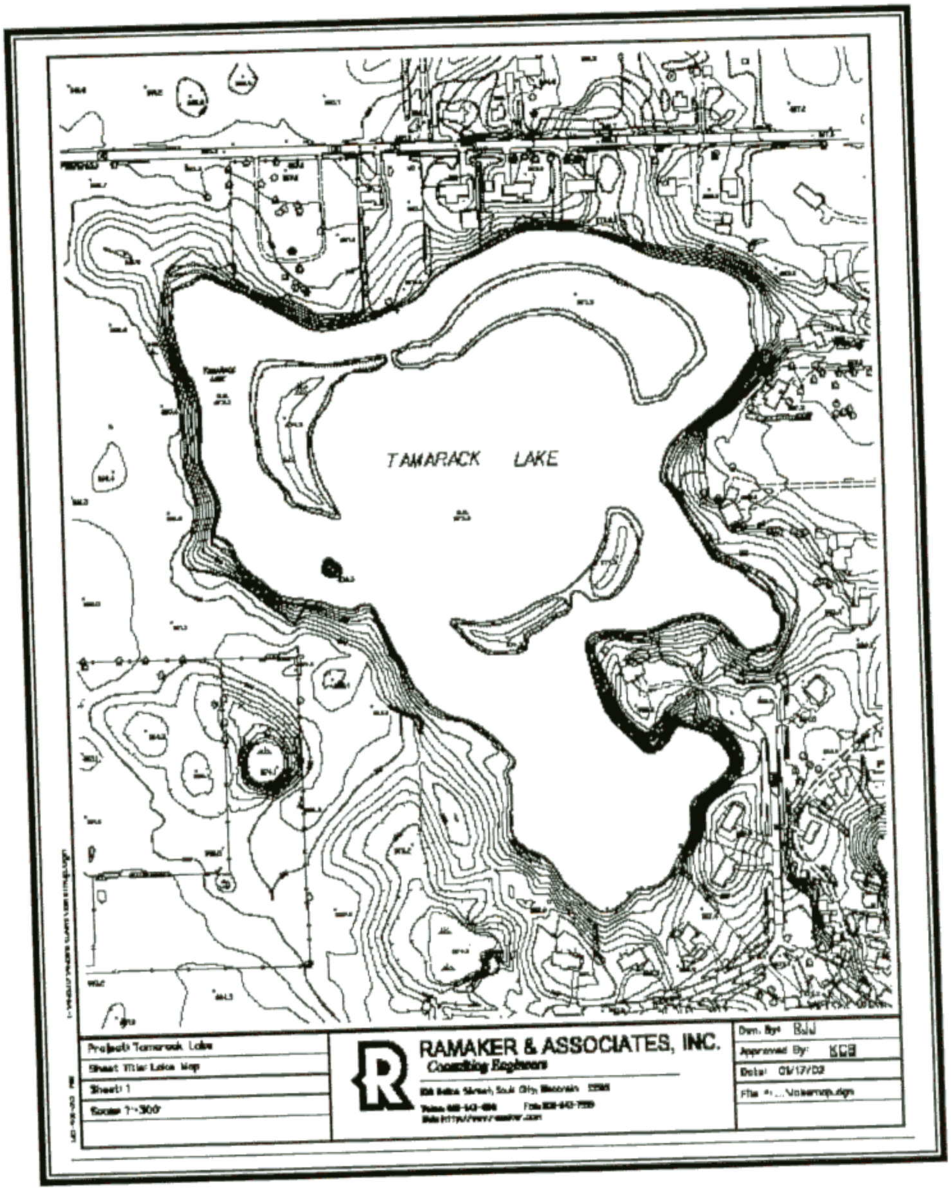
TAMARACK LAKE MANAGEMENT PLAN



Prepared by:
Ramaker & Associates, Inc.

TAMARACK LAKE MANAGEMENT PLAN

PROJECT LOCATION:	Tamarack Lake Town of Oconomowoc Waukesha County, Wisconsin
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PROJECT REFERENCE #:	4299
PLAN COMPETION DATE:	February 25, 2002

_______________________________ ____________

Paul D. Dearlove — Date
Lake Management Planner

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Terry J. Ramaker, P.E. — Date
President

I, Terry J. Ramaker, hereby certify that I am a registered professional engineer in the State of Wisconsin, registered in accordance with the requirements of ch. A-E, Wis. Adm. Code; that this document has been prepared in accordance with the Rules of Professional Conduct in ch. A-E 8, Wis. Adm. Code; and that, to the best of my knowledge, all information contained in this document is correct.

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CHAPTER 1: INTRODUCTION

Seepage = primary surface runoff supplemented by groundwater

1-1 BACKGROUND

Tamarack Lake is a fairly shallow, 30-acre seepage lake located within the Town of Oconomowoc in Waukesha County, Wisconsin. As a seepage lake, the water body derives most of its water from groundwater sources. A two-square-mile watershed, comprised primarily of agricultural land uses, also drains surface water to the lake in the form of stormwater runoff. Although farmland continues to represent the watershed's dominant land-use, residential development pressures are increasingly occurring around portions of the lake's 1.26-mile periphery.

The abundant vegetation helps keep down turbidity

Tamarack Lake has a maximum depth of approximately 15 feet near its center. The combined impact of shallow water depths, good water clarity, and a fertile bottom substrate promotes an abundance of aquatic vegetation. Heavy submersed and floating-leaf plant growth has become prevalent throughout much of the lake, and is considered a chief issue of concern among local residents.

Popular activities on Tamarack include canoeing and paddle boating, peaceful relaxation, enjoying the natural scenery, observing wildlife and fishing. Because of its small size and lack of improved public access facilities, the lake is not currently considered a highly popular tourism destination. Consequently, local residents with deeded lake rights dominate the recreational interests on the water body. Tamarack Lake is also a State-mandated, slow-no-wake lake since it is less than 50 acres in size.

Residents around the lake began organizing as a qualified lake management association in early 2000. Motivating factors centered on accessibility problems caused by prolific aquatic plant growth, as well as concerns of deteriorating water quality conditions. Given the regional value of the resource and the perceived urgency of its management challenges, the Town of Oconomowoc agreed to sponsor a Wisconsin Department of Natural Resources' (DNR) Lake Planning Grant on behalf of the newly formed association. The Tamarack Lake Management Association was awarded the grant in the spring of 2000.

1-2 GOALS & OBJECTIVES

DNR funding was obtained to develop a comprehensive lake management plan that could be used to guide future improvement actions on Tamarack Lake. This effort is intended to identify, evaluate and resolve the various concerns that negatively affect the quality and enjoyment of the resource. The Tamarack Lake Management Plan is designed as a one-source strategy document containing relevant information and guidance necessary for making sound, cost-effective decisions. It offers a holistic, watershed-based approach to sustaining the lake's long-term ecological health and recreational viability. Some of the more general goals include:

- <u>Education</u>: Assist residents, users and other key stakeholders in understanding the complex and dynamic interrelationships that define the resource. Effective consensus building and strategy implementation is dependent upon first recognizing the essential components of a sustainable ecosystem, as well as the various factors that threaten that sustainability.
- <u>Problem Identification</u>: Isolate the actual root causes of problems from their underlying symptoms. Solutions cannot be appropriately targeted unless it is clear precisely what factors are causing the perceived problems. Furthermore, some desired results may be unattainable given either the natural constraints of the resource, or our current level of understanding and technological capability.
- <u>Problem Rectification</u>: Propose solutions to problems (both existing and anticipated) that serve to protect the ecological integrity and reasonable use of the resource. To help ensure cost-effectiveness, solutions should (1) be predicated on sound science, and (2) satisfy publicly supported management priorities.

1-3 PROJECT DELIVERABLES

- A map delineating the watershed boundaries and depicting associated land uses.
- Consideration of past and ongoing management efforts and their perceived impact on the lake.
- A ranking and prioritization of desired lake uses, perceived problems and management needs as determined through public opinion surveys.
- A description of the various problems that limit the use and enjoyment of the lake.
- A cost-benefit analysis of applicable management strategies.
- A written report documenting all findings, conclusions and recommendations.
- A multi-year strategic plan to guide actions related to educational outreach, additional data gathering, and management implementation.

1-4 METHODS

PHASE I: GATHER USER INPUT

The first phase of the project was to assess lake resident opinions and concerns regarding the condition, use and management of Tamarack Lake. Input was obtained through a user survey, public meetings, and interviews with some of the local residents. The resulting feedback was used to identify perceived problems, and to determine lake-use and management priorities.

PHASE II: COLLECT & SUMMARIZE EXISTING INFORMATION

Existing physical, chemical and biological data pertaining to the lake and its adjoining watershed were collected and summarized. Information was obtained from various sources, including the Wisconsin Department of Natural Resources and the Waukesha County Land & Water Conservation Department. Basic water quality data were also gathered as part of this project with assistance from volunteer monitors. The results of the water quality tests were used to supplement already existing information to evaluate the present condition of Tamarack Lake.

PHASE III: IDENTIFY PROBLEMS & MANAGEMENT PRIORITIES

Problems threatening the ecological health and recreational potential of Tamarack Lake were diagnosed during the third phase of the project. The sources and symptoms of these problems were explored, and management priorities were established based on magnitude of impact, affected lake uses, and other criteria.

PHASE IV: EVALUATE MANAGEMENT OPTIONS

The fourth phase was to evaluate management strategies using cost-benefit feasibility analyses. Factors considered included estimated implementation cost, potential recreational and ecological impacts, and overall likelihood of success. Management strategies were categorized according to the particular problem or symptomatic response that was being addressed.

PHASE V: RECOMMEND ACTION STRATEGY

The final project phase was to prepare a written report documenting all findings, conclusions and recommendations, and to outline a multi-year course of action. This information shall be disseminated to lake residents and key stakeholders through public meetings, press releases and summary reports.

CHAPTER 2: EXISTING CONDITIONS

2-1 LOCATION

Tamarack Lake is a 30-acre water body located within the Town of Oconomowoc in Waukesha County, Wisconsin (Township 8 North, Range 17 East, Section 23). Its adjoining watershed is defined as the upland land area that drains surface water to the lake. This two-square-mile area is situated generally north and west of Tamarack Lake, and is part of the larger, 128-square-mile Oconomowoc River Watershed in Southeast Wisconsin. Location maps are presented below as Figure 1.

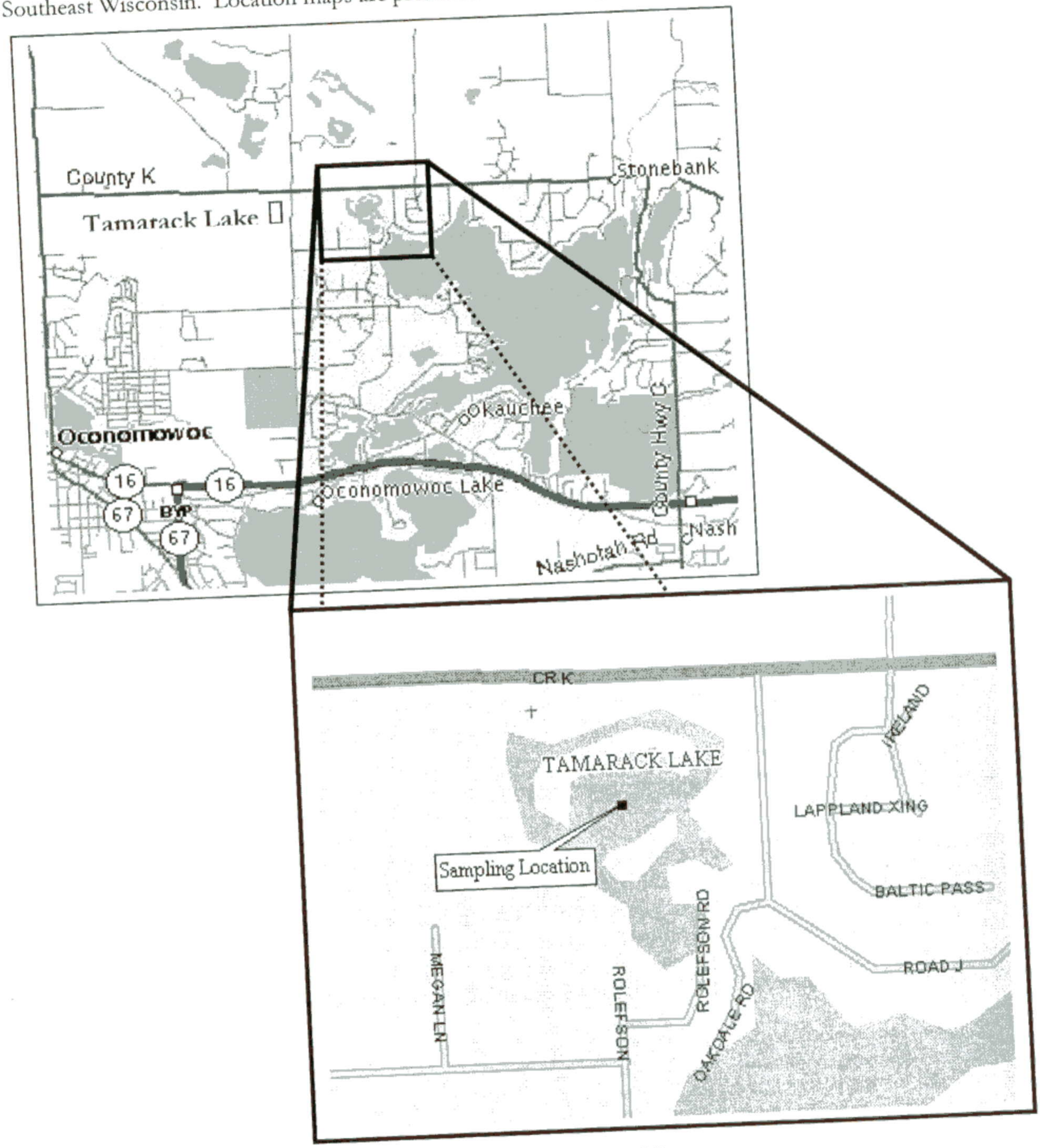


Figure 1: Location Maps

2-2 WATERSHED DESCRIPTION

Definition

Water resource professionals often describe lakes as being reflections of their watersheds. This is because the health and quality of a lake is directly linked to the condition of the land that drains surface water to the lake, also known as a watershed. A watershed is the total land area that is capable of shedding surface runoff to a particular water body. Its outermost boundary is defined by topographic high points on the adjoining landscape, and can be visualized as a giant bathtub with the lake situated where the drain is located. The watershed area is delineated from the lake's outlet (if present) and includes the surface area of the lake. The larger the watershed area, the more water it is able to collect and convey downstream as overland surface flow, also known as stormwater runoff. In the Tamarack Lake watershed, both surface water and regional groundwater flow generally in a southerly direction toward the lake.

Watershed-To-Lake Surface Area Ratio

Watershed-to-lake surface area ratios are used to estimate the level of influence the surrounding landscape has on water quality. As the size of the watershed increases in relation to the size of the lake, the greater the likelihood of pollutants entering the lake by means of stormwater runoff. This runoff is generated from snowmelt, precipitation and groundwater-derived discharge that does not evaporate or infiltrate into the soil. Instead, this water collects on the landscape and is eventually funneled down gradient toward a receiving water body, transporting everything it can pick up and carry from the watershed to the lake. The actual amount of pollutants, sediment and other material delivered depends on watershed size, soil type, topographic relief, land-use practices, and runoff flow characteristics.

Tamarack Lake lies at the terminus of a two-square-mile watershed that drains mostly farmland. The lake has a 0.06 square-mile surface area, which equates to a watershed-to-lake surface area ratio of just over 44:1. Lakes with ratios greater than 10:1 are shown to more commonly experience water quality problems when compared to lakes with smaller ratios. This is especially true in developed watersheds that are dominated by fertile, easily eroded soils, and where poor land-use practices produce excess runoff and erosion. Knowing the size of a particular watershed, as well as its defining topographic features, soil types and land uses will offer clues as to how much management effort will need to be focused in these critical upland areas.

	Area (Square Miles)	Area (Acres)
Watershed Area	2.075	1325.464
Lake w/o Islands	0.047	29.888
Lake w/ Islands	0.060	38.208

Tamarack Lake is fortunate to exhibit relatively good water quality given its larger watershed-to-lake surface area ratio. It is believed that a high percentage of the lake's water is derived from groundwater flow, while surface drainage mainly originates from lands immediately adjacent to the water body. A large groundwater component would most likely moderate the potential impacts associated with non-point source pollution from the surrounding watershed. A map depicting the Tamarack Lake Watershed in relation to the larger regional drainage basins is illustrated in Figure 2 below.

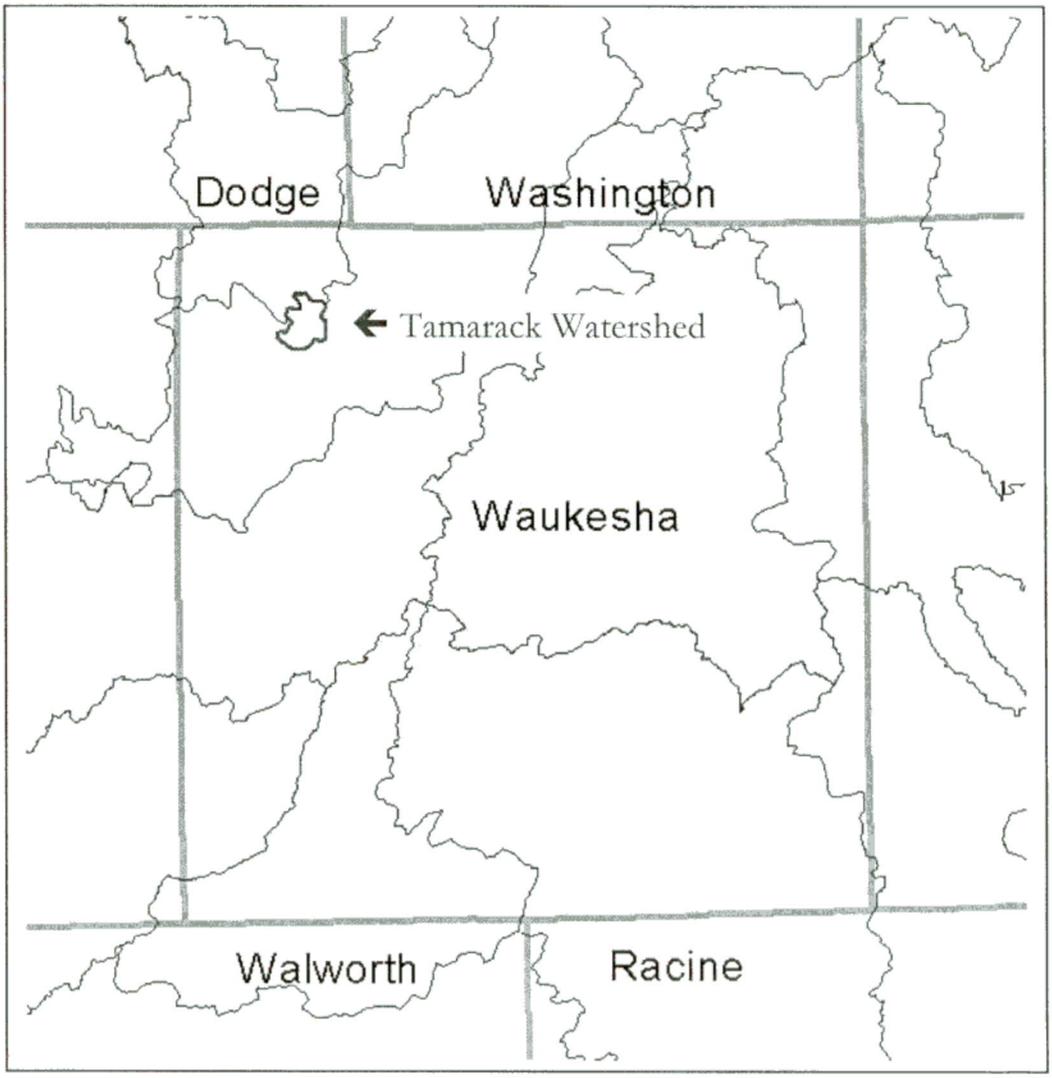


Figure 2: Tamarack Lake Watershed in Relation to Larger Regional Drainage Basins

Physical Setting

Tamarack Lake has a surface water elevation of approximately 870 feet above mean sea level. There is a 100-foot maximum elevation change between the lake and its northernmost watershed boundary. Topography is generally flat, however, with an average 30-foot rise in elevation per mile of watershed.

The Tamarack Lake Watershed is located in the glaciated portion of southeastern Wisconsin, and is comprised primarily of the Fox-Casco soils association. These soils are characterized as well drained silt loams with subsoils of clay loam. They are moderately deep to shallow over calcareous sand and gravel outwash. Typical slopes are 0-12%, with some slopes reaching 20-30% grades. The Fox-Casco association is typically associated with glacial outwash plains and stream terraces. Regional depth to bedrock ranges from 50-100 feet. The sedimentary bedrock is part of the Ordovician System, Sinnipee Group. It is primarily dolomite with some limestone and shale, and includes the Galena, Decorah and Platteville Formations.

Maps depicting regional topography and soil types are included below as Figures 3 and 4, respectively.

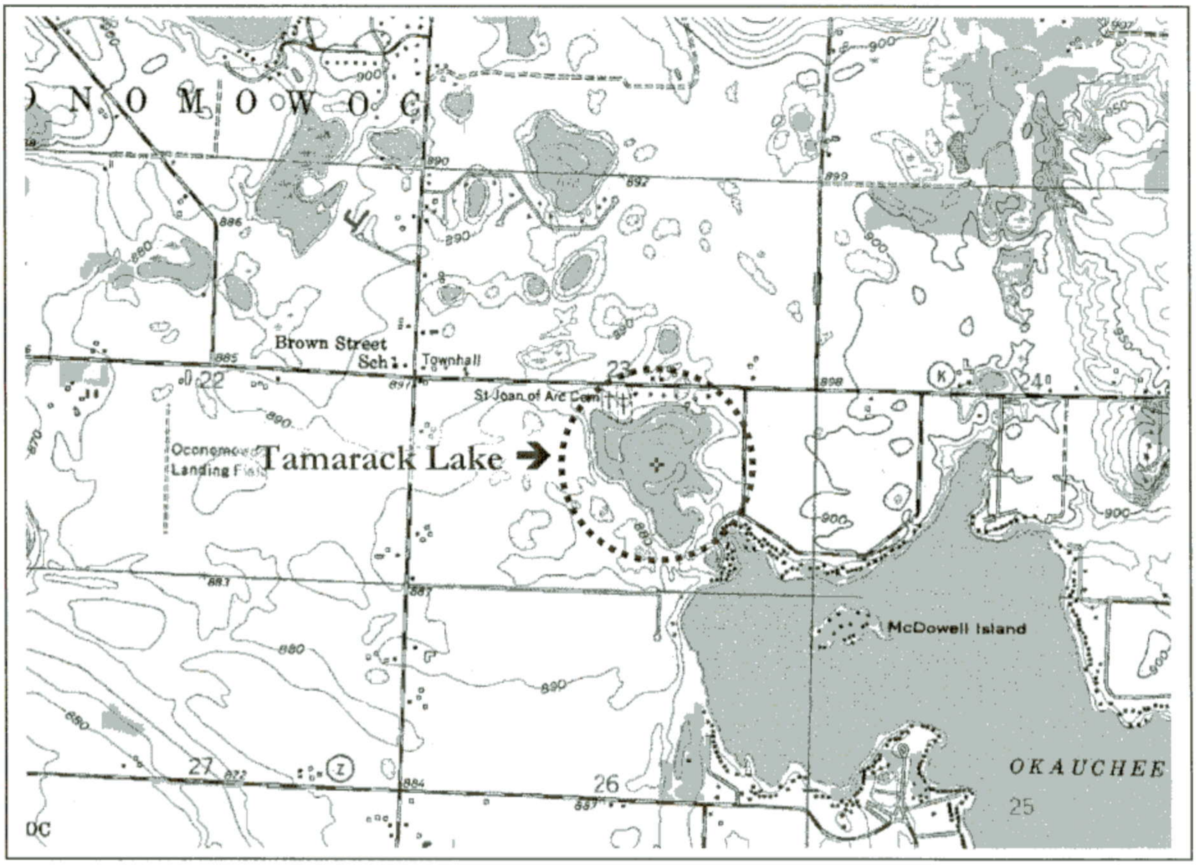


Figure 3: Regional Topography and Hydrography

SYMBOL	NAME
CeC2	Casco loam, 6 to 12% slopes, eroded
CrE	Casco-Rodman complex, 20-30% slopes
FsA	Fox Silt Loam, 0-2% slopes
FsB	Fox Silt Loam, 2-6% slopes
Mf	Marsh
SeA	St. Charles silt loam, gravelly substratum, 0-2% slopes

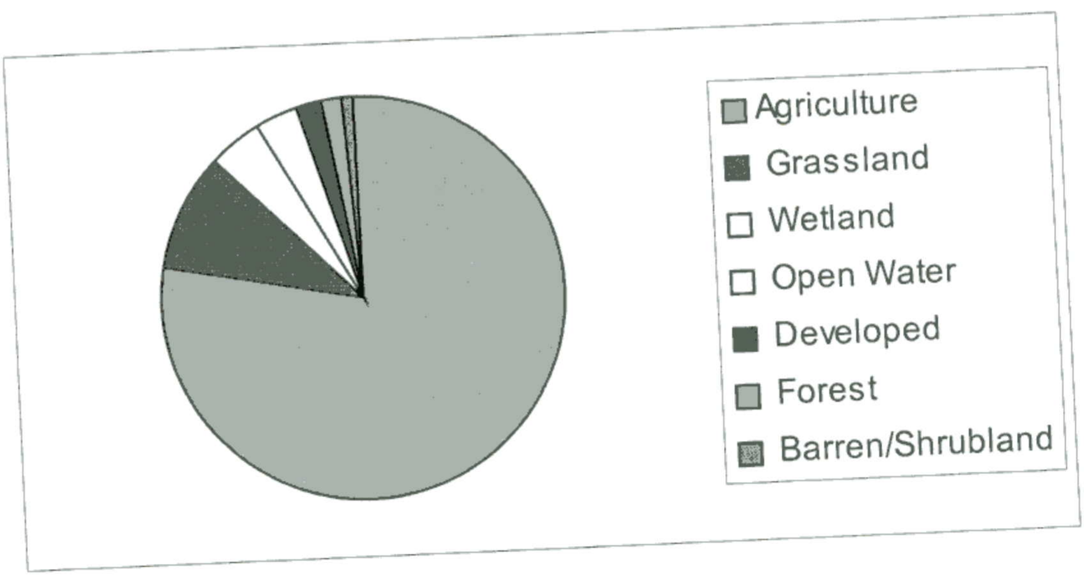
Figure 4: Regional Soil Types

WATERSHED LAND USES/COVER

The predominant land use in the Tamarack Lake Watershed is agriculture, representing nearly 78% of the land area. A breakdown of general land use/cover types by area is presented in Table 1 below, and shown graphically in the associated figure. An accompanying land-use map is illustrated as Figure 5. Development trends around the lake are depicted in historical aerial photographs shown in Figures 6-11.

