Lake Manitou Association
Process & Procedure Documentation
Lake Water Quality Management Strategy

Process 4	The electronic version of this document is controlled; all other versions are uncontrolled (for reference only)	
Process Owner:	Date Approved:	Version Number:
Lake Manitou President	09/14/06	1.2

1. **OBJECTIVE/PURPOSE:**

   The purpose of having a Lake Water Quality Management Strategy and process is to document the environmental variables associated with our lake, various treatment options used and not used, reasons for these decisions, and to record expected and actual results.

2. **RESPONSIBILITIES:**

   Lake Manitou President – Lake Officer responsible for implementing the Lake Water Quality Management Strategy

   Chemical Control Committee – Committee responsible to apply and manage the chemical portion of the Lake Water Quality Management Strategy including procurement of the chemicals and their permit(s) for application

   Lake Manitou Board – responsible to set and approve the Lake Water Quality Management Strategy

3. **DEFINITIONS:**

   Macrophytes – the rooted plants found in a lake or pond

   Board – Lake Manitou Board of Directors & Officers

   Limnologists – Lake Scientists

4. **PROCEDURE / DESCRIPTION:**

<u>Management Strategy for Lake Manitou Aquatic Plants</u>

Aquatic plants are a vital part of any lake or pond. They convert sunlight and chemical elements into living plant tissue. Fish, waterfowl, insects, mammals, and microscopic animals use the plants for food. Plants also replenish the aquatic environment with oxygen, which is essential to aquatic animals. Additionally, rooted plants create a varied aquatic environment in which fish food organisms reside. They also provide cover for spawning fish, nesting waterfowl, shoreline mammals, and their young.

Although they are important to the aquatic environment, plants frequently conflict with recreational and economic interests. A need, therefore, exists for proper aquatic plant management in Lake Manitou to insure that the natural environment and resident's interests are mutually protected.

This process/procedure describes the various issues regarding aquatic plant control, how these issues specifically impact Lake Manitou, which of these strategies we are following, and reasons for those decisions.

Aquatic Plant Types:

The first step in our lake management program is to identify the aquatic plants present in our water body. The proper management of aquatic vegetation requires knowledge of the various plants that grow in our lake and their importance to the aquatic ecosystem. Although aquatic plants may be divided into many categories, we have chosen a simple classification according to life forms and growth patterns and divided them into two categories: the algae and the macrophytes (rooted aquatic plants).

Algae

Algae are divided basically into planktonic, filamentous and macro-algae forms. Planktonic forms are microscopic, free-floating plants often referred to as "water bloom". In large numbers, these algae can cause water to appear green, brown, yellow or even red, depending upon the species present. Filamentous algae, commonly called "pond scum", can form raft-like masses over the water surface, but since they are vulnerable to winds and currents, they are generally restricted to bays, bayous and sheltered shorelines. Filamentous algae can also grow attached to the lake bottom, the macrophytes, piers, and docks. The filamentous algae will frequently detach from the substrate and form floating mats. The macro-algae include the two types referred to as Chara and Nitella, which are large and resemble macrophytes.

Macrophytes

The macrophytes are the rooted plants found in our lake. They are usually large, easily seen plants; however, some are small enough that dozens of plants can be held in one's hand. The macrophytes may be divided into three basic forms: submergent, emergent, and free-floating.

Submergent macrophytes usually grow rooted to the bottom with stems and leaves below the water surface, except for some plants, which may produce a few small floating or aerial leaves. Submergent plants provide food and cover for fish, waterfowl, and other aquatic life.

Emergent plants grow in shallow water, with most of the plant protruding above the water surface. Cattails, water lilies, arrowhead, rushes, and reeds are examples of emergent plants and, like the submerged plants, are important as food and cover for fish, waterfowl and other shoreline animals.

The **free-floating** macrophytes in Michigan are the duckweeds. These tiny plants are not attached to any substrate, but float freely upon the water. They are subject to current and wind action, which will concentrate them in certain portions of a lake. Some waterfowl utilize duckweed as food.

What Makes Aquatic Plants Grow in Lake Manitou?

The distribution and abundance of aquatic plants in our lake is dependent upon the lake's chemical and physical properties including:

- the amount of light available,
- water levels,
- water temperatures,
- type of lake bottom sediments,
- current or wave action, and
- the concentration of dissolved gasses and nutrients.

In lakes, nutrients and light availability are most often the factors that limit plant growth. Nutrients are the chemicals such as nitrogen, phosphorus, carbon, and potassium, which plants require for their growth. These nutrients originate in the rocks and soils surrounding the lake. Natural processes at work within the surrounding watershed continually carry some of these nutrients into the lake. A lake's watershed is the land around the lake from which water drains to the lake (Figure 1). Lake watersheds vary greatly in size, topographic relief and the means by which water moves through the watershed (stream flow, groundwater movement, surface runoff, etc.). The natural movement of nutrients to lakes is, therefore, dependent upon the characteristics of the watershed.

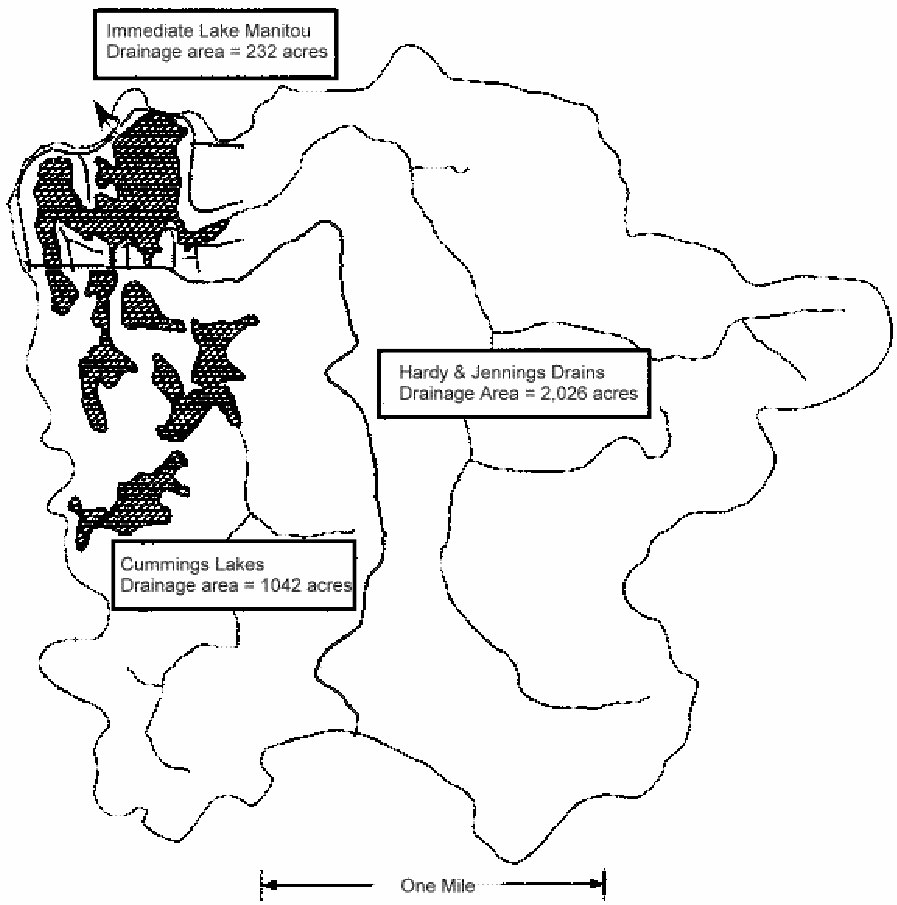


Figure 1. Lake Manitou watershed

As nutrients enter the lake from the watersheds, the lake responds by producing aquatic plants and algae. Limnologists have grouped lakes by a classification system based upon their productivity or ability to produce plants. Lakes that are low in productivity are called oligotrophic, while lakes high in productivity are called eutrophic.

