella spp*.) used to control purple loosestrife originates from Europe, but underwent extensive testing before being released in the United States. The beetle (*Euhrychiopsis lecontei*) used to control Eurasian watermilfoil is native to Michigan due to the presence of native watermilfoils, but feeds preferentially on the exotic watermilfoil. Both of these bio-control agents have been quite successful in controlling growth of the target species.

The biggest drawback to using biological control is the potential for non-native bio-control agents, such as the purple loosestrife beetle, to proliferate, become a nuisance and cause ecosystem disruptions. Non-native species should never be introduced as bio-control agents unless approved by regulatory agencies (i.e., DEQ). The introduction of untested, non-native bio-control organisms can severely alter the native ecosystem.

Bio-control is often expensive or may not even be available for the nuisance aquatic plant species in question. The native weevil that feeds upon watermilfoil is available through EnviroScience, Inc. in Ohio, but costs over one dollar each and thousands or often, tens of thousands, need to be stocked to be effective. Surveys conducted before, during and after stocking efforts to gauge project progress result in additional costs. The purple loosestrife beetle is currently not commercially available, but instead, has to be gathered by hand from locations where it has become established. Safe bio-control agents have not yet been found for other invasive aquatic plant species such as curly-leaved pondweed.

Biological control can potentially take many years and there is no guarantee that it will be effective. The success of controlling Eurasian watermilfoil using weevils hinges on many factors including: availability of suitable habitat for weevil over-wintering, sufficient stocking numbers, and recreational impacts on stocked weevils (such as boating and swimming). Furthermore, there is always the potential need for additional stocking in the future if ecosystem equilibrium is disrupted and the invasive aquatic plants gain the upper hand.

There are many success stories throughout Michigan and the nation using beetles to control purple loosestrife and Eurasian watermilfoil. The most notable is the resounding and enduring success of the first Eurasian watermilfoil control project in Michigan where weevils were stocked. While conducting an aquatic plant survey in 1996, Tip of the Mitt Watershed Council documented problematic Eurasian watermilfoil growth in Paradise Lake in Cheboygan County. The Paradise Lake Association contracted EnviroScience to stock weevils for a period of several years, but surveys conducted after the first two years of stocking indicated that further treatment was unnecessary and no stocking has been required since.

In spite of the fact that biological control is not guaranteed and takes time, patience, and money, there are many benefits that may outweigh these drawbacks. If successful, biological control provides a fairly long-term solution for target nuisance species without introducing chemicals into the environment, disturbing sediments, or killing other aquatic organisms. Maintenance is minimal, restocking only if the system again becomes imbalanced. In the case of the watermilfoil weevil the introduction of an exotic species is not an issue as the weevil is native.

Integrated control

Integrated control consists of a mix of any of the previously described methods of aquatic plant control. Some situations may require an integrated approach as one method may not be suitable for controlling differing types of nuisance aquatic plant growth within a lake. For example, a lake association may opt for stocking weevils to control an area of the lake infested with watermilfoil while at the same time installing benthic barriers in a public swimming area that is experiencing nuisance native aquatic plant growth.

By taking an integrated approach you get the combined benefits of all methods used, but also the combined problems of all methods. In addition, one method may affect the success of another. For example, cutting aquatic plants may spread plant fragments that recolonize other parts of the lake where other methods like manual removal were employed. Another situation where mixing control methods causes problems is when widespread chemical treatment destroys the food source which sustains a biological control organism that is being used.

Recommendations for aquatic plant and lake management:

1. Develop aquatic plant management plan

   The aquatic plant community is a vital component of the aquatic ecosystem, such that good aquatic plant management translates to good lake ecosystem management. To properly manage aquatic plants in your lake, an aquatic plant management plan should be developed. There are a number of guides available to help your organization develop such a plan, including *Management of Aquatic Plants* by Michigan DEQ, *Aquatic Plant Management in Wisconsin* by University of Wisconsin Extension, and *A Citizen's Manual for Developing Integrated Aquatic Vegetation Management Plans* by the Washington State Department of Ecology. Your organization's decision to have this survey conducted was a good first step in creating a management plan.

2. Information and education outreach

   Human activity in a multitude of forms typically has the greatest impact on a lake's aquatic plant community. Therefore, effectively managing the lake's aquatic plants requires information and education outreach projects that target shoreline property owners, watershed residents and all other lake users. Residents can improve land management practices to reduce nutrient loading (to control excessive plant growth) by establishing naturally vegetated buffers along the shoreline, reducing or eliminating yard fertilizers, and properly maintaining septic systems. Lake associations can help prevent the introduction of non-native species (such as Eurasian watermilfoil) by posting signs and educating members and other lake users. Outreach activities should not be limited to do's and don'ts, but also include general information about aquatic plants and their importance to the lake ecosystem.

3. Disseminate survey results

   The results of this study should be widely dispersed to get maximum returns on the Club's investment. Sharing the results with members, non-member lake users, government officials, and others will alert the public to problems occurring in the lake and provide information regarding strategies for resolving the problems. If the public fully understands aquatic plant management issues on Millecoquin Lake, there will be less resistance to proposed solutions. Furthermore, an informed public may result in behavioral changes that benefit aquatic plant management, such as reducing lake nutrient loads and preventing the introduction of additional non-native species.

