A Shoreline Survey On Sixmile Lake, 2008

By Tip of the Mitt Watershed Council

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SUMMARY

During late May and early June of 2008 the Tip of the Mitt Watershed Council conducted a shoreline survey on Sixmile Lake that was funded by the Sixmile Lake Association. Watershed Council staff surveyed the entire shoreline to document the occurrence of nutrient pollution indicators and other factors that potentially contribute to water quality degradation. The parameters surveyed include: algae as a bio-indicator of nutrient pollution, greenbelt status, shoreline erosion, shoreline alterations, nearshore substrate types, and stream inlets and outlets.

Shoreline property management practices have the potential to negatively impact water quality in many ways. Nutrients are necessary to sustain a healthy aquatic ecosystem, but excess can adversely impact an aquatic ecosystem, and indirectly poses a danger to human health. Greenbelts provide many benefits to the lake ecosystem, which are lost when shoreline vegetation is removed. Erosion and shoreline alterations (seawalls, rip-rap, etc.) both have the potential to degrade water quality.

Data collected during the shoreline survey indicates that human activity along the shores of Sixmile Lake is probably having negative impacts on the lake ecosystem and water quality. *Cladophora* algae was noted at 14% of shoreline properties, erosion was documented at 11% of properties, greenbelts were found to be in poor condition at 34% of properties, and shoreline alterations were found at 30% of properties. Most problems were documented in the southern half of the lake, which is where the shoreline is more developed.

Nearshore aquatic plant communities were also surveyed due to lakeshore residents' concerns regarding excessive growth. Moderate to heavy-density plant growth was documented in front of ~65% of lakeshore properties, the majority of which were located in the northern half of the lake and in the southeast corner. Additionally, a small bed of Eurasian watermilfoil, an invasive aquatic plant, was found to the north of the DNR boat launch on the east side of

the lake. A comprehensive aquatic plant survey should be carried out to assist in aquatic plant management by documenting locations of native versus invasive aquatic plants and communities. At a minimum, the Eurasian watermilfoil infestation should be mapped out to develop a control plan. Biological control using a native aquatic weevil is recommended as it is an environmentally safe and potentially long-term solution.

To achieve the full value of this survey, the association should engage in follow-up activities aimed at educating riparian property owners about preserving water quality, and to help them rectify any problem situations. Summary information regarding the survey should be provided to all shoreline residents along with information about what each person can do to help, but specific information for individual properties should remain confidential. Individual property owners should be contacted confidentially and encouraged to participate in identifying and rectifying any problems that may exist on their property. An informational session could be organized to share survey results and provide information about best management practices on shoreline properties that help protect and improve lake water quality. Ideally, shoreline surveys should be repeated every 3-5 years as shoreline ownership, management, and conditions change continually.

INTRODUCTION

Background:

During the summer of 2008, a shoreline survey was conducted on Sixmile Lake by the Tip of the Mitt Watershed Council to document shoreline conditions that potentially impact water quality with a particular focus on nutrient pollution. The entire shoreline was surveyed to document the following: algae as a nutrient pollution indicator, erosion, shoreline alterations, greenbelts, tributary inlets and outlets, and nearshore aquatic plant densities. The survey was funded by the Sixmile Lake Property Owners Association.

Shoreline surveys for pollution and resource features have been conducted previously on Six Mile Lake. In 1993, the Six Mile Lake Association contracted with the Tip of the Mitt Watershed Council to conduct a survey using a conductivity meter to detect locations of septic system problems. A database of shoreline property features and ownership information, and parcel maps were also developed during that survey. The project included a questionnaire mailing to shoreline property owners, an individualized response with recommendations, and ground water testing at 14 suspected problem sites. From 1996 to 1998, another survey was conducted as part of the State and Federally-funded Elk River Chain of Lakes Watershed Project. That survey documented occurrences of filamentous algae growth and shoreline erosion problems, as well as other resource features such as wetlands, aquatic plant beds, and bottom sediments. The shoreline database and parcel maps were updated at that time. There were no individualized follow-up activities. In 2000, a third survey was performed to document nutrient pollution (using both algae and conductivity) and greenbelt status, but there were no individualized follow-up activities.

This survey provides another comprehensive data set documenting shoreline conditions on Sixmile Lake; a valuable data set that can be used as a lake management tool. Combined with follow-up activities, such as questionnaires and on-site visits, sources of nutrient pollution to the lake can be identified and controlled. Subsequently, a reduction in nutrient loading can often be achieved by working with homeowners to solve problems. These solutions are often simple and low cost, such as regular septic system maintenance, proper lawn care practices, and wise land use along the shoreline. Prevention of problem situations can also be achieved through the publicity and education associated with the survey. Periodic repetition of shoreline surveys is important for identifying new and chronic problem sites, determining long-term trends of near-shore nutrient inputs associated with land-use changes, and for assessing the success of remedial actions.

Shoreline development impacts:

The lake shoreline is the critical interface between land and water, where human activity has the greatest potential for degrading water quality. Developing shoreline properties for residential, commercial or other uses invariably has impacts on the aquatic ecosystem. During the development process, the natural landscape is altered in a variety of ways; vegetation is removed, the terrain is graded, utilities installed, structures are built, and areas are paved. These changes to the landscape and subsequent human activity in the shoreline area have consequences on the aquatic ecosystem. Nutrients from wastes, contaminants from cars and roads, and soils from eroded areas are among some of the pollutants that end up in and impact the lake following shoreline development.

Nutrient pollution can have adverse impacts on an aquatic ecosystem, and indirectly poses a danger to human health. Nutrients are necessary to sustain a healthy aquatic ecosystem, but excess will stimulate unnatural plant growth. Increased abundance of aquatic macrophytes (higher or vascular plants) can become a nuisance to recreation in shallow areas (typically less than 20 feet of depth). An increase in algal blooms also has the potential to become a recreational nuisance when algal mats and scum are formed on the lake's surface. Additionally, algal blooms pose a public health risk as some species produce toxins including hepatotoxins (toxins that cause liver damage) and neurotoxins (toxins that affect the nervous system).

Excess growth of both macrophytes and algae has the potential to degrade water quality by depleting the ecosystem's dissolved oxygen stores. During nighttime respiration, plants compete with other organisms for a limited oxygen supply. Furthermore, the decomposition of dead algae and plant material has the potential to deplete dissolved oxygen supplies due to the aerobic activity of decomposers, particularly in the deeper waters of stratified lakes.

In general, small, shallow lakes such as Sixmile are more sensitive to nutrient pollution than large, deep lakes. Large, deep lakes are more effective at absorbing the impacts of nutrient pollution due to greater water volume and dilution. In addition, large lakes generally have greater dissolved oxygen stores than small lakes, which reduces the risk of oxygen depletion. Sixmile Lake is susceptible to nutrient pollution in that it is a relatively small, shallow lake, but it benefits from being a drainage lake with inflows and outflow, which provides a mechanism to flush excess nutrients out of the system.

Surface waters receive nutrients through a variety of natural and cultural (human) sources. Natural sources of nutrients include stream inflows, groundwater inputs, surface runoff, organic inputs from the riparian (shoreline) area and atmospheric deposition. Springs, streams, and artesian wells are often naturally high in nutrients due to the geologic strata they encounter and wetland seepages may discharge nutrients at certain times of the year. Cultural sources include septic and sewer systems, fertilizer application, and stormwater runoff from roads, driveways, parking lots, roofs, and other impervious surfaces. Poor agricultural practices, soil erosion, and wetland destruction also contribute to nutrient pollution. Furthermore, some cultural sources (e.g., malfunctioning septic systems and animal wastes) pose a potential health risk due to bacterial and viral contamination.