Oligotrophic lakes usually:

- are deep,
- have high oxygen concentrations in the deeper water,
- are very clear,
- have sparse populations of aquatic plants, and

- are populated with cold water fishes such as trout and whitefish.

Eutrophic lakes usually;

- are shallow,
- have little oxygen in waters deeper than 30 feet,
- have murky water,
- have substantial growths of aquatic plants, and
- are populated with warm water fishes such as bass, pike, and bluegills.

The term mesotrophic is often used to describe a lake with characteristics between oligotrophic and eutrophic.

All lakes will become more productive or "age" with time. This aging process, commonly referred to as "eutrophication", is dependent upon the lake's physical characteristics and upon the quantity of sediments and nutrients washed into the lake from its watershed. Without human influence, the natural aging process is extremely slow often taking thousands of years to result in any noticeable changes in any lakes. Human activity on the watershed, however, may greatly accelerate the aging process by increasing the quantity of sediments and nutrients entering the lake. This fact emphasizes the importance of proper watershed management, especially at the shoreline of lakes and streams. Figure 2 illustrates a preferred watershed management plan versus poor or unplanned management of the watershed.

The Aquatic Plant Management Program

The goal of our plant management program is to maintain a proper balance of plants within Lake Manitou. Our aquatic plant management program has two phases:

- long-term management (nutrient control) and
- short-term management (direct manipulation of macrophyte and algae populations).

Short-term management is relatively easy to implement, but long-term management is more complicated. It requires considerable community involvement and cooperation, and results take years rather than days to develop.

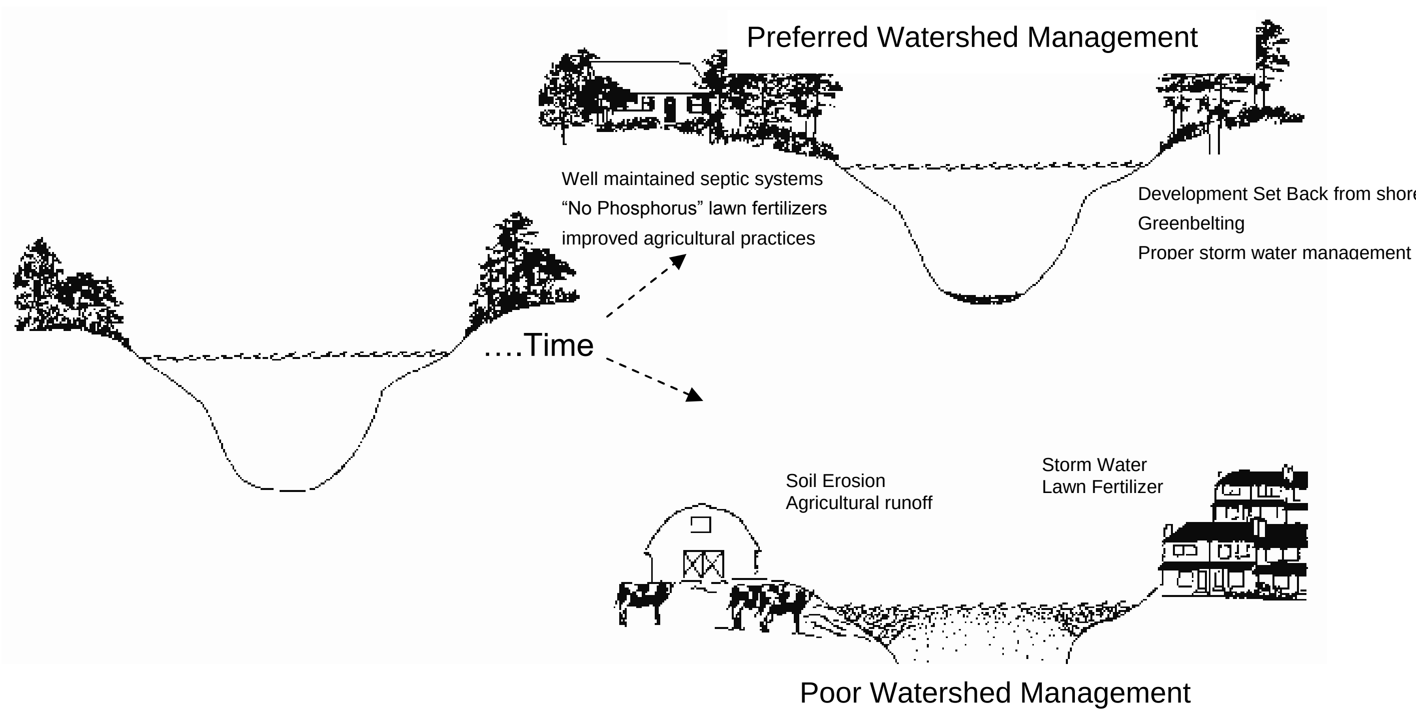


Figure 2. Preferred Watershed Management versus Poor or Unplanned Watershed Management

The remainder of this document will identify principles and techniques of long-term and short-term aquatic plant management. Not every principle or technique listed here is applicable to Lake Manitou at this time, however, they are documented to fully describe the topics, options available, applicability to our lake, evaluations, and decisions regarding implementation or inclusion of these items in our Lake Water Quality Management Strategy. Economics are considered, however, ecological values receive the prime consideration in our water quality management techniques. We believe that attention to the ecological values result in a program that is less costly over time.

Long Term Management (Nutrient Control)

Aquatic plants require many nutrients for growth and reproduction. The nutrients most often considered being in the shortest supply and, therefore, limiting plant growth are phosphorus and nitrogen. Since aquatic plant populations are directly dependent upon the amount of nutrients available, nuisance growths of plants are only symptoms of high nutrient levels. This is an important factor to consider as many aquatic plant control programs are directed only at the growing aquatic plants, and not at what causes the plants to grow (nutrients). The Lake Manitou aquatic plant management program gives proper consideration to the amount of nutrients entering the lake in order to improve the effectiveness of the control strategy. Aquatic plant management techniques designed only to "kill weeds" must be considered as only a temporary cosmetic measure to reduce the symptoms of high nutrient levels. It is more effective and beneficial to control the movement of nutrients (and sediments) from the watershed, whenever possible, than to attempt remedial action after nutrients have already entered the lake.

Our lake water quality strategy considers the inclusion of management techniques to control external nutrient sources so that, over time, we may help to reduce the rate of lake aging for Lake Manitou. Limiting the movement of nutrients off the watershed and into the lake requires the management of nutrient sources. Some sources of nutrients, both natural and cultural are listed in Table 1. Natural sources of nutrients are those, which would enter a lake, even without human influence. Most natural sources contain only very small amounts of nutrients. Human sources of nutrients are usually in large volumes and high concentrations, which can greatly accelerate the rate of lake eutrophication.

All nutrient sources will have different levels of manageability. Some may be uncontrollable, while others may be controlled with little effort or cost. Ideally, it is desirable to know which sources are contributing nutrients to a lake and in what quantities. It is then possible to adjust funds and activities to control nutrient sources to most effectively reduce the amount of nutrients entering the lake. This approach, in most situations, requires an extensive study by a trained limnologist. Lake Manitou contracted with Dr. Wally Fusiler for execution of a professional lake study in 1993 and updated the study in 2002.

The best time to begin a nutrient control program is before aquatic plants have attained nuisance levels. The management of nutrient sources is an on-going responsibility, which must be intensified as development of the watershed continues. Methods of nutrient source management include:

- proper land use,
- wise consumer use of commercial products,
- treatment of inflowing waters high in nutrients,
- diversion of water high in nutrients, and
- municipal and industrial waste water treatment.

Natural	**Cultural**
Wetland runoff	Domestic and industrial wastewater
Meadow land runoff	Agricultural runoff (cropland & pasture)
Forest runoff	Agricultural wetland drainage
Precipitation on the lake surface	Managed forest runoff
Soil erosion	Urban storm water runoff
Aquatic bird and animal wastes	Septic tank discharges
Leaf, pollen and dust deposition	Landfill drainage
Groundwater influxes	Construction activities
Nitrogen fixation by plants	Lake shore lawn runoff
Sediment recycling	Atmospheric fall-out of wind borne fertilizers from land and industry

Table 1

Natural and cultural (human) sources of plant nutrients
(chemical elements) to the aquatic environment.