4. Short-term aquatic plant control

Aquatic plant control options should be carefully evaluated, weighing the positive against the negative aspects of each. Following the wrong road could lead to even greater problems. Aquatic plants that seem like a nuisance to a swimmer or boater may be a sanctuary for small fish, macroinvertebrates and other aquatic life. Drastic alteration of the aquatic plant community could have far-reaching and devastating impacts on fisheries and the entire ecosystem.

Aquatic herbicides are already being utilized on Millecoquin Lake to control aquatic plant growth in a small area. In general, the Watershed Council does not support the use of chemicals for controlling aquatic plants due to the many known negative impacts to the aquatic ecosystem, but perhaps more importantly, because of the unknown effects of releasing chemicals into the water. In particular, chemical control on the scale necessary for the dense plant growth on Millecoquin Lake could severely reduce dissolved oxygen concentrations.

Neither dredging nor lake drawdown are deemed appropriate for Millecoquin Lake due to the size of the lake, the areal extent of aquatic plant growth, and the potential to severely impact the ecosystem. Diver-dredging could be an appropriate technique for the circumstances as optimally, the entire plant is removed, but it is expensive and generally only applicable in small areas. Benthic barrier installation would also be appropriate for controlling aquatic plant growth in limited areas.

The remaining physical control method, plant cutting and removal, could be applied in limited areas to reduce the aquatic vegetation density. There would be some loss of aquatic animal life living among or on the plants. As long as plant material is removed (harvested) and disposed of in areas isolated from the lake, then dissolved oxygen reductions as a result of decaying plant matter should be minimal. A number of aquatic plants spread through fragmentation including coontail, elodea, and watermilfoils. Although fragmentation of certain aquatic plants may be abetted by harvesting operations, there are few if any areas in the lake to be colonized and therefore, should not exacerbate the lake's aquatic plant problem.

Hiawatha Sportsman's Club members suggested composting the harvested aquatic plant material and selling it to financially support harvester equipment maintenance. This seems like a great idea and would not have water quality impacts as long as composting operations are far-removed from the water's edge (such that storm runoff from decaying plant matter cannot reach the lake).

5. Long-term aquatic plant control

Millecoquin Lake is prone to dense aquatic plant growth due to its shallowness and to the fact that it is an impounded lake on a river system and thus accumulates sediments and nutrients. Thus, long-term aquatic plant control efforts must focus on these factors.

Surveys by DEQ and DNR indicate that agricultural land use in Furlong and Doe Creeks is contributing excess nutrients, artificial trout ponds in Cold and Three-mile Creeks could be contributing nutrients, and all tributaries have excessive sand and silt loads. To reduce nutrient and sediment inputs to Millecoquin Lake, the problems should be dealt with at the source whenever possible.

Although agricultural best management practices have been instituted along Furlong and Doe Creeks, the 2000 DEQ report stated that livestock were still accessing and eroding stream banks as well as contributing animal waste. The Hiawatha Sportsman's Club should do all that is possible to encourage farmers to properly manage livestock and livestock wastes to reduce or eliminate sedimentation and nutrient pollution to the streams.

Nutrient-rich water from trout farms may also be contributing to the lake's total nutrient load. Education and outreach to fish farmers, which encourages them to adopt best management practices that reduce or eliminate nutrient inputs to the creeks, could help control aquatic plant growth in Millecoquin Lake.

Sediments in the tributaries eventually reach the lake, gradually filling the basin and reducing depth. Sediments coming into the lake may have also adsorbed nutrients and therefore, create fertile bedding for aquatic plants. Sedimentation can be reduced or eliminated at the source in certain situations. Preventing livestock from accessing streams, stabilizing eroded stream banks, and installing best management practices at road-stream crossings will help reduce sediments. However, the DEQ survey alludes to a substantial portion of the sediment load originating from historic logging practices and beaver dams. Sand traps installed in the inlet streams could potentially reduce the amount of sediments filling the lake.

Most of the nutrient and sediment load is trapped in Millecoquin Lake as a result of the water control structure at the outlet. If the structure were removed, the river system would be returned to a natural state that would allow nutrients and sediments to more easily exit the lake ecosystem. However, there would be a number of ramifications including: 1) sediment and nutrient pollution in the Lower Millecoquins River, 2) a reduction in lake depth and size and 3) ecosystem impacts from a lowered lake level. Pursuing water control structure removal would require an in-depth assessment of environmental impacts and a difficult permitting process.

6. Lake dissolved oxygen monitoring

Excessive aquatic plant growth has the potential to create dissolved oxygen deficits in the aquatic ecosystem due to both decomposition and respiration. For a variety of reasons, aquatic plants die and decompose. Aerobic bacteria involved in the decomposition process have the potential to consume large amounts of dissolved oxygen. This process is concentrated in deeper waters where decomposing plants settle, which is an area of the lake where dissolved oxygen is not easily replenished by atmospheric exchange due to distance from the surface. In addition, plants produce oxygen during daylight hours, but respire and consume oxygen in the dark hours of the night. Therefore, aquatic plants compete with animals for dissolved oxygen at night, with the lowest concentrations typically occurring in early morning, just before dawn.

