Silver Lake
2011 Water Quality Monitoring Report

Water Quality Monitoring

Prepared for:
Silver Lake Improvement Board
c/o Oceana County Drain Commissioner's Office
100 State Street
Hart, MI 49420

Prepared by:
Progressive AE
1811 4 Mile Road, NE
Grand Rapids, MI 49525-2442
616/361-2664

September 2011

Project No: 50740101

progressive | ae

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Introduction

Water quality monitoring of Silver Lake has been conducted on a periodic basis since 1989 to evaluate baseline water quality conditions in the lake. This report contains background information on the various water quality parameters sampled and a discussion of the data collected to date.

Lake water quality is determined by a unique combination of processes that occur both within and outside of the lake. In order to make sound management decisions, it is necessary to have an understanding of the current physical, chemical, and biological condition of the lake, and the potential impact of drainage from the surrounding watershed.

Lakes are commonly classified as oligotrophic, mesotrophic, or eutrophic (Figure 1). Oligotrophic lakes are generally deep and clear with little aquatic plant growth. These lakes maintain sufficient dissolved oxygen in the cool, deep bottom waters during late summer to support cold water fish such as trout and whitefish. By contrast, eutrophic lakes are generally shallow, turbid, and support abundant aquatic plant growth. In deep eutrophic lakes, the cool bottom waters usually contain little or no dissolved oxygen. Therefore, these lakes can only support warm water fish such as bass and pike. Lakes that fall between these two extremes are called mesotrophic lakes.

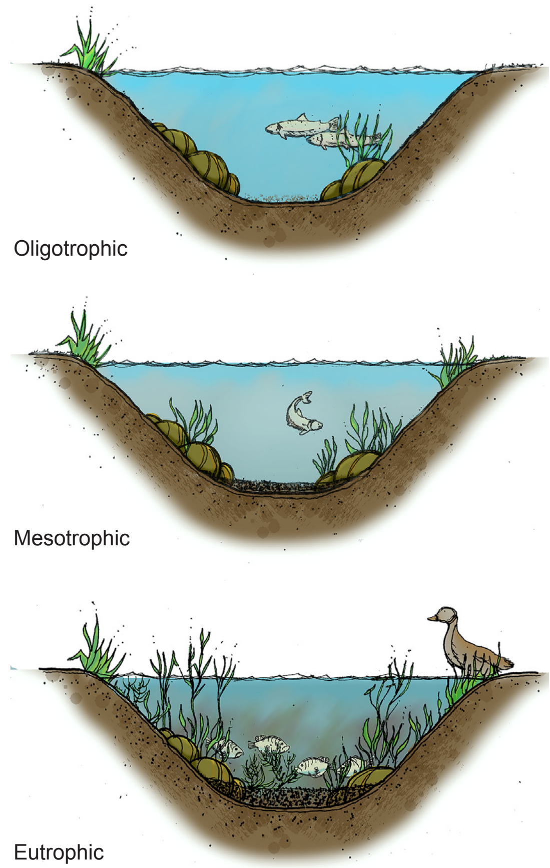

Figure 1. Lake classification.

Under natural conditions, most lakes will ultimately evolve to a eutrophic state as they gradually fill with sediment and organic matter transported to the lake from the surrounding watershed. As the lake becomes shallower, the process accelerates. When aquatic plants become abundant, the lake slowly begins to fill in as sediment and decaying plant matter accumulate on the lake bottom. Eventually, terrestrial plants become established and the lake is transformed to a marshland. The aging process in lakes is called "eutrophication" and may take anywhere from a few hundred to several thousand years, generally depending on the size of the lake and its watershed. The natural lake aging process can be greatly accelerated if excessive amounts of sediment and nutrients (which stimulate aquatic plant growth) enter the lake from the surrounding watershed. Because these added inputs are usually associated with human activity, this accelerated lake aging process is often referred to as "cultural eutrophication." The problem of cultural eutrophication can be managed by identifying sources of sediment and nutrient loading (i.e., inputs) to the lake and developing strategies to halt or slow the inputs. Thus, in developing a management plan, it is necessary to determine the limnological (i.e., the physical, chemical, and biological) condition of the lake and the physical characteristics of the watershed as well. Key parameters used to evaluate the limnological condition of a lake include temperature, dissolved oxygen, total phosphorus, chlorophyll-*a*, and Secchi transparency.