Severe nutrient pollution is detectable through chemical analyses of water samples, physical water measurements, and the utilization of biological indicators (a.k.a., bio-indicators). Chemical analyses of water samples to check for nutrient pollution is effective, though costlier and more labor intensive than other methods. Typically, samples are analyzed to determine nutrient concentrations (usually forms of phosphorus and nitrogen), but other chemical constituent concentrations can be measured, such as chloride, which are related to human activity and often elevated in areas impacted by malfunctioning septic or sewer systems. Physical measurements are primarily used to detect malfunctioning septic and sewer systems, which can cause localized increases in water temperature and conductivity (i.e., the water's ability to conduct an electric current). Biologically, nutrient pollution can be detected along the lake shore by noting the presence of *Cladophora* algae.

Cladophora is a branched, filamentous green algal species that occurs naturally in small amounts in northern Michigan lakes. Its occurrence is governed by specific environmental requirements for temperature, substrate, nutrients, and other factors. It is found most commonly in the wave splash zone and shallow shoreline areas of lakes, and can also be found in streams. It grows best on stable substrates such as rocks and logs, though artificial substrates such as concrete or wood seawalls are also suitable. *Cladophora* prefers water temperatures in a range of 50 to 70 degrees Fahrenheit, which means that the optimal time for its growth and thus, detection, in northern Michigan lakes is from late May to early July, and from September to October.

The nutrient requirements for *Cladophora* to achieve large, dense growths are typically greater than the nutrient availability in the lakes of northern Michigan. Therefore, the presence of *Cladophora* can indicate locations where relatively high concentrations of nutrients, particularly phosphorus, are entering a lake.   Although the size of the growth on an individual basis is important in helping to interpret the cause of the growth, growth features of *Cladophora* are greatly influenced by such factors as current patterns, shoreline topography, size and distribution of substrate, and the amount of wave action the shoreline is subject to. Therefore, the description has limited value when making year to year comparisons at a single location or estimating the relative amount of shoreline nutrient inputs. Rather, the presence or absence of any significant growth at a single site over several years is the most valuable comparison. It can reveal the existence of chronic nutrient loading problems, help interpret the cause of the problems, and assess the effectiveness of any remedial actions. Comparisons of the total number of algal growths can reveal trends in nutrient input due to changing land use.

Erosion along the shoreline has the potential to degrade the lake's water quality. Stormwater runoff through eroded areas carries sediments into the lake and impacts the lake ecosystem in a variety of ways. Sediments clog the gills of fish, aquatic insects and other aquatic organisms. Excessive sediments smother fish spawning beds and fill interstitial spaces that provide habitat for a variety of aquatic organisms. While moving through the water column, sediments absorb sunlight energy and increase water temperatures. In addition, nutrients adhere to sediments that wash in from eroded areas, which can lead to nuisance aquatic plant growth and large algae blooms.

Shoreline greenbelts are essential for maintaining a healthy aquatic ecosystem. A greenbelt consisting of a variety of native woody and herbaceous plant species provides habitat for near-shore aquatic organisms as well as terrestrial animals. Greenbelts function as erosion control devices, stabilizing the shoreline with plant root structures that protect against wave action and ice. The canopy of the greenbelt provides shade to near-shore areas, which is particularly important for lakes with cold-water fisheries. In addition, greenbelts provide a mechanism to reduce overland surface flow and absorb pollutants carried by stormwater from rain events and snowmelt.

Tributaries have great potential for influencing a lake's water quality as they are one of the primary conduits through which water is delivered to a lake from its watershed. Inlet streams may provide exceptionally high quality waters that benefit the lake ecosystem, but conversely have the potential to deliver polluted waters that degrade the lake's water quality. Outlet streams flush water out of the lake, providing a mechanism to remove contaminants that have accumulated in the lake ecosystem.   With regards to shore surveys, noting the location of inlet tributaries is very helpful when evaluating shoreline algae conditions because nutrient concentrations are generally higher in streams than in lakes. The relatively higher nutrient levels delivered from streams often lead to naturally heavier *Cladophora* and other algae growth along the shoreline.

Responsible, low-impact, lake shoreline property management is paramount for protecting water quality. Maintaining a healthy greenbelt, regular septic tank pumping, treating stormwater with rain gardens, addressing erosion sites, and eliminating fertilizer, herbicide, and pesticide application are among many low-cost best management practices that minimize the impact of shoreline properties on lake water quality. Shoreline property owners are the stewards of the lake they live on, the lake that is an ecosystems full of life, and life that is dependent upon their actions.

Aquatic plants:

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

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

In spite of all the benefits associated with aquatic plants, some aquatic ecosystems suffer from overabundance, particularly where non-native nuisance species have been introduced. Excessive plant growth can create a recreational nuisance by making it difficult or undesirable to boat, fish and swim, but it also has the potential to cause aquatic ecosystem disruptions. In lakes plagued by nuisance plant species, it sometimes becomes necessary to develop and implement programs to control excessive growth and non-native species.

Aquatic plant management is a critical component of lake management. Thus, an important first step in developing a sound lake management program is to survey the aquatic plant communities to document species, abundance, density, and the presence or absence of non-native species. Due to concerns about excessive aquatic plant growth, the Sixmile Lake Association requested that nearshore aquatic plant densities be surveyed as a component of this project.

Study area:

Sixmile Lake is located in the northern Lower Peninsula of Michigan in southern Charlevoix County and northern Antrim County. Approximately two-thirds of the lake falls within South Arm Township in Charlevoix County with the remainder in Echo Township in Antrim County. Based upon shoreline digitizing using 2005 aerial photographs, the surface area of Sixmile Lake is approximately 350 acres and the shoreline distance totals ~9 miles. The deepest point is located near the center of the lake and is reported to be from 30-32' deep.

Sixmile Lake is a glacially formed lake that is located near the headwaters of the Elk River Chain of Lakes. There are numerous inlet streams; the largest being the Dingman River at the southern end, which drains Scotts and Beals Lakes to the south. The next largest inlet streams include Vance Creek in the southeast and Liscon Creek in the northeast. The only outlet is located in the northern end, which carries water to St. Clair Lake and down through the rest of the chain.

The Sixmile Lake watershed is a sub-watershed of the Elk River watershed, which is, in turn, part of the larger Grand Traverse Bay Watershed. Sixmile Lake has a large watershed in relation to the lake's surface area, measuring approximately 22,452 acres (does not include lake area). The watershed area to lake surface area ratio is ~64:1, which, compared to other lakes in Michigan, is quite high (e.g., Walloon Lake has a ratio of ~5:1). This ratio provides a statistic for gauging susceptibility of lake water quality to changes in watershed land cover. Essentially, the statistic indicates that the Sixmile Lake watershed is large enough, relative to lake area, to provide a protective buffer, such that small areas of development will probably not negatively impact water quality. However, the cumulative impact of rampant landscape development throughout the watershed could have serious adverse impacts on the lake's water quality.

According to land cover statistics from a 2000 land cover analysis (NOAA, 2003), the majority of the watershed is forested. Of land cover types that typically contribute to water quality degradation, there is little urban/residential and a moderate amount of agriculture in the watershed (Table 1).