Proper Land Use

The importance of proper land use and watershed planning is beginning to stimulate many units of government, at all levels, to enact ordinances and laws to regulate land use. In Michigan, the State Legislature enacted the Soil Erosion and Sedimentation Control Act of 1972 (Act No. 347 of Public Acts of 1972) to limit the movement of sediments and associated nutrients into surface waters during earth moving activities (except agricultural tillage).

Minnesota, Wisconsin and Maine now require local government units to establish zoning ordinances for lake and stream front properties to protect the quality of these aquatic environments. Table 2 presents land use practices that should be considered when developing a nutrient control program.

a.	Advocate sediment control from logging, agricultural activities and urban construction.
b.	Preserve wetlands as no development areas.
c.	Require or encourage greenbelting to preserve native vegetation along lake and stream banks.
d.	Promote proper collection and disposal of or treatment of farm and feedlot animal wastes.
e.	Encourage sound farm fertilization practices.
f.	Urge community collection and disposal of leaves in urban areas adjacent to large recreational water systems.
g.	Require routine inspection and maintenance of catch basins in city storm drains.
h.	Limit or restrict the use of fertilizers on lawns adjacent to lakes and streams.
i.	Prevent urban storm water drainage, with its high nutrients, from directly entering a lake, rather encourage subdivision designs that maximize infiltration and groundwater recharge.
j.	Regulate the size and use of lake and stream front lots and back lots to prevent over-development of the environment and its associated high nutrient loading.
k.	Stipulate a minimum distance of at least 100 feet between the shoreline and installation of private septic systems and tile fields.
l.	Prevent development in areas where the groundwater is high or soils are poor nutrient traps for private sewage-disposal systems.
m.	Require an environmental impact statement for all development that could significantly degrade environmental quality.

Table 2
Examples of wise land use practices that can reduce
the movement of nutrients from the watershed into lakes.

Wise Consumer Use of Commercial Products

There are several commercial products, such as detergents and fertilizers, used for domestic and commercial purposes, which can contribute significant amounts of nitrogen and phosphorus to natural waters. Curtailing or restricting the use of these products or substituting similar products of low nitrogen and phosphorus content would substantially reduce the loading of nutrients to natural waters.

Waterfront property owners should take special care in the use of detergents and fertilizers. To reduce phosphorus loading into waterways, high-phosphate detergents have been banned in Michigan and several surrounding states.

If lawns must be fertilized, soils should be tested to determine which chemical nutrients are needed. If the soil does not require phosphorus, a fertilizer with little or no phosphorus should be used. County cooperative extension agents can provide information on soil testing procedures and the best methods for applying fertilizers.

Treatment of Inflowing Waters High in Nutrients

In certain situations it may be possible or necessary to treat inflowing waters to reduce nutrient levels before they enter a lake. An inflowing stream or drain may carry substantial amounts of nutrients collected from many sources, such as agricultural drainage or urban storm water drainage. In certain situations it may be more feasible to chemically or physically treat the inflowing water to reduce nutrients than to control the many diffuse nutrient sources draining into it. We have partially addressed this control by having a settling area for water coming into Waugh Channel from the Hardy Drain. This area is intended to allow sediments to settle out before entering Lake Manitou. More work is needed in this area to improve the effectiveness of this control. For example, during heavy rains, the volume and rate of water flow entering the lake does not allow for much settling of sediment to occur in these cases. Additionally, the creation of a "wetland like" area where the settling area is would allow more nutrients to be removed and filtered from the water before it enters Lake Manitou.

Diversion of Waters High in Nutrients

Diversion is the rerouting of water high in nutrients around or away from a lake. The principle of diversion is applicable to most nutrient sources that can be physically contained or rerouted. The application of this nutrient control technique has been most frequently applied to the diversion of municipal wastewater, but the concept can apply to waters containing high nutrient levels derived from other sources as well. In many cases where nutrient rich water has been diverted away from a lake, there has been a marked increase in water quality. It must be emphasized, however, that diversion is not a substitute for treatment or proper land management. The diversion of non-treated nutrient rich waters is only a transfer of nutrient control problems to downstream communities. We are not using the diversion technique at this time. Lake Manitou is a man-made lake and would likely not have sufficient inflows to maintain the current lake level if we diverted the higher nutrient water entering from Waugh Channel.

Municipal Treatment and Industrial Wastewater

Few Michigan inland lakes receive municipal wastewater discharge, but when present, it can be a major source of nutrients for aquatic plant growth. Several methods are now available to reduce the level of plant nutrients in wastewater. But even when these methods are used, a wastewater treatment plant discharging to a lake or its tributaries will contribute greatly to the loading of nutrients to a lake. Diversions of wastewater around lakes or land disposal are possible alternatives for eliminating completely the impact of this nutrient source upon lakes.

Industrial wastewater is highly variable in quality. Those that contain substantial amounts of plant nutrients or toxic materials must be considered in any lake management program. We currently do not have any municipally treated or industrial wastewater directly or indirectly entering Lake Manitou.

Short Term Management of Aquatic Plants

Although the initial and continuing phase of aquatic plant management should be the control of nutrient sources, many lakes have such serious plant problems that short-term management techniques may be needed to maintain the recreational and economic interests in the lake. In cases where nutrient control is impractical, such as shallow reservoirs on major agricultural or urbanized river systems, short-term management practices may have to be conducted annually. Even in such cases, however, under no circumstances should the complete eradication of aquatic plants be considered. This practice is environmentally unsound and could have very undesirable consequences. In some lakes it may be necessary to alter recreational activities somewhat to suit the lake's state of eutrophication, rather than attempt to change the lake to meet recreational demands. In situations where nutrient control is possible, short-term management techniques should be considered only as temporary measures, designed to replace nuisance plant species with plant species that conflict less with recreational and economic interests.

The short-term methods for managing aquatic plants include:

1. biological control,
2. mechanical harvesting,
3. environmental manipulation, and
4. use of herbicides.

These methods are directed primarily at the results (aquatic plants) of nutrients entering the lake and not at reducing the flow of nutrients. In some cases, however, nutrient levels within the water system may be reduced incidentally with certain techniques. Lake Manitou has incorporated the mechanical harvesting control as an on-going element of our Lake Water Quality Management Strategy.

Biological Control

Biological control of aquatic vegetation is presently the least understood and utilized of the four short-term management techniques. Biological control normally includes the introduction of an organism that competes with, preys upon, inhibits the growth of, causes disease in, or parasitizes the plant species that has created the problem.

The use of biological agents has many potential hazards. Therefore, the use of this control technique in either the terrestrial or the aquatic environment will always be under the direct supervision of state agencies. The introduction and release of exotic, foreign or non-native insects, fish or other animals into Michigan without specific authorization is strictly forbidden by state laws (Act No.286 of the Public Acts of 1929; Act No.196 of the Public Acts of 1958).

At the present time, there are no specific biological control techniques being applied in Lake Manitou waters.

Mechanical Harvesting

Mechanical harvesting involves the pulling or cutting and removal of macrophytes from selected areas of a lake. It may employ hand tools or highly sophisticated motorized cutting or rotovating devices. The harvesting of algae from lakes appears presently to be economically infeasible primarily due to very high energy costs to remove the microscopic plants from water.

When large areas of aquatic plants are harvested, the cut material should be removed from the lake. If left in the lake, the cut plant parts will decompose, sometimes only partially, and contribute nutrients and organic material to the lake bottom. This, in turn, helps to nourish new plant growth. In addition, during biological decomposition of the cut plant material, dissolved oxygen levels may be lowered. This can affect the delicate balance between the water and sediment chemistry. Low oxygen levels also affect fish and fish-food organisms. Removing cut material from a lake improves water quality if the amount of nutrients removed (in plant material and algae attached to the macrophyte) is greater than the amount of nutrients entering the lake from the watershed.