TEMPERATURE

Temperature is important in determining the type of organisms that may live in a lake. For example, trout prefer temperatures below 68°F. Temperature also determines how water mixes in a lake. As the ice cover breaks up on a lake in the spring, the water temperature becomes uniform from the surface to the bottom. This period is referred to as "spring turnover" because water mixes throughout the entire water column. As the surface waters warm, they are underlain by a colder, more dense strata of water. This process is called thermal stratification. Once thermal stratification occurs, there is little mixing of the warm surface waters with the cooler bottom waters. The transition layer that separates these layers is referred to as the "thermocline." The thermocline is characterized as the zone where temperature drops rapidly with depth. As fall approaches, the warm surface waters begin to cool and become more dense. Eventually, the surface temperature drops to a point that allows the lake to undergo complete mixing. This period is referred to as "fall turnover." As the season progresses and ice begins to form on the lake, the lake may stratify again. However, during winter stratification, the surface waters (at or near 32°F) are underlain by slightly warmer water (about 39°F). This is sometimes referred to as "inverse stratification" and occurs because water is most dense at a temperature of about 39°F. As the lake ice melts in the spring, these stratification cycles are repeated (Figure 2). Shallow lakes do not stratify. Lakes that are 15 to 30 feet deep may stratify and destratify with storm events several times during the year.

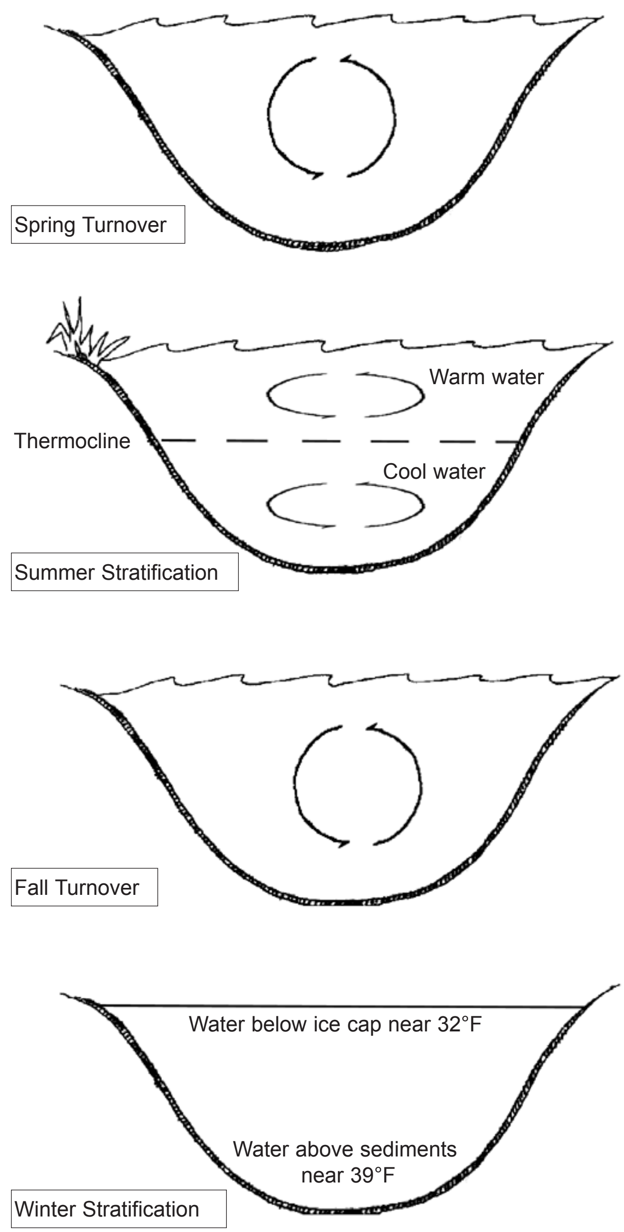

Figure 2. Seasonal thermal stratification cycles.