Table 1. Sixmile Lake watershed land cover, 2000.

Land Cover Type	Acres	Percent
Agriculture	3320.53	14.55
Barren	20.53	0.09
Forested	12924.87	56.64
Grassland	2284.42	10.01
Scrub/Shrub	448.38	1.96
Urban/residential	359.92	1.58
Wetland	2979.20	13.05
Water	483.17	2.12
TOTAL	22821.03	100.00

According to data collected in programs coordinated by the Tip of the Mitt Watershed Council, Sixmile Lake contains high quality waters that are typical for the region. As part of the Watershed Council's Comprehensive Water Quality

Monitoring Program (CWQM), numerous parameters have been monitored in Sixmile Lake on a triennial basis since 1995. Dissolved oxygen concentrations have typically exceeded standards established by the State of Michigan and pH has consistently complied with State standards (Table 2). Chloride levels have increased gradually over time, indicating that there are some impacts from urbanization and residential development. Typical of high-quality lakes in northern Michigan, nutrient concentrations on Sixmile Lake have been quite low (total phosphorus, nitrate and total nitrogen), with phosphorus levels decreasing through time. Based on the Redfield Ratio of 16:1 (nitrogen: phosphorus), the limiting nutrient in Sixmile Lake is phosphorus, which means that phosphorus is the nutrient in smallest supply and which would stimulate the most plant growth.

Table 2. Sixmile Lake data from the CWQM program.

	DO	**pH**	**Conductivity**	**Chloride**	**Nitrate**	**TN**	**TP**
Units	PPM	Units	microSiemens	PPM	PPB	PPB	PPB
Average	9.98	7.93	301.83	5.39	210.00	490.00	11.31
Minimum	3.22	7.30	259.10	4.00	120.00	433.00	3.20
Maximum	11.90	8.51	357.00	6.90	290.00	560.00	34.2
Range	3.22 - 11.90	7.30 - 8.51	259 - 357	4.0-6.9	120-290	433-560	3.2-34.2

*DO = dissolved oxygen, TN = total nitrogen, TP = total phosphorus, PPM = parts per million, PPB=parts per billion.

Based on data collected as part of the Watershed Council's Volunteer Lake Monitoring Program, Sixmile Lake is classified as a mesotrophic lake (trophic status index values have ranged from 39 to 48). Mesotrophic lakes are in the middle of the road in terms of biological productivity; somewhere between the nutrient poor large, deep lakes with lackluster fisheries and the overly productive small, shallow lakes with excessive algae and plant growth. Phosphorus data from the CWQM program supports this characterization as averaged concentrations have typically been higher than large, deep lakes in the area. However, both chlorophyll-a concentrations and Secchi disc depths in Sixmile Lake have increased in recent years, which is somewhat unusual as generally one parameter increases as the other decreases (Figures 1 and 2). Invasive zebra mussels, which are now found in Sixmile Lake, usually cause increased water clarity and reduced algal biomass (i.e., reduced chlorophyll-a) by filter feeding on planktonic algae. Zebra mussels provide and explanation for the increase in water clarity seen in the Secchi disc depth data, but should have concurrently caused a decrease in chlorophyll-a concentrations.

Figure1. Chart of average Secchi disc depths in Sixmile Lake.

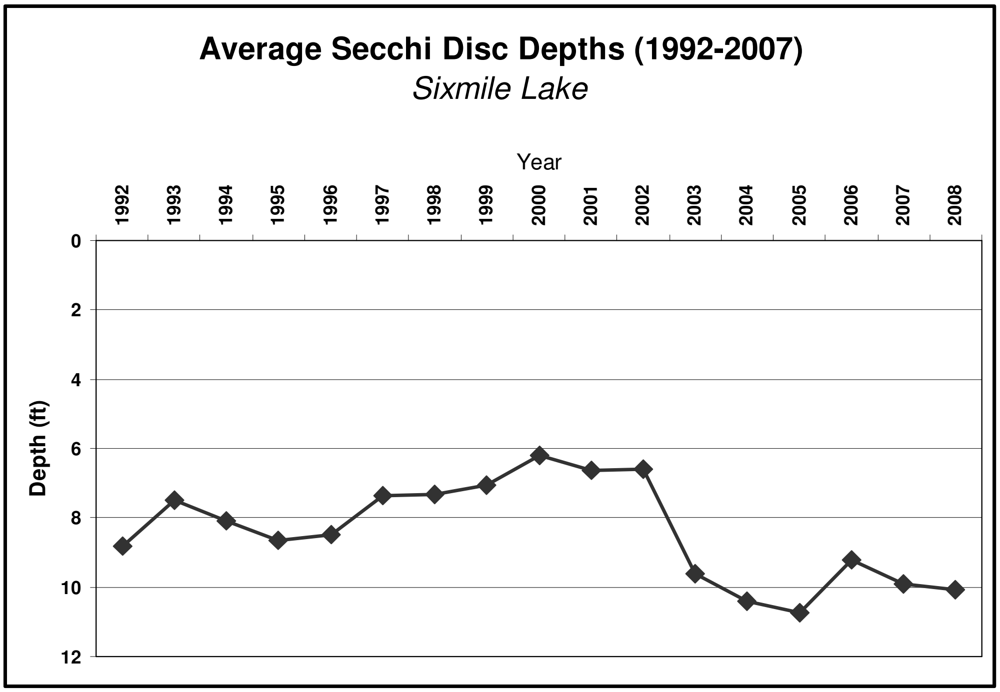


Figure2. Chart of average chlorophyll-a concentrations in Sixmile Lake.