Table 1: Watershed land use/cover by acreage.

General Land Use/Cover	Type	Watershed Area (Acres)	% Area
Urban/Developed	High Intensity	4.448	0.330
	Low Intensity	25.131	1.890
Agriculture	Corn	753.248	56.640
	Other Row Crops	36.473	2.740
	Forage Crops	246.632	18.550
Grassland	Grassland	128.544	9.670
Forest	Broad-leaved Deciduous	22.017	1.660
Water	Open Water	44.479	3.340
Wetland	Emergent/Wet Meadow	28.244	2.120
	Lowland Shrub – Broad-leaved Deciduous	2.669	0.200
	Lowland Shrub – Broad-leaved Evergreen	0.667	0.050
	Lowland Shrub – Needle-leafed	1.556	0.120
	Forested – Broad-leaved Deciduous	17.124	1.290
	Forested – Coniferous	6.449	0.480
Barren	Barren	10.897	0.820
Shrubland	Shrubland	1.334	0.010
		1325.464	100.000



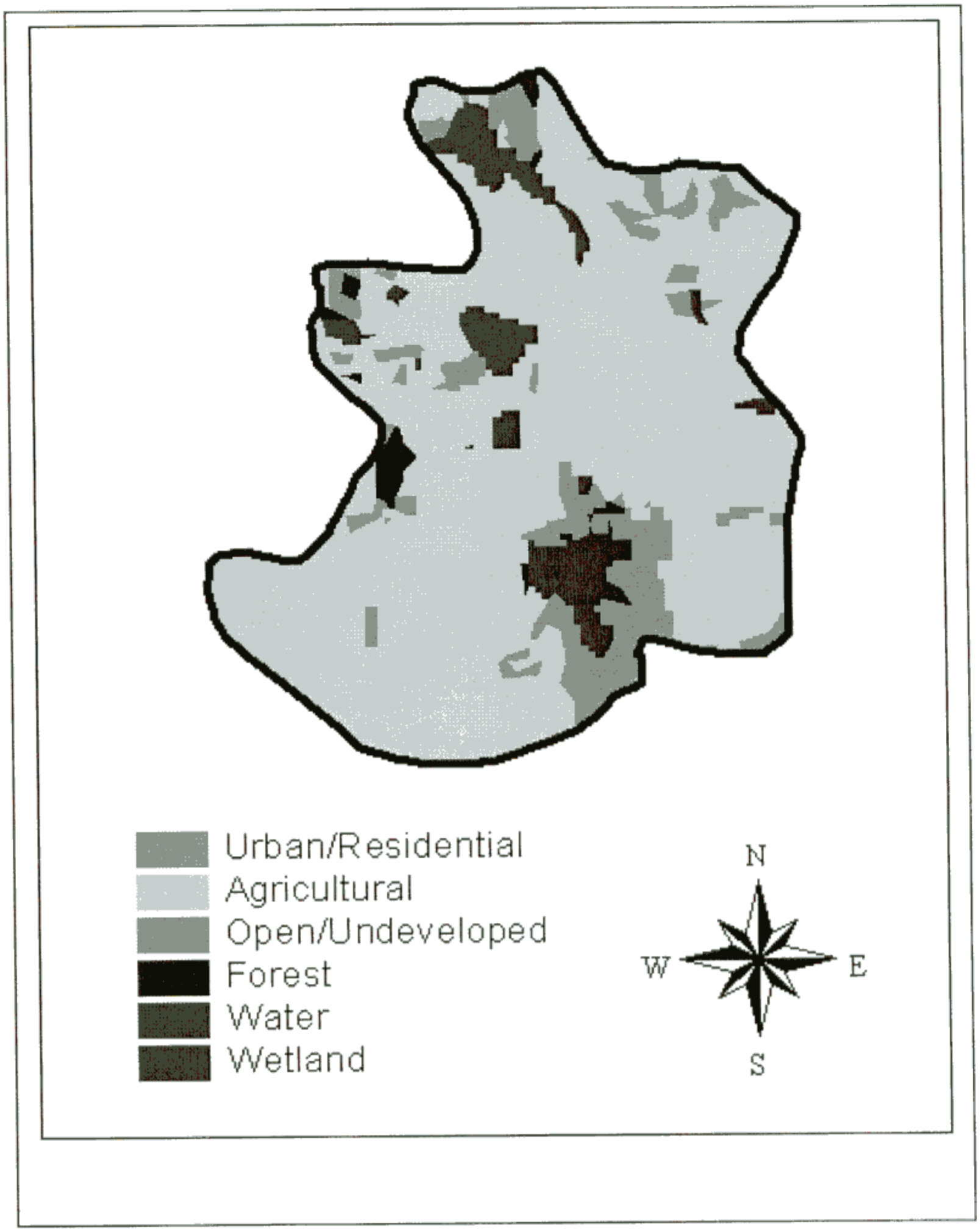


Figure 5: Watershed Land Use/Cover

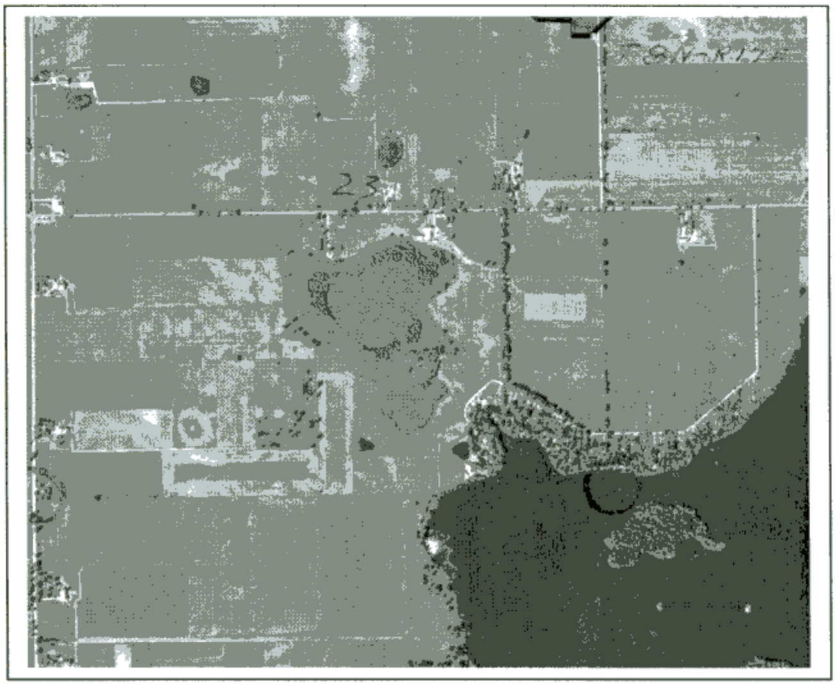


Figure 6: 1950 Aerial Photograph

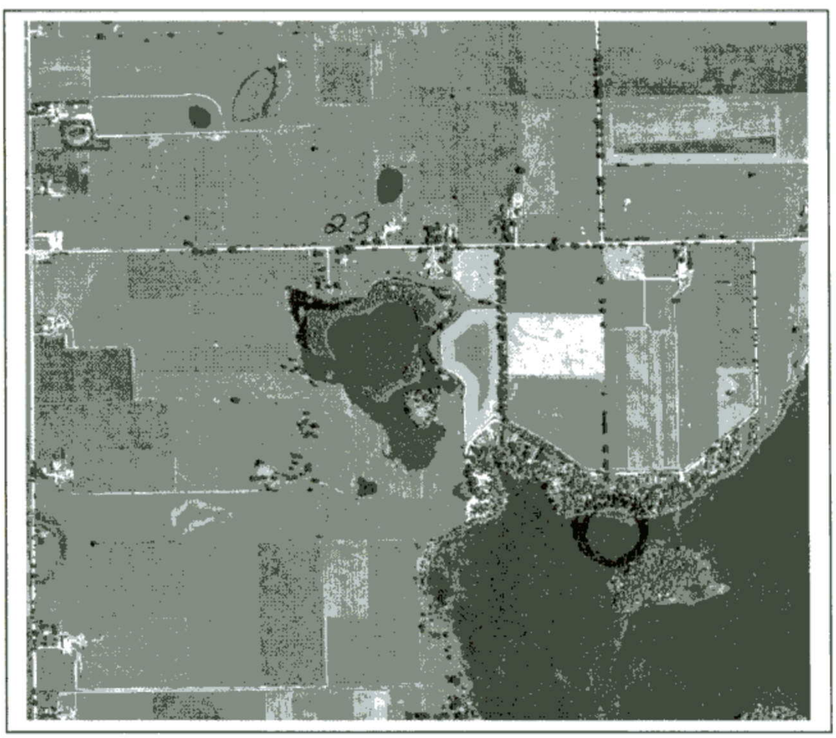


Figure 7: 1956 Aerial Photograph

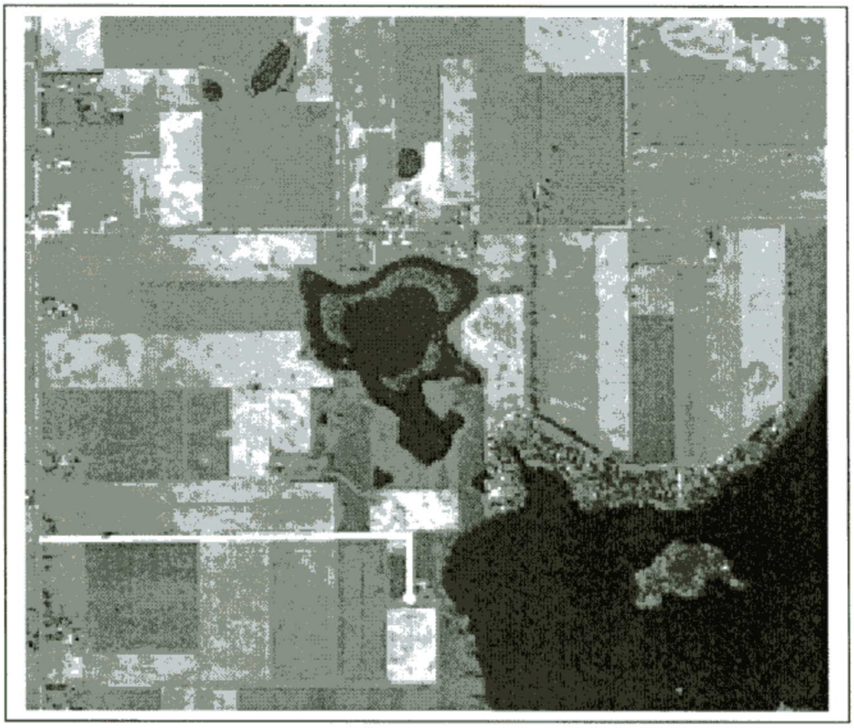


Figure 8: 1966 Aerial Photograph

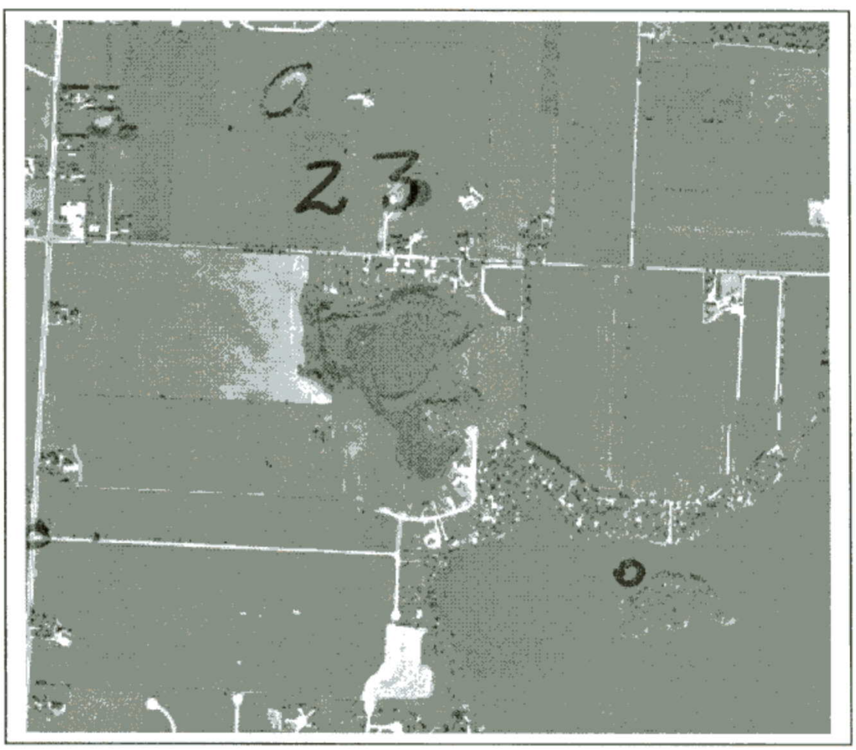


Figure 9: 1969 Aerial Photograph

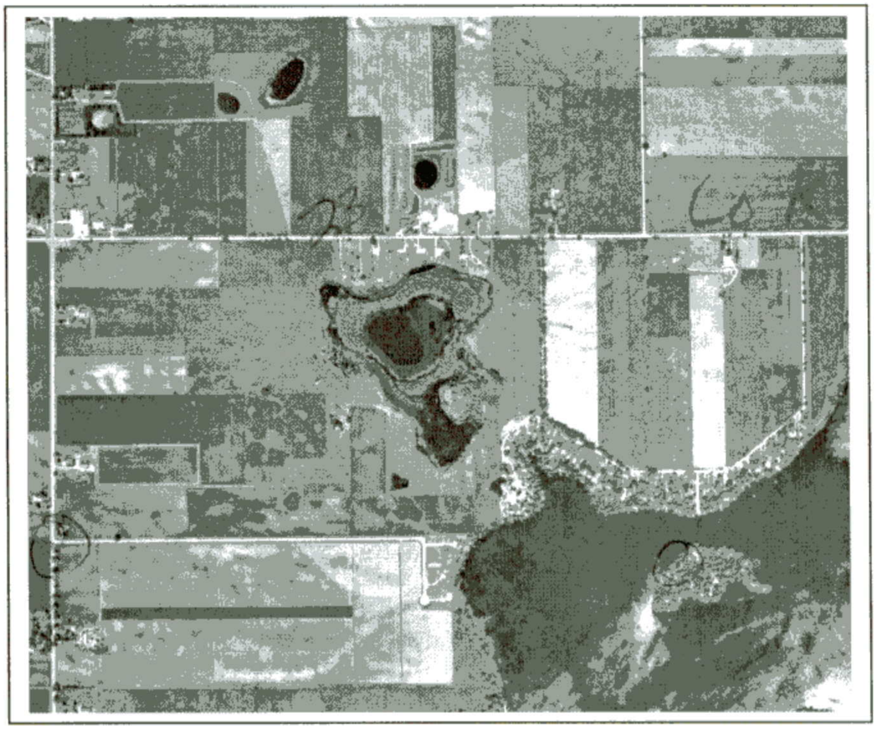


Figure 10: 1979 Aerial Photograph

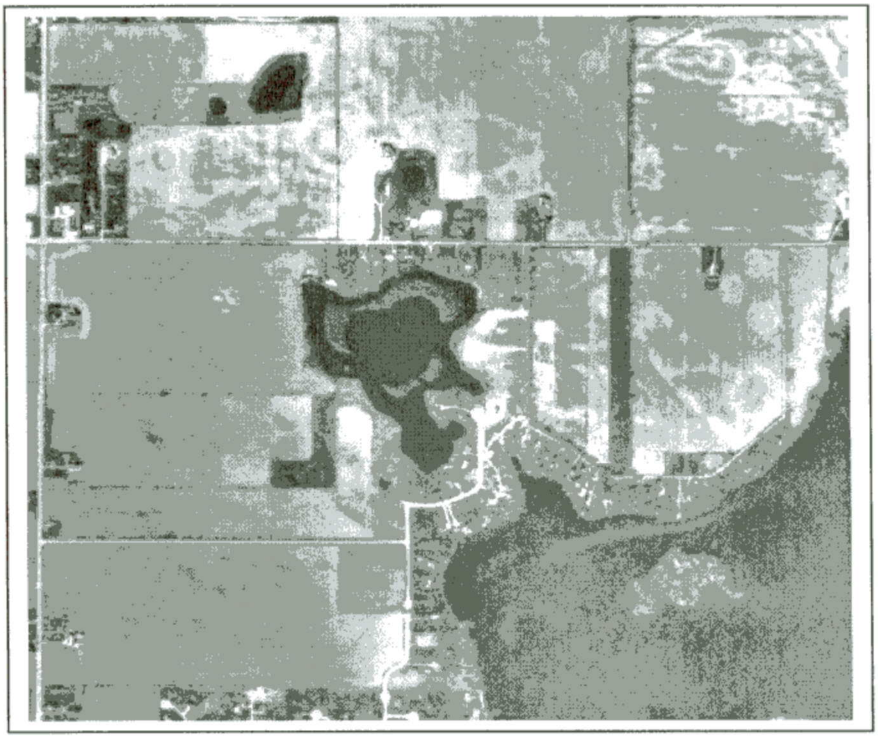


Figure 11: 1992 Aerial Photograph

2-3 LAKE DESCRIPTION

OVERVIEW

Tamarack Lake is a 30-acre, groundwater seepage lake with about a 15-foot maximum depth. The lake receives surface water from a 1,325-acre, agriculturally dominated watershed. Shallow water depths and moderately high nutrient concentrations have resulted in a meso-eutrophic water body. Moderate to high levels of primary productivity and fertility are characteristic of this type of system. Despite an advanced trophic state, Tamarack Lake currently exhibits good water clarity along with an abundance of aquatic vegetation, and supports a healthy warm-water sport fishery consisting of northern pike, largemouth bass, crappie and a variety of panfish. In terms of recreation, people mostly use the lake for peaceful relaxation, paddling, canoeing, fishing, observing wildlife, and enjoying the natural scenic beauty.

LAKE TYPE

Lakes may be classified according to their primary source of water, and how that water enters and leaves the water body. Tamarack Lake is classified as a seepage lake. Seepage lakes derive most of their water from groundwater. Water enters the lake through springs and other groundwater discharge areas, and, to a lesser extent, overland flow from the immediate drainage basin. Tamarack Lake does not have a defined inlet or outlet. As a landlocked water body, stream drainage and surface runoff represent a smaller proportion of the total water budget.

Knowledge of lake types is important when attempting to identify and address various water quality and quantity problems. By examining the different sources and quality of water that recharge a lake, water resource professionals are better able to pinpoint the root causes of water quality impairments. For example, if stream discharge provides the major source of water, nutrient levels are often high and water exchange takes place more rapidly. These lake types have the most variable water quality, depending on the amount of runoff and human activity in the watershed. Conversely, if groundwater is the major water source, the lake is usually well buffered against acid rain, contains low to moderate amounts of nutrients, and has fairly slow water exchange rates. This includes all groundwater drainage lakes and some seepage lakes. Leaking septic systems or groundwater contamination could cause water quality problems in these lake systems. They may also take longer to respond to management efforts.

MORPHOMETRIC CHARACTERISTICS

Lake morphometry—or bathymetry—describes a lake's physical dimensions. Tamarack Lake's physical characteristics include lake volume (estimated: 225 acre-feet), surface area (30 acres), shoreline length (1.26 miles), mean depth (estimated: 7.5 feet), maximum depth (15 feet), lineal length (1,825 feet) and width (1,550 feet).

Surface area, maximum and mean water depths, basin shape, shoreline length, water volume, and other physical measurements can offer many clues as to how a lake should appear and function in a natural state. For example, a lake's morphometry will dictate how well its water column is able to mix and self-aerate. The extent to which the water mixes affects the lake's water quality and ability to support a diversity of aquatic life. The complete mixing of a lake's water column is called turnover. While shallow lakes tend to continuously mix or turn over throughout the year due to wind and wave action, deeper lakes turn over less frequently and typically as a result of seasonal temperature changes or large storm events. This is because deeper lakes undergo a process known as thermal stratification (defined in the section below).

Tamarack Lake is fairly small, which means it has a short fetch. Fetch describes the maximum distance across a lake that would be subjected to the effects of prevailing winds. Because of its limited fetch, the lake is relatively sheltered from wind-induced mixing. However, given its shallow water depths, even lower-energy winds could potentially keep the lake from thermally stratifying.

THERMAL STRATIFICATION

Thermal stratification occurs in deep lakes during stable weather conditions when the water column forms horizontal water layers of varying temperatures and densities. As air temperatures rise in the spring, a temperature-density "barrier" begins to form in deeper water bodies between the warmer, lighter surface water that is heated by solar energy and the underlying denser, colder water. This barrier is marked by a sharp temperature gradient called the thermocline. The zone where the thermocline occurs is known as the metalimnion. It separates the warmer, less dense, upper zone of water called the epilimnion, from the cooler, more dense, lower zone called the hypolimnion. Summer stratification generally occurs in lakes where depths are greater than 20 feet. However, depending on their shape, small lakes can stratify even if they are less than 20 feet deep. Tamarack Lake, for instance, could potentially exhibit weak thermal stratification in its deepest points during mid-summer. In larger lakes with greater fetch, the wind may continuously mix the water to a depth of 30 feet or more.

Lakes may also undergo a second stratification period during the winter months. Because water density peaks at 39°F, winter stratification develops with a temperature difference of only 7°F between the top and bottom (32°F right below the ice versus 39°F on the lake bottom). This explains why ice floats and forms at the water's surface. The ice layer at the surface helps maintain stratification by preventing wind from mixing the water column. The ice also helps insulate the water beneath it, which prevents deeper lakes from freezing solid.

The temperature and density of the water column will be fairly consistent from top to bottom in both the early spring and late fall when seasonal changes occur. The uniform water density allows the lake to mix completely, replenishing the bottom water with dissolved oxygen and recycling nutrients up to the surface. This destratification process is called spring and fall turnover. Algal blooms often proceed turnover events in stratified, eutrophic lakes when nutrients are suddenly infused into the upper photic zone of the lake.

It is important to note that lakes experiencing strong thermal stratification are frequently subject to oxygen depletion in the hypolimnion. As algae, plant debris and other organic material fall into the hypolimnion to decay, oxygen becomes depleted to the extent that anaerobic conditions may develop. A strong sulfur odor is frequently associated with such waters. This oxygen deficiency can stress a cool water fishery that requires deeper water habitats, and may cause the mobilization of phosphorus from nutrient-rich bottom sediment into the overlying water. During turnover, the fertile bottom water is then mixed throughout the water column, creating a situation that favors nuisance algal blooms.