Mechanical harvesting also has drawbacks which must be considered. It has a high initial investment if a specially manufactured harvester is purchased. Many of these machines are large, heavy and can be damaged by obstructions (logs, boulders, and debris) hidden below the lake surface. Additionally, harvesting could aid the spread of a plant problem, since fragments of certain plants could drift into unaffected areas, take root and grow. The Lake Manitou Board of Directors and Officers have considered the benefits of mechanical harvesting to outweigh the potential drawbacks and have incorporated the mechanical harvesting control as an on-going element of our Lake Water Quality Management Strategy.

Environmental Manipulation:

The objective of environmental manipulation is to alter one or more physical or chemical factors critical to plant reproduction and growth thereby making the environment less suitable to the plant. Several techniques have been used with varying degrees of success. These methods may not be economically or environmentally practical in every lake. Even in practical situations, a technique should be employed only after the particular plant problem, and social and economic factors have been care fully considered. Environmental manipulation can provide some control of aquatic plants, but without reduction of nutrient inputs, any results achieved will be only temporary. Since most of these methods are somewhat technical, only a brief discussion of each is given below. Most of these activities require a permit from the Michigan Department of Environmental Quality.

Dredging reduces nuisance aquatic macrophytes by deepening the lake bottom below the depth of light penetration. Reduction of the size of the well-lighted zone around the shore will reduce the total amount of macrophytes. The disadvantages of dredging include a temporary increase in silt suspended in the water, which on settling in non-dredged areas, can smother bottom living animals. Additionally, a suitable upland site must be available for the disposal of dredge spoils. Lake Manitou supports dredging to remove accumulated sediments in the channels where water inflows containing sediment is prevalent. The primary location for this is Waugh Channel.

Aeration is the introduction of air into the waters of a lake for the purpose of increasing the dissolved oxygen concentration of the water. Aeration is most effective in lakes that are devoid of oxygen in the deep water. Keeping oxygen in the bottom waters will prevent the release of nutrients from sediments. As long as nutrients remain chemically bound to the sediments in the deeper parts of the lake, they are less available for aquatic plant growth. Decreases in nuisance algal populations and a shift to more favorable species have been reported following aeration, but this result is not always observed. Control of aquatic plants by aeration has not been demonstrated. A possible disadvantage of aeration is that it can be detrimental to cold-water fishes (trout) if warm surface waters are mixed with cool bottom waters making the total lake environment unsuitable for these fish species. There are methods of aerating only the deeper waters, however. The use of an aerator may also cause the re-suspension of bottom mud(s) which may increase turbidity (‘cloudiness” of the water).

Lake Manitou has adopted an aeration strategy in the shallow, less agitated areas of the lake to improve the water quality in those areas. The bottomland in Lake Manitou contains a variety of organic materials and sediment. For the organic material to decay, it needs and consumes oxygen in the decomposition process. In the areas of low activity and where decaying organic components are present, the available oxygen in the water column becomes depleted which limits or stops the bottomland decomposition process. In addition, the iron molecules in the water column bind with nutrients in oxygenated water, however, they release the bound nutrients in oxygen-depleted water allowing the nutrients to be made available for algae and plant production.

The way in which aeration works is to oxygenate the bottom organic sediment encouraging decomposition and continuing to keep the plant and algae nutrients bound to the iron molecules rendering them unavailable for plant consumption. This is one reason why aeration may help to reduce the floating algae mats that typically develop by the shoreline in June/July. Depending on the composition of the bottomland, there may an unpleasant odor as the materials decompose and would be an indication that the aeration is having it's intended effect and is working properly as oxygen is provided to the bottom sediment to continue and accelerate the decomposition process.

Nutrient Inactivation is the application of a chemical to a lake that binds with and immobilizes nutrients necessary for plant growth. Once immobilized, the nutrients settle to the lake bottom. This method is appropriate for algae control, but has little effect on the growth of aquatic plants. The chemical substance used to immobilize and settle out the nutrients is usually a metal ion (iron, aluminum, calcium, copper). The settling process may also reduce suspended solids and decrease turbidity and color, in addition to inactivating the nutrients. This technique is effective and somewhat expensive. It may also adversely affect the small animals living in the bottom sediments that serve as fish food. Lake Manitou incorporates nutrient inactivation as a key element of our Lake Water Quality Strategy. The chemicals must be applied under permit from the Michigan Department of Environmental Quality by persons trained in their application. Lake Manitou receives it's training from the chemical company we purchase the chemicals from who is licensed by the State of Michigan.

Drawdown or **Water Level Manipulation** is a potential mechanism for controlling certain types of aquatic vegetation. In this technique, water levels are lowered for a period of time to expose shallow water areas. This dries out the exposed plants and kills them. Many submergent macrophytes are susceptible to this procedure, but certain emergent macrophytes actually benefit from it. In addition, this method does not control algae. A drawdown period of approximately two months is necessary for drying and freezing to be effective during winter drawdown.

The water level in Lake Manitou is controlled by the installation or removal of wooden boards in the spillway located on the north side of the lake. The spillway has three sections of boards which control the volume of water leaving the lake, however, the lowest installed board will control the level of the lake as water will seek it's own level and will not be higher than the lowest board.

A Lake Manitou Board Member is assigned the responsibility of installation and removal of the boards in the spillway. The Lake Manitou Board of Directors approved an addition to the Lake Manitou Special Record in 2002 stating that only a Lake Manitou Officer, Board Member, or someone working at the direction of the Lake Manitou Board of Directors is authorized to install or remove boards from the spillway. All others are not authorized to install or remove the boards and violations of this restriction would likely result in litigation.

There are several landmarks that have been used to measure Lake level: The culvert under Waugh Road, the Spillway itself, the seawall installed by Dave Acton, and the stump in Waugh channel. The use of the shoreline is not a good indication of water level as continual erosion of the shoreline typically occurs and shoreline landmarks cannot adequately define lake levels.

The flushing rate for Lake Manitou is 2.2 times per year… this means that the total water volume of Lake Manitou flows in and out of Lake Manitou an equivalent of 2.2 times each year. With that level of flushing, the water level is closely monitored to ensure we are effectively managing the lake level. The strategy for Lake Manitou is to remove six inches of boards in the fall, lowering the lake level to allow aquatic shore vegetation to be removed, provide additional shore protection during the icy periods, and to reduce the damage of ice on seawalls, docks, spillway, dam, etc.

The boards are kept out until after the spring rains, usually late May, and the lake level is increased to allow sufficient depth for boating, and to provide water for lawn irrigation. During the summer months and especially through periods of low rain, the lake level naturally drops due to evaporation and irrigation and will quite often stop flowing over the spillway due to the lack of water input. Once the summer boating season has concluded, several boards are usually removed in October and the lake level management cycle completes. There are special situations where additional board adjustments are made throughout the year. These adjustments are typically in response to inordinate rainfalls where additional boards must be quickly removed to lower the lake level that invariably encroaches on the homeowner properties on the west side of the lake.

During the 2004 Lake Association summer annual meeting, the Lake Board and membership approved a new policy in the event of a high moisture year as follows:

1. Leave the spillway boards out in April thru late May.
2. Install all the spillway boards in either very late May or early June depending on conditions.
   - In a normal year, evaporation will draw down the lake level naturally in June and July.
3. There are 3 rows of boards, any time water goes over the top of the 3rd board we will pull a board.
4. In an abnormally wet year, we will install a 4" board July 1 lowering the lake level down 2", replace the 4" board with a 2" board July 15th lowering the lake level another 2", and remove the board on August 1st to simulate a normal evaporative draw down.
5. We will remove a total of two full 6" boards from the center row of the spillway between Oct 1st and Oct 15th depending on continued warm weather to support the boating season.