DISSOLVED OXYGEN

An important factor influencing lake water quality is the quantity of dissolved oxygen in the water column. The major inputs of dissolved oxygen to lakes are the atmosphere and photosynthetic activity by aquatic plants. An oxygen level of about 5 mg/L (milligrams per liter, or parts per million) is required to support warm water fish. In lakes deep enough to exhibit thermal stratification, oxygen levels are often reduced or depleted below the thermocline once the lake has stratified. This is because deep water is cut off from plant photosynthesis and the atmosphere, and oxygen is consumed by bacteria that use oxygen as they decompose organic matter (plant and animal remains) at the bottom of the lake. Bottom-water oxygen depletion is a common occurrence in eutrophic and some mesotrophic lakes. Thus, eutrophic and most mesotrophic lakes cannot support cold water fish because the cool, deep water (that the fish require to live) does not contain sufficient oxygen.

PHOSPHORUS

The quantity of phosphorus present in the water column is especially important since phosphorus is the nutrient that most often controls aquatic plant growth and the rate at which a lake ages and becomes more eutrophic. In the presence of oxygen, lake sediments act as a phosphorus trap, retaining phosphorus and, thus, making it unavailable for aquatic plant growth. However, if bottom-water oxygen is depleted, phosphorus will be released from the sediments and may be available to promote aquatic plant growth. In some lakes, the internal release of phosphorus from the bottom sediments is the primary source of phosphorus loading (or input).

By reducing the amount of phosphorus in a lake, it may be possible to control the amount of aquatic plant growth. In general, lakes with a phosphorus concentration greater than 20 µg/L (micrograms per liter, or parts per billion) are able to support abundant plant growth and are classified as nutrient-enriched or eutrophic.

CHLOROPHYLL-*a*

Chlorophyll-*a* is a pigment that imparts the green color to plants and algae. A rough estimate of the quantity of algae present in lake water can be made by measuring the amount of chlorophyll-*a* in the water column. A chlorophyll-*a* concentration greater than 6 µg/L is considered characteristic of a eutrophic condition.

SECCHI TRANSPARENCY

A Secchi disk is often used to estimate water clarity. The measurement is made by fastening a round, black and white, 8-inch disk to a calibrated line (Figure 3). The disk is lowered over the deepest point of the lake until it is no longer visible, and the depth is noted. The disk is then raised until it reappears. The average between these two depths is the Secchi transparency. Generally, it has been found that aquatic plants can grow at a depth of approximately twice the Secchi transparency measurement. In eutrophic lakes, water clarity is often reduced by algae growth in the water column, and Secchi disk readings of 7.5 feet or less are common.

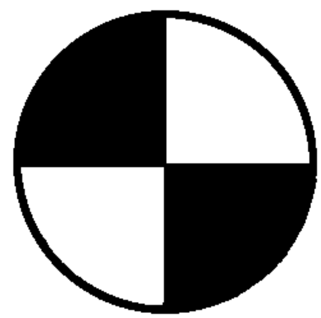

Figure 3. Secchi disk.

Ordinarily, as phosphorus inputs (both internal and external) to a lake increase, the amount of algae the lake can support will also increase. Thus, the lake will exhibit increased chlorophyll-*a* levels and decreased transparency. A summary of lake classification criteria developed by the Michigan Department of Environmental Quality is shown in Table 1.

TABLE 1
LAKE CLASSIFICATION CRITERIA

Lake Classification	Total Phosphorus (µg/L)[1]	Chlorophyll-*a* (µg/L)[1]	Secchi Transparency (feet)
Oligotrophic	Less than 10	Less than 2.2	Greater than 15.0
Mesotrophic	10 to 20	2.2 to 6.0	7.5 to 15.0
Eutrophic	Greater than 20	Greater than 6.0	Less than 7.5

1 µg/L = micrograms per liter = parts per billion.

FECAL COLIFORM BACTERIA

A primary consideration in evaluating the suitability of a lake to support swimming and other water-based recreational activities is the level of bacteria in the water. *Escherichia coli* (*E. coli*) is a bacteria commonly associated with fecal contamination. The current State of Michigan public health standard for total body contact recreation (e.g., swimming) requires that the number of *E. coli* bacteria not exceed 300 per 100 milliliters of water for a single sampling event.