To determine whether Tamarack Lake undergoes summer stratification, temperature profiles would need to be taken of the water column during mid summer. [These measurements have not yet been collected.] The depth and morphometry of the lake suggest that it may exhibit weak thermal stratification under stable weather conditions. However, it very likely remains fairly well mixed during most of the year. If this turns out to be true, the lake would not form an extensive hypolimnetic zone, nor would it significantly suffer from the effects of oxygen depletion caused by strong thermal gradients.

RETENTION TIME/FLUSHING RATE

The average length of time water remains in a lake is called the retention time, or hydraulic residence time. It is primarily determined by lake size, water source, and watershed size. Rapid water exchange (flushing) rates allow nutrients to be flushed out of the lake quickly. Such lakes respond best to management practices that decrease nutrient input. Drainage systems and impoundments fit this category. Conversely, longer retention times occur in seepage lakes that do not have surface outlets—like Tamarack. Nutrients that accumulate over a number of years in lakes with long retention times can be recycled annually with spring and fall mixing. Thus, the effects of watershed protection may not be apparent for a number of years.

Nevertheless, lakes with long retention times tend to have the best water quality since they are usually deeper with smaller watersheds.

TROPHIC STATE

Eutrophication is a term used to define the natural aging process of a lake, and describes the primary productivity response of a lake to nutrient enrichment. Left in its natural state, a lake would generally age by slowly filling in with sediment over thousands of years. However, human activities within the watershed can dramatically accelerate the rate of eutrophication through increased nutrient enrichment. Water bodies that receive excessive amounts of nutrients, such as phosphorus and nitrogen, are most likely to become eutrophic systems. Once in the lake, these excess nutrients increase fertility levels and contribute to murky water conditions, algal blooms and/or nuisance weed growth—the symptoms of eutrophication.

A lake's trophic state describes its degree of eutrophication or level of primary productivity. Lakes can be classified as either oligotrophic, mesotrophic or eutrophic. Oligotrophic lakes are generally clear, deep and free of weeds or algal blooms. They are low in nutrients and are not capable of supporting large fish populations. Eutrophic lakes have poor water clarity, are high in nutrients, and support a large biomass of aquatic plants and animals. They are usually either weedy or subject to frequent algal blooms, or both. Although capable of supporting large fish populations, these lakes are also susceptible to oxygen depletion and other problems. Devoid of oxygen in late summer, their hypolimnia become intolerable to cold water fishes and cause phosphorous cycling from bottom sediments. Large rough fish populations (e.g. carp) are commonly found in eutrophic lakes. Mesotrophic lakes lie between the oligotrophic and eutrophic stages. It is important to remember that a natural aging process occurs in all lakes that cause them to become shallower and increasingly eutrophic over time. However, as mentioned earlier, human activity can accelerate the eutrophication process by allowing greater quantities of nutrients to enter the lake.

Trophic state is determined by correlating three water quality parameters—total phosphorus concentration, chlorophyll *a* concentration and Secchi transparency values. The trophic state of Tamarack Lake is meso-eutrophic, indicating that it fluctuates between a mesotrophic and slightly eutrophic condition. The 2001 monitoring results from the Wisconsin State Laboratory of Hygiene were used to classify Tamarack's trophic state. These results are found in Appendix A. Water quality data and corresponding trophic state indices from the 2001 sampling period are presented in Table 2, while a graphical representation of these data is shown in Figure 12. Wisconsin lake trophic states based on chlorophyll a, Secchi depth, and total phosphorus values is presented in Table 3.

Table 2: Trophic classification of Tamarack Lake based on total phosphorus, chlorophyll a, and Secchi depth values for 2001.

	Total Phosphorus		**Chlorophyll a**		**Secchi Depth**	
Date	Concentration (ug/l)	TSI (phosphorus)	Concentration (ug/l)	TSI (chl. A)	Depth (meters)	TSI (Secchi)
5/23/01	31	55	5	47	3.0	44
6/29/01	23	52	6	48	3.0	44
8/06/01	7*	43*	1.4*	37*	1.8	52
9/28/01	10*	46*	NA	NA	2.7	46
12/11/01	17	50	NA	NA	3.4	42

* = Data quality is questionable. Result is approximate.

Oligotrophic	Mesotrophic	Eutrophic
TSI < 40	40 < TSI < 50	TSI > 50

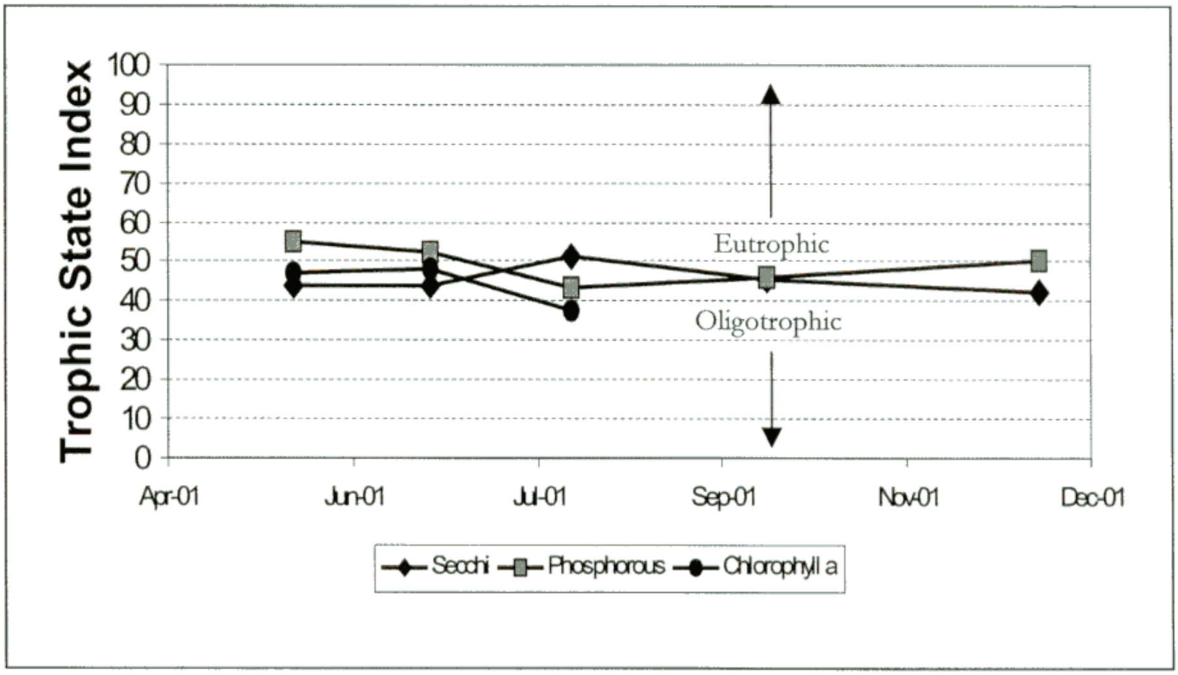


Figure 12: 2001 Trophic State of Tamarack Lake

Table 3: Trophic classification of Wisconsin lakes based on total phosphorus, chlorophyll a, and Secchi depth values.

(Adapted from Lillie and Mason, 1983.)

Trophic Level	Trophic State Index	Total Phosphorus (mg/l)	Chlorophyll *a* (ug/l)	Secchi Depth (meters)
Eutrophic				
------------------------	-----------50----------	--------0.017----------	-----------7.4----------	-----------2.0----------
Mesotrophic				
------------------------	-----------40----------	--------0.005----------	-----------2.0----------	-----------4.0----------
Oligotrophic				

Limiting Nutrient

Phosphorus (P) and nitrogen (N) are the two nutrients that most directly influence plant and algae growth; the extent of which depends on the relative abundance and availability of each nutrient. These nutrients usually enter lakes in the form of polluted runoff that may contain sediment, manure, pet waste, chemical fertilizers, and organic debris, among other materials. The erosion of stream banks, construction sites, shorelines and farmland all contribute sediment and nutrients to downstream lakes. Failing septic systems on smaller, heavily developed lakes with small flushing rates can also contribute significantly to nutrient-loading problems. Septic contributions might therefore pose a significant problem on Tamarack Lake. Regular fertilizer applications used to maintain expanding lawn areas is another likely threat to the lake.

Plants need both phosphorus and nitrogen to grow. However, phosphorus minimization is generally the focus of lake-management programs because it is (1) most frequently the limiting nutrient that controls the rate of algae growth, and (2) it is easiest to manipulate since the element has no gaseous component in its biogeochemical cycle. N:P ratios are used to determine which nutrient most "limits" or controls algae productivity by comparing the relative availability of each nutrient within the water column. A limiting nutrient is an element that is critical to the growth of primary producers, but is found in short supply relative to other required elements found in a particular water body. Because the essential nutrient is in short supply, it effectively limits the amount of primary productivity the lake is capable of supporting. A N:P ratio greater than 15:1 near the water surface may generally be considered phosphorus limiting; a ratio from 10:1 to 15:1 indicates a transition situation; and a ratio less than 10:1 usually indicates nitrogen limitation. Lakes with intermediate ratios could be limited from time to time by either element, but by reducing phosphorus availability, phosphorus could be made the limiting factor.

N:P ratios were computed for Tamarack Lake during the 2001 monitoring period. Values ranged from 44:1 to 59:1. These values indicate that phosphorus is the limiting nutrient that controls algae growth in Tamarack Lake. This is not surprising since phosphorus is the key nutrient affecting the amount of algae and weed growth in the vast majority of Wisconsin's lakes. A detailed watershed inventory and phosphorus budget can be employed to identify major non-point source pollutant loading hot spots. By addressing non-point source pollution, phosphorus loading can be reduced to improve water clarity.

The lake bottom may also be a significant source of phosphorus. Phosphorus is commonly released from nutrient-rich bottom sediment as a result of physical disturbance, high pH levels, and/or anoxic conditions. This phosphorus may cause noxious algal blooms, especially when it is mixed throughout the water column during the summer growing season. Knowledge of the phosphorus content of sediment in various locations along the lakebed is useful in identifying potential "hot spots" that are most likely to contribute the largest amounts of nutrients to the lake. This information can be used to determine whether management techniques such as dredging and alum treatments will effectively correct a potential in-lake, nutrient-recycling problem. Sediment cores are generally taken at certain locations in a lake to better characterize the depth and distribution of nutrient-rich bottom sediments. Sediment core information has not been collected for Tamarack Lake as of the date of this report.

In addition to using the sediment core technique, total phosphorus concentrations at the top and bottom of the water column can be compared. These measurements can suggest whether phosphorus is actually collecting in the anoxic hypolimnion from sediment releases during the summer stratification period. Because Tamarack Lake is so shallow, phosphorus release due to stratification-induced anoxia is not believed to be a serious concern.

When phosphorus concentrations exceed 0.025 mg/l at the time of spring turnover in natural lakes and impoundments, these water bodies may occasionally experience excess growth of algae or other aquatic plants. In hard water lakes where limestone is dissolved in the water, marl (calcium carbonate) can precipitate and fall to the bottom. These marl formations absorb phosphorus, reducing its overall concentration as well as algae growth. Hard water lakes often have clear water, but may be weedy since rooted aquatic plants can still get phosphorus from the sediments.

Phytoplankton (Algae)

Phytoplankton, more commonly known as algae, describes free-floating, microscopic plant life. Algae are the primary producers that form the base of the aquatic food chain. The amount of sunlight and nutrients that are available in a lake, among other factors, will dictate algal abundance. In eutrophic lakes, high nutrient fertility can cause nuisance algal blooms that make the water appear very green and murky. Blue green algae (cyanobacteria) are even known to produce a floating green scum thick enough to shade out aquatic plants. High concentrations of wind-blown algae may accumulate on shorelines where they die and decompose, causing noxious odors, unsightly conditions and oxygen depletion.

Controlling nuisance algae in lakes is a difficult undertaking. Because algae are microscopic plants that are free-floating and even free-swimming in the water column, managing the whole lake rather than just the problem areas is usually necessary. Since algal populations are caused by high nutrient concentrations, attempting to eliminate algae by attacking it directly with algaecides (chemical herbicides) is a short-term solution that may become a costly management approach over the long run. The best way to manage excessive algae is to both reduce the flow of nutrients into the lake, and control the availability of nutrients that are already contained within the lake. Chlorophyll *a*, the green pigment found in all photosynthesizing organisms, is commonly used as an indicator of algal biomass. Chlorophyll *a* values for Tamarack Lake during the 2001 monitoring period were between 5.0 and 6.0 ug/l. These values are generally indicative of a mesotrophic, or moderately productive ecosystem.

WATER CLARITY

Water transparency measurements are taken with a device known as a Secchi disc, which is used to evaluate the clarity of a lake's water column. A Secchi disc is an eight-inch-diameter, black-and-white patterned plate that is lowered into the water until it reaches a depth at which it is no longer visible from the water surface. The recorded depth can be compared to values from other lakes and used as an indicator of overall water clarity.

Generally, sunlight can penetrate to a depth equal to 1.7 times the Secchi depth. The depth to which light is able to penetrate, defined as the photic zone, roughly coincides with the depth where there is enough photosynthetic oxygen to support fish and other aquatic life. Transparency may be affected by factors such as turbidity (suspended sediment and particulate matter), water color, and free-floating algae cells. Secchi depth measurements are often used in conjunction with chlorophyll *a* and total phosphorus concentrations to determine a lake's trophic state and overall water quality condition.

Secchi measurements for Tamarack Lake during the 2001 monitoring period averaged 3.0 meters. These measurements are indicative of a mesotrophic, or moderately productive and fertile ecosystem. The lake is wholly contained within the photic zone given its shallow water depth and good water clarity. This situation largely explains the prolific aquatic plant growth. Abundant rooted plant growth and a lack of sediment re-suspension from boating activity should prevent a further decline in water clarity as long as non-point source pollution remains in check.

WATER QUALITY INDEX

Lillie and Mason (1983) classified all Wisconsin lakes using a random data set collected in the months of July and August. The water-quality index that was developed is based on surface total-phosphorus and chlorophyll *a* concentrations and Secchi depths. Applying the water-quality index to Tamarack Lake revealed that the measured surface total-phosphorus concentrations were generally indicative of "good" to "fair" water quality, while Secchi transparency and chlorophyll *a* concentrations were generally indicative of "very good" to "good" water quality. Table 4 shows the total phosphorus, chlorophyll *a* and Secchi depth ranges that correspond with each water quality ranking. Typical value ranges for Tamarack Lake's 2001 monitoring period are highlighted in gray. Table 5 shows the relative condition and percent distribution of central Wisconsin lakes that exhibit various total phosphorus, chlorophyll *a* and Secchi depth ranges. Once again, typical value ranges for Tamarack Lake's 2001 monitoring period are highlighted in gray.

Table 4: Water quality index for Wisconsin lakes based on total phosphorus, chlorophyll a and Secchi depth values.

(Adapted from Lillie and Mason, 1983)

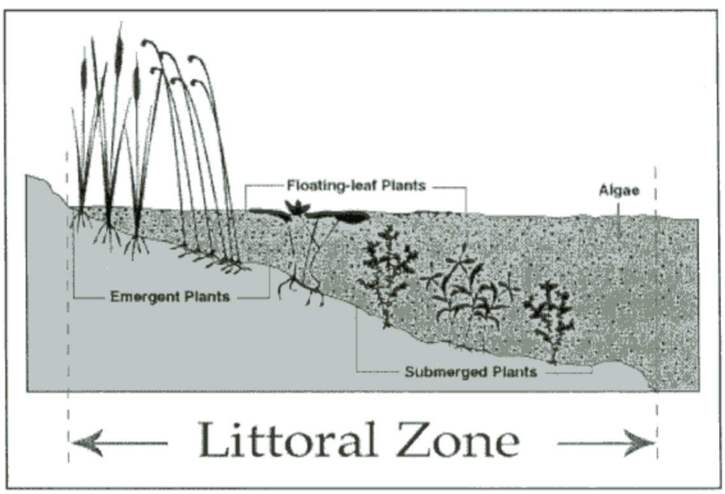
Water Quality Index	Total Phosphorus (mg/l)	Chlorophyll a ([g/l)	Secchi Depth (meters)
Excellent	<0.001	<1	>6.0
Very good	0.001-0.010	1-5	3.0-6.0
Good	0.010-0.030	5-10	2.0-3.0
Fair	0.030-0.050	10-15	1.5-2.0
Poor	0.050-0.150	15-30	1.0-1.5
Very poor	>0.150	>30	<1.0

Table 5: Relative condition and percent distribution of southeast Wisconsin lakes within various parameter ranges.

Parameter	Relative Condition	% distribution of southeast WI lakes within parameter ranges
Total-phosphorus (mg/L)		
<0.010	Best condition	7
0.010-0.020	▼	21
0.020-0.030	▼	15
0.030-0.050	▼	21
0.050-0.100	▼	21
0.100-0.150	▼	3
>0.150	Worst condition	12
Chlorophyll a (ug/L)		
0-5	Best condition	22
5-10	▼	31
10-15	▼	14
15-30		12
>30	Worst condition	22
Secchi depth (feet)		
>19.7	Best condition	
9.8-19.7	▼	9
6.6-9.8	▼	26
3.3-6.6	▼	31
<3.3	Worst condition	33

Littoral Zone

The relative abundance, distribution and types of rooted aquatic plants (macrophytes), fish, and other aquatic organisms provide an excellent indicator of lake quality. This is why the shallow, biologically rich areas on a lake are so important. These areas represent the lake's littoral zone. The depth at which sunlight is able to penetrate the water column in quantities necessary to promote photosynthesis determines the extent of the littoral zone. Like a rainforest, it is where you will find the greatest biological diversity.



The littoral zone's counterpart is the deep, open water pelagic zone. Uniformly shallow lakes like Tamarack will usually have insignificant pelagic zones when compared to their vast littoral areas. However, deeper lakes that have extensive, irregular shorelines with lots of small bays and narrow channels may also support large littoral zones. Macrophytic vegetation dominates both these types of systems, especially under conditions of good water clarity and nutrient-rich bottom sediments. Tamarack Lake's littoral zone supports a diversity of flora and fauna, and it occupies most of the lake's total surface area. As a result, the lake has natural limitations that will preclude any lake uses that require large areas of deep, open water.

Aquatic Plant Community

A diversity of native aquatic vegetation is the foundation of a healthy and balanced lake ecosystem. Such a situation is ideal for maintaining good water quality and wildlife habitat conditions. Plants provide nutrient buffers, stabilize bottom sediment, oxygenate the water during photosynthesis, provide shelter and spawning habitats for fish, act as refuges for zooplankton (microscopic animals that graze on algae), and serve as food sources for wildlife. Aquatic plant growth is limited by factors such as sunlight availability and sediment type.

Degraded lakes are disturbed ecosystems characterized by too much or too little aquatic vegetation that is usually dominated by non-native, invasive "weeds." An absence of vegetation usually leads to poor water quality and a loss of fish and wildlife habitat. This situation favors an increase in algae growth and a reduction in water clarity. A different set of problems occurs when non-native aquatic weeds become overly abundant. This situation reduces native plant diversity, impedes certain recreational functions of the lake, stunts fish growth, and can cause dramatic fluctuations in dissolved oxygen levels. The decomposition of plant material is also shown to release nutrients that were previously tied up in the living plant tissues. Isolated areas in a lake where either native plant growth is sparse or a nuisance weed condition exists are excellent indicators of localized disturbances. Disturbances can be in the form of pollution, sedimentation, motor boat damage, or the chemical eradication or over harvesting of plant beds.

Examples of beneficial native plants include water lilies, bulrushes and the various pondweeds, among others. Eurasian watermilfoil, on the other hand, is a nuisance species that is not native to Wisconsin. Under the right conditions, such exotic invaders will out-compete native plants and form monotypic stands of dense vegetation. Such prolific growth can eventually reduce biological diversity and restrict recreational use of the water. This may hold true for Tamarack Lake since Eurasian watermilfoil was identified in the lake during the 2001 monitoring period. If left unchecked, this particular weed can eventually restrict recreational access to open water areas and result in stunted panfish populations.

Fishery

The presence of relatively undisturbed, natural shorelines and extensive wetland areas enhance the spawning and nursery habitat of a healthy sport fishery. Shoreland wetlands and abundant aquatic plant growth provide refuge and cover for diverse aquatic life, while providing natural water quality buffers that mitigate the effects of nonpoint source pollution. Tamarack Lake appears to support a good diversity of aquatic plants that are valued as food sources for fish and wildlife. Quiet wetland areas and tree falls along the lake's periphery should also benefit the fishery by providing structural refuge and spawning sites.

Unfortunately, overly dense plant growth can prevent larger predator fish from grazing on smaller panfish. This situation leads to the overpopulation and stunting of panfish populations, and can negatively affect growth rates of larger piscivores. Protecting high-quality plant communities while controlling the spread of non-native species will benefit the fishery as a whole. Other improvement strategies include harvest restrictions, creation of edge habitat in weed-choked locations, maintaining good water clarity, and protecting wetlands and natural shorelines.

Major game fish species currently include largemouth bass, northern pike, crappie and panfish. An electro-shocking survey is needed to thoroughly evaluate the composition and size distribution of the fishery. These surveys are frequently performed by the Wisconsin Department of Natural Resources, and can provide important information as to the health of the fishery and applicability of more stringent harvest restrictions.

Dissolved Oxygen & Temperature

Dissolved oxygen is one of the most critical factors affecting lake ecosystems, and is essential to all aquatic organisms that require aerobic conditions to survive. The solubility of oxygen is dictated by water temperature. Basically, the colder the water temperature, the more oxygen it is able to hold in solution. Dissolved oxygen is also more abundant in water that is well mixed and in greater contact with the atmosphere. Areas in a lake that support photosynthesis will further enhance dissolved oxygen levels during daylight hours. This helps explain why oxygen levels fluctuate throughout the water column depending on variables such as time of day, water depth, clarity and temperature. When dissolved oxygen concentrations become depleted, the survival of fish and other oxygen-dependent aquatic life becomes compromised. The water quality standard for oxygen in "warm water" lakes like Tamarack is 5.0 mg/l, which is the minimum amount of oxygen needed for most fish to survive and grow.

As discussed earlier, the amount of oxygen present within the hypolimnion of deeper lakes plays an important role in the mobilization of nutrients from the bottom sediments into the surrounding water column. Phosphorus can be chemically converted into a more soluble state and released from bottom sediments when the overlying water becomes devoid of oxygen, or anoxic. These anoxic conditions commonly occur within the hypolimnia of deeper, eutrophic lakes where the rate of decomposition and bacterial respiration exceeds the rate of photosynthesis and natural aeration. For instance, as thermal stratification isolates the hypolimnion from the atmosphere, the surface supply of oxygen from the atmosphere is sealed off. The remaining dissolved oxygen is often rapidly consumed when respiration rates increase due to excessive decomposition of organic material that settles to the bottom. As anoxia develops, phosphorus contained in the sediments chemically converts into a more soluble state, migrating from the sediments to the surrounding water. When the lake eventually destratifies (mixes), any nutrients that were released from the bottom sediments are transported throughout the water column where they become available for algae growth. It should be noted that anoxic conditions are also capable of developing in weedy, shallow lakes, especially during non-daylight hours when bacterial and microbial respiration is likely to exceed photosynthesis.

Vertical profiles of dissolved oxygen should be measured on Tamarack Lake during different times of the year. This information will indicate if oxygen depletion is a problem that could negatively impact aquatic life.

ACIDIFICATION

pH measures the concentration of hydrogen ions in a lake. Lower pH waters have more hydrogen ions and are more acidic than higher pH waters. A pH of 0 indicates that a particular water sample is highly acidic, while a pH of 14 suggests a highly basic sample (7 is considered neutral). Every 1.0 unit change in pH represents a tenfold change in hydrogen ion concentration. Therefore, a lake with a pH of 6 is ten times more acidic than a lake with a pH of 7.

Low pH is shown to increase the solubility of certain metals that can become toxic in higher concentrations, such as aluminum, zinc and mercury. It is also harmful to the survivability of fish and other aquatic organisms. In Wisconsin, pH ranges from 4.5 (acid bog lakes) to 8.4 (hard water, marl lakes). Lakes having good fish populations and productivity generally have a pH between 6.7 and 8.2. Lower pH lakes are often found in the northern part of the state where acid rain has a greater impact on surface waters due to the limited buffering capacity of regional soil types. Natural, unpolluted rainfall is relatively acidic, and typically has a pH of between 5 and 6. However, rainfall varies from a pH of 4.4 in southeastern Wisconsin to nearly 5.0 in northwestern Wisconsin. Fortunately, naturally acidic precipitation is usually neutralized as it is exposed to acid-buffering carbonates in the soil.

The amount of dissolved carbon dioxide in a lake, which is influenced by photosynthesis and respiration processes, generally affects pH levels. For instance, as carbon dioxide levels increase, pH will correspondingly decrease, and vice versa. 2001 water chemistry data indicate that the pH of Tamarack Lake is approximately 8.0 standard units. These values are common for lakes in this part of Wisconsin, pose no problems for aquatic life, and indicate that the system is well buffered from acidification. Acidity effects on different fish species are presented in Table 6 below.