Dilution or Displacement of low quality water with water of higher quality may lessen algae problems, but may not affect plant growth. A supply of higher quality replacement water must be available as well as an acceptable means of disposing of lower quality lake water. This technique is not being used in Lake Manitou at this time. There currently is no higher quality water source available to replace the Waugh Channel water inflow volume.

Shading for prolonged periods (4 weeks or longer) has been effective in reducing certain submergent macrophytes by light limitation. Light reduction through the use of water dyes has been tried with some success in ponds and small embayments in lakes, however, has never been used in Lake Manitou. Black plastic sheeting could be used as a floating shade. Its success on small areas (swimming beaches) is good for certain submergent macrophytes and of limited control value for emergent vegetation. However, problems with wave action and currents limit the usefulness of a floating plastic shade primarily to small ponds. The plastic sheeting should be removed after five to six weeks of shading in the spring. This method does not effectively control the growth of algae and has not been used in Lake Manitou.

Covering of Bottom Sediments with sheeting material (such as black plastic) and/or particulate material (sand, clay) can perform two functions in controlling aquatic plants. It can prevent the exchange of nutrients from the sediments to the overlying water and it can retard the establishment of rooted aquatic macrophytes. Disadvantages of this technique are that bottom dwelling animals are usually killed when the sediment is covered and often gas is produced under the plastic sheeting causing it to float to the surface. Sheeting is now available that have pores which allow gases to escape. Experience with this technique has resulted in good temporary control, however, macrophytes will gradually re-colonize the area unless the sheeting is removed periodically and cleared of any growth. Individual property owners have used this technique to cover the soft bottom with sand and several have used plastic sheeting covered over with sand to improve the wading quality of their shoreline.

Intensive Use and Periodic Manual Clearing of shoreline areas will, in many instances, prove to be an effective means of aquatic plant control in small beach areas. The rooted plants must produce sufficient food in their leaves to maintain their root systems. Frequent cutting of the leaves or their destruction by wading and swimming will eventually lead to death of the root system. This technique is particularly effective with emergent vegetation such as water lilies. Like weeding the garden, it is necessary to watch for the early development of potential problems and remove the plants as they become established and before they spread over large areas. Individual Lake Manitou property owners use this technique.

Use of Herbicides

Chemical control is another means of temporarily controlling aquatic plants and algae. There are a number of chemicals available which offer varying degrees of action time, persistence, cost, selectivity and safety to humans, other mammals and aquatic animal life.

When herbicides are part of an aquatic plant management program, special care must be taken to protect both the environment and individuals involved, since herbicides are potentially dangerous to both. To promote the proper use of aquatic herbicides Act No. 368 of the Public Acts of 1978, has granted regulating authority over the application of these compounds to the Michigan Department of Natural Resources. A permit is required from the Michigan Department of Environmental Quality prior to any chemical treatment of a waterbody. The only exemption from this permit requirement is treatment of a pond which is less than ten (10) acres, does not have an outlet, and which is owned by only one person or corporation. Even in situations where a permit is not required, only herbicides registered for use in lakes and ponds may be used. A current list of these herbicides, and permit applications, are available from the Department of Environmental Quality, Land and Water Management Division, Inland Lakes and Wetlands Unit, P.O. Box 30458, Lansing, MI 48909-7958.

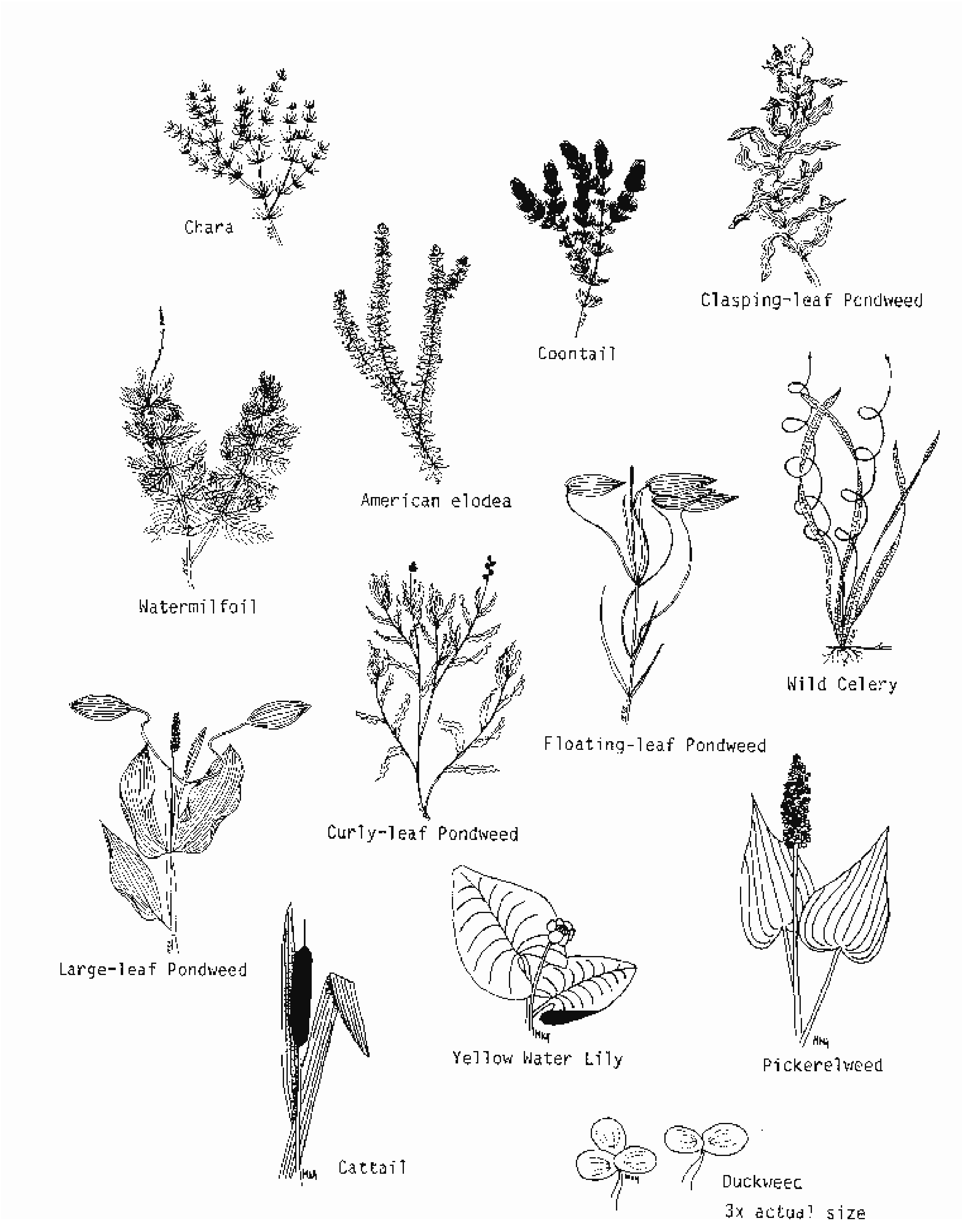
It is important that herbicides be used with extreme care. Herbicides require special handling such as protective clothing for application and posting of treated water so that swimmers or fishermen are not inadvertently exposed to potentially harmful chemicals. Before applying any chemical, one must always read the product label completely and follow all instructions. The applicator takes special note of all warnings on the label to avoid any personal injury and disposes of all empty chemical containers as directed. The product label also explains the best method(s) for using the product, as well as rate of application and a list of plants that may be controlled by the product.

At Lake Manitou, we receive the proper training in chemical use, use the proper equipment, and obtain permits to apply the herbicides. An alternative would be to contract with a licensed aquatic herbicide applicator. A list of commercial applicators licensed by the Michigan Department of Agriculture to apply herbicides to the aquatic environment is available from the Michigan Department of Natural Resources, Inland Lake Management Unit. Additionally, the Inland Lake Management Unit is available to answer questions that may arise concerning chemical control of aquatic plants or other aspects of inland lake management.