In light of these ecosystem processes and the abundant plant growth on Millecoquin Lake, it is recommended that the Club monitor dissolved oxygen concentrations. Monitoring dissolved oxygen would also help assess impacts of harvesting, particularly oxygen losses due to decomposition of cut plant material that is inadvertently not collected by the harvester. Dissolved oxygen should be monitored regularly throughout the entire water column from late spring to late fall or all year long if possible.

Equipment for monitoring dissolved oxygen is easy to use and maintain. The Watershed Council can provide names of preferred vendors if needed.

7. Other lake water quality monitoring

Beyond dissolved oxygen, there are other water quality parameters that could easily be monitored by volunteers from the Millecoquin Lake community. Additional water quality data would help the Club with lake management and tracking changes over time. The Cooperative Lakes Monitoring Program is a partnership between the Land and Water Management Division of the Department of Environmental Quality and the Michigan Lake and Stream Associations that helps citizens monitor lake water quality. Volunteers in this program monitor water transparency, chlorophyll-a, total phosphorus, dissolved oxygen and water temperature. To learn more about this program or to get involved, visit their web page at: http://www.mi-water-cmp.org/index.htm.

8. Tributary monitoring

One component of this study, which was not completed due to time limitations and equipment failure, was to monitor the tributaries of Millecoquin Lake to determine nutrient loads from each stream. Although DNR and DEQ reports have documented impacts in the different stream systems flowing into Millecoquin Lake, there is no data reporting the relative contribution of nutrients from each tributary. To fully understand the impacts of individual tributaries and thus focus on those that are most problematic, a monitoring survey should be conducted to determine both nutrient and sediment contributions of each stream flowing into the lake. This survey should be conducted over the period of at least one year, collecting data from streams under a variety of flow conditions and during different seasons.

9. Additional aquatic plant surveys

To properly manage the aquatic plant community of Millecoquin Lake, additional aquatic plant surveys should be conducted in the future. Future surveys will provide the Club with valuable data for determining trends over time, evaluating successes or failures of aquatic plant management projects, and documenting the presence of introduced non-native aquatic plant species. Although dependent upon many different variables, a comprehensive survey of the aquatic plant community should be conducted on a 5-10 year basis. In addition, Club members or other lake users should be trained to identify non-native aquatic plant species to catch an infestation early on and minimize impacts by adjusting aquatic plant management practices. The Watershed Council will be holding training sessions to teach the identification of select aquatic invasive species during the summer of 2006.

Recommendations for future aquatic plant surveys:

Although this study was thorough, there are factors that compromised the quality of the final product. These factors include methodology, equipment and time/funding resources.

Field data collection at 75 sites provided enough data to document species composition, plant densities and dominant aquatic plants. Collecting data from additional sites would have provided greater detail for delineating aquatic plant communities, but the return on the investment would probably not been justified in improvements to the final product. Although sample site selection was not completely random, which has consequences for statistical analysis and study repeatability, the method used was deemed appropriate for this study.

Fairly rigorous sampling techniques and effort were employed, but there is a possibility that not all species were collected at each site. Certain aquatic plant species, such as *Potamogeton pusillus,* are difficult to collect with the sampling device that was used. Other types of sampling gear may improve chances of collecting a fully representative sample during future studies.

The mapping-grade GPS unit used for this survey has a reported accuracy of 1 to 3 meters, which is more than adequate for the needs of this study. Some plant communities, particularly emergents and near-shore submergents, were often mapped at an offset due to inaccessibility and time constraints. Much of the aquatic plant community mapping was performed in a GIS by interpolation between sampling points or extrapolation from sampling points. More time dedicated to thorough field data collection would improve mapping accuracy of future surveys.

Watershed Council staff collected the most accurate field data possible considering time and resource constraints. A considerable amount of time was devoted to quality control while collecting data in the field and processing and analyzing data in the office to guarantee a high-quality product. The Watershed Council is confident that the final results represent the best product possible under the circumstances.

CONCLUSION

Lakes go through a natural aging process, gradually filling in over the course of hundreds or thousands of years with sediments and organic materials that are washed in from tributaries and the surrounding landscape. Millecoquin Lake, a shallow eutrophic lake with abundant vegetation, is at the end of this aging process. Under natural conditions, depth would continue to decrease from sedimentation and the lake would likely transform into an expansive wetland system with streams flowing through.

Human intervention, the installation of a water level control structure at the outlet, has altered the natural aging process. The water control structure maintains a higher water level, but at the same time traps sediments in the lake system and reduces the average depth. In addition, blocking the natural flow of the river increases nutrient loading by increasing the residence time of water in the lake and by adsorption of nutrients to sediments deposited in the lake.