SAMPLING METHODS

Water quality sampling was conducted in the spring and summer of 2011 at the deep basin within Silver Lake (Figure 4). Temperature was measured using a YSI Model 550A probe. Samples were collected at the surface, mid-depth, and just above the lake bottom with a Kemmerer bottle to be analyzed for dissolved oxygen and total phosphorus. Dissolved oxygen samples were fixed in the field and then transported to Progressive AE for analysis using the modified Winkler method (Standard Methods procedure 4500-O C). Total phosphorus samples were placed on ice and transported to Prein and Newhof[1] for analysis using Standard Methods procedure 4500-P E. In addition to the depth-interval samples from the deep basin, Secchi transparency was measured and composite chlorophyll-*a* samples were collected from the surface to a depth equal to twice the Secchi transparency. Chlorophyll-*a* samples were analyzed by Prein and Newhof using Standard Methods procedure 10200 H. Ten samples were collected along the shoreline of Silver Lake on August 8, 2011 and analyzed for fecal coliform bacteria at the Kent County Health Department Laboratory in Grand Rapids.

1 Prein and Newhof Prein and Newhof, 3260 Evergreen Drive, NE, Grand Rapids, MI 49525.

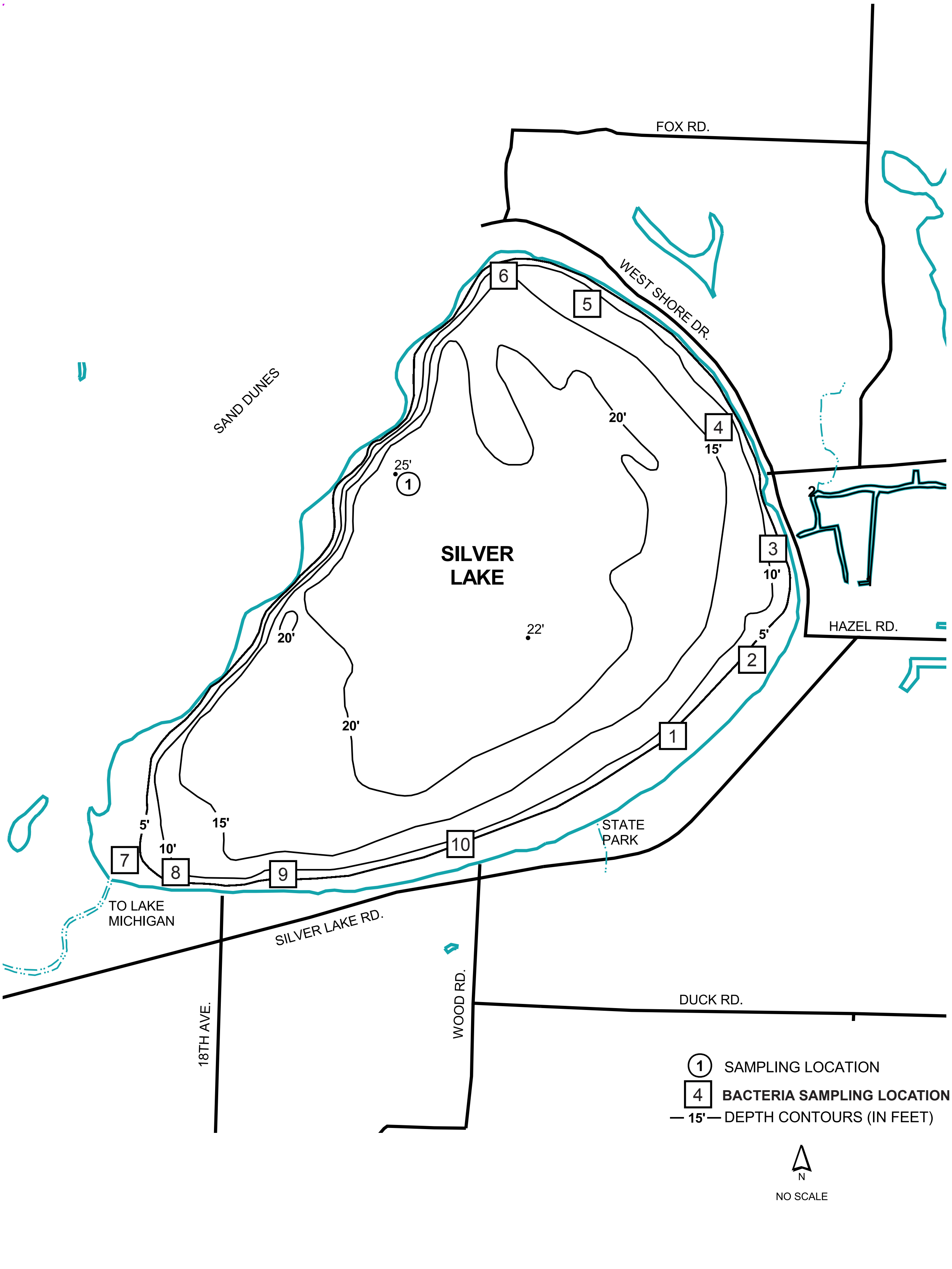

Figure 4. Silver Lake sampling location map.

Sampling Results and Discussion

Water quality sampling results for 2011 are provided in Tables 2 through 4, and descriptive statistics are summarized in Table 5. Historical water quality data collected from Silver Lake is contained in Appendix A and is summarized in Figures 5 through 7.