It is important to point out that the use of herbicides to control aquatic plants has certain drawbacks. Most herbicides control all forms of plant life to some extent. Beneficial aquatic plants may be killed along with the nuisance plants. It is also difficult to control the drift of herbicides under certain conditions, consequently plants may be killed over a much wider area than intended. Additionally, herbicides give only temporary control. In lakes where herbicides are used repeatedly on a large scale, dramatic shifts in plant populations can occur which may seriously alter the lake's ecology. This is one reason why the Lake Manitou Board of Directors has chosen to apply the herbicides ourselves - to limit the variables and risks associated with over-application of herbicides in our lake.

In calculating the proper amount of herbicide to use, the first step is to determine the surface area to be treated. In the case of small ponds, this can be done by direct measurement with a tape. For waterbodies of unusual shape, divide the surface into distinct areas, each of which is a shape with which you can address. The surface area of each section can be calculated, and the areas added together to give the total area of the waterbody. In the case of man-made ponds, the engineer or surveyor who designed the pond may already have the surface area calculated. If the area has been calculated in square feet, divide the number by 43,560 square feet/acre to obtain the number of acres. Example: treatment area of 100 feet x 200 feet = 20,000 ft.^{2}; 20,000 ft.^{2} / 43,560 ft.^{2}./acre = .459 acre, or about one-half acre.

For some herbicides, the application rate is expressed as gallons or pounds per acre-foot. To calculate the acre-feet of a treatment area, multiply the surface area (in acres) by the average depth (in feet). If a depth contour map of the lake or pond is available, the average depth can be calculated from it. If not, the average depth can be measured through the use of a pole or sounding line (a calibrated cord with a weight at one end). Generally, in an area used for swimming or docking of boats, an average depth of 3 to 5 feet can be used.



Chara
Coontail
Clasping-leaf Pondweed
American elodea
Watermilfoil
Wild Celery
Floating-leaf Pondweed
Curly-leaf Pondweed
Large-leaf Pondweed
Yellow Water Lily
Pickerelweed
Cattail
Duckweec
3x actual size

Water quality testing program for Lake Manitou

The preceding discussion established the Water Quality Management Strategy for Lake Manitou. The following sections describe the water quality monitoring and testing program that consists of a series of tests and observations regarding oxygen and other gases commonly dissolved in water and observations regarding the properties of water and the water cycle.

Lake Manitou is a 94-acre natural moderately hard water to hard water reservoir located in sections 10 and 11, Bennington Township (T6N R2E), Shiawassee County Michigan. There are two islands totaling less than two acres in the lake. Hence the surface area is about 92 acres. The lake has a maximum depth of 19 feet (in the old streambed), a water volume of 1,029 acre-feet, and a mean depth of 11.2 feet. It has 16,526 feet of shoreline, not including the island shorelines. The elevation of the lake is 781 feet above sea level. The lake was formed in 1958 when a 385 foot long earthen dam was constructed across the outlet of the Hardy-Jennings drain.

The lake has three inlets. The Hardy-Jennings drain enters the lake through the Waugh Road arm on the east side. Mirror Lake drains into Lake Manitou from the South under Garrison Road as does water from Forest Lake. The outlet is located on the north side of the lake.

The size of the watershed, which is the land area that contributes water to the lake, but does not include the lake, is 3,206 acres. The drainage area, which includes the lake and the watershed is 3,300 acres. The watershed to lake ratio is 34.1 to 1, which is high for a Michigan Inland Lake but normal for the lake formed by damning a stream. Because of this high ratio, the lake flushes rapidly about once every 0.45 years (or 165 days), on an average. The drainage area of the Hardy-Jennings drain is 2,026 acres. The drainage area for the Cummings Lakes is 1042 acres. The immediate drainage area of Lake Manitou (including the lake) is 232 acres.

Based on the above drainage areas, the average flow from the 3,300 acre Lake Manitou drainage area is 3.17 cubic fps or 6.24 billion pounds per year.

The average flow from the 2,026 acre Hardy-Jennings drain drainage area is 1.95 cubic fps or 3.83 billion pounds per year

The average flow from though 1042 acre Cummings Lakes drainage area is 1.00 cubic fps or 1.97 billion pounds per year.

Water from Lake Manitou flows into the Willow Brook Drain, then into the Maple River and then into the Grand River. The Grand River discharges into Lake Michigan at Grand Haven. The longitudinal and latitude of the 19 foot deep hole is 84 degrees 12.188 West and 42 degrees 55.479 North.

CLMP (Cooperative Lakes Monitoring Program)

Limnologists have developed a variety of numerical indexes based on water quality data to express productivity on a continuous numerical scale. The widely used Carlson Trophic State Index (TSI) incorporates water clarity, or transparency, as measured by a Secchi disk; the algal plant pigment chlorophyll *a*: and total phosphorus as indicators of lake productivity. The CLMP provides data on these parameters as well as dissolved oxygen and temperature. Long-term monitoring of these parameters on a consistent and regular basis provides the data needed to recognize changes or trends in lake productivity. Lake Manitou supports this program.

CLMP Measurements include:

- Secchi Disk Transparency
- Spring Total Phosphorus
- Summer Total Phosphorus
- Chlorophyll a
- Dissolved Oxygen / Temperature
- Aquatic Plants

WHY SAMPLING OF LAKES IS RECOMMENDED IN THE SPRING

It has to do with how phosphorus is distributed in lakes, but the story is not quite so simple.

A slightly longer answer is that measuring the phosphorus concentration in a lake in spring gives a fairly good picture regarding the amount of phosphorus available to plants and algae during the year.

The phosphorus levels are different in the spring than at any other time of the year because of the way iron and phosphorus are cycled in lakes each year. Iron will precipitate to the bottom sediments as long as there is dissolved oxygen in the water and iron will dissolve in water that has no dissolved oxygen.

You may have observed this process when you see iron-stained sidewalks and sides of buildings from lawn watering operations. What happens is the well from which the water is being drawn is deep enough that there is no oxygen dissolved in that water. So water at the well-screen has iron dissolved in it. Then when the water (with no dissolved oxygen, and lots of dissolved iron) is sprayed into the air, and hits the side of the building or the sidewalk, oxygen is dissolved in it and the iron precipitates out.

Phosphorus is added to many soaps to bind (grab hold) of metals and because phosphorus grabs metals, the opposite is also true, metals grab phosphorus. Since the amount of iron in most Michigan inland lakes is much greater than the amount of phosphorus, iron is a pretty efficient scavenger of phosphorus in our inland lakes, as long as there is oxygen dissolved in the water. In the spring and fall, when the lakes mix (turn over, if you will), dissolved oxygen is distributed through out the entire lake, so any iron present precipitates to the bottom sediments, carrying phosphorus with it. If the lake retained dissolved oxygen top to bottom this process would pretty effectively tie up phosphorus in the bottom sediments.

However, lakes form layers of water, usually due to temperature differences, which prevents the water at the surface from mixing with the water in the lake bottom. When that occurs, if there is enough organic material in the bottom of the lake, bacteria decomposing that material will remove the oxygen dissolved in the bottom water.

Once a lake loses this dissolved oxygen in the bottom water, the iron (which precipitated when there was oxygen dissolved in the water,) now dissolves in the water that has no oxygen dissolved in it, and when this occurs, the phosphorus which was tied up with the iron is also released into the water at the bottom of the lake. This phosphorus stays at the bottom of the lake until the lake mixes in spring or fall, when it is mixed into the entire water column of the lake. It is this phosphorus that is released into the bottom water under anaerobic (no dissolved oxygen) conditions, and then mixed into the water column when the lake mixes that the spring sampling is intended to capture.

When we experience a warm winter, the lakes don't form an ice cover during the winter, or the ice cover season is short, the lakes generally end up mixing most of the winter. Because of this, oxygen is continually distributed throughout the water column, so the iron in the bottom sediments remains in the bottom sediment, tying up the phosphorus. Sampling lakes under these conditions is not as critical as when the lake was ice covered all winter long as there will be little or no phosphorus released from the bottom sediments.