Owing to the natural aging process and sediment and nutrient loading in a reservoir-like system, Millecoquin Lake is experiencing extensive and abundant aquatic plant growth. Aquatic plants occupy approximately 95% of the lake's surface area and growth is dense in most areas. The abundant aquatic vegetation has become a nuisance to recreational activities, such as swimming, fishing and boating, but has not been documented to degrade water quality or negatively impact the lake's fisheries. With the necessary information and resources, a plan can be devised to manage the aquatic plant community in such a way as to reduce nuisance plant growth, yet maintain a healthy ecosystem with vibrant fisheries.

The Hiawatha Sportsman's Club wisely chose to manage aquatic plants by collecting information on the aquatic plant communities in Millecoquin Lake and research options for aquatic plant control. This study provides the Club with valuable information regarding the areal extent of aquatic plant growth, plant density, species composition, and factors potentially contributing to plant growth. Furthermore, aquatic plant management options were thoroughly researched and presented along with recommendations.

The first step for the Club will be to sit down and draw up an aquatic plant management plan that includes elements of the findings and recommendations included in this report. For example, an element of the plan may include the purchase and maintenance of an aquatic plant harvester as well as schedules for operation and arrangements for material disposal or composting. Harvesting aquatic plants in limited areas should alleviate recreational conflicts without negatively impacting the lake ecosystem, but is only one, reactive element of the plan. The plan should also include more proactive elements such as projects focusing on nutrient and sediment controls in tributaries flowing into Millecoquin Lake as well as along the developed shoreline to control aquatic plant growth over the long-term. Preventing the introduction of non-native species is another extremely important piece of aquatic plant management that could and should be included in the plan. By developing and implementing a comprehensive aquatic plant management plan using information from this report and other relevant sources, the Hiawatha Sportsman's Club will have much greater success in managing aquatic plants in Millecoquin Lake.

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Appendix A: Sample Site Data.

Site ID	Depth (feet)	Coontail	Muskgrass	Waterweed (Elodea)	Water Stargrass	Water Marigold	Variable-leaf Watermilfoil	Common watermilfoil	Slender naiad
1	No data	H	No	M	No	L	No	H	No
2	No data	VH	No	H	No	No	No	M	No
3	No data	No	No	No	M	No	No	M	No
4	6.5	M	No	M	No	No	No	H	No
5	6.8	VH	No	No	No	No	No	VL	No
6	5	VH	No	M	VL	No	No	L	No
7	2.2	H	No	VH	No	L	No	M	No
8	3	H	No	H	L	No	No	H	No
9	3.3	VL	No	VL	No	VL	No	No	No
10	2.5	M	No	L	No	No	No	VL	No
11	3.5	M	No	M	No	No	No	M	No
12	4.4	H	No	L	No	No	No	VL	No
13	5.9	L	No	L	No	No	No	H	No
14	7.2	VH	No	L	L	L	No	H	No
15	7.4	M	No	M	No	No	No	M	No
16	7.5	H	No	L	No	No	No	No	No
17	6.5	VH	No	L	No	No	No	No	No
18	5.2	No	No	VL	No	No	No	H	No
19	1.1	No	No	VL-L	No	No	No	M	No
20	1.6	L	No	H	No	No	No	H	No
21	5.2	H	No	M	No	No	No	H	No
22	6.5	H	No	M-H	No	No	No	M-H	No
23	6.1	VH	No	L	No	No	No	No	No
24	3.2	No	No	No	No	No	No	No	No
25	5.3	No	No	M	No	No	No	M	No
26	6.4	L	No	M	No	No	No	No	No
27	7	H	No	H	No	No	No	M-H	No
28	9.1	VL	No	No	No	No	No	No	No
29	8.7	H	No	L	L	No	No	VL	No
30	8.6	H	No	No	No	No	No	M	No
31	8.2	M	No	M	No	VL	No	H	No
32	6.9	VH	No	VL	L	No	No	M	No
33	3.6	VH	No	L	No	No	No	L	No
34	6.4	VH	No	L	No	VL	No	No	No
35	7.4	M-H	No	No	No	No	No	M-H	No
36	7.9	M	No	VL	No	VL	No	No	No
37	7.8	H	No	L	No	No	No	M	No
38	7.1	L	No	H	No	No	No	L	No
39	5.9	No	No	VL	No	VL	No	VL	No
40	7.5	VH	No	M	No	No	No	L	No
41	8.5	VH	No	L	No	No	No	H	No
42	8.6	H	No	L	No	No	No	L	No
43	9.2	L	No	No	No	No	No	L	No
44	8.2	VL	No	No	No	No	No	H	No
45	8	VH	No	No	No	No	No	H	No
46	8.9	VH	No	No	No	No	No	No	No
47	7.7	VH	No	VL	No	No	No	L	No
48	8.6	H	VL	No	No	No	No	VH	No
49	7.4	VH	No	L	No	No	No	H	No
50	4.8	No	No	M	No	VL	No	L	No