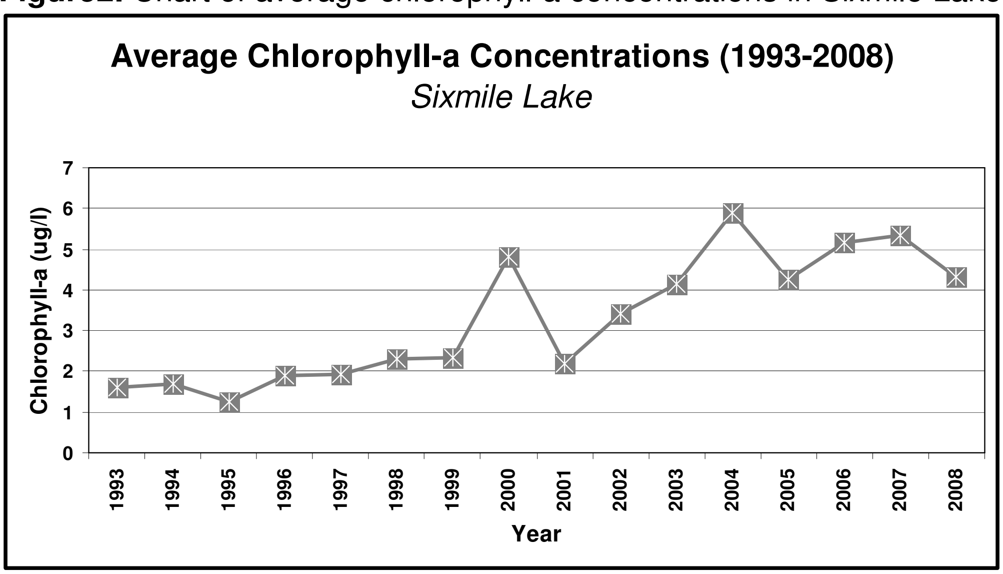
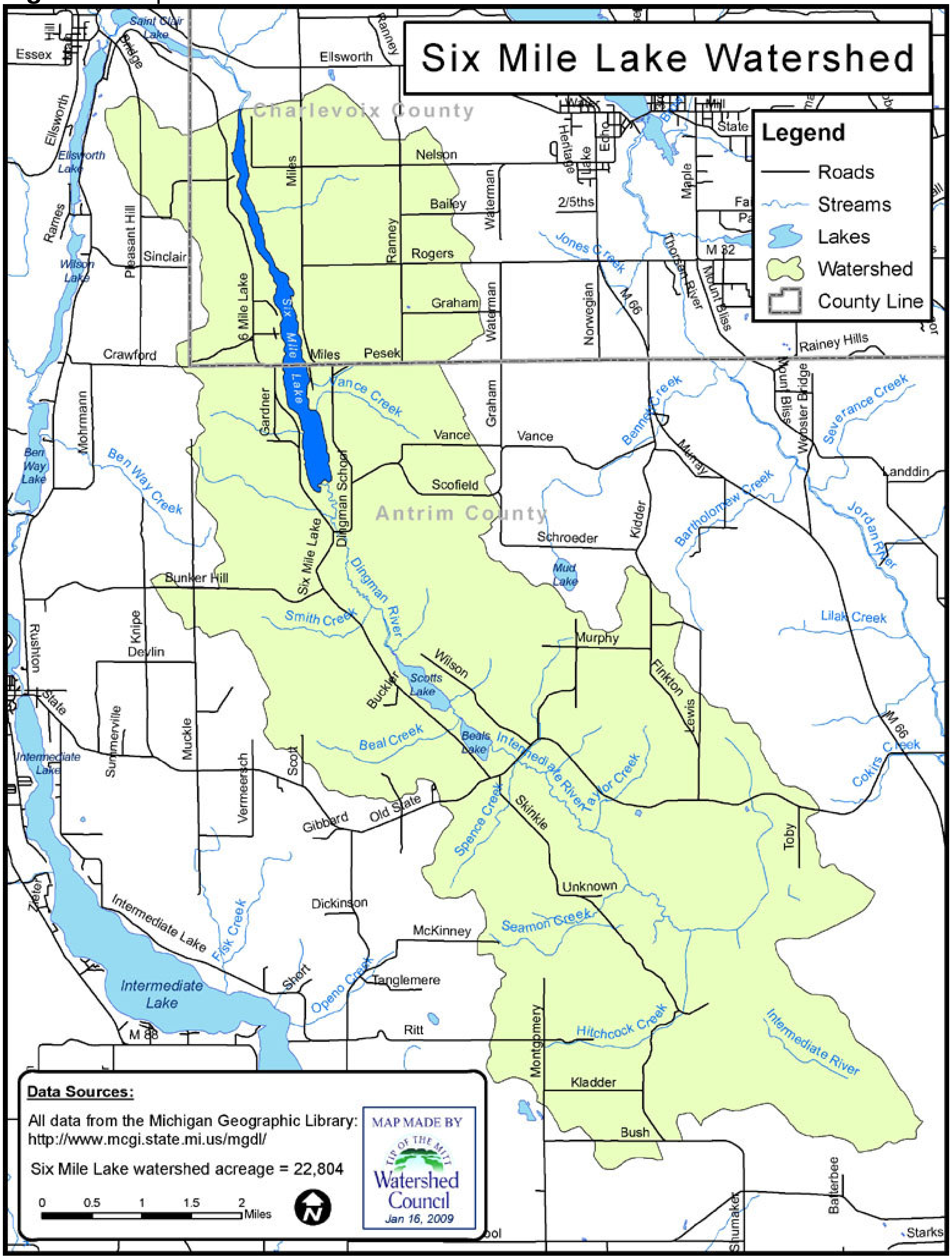


Figure 3. Map of the Sixmile Lake watershed.



METHODS

The Sixmile Lake shoreline was surveyed in kayak from May 28 to June 2, 2008 to document signs of nutrient pollution. On a first pass around the lake, all shoreline parcels were photographed with a digital GPS camera and property features were noted. On a second pass, shoreline conditions were surveyed by traveling as close to the shoreline as possible (usually within 20 feet) and noting *Cladophora* growth, substrate type, erosion, greenbelt length, greenbelt depth, tributaries, shoreline alterations, and nearshore aquatic plant densities. All information was recorded on field data sheets, subsequently inputted into a database, and used in conjunction with GPS data to link field data and photographs with property owner (equalization) data.

Field Survey Parameters

Shoreline property features were documented by taking pictures with a Ricoh Caplio Pro G3 GPS camera and by noting physical features on a data sheet, such as building descriptions, public access sites, and county road endings. Due to data sheet space limits, building descriptions were recorded in an abbreviated cryptic style. For example, *Red 2 sty, brn rf, wht trm, fldstn chim, lg pine* means that the property has a red two-story house with a brown roof, white trim, fieldstone chimney, and a large pine tree in the yard. Whenever possible, names of property owners and addresses were included.

Developed parcels were noted on field data sheets and included as a separate column in the database. Properties described as developed indicate the presence of buildings or other significant permanent structures, including roadways, boat launching sites, and recreational properties (such as parks with pavilions and parking lots). Properties with only mowed or cleared areas, seasonal structures (such as docks or travel trailers), or unpaved pathways were not considered developed. Additionally, large parcels that had structures in an area far from the water's edge were not considered developed. The length and area of developed versus undeveloped shoreline was not calculated.

Many species of filamentous green algae are commonly found growing in the nearshore regions of lakes. Positive identification of these species usually requires the aid of a microscope. However, *Cladophora* usually has an appearance and texture that is quite distinct to a trained surveyor, and these were the sole criteria upon which identification was based. Other species of filamentous green algae can respond to an external nutrient source in much the same way as *Cladophora*, though their value as an indicator species is not thought to be as reliable. When other species occurred in especially noticeable, large, dense growths, they were recorded on the data sheets and described the same as those of *Cladophora*.

When *Cladophora* was observed, it was described in terms of the length of shoreline with growth, the relative growth density, and any observed shoreline features potentially contributing to the growth. For example, “MHx30 – seeps” denotes a moderate to heavy growth that covered 30’ of the shoreline and with groundwater seeps in the area that may have been contributing to the growth. Both shoreline length and growth density are subjective estimates. Growth density is determined by estimating the percentage of substrate covered with *Cladophora* using the following categorization system:

Table 3. Categorization system for *Cladophora* density.

Density Category	Field Notation	Substrate Coverage
Very Light	(VL)	0% *
Light	(L)	1- 20%
Light to Moderate	(LM)	21-40%
Moderate	(M)	41-60%
Moderate to Heavy	(MH)	61-80%
Heavy	(H)	81-99%
Very Heavy	(VH)	90-100% *

**Very Light is noted when a green shimmer is noticed on hard substrate, but no filamentous growth present. Very Heavy overlaps with heavy and is distinguished by both high percentage of substrate coverage and long filamentous growth.*

Among other things, the distribution and size of each *Cladophora* growth is dependent on the amount of suitable substrate present. The extent of suitable substrate should therefore be taken into account when interpreting the occurrence of individual growths, and assessing the overall distribution of *Cladophora* along a particular stretch of shoreline. Substrate types were noted during the survey, using the following abbreviations: m = soft muck or marl, s = sand, g = gravel (0.1" to 2.5" diameter), r = rock (2.5" to 10" diameter), b = boulder (>10" diameter), and w = woody debris. Substrate suitable for *Cladophora* growth include the g, r, b, and w types. However, the extent of suitable substrate along a shoreline parcel in terms of distance was not documented.