Table 6: Effects of acidity on fish.

(Adapted from Olszyk, 1980)

Water pH	Effects
6.5	Walleye spawning inhibited
5.8	Lake trout spawning inhibited
5.5	Smallmouth bass disappear
5.2	Walleye, burbot, lake trout disappear
5.0	Spawning inhibited in many fish
4.7	Northern pike, white sucker, brown bullhead, pumpkinseed sunfish, rock bass disappear
4.5	Perch spawning inhibited
3.5	Perch disappear
3.0	Toxic to al fish

Alkalinity & Hardness

A lake's hardness and alkalinity are each affected by the types of minerals found within the watershed's soils. Hardness and alkalinity increase the more the lake water comes into contact with minerals containing bicarbonate and carbonate compounds. These compounds are usually found with two hardness ions: calcium and magnesium. If a lake receives groundwater from aquifers containing limestone minerals such as calcite and dolomite, hardness and alkalinity will be high. High levels of hardness (>150 mg/l) and alkalinity can cause marl (calcium carbonate) to precipitate out of the water. Hard water lakes like Tamarack Lake tend to be more productive and support larger quantities of fish and aquatic plants than soft water lakes. They are also usually located in watersheds with fertile soils that add phosphorus to the lake. As a balancing mechanism, however, phosphorus precipitates with marl, thereby controlling algae blooms. If the soils are sandy and composed of quartz or other insoluble minerals, or if direct rainfall is a major source of lake water, hardness and alkalinity will be low. Lakes with low amounts of alkalinity are more susceptible to acidification by acid rain and are generally unproductive.

Tamarack Lake has above average alkalinity and "low" sensitivity to acid rain due to its significant buffering capacity. Table 7 shows relative hardness levels for lakes with varying concentrations of calcium carbonate (CaCO3). Hardness values for Tamarack Lake during the 2001 sampling period were between 86.3 and 90.7 mg/l (highlighted in gray in the table below), indicating moderately hard water. Table 8 shows relative sensitivity levels of lakes to acid rain based on alkalinity values. During the 2001 sampling period, these values were around 80.0 mg/l for Tamarack Lake (highlighted in gray in the table below), indicating that the lake is not sensitive to the effects of acid rain.

Table 7: Categorization of hardness by mg/L of calcium carbonate (CaCo3).

Level of Hardness	Total Hardness as mg/l CaCO3
Soft	0-60
Moderately hard	61-120
Hard	121-180
Very Hard	>180

Table 8: Sensitivity of lakes to acid rain based on alkalinity values.

(Adapted from Taylor, 1984)

Sensitivity to Acid Rain	Alkalinity (ppm CaCO3)	Alkalinity (ueq/l CaCO3)
High	0-2	0-39
Moderate	2-10	40-199
Low	10-25	200-499
Nonsensitive	>25	>500

A summary of the lake and watershed's physical, chemical, biological & demographic characteristics is included in Table 9 below.

Table 9: Summary of physical, chemical and biological characteristics.

PHYSICAL DESCRIPTION (LAKE)	
Lake type:	Seepage
Surface area:	30 acres without islands (0.47 square mile)
Dimensions:	1,825 feet long X 1,550 wide
Shoreline length:	1.26 miles
Mean depth:	7.5 feet (estimated – no data available)
Maximum depth:	15 feet
Volume:	225 acre-feet (estimated – no data available)
Primary water source:	Groundwater
Flushing rate:	Very slow
Thermal stratification:	Polymictic (no supporting data available)
Shoreline development factor:	0.45 (1 = perfect circle; lesser values indicate irregular shoreline)
PHYSICAL DESCRIPTION (WATERSHED)	
Watershed area:	1,325 acres (2 square miles)
Watershed-to-lake surface area ratio:	44:1
Land uses:	Agriculture (78%); grassland (10%); wetland (4%); water (3%); urban/developed (2%); forest (2%); barren (1%)
Major soil types:	Fox-Casco silt loams
Topography:	Flat to gently rolling
Public lake access:	Limited; unimproved
CHEMICAL & BIOLOGICAL DESCRIPTION	
Limiting nutrient:	Phosphorus
Trophic state:	Mesotrophic to slightly eutrophic
Water quality indices:	Good
Nutrient sensitivity:	High
Alkalinity & hardness:	Moderate to high
Acidification sensitivity:	Low
Winter fish kill sensitivity:	Moderate
Major sport fisheries:	Largemouth bass, northern pike, crappie and panfish

CHAPTER 3: PUBLIC PRIORITIES & NEEDS ASSESSMENT

3-1 INTRODUCTION

Actively involving the public is important in facilitating the identification and prioritization of desired lake uses and problems. In addition, public involvement helps educate users about the lake ecosystem, their role in contributing to certain problems, and the actions they can take to eliminate or reduce the severity of these problems. Greater understanding and awareness of problems will generally lead to increased cooperation in their solution and thus a greater likelihood of program success.

We recognize that lakes cannot be all things to all people at all times, and that lake uses often conflict and must be separated. Therefore, desired lake uses and values must be prioritized based on considerations such as level of lake resident support, and the feasibility of attainment given the natural limitations of the particular aquatic environment. Prioritizing is commonly used to resolve mutually exclusive recreational desires and management goals. It also reduces the likelihood that any random interest group would be able to unduly influence the decision-making process by making false claims of "need" or "resident support."

Resident opinions pertaining to lake-use priorities and perceived problems were determined using feedback from public meetings and a written survey conducted in 2000. The purpose of the meetings and opinion survey was to gauge people's general feelings regarding the lake, their impression of the overall management policies, and whether there were any suggestions regarding new policies or ideas for improving the lake.

3-2 PUBLIC SURVEY RESULTS

In the summer of 2000, a survey was developed and distributed to all property owners around Tamarack Lake. The purpose of the effort was to engage public participation in the lake planning process by soliciting the opinions and concerns of residents regarding the lake and its management. Responses were used to help prioritize and rank desired lake uses, and to identify the problems jeopardizing the health and recreational value of the resource. Ultimately, 16 of 16 surveys were completed and returned for analysis, representing a 100% response rate. The perfect response rate may be indicative of a prevalent interest to protect and enhance this valued resource. Results from the survey are presented below. Refer to Appendix B for a copy of the questionnaire and a graphical presentation of the 2000 survey results.

DEMOGRAPHICS

All survey respondents claimed to be year-round residents, with the vast majority owning residential property near the lake and belonging to the association. Most described themselves as new property owners who have lived near the lake for only a short number of years. However, a couple of the respondents have owned property on the lake for over 30 years. The top reason for owning property on or near Tamarack Lake was for the enjoyment of peace and solitude. Although a very small percentage of survey respondents claim never to spend time recreating on Tamarack, most use the lake on a consistent, year-round basis.

USER PREFERENCES

Lakefront residents most commonly describe their immediate lake frontage as being unaltered and thickly vegetated. Many others describe their frontage as consisting of a mowed lawn, frequently leading to a pier at the water's edge. Beaches, boat ramps and rock-reinforced shorelines are currently uncommon. Many respondents are of the opinion that chemical lawn treatments are necessary and should be applied at least two times per year. The most popular types of watercraft used on Tamarack Lake include (in descending order):

small paddle boats, canoes/kayaks, fishing boats with trolling motors, and pontoon boats. According to the survey, there are presently no powerboats, sailboats or personal watercraft used on the lake.

Lake qualities of greatest importance include (in descending order): clear water, navigability, wildlife/habitat, and a three-way tie between solitude, moderate plant growth and abundant fish. Strong support was also given to a sandy lake bottom and overall ecosystem health. Recreational activities of choice were canoeing and enjoying the peace and solitude. Fishing, appreciating the scenery, and observing wildlife were also popular activities. Of those who fish, 80% indicate that they practice catch-and-release on a consistent basis when fishing for species other than panfish. The remaining 20% claim that they practice catch-and-release at least occasionally. Anglers mostly enjoy pursuing largemouth bass on Tamarack. However, fishing for northern pike, bluegill/sunfish and crappie is also popular. A majority of respondents feel Tamarack Lake offers adequate public access.

Opinions on Existing Conditions

When asked how various conditions have changed over time, four factors were perceived to have worsened to the greatest degree over time. These factors included aquatic weed growth, aquatic habitat, algae growth and muckiness of the lake bottom, respectively. The aquatic plant growth in Tamarack Lake was considered excessive by 94% of survey respondents. Another 94% believe there are areas on the lake where aquatic plant growth becomes especially problematic, but referenced locations were highly variable. Abundant plant growth was viewed as problematic to primarily navigation and swimming. Most people (94%) do not feel the current weed control efforts are adequately controlling nuisance plant growth.

Overall, respondents describe Tamarack Lake's water clarity as generally clear during the summer months. Water clarity is perceived to be at its worst in the summer following heavy rainfall. This suggests that stormwater runoff and nonpoint source pollution is at least partially responsible for decreased water clarity conditions. As far as the angling community is concerned, most rank the quality of fishing as poor to fair in terms of fish size, and fair to good in terms of fish numbers.

Lake-use conflicts do not currently appear to be an issue of concern for Tamarack Lake. Furthermore, the majority of respondents do not feel there are any types of behavior, recreational activities or uses that seriously jeopardize the health and safety of the lake. Possible reasons include relatively low lake-use pressure, and the fact that the lake is a state-mandated, slow-no-wake water body. Of the 31% who disagreed with this assessment, most blamed farm runoff, winter snowmobiling/four-wheeling and lack of effective management. Survey respondents predominantly felt the lake was sufficiently regulated, although some considered it under regulated.

Perceived Problems

Survey respondents overwhelmingly consider nuisance weed/algae growth and sedimentation as the factors that most negatively impact their use and enjoyment of Tamarack Lake. Declining water clarity also appeared to be an issue of concern. Top factors that are perceived to contribute to these types of problems included farmland erosion, ineffective management efforts, and fertilizer applications, respectively.

Management Opinions

Most people appear to be of the opinion that current management efforts have been ineffective at controlling excessive weed growth, algae and silt accumulation. There does not seem to be much concern with recreational conflicts at this time. In fact, as mentioned earlier, most people feel the lake is adequately regulated. Respondents generally appear quite satisfied with the lake's above-average water clarity conditions and abundant wildlife habitat. They are also pleased that residents are starting to get organized for the purpose of maintaining the health and quality of the lake. A majority of survey respondents (87%) feel they are adequately informed of lake-management decisions, and that they have a voice in decision-making matters regarding the management of the lake (81%). The best way for the Lake Association to communicate with its members is through public meetings, door-to-door visits, newsletters and special mailers, respectively.

3-3 MANAGEMENT IMPLICATIONS

According to the results of public opinion surveys, management strategies should be selected that meet as many of the following criteria as possible:

1. **Maintains good water clarity conditions.**
2. **Manages excessive aquatic "weed" growth (specifically in confined, high-traffic areas where recreational access and habitat value is severely impaired).**
3. **Protects diverse aquatic plant beds and shoreland habitats that sustain a healthy fishery and resident wildlife population.**
4. **Preserves the existing peace and tranquility found on the lake.**
5. **Prioritizes "silent-sport" activities (e.g. fishing, swimming and paddling) over those involving large, motorized watercraft.**
6. **Minimizes silt and detritus accumulation that leads to a mucky lake bottom.**
7. **Maintains current fish numbers, but favors an increase in the size of popular sport fish.**
8. **Decreases polluted runoff from neighboring farm fields and fertilized lawns.**

Aside from satisfying the public criteria test to the greatest extent possible, strategy selection will be equally based on the availability of supporting scientific findings (as was presented in the previous chapter). This two-tiered approach will help keep popular opinion from disproportionately influencing management decisions. Management actions driven solely by public sentiment are often not the most prudent choices. They frequently involve rash decisions that are predicated on misdiagnosed problems and an incomplete understanding of all the possible side effects. As a result, problems could be inadvertently perpetuated or even worsened.

CHAPTER 4: PROBLEM ANALYSIS

4-1 INTRODUCTION

Many factors can negatively influence the health and quality of a lake. Irresponsible shoreline and watershed development, wetland drainage, habitat destruction, and lake-use pressures are just some of the factors that might contribute to any number of problems and recreational impairments. Each of these activities is capable of upsetting the stability of a balanced ecosystem and producing a variety of undesirable consequences. Separating the root cause of a particular problem from its more observable symptoms is the key to a successful lake management program.

To illustrate, consider that widespread public opinion feels Tamarack Lake is plagued with excessive aquatic plant growth. Because nuisance plant growth can prevent many lake users from fully enjoying the resource, it is tempting to mistakenly characterize it as the true "problem" in this situation. In actuality, however, the abundant plant production is more likely the "symptom" of a much larger problem called cultural eutrophication – or the premature aging of a lake caused by excessive nutrient enrichment and runoff pollution. It is also most likely the natural by-product of a shallow lake. In other words, the real problems are excessive nutrient enrichment from the adjoining watershed that favors abundant and prolific plant growth, and our own misguided perceptions as to what the lake should look like and the types of activities it should be capable of supporting.

Employing strictly symptomatic solutions that attack the nuisance plant growth directly rather than controlling the root cause or source of the problem is a recipe for failure over the long run. Common mistakes such as these often prove costly, especially if management strategies are prematurely and incorrectly chosen that do not appropriately address the real issue at hand. It is also important to determine if the concerns identified can realistically be alleviated through appropriately targeted lake-management efforts.

The following section discusses the three major factors contributing to the identified problems on Tamarack Lake. These factors include:

1. **Public perceptions and expectations are (to some degree) in conflict with the natural limitations of a small, shallow, meso-eutrophic ecosystem.**

2. **The lake is receiving excessive, nutrient-rich runoff pollution from the immediate watershed due to poor land-use practices.**

3. **Quality aquatic and shoreland habitat is disappearing because of current development and lake-use pressures.**

4-2 PUBLIC PERCEPTION FACTOR

Tamarack Lake does and should naturally support abundant rooted aquatic plant growth. Shallow water depths, good water clarity and naturally fertile bottom substrates provide the ideal conditions that favor this biological response. Residents and lake users must recognize and accept this fact. Expectations of transforming the lake into a deep, weed-free, and clear blue water body are probably not very realistic without incurring great expense and other undesired consequences. Neither is it realistic to expect the lake to support activities such as water skiing, sailing or Jet Skiing that require large open water areas. In any event, the State of Wisconsin has designated Tamarack Lake as a "slow-no-wake" water body since it has a surface area of less than 50 acres.

Public understanding and acceptance of the lake's natural limitations is the first step in dealing with perceived lake-use impairments. This is best achieved through an ongoing information and education campaign. Newsletters, press releases, public meetings, and educational brochures are all effective methods for elevating awareness and dispelling popular myths and misconceptions. An educated public is also more likely to voluntarily comply with rules and regulations that may be in place for lake-protection purposes.

4-3 NON-POINT SOURCE POLLUTION FACTOR

Accelerated eutrophication caused by non-point source pollution is arguably the most significant problem affecting Tamarack Lake today. Eutrophic waters are those that are severely impacted by nutrient enrichment that causes excessive productivity in the form of nuisance weed and algae growth. Surface waters located within larger watersheds that are urbanized, intensively farmed, or face strong development pressures are at the highest risk of exhibiting eutrophication problems. Symptoms include nuisance algal blooms, excessive weed growth, poor water clarity and/or mucky lake bottoms. External nutrient loading from the watershed (e.g. phosphorus and nitrogen), and in-lake nutrient recycling are the primary culprits. Identifying the relative nutrient contributions from each source is usually necessary before the right management strategy can be formulated to control this problem.

External Nutrient Loading

External nutrient loading is the influx of eroded soil, fertilizers, polluted runoff, organic debris and other material from the surrounding watershed to the receiving water body. This material is delivered to the lake primarily as stormwater runoff, and may contain large amounts of phosphorus and other nutrients that fuel algal blooms and weed growth. Improperly managed construction sites, poor farming practices, irresponsible fertilizer applications, leaking septic systems, loss of upstream wetlands, vegetative clear-cutting, and eroding shorelines and drainage ditches are just some of the more common factors that can increase nutrient and sediment inputs to the lake. This is especially true in the absence of proper measures designed to limit stormwater runoff and control soil erosion.

Water bodies with large watershed-to-lake surface area ratios (>10:1) are much more likely to experience water quality problems due to nutrient loading from the adjacent landscape. Since Tamarack Lake has a ratio of approximately 44:1, activities occurring in the watershed could have a great influence on water quality and the level of primary productivity. Consequently, external loading is believed to be responsible for a significant portion of the nutrient inputs to Tamarack Lake.

Protecting and managing the watershed is paramount to maintaining the health and quality of Tamarack Lake. Erosion-control measures known as Best Management Practices (BMPs) are used to control the sources of external nutrient loading. BMPs include grassed waterways, shoreline vegetative buffers, reduced tillage, field stripcropping, contour cropping, nutrient management, shoreline erosion control, and wetland restoration. The sources of external nutrient loading should be addressed before any in-lake management techniques are implemented. If not, in-lake management efforts will not be as effective over the long run, especially if external nutrient loading is proportionately significant.

Internal Nutrient Recycling

Internal nutrient loading, also called in-lake phosphorus recycling, occurs when nutrients are released from the lake bottom or by the life cycles of aquatic plants and organisms. This process is usually more of a factor in lakes with smaller watersheds and longer hydraulic retention times. Hydraulic retention describes the length of time a given volume of water remains in the lake before it is able to be replenished by new water entering the system. When this timeframe is short, in-lake nutrient recycling is less likely to account for a significant proportion of the total nutrient loading to the lake. Tamarack Lake is believed to have a fairly long hydraulic retention time, and therefore may be more prone to internal nutrient recycling problems. On the other hand, since Tamarack Lake remains fairly well mixed due to shallow water depths, it is probably not very susceptible to internal phosphorus release caused by hypolimnetic oxygen deficiency.

An anoxic hypolimnion, however, is not the only mechanism known to cause large-scale, in-lake phosphorus releases. The shallow, littoral zone of many lakes is also shown to contribute to internal phosphorus recycling as a result of anoxia, sediment re-suspension and elevated pH. Anoxic conditions may develop in shallower areas during non-daylight hours when respiration exceeds photosynthesis, causing phosphorus to be released from the near shore bottom sediments. Also, sediment disturbance from wind and wave action and motor boating activity may re-suspend bottom sediment that is rich in phosphorus, increasing nutrient availability in the water column. Finally, pH levels may increase as carbon dioxide concentrations are depleted during photosynthesis. These high pH conditions are shown to be a mechanism for phosphorus release due to complex biochemical processes. These processes have not yet been studied on Tamarack Lake, so it is unknown how much they contribute to overall nutrient loading.

Developing a phosphorus budget is usually recommended to more accurately identify the actual sources of internal nutrient loading if it is believed to be a problem. The completion of this type of study is warranted prior to consideration of an expensive management technique that may not target the actual problem area. The range of strategies to control internal nutrient loading include phosphorus precipitation and inactivation (alum treatments), hypolimnetic withdrawal, artificial circulation, hypolimnetic aeration, sediment removal (dredging), and dilution/flushing techniques. Each of these options and its relevance to Tamarack is described in detail in the following chapter.

Although in-lake nutrient recycling probably occurs to some extent in Tamarack Lake, it's relative significance has not been quantified. Existing anecdotal evidence suggests that it is not currently an issue of concern, especially when compared to external nutrient loading from the immediate drainage basin.

Management Considerations

The most obvious symptoms of eutrophication are nuisance plant and algae growth. Therefore, a great deal of time and effort is spent managing these biological consequences of a eutrophic water body. Even if all major nutrient sources are being addressed, plant and algae production could continue to represent an ongoing problem. This may be the case for Tamarack Lake. Therefore, combining nutrient-reduction strategies with more symptomatic-oriented solutions is probably both appropriate and unavoidable. For aquatic plant control, the range of commonly employed strategies include mechanical and manual harvesting, plant screens (sediment barriers), water level manipulation (drawdowns), dredging, and chemical treatment (herbicides). Algae control techniques include biomanipulation as a top-down approach, nutrient reduction as a bottom-up approach, and chemical treatment (algaecides) as a symptomatic approach. Each of these options is described and evaluated in the following chapter.

It should be noted that Tamarack Lake is an ecosystem with two alternative stable states of equilibrium—algae dominated or rooted aquatic plant dominated. Algae and aquatic plant abundance represent two ecological variables that are inextricably linked. This relationship makes it difficult if not impossible to manipulate one variable without dramatically affecting the other variable. For example, reducing or eliminating algae growth will result in improved water clarity, enhancing sunlight penetration through the water column and, thus, plant growth. Conversely, eliminating plant growth will free up nutrients and create conditions favorable for increased algae growth. The elimination of aquatic vegetation removes the lake's ability to stabilize its own bottom sediment and assimilate the nutrients that fuel algal blooms. It also reduces the amount of structural habitat used by algae-consuming zooplankton. ~~As you can see,~~ It is very easy to trade one problem for another if special precautions are not taken.

Controlling nuisance aquatic plant growth is one of the major objectives of this lake management plan. However, because there are numerous benefits associated with a healthy and diverse native plant community, aquatic plant control should only target specific species in especially problematic, high-use areas. A majority of the desired lake uses and values will be supported if a targeted reduction in nuisance weed growth is achieved strictly to facilitate reasonable public navigation and to create edge habitat for the benefit of the fishery.

4-4 SHORELAND HABITAT FACTOR

A lake left in its natural state should support a diversity of native vegetation that transitions from aquatic into upland habitat in a vertically stratified manner. Moving from deeper water toward shore, you would discover the following progression:

1. Submergent plants growing completely underwater (i.e., coontail & pondweeds)
2. Floating leafed plants anchored to the lake bottom with leaves resting on the water surface (i.e., lily pads)
3. Emergent plants found along wet shoreline margins with most of the plant growing above the water surface (i.e., cattail & bulrushes)
4. Upland plants and shrubs that form the under-story vegetative layer
5. Upland, mature trees that form the canopy layer

As an uninterrupted vegetative sequence, sufficient habitat is provided to support the life stages of a diversity of fish and wildlife. It also provides an effective water quality buffer that is capable of filtering and assimilating pollutants before they are allowed to reach the lake (called bioretention).

Unfortunately, development trends around Tamarack Lake are fragmenting these essential transition zones. The cumulative impacts of sand beaches, sea walls, turf grass, houses, driveways and other structures are generally to blame. As a result, biological diversity is reduced through the loss of native habitat, while water quality suffers from the effects of increased non-point source pollution. The expansion of water-impervious surfaces leads to less groundwater recharge and more stormwater runoff. At the same time, the replacement of native shoreline vegetation with lawns diminishes near-shore habitat while increasing the need for chemical fertilizers and herbicides that can pollute the lake.

CHAPTER 5: REVIEW OF MANAGEMENT OPTIONS

5-1 INTRODUCTION

This chapter provides an overview of strategies that are commonly used to manage: (1) recreational conflict, (2) external pollutant loading, (3) internal nutrient recycling, and (4) the biological symptoms of eutrophication. The management techniques discussed below may or may not be appropriate for Tamarack Lake. Techniques and strategies that are found to be applicable to Tamarack Lake generally receive more in-depth analysis and evaluation. The purpose of this chapter is to mainly provide additional information on popular lake-improvement methods for future reference and possible consideration. A recommended action strategy employing many of these management strategies is presented in Chapter 6.

5-2 RECREATIONAL CONFLICT RESOLUTION

Many problems arise when conflicting recreational uses compete for time and space on the lake. Since lakes cannot be all things to all people, certain sacrifices and compromises must be made to support a mixed-use recreational environment. The first logical step is to determine what types of activities a particular lake is even capable of supporting. For instance, a very small, shallow and plant-dominated lake like Tamarack is more appropriate for recreation such as fishing and paddle boating versus power boating and water skiing. Conversely, a larger and deeper lake might be better suited for more aggressive activities that require larger, deeper areas. The next step is to then determine how the majority of lake residents prefer to enjoy the lake, and how these priorities may be jeopardized due to the current condition or use of the resource. The following are a couple common methods for managing lake uses to resolve recreational conflicts.

Education

Educating the public is the first and perhaps most important step in resolving recreational conflicts. This can be achieved through an information and education campaign that might include newsletters, public meetings, "Welcome Wagon" informational packets for new residents, press releases, radio spots, Web sites, fact sheets, brochures and lake fairs. Explaining the actions that individuals can take to protect the lake and share it with others is often very conducive to increasing awareness and changing bad behavior. Problems can frequently be avoided simply by teaching lake-use etiquette and sharing common sense approaches to sharing a finite and fragile resource. An educated public is also more likely to accept greater levels of personal responsibility and accountability for its actions.

Applicable: YES
Recommended: YES
Public education programs are both applicable and recommended for Tamarack Lake. Educational efforts should increase the public's understanding and acceptance of protection and management programs.

Longevity of Effectiveness: To ensure effectiveness, an educational program should be considered a long-term and ongoing activity. Constant reminders are often needed to hammer home points and keep up with resident turnover.