Site ID	Yellow Pond-lily	Largeleaf pondweed	Fries's pondweed	Floatingleaf Pondweed	Whitestem pondweed	Richardson pondweed	Robbins' pondweed	Flatstem pondweed	Water Buttercup
1	No	No	No	VL	No	No	H	H	No
2	No	No	L	No	No	No	VL	M	No
3	No	No	No	No	No	No	L	VH	No
4	No	L	No	No	No	No	H	M	No
5	No	No	No	No	No	M	VH	M	No
6	No	No	No	No	No	No	M	No	No
7	No	M	L	M	No	No	No	M-H	No
8	M-H	No	No	L	No	M	No	L	No
9	No	No	No	No	No	No	VH	No	No
10	No	No	No	No	No	No	VH	No	No
11	No	No	No	No	No	No	VH	VL	No
12	No	No	No	No	No	No	VH	VL	No
13	No	H	No	No	No	No	No	VL	No
14	No	L	No	No	No	No	M	L-M	No
15	No	L	M	No	No	No	L	M	No
16	No	H	No	No	No	No	L	M-H	No
17	No	M-H	No	No	No	No	M	M-H	No
18	No	No	M	No	No	No	M	M-H	No
19	No	No	No	No	No	No	No	No	No
20	No	No	No	No	No	L	No	No	M
21	No	VL	No	No	No	No	L	H	No
22	No	M-H	M	No	No	No	No	M-H	No
23	No	No	No	No	M	No	M-H	VH	No
24	No	No	No	No	No	No	No	No	No
25	No	H	No	No	No	No	VH	No	No
26	No	M	L	No	No	M	VH	L	No
27	No	H	No	No	No	No	H	L	No
28	No	L	VH	No	No	L	No	M	No
29	No	No	H	No	No	H	VL	No	No
30	No	No	VL-L	No	No	M-H	VH	H	No
31	No	L	No	No	L	No	VH	H	No
32	No	No	No	No	No	No	M	No	No
33	No	M	No	No	No	No	L	M	No
34	No	No	No	No	No	No	VH	No	No
35	No	L	No	No	No	M-H	M-H	L	No
36	No	No	No	No	No	No	H	L	No
37	No	M	L	No	No	No	H	VL-L	No
38	No	H	M	No	L	No	L	L	No
39	No	VH	No	No	No	No	VH	No	No
40	No	H-VH	No	No	No	No	L	L	No
41	No	L	No	No	L	No	L	M	No
42	No	VL	M	No	H	No	No	H	No
43	No	No	H	No	No	M	No	M	No
44	No	No	VL-L	No	No	No	H	No	No
45	No	No	M	No	L-M	No	No	M	No
46	No	No	No	No	No	No	M	L	No
47	No	L	No	No	L	No	H	M	No
48	No	No	M-H	No	No	No	VL	M-H	No
49	No	H	No	No	No	L-M	L	No	No
50	No	No	No	VL	No	No	H	H	No

Site ID	Hardstem Bulrush	Sago Pondweed	Eelgrass	# of Taxa	Density	Dominant Plants
1	No	No	VL	8	4	Coontail, Pondweed, Watermilfoil
2	No	No	No	6	3	Coontail, Pondweed, Watermilfoil
3	No	No	VL	5	2	Pondweed
4	No	No	No	6	2	Pondweed, Watermilfoil
5	No	No	No	6	4	Coontail, Pondweed
6	No	No	VL	6	2	Coontail
7	No	M	No	9	4	Elodea
8	No	No	M	10	4	Coontail, Watermilfoil
9	No	No	No	4	2	Pondweed
10	No	No	No	4	2	Pondweed
11	No	No	No	5	2	Pondweed
12	No	No	No	5	3	Pondweed
13	No	No	L	6	2	Coontail, Pondweed
14	No	L	L	10	3	Watermilfoil
15	No	No	No	7	0	Coontail, Elodea, Pondweed, Watermilfoil
16	No	No	No	5	3	Coontail, Pondweed
17	No	No	No	5	4	Coontail
18	No	No	No	5	2	Watermilfoil
19	No	No	VL-L	3	0	Watermilfoil
20	No	M	No	6	2	Elodea, Watermilfoil
21	No	No	No	6	3	Coontail, Pondweed, Watermilfoil
22	No	No	No	6	5	Coontail
23	No	No	No	5	5	Coontail, Pondweed
24	L	No	No	1	0	Schoenoplectus acutus
25	No	No	No	4	2	Pondweed
26	No	No	No	7	2	Pondweed
27	No	No	No	6	5	Coontail, Elodea, Pondweed
28	No	No	VL	6	2	Pondweed
29	No	L	No	8	3	Coontail, Pondweed
30	No	No	No	6	5	Pondweed
31	No	No	No	8	4	Pondweed
32	No	No	L-M	6	2	Coontail
33	No	No	No	6	2	Coontail
34	No	No	No	4	4	Coontail, Pondweed
35	No	L	L	8	4	Coontail, Pondweed, Watermilfoil
36	No	No	No	4	1	Pondweed
37	No	No	No	7	2	Coontail, Pondweed
38	No	No	No	8	2	Elodea, Pondweed
39	No	No	No	5	4	Pondweed
40	No	No	VL	7	4	Coontail, Pondweed
41	No	No	No	7	3	Coontail
42	No	No	L-M	8	3	Coontail, Pondweed
43	No	No	M	6	1	Pondweed
44	No	No	No	4	2	Pondweed, Watermilfoil
45	No	No	L	6	3	Coontail
46	No	No	VL	4	2	Coontail
47	No	No	No	7	3	Coontail
48	No	No	No	5	5	Watermilfoil
49	No	No	No	6	4	Coontail
50	No	No	VL	8	4	Pondweed