Erosion was noted based on shoreline areas that exhibited: areas of bare soil, leaning or downed trees, exposed tree roots, undercut banks, slumping hunks of sod, excessive deposits of sediments, or muddy water. Similar to *Cladophora*, shoreline erosion was recorded on field data sheets with estimates of its extent and relative severity (light, moderate, or heavy/severe). For example "Mx20" indicated 20 feet of shoreline with moderate erosion. Additional information about the nature of the erosion, such as potential causes, were also noted.

Greenbelts were rated based on the length of shoreline with a greenbelt and the average depth of the greenbelt from the shoreline into the property. Ratings ranged from zero to four and were based on the following.

Length	0: None, 1: <25%, 2: 25-75%, 3: >75%
Depth	0: None, 1: <10 ft, 2: 10-40 ft, 3: >40 ft

Greenbelt ratings for length and depth were summed to produce an overall greenbelt score.

Tributaries were noted on the field data sheets and included in a separate column in the database. Locations of some of the bigger streams were also recorded with a GPS.

Aquatic plant populations in front of shoreline parcels were surveyed and plant densities were recorded using the same categorization system used for *Cladophora* (i.e., VL, L, LM, M, MH, H, and VH). Although subjective, categorization provided the necessary information to determine which shoreline areas had dense and potentially problematic aquatic plant growth. Aquatic plant species were not recorded during this survey.

Additional information regarding shoreline property features or shoreline conditions written on field data sheets was included in the database in a "comments" column. The comments column also included notes about shoreline alterations. Shoreline alterations (structures) were noted with the following abbreviated descriptions:

SB = steel bulkhead (i.e., seawall)
CB = concrete bulkhead
WB = wood bulkhead
BB = boulder bulkhead
RR = rock rip-rap
BH = permanent boathouse
DP = discharge pipe

Sometimes abbreviations were mixed or vary from what is listed above.

Stream Monitoring

Due to concerns about nutrient loading from inlet tributaries, the Sixmile Lake Association arranged for water samples and discharge measurements to be collected from the Dingman River. In June of 2008, water samples were collected and sent to the University of Michigan Biostation where they were analyzed to determine nutrient (total phosphorus, orthophosphates, total nitrogen, and nitrate-nitrogen) and chloride concentrations. Discharge data were collected using a Marsh-McBirney flow velocity meter. Stream width, water depth, and flow velocity measurements were recorded along a transect across the river. Discharge and nutrient concentration data were used to determine nutrient loads in pounds per day.

Data Processing

Upon completing field work, all field data were transferred to computer. Information recorded on field data sheets was inputted into a Microsoft Excel® workbook. Digital photographs and GPS data were uploaded to a computer at the Watershed Council office and processed for use.

Maps were developed and field data linked to Charlevoix and Antrim County equalization data by using GPS data collected in the field and a Geographical Information System (GIS). Parcel map data layers acquired from the county GIS departments were used with a Sixmile Lake shoreline layer to produce a new map layer to display survey data in relation to shoreline parcels. Using GPS field data for guidance, and working in a GIS, field data were linked to the new display layer. This data layer was overlaid with other GIS data from the State of Michigan to produce the maps contained in this report.

Final products include a comprehensive database, a complete set of digital GPS photographs, and a GIS data layer representing shoreline parcels and including both county equalization and shore survey data. The shoreline survey database contains a sequential listing of properties beginning at the Michigan Department of Natural Resources (MDNR) boat launch on the southeast side of the lake and traveling counter-clockwise around the entire perimeter of the lake. The database contains all data collected in the field and identification numbers in the database correspond to those in the GIS data layer and on the hard-copy map. Digital photographs were named using the same identification numbers and are linked to the GIS data layer.

RESULTS

This survey documented shoreline conditions at 296 parcels on Sixmile Lake. Some portion of the shoreline was developed at 195 of these parcels (66%). Field data were connected to county parcel data with the aid of GPS photos in a GIS, which allows shoreline conditions documented during the survey to be referenced by parcel identification number or parcel owner name. However, there may be some errors wherein field data was not linked to the appropriate parcel.

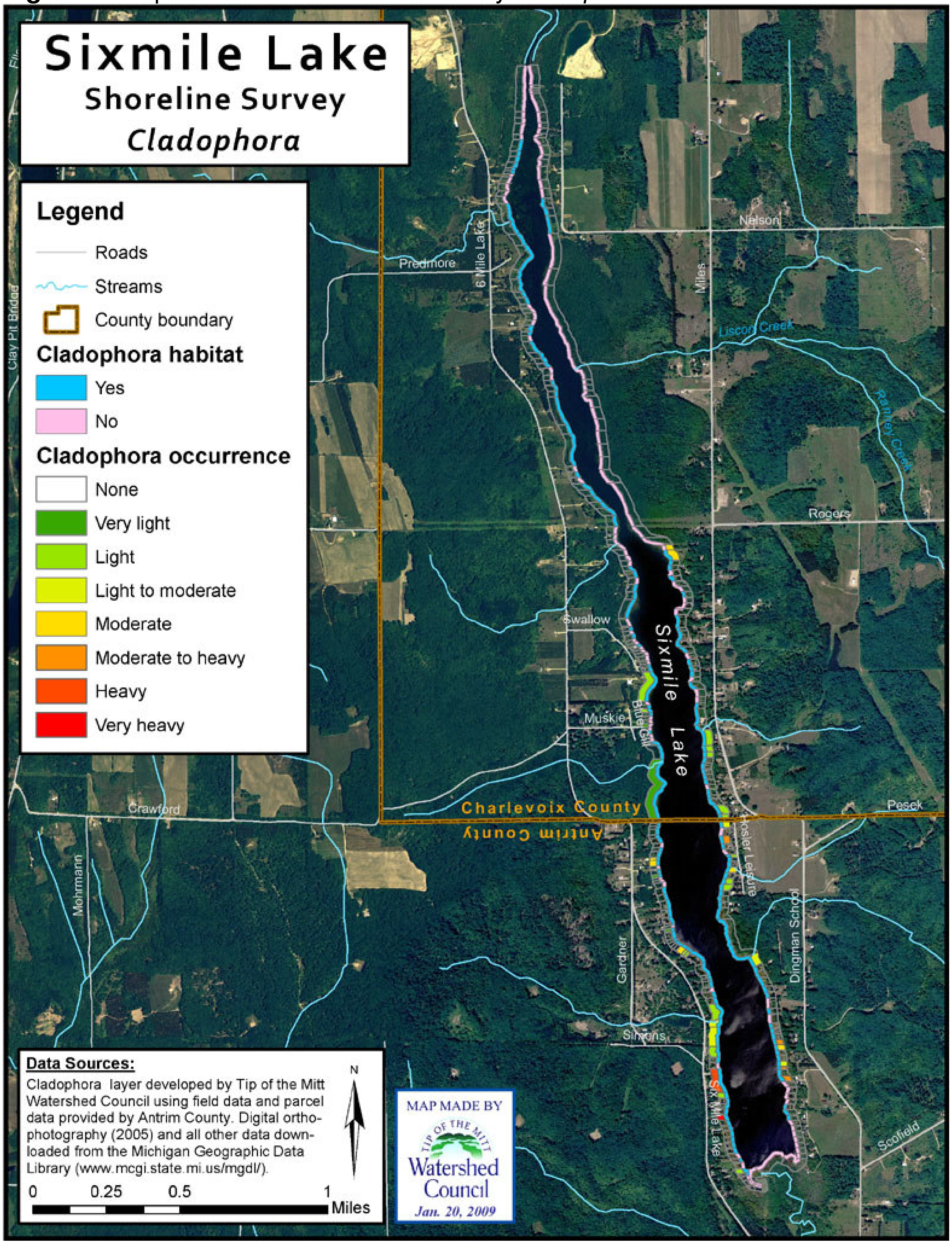
Habitat generally considered suitable for *Cladophora* growth was present along at least part of the shoreline of 177 properties (60%). Noticeable growths of *Cladophora* or other filamentous green algae were found along the shoreline of 40 parcels (14% of the total or 23% of properties with suitable habitat). At properties where *Cladophora* growth was observed, the majority consisted of light and very light growths (Table 4). Only 2 parcels (5%) had growth in the heavy or very heavy categories. Most of the *Cladophora* growths were associated with developed shoreline properties (~88%), though growths were also noted at five undeveloped properties.