Estimated Costs: There is usually only minimal cost (in terms of donated time) associated with public meetings and the submittal of press releases to the local media. Educational materials such as newsletters and informational flyers require more preparation time, and involve reproduction and mailing costs.

Potential Benefits:

- Increased awareness and understanding of issues and management programs
- Greater appreciation and acceptance of lake rules and regulations
- Behavioral improvements as people recognize the consequences of their actions

Potential Drawbacks:

- Inability to control whether people take the time to become better informed
- Time commitment and certain level of expertise required to produce effective educational materials
- Costs associated with production and dissemination of these materials

TIME & SPACE ZONING

A lake can be zoned in a manner that best supports conflicting, mutually exclusive interests. Conflicts occur when two different recreation types attempt to occupy the same general locations at the same time. When this happens, more aggressive recreation types (e.g. power boating & Jet Skiing) are usually able to displace passive recreation types (e.g. canoeing, fishing and swimming). Conflicts may also arise between different activities that fall within the same recreational classification. For example, although fishing and swimming are each considered passive forms of recreation, they also require their own space and unique lake conditions. Anglers may prefer a quiet, undisturbed area with an abundance of aquatic plants and bottom structure. Swimmers, on the other hand, may demand sandy bottoms, no aquatic vegetation, and an area free of fishing boats and dangerous hooks. Time and space zoning can help manage different lake activities to minimize conflict.

not applicable here

Time and space zoning can also be used to facilitate the protection and management of ecologically sensitive areas that are not compatible with certain lake uses. For example, underwater turbulence produced by personal watercraft and motor boats is frequently strong enough to disturb plant beds and bottom sediments in shallow water. This constant scouring of the lake bottom is detrimental to sensitive aquatic habitat, re-suspends phosphorus-rich sediment, and encourages the spread of undesirable plant species. Since eliminating boats or banning certain horsepower engines may not be feasible on many lakes, it might be appropriate to restrict certain activities to specified locations on the lake that are best suited for that lake use. Passive recreational uses such as fishing and canoeing might be permitted in the shallow, weedy areas, while more aggressive activities like water skiing and Jet Skiing might be directed to deeper, open water areas.

Applicable: YES
Recommended: CONDITIONALLY
This strategy is applicable, but may not be currently needed. Resident feedback suggests that lake-use conflicts are not currently an issue of concern. The State of Wisconsin also designates Tamarack as a mandatory "slow-no-wake" lake since it is less than 50 acres in size. This designation coupled with limited public access opportunities seems to minimize most problems that would warrant lake-use zoning. However, lake-use conflict may increase over time as more growth occurs around the lake, or as new forms of recreational watercraft are popularized. In addition, it may become prudent to set aside special protection areas. These areas are generally deemed ecologically vital to the long-term health of the lake, but threatened with irreparable harm due to certain lake uses.

Longevity of Effectiveness: This particular strategy would remain in effect for as long as the time/space zoning regulation is in place.

Estimated Costs: Costs would be associated with education, compliance monitoring and enforcement. Informational signage and the installation and removal of regulatory buoys are potential cost considerations. Regulatory buoy systems typically cost about $100-200 each to purchase.

Potential Benefits:

- Separation of conflicting lake uses

- Improved safety and enjoyment by competing recreational activities
- Means of balancing the protection of ecologically sensitive areas with disruptive recreational demands

Potential Drawbacks:

- Adds another layer of regulation to the lake
- Requires additional time and resources for implementation and enforcement
- Installation of special buoys may detract from the lake's natural, aesthetic appeal
- Certain types of recreation may become more restricted following lake zoning

5-3 CONTROL OF EXTERNAL POLLUTANT LOADING

External pollutant loading is that which is derived from the watershed, and includes both point and non-point sources. Point sources are the easiest to identify and control since they are typically associated with industrial processes that directly discharge waste product. Non-point sources describe just about everything else that could possibly be washed into the lake, making them much more difficult to manage. The activities that take place throughout the surrounding watershed essentially dictate both the quality and quantity of water that eventually enters the lake. Therefore, watershed management attempts to minimize the amount of stormwater runoff and soil erosion taking place on the landscape. The methods used to accomplish this goal—short of dictating where and what type of development can occur—are called Best Management Practices, or BMPs. A list of some popular BMPs is presented below.

• Contour farming	• No-till planting
• Strip-cropping	• Wetland restoration
• Grassed waterways	• Stormwater detention/diversion
• Nutrient (fertilizer) management	• Construction site erosion control
• Riparian buffer strips	• Stream & ditch bank stabilization

Applicable: YES
Recommended: YES
The use of watershed BMPs to control stormwater runoff and soil erosion is both applicable and recommended for Tamarack Lake. In particular, BMPs should be used to prevent polluted runoff from construction sites, farmland and fertilized lawns from reaching the lake. There are many different varieties of BMPs that must be selected on a case-by-case basis. Given the large number of available BMPs and their range of applications, a more complete cost-benefit analysis regarding each of these management tools was not performed as part of this report. BMP selection is best performed after conducting a detailed watershed and land-use inventory. These studies can isolate potential non-point source pollutant loading hot spots, characterize the downstream delivery mechanisms, and recommend the appropriate mitigation measures.

5-4 CONTROL OF INTERNAL NUTRIENT RECYCLING

There are two general options for internal loading control. One option involves removal of in-lake phosphorus sources, usually through sediment removal, hypolimnetic withdrawal, or rough fish harvesting. The other option is to inhibit sediment phosphorus release through phosphorus inactivation (i.e., alum treatments), and/or through elimination of reducing conditions at the sediment-water interface by hypolimnetic aeration, artificial circulation, or sediment oxidation. Each of these individual techniques is described in further detail below.

Alum Treatments

A chemical compound known as aluminum sulfate (alum) is widely used in deep eutrophic lakes to remove phosphorus from the water column and retard its release from anoxic lake sediments. Alum is considered nontoxic and effective at lowering phosphorus levels of certain types of lakes, thereby controlling the nutrient that encourages algae growth. On contact with water, alum forms an aluminum hydroxide precipitate known as floc. Aluminum hydroxide reacts with phosphorus to form an aluminum phosphate compound that is insoluble in water under most conditions, depriving algae of this critical nutrient. As the floc settles, inorganic phosphorus and phosphorus-containing particulate matter is removed from the water column. When applied in sufficient quantities, the floc may form a lasting chemical barrier that retards phosphorus release at the sediment-water interface as anoxic conditions develop in the hypolimnion.

Hypolimnetic alum treatments do not address phosphorus that may be released from the shallow, littoral areas as a result of elevated pH, sediment disturbance and/or anoxia during non-daylight hours. Some lakes may be good candidates for this procedure, however, especially if external nutrient loading is brought under control and high internal phosphorus releases are shown to occur within the anoxic hypolimnion of the lake. When implemented correctly, this technique can provide an effective, nontoxic and long-term approach to algae control by reducing concentrations of the limiting nutrient that usually drives algae growth. However, it should be noted that increased plant growth often occurs due to improved water clarity conditions following an alum treatment. Although alum treatments can increase a lake's acidity, toxicity problems from lowered pH are unlikely in lakes with high alkalinity and buffering capacity.

Applicable: QUESTIONABLE
Recommended: NO
Tamarack Lake is not a good candidate for this procedure. The lake is not believed to be of sufficient depth, nor does existing evidence suggest a serious problem with hypolimnetic phosphorus release and related algae blooms.

Artificial Circulation

The purpose of this management technique is to destratify and mix the water column of a lake by injecting compressed air near the lake bottom. If sufficiently powered, rising air bubbles will induce lake-wide mixing, eliminating thermal gradients within the water column while aerating portions of the lake that were previously devoid of oxygen. Artificial circulation is used to prevent an anoxic hypolimnion from forming near the bottom of deeper lakes, thereby preventing the release of phosphorus from the bottom sediments. Circulation pumps are usually operated continuously throughout the summer stratification period so that aerobic conditions are always maintained. Improper use of this technique could harm an established cool-water fishery, or mix nutrient-rich water throughout the water column, exacerbating an existing algae problem.

Applicable: QUESTIONABLE
Recommended: NO
Artificial circulation is not appropriate for Tamarack Lake. The lake's shallow water depths are believed to keep it fairly well mixed, and severe algae blooms have not been shown to be a serious problem.

Hypolimnetic Aeration

This management technique uses an airlift device to bring nutrient-rich and oxygen-poor water from the hypolimnion of deeper lakes to the surface where it can be aerated without thermally destratifying the lake. Hypolimnetic aeration attempts to reduce the extent of an anoxic hypolimnion that forms near the bottom of deeper, eutrophic lakes. As a result, a smaller portion of the lake bottom is allowed to become oxygen deficient and capable of releasing phosphorus into the water. Because the lake is not allowed to destratify, a cool-water fishery can be adequately protected. Aerators need a large hypolimnion to work properly, and are most effective in deep lakes. As with artificial circulation, improper use of this technique may circulate nutrient-rich water. A poorly designed aeration system may also destratify a lake, or keep sediment and organic matter in suspension for longer periods of time.

Applicable: NO
Hypolimnetic aeration would not be applicable for a shallow water body like Tamarack Lake. Tamarack Lake would have to undergo strong thermal stratification to warrant this management technique. An extensive and anoxic hypoliminion does not appear to be a problem.

Hypolimnetic Withdrawal

Hypolimnetic withdrawal addresses phosphorus releases that occur within the deep, anoxic zone by removing nutrient-rich, hypolimnetic water before it mixes with the entire water column. The principal purpose of this technique is to change the depth at which water leaves the lake, from the surface to the deep hypolimnion, so that higher nutrient-content water is discharged from the lake. Hypolimnetic withdrawal is accomplished by installing a tube along the lake bottom from the deepest point to the outlet. The tube acts as a siphon, removing nutrient-rich water from the hypolimnion and discharging it at the outlet.

The technique requires a sufficient water exchange rate to replenish the amount of water that needs to be discharged. Hypolimnetic withdrawal should only be implemented during the summer stratification period when anoxic conditions develop in the hypolimnion. If not used appropriately, it may produce thermal instability and destratification that could introduce nutrient-rich, anoxic water to the lake's epilimnion. There may also be negative impacts downstream caused by the discharge of poor quality water. There are few documented case histories regarding this procedure. The technique is most applicable to stratified lakes and small reservoirs in which anaerobic hypolimnia restrict fish habitat and promote the release of phosphorus from the sediments.

Applicable: NO
Hypolimnetic withdrawal would not be applicable for a shallow water body like Tamarack Lake, especially in the absence of a suitable outlet that could be used for wastewater discharge purposes.

Dilution & Flushing

Dilution and flushing is a management technique that uses large quantities of nutrient-poor water from an upstream source to dilute nutrient concentrations in the lake and flush out algae cells. Lakes with low initial flushing rates, or hydraulic retention times, are poor candidates because in-lake phosphorus concentrations could increase unless the dilution water is essentially devoid of phosphorus. Flushing rates of 10-15% of the lake volume per day are believed to be sufficient in most cases.

Applicable: NO
Tamarack is not a good candidate for this management approach for two reasons. First, a large, upstream source of nutrient-poor water has not been identified. Second, the lake does not have a serious algae problem, nor would such action provide relief from nuisance plant growth. Aquatic plants are able to derive most of their nutrient requirements from the bottom substrate, rather than from the surrounding water column.

Sediment Removal (Dredging)

This management alternative may be used to address phosphorus releases that occur in the shallow, littoral areas of a lake. However, dredging is more frequently employed to deepen a lake, or remove aquatic plants (discussed under Section 5-3). If sediments are the source of internal nutrient loading, and the bulk of nutrients are located in the top 1-1.5 feet of a sediment core, then removal of that layer by dredging may provide the most reliable and permanent solution. If bottom sediment is rich in nutrients below that depth, then dredging would only expose more sediment with the same high nutrient content, providing little or no expected decrease in internal loading. This technique will also have limited effectiveness if external sediment loading is not controlled prior to implementation. Dredging may be very effective if small, accessible areas have sediment that is high in phosphorus. Lakes most suitable for dredging have shallow depths, low sedimentation rates, organically rich sediments, long hydraulic retention times, and the potential for extensive use following dredging.

Sediment must be analyzed to determine how difficult it will be to dredge the material and its appropriateness for land disposal. Selective "spot" dredging is less expensive and is not as detrimental to aquatic plant and animal habitat, biodiversity, various recreational uses, and aesthetics. One strategy is to breach a dam, if available, in order to draw down the lake and expose near shore sediment that can then be removed by earth-moving equipment. This may be the simplest and most cost-effective method, even though mechanical and hydraulic dredging are much more common approaches to sediment removal. Dredging is an extremely expensive and involved process. It requires identifying the source of sediment; evaluating sediment cores (thickness, distribution, grain size, organic content, contaminant analysis, nutrient analysis); determining the volume of sediment to be removed; evaluating potential environmental impacts; securing a large de-watering and disposal site; and obtaining the appropriate local, state and federal permits.

Applicable: YES
Recommended: NO
This strategy is not currently recommended for Tamarack Lake for in-lake nutrient control purposes. Phosphorus recycling dynamics are presently undefined. Further study would be required to determine whether sediment phosphorus release is a serious problem. However, dredging would be applicable if used primarily as a plant control technique, and to facilitate navigation (see Section 5-5 below).

5-5 CONTROL OF EUTROPHICATION SYMPTOMS

MECHANICAL WEED HARVESTING

When excessive weed growth becomes a problem, mechanical harvesting can be used to cut and remove the upper portion of rooted aquatic plants that grow close to the water's surface. Standard equipment includes a mechanical weed harvester, harvester trailer, dump truck, and shore conveyor. Unlike herbicide applications that leave plants in the lake to decompose, mechanical harvesters are designed to physically cut and remove plant material from the water. This prevents decaying plant matter from depleting dissolved oxygen levels and releasing nutrients that could culminate in further plant and algae growth. Harvesters can also clear an area of vegetation without the post-treatment waiting period associated with herbicides, and without significant danger to non-target species when controlled by a trained operator.

The typical harvester is a highly maneuverable, low-draft barge designed with one horizontal and two vertical cutting bars, a conveyor to remove cut plants to a storage unit on the machine, and another conveyor to unload plants onto shore. Harvesters vary in size and storage capacity from about 200 cubic feet of cut vegetation to 800 cubic feet. Cutting rates range from about 0.2 to 0.6 acres per hour, depending on machine size. Harvesting works best in open, unobstructed areas of the lake where the water is three to six feet deep. A selective harvesting approach, rather than clear cutting, is recommended to avoid causing serious habitat disturbance. Mechanical harvesting is most effective when used to: (1) open navigation lanes to access open water areas; (2) control nuisance vegetation in high-intensity recreational user zones; and (3) create edge habitat for fish in weed-choked fishing areas. Most harvesting operations are successful in producing at least temporary relief from nuisance plants by removing organic matter and associated nutrients without the addition of potentially deleterious substances.

Applicable: YES
Recommended: CONDITIONALLY
Tamarack Lake may benefit from an ongoing weed-harvesting program to control nuisance plant growth. However, due to the lake's very small size and shallow water depths, only a small, low draft and highly maneuverable harvester would be appropriate. This strategy involves a large capital outlay for equipment and continual operating expenses. It may not prove cost-effective unless a fairly extensive portion of the lake (in greater than three-foot water depths) is determined to necessitate regular harvesting.

Longevity of Effectiveness: This strategy allows only temporary relief of nuisance aquatic weeds. Harvesting is most effective when it is repeated multiple times during each growing season. Research indicates that there is often a carry-over effect from season to season where less growth occurs in subsequent years following multiple harvests.

Estimated Costs: A high capital outlay for equipment is required, and may be energy- and labor-intensive and thus expensive. However, it is usually somewhat less expensive than herbicide treatments over the long run. Expenditures for a particular project will vary depending on machine cost and reliability, operator wages, fuel, insurance, equipment storage, and the amount of down time. Operating costs can be quite variable, but generally average around several thousand dollars per year with labor comprising from 20-65% of the total operating costs. Operating costs on Tamarack would be less expensive given its small size.

Potential Benefits:

- Removes nuisance plant material and associated nutrients from the lake
- Provides temporary but immediate relief from nuisance aquatic plants
- Could encourage positive shifts in species composition by reducing competition from aggressive species
- Reduces the thick vegetative cover that causes stunting of panfish
- Avoids the use of potentially harmful chemicals
- Allows specific areas and plant beds to be targeted for control
- Permits most recreational use of the water to continue during operations
- Poses little danger to non-target organisms (except when inadvertently removed with the cut plants)
- Harvested plants may be used as a nutrient-rich soil conditioner or fertilizer

Potential Drawbacks:

- Controls relatively small areas per unit of treatment time (may not be an issue for Tamarack)
- Harvesting can be over-used, destroying critical aquatic habitat
- Could contribute to vegetative fragmentation and spread of nuisance, non-native species
- Could encourage unfavorable shifts in species composition by promoting opportunistic species
- There is the potential to inadvertently harvest small gamefish along with the plant material
- Operating depths are limited to areas greater than three feet
- Requires regular cutting during each growing season for effective control
- Excessive plant growth may continue in extremely shallow areas where access is not possible
- Involves ongoing costs associated with equipment maintenance/storage, operator wages, etc.

MANUAL WEED HARVESTING

Manual harvesting of aquatic weeds can also be used to control plant growth in smaller, more confined areas. This technique is usually the simplest, most species-selective method for small, shallow water areas. However, it is also the most labor-intensive method. The frequency and practicality of manual harvesting depend on the availability of labor, the re-growth or re-introduction potential of the vegetation, and the level of control desired.

Manual harvesting techniques include dragging, raking, cutting and pulling. Dragging is an inexpensive method that involves pulling "draglines" through weed beds. Draglines are constructed of rope, wire or chains that can be placed into the water from either shore or boat, and then pulled in manually or towed. They are often used in water that is greater than six feet deep, but are not effective at removing root systems. Raking can be done in shallow water with a long-handled steel garden rake. The root systems of certain plant species will be removed, while others will remain in place. While rakes can remove the entire root systems, cutters usually leave root systems to regenerate. Hand pulling is the most labor-intensive method, but it is also the most effective and species-specific.

Applicable: YES
Recommended: YES
Manual harvesting of nuisance aquatic vegetation is both applicable and recommended as a control strategy for Tamarack Lake. This strategy would be most effective if individual lakefront property owners maintained their own riparian spaces. Property owners could be encouraged to rake and hand-pull nuisance weed growth around piers, boatlifts and small wading areas. Meanwhile, the Association may wish to coordinate the harvesting of navigation lanes and edge habitat for fish using towed cutters and draglines. This would be an inexpensive method of controlling nuisance weed growth within smaller and more confined areas of the lake.

Longevity of Effectiveness: This strategy is effective for immediate relief of nuisance vegetation, but is relatively short lived and requires repeated effort.

Estimated Costs: Costs are associated with labor time and the purchase of rakes or other personal harvesting devices.

Potential Benefits:
- Localized, species-specific control of nuisance vegetation
- Strategy can be performed in areas that are inaccessible to mechanical weed harvesters
- Does not involve the use of potentially harmful chemical herbicides
- Plant material is removed from the lake

Potential Drawbacks:
- Very labor intensive and slow
- Lake-wide application of this strategy is not feasible
- Requires educating lakefront property owners in the identification of "good" versus "bad" plants
- Cut plant fragments must be collected and removed from the lake manually

Aquatic Plant Screens (Sediment Covers)

Aquatic plant screens, also called bottom barriers, are typically constructed of fiberglass mesh or polyvinyl fabric and placed on the lake bottom in near-shore areas. The purpose of the screens is to smother existing vegetation, inhibit light penetration and prevent new plants from rooting. The most effective covers are opaque, durable, negatively buoyant, vented and gas-permeable. Plastic sheets of polyethylene, polypropylene, fiberglass or nylon are all used as synthetic plant screens. Gravel, sand, clay, straw, burlap, coir and jute may also be used as sediment covers, although these materials are less effective plant barriers.

Installation requires securely anchoring the screens to the substrate in the winter or early spring before plants begin growing. It is often difficult to accomplish over heavy plant growth, in soft sediment, and on steep slopes. Aquatic plant screens work well in small, flat, shallow areas or where other control methods are not feasible. These barriers will need to be periodically removed and cleaned as sediment deposits on the screen surface. They should be removed every 1-3 years in the fall for cleaning. The barriers do not effectively control algae or free-floating plants. Effectiveness is highly correlated with application techniques and type of material used.

Applicable: YES
Recommended: CONDITIONALLY
This strategy is applicable to Tamarack Lake, but recommended only in small, flat, shallow areas with firm substrates and where recreation is unreasonably impacted by nuisance plant growth. Suitable locations include swimming and wading areas, and around piers and boat moorings. Fiberglass screens can be used with a mesh size of 0.0015-square-inch. These screens are durable, negatively buoyant, easier to anchor, and still allow microbial decomposition underneath the barrier.

Longevity of Effectiveness: Strategy effectiveness depends on the quality of the materials and installation methods used. At a minimum, plant screens should be removed and cleaned every one to two years to prevent sediment build-up and re-rooting.

Estimated Costs: The more effective synthetic materials are very expensive, running at least several thousand dollars per acre of coverage. Installation is also very labor intensive, which will drive up costs.

Potential Benefits:

- Causes little negative impact to the lake
- Use is confined to small, site-specific areas
- Sediment covers can be installed in areas that will not be disrupted by boat traffic or harvesters
- No toxic chemicals are used
- Creates edge habitat for gamefish in weed-choked locations

Potential Drawbacks:

- More durable and effective materials are usually expensive to purchase
- Requires a permit under Chapter 30 of Wisconsin Statutes to allow placement of material on the lake bed
- Plant screens are difficult to apply over large areas, over obstructions, in deeper water, and on slopes
- May be difficult to secure to the bottom, especially if gases are trapped beneath the covers
- Plant screens may be difficult to remove or relocate, and may tear during installation
- Some materials do not last more than a few seasons, and are degraded by sunlight
- A permit may be required before installation can take place
- Benthic invertebrates may be eliminated in treatment areas

* destruction of fish spawning areas

Water Level Manipulation (Drawdown)

Altering the water levels in lakes is sometimes used to manage nuisance weed growth that may occur in shallower areas. This is accomplished by either significantly raising or lowering water levels, usually by regulating an outlet-control structure. Recreational use of the water is often severely restricted during implementation, especially if a drawdown is performed.

Raising water levels will essentially drown out certain plant species by limiting sunlight availability through increased water depths. This strategy is often not feasible as previously dry, lowland areas would be subjected to flooding and increased shoreline erosion. It also requires a significant amount of extra freeboard on a dam to retain sufficient quantities of water. Alternatively, lake level drawdowns are used to expose near-shore sediments to prolonged freezing and drying. Some rooted plant species are permanently damaged by these conditions and the entire plant is killed if exposed to freezing for two to four weeks. Other species, however, are either unaffected or enhanced. Sediment compaction and oxidation is a secondary benefit that can increase near-shore water depths.

This management technique is best suited for reservoirs or water bodies that have a suitable outlet control structure and a steady water flow that will refill the lake or reservoir by the summer. On smaller water bodies where a drawdown is performed, the reduced volume of water and dissolved oxygen can cause fish kills. Similar to artificially raising water levels, a drawdown may damage banks and shorelines, and fish spawning grounds may be adversely affected. A winter drawdown should be conducted to control vegetation through freezing and scouring, as opposed to a summer drawdown that will usually encourage plant growth. To be most effective, complete freezing and desiccation are required, and freezing operations should be alternated every two years with no drawdown so that resistant species do not become firmly established.

Applicable: NO
Recommended: NO
Water level manipulation as a plant-control strategy is not applicable for Tamarack Lake. Because Tamarack is a seepage lake, there is no ability to manipulate water levels via an outlet control structure.

Plant Removal by Dredging

Dredging involves the physical removal of sediment and associated rooted plants. In extreme cases of overgrown aquatic vegetation, conventional or specially adapted dredging machines may be used to remove vegetation and underlying sediments. The resulting depth increase, if sufficient, will reduce or eliminate the potential for rooted vegetation to become re-established by inhibiting light penetration. However, this effective depth would have to exceed Tamarack Lake's maximum water depth. Dredging operations are expensive to implement, and the disposal of sediments can be difficult if a nearby disposal site is not available. This strategy will be a short-lived treatment method unless sediment is removed entirely from the lake's photic (light-penetrating) zone. Spot dredging to create boat channels or deepen high-use areas is a cheaper compromise to dredging an entire lakebed.

Applicable: YES
Recommended: CONDITIONALLY
Spot dredging would be applicable to Tamarack Lake as a plant control technique, as well as to increase water depths to facilitate navigation. Sediment removal would be most appropriate to deepen high-traffic boating lanes that are becoming impassable due to excessive weed growth and sediment accumulation. Dredging can provide a secondary benefit by creating edge habitat and cruising lanes for gamefish. However, this technique should be used sparingly to avoid any large-scale ecological impact, and to keep costs under control.