Site ID	Depth (ft)	Coontail	Muskgrass	Waterweed (Elodea)	Water Stargrass	Water Marigold	Variable-leaf Watermilfoil	Common watermilfoil	Slender naiad
51	7.7	H	No	No	No	No	No	L	No
52	8.3	M	No	No	No	No	No	L	No
53	8.8	H	No	No	No	No	No	H	No
54	8.8	M-H	No	L-M	No	No	No	M-H	No
55	8.4	L	No	No	No	No	No	H	No
56	8.2	L	No	VL	No	No	No	L	No
57	8.8	H	VL	VL	No	No	No	M-H	No
58	8.6	VH	No	No	No	No	No	M	No
59	8.3	VH	No	No	No	No	No	L	No
60	6.5	L	No	VL	No	VL	No	VH	No
61	5.9	No	L	L	No	No	No	M	No
62	8.4	H	No	No	No	No	No	H	No
63	8.7	H	No	VL	No	No	No	M	No
64	6.8	No	No	M	No	No	No	M-H	No
65	4.4	H	No	VL	No	No	No	VL-L	No
66	8.2	VH	No	L	No	No	No	VL	No
67	4.2	VL	No	M	M	VL	No	H	No
68	7.8	L	No	L-M	No	No	No	No	No
69	7.5	L	No	No	No	No	No	No	L
70	8	VH	No	No	No	No	No	M-H	No
71	5.7	No	No	L	No	No	No	VL	No
72	7.5	VL-L	No	No	No	No	No	VL	No
73	7.4	M-H	No	No	No	No	No	No	No
74	4.8	M	No	H	No	No	No	H	No
75	2.3	No	No	H	No	No	M	H	No
Total # spp/site:		64	3	53	7	11	1	62	1

Site ID	Yellow Pond-lily	Largeleaf pondweed	Fries's pondweed	Floatingleaf Pondweed	Whitestem pondweed	Richardson pondweed	Robbins' pondweed	Flatstem pondweed	Water Buttercup
51	No	L	No	No	No	No	H	No	No
52	No	L	VH	No	No	No	No	L	No
53	No	No	H	No	No	H	No	M	No
54	No	No	M-H	No	No	H	L-M	M-H	No
55	No	No	L	No	No	No	L	VH	No
56	No	No	H	No	No	H	L	H	No
57	No	No	M	No	No	VH	L	H	No
58	No	No	H	No	No	VH	L	VH	No
59	No	No	No	No	H	No	H	M	No
60	No	VL	No	No	No	M-H	H	No	No
61	No	No	No	No	No	L	H	No	No
62	No	No	M	No	No	M-H	M	M	No
63	No	No	No	No	No	H	H	H	No
64	No	M	No	No	L-M	No	H	No	No
65	No	VH	No	No	No	No	M	L	No
66	No	No	VL	No	VL	No	L-M	M-H	No
67	No	H	No	No	No	No	H	No	No
68	No	No	L-M	No	No	H	No	VH	No
69	No	No	No	No	No	M	H	H	No
70	No	No	M	No	No	No	VL	VH	No
71	No	VH	No	No	No	No	VH	No	No
72	No	No	H	No	No	H	H	VL-L	No
73	No	No	No	No	No	No	VH	L	No
74	No	H	No	No	No	No	H	No	No
75	No	No	H	L	No	M	No	M	No
	1	33	29	4	10	24	60	54	1

Site ID	Hardstem Bulrush	Sago Pondweed	Eelgrass	# of Taxa	Density	Dominant Plants
51	No	No	No	4	2	Coontail, Pondweed
52	No	No	No	5	2	Pondweed
53	No	No	No	5	4	Coontail, Pondweed, Watermilfoil
54	No	No	No	7	5	Pondweed
55	No	No	L	6	3	Pondweed
56	No	No	No	7	3	Coontail, Pondweed
57	No	No	No	8	5	Coontail, Pondweed
58	No	No	No	6	7	Coontail, Pondweed
59	No	L	No	6	4	Coontail
60	No	No	L-M	8	4	Watermilfoil
61	No	No	No	5	1	Pondweed
62	No	M	No	7	3	Coontail, Watermilfoil
63	No	No	No	6	4	Coontail, Pondweed
64	No	No	VL	6	2	Pondweed
65	No	No	No	6	3	Pondweed
66	No	No	No	7	3	Coontail
67	No	No	No	7	3	Pondweed, Watermilfoil
68	No	VL	No	6	3	Pondweed
69	No	L	No	6	2	Pondweed
70	No	No	No	5	5	Coontail, Pondweed
71	No	No	VL	5	4	Pondweed
72	No	No	No	6	3	Pondweed
73	No	No	No	3	3	Pondweed
74	No	No	No	5	4	Coontail, Elodea, Pondweed
75	No	M	No	8	3	Elodea, Watermilfoil, Pondweed
#/site:	1	10	19	Avg = 6.0		

Appendix B: Aquatic plant control options matrix.