Table 4. *Cladophora* density statistics.

***Cladophora* Density**	**Parcels**	**Percent**
Very light to light	22	55
Light-moderate to moderate-heavy	16	40
Heavy to very heavy	2	5

Maps made using GPS data and GIS software were reviewed to determine patterns in the occurrence of *Cladophora* growth (Figure 4). The majority of *Cladophora* occurred in the southern half of the lake and moderate to heavy growth was more prevalent in the southern end. *Cladophora* habitat availability was greater in the southern end, where there was more residential development and shoreline alterations. Although parameters surveyed indicate that nutrient pollution is occurring, factors such as wind, wave action, currents,

Figure 4. Map of Sixmile Lake shore survey *Cladophora* results.



and groundwater paths make it difficult to definitively determine pollution sources.

A total of 61 tributary streams were documented during the survey. Of these, the majority were very small, likely originating from nearby groundwater seeps. The largest inlet stream, Dingman River, enters Sixmile Lake in the southern end, supplying the greatest quantity of water and therefore, potentially the greatest quantity of nutrients to the lake. Data show that dissolve oxygen levels were just below the State standard for cold-water fisheries of 7 mg/l, but values for all other parameters measured were typical for this region (Table 5). Based on data from this single monitoring event, it appears that the Dingman River does not contribute excessive nutrients.

Table 5. Dingman River monitoring data.

Parameter	**Values***	**Load (lbs/day)†**	**Load (lbs/year)†**
Orthophosphate ($PO4^-$)	3.70	0.65	236.25
Total phosphate	10.00	0.24	87.41
Nitrate ($NO3^-$)	233.50	21.62	7890.61
Total nitrogen	334.00	15.11	5516.34
Chloride (CL^-)	5.50	---	---
Dissolved oxygen	6.97	---	---
Conductivity	332.50	---	---
pH	7.40	---	---

**concentrations of nutrients measured in ug/l (parts per billion), chloride and dissolved oxygen measured in mg/l (parts per million), and conductivity in microSiemens/centimeter.*
†discharge = 12.0 cubic feet/second.

Erosion was noted along the shoreline at 32 parcels (11%). Just over half of the erosion areas were categorized as light and less than 10% were heavy. The majority of erosion sites (>90%) occurred in the southern, more developed, part of the lake (south of Rogers Road and the power lines).

Greenbelts along the Sixmile Lake shoreline were found to be in good condition at nearly half of lakeside parcels (Table 6). Scores ranged from 0 (little to no greenbelt) to 6 (exemplary greenbelt). Over 40% of the parcels received the highest score and an additional ~7% were considered to be in good shape. Nearly 20% of parcels were in the moderate rankings (score = 3 to 4) and approximately 34% were classified as poor (score = 0 to 2). In general, parcels with high greenbelt scores were undeveloped. Over 70% of parcels receiving the highest score were undeveloped compared to 7% undeveloped for parcels with the lowest score. Overall, the north half of the lake had the best greenbelts, though there were good greenbelts along several shoreline areas in the southern half (Figures 5 and 6).

Table 6. Greenbelt scores and relationship to shoreline development.

Greenbelt Score*	Number of Parcels	Percent of Parcels	Percent Undeveloped
0	44	15.17	6.82
2	55	18.97	7.27
3	23	7.93	8.70
4	35	12.07	0.00
5	20	6.90	20.00
6	119	41.03	73.11

**greenbelt scores ranged from 0 (poor) to 6 (excellent).*

Aquatic plant densities in front of shoreline parcels ranged from moderate to heavy throughout most of Sixmile Lake. Data from the survey show moderate to heavy growth in front of nearly 65% of shoreline parcels (Table 7). Spatially, the moderate to heavy plant growth occurred in the north half and southeast corner of the lake (Figures 5 and 6). Eurasian watermilfoil (*Myriophyllum spicatum*), an invasive aquatic plant, was found in a few locations on the east side of the lake, to the north of the DNR boat launch.

Table 7. Aquatic plant density statistics.

Plant Density	Number of Parcels	Percent of Parcels
VL	41	14.14
L	47	16.21
LM	20	6.90
M	44	15.17
MH	55	18.97
H	89	30.69

Some form of shoreline alteration was noted at 30% of properties surveyed (Table 8). Approximately half of shoreline alterations consisted of riprap. All but four shoreline alterations were documented in the southern half of the lake.

Table 8. Shoreline alteration statistics.

Alteration Type	Number of Parcels	Percent of Parcels
Riprap	45	15.20
Big boulder	2	0.68
Concrete bulkhead	2	0.68
Wood bulkhead	9	3.04
Steel bulkhead	1	0.34
Beach sand	7	2.36
Mixed	25	8.45
None	205	69.26

Figure 5. Map of greenbelt and aquatic plant results, north Sixmile Lake.