Longevity of Effectiveness: Long-term effectiveness is likely if external sediment loading is adequately addressed beforehand, and all nutrient-rich sediment is removed beyond the photic zone. Dredging may need to be repeated depending on sedimentation rates.

Estimated Costs: Sediment removal is currently an extremely expensive management strategy. Costs are highly variable, depending upon site conditions, access, nature of the dredge material, disposal method, monitoring and other factors. It is not uncommon for lake-dredging efforts to end up being multi-million dollar projects.

Potential Benefits:
- Deepens the lake and may improve navigation
- Removes plant material and associated sediment from the lake
- May remove the nutrient-rich material that contributes to in-lake nutrient recycling

Potential Drawbacks:
- Represents a very massive and expensive undertaking
- Requires a permit under Chapter 30 of the Wisconsin Statutes
- Causes temporary increase in turbidity due to re-suspension of sediment
- Damages or destroys fish spawning habitat
- Destroys benthic (bottom-dwelling) organisms that represent an important component of the food chain
- Releases heavy metals and other contaminants within the sediment (if present)
- Releases anaerobic gases such as ammonia and hydrogen sulfide, which can threaten aquatic life
- Requires a large, suitable land area near the lake for sediment de-watering and disposal purposes

Chemical Control (Herbicides)

Aquatic herbicides are often used in problematic areas to aggressively control small pockets of nuisance, pioneer species before they can spread throughout the lake. Preferred treatment areas are small, confined and absent of high quality native species. Herbicides can be either broad spectrum or fairly species-specific. Contact and systemic herbicides are both available and commonly employed, but each leaves plants in the water to decay. Application rates and frequencies depend upon physical conditions (e.g. wave action, currents, dilution, water temperature, etc.). Plants differ considerably in their susceptibility to chemical treatment. Chemical treatment should be viewed as a last resort when other methods fail or prove infeasible. This treatment method may limit certain water uses, and chemical drift can potentially damage or destroy desirable plant beds.

The herbicide 2, 4-D (2,4-dichlorophenoxyacetic acid) is one of the most common and most effective chemicals used to systemically control Eurasian watermilfoil. This particular herbicide has been shown in certain situations to shift community composition from watermilfoil and coontail, to beneficial pondweeds and wild celery. Proper timing of herbicide applications is extremely important for both effective control and to avoid other potential problems. Timing involves knowing water temperatures and waiting until vigorous plant growth is present, but not waiting until plants are fully grown which would result in large amounts of weeds decomposing and robbing the water of oxygen.

Although herbicides do not address the source or underlying cause of the problem, it may be the only option available for short-term relief if nutrient sources cannot be addressed. It is recommended that this management technique be implemented only if other strategies are determined to be infeasible due to costs or other considerations. If necessary, herbicides should be targeted to small areas to control isolated stands of exotic, invasive plant species.

Applicable: YES
Recommended: CONDITIONALLY
This strategy may be appropriate for Tamarack Lake under certain conditions. Due to the considerable extent and abundance of plant growth, applications would only be cost-effective if performed within limited areas. Applications should only target small, isolated pockets of nuisance weed growth that impede access and cannot be controlled by other methods. Lake-wide applications are not recommended.

Longevity of Effectiveness: Chemical control is a temporary control strategy, and must be repeated on a fairly regular basis.

Estimated Costs: Costs depend on the size of the area being treated and the type of chemical used. Regular, lake-wide applications would be expensive and are not recommended.

Potential Benefits:
- Temporary and relatively fast relief of nuisance aquatic weed growth
- Offers some selectivity so certain specie types can be targeted
- Chemical applications are not very labor intensive
- Provides longer control when compared to mechanical harvesting

Potential Drawbacks:
- Provides only temporary relief of nuisance aquatic plant growth
- Fails to remove plant material and associated nutrients from the lake
- Decreases in dissolved oxygen levels due to decomposition of plant matter
- Some nuisance species may be unaffected by the herbicides
- Aggressive, pioneer species can re-colonize treated areas
- Could produce more frequent and severe algae blooms
- Toxicity issues are poorly understood
- Herbicides produce no restorative benefit, show no carryover of effectiveness to the following season, and may require several applications per year

Chemical Control (Algaecides)

Algaecides are chemical agents that are applied to the water to control algae growth. These chemicals are usually applied in liquid form at the lake's surface, killing algae cells on contact through selective toxicity. Although this technique does not address the source or underlying cause of the algae problem, it may be the only option available for short-term relief if nutrient sources cannot be addressed. Algaecides are generally applied in small ponds, and may be appropriate when other strategies are infeasible due to costs or other considerations. Before using algaecides, it is important to understand all the risks that are associated with a particular chemical. Considerations include toxicity to non-target aquatic life, chemical persistence in the environment, and indirect impacts to dissolved oxygen levels.

Applicable: QUESTIONABLE
Recommended: NO
Algaecides are probably not applicable and are not recommended for use on Tamarack Lake, mainly because nuisance algae blooms are not considered a significant problem. Drawbacks of using this strategy to control algae in Tamarack Lake include the following:

- Chemical applications may be toxic to non-target aquatic life
- Oxygen depletion may occur from the rapid die-off and subsequent decomposition of algae (if present)
- Blue-green algae are known to become increasingly tolerant to algaecides
- Chemicals residues may accumulate in the sediment
- Must be repeated on a regular basis, and may be expensive over the long run

BIOMANIPULATION

Biomanipulation attempts to alter the food web (usually through fish management and stocking programs) to create a less favorable environment for algae, thereby improving water quality conditions. It is a top-down, food-web management strategy that may be used to compliment bottom-up management strategies that manipulate nutrient inputs. Biomanipulation is based on a theory known as the Trophic Cascade Hypothesis. Simply stated, top predators such as large gamefish can ultimately control the abundance and productivity of lower trophic levels, such as algae, which in turn can affect water clarity and nutrient recycling. The Trophic Cascade Hypothesis predicts that a large number of piscivorous (fish-eating) fish will consume large numbers of smaller, planktivorous (plankton-eating) fish, resulting in a decline in the abundance of planktivores. Lower numbers of planktivores will consequently consume fewer zooplankton (algae consumers), allowing for the development of a large zooplankton population. Large numbers of zooplankton will then consume large numbers of algae, reducing algae abundance and increasing water clarity.

Biomanipulation may be accomplished by directly enhancing the success of piscivores (e.g. walleye, bass, northern pike, etc.) through stocking programs, angler harvest restrictions, and/or habitat improvements. Another option is to reduce the number of planktivores (e.g. perch, bluegill, sunfish, etc.) within a lake through selective fish removal programs and habitat manipulations. Fewer planktivores translates into a higher survival rate for algae-grazing zooplankton. Reducing planktivore populations has the added benefit of freeing up food resources for small piscivores that could otherwise get out-competed during early life stages. Creating habitat conditions that are more favorable to zooplankton will further enhance the effects of biomanipulation. For example, oxygenating the hypoliminion will allow for greater vertical migration of zooplankton within the water column, increasing their ability to avoid capture by planktivores. Aquatic plant beds can also be protected to provide structural refuge for zooplankton.

Applicable: YES
Recommended: CONDITIONALLY
Biomanipulation is generally used to help control nuisance algal blooms through food web manipulations. Its applicability on Tamarack is therefore questionable. This technique should only be used in conjunction with other strategies if a significant, long-term improvement is going to be achieved. Full implementation of a biomanipulation project, which prohibits the harvesting of larger gamefish, may be unpopular since fishing is identified as a top priority lake use.

Longevity of Effectiveness: If the sources of excess nutrients to the lake are fully addressed, biomanipulation can have a lasting and sustained effect. The success of this technique relies heavily on the continued health and viability of the sport fishery (e.g. walleye, largemouth bass and northern pike).

Estimated Costs: Costs are relatively low, and are associated with fish stocking and habitat enhancement efforts. Habitat enhancement may involve using the mechanical harvester to control Eurasian watermilfoil and create fish-cruising lanes through dense vegetation. Costs are also associated with information and education programs that encourage anglers to practice catch-and-release.

Potential Benefits:

- Harnesses the natural power of the food web to keep algae production in check
- May provide a fairly self-sustaining control mechanism
- Does not involve the use of potentially harmful chemicals or expensive equipment
- Improves the sport fishery

Potential Drawbacks:

- Can be very difficult to effectively manipulate the food web
- Requires angler participation to prevent the over-harvest of sport fishes
- Must usually be used in conjunction with other strategies (e.g. nutrient reduction) to produce observable changes

5-6 COST-COMPARISON SUMMARY (AQUATIC PLANT CONTROL)

Cost-comparison summaries of plant-control strategies applicable to Tamarack Lake are presented below. Estimated cost breakdowns are based on verbal quotes received from several Wisconsin-based contractors. Note that actual costs may vary significantly depending on current rates and scope of project.

Plant-control Option	Cost Breakdown
Dredging	Equipment mobilization charge: $5,000 Excavate spoil site: $2/cubic yard to move dirt Road crossings: $1,500/crossing Sediment removal: $12/cubic yard (hydraulic); $2.50/cubic yard (mechanical) Other minor costs: Lab analysis of sediment and permit fees (Note: Grant assistance is generally not available unless for purposes of public access.)
Herbicides	Chemicals: $350-450/acre Application: $700 for first five acres, $50/acre thereafter Other minor costs: Permit fees (Notes: Herbicide applications must be repeated on a frequent and consistent basis, depending on rate of re-growth. Cost-share assistance is generally not available.)
Mechanical Harvesting	Small mechanical harvester: $50,000-75,000 (new) Harvester trailer: $10,000 (new) Shore conveyor: $15,000 (new) Dump truck: $50,000 (new) Operating costs: $5,000-10,000/year (wages, insurance, storage, repair costs, etc.) (Notes: Mechanical harvesting must be repeated on a frequent and consistent basis, depending on rate of re-growth. Cost-share assistance may be available for the purchase of equipment.)

CHAPTER 6: RECOMMENDED ACTIONS

6-1 INTRODUCTION

Selecting an appropriate course of action requires an understanding of all the potential limitations, tradeoffs and consequences associated with each available management option. Regardless of the management strategy chosen, it should be recognized that permanent and observable changes in the overall condition of a lake are rarely if ever accomplished over night. Lakes can take years to respond to manipulations, especially if they are already severely impacted or degraded. The following questions should always be answered prior to selecting and implementing a potentially costly management program.

- What is the problem, and what are its underlying causes?
- Which interest groups does the problem affect and how?
- Is it economically, ecologically and publicly feasible to address the underlying causes of the problem?
- What management strategies are available that can remedy the situation?
- Do these strategies address the cause of the problem, or do they attack the symptoms?
- What are the potential drawbacks and side-affects associated with each strategy?
- How immediate are the results?
- How long does the strategy remain effective once implemented?
- Will the strategy in any way restrict the use of the water?
- Are any special permits or approvals needed prior to implementation?
- What are the short and long-term costs and benefits compared to other available options?

Questions such as these will need to be answered before the right strategy can be selected and implemented successfully. It is a good rule of thumb to first protect what you have before attempting to rehabilitate what has been lost. This is because protection is almost always more effective and less expensive than rehabilitation. Therefore, environmentally critical sites that function to maintain the health and quality of the resource should be protected from possible degradation. The faster these sites are identified, the faster they can be preserved and properly managed for the benefit of the lake. Critical sites include high-quality aquatic plant beds, wetlands, undisturbed shorelines and riparian buffers. These areas help mitigate pollution and provide ideal habitat conditions for a diversity of wildlife, among other benefits. Once a critical site is identified, there are a number of ways to ensure long-term protection. Conservation easements, purchase of development rights, property acquisitions, landowner education, and special zoning restrictions can all be used effectively, depending on the situation.

6-2 STRATEGY SELECTION METHODOLOGY

Management techniques were selected only after careful consideration was given to potential ecological and recreational impacts, estimated cost of implementation, longevity of effectiveness, and overall potential for success. In most cases, strategies that address the root causes of problems were favored over symptomatic solutions. Although many symptom-oriented techniques enjoy faster results and lower initial costs, the benefit-to-cost ratio usually decreases over time as the underlying problem is left unresolved. Efforts were also made to avoid lake-protection strategies that would serve only to add unnecessary or duplicative layers of regulation.

In selecting viable management strategies, it was recognized that Tamarack Lake is influenced by a number of complex physical, chemical and biological interrelationships. These interrelationships are extremely dynamic and affect the lake's responsiveness to management efforts. Because the lake is a highly interactive system, it is impossible to alter one component, such as rooted plant growth, without affecting some other component, such as algae growth or the clarity of the water. The selection of management options was based on high priority lake uses and problems identified through a combination of public input and the evaluation of available scientific data.

6-3 RECOMMENDED STRATEGIES

EDUCATION & COMMUNICATION

- Implement a public information and education campaign. Ongoing communication with residents and key stakeholders increases the public's awareness and understanding of lake-improvement programs. Education is vitally important if the Tamarack Lake Management Association hopes to build support and cooperation as it works to protect and manage the lake. Regular newsletters, special informational mailers and public meetings are identified as the preferred means of sharing information and providing access to the decision-making process. 'Welcome Wagon' informational packets should also be sent to new property owners around the lake.

  Action timeline: Commence immediately by issuing a regular newsletter and holding at least one public meeting per year. Begin developing an educational packet that can be given to current residents, and prepare reproductions for when property ownership changes hands. Survey the opinions and concerns of residents and lake users every few years. This information can be helpful in diagnosing new problems and evaluating ongoing management programs.

INFORMATION GATHERING NEEDS

- Conduct regular water quality and biological monitoring. Basic water quality sampling parameters such as Secchi transparency, temperature-dissolved oxygen depth profiles, total phosphorus, pH, lake stage and chlorophyll *a* are needed to scientifically diagnose problems and gauge the effectiveness of management programs. An aquatic plant inventory and fishery survey is also recommended.

  Action timeline: Acquire testing kits and begin training volunteers to perform basic water quality monitoring over the lake's deepest point. At a minimum, water quality testing should be conducted three times per year on a perpetual basis – (1) early spring, (2) mid-summer, and (3) late fall. Dissolved oxygen readings should also be taken through the ice during mid winter to determine if adequate concentrations are maintained to sustain a healthy fishery.

  Perform an aquatic plant and fishery inventory before implementing any large-scale ecosystem manipulation project such as weed harvesting, chemical treatments or dredging. Follow-up studies should be conducted after such projects are completed to gauge effectiveness. A DNR Lake Planning Grant and other funding sources can be used to cost-share these types of studies.

- Perform a watershed inventory to identify critical sites that either mitigate or contribute to non-point source pollution. Non-point source pollution is one of the most significant threats to the long-term health and quality of Tamarack Lake. A detailed watershed inventory could be used to evaluate current land uses, and to pinpoint potential problem areas that require Best Management Practices (BMPs). Problem areas might include failing septic systems, excessive fertilizer applications, poorly managed barnyards/manure pits, and eroding farm fields and construction sites. BMPs would consist of various measures designed to minimize soil erosion and stormwater runoff from these problem sites. Conversely, areas requiring special protections would include wetlands, natural shorelines, groundwater recharge areas, and other high quality landscape features. These types of threatened landscape features provide water quality protection buffers, and/or serve as critical fish and wildlife habitat. A DNR Lake Planning Grant and other funding sources can be used to cost-share this type of study.

  Action timeline: Implement as soon as funding permits, especially if chemical and biological monitoring indicates declining water quality conditions that may be attributed to runoff pollution. In addition, a watershed inventory should be implemented before initiating an expensive in-lake management strategy that may later fail due to unaccounted non-point source pollutant loads.

POLLUTION CONTROL & HABITAT ENHANCEMENT

- Utilize site-specific Best Management Practices (BMPs) to control erosion, reduce stormwater runoff, and improve wildlife habitat in the watershed. There are many simple and inexpensive actions that can be taken to enhance water quality and wildlife habitat. They include:

- Regularly inspect and maintain septic systems to ensure they function properly.
- Leave a wide buffer zone of uncut, native vegetation around the shoreline to provide habitat and filter polluted runoff. Buffers can be planted like gardens with a diversity of native grasses, forbs, shrubs and trees.
- Stabilize eroding shoreline using bioengineering (e.g. coconut fiber rolls and wetland plants) or, if absolutely necessary, rock riprap.
- Avoid using lawn fertilizers and herbicides, or use phosphorus-free products in areas that drain to the lake.
- Keep lawn clippings, leaf litter and other organic debris from entering the lake whenever possible.
- Discourage large congregations of geese and other waterfowl by maintaining natural shorelines, reducing turf grass, and by not offering food handouts.
- Communicate with farmers and developers in the watershed to encourage the use of BMPs to control soil erosion and stormwater runoff.
- Monitor construction sites and contact your local zoning officials if you suspect erosion-control violations.

Action timeline: Carry out immediately and on a perpetual basis. Coordinate septic system inspections and maintenance to take advantage of group rates. Perform a shoreline restoration and plant a buffer strip as a demonstration project using Association members as volunteers. Meet with local farmers and residents to explain how certain land-use practices can benefit both their property and Tamarack Lake. Finally, check with your local hardware store or fertilizer distributor to see if they would be willing to stock no-phosphorus fertilizers.

AQUATIC PLANT MANAGEMENT

- Maintain conditions that support a flourishing and diverse native plant community. Residents and lake users need to recognize that Tamarack Lake does and should continue to support abundant aquatic plant growth. Promoting a healthy and diverse native plant community is the best way to protect the quality of the lake. Aquatic vegetation provides oxygen, food and habitat for fish and wildlife. It is also the best defense against poor water clarity (by stabilizing bottom sediment), algae blooms (by absorbing nutrients and sheltering algae-consuming zooplankton), and foreign invaders like Eurasian watermilfoil (by preventing their spread into unoccupied areas). Shallow-water motor boating, pollution, and inappropriate management methods are often the main disturbance factors leading to nuisance weed problems.

  Action timeline: This general strategy recommendation is best addressed through ongoing educational efforts. Designating protection areas and limiting harmful lake uses through local ordinance may become necessary, especially if valuable native plant beds continue to be replaced by nuisance weed growth.

- Selectively manage nuisance "weed" growth in high-traffic areas to facilitate reasonable public access and navigation. Unfortunately, Tamarack Lake may very well be suffering from too much of a good thing. Although plants provide numerous benefits, their rapid and prolific growth can create conflicts with certain recreational demands that would otherwise be supported. Aggressive, non-native species ("weeds") are generally the most problematic. If left unchecked, these exotics can form vast, singlespecies monocultures that are less valuable as habitat, more susceptible to disease and more likely to turn into a recreational nuisance. Because these weedy species have few competitors and are tolerant to eutrophic conditions, they tend to grow to nuisance proportions to the detriment of native, beneficial species. This in turn detracts from the recreational enjoyment of the lake, and justifies the use of appropriately targeted plant-control methods. Control efforts that target non-native plant infestations along major navigational routes and around public access points would be most cost-effective.

Action timeline: Implement on an as-needed and continual basis. (See below for specific recommendations.)

- Utilize manual weed-harvesting techniques and/or plant screens with the cooperation of lakefront property owners. Property owners around the lake should be instructed on how to distinguish between native, beneficial plant species and non-native, nuisance species. Residents can then use hand raking or bottom barriers to manage weed growth around their own piers, boat hoists and swim areas that may be too difficult to access or manage using other strategies. These can be very labor- and time-intensive methods, but they can also be very effective at controlling nuisance weed growth. Meanwhile, the Association may wish to coordinate selective harvesting using towed cutters and draglines to both maintain navigation lanes and create edge habitat for gamefish. All plant material must be removed from the lake following cutting.

  Action timeline: Encourage property owners to implement on an as-needed and continual basis. Begin distributing literature that teaches how to distinguish between native and non-native species, and how to properly manage nuisance growth. Check with the Wisconsin Department of Natural Resources, University of Wisconsin – Extension, Wisconsin Association of Lakes and other organizations for free publications. To avoid damaging valuable plant beds, the Association should coordinate activities involving towed cutters and draglines.

- If necessary, use targeted mechanical harvesting, selective herbicide treatments or spot dredging to maintain navigable access channels and edge habitat in weed-choked problem areas. Each strategy has its own set of strengths and weaknesses that warrants careful consideration prior to implementation (see Chapter 5). The following options are appropriate for Tamarack Lake.

  Mechanical harvesting: A small, light-weight and highly maneuverable mechanical harvester is best suited for Tamarack Lake, as long as it only operates in adequate water depths (>3ft) to avoid sediment disturbance. Operating in shallower water risks damaging the equipment, stirring up bottom sediment, and facilitating the spread of nuisance species. Harvesting should be confined to high traffic areas, such as navigation channels and public access sites, where nuisance weed growth reaches the surface. It can also be used to create fish-cruising lanes for the purpose of establishing edge habitat in excessively weed-choked areas. All harvested plant material must be collected and removed from the water, and should be disposed at a location far from shore. The Association could purchase and maintain its own equipment, or hire a contractor to provide the service upon request. Following completion of an aquatic plant management plan, the Association may be eligible for 50% cost-share assistance to purchase equipment through a Wisconsin Waterways Commission Grant. Note that the lake may prove too small to warrant such a large investment. A detailed harvesting plan, trained equipment operators, an off-season storage facility, an experienced mechanic, and a suitable plant-disposal site are each necessary to ensure a successful program.

  Spot herbicide treatments: If navigability is necessary but unduly impeded in shallower locations (< 3 feet), a mechanical harvester may not be capable of accessing those locations without damaging the equipment or disturbing the bottom of the lake. Targeted herbicide treatments may be used in these situations as long as applications are confined to specific and isolated problem areas. Unfortunately, plant material is left in the lake to decompose (releasing nutrients, contributing to silt accumulation and robbing the water of dissolved oxygen), and chemical drift could destroy non-targeted plant species. Treatments must be performed by a licensed applicator, and generally need to be repeated on at least an annual basis. Again, this strategy could cause a number of undesirable consequences, especially if it is overused or misapplied.

Spot dredging: In weed-choked, high-traffic areas where depth is the true limiting factor, dredging can be performed to facilitate navigability and access to open water. This technique can be extremely effective at removing accumulated bottom sediment and associated plant material. Dredging will not eliminate weed growth over the long run unless water depths exceed the photic zone where sunlight penetration can no longer promote photosynthesis. This is unlikely to occur in a shallow and relatively clear lake like Tamarack. Dredging is also usually a very involved and expensive process that can completely destroy benthic habitat, temporarily increase turbidity, and promote the spread of exotic species.

Action timeline: Implement any of the above management techniques if the need arises and when funding becomes available. Carefully delineate target areas and recognize all potential repercussions before taking any action. Dredging and herbicide treatments will require special permit approval. Comprehensive water quality and biological monitoring should be performed before, during and after the completion of such strategies.

CHAPTER 8: CONCLUSION

Tamarack Lake should be managed as a small, shallow, and aquatic plant dominated water body. A thriving and diverse native plant community provides the foundation of a healthy aquatic ecosystem. Rooted aquatic vegetation provides important fish and wildlife habitat, and protects water quality by filtering and assimilating pollutants, stabilizing bottom sediment, and oxygenating the water column through photosynthesis. Abundant plant growth is also a natural by-product of a shallow and relatively clear water body.

Attempting to change the lake into something entirely different would be cost prohibitive and ecologically disruptive. For instance, large scale plant removal risks shifting the lake into an alternate, less desirable state of equilibrium in which algal blooms and high turbidity replace rooted plant growth and clear water conditions. It is therefore imperative that residents and lake users recognize the lake's natural limitations, and adjust their lake-use and management expectations accordingly. Overcoming public misconceptions about the resource is the first step in implementing a successful management program. The Association is encouraged to use regular newsletters and public meetings (among other strategies) to better inform and educate the general lake community.

Unfortunately, Tamarack Lake does appear to be suffering from too much of a good thing. It also struggles with the effects of non-native, "exotic" species like Eurasian watermilfoil. Current lake-use impairments are primarily attributed to this nuisance weed growth, which also contributes to excessive silt accumulation—due to the decomposition of organic material—and a stunted panfish population. The biggest challenge is to address these recreational impairments in a cost-effective and priority-driven manner, and without inadvertently causing other problems. To do this, public opinion surveys were combined with sound, scientific analysis to help select the most appropriate management options. Recommended management strategies were those that best satisfied as many of the following criteria as possible:

- Controls nuisance weed growth to facilitate reasonable public access and lake use.
- Protects ecologically sensitive areas, and maintains a diversity of native plant species for habitat and water quality protection.
- Addresses the accumulation of sediment and organic matter that leads to a mucky lake bottom.
- Promotes conditions that sustain a healthy fishery and diverse wildlife population.
- Protects or improves existing water clarity.
- Maintains the lake's peace and tranquility.