During both the spring and summer sampling periods in 2011, Silver Lake did not exhibit thermal stratification as water temperatures were nearly uniform from the lake surface to the bottom (Table 2). Temperature and dissolved oxygen data collected to date from Silver Lake indicate that the lake is isothermic and well-oxygenated surface to bottom during ice-free periods (Appendix A). No indication of bottom-water oxygen depletion has been observed in Silver Lake since sampling began in 1989. Dissolved oxygen levels in the lake are sufficient to support warm-water fish throughout the water column; however, the lake is too warm to support cold-water fish species such as trout.

TABLE 2
SILVER LAKE
2011 DEEP BASIN WATER QUALITY DATA

Date	Sample Depth (feet)	Temperature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]
21-Apr-11	1	46	12.0	10
21-Apr-11	10	45	11.5	6
21-Apr-11	20	45	11.5	<5
8-Aug-11	1	80	8.2	43
8-Aug-11	10	79	8.5	35
8-Aug-11	20	79	7.6	26

TABLE 3
SILVER LAKE
2011 SURFACE WATER QUALITY DATA

Date	Station	Secchi Transparency (feet)	Chlorophyll-*a* (µg/L)[2]
21-Apr-11	1	8.5	3
8-Aug-11	1	2.8	6

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.

TABLE 4
SILVER LAKE
2011 BACTERIOLOGICAL DATA

Date	Sample Location	*E. coli* Bacteria (per 100 mL)[1]
8-Aug-11	1	7
8-Aug-11	2	4
8-Aug-11	3	2
8-Aug-11	4	1
8-Aug-11	5	5
8-Aug-11	6	4
8-Aug-11	7	11
8-Aug-11	8	3
8-Aug-11	9	7
8-Aug-11	10	3

TABLE 5
SILVER LAKE
WATER QUALITY SUMMARY STATISTICS, 1989 - 2011

	Total Phosphorus (µg/L)[2]	Secchi Transparency (feet)	Chlorophyll-*a* (µg/L)[2]
Mean	23	7.1	5
Standard deviation	16	3.4	4
Median	20	6.5	3
Minimum	3	2.5	0
Maximum	89	22.0	23
Number of samples	133	38	39

1 mL = milliliter
2 µg/L = micrograms per liter = parts per billion.