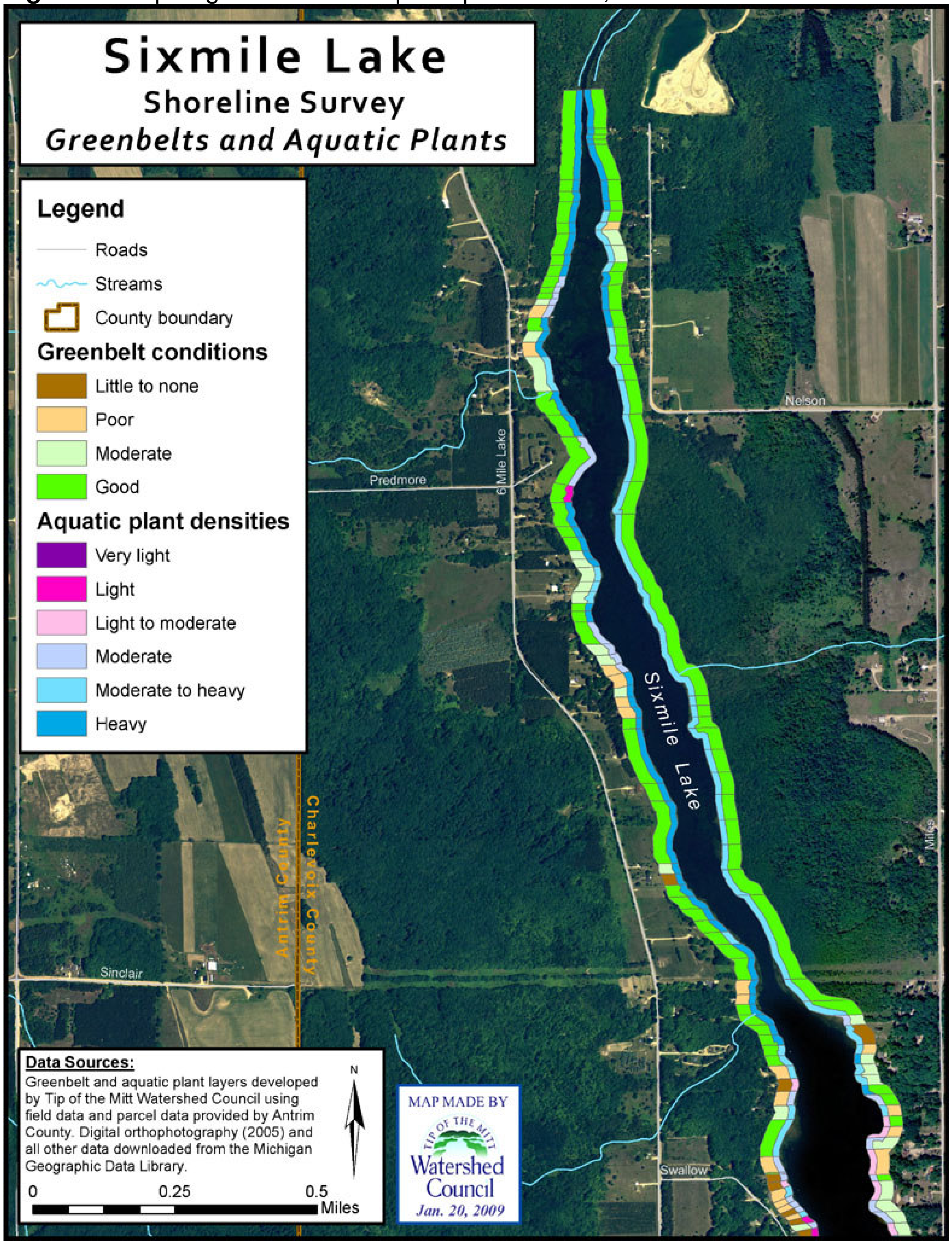
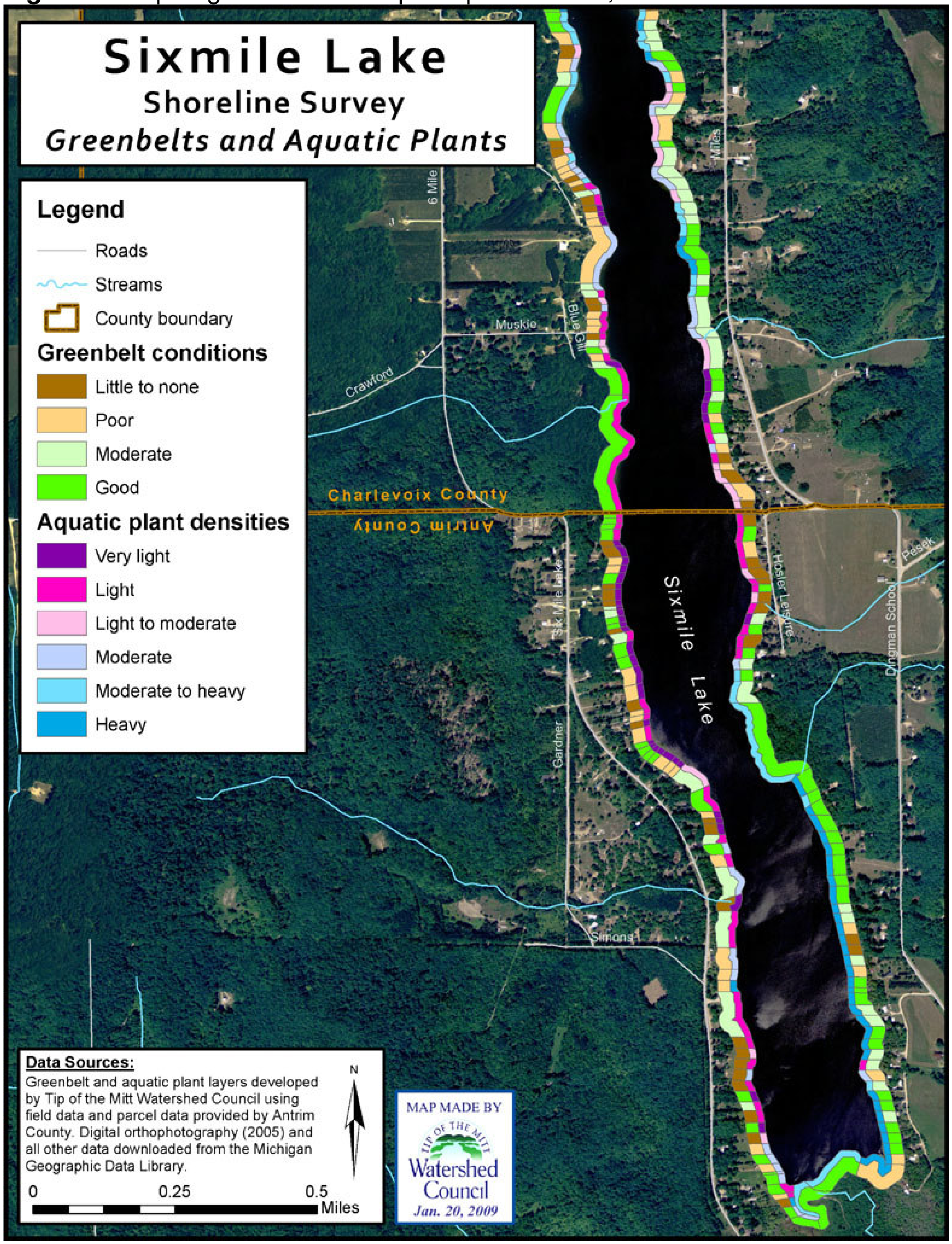


Figure 6. Map of greenbelt and aquatic plant results, south Sixmile Lake.



DISCUSSION

Survey results indicate that water quality impacts from human activity are occurring primarily in the southern half of the Sixmile Lake. The majority of *Cladophora* occurrences, erosion, poor greenbelts and altered shorelines were documented in the southern end of the lake. Furthermore, invasive Eurasian watermilfoil was found in the southern end.

The concentration of shoreline conditions that potentially degrade water quality in the southern end of the lake is not surprising considering development patterns around Sixmile Lake. Shoreline development is much more pronounced in the southern end and long lengths of undeveloped shoreline exist in the northern half. Development of shoreline parcels generally has negative impacts on the water quality of the lake due to a multitude of factors including: 1) loss of vegetation that would otherwise absorb and filter pollutants in stormwater runoff as well as stabilize shoreline areas and prevent erosion, 2) increased impervious surface area such as roofs, driveways and roads, which leads to greater amounts of stormwater runoff and an increase in pollutants associated with roads, and 3) waste and byproducts of human activity such as septic leachate, fertilizers and decomposing yard waste that potentially reach and contaminate the lake water.