To achieve these objectives, a combination of lake-improvement strategies is recommended. First, management efforts should begin in the watershed by addressing the root cause of most problems—namely non-point sources of pollution. These pollutants include sediment, manure, fertilizers and herbicides, heavy metals, organic debris and various other materials. They are delivered to the lake predominantly in the form of stormwater runoff. A detailed watershed inventory is needed to assist the Association in evaluating current land uses, and identifying potential pollutant-loading hot spots. These hot spots might consist of poorly managed construction sites, eroding farmland, heavily fertilized lawns, failing septic systems, and inappropriate or unplanned development. A watershed inventory is also useful in locating critical areas that serve to protect the health and quality of Tamarack Lake. Critical sites can include wetlands, natural shorelines, groundwater recharge zones and other landscape features that warrant special protections. Once all these sites are identified, a number of Best Management Practices can be used to minimize the amount of polluted runoff that ultimately reaches the lake.

In-lake management options are also warranted, and should be implemented in conjunction with watershed protection efforts. Applicable management options include small-scale mechanical weed harvesting, targeted herbicide applications and/or spot dredging. Both harvesting and herbicide applications require long-term commitments if they are to be used as effective plant-control methods. They represent symptomatic solutions, and offer more immediate, albeit temporary, relief of nuisance weeds. Spot dredging, however, is a more expensive but longer-term solution. It may be especially effective at removing accumulated bottom sediment and associated plant material in extremely shallow, weed-choked areas. The Association should take special precautions so as not to overuse or misdirect these management strategies. Aggressive dredging, weed harvesting or chemical spraying would not only be costly, but could turn small problems into much larger ones. They may also negatively impact water quality, destroy fish and wildlife habitat, facilitate the proliferation of exotic species, and increase motorized boat traffic.

The Tamarack Lake Management Association is to be commended in taking the proper steps toward protecting and improving the resource. Through careful planning and a commitment to the lake's long-term ecological health, the Association is well on its way to implementing a successful management program that can benefit all its users.

APPENDIX A

2001 WATER QUALITY MONITORING RESULTS

State Laboratory of Hygiene
University of Wisconsin Center for Health Sciences
2601 Agriculture Drive, Madison, WI 53707-7996
R.H. Laessig, Ph.D., Director D.F. Kurtycz, M.D., Medical Director

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Environmental Science Section (608) 224-6277 DNR LAB ID 113133790
Inorganic chemistry

Id: Point/Well/..: Field #: Route:
Collection Date: 05/23/01 Time: 17:45 County: (Unknown)
From: NONE GIVEN
To: ROBERT TRAXLER
1120 DALLAS ST
SAUK CITY WI 53583
Source: Surface Water
Sample depth: 0.5 Feet
Account number: LM007
Collected by: RAMAKER & ASSOCIATES
Date Received: 05/24/01 Labslip #: IL024888 Reported: 06/26/01

CHLOROPHYLL A, UNCORRECTED, LAB FILT (SM 10200H)	5.	UG/L
TOTAL PHOSPHORUS (AS P) (EPA 365.1)	0.031	MG/L
TEMPERATURE ON RECEIPT-ICED	ICED	C
PRESERVATION & PH VERIFICATION	YES	

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Environmental Science Section (608) 224-6277 DNR LAB ID 113133790
Inorganic chemistry

Id: Point/Well/..:
Collection Date: 06/29/01 Time: 00:00 Field #: County: 68 (Waukesha) Route:
From: TAMARACK LAKE
To: RAMAKER & ASSOCIATES
1120 DALLAS ST
SAUK CITY WI 53583 Source: Surface Water
Account number: LM007
Date Received: 06/29/01 Labslip #: IL029461 Collected by: Reported: 07/31/01

CHLOROPHYLL A, UNCORRECTED, LAB FILT (SM 10200H)	6.	UG/L
TOTAL DISS PHOSPHORUS (AS P), (EPA 365.1)	0.023	MG/L
CLOUD COVER %	0	%
TEMPERATURE ON RECEIPT-ICED	ICED	C
PRESERVATION & PH VERIFICATION - FIELD	YES	

Test results for NELAP accredited tests are certified to meet the requirements of the NELAC standards. For a list of accredited analytes see http://www.slh.wisc.edu/nelap/

State Laboratory of Hygiene
University of Wisconsin Center for Health Sciences
2601 Agriculture Drive, PO Box 7996, Madison, WI 53707-7996
R.H. Laessig, Ph.D., Director D.F. Kurtycz, M.D., Medical Director

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Environmental Science Section (608) 224-6277 DNR LAB ID 113133790
Inorganic chemistry

Id: Point/Well/..: Field #: Route: FH2
Collection Date: 08/06/01 Time: 11:30 County: 68 (Waukesha)
From: TAMARACK LAKE, OCONOMOWOC
To: BUNKH
DNR
MILWAUKEE
Source: Surface Water
Account number: LM008 Collected by: RAMAKER & ASSOCIATES
Waterbody/permit/..: 780600
Date Received: 08/08/01 Labslip #: IM003426 Reported: 10/16/01

CHLOROPHYLL A, UNCORRECTED, LAB FILT (SM 10200H)	*1.4	UG/L #1
TOTAL DISS PHOSPHORUS (AS P), (EPA 365.1)	*0.007	MG/L #2
TEMPERATURE ON RECEIPT-ICED	ICED	C
PRESERVATION & PH VERIFICATION - LAB	YES	

--- Footnotes ---
Remark #1: LOW ABSORBANCE, RESULT APPROXIMATE
Remark #2: SAMPLE NOT FIELD FILTERED, RESULT APPROXIMATE

Test results for NELAP accredited tests are certified to meet the requirements of the NELAC standards. For a list of accredited analytes see http://www.slh.wisc.edu/nelap/

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Environmental Science Section (608) 224-6277 DNR LAB ID 113133790
Inorganic chemistry

Id: Point/Well/..: Field #: Route:
Collection Date: 09/28/01 Time: 14:00 County: (Unknown)
From: TAMARACK LAKE
To: BUNKH
DNR
MILWAUKEE Source: Surface Water
Account number: LM008 Collected by: KAPPEL
Date Received: 10/01/01 Labslip #: IM009286 Reported: 10/17/01

CALCIUM, DISS, ICP (EPA 200.7)	20.8	MG/L
CONDUCTIVITY (AT 25 DEG C), DISS (SM 2510B)	*187	UMHOS/CM #1
PH, LAB, DISS (EPA 150.1)	*7.93	SU #1
ALKALINITY (AS CACO3), DISS (SM2320B)	*80	MG/L #1
HARDNESS (AS CACO3), DISS, CALC (SM2340B)	90.7	MG/L
MAGNESIUM, DISS, ICP (EPA 200.7)	9.4	MG/L
TOTAL KJELDAHL NITROGEN (AS N), DISS (EPA 351.2)	*0.59	MG/L #2
TOTAL DISS PHOSPHORUS (AS P), (EPA 365.1)	*0.010	MG/L #3
TURBIDITY SCREENING FOR SDWA METALS (SM 2130B)	1.	NTU
TEMPERATURE ON RECEIPT	17.	C
PRESERVATION & PH VERIFICATION - LAB	YES	
ICP TEST	COMPLETE	

--- Footnotes ---
Remark #1: SAMPLE RECEIVED WITH ICE MELTED, RESULT APPROX
Remark #2: SAMPLE RECEIVED WITH ICE MELTED
Remark #3: SAMPLE RECEIVED WITH ICE MELTED

Test results for NELAP accredited tests are certified to meet the requirements of the NELAC standards. For a list of accredited analytes see http://www.slh.wisc.edu/nelap/

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Environmental Science Section (608) 224-6277 DNR LAB ID 113133790
Inorganic chemistry

Id: Point/Well/..: Field #: Route: DG2
Collection Date: 12/11/01 Time: 00:00 County: 68 (Waukesha)
From: TAMARACK LAKE
To: BUNKH
DNR
MILWAUKEE
Source: Surface Water
Account number: LM008 Collected by:
Date Received: 12/13/01 Labslip #: IM013738 Reported: 02/07/02

CALCIUM, TOTAL REC, ICP (EPA 200.7)	19.4	MG/L
CHLORIDE (EPA 325.2)	8.3	MG/L
CONDUCTIVITY (AT 25 DEG C) (SM 2510B)	185.	UMHOS/CM
PH, LAB (EPA 150.1)	7.98	SU
ALKALINITY (AS CACO3) (SM 2320B)	79.	MG/L
DIG, TOTAL REC, ICP, LIQUIDS (SW846 3005A)	COMPLETE	
HARDNESS (AS CACO3), TOTAL REC, CALC (SM 2340B)	86.3	MG/L
IRON, TOTAL REC, ICP (EPA 200.7)	ND (LOD=0.1 MG/L)	
MAGNESIUM, TOTAL REC, ICP (EPA 200.7)	9.2	MG/L
MANGANESE, TOTAL REC, ICP (EPA 200.7)	9.	UG/L
TOTAL KJELDAHL NITROGEN (AS N) (EPA 351.2)	0.74	MG/L
TOTAL PHOSPHORUS (AS P) (EPA 365.1)	0.017	MG/L
POTASSIUM, TOTAL REC, ICP (EPA 200.7)	2.	MG/L
detected between 1 (LOD) and 3 (LOQ) MG/L		
SILICA, DISS, LOW LEVEL (SM 4500 SI-F)	*0.184	MG/L #1
SODIUM, TOTAL REC, ICP (EPA 200.7)	3.2	MG/L
SULFATE (EPA 375.2)	ND (LOD=4.5 MG/L)	
TURBIDITY, NON-SDWA COMPLIANCE (SM 2130B)	*1.6	NTU #2
TEMPERATURE ON RECEIPT-ICED	ICED	C
ICP TEST	COMPLETE	

--- Footnotes ---
Remark #1: HOLDING TIME EXCEEDED BY 28 DAYS
Remark #2: RECOMMENDED HOLDING TIME EXCEEDED BY 7 DAYS

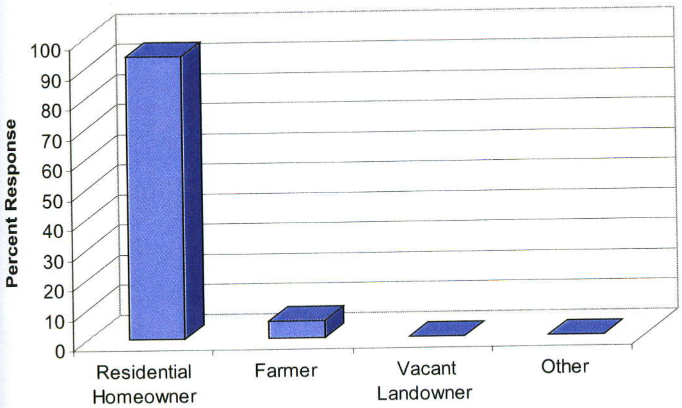
Test results for NELAP accredited tests are certified to meet the requirements of the NELAC standards. For a list of accredited analytes see http://www.slh.wisc.edu/nelap/

APPENDIX B

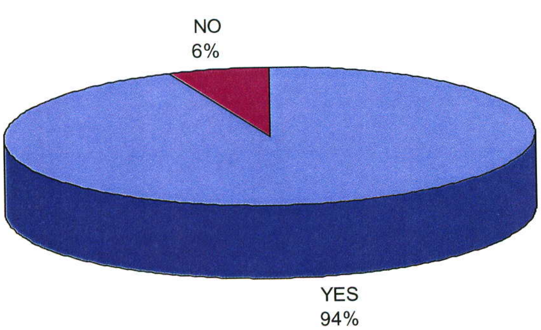
RESULTS OF 2000 RESIDENT OPINION SURVEY

2000 SURVEY RESULTS
TAMARACK LAKE MANAGEMENT ASSOCIATION

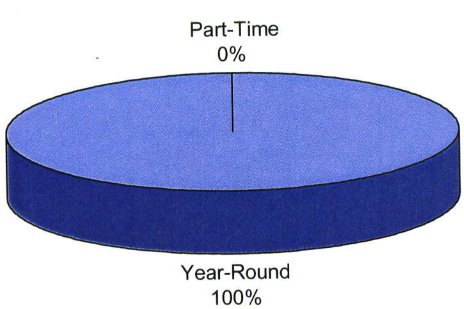
1. What type of property owner are you?



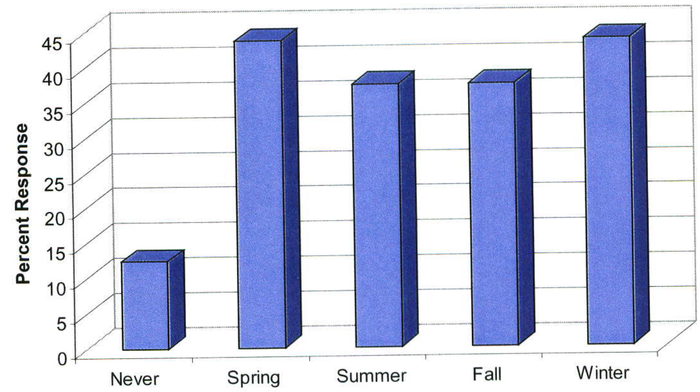
2. Are you a member of the Tamarack Lake Association?



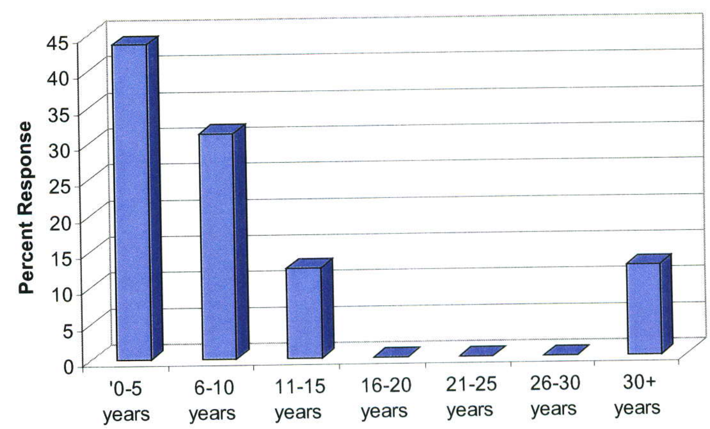
3. Which of the following best describes your residency status?



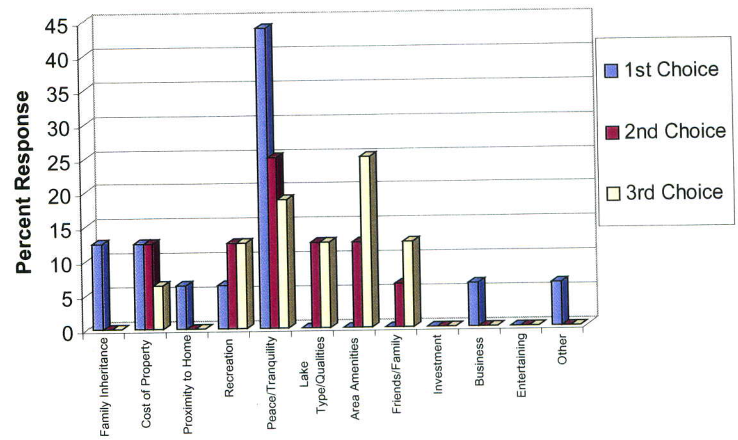
4. When do you most often spend time recreating on Tamarack Lake?



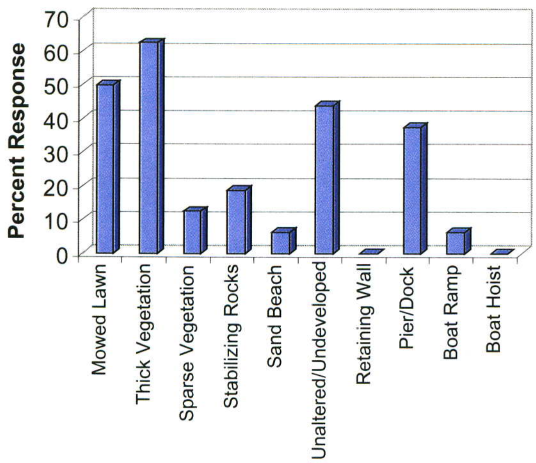
5. How many years have you owned property on Tamarack Lake?



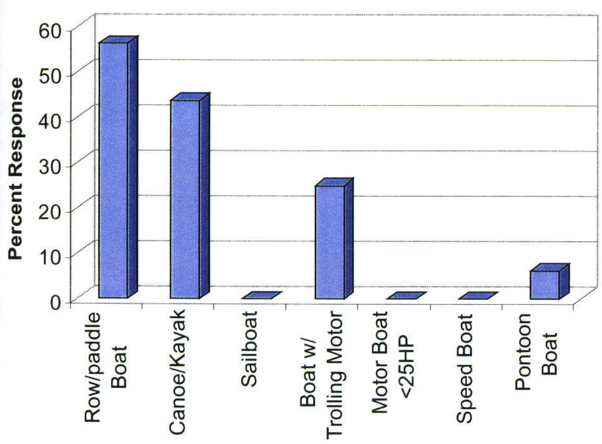
6. List the top three reasons why you chose to own



7. Which of the following describes your lake frontage within 25 feet of the water's edge?

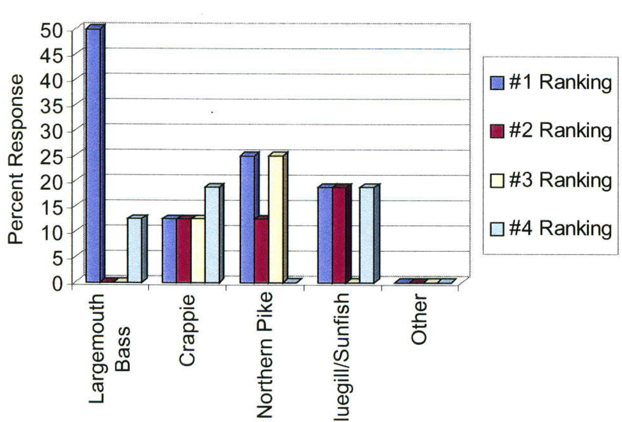


8. What types of watercraft do you routinely use on Tamarack Lake?

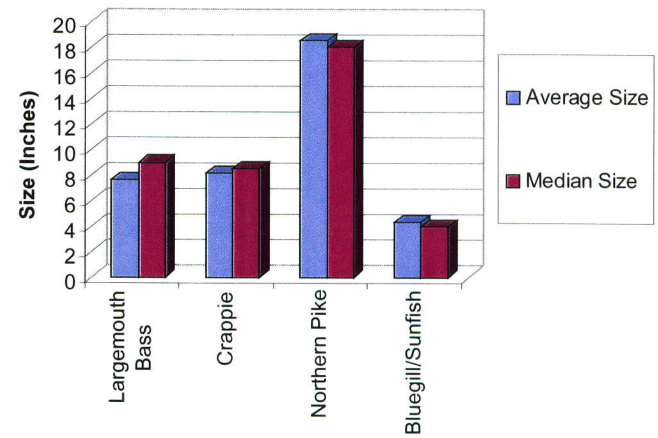


<u>If you are an angler, please answer the following:</u>

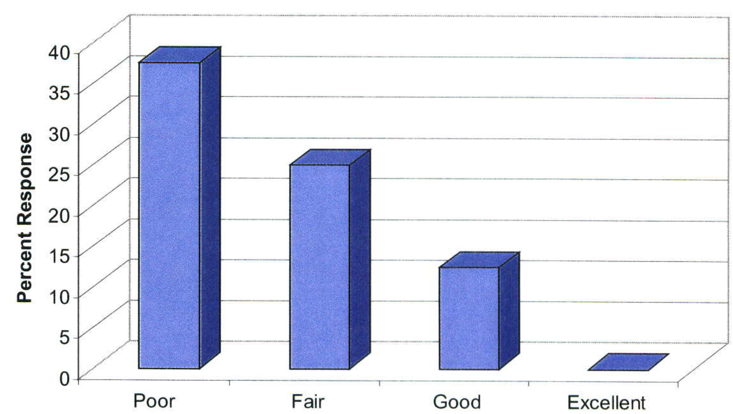
9A. Rank the following fish species that you prefer to catch on Tamarack Lake.



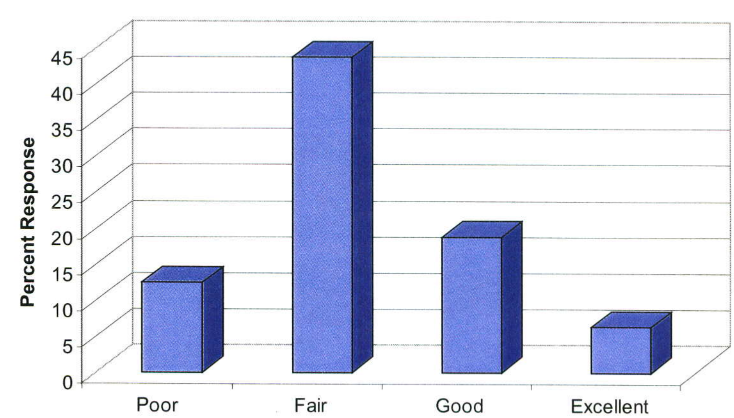
9B. What is the average size of each type of fish that can be caught on Tamarack Lake?



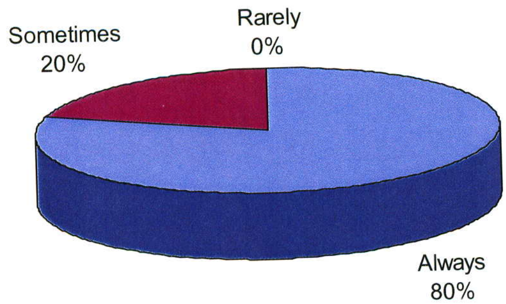
9C. How would you rate the quality of fishing on Tamarack Lake in terms of fish SIZE?



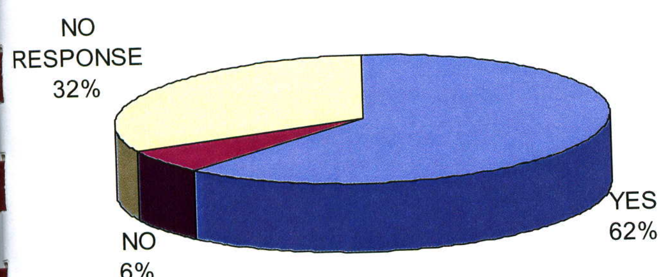
9D. How would you rate the quality of fishing on Tamarack Lake in terms of fish NUMBERS?



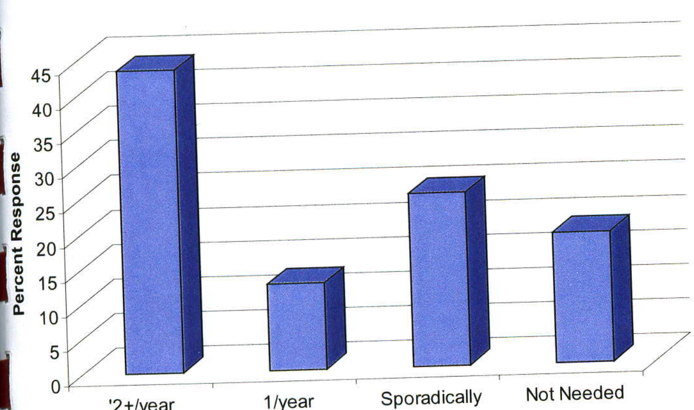
9E. Do you voluntarily practice "catch-and-release" when fishing for species other than panfish?



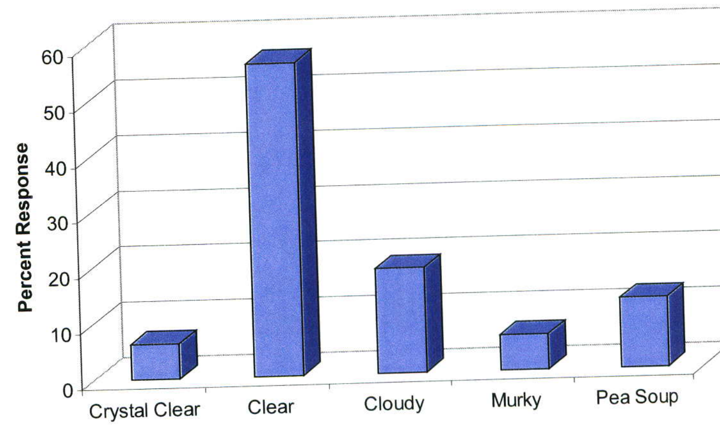
10. Do you feel Tamarack Lake has adequate public access?