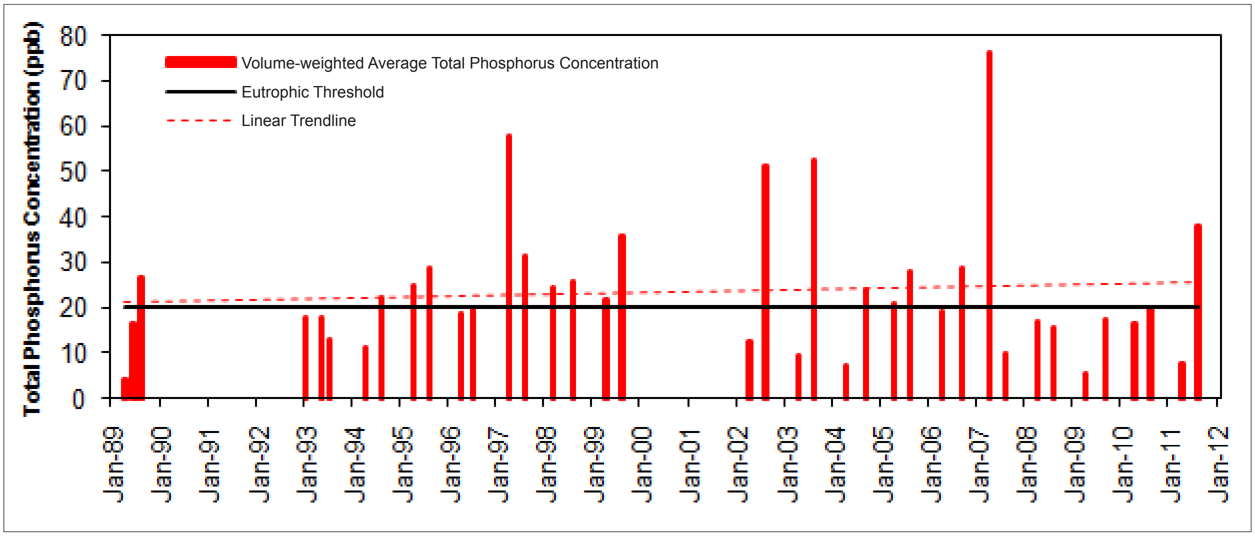

Figure 5. Volume-weighted average total phosphorus concentrations, 1989 - 2011.

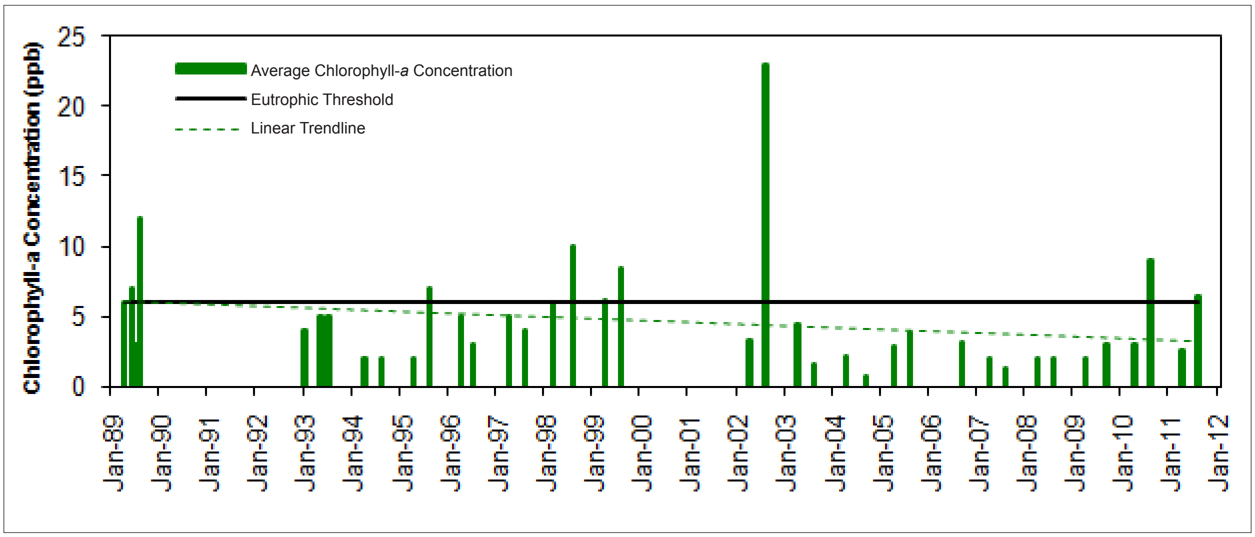

Figure 6. Average chlorophyll-*a* concentrations, 1989 - 2011.