There are numerous best management practices that can be utilized during or retroactively after the development of shoreline parcels, which minimize negative impacts to water quality. A buffer of diverse, native plants can be maintained along the shoreline to filter pollutants and reduce erosion. Impacts from stormwater generated from roofs, roads, and driveways can be reduced using rain barrels, rain gardens, grassy swales, and many other techniques. Leachate reaching the lake from septic systems can be minimized by pumping the septic tank regularly, having all components of the septic system inspected regularly and replacing the septic system when necessary. Mulch can be composted far from the shoreline and fertilizers applied sparingly if at all.

Of the shoreline areas showing evidence of potential nutrient pollution, some of the algae growth is undoubtedly associated with septic system leachate or other factors associated with development and human activities, but others are probably due to natural factors. There are numerous streams, springs and seeps flowing into Sixmile Lake at different points along the shoreline that may be delivering nutrients that naturally increase algal growth.

Water quality monitoring programs conducted on Sixmile Lake provide some indication that nutrient pollution is occurring. Nutrient pollution usually results in algal blooms, which decreases water clarity. Data collected in the Tip of the Mitt Watershed Council Volunteer Lake Monitoring Program show that chlorophyll-a concentrations (algal abundance) have increased during the last decade. Conversely, during the same timer period water clarity has increased. Theoretically, other factors such as a reduction in sediments in the water column could be responsible for increased water clarity. Despite somewhat contradictory results, the observed increase in algal biomass provides further evidence that nutrient pollution is occurring and emphasizes the need to control nutrient input sources.

The moderate to heavy aquatic plant growth observed along most of the Sixmile Lake shoreline may also be influenced by nutrient inputs from anthropogenic (human) sources. Like algae, the growth of aquatic macrophytes (more complex aquatic plants) is dependent in part upon the availability of nutrients. Aquatic plants tend to thrive when nutrient inputs increase, particularly with increased phosphorus inputs in the case of Sixmile Lake. The lake areas with the heaviest growth did not co-occur with developed shoreline areas, though dissolved nutrients in the water can spread throughout the lake and supply plants in other areas. Additionally, other factors, such as water depth and proximity to stream inlets, are important in determining areas of heavy aquatic plant growth. Another factor potentially contributing to increased plant growth in Sixmile Lake is the observed increased in water clarity, which allows sunlight to penetrate deeper into the water (probably caused by zebra mussels).

Shoreline greenbelts were quite healthy throughout much of the lake, but there is also a lot of room for improvement. Over 40% of parcels received the highest score from greenbelts, indicating a long and wide buffer of vegetation along the shoreline for these parcels. However, over a third of parcels surveyed fell into the poor greenbelt category and roughly half of these had little to no greenbelt. Improving the quality of greenbelts on these parcels would invariably have positive impacts on the lake's water quality.

Erosion and shoreline alterations were noted on many parcels, but the numbers were not alarming. Only 11% of shoreline parcels showed signs of erosion and few displayed heavy erosion. Approximately 30% of parcels had some type of shoreline alteration with about half of these consisting or riprap, which as far as alterations go is one of the least damaging types in regards to lake ecosystem health. Although the numbers were low, correcting eroded areas, preventing further erosion and limiting or even reducing the quantity of shoreline alterations will benefit the water quality of Sixmile Lake.

Comparisons with the last shoreline survey performed in 2000 indicate that problems associated with shoreline development on Sixmile Lake are worsening. Filamentous algae growth along the shoreline increased from 23 properties in 2000 to 40 properties in 2008, representing a 74% increase. Regarding greenbelts, properties that received a poor rating increased from 23% in 2000 to 34% in 2008. Erosion was only noted at 3 properties during the 2000 survey, increasing to 32 properties in the 2008 survey. Shoreline alterations were not recorded during the 2000 survey and therefore, such comparisons cannot be made. It should be noted that there were some changes in methodologies between the two surveys and that the 2008 survey incorporated the use of GPS and GIS technologies to more accurately track field conditions in relation to parcel delineations. Regardless, there appears to be a trend of increasing water quality impacts as a result of human activity on the Sixmile Lake shoreline.

Recommendations

The full value of a shoreline survey is only achieved when the information is used to educate riparian property owners about preserving water quality, and to help them rectify any problem situations. The following are recommended follow-up actions:

1. Keep the specific results of the survey confidential (i.e., do not publish a list of sites where *Cladophora* algae were found) as some property owners may be sensitive to publicizing information regarding their property.

2. Send a <u>general</u> summary of the survey results to all shoreline residents, along with a packet of informational brochures produced by the Watershed Council and other organizations to provide information about dangers to the lake ecosystem and public health as a result of poor shoreline property management practices as well as practical, feasible, and effective actions to protect water quality.

3. Consider organizing and sponsoring an informational session to present findings of the survey to shoreline residents and provide ideas and options for improving shoreline management practices that would help protect and improve the lake's water quality.

4. Inform owners of properties with *Cladophora* growths of the specific results for their property, ask them to fill out a questionnaire in an attempt to interpret causes of the growth, and offer individualized recommendations for water quality protection. Following the questionnaire survey, property owners have the option to contract the Watershed Council to perform site visits and even conduct ground water testing in an effort to gain more insight into the nature of the findings. Again, it should be stressed that all information regarding names, specific locations, and

findings be kept confidential to encourage property owner participation in this project.

5. Inform owners of properties with poor greenbelt scores and those with eroded shorelines of specific results for their property. Supply these property owners with information (e.g., brochures) regarding the benefits of greenbelts and/or the problems associated with erosion. Encourage property owners to improve greenbelts using a mix of native plants and to correct erosion problems. Property owners have the option to contract the Watershed Council to perform site assessments and carry out projects to improve greenbelts and/or correct erosion problems.

6. Address the Eurasian watermilfoil problem by fully documenting the extent of the infestation and developing a plan for controlling its growth. Ideally, a comprehensive aquatic plant survey should be conducted throughout the entire lake to document locations and areal extent of both invasive and native plant species and communities. At a minimum, the known areas of Eurasian watermilfoil growth should be accurately mapped out, either by lake association members or professionals (Tip of the Mitt Watershed Council staff or other water resource managers) to properly manage the problem, gauge the effectiveness of control treatments, and track changes over time. For Eurasian watermilfoil, the Watershed Council recommends biological control using a native weevil (*Euhrychiopsis lecontei*), which is an environmentally safe and potentially long-term solution. The lake association should contact EnviroScience, Inc. to explore options and make arrangements for biological control using the weevil.

7. Repeat some version of the survey periodically (ideally every 3-5 years), coupled with the follow-up activities described previously, in order to promote water quality awareness and good management practices on an

ongoing basis. During each subsequent survey, more details about shoreline features are added to the database, which can be utilized for other water resource management applications.

8. Verify links made between shore survey results and land parcel data to ensure that information is being properly reported. Shoreline residents can assist the Watershed Council in determining if house descriptions in survey database match correctly with County land owner information. By doing so, property owners will receive the correct information regarding their parcel. This information is also useful for empowering the lake association to monitor shoreline activities, recruit new members, and compile and manage other water resource information.

9. Continue to support the Tip of the Mitt Watershed Council Volunteer Lake Monitoring program by providing volunteer support. The information collected by volunteers is extremely valuable for evaluating long-term trends and determining causes of change in water clarity. The Association is encouraged to continue supplying volunteer help and volunteers should attend training sessions held by the Watershed Council to ensure that a complete set of quality data is being collected each year.

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