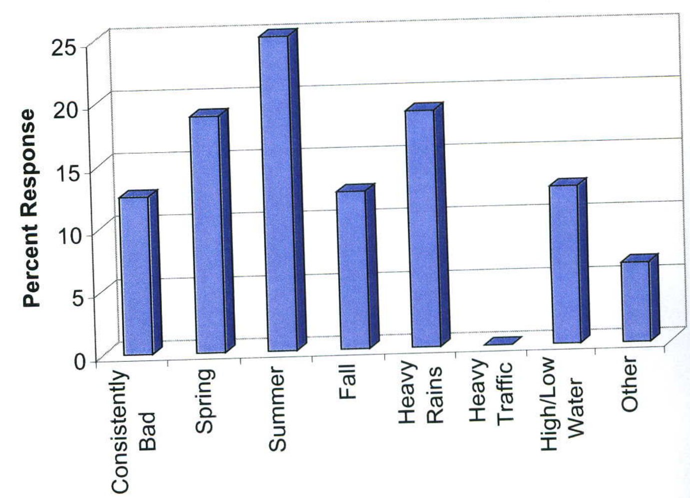
11. What is your opinion regarding the use of fertilizers and/or weed killer to maintain lawns around Tamarack Lake?



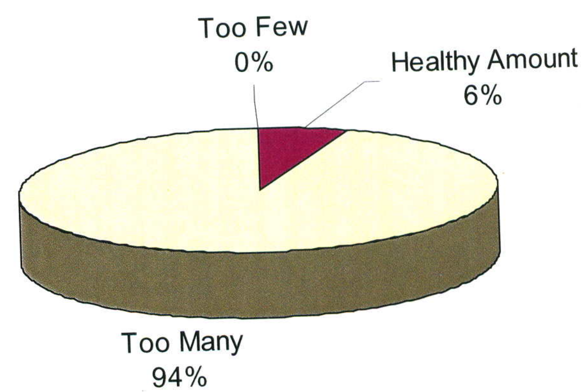
12. Overall, how would you describe the water clarity in Tamarack Lake during the summer months?



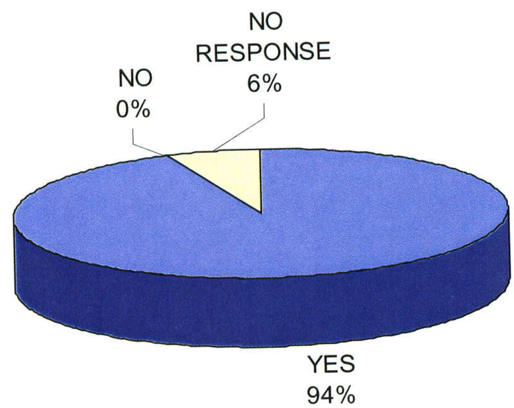
13. When is water clarity at its worst?



14. Overall, how would you describe Tamarack Lake's aquatic plant growth?



15. Are there areas on the lake where aquatic plant growth becomes especially problematic?

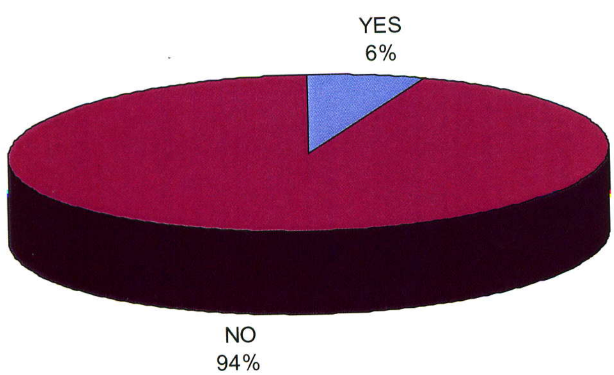


16. If you answered "yes" above, please specify the location and nature of the problem. (Provide as much information as possible, such as water depth, location on the lake, etc. Also, describe how or why the plant growth is a problem.)

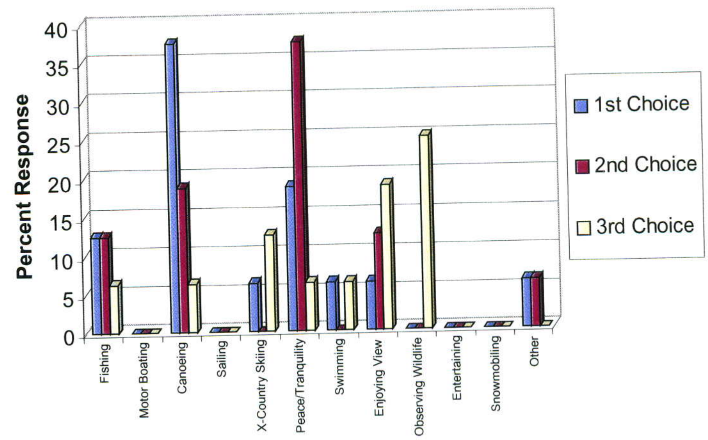
<u>SUMMARY</u>:

The general consensus is that the entire lake is subject to nuisance plant growth because of shallow water depths. Lily pads and coontail appear to be the species of greatest concern. Excessive plant growth is interfering primarily with swimming and navigation (even for non-motorized watercraft). Many believe plant growth is getting worse each year, and that chemical spraying is not effective.

17. Do you feel the current weed management, which is carried out by the lake residents, is effectively controlling nuisance plant growth?

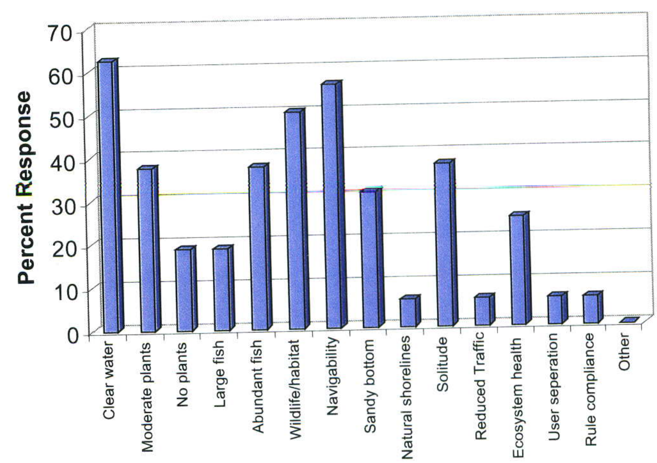


18. What activities do you and the members of your household most enjoy while recreating on Tamarack Lake?

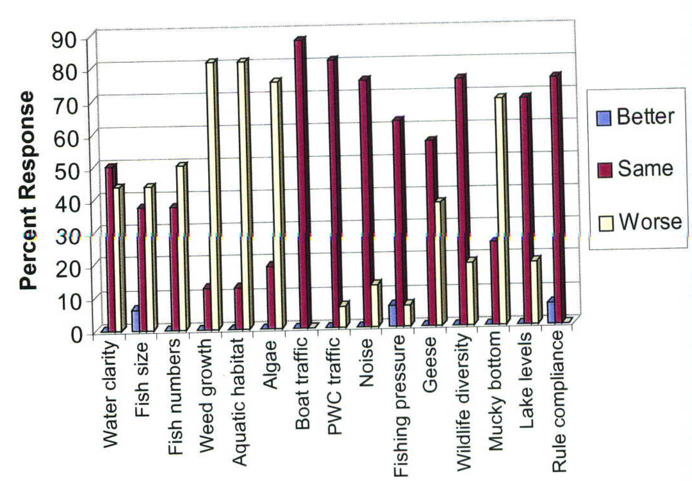


OTHER: Ice skating

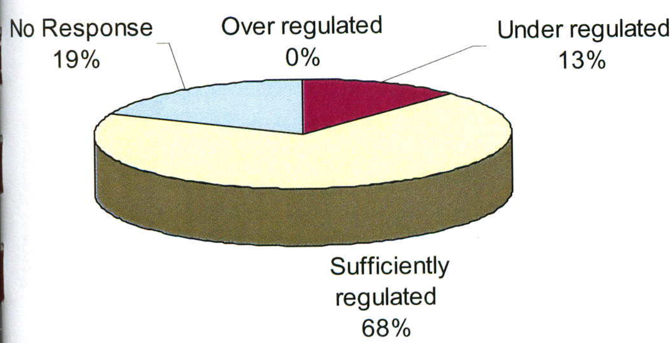
19. Rank the following lake qualities according to their level of importance to you.



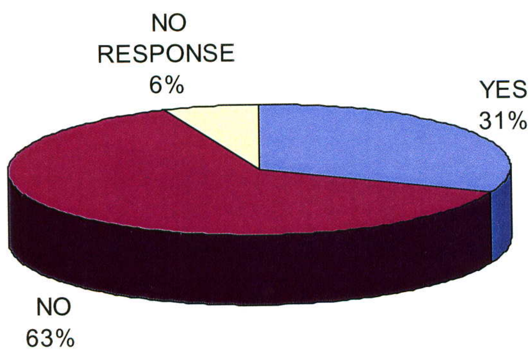
20. How have the following changed since you've lived on or near Tamarack Lake?



21. What is your opinion regarding lake-use regulations on Tamarack Lake in general?

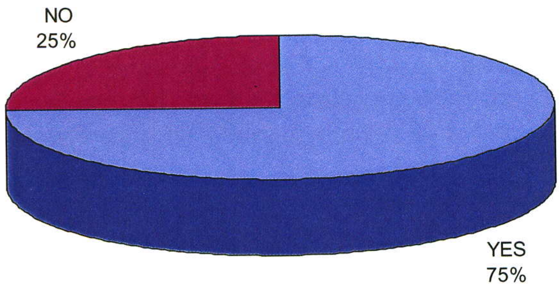


22. Are there any types of behavior, recreational activities or lake uses that you believe are seriously jeopardizing the health and safety of the lake?



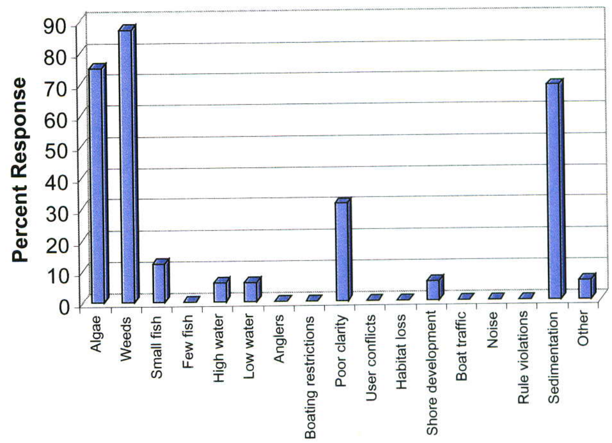
YES: Winter snowmobiling & 4-wheeling; farm runoff; lack of management

23. Would you be in favor of limiting lake access to only non-motorized boats and boats with trolling motors on Tamarack Lake?

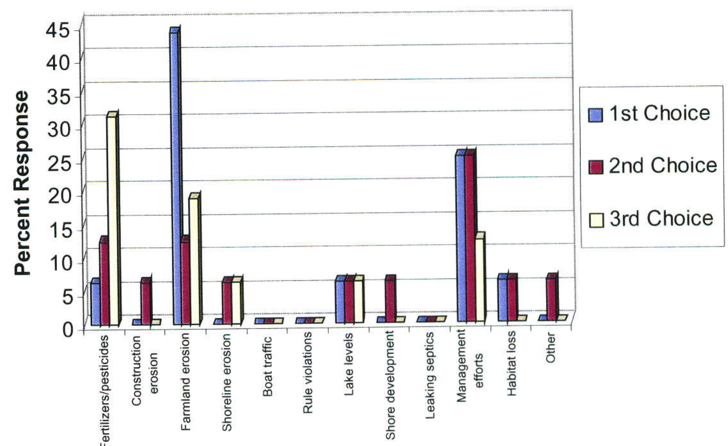


CONSENSUS OPINION: Lake is too small, shallow and weedy to support motor boats.

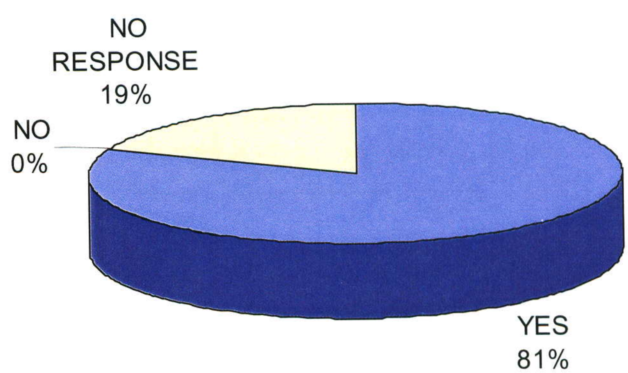
24. Rank the following according to the degree each condition negatively impacts your use or enjoyment of Tamarack Lake.



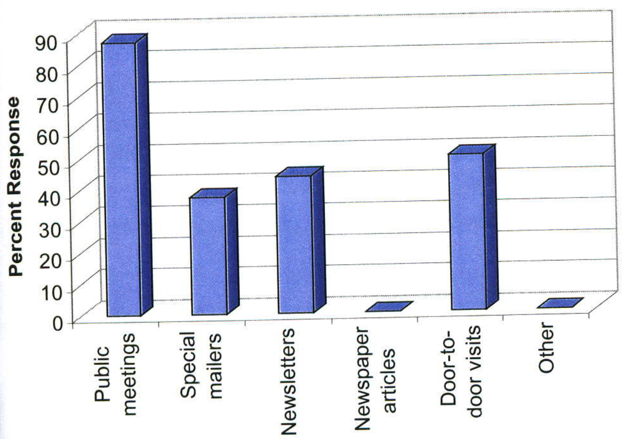
25. What do you feel are the top three factors that contribute to problems on Tamarack Lake?



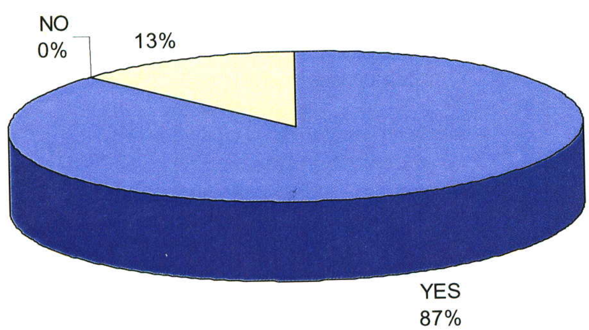
26. Do you feel that your have a voice in decision-making matters regarding the management of Tamarack Lake?



27. What is the best way for the Tamarack Lake Management Association to communicate with its members?



28. Do you feel that you are adequately informed of lake-management decisions?



29. What do you think is the <u>most negative</u> aspect of Tamarack Lake or its management?

<u>SUMMARY</u>:

The consensus opinion is that nuisance weed growth conditions and a lack of management are the most negative aspects. Other comments included:

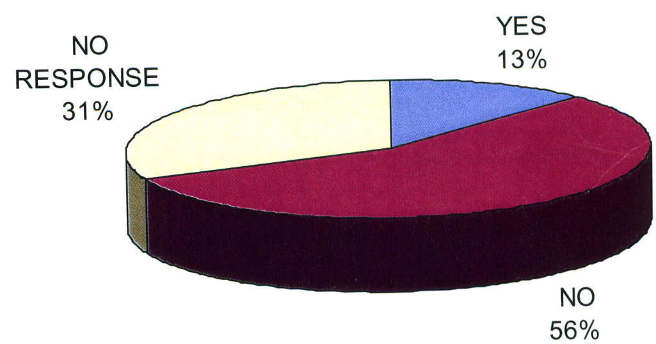
- People who live and recreate on the lake but refuse to join the lake management association
- Not being advised of upcoming meetings
- The lake community's youth and inexperience
- Cost to live on the lake

30. What do you think is the <u>most positive</u> aspect of Tamarack Lake or its management?

<u>SUMMARY:</u>

The consensus opinion is that Tamarack is a beautiful lake with clear water and good wildlife habitat. Most seem pleased that residents are starting to get organized to maintain the quality of the resource for years to come.

31. Do you have other concerns or questions that were not addressed in this survey?



YES: How long is going to take to improve the lake; Will the DNR allow dredging

<u>STATISTICS</u>

Surveys distributed:	16
Surveys completed:	16
Response rate:	100%

RESIDENT SURVEY
TAMARACK LAKE ASSOCIATION

ATTENTION: *The Tamarack Lake Association would like your feedback to the following questions. Your comments and opinions are very important to us, and will form the basis of developing a Comprehensive Lake Management Plan for Tamarack Lake. The Plan will be used to guide the implementation of lake-protection and improvement strategies over at least the next several years. Please answer all the questions to the best of your ability. Completed surveys should be returned to Ramaker & Associates, Inc. no later than* **August 4, 2000**. *To send, simply re-fold so the return address at the end of the survey is clearly visible, tape shut (please do not staple), and mail before the deadline. Thank you in advance for your input!*

1. What type of property owner are you? (Check all that apply.)
___ Residential Homeowner ___Farmer ___ Vacant Landowner ___Other (specify)_______________________________

2. Are you a member of the Tamarack Lake Association?
___ Yes ___ No

3. Which of the following best describes your residency status?
___Year-round/Permanent ___Seasonal/Part-time

4. When do you most often spend time recreating on Tamarack Lake?
___Never ___Spring (Mar – May) ___Summer (Jun – Aug) ___Fall (Sept – Nov) ___Winter (Dec – Feb)

5. How many years have you owned property in the Tamarack Lake Area?
___0-5 years ___ 6-10 years ___11-15 years ___16-20 years ___ 21-25 years ___26-30 years ___30+ years

6. List the top three reasons why you chose to own property on Tamarack Lake? (List the letters of your top three choices.)

A.	Family inheritance/tradition	G.	Area amenities (small town atmosphere, etc.)
B.	Cost of property	H.	Location of friends or family
C.	Proximity to primary residence	I.	Real estate investment
D.	Recreational opportunities	J.	Business purposes
E.	Peace/tranquility	K.	Entertaining
F.	Type & quality of lake	L.	Other (Specify)_______________________________

1st ___ 2nd ___ 3rd ___

7. Which of the following describes your lake frontage within 25 feet of the water's edge? (Check all that apply.)
___Mowed lawn ___ Thick vegetation ___Sparse vegetation ___Stabilizing rocks ___ Sand beach ___Unaltered/undeveloped
___Retaining wall ___Pier/dock ___ Private boat ramp ___ Boat hoist

8. What types of watercraft do you routinely use on Tamarack Lake? (Check all that apply.)
___ Rowboat/Paddle boat ___ Canoe/Kayak ___ Sailboat ___ Boat with trolling motor ___ Motor boat under 25HP
___ Speed boat ___ Pontoon boat ___Other (Specify)_______________________________

9. If you are an angler, please answer the following questions.

A) Rank the following fish species that you prefer to catch on Tamarack Lake? (Rank 1-4: 1 = most important and 4 = least important)
___Largemouth Bass ___Northern pike
___Crappie ___Bluegill/Sunfish ___Other (Specify)_______________________________

B) What is the average size of each type of fish that can be caught on Tamarack Lake?
Largemouth Bass: ___ inches Northern Pike: ___ inches
Crappie: ___ inches Bluegill/Sunfish: ___ inches
Other (____________): ___ inches

C) How would you rate the quality of fishing on Tamarack Lake in terms of fish SIZE?
___ Poor ___ Fair ___ Good ___ Excellent

D) How would you rate the quality of fishing on Tamarack Lake in terms of fish NUMBERS?
___ Poor ___ Fair ___ Good ___ Excellent

E) Do you voluntarily practice "catch-and-release" when fishing for species other than panfish?
___ Always ___ Sometimes ___ Rarely

10. Do you feel Tamarack Lake has adequate public access? If not, what type of access is most needed?
___ Yes ___ No (type most needed:____)

11. What is your opinion regarding the use of fertilizers and/or weed killer to maintain lawns around Tamarack Lake? (Check all that apply.)
___Two or more applications needed per year
___ One application needed per year
___ Needed only on a sporadic basis depending on soil and plant growth conditions
___ Not needed or not justified due to perceived health/environmental effects

12. Overall, how would you describe the water clarity in Tamarack Lake during the summer months?
___Crystal clear ___Clear ___Cloudy ___Murky ___Pea soup

13. When is water clarity at its worse? (Check all that apply.)

___Consistently bad	___After heavy rains
___Spring	___After heavy motor boat traffic
___Summer	___During abnormally high/low lake levels
___Fall	___Other (Specify)________________________

14. Overall, how would you describe Tamarack Lake's aquatic plant growth?
___ Too few plants ___ Healthy amount of plant growth ___ Too many plants

15. Are there areas on the lake where aquatic plant growth becomes especially problematic?
___Yes ___No

16. If you answered "yes" above, please specify the location and nature of the problem. Provide as much information as possible, such as water depth, direction on the lake (example north side). Also, describe how or why the plant growth is a problem.____
____
____

17. Do you feel the current weed management, which is carried out by the lake residents, is effectively controlling nuisance plant growth? If not, please explain.
___Yes ___No
____
____

18. What activities do you and the members of your household most enjoy while recreating on Tamarack Lake? (List the letters of your top three choices.)

A.	Fishing	G.	Swimming/Snorkling
B.	Motor boating	H.	Enjoying the view
C.	Canoeing/Paddle boating	I.	Observing wildlife
D.	Sailing/Wind surfing	J.	Entertaining
E.	Cross-country skiing	K.	Snowmobiling
F.	Enjoying peace & tranquility	L.	Other (Specify)____________________

1st____ 2nd____ 3rd____

19. Rank the following according to their level of importance to you. (Rank 1-14: 1 = most important, 14 = least important)

___ Clear water	___ Sandy bottom
___ Moderate amount of aquatic plant growth	___ Natural, well-vegetated shorelines
___ Little or no aquatic plant growth	___ Solitude
___ Large fish	___ Reduced boat traffic & congestion
___ Abundant fish	___ Overall ecosystem health
___ Presence of wildlife/habitat	___ Separation of conflicting lake uses
___ Lake depth and navigability	___ Rule compliance
	___ Other (Specify)____________________

20. How have the following changed since you've lived on or near Tamarack Lake?

	BETTER	SAME	WORSE
Water clarity:	___	___	___
Fish size:	___	___	___
Fish abundance:	___	___	___
Nuisance "weed" growth:	___	___	___
Aquatic plant habitat:	___	___	___
Algae growth:	___	___	___
Motor boat traffic:	___	___	___
Personal watercraft traffic:	___	___	___
Noise:	___	___	___
Fishing pressure:	___	___	___
Nuisance Geese:	___	___	___
Wildlife diversity:	___	___	___
Muckiness of lake bottom:	___	___	___
Lake-level fluctuations:	___	___	___
Rule compliance/enforcement:	___	___	___

21. What is your opinion regarding lake-use regulations on Tamarack Lake in general?
___ Over regulated ___ Under regulated ___ Sufficiently regulated

22. Are there any types of behavior, recreational activities or lake uses that you believe are seriously jeopardizing the health and safety of the lake? If yes, please explain.
___Yes ___No

____

____

23. Would you be in favor of limiting lake access to non-motorized boats and boats with trolling motors only on Tamarack Lake? Please explain why or why not.
___ Yes ___ No

____

____

24. Rank the following according to the degree each condition negatively impacts your use or enjoyment of Tamarack Lake? (Rank 1-16: 1 = biggest problem, 16 = smallest problem)

___Nuisance algae blooms
___Excessive weed growth
___Small fish size
___Small fish quantity
___Lake-level too high
___Lake-level too low
___Too many fisherman
___Too many boating restrictions
___Poor water clarity
___Passive vs. active recreational conflicts
___Loss of wildlife habitat (e.g. shoreland & aquatic vegetation)
___Shoreline development
___Boat traffic/congestion
___Noise
___Lack of rule compliance/enforcement
___ Excessive sedimentation (silt and muck)
___Other (Specify)______________________

25. What do you feel are the top three factors that contribute to problems on Tamarack Lake? (List the letters of your top three choices)

A. Fertilizer/pesticide use
B. Construction site erosion & runoff
C. Farm field erosion & runoff
D. Shoreline and stream bank erosion
E. Motor boat ski traffic
F. Inadequate law enforcement
G. Lake-level fluctuations
H. Shoreline development pressures
I. Leaking septic fields
J. Inappropriate lake management efforts
K. Wetland & wildlife habitat destruction
L. Other (Specify)______________________

1^{st}___ 2^{nd}___ 3^{rd}___

26. Do you feel that you have a voice in decision-making matters regarding the management of Tamarack Lake? If not, please explain why you think this is the case.
___ Yes ___ No

____

____

27. What is the best way for the Tamarack Lake Management Association to communicate with its members? (Please rank 1-5: 1 = most effective, 5 = least effective)

___ Public meetings ___ Special mailers ___ Newsletters

___ Local newspaper articles ___ Door-to-door visits ___ Other (Specify)________________________

28. Do you feel that you are adequately informed of lake-management decisions? If not, what should be done to facilitate better communication?

___ Yes ___ No

____

____

29. What do you think is the most negative aspect of Tamarack Lake or its management?

____

____

____

30. What do you think is the most positive aspect of Tamarack Lake or its management?

____

____

____

31. Do you have other concerns or questions that were not addressed in this survey? If not, please explain.

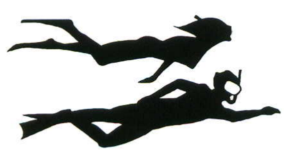
___Yes ___No

____

____

____

THANK YOU FOR YOUR INPUT!



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