AQUATIC PLANT CONTROL OPTIONS MATRIX		
**primary source: http://www.ecy.wa.gov/programs/wq/plants/management/*		
Control Method	**Advantages**	**Disadvantages**
Herbicide Application	Recreational activities such as swimming and boating improve.	Habitat and refuge loss for aquatic species that depend upon aquatic plants.
	Often get quick results, though some treatments take weeks or months.	Food source reduced or eliminated for aquatic organisms that feed on plants or on other organisms that live on/in plants.
	Short-term costs are generally low compared to other forms of treatment.	Native species may also be killed by the herbicide, weakening the native plant community and opening door to invasives.
	Herbicides and application services are readily available through a variety of companies.	Herbicides kill plants, but leaves decaying plant material in the water, which can lead to oxygen depletion and fish kills.
		Spot treatment using herbicide is prone to dispersal by winds, waves, and currents, potentially impacting non-target areas.
		Herbicides have been shown to migrate from surface waters into and contaminate groundwater.
		Some chemicals accumulate in sediments and may reach toxic levels for aquatic life occupying that niche.
		Full extent of chemical impacts on other organisms within the ecosystem are usually unknown.
		Resource expenditure (money and effort) is usually continual and long-term.
		Restricts use of some lake areas that must be closed for a time after herbicide application.
Manual plant removal	Able to remove plants from dock and swimming areas.	Treatment may need to be repeated several times each summer.
	Inexpensive.	Not practical for large areas or thick weed beds.
	Selective aquatic plant removal.	It is difficult to collect all plant fragments (most aquatic plants can re-grow from fragments).
	Environmentally sound.	Plants with large rhizomes, like water lilies, are difficult to remove.
		Loosened sediments have biological impacts in immediate area and makes it difficult to see remaining plants.
		Bottom-dwelling animals in affected area disturbed or killed.

Control Method	Advantages	Disadvantages
Cutters	Water area immediately opened, improving recreational opportunities.	Plants may need to be cut several times per season.
	May work in shallow waters not accessible to larger harvesters.	Some species are difficult to cut.
	Habitat for fish and other organisms is retained if the plants are not cut too short.	Plant fragments from cutting may enhance the spread of invasive plants such as Eurasian watermilfoil.
	Can target specific locations and protect designated conservancy areas.	Decomposing plant fragments potentially reduce dissolved oxygen in water (and create a nuisance when drifting to shore).
	Prices are much lower than harvesters.	Little or no reduction in plant density.
		Stirred sediments clog gills of fish and macroinvertebrates, smother small organisms and potentially reduce habitat when resettling.
Harvesting	Water area immediately opened, improving recreational opportunities.	Initial costs for equipment are high and maintenance is required.
	Removes plant nutrients, such as nitrogen and phosphorus, from the lake.	Plants may need to be cut several times per season.
	Harvesting as aquatic plants are dying back for the winter can remove organic material and help slow the sedimentation rate in a waterbody.	Little or no reduction in plant density (# of plants per area).
	Habitat for fish and other organisms is retained if the plants are not cut too short.	Must have off-loading sites and disposal areas for cut plants.
	Can target specific locations and protect designated conservancy areas.	Not easily maneuverable in shallow water or around docks or other obstructions.
		Small fish and other aquatic organisms are often collected and killed.
		Plant fragments from cutting may enhance the spread of invasive plants such as Eurasian watermilfoil.
		Decomposing plant fragments potentially reduce dissolved oxygen in water (and create a nuisance when drifting to shore).
		Stirred sediments clog gills of fish and macroinvertebrates, smother small organisms and potentially reduce habitat when resettling.
		May not be suitable for lakes with many bottom obstructions (stumps, logs).
		May not be suitable for very shallow lakes (3-5 feet of water) with loose organic sediments
		Harvesters from other waterbodies must be thoroughly cleaned and inspected to avoid introduction of exotic species.

Control Method	Advantages	Disadvantages
Dredging	Long-term control in areas that are sufficiently deepened.	Expensive.
	Water area immediately opened, improving recreational opportunities.	Sediments are stirred up, which could release nutrients or long-buried toxic materials into the water column.
	Plant material and nutrients or contaminants permanently removed from the lake.	Stirred sediments clog gills of fish and macroinvertebrates, smother small organisms and potentially reduce habitat when resettling.
	Diver dredging can selectively remove target species.	Bottom-dwelling animals in affected area disturbed or killed.
	Diver dredging can remove plants around docks and in other difficult to reach areas.	Aquatic plant root removal may destabilize lake bottom.
		Aquatic plant removal could lead to shoreline erosion as wave energy and currents are no longer absorbed.
		Root crowns may be missed and lead to future growth.
		Spoils must be properly disposed of.
Lake Drawdown	Cost effective, if water control structure is in place.	Costly if a water level control structure is not in place (requires high capacity pumps).
	Re-colonization by native aquatic plants in areas formerly occupied by exotic species can be enhanced.	Does not kill all plants and enhances growth of some aquatic plants.
	Game fish populations are reported to improve after drawdown.	Success in killing the target species dependent on weather (e.g. warm winters or wet summers).
	Provides an opportunity to repair and improve docks and other structures.	Docks and water intakes left high and dry, boat launching complicated, and well water levels may lower.
	Loose, flocculent sediments can become consolidated.	Exposing lake bottom areas impacts fish and other aquatic wildlife.
		Algal blooms have been reported to occur after drawdowns.