Chemical Testing

This testing program includes references to background material including environmental issues that pertain to water quality. Much of the material can typically found on the Internet. The following are the specifics on the physical and chemical testing program.

- dissolved carbon dioxide
- temperature readings
- pH
- sulfate
- conductivity
- dissolved oxygen
- hardness due to calcium ions
- chloride
- nitrate
- ammonium ions
- turbidity

Physical Data Taken on Samples

Initial physical observations based on the water's color, clarity and odor are taken. These observations include taking a Secchi Disk reading to determine water clarity. This reading is typically taken at Testing locations #1, #2, and #6.

Secchi Disk Transparency

Secchi disk testing involves lowering a yellow & black painted twelve-inch diameter disk into the water and recording the depth that the yellow/black pattern is no longer visible. The average Secchi disk readings for Lake Manitou is around 5 feet.

Temperature Readings

Temperatures are taken at each site and each sample location. Since temperature can directly affect the amount of dissolved ions in water, this preliminary step is included.

Chlorophyll a

Chlorophyll a, reported in micrograms per liter (or ppb) generally gives an estimate of algal densities. The best reading is below 1 microgram per liter. Lake Manitou has had a wide variation of Chlorophyll a readings throughout its history depending upon the sampling time and conditions at the time of the readings… they range from a low of 3.3 to a high of 80.

Conductivity of Water

All natural water sources contain dissolved ions called electrolytes. These ions allow the water to conduct an electric current. The higher the concentration of the dissolved electrolyte, the greater is the capacity of the water to conduct electricity. Measuring the conductivity of a water sample is a way of measuring the electrolyte level in a sample of water. Lake Manitou conductivity should be in the range of 350 to 450 umhos/cm.

Testing for Carbon Dioxide

Carbon dioxide is present in water supplies in the form of dissolved gas. Surface waters normally contain less than 10 ppm (parts per million). Corrosion is the principal problem caused by high concentrations of carbon dioxide in water. This is due to the lowering of pH when carbon dioxide dissolves to form carbonic acid. Aquatic plant life depends upon carbon dioxide and bicarbonates in water for growth. They utilize the carbon dioxide in the photosynthesis of plant materials, starches, sugars, oils, protein, etc. When the oxygen concentration in waters containing organic wastes is reduced, the level of carbon dioxide is increased which makes it more difficult for the fish to use the limited amount of oxygen present. Lake Manitou levels should be in the 8 ppm region.

pH Testing

The pH of a natural water sample is essentially a measurement of its hydrogen ion concentration (which is a measurement of the water sample's acidity). The pH of a water sample is one measurement that gives an indication of its overall heath. Most aquatic organisms typically thrive in waters whose pH range is from 6.0 to 8.5. As the pH of the surface water decreases, concentrations of metal ions may increase posing a threat to young fish. Acid rain can affect the pH of natural water systems.

Lake Manitou has pH values ranging from 8.0 to 8.5. These are low values for a southeast Michigan inland lake with intense algal blooms. The high flushing rate most likely had an impact of keeping the pH values lower than expected. Lakes with extensive plant communities often have a high summer pH value (greater than 9.0) as the plants use the carbonates in the water as a carbon source. This causes a decrease in the buffering capacity of the water, and allows the pH to rise.

Alkalinity

Alkalinity measures carbonates and bicarbonates in the water. Soft water lakes have alkalinities below 75 mg per liter. Moderately hard water lakes have alkalinities between 75 and 150 mg per liter. Hard water lakes have alkalinities above 150 mg per liter.

Lake Manitou is a moderately hard water to hard water Lake and should have levels in the 174 to 180 mg/L range in the spring and 125 to 171 mg/L in the summer.

Dissolved Oxygen Testing

Oxygen is extremely vital to the life cycle processes in water systems. It is essential to keep organisms living within the water and allow for healthy reproduction in aquatic species. This leads to the development of all aquatic populations in the water body. Oxygen enters the water by absorption directly from the atmosphere or from the photosynthesis of plants living within the water system. Oxygen is removed from a water system by respiration of organisms and by organic decomposition of aquatic organisms. Organic wastes from sources such as municipal, agricultural, and industrial sources may overload the natural progression of dissolved oxygen within the water. A water source that is rich in nutrients will produce algae in sufficient quantity that upon decomposition, the dissolved oxygen supply is depleted and fish and other aquatic organisms are killed (eutrophication).

Standards for dissolved oxygen do vary, however, governmental standards indicate that warm water fish require water with a dissolved oxygen concentration that is no lower than 4.0 mg/L. Fish that live in colder water should have a dissolved oxygen concentration no lower than 5.0 mg/L. Lake Manitou levels should be in the region of 4.0.

Testing for Sulfate Ions

Sulfate ions react in a solution made acidic with barium chloride to form an insoluble barium sulfate crystal. The crystals become suspended in the solution causing turbidity. In most fresh water systems the sulfate ion is the second or third most abundant ion. Sulfur in the form of sulfate is considered an important nutrient element. Many bacteria obtain sulfur from sulfate for their synthesis of amino acids. In lakes and streams low in oxygen, the process of sulfate reduction produces hydrogen sulfide (with its characteristic offensive odor). Lake Manitou levels should be in the “X” to “Y” region.

Testing for Phosphate Ions

Phosphorus is an important nutrient for aquatic plants. The amount found in water is generally not more than 0.1 ppm (or 10 micrograms per liter), unless the water has been polluted from wastewater sources or excessive drainage from agricultural areas. When phosphorus is present in excess of the concentrations required for normal aquatic plant growth, a process called eutrophication takes place. This creates a favorable environment for the increase of algae and weed nuisances. When this excess algae dies, oxygen is used in its decomposition, which often leads to fish kill. Lake Manitou levels of phosphate ranges from 20 to 60 microgram per liter.

Testing Water Hardness due to Calcium Ions

The hardness of water is generally represented by the total concentration of calcium ions (expressed as calcium carbonate) and magnesium ions in solution. Other ions may, in fact, contribute to the overall hardness of water, but in natural water sources, all but calcium and magnesium are present in relatively insignificant amounts. The United States Public Health Service has set limits of calcium hardness at 200 ppm and magnesium hardness at 150 ppm. Water that contains a small concentration of the calcium and magnesium ions is considered to be "soft" water (0 - 60 ppm). Water, with a total hardness in the range of 120 - 180 ppm, is considered "hard" water. It is important to recognize that, due to the limited testing facilities and tools used, the test results are finding only hardness due to calcium not the total hardness of water. The Lake Manitou hardness is in the range of 130 ppm.

Chloride Ion Testing

The chloride ion is one of the predominant ions that can be found in water systems and treated sewage. It can occur naturally when the water source passes through natural salt formations in the earth. It can also be an indication of pollution from industrial and domestic wastes. The United States Public Health Services has set the standard for chloride ion in safe drinking water at 250 ppm. It should be noted that there is a difference in the concentration of the chloride ion in water and the amount of chlorine in a water sample. Water for public consumption in cities and communities usually undergoes a disinfection process involving chlorine before it reaches the consumer. Salinity can be calculated from a measurement of chloride ion concentration by using the following equation:

Salinity (mg/L or ppm) = 1.805 x [chloride ion] (mg/L) + 30

Lake Manitou has a salinity measurement in the range of “X” to “Y”.

Nitrate Ion Testing

Nitrogen is essential for plant growth both within and outside water systems. An excessive amount of nitrogen in water supplies poses a serious pollution problem. Nitrogen compounds may enter a water supply as nitrates, or be converted to nitrates from agricultural fertilizers, sewage, drainage from livestock feeding areas and farm manure’s. In all these cases, as plant and animal organisms die, bacterial action breaks down the protein into ammonia, NH_3. Some ammonia is converted into ammonium ions, NH_4^+; some is converted into nitrite ions, NO_2^- and then into nitrate ions, NO_3^-. Nitrates in larger amount have been linked to the disease methemoglobinemia (blue baby disease).