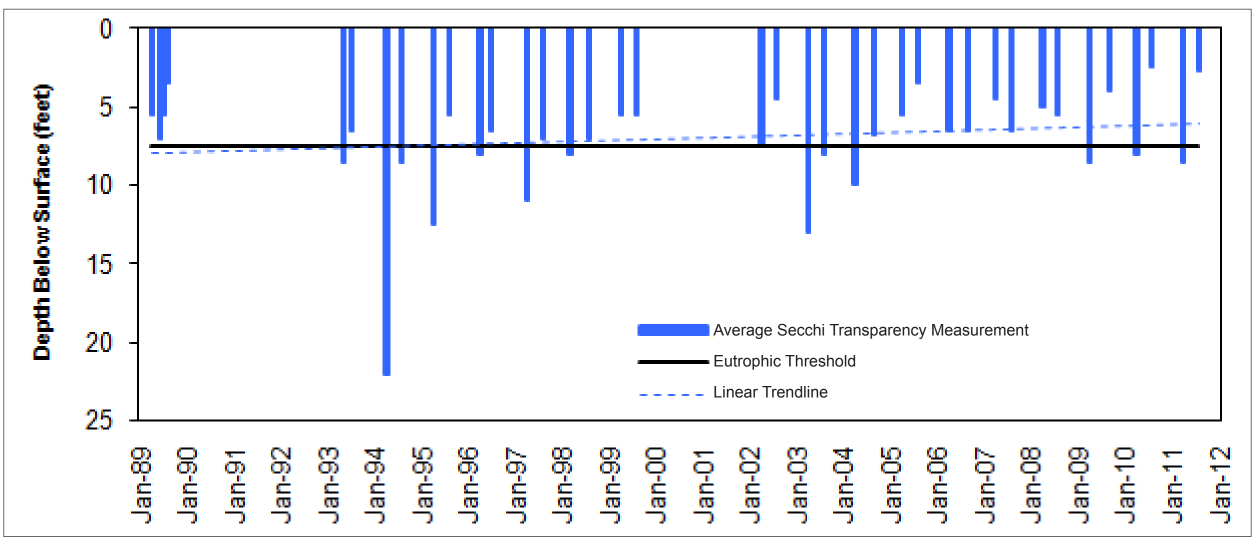

Figure 7. Average Secchi transparency measurements, 1989 - 2011.

During 2011, total phosphorus concentrations in Silver Lake were relatively low in spring and considerably higher in summer (Table 2). The summer increase in phosphorus concentration is a pattern that has been repeated periodically since 1989 (Appendix A). It is possible that these seasonal variations reflect seasonal lake use in which boat traffic (which stirs nutrient-rich bottom sediments) and septic system use increase dramatically during the summer months. The median phosphorus concentration of all data collected to date is 20 parts per billion (ppb), which is at the eutrophic threshold value (Table 1 and Table 5). Since sampling began in 1989, phosphorus levels in Silver Lake have been trending upward (Figure 5). Internal phosphorus loading (in which phosphorus is released from deep lake sediments during periods of oxygen depletion) does not appear significant in Silver Lake.

In 2011, chlorophyll-*a* levels indicate algae growth was moderate in spring and high in summer (Table 3). The high summer chlorophyll-*a* readings coincided with an algae bloom that occurred in the lake in 2011. A similar algae bloom occurred in the summer of 2010 (Appendix A). While the median chlorophyll-*a* value in Silver Lake is below the eutrophic threshold (Table 1 and Table 5) and the overall chlorophyll-*a* level in the lake has trended slightly downward over the years (Figure 6), persistent summer algae blooms occurred in Silver Lake in both 2010 and 2011.

Secchi transparency measurements in 2011 indicate that water clarity was moderate in spring and low in summer (Table 3). The low transparency in Silver Lake during the summer of 2011 was likely the result of algae growth in the lake. Similar to the seasonal variations observed in phosphorus levels, Secchi readings in Silver Lake are generally greater in spring than during the summer months. The median Secchi transparency measured in Silver Lake during the period of sampling is 6.5 feet (Table 5). The generally low transparency measured in Silver Lake may be due, in part, to the constant mixing of the lake. This mixing action promotes the suspension of bottom sediments in the water column and reduces water transparency. Secchi transparency in Silver Lake has decreased since sampling began in 1989.