Control Method	Advantages	Disadvantages
Benthic Barriers	Water area immediately opened, improving recreational opportunities.	Only suitable for localized control, as barriers cover sediment and reduce habitat.
	Easy installation around docks and in swimming areas.	Require regular inspection and maintenance for safety and performance.
	Can control 100 percent of aquatic plants, if properly installed.	May be damaged or dislodged by anchors, harvesters, rotovators, fishing gear, propeller backwash, weather, etc.
	Materials for constructing barriers are often readily available.	Dislodged or improperly anchored barriers may create safety hazards for boaters and swimmers.
	Can be installed by homeowners or divers.	Swimmers may be injured by anchors used to fasten barriers.
		Some bottom screens are difficult to anchor on deep muck sediments.
		Barriers interfere with fish spawning and bottom-dwelling animals.
		Aquatic plants may quickly recolonize if barrier is not maintained.
		Not effective against free-floating plants.
Biological control	Long-term solution, if successful.	Usually only effective against one target species.
	Long-term maintenance is minimal.	May introduce a non-native species.
	No chemicals introduced, sediments are not disturbed, other aquatic organisms not sacrificed.	Bio-control agents may not be available for plant in question or not commercially available.
		Slow process, taking years.
		Success is not guaranteed.
		Initial stocking and survey costs are usually high.

Appendix C: Herbicides approved by Michigan DEQ and target species.

DEQ

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
WATER BUREAU

This table contains information concerning the herbicides permitted for aquatic plant and algae control in Michigan and the plant species for which they may serve as potential control agents. Refer to product labels for additional details.

Permits may be required prior to use of any pesticide, including "unclassified" pesticides. Contact the DEQ, Aquatic Nuisance Control & Remedial Action Unit at 517-241-7734, by e-mail at DEQ-LWM-ANC@michigan.gov, or visit our website at www.michigan.gov/deq.

Common Plant Species	Copper Sulfate	Chelated Copper	Amine Salts of Endothall* (Hydrothol 191)	Dipotassium Salts of Endothall* (Aquathol K)	Diquat dibromide** (Reward)	2,4-D* (Navigate, Aquakleen, Aquacide)
Algae						
Filamentous	X	X	X		X	
Macroalgae (e.g., Chara)	X	X	X			
Planktonic	X	X	X			
Macrophytes						
Submergents						
Coontail			X	X	X	X
Curly leaf pondweed			X	X	X	
Elodea			X		X	
Large leaf pondweed			X	X	X	
Milfoil			X	X	X	X
Naiad			X	X	X	
Sago pondweed			X	X	X	
Wild Celery			X		X	
Emergents						
Arrowhead						X
Bulrush						X
Cattails						X
Phragmites						
Purple Loosestrife						
Water lily						X
Free Floating						
Duckweed					X	

* Granular endothall and/or granular 2,4-D products may not be applied within 75 feet of ANY drinking water well or within 250 feet of drinking water wells that are less than 30 feet deep. Isolation distances are measured from the well location, not the shoreline.

** Diquat products are restricted for all aquatic uses, except in small ponds, such as farm ponds that have no outflow and are under the control of the user. This means that you must be licensed by the Michigan Department of Agriculture as a certified pest control applicator to use this material in all waterbodies except small ponds. Diquat is the only "Restricted Use" pesticide on the chart. All others are "Unclassified."

DEQ

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Common Plant Species	Fluridone (Sonar, AVAST!)	Glyphosate (Rodeo, Eagre, AquaNeat)	Imazapyr**** (Habitat)	Komeen	Nautique	Sodium Carbonate Peroxyhydrate (GreenClean Pro, Pak 27*****)	Triclopyr (Renovate 3)
Algae							
Filamentous						x	
Macroalgae (e.g., Chara)							
Planktonic						x	
Macrophytes							
Submergents							
Coontail				x			
Curly leaf pondweed							
Elodea				x			
Large leaf pondweed							
Milfoil	x***			x			x
Naiad				x	x		
Sago pondweed				x			
Wild Celery					x		
Emergents							
Arrowhead							
Bulrush			x				
Cattails		x	x				
Phragmites							
Purple Loosestrife		x	x				x
Water lily	x	x					x
Free Floating							
Duckweed			x				

*** Fluridone use may require a Lake Management Plan. Rates requested above 6 ppb must follow evaluation protocol.

**** As indicated on the label, application of Habitat can only be made by applicators who are licensed or certified as aquatic pest control applicators and are authorized by the state or local government.

***** The label indicates use for treatment of blue-green algae.