Nitrates in conjunction with phosphates stimulate the growth of algae that brings all the related difficulties associated with excessive algae growth. The United States Public Health Service has set the level of 10 ppm nitrate as the upper limit to "safe" drinking water. Unpolluted waters usually have nitrate-nitrogen levels below 1 mg/L.

Nitrate ion concentration is usually expressed in units of mg/L of NO_3^- as N, also known as "nitrate-nitrogen". This means that the concentration of nitrate is expressed as if the nitrates are only in the form of nitrogen itself. Water test results are sometimes published in units of mg/L NO_3^- instead of NO_3^- to N. To convert, say 100 mg/L NO_3^- as N to just mg/L NO_3^-, you perform the following conversion:

100 mg N x 63 g NO_3^- = 443 mg/L NO_3^- ; 1 L 14 g N

Most Michigan inland lakes have spring nitrate nitrogen concentrations around 200 micrograms per liter (or ppb). Summer nitrate nitrogen concentrations are generally much lower, in the 10 to 40 micrograms per liter range. The level of spring nitrate ions in Lake Manitou are in the range of 125 to 175 mg/L, and the range of summer nitrogen ranges from 5 to 25 mg/L.

Ammonium Ion Testing

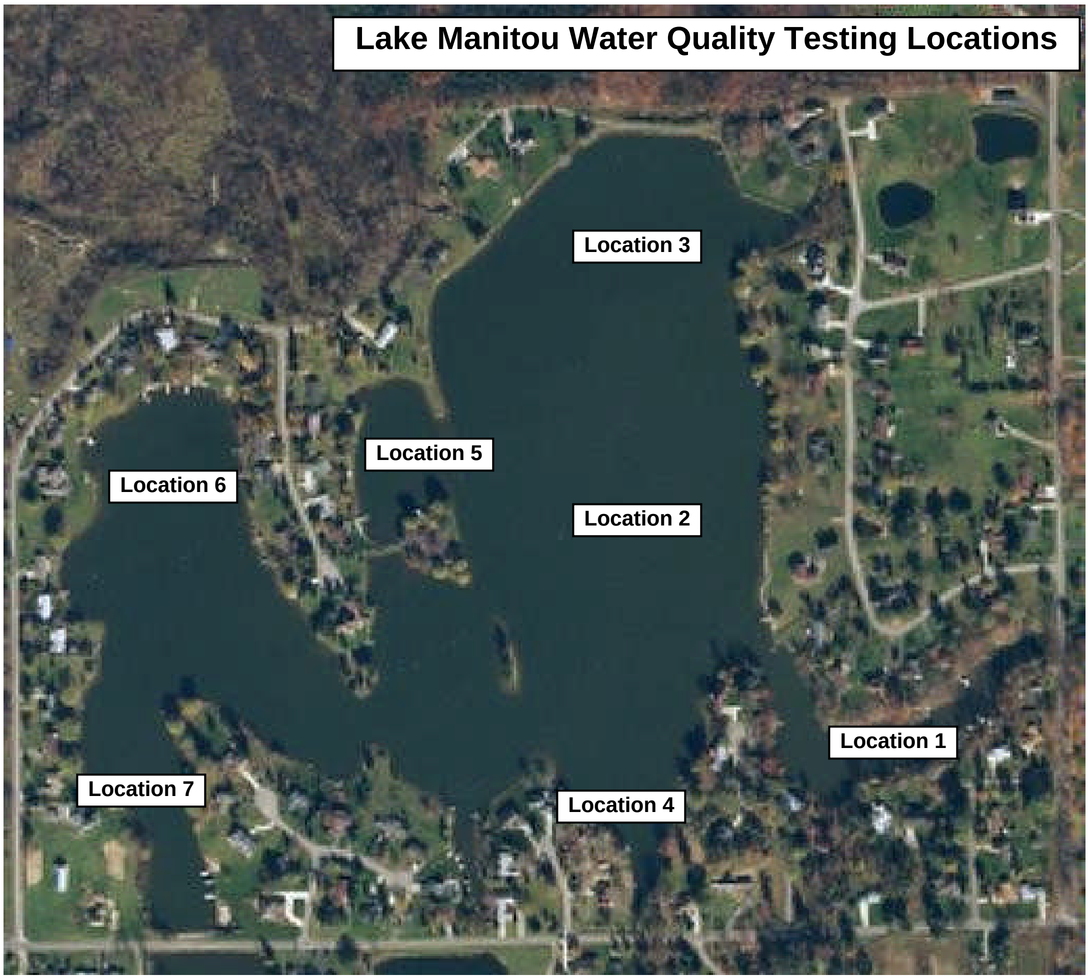
The United States Public Health Service has established permissible levels of ammonium ions in drinking water to not exceed 0.5 mg/L. Ammonium ion concentrations can be higher near agricultural areas as many commercial fertilizers contain ammonium sulfate or ammonium nitrate (or combinations of both). Usually in water studies including ammonium ion testing, pH measurements are also taken as higher or lower pH values can greatly affect the ratio of NH_4+ / NH_3 in a water sample. The concentrations of these two species, though different, are often involved in the same equilibrium reaction:

NH_3 (aqueous) + H^+ (aqueous) $\leftarrow \rightarrow$ NH_4^+ (aqueous)

It should be noted that the concentration of aqueous ammonium ions should not be mistaken for concentration of aqueous ammonia. In a more acidic environment, higher concentrations of the hydrogen ion will cause the reaction to shift to the right, resulting in higher concentrations of NH_4^+ (aqueous). At pH values greater that 10, most of the ammonium ions will be converted to ammonia. At pH values less than 7.5, most of the aqueous ammonia will be converted to ammonium ions.

For Lake Manitou, the range of Ammonium Ions are “X” to “Y”.

Testing of Lake Manitou waters are recommended 3 times per year during the Spring (April), Mid-Summer (July), and late Fall (October). There are 7 recommended testing locations. Refer to the following picture for the locations:



The Global Positioning System location for the testing sites are as follows:

Location	Description	Latitude	Longitude
1	Inflow from Waugh Channel	42° 55' 24" 42.9235	-84° 11' 59" -84.1998
2	Middle of the big section of the lake	42° 55' 29" 42.9249	-84° 12' 11" -84.2031
3	South of the Dam	42° 55' 38" 42.9273	-84° 12' 10" -84.2028
4	Inflow from Mirror Lake	42° 55' 23" 42.9231	-84° 12' 10" -84.2029
5	No wake area east of Apache Path	42° 55' 31" 42.9254	-84° 12' 18" -84.2052

6	North area of the small side of the lake	42° 55' 31" 42.9254	-84° 12' 26" -84.2075
7	Inflow from Forrest Lake	42° 55' 24" 42.9235	-84° 12' 30" -84.2084

5. REQUIREMENTS / NOTIFICATION:

Residents are to be notified when chemicals are being used that would limit aquatic activities such as swimming, boating, fishing, irrigation from lake water, or other similar usages.

6. REFERENCES, SUPPORTING PROCESSES, AND TOOLS:

- Chemical Procurement Process
- Chemical Permitting Process
- Equipment Usage procedure
- Water Quality Testing results data recording forms and graphs

7. KEY CRITICAL SUCCESS FACTORS:

- Resident's participation and support of the strategy
- Funding to procure chemicals and pay for summer help to apply the chemicals
- Qualified chemical applicators
- Qualified Weedcutter operator(s)
- Qualified Water Quality Testers

8. CHANGE CONTROL:

Changed By	**Date**	**Version**	**Description**
J. Forsythe	09/14/2006	1.2	Added discussion on the background and intent for the Spring Phosphorus testing
J. Forsythe	12/24/2004	1.1	Added GPS Coordinates to the testing locations on page 22 and added Water Level Management strategy from the 2004 Summer meeting.
J. Forsythe	10/27/2002	1.0	Initial Release