Fecal coliform bacteria samples collected in August of 2011 from near-shore areas were low indicating no evidence of fecal contamination from waterfowl or septic seepage at that time (Table 5). Historical sampling near developed shoreline areas in Silver Lake has not detected persistent elevated bacteria levels that would preclude swimming and other recreational activities in Silver Lake (Appendix A).

In August of 2011, a substantial fish die-off occurred in Silver Lake, primarily affecting common carp. Dissolved oxygen levels measured on August 8 were 7.7 parts per million or higher (Table 2), and no herbicides were applied to Silver Lake in 2011, therefore it is unlikely the die-off is related to either low oxygen or herbicide use. In some instances, pathogens can cause fish kills. The cause of the die-off is currently being evaluated by the Michigan Department of Natural Resources and Michigan State University.

Based on the data collected to date, Silver Lake is currently classified as meso-eutrophic in that it exhibits elevated phosphorus concentrations, moderate chlorophyll-*a* levels, and low Secchi transparency. However, recent and historical sampling data indicate that Silver Lake is undergoing accelerated eutrophication. If this trend continues, the lake will likely experience increased phosphorus levels, more frequent and prolonged algae blooms, reduced transparency, and a decline in overall water quality.

Conclusions and Recommendations

Given the recent decline in the quality of Silver Lake, a number of initiatives need to be considered to address the problem.

SHORELINE SEPTIC SYSTEMS

The homes, cottages, and businesses around Silver Lake are all served by on-site septic systems. Septic seepage is likely the largest controllable source of phosphorus loading to Silver Lake. The efficacy of septic systems at removing phosphorus and other pollutants from septic effluent is dependent on several variables including soil type, depth to the water table, septic system use frequency, and distance from the lake. According to the Soil Survey of Oceana County, Michigan (United States Department of Agriculture, Natural Resources Conservation Service, and Forest Service 1996), the soils surrounding Silver Lake are primarily Pipestone, Epworth, and Covert sands. The soil survey indicates that these soil types pose severe limitations for septic systems due to poor filtering capability.

Given the close proximity of most lakeside properties to Silver Lake, septic pollutants can readily drain to the lake. Indeed, there is nowhere else for the systems to drain. Eventually, the finite capacity of area soils to retain phosphorus will be exceeded allowing phosphorus and other contaminants to leach to the lake. As more homes in the area are converted from seasonal to year-round use, the problem can be expected to worsen. A community sewer system would eliminate a major source of pollution to Silver Lake.

BOAT TRAFFIC

Boating traffic on Silver Lake is generally heavy. Given the size and speed of today's boats and the fact that Silver Lake has a mean or average depth of only about 15 feet, motor boats can suspend bottom sediments and increase turbidity in the lake. Further, during periods of peak use such as summer weekends and holidays, the lake often becomes congested and overcrowded with boats. To help address these issues, special use restrictions on Silver Lake that limit hours of high-speed boating should be considered.

SHORELAND MANAGEMENT

Much of the development around Silver Lake is concentrated in close proximity to the lake. As this development occurred, many of the natural areas bordering the lake were replaced by roof tops, roads, driveways and other impervious surfaces. Water that once infiltrated into the ground now runs off these hard surfaces directly to the lake. In the first-ever nationwide assessment of lakes, the United States Environmental Protection Agency evaluated several stressors of lakes, and found that loss of shoreline habitat was the biggest problem facing the nation's lakes (USEPA 2010). Lakes with poor shoreline habitat were three times more likely to be in poor biological condition. For a lake property owner, these are extremely important findings and underscore the need to properly manage lakefront property. A number of steps lakefront property owners can take to protect the lake are discussed in Appendix B.

WATERSHED MAPPING

It is recommended that detailed maps of the Silver Lake watershed be created so that soils, surface drainage patterns, land cover, topography and the influence of watershed drainage on the quality of Silver Lake can be better evaluated.

MONITORING

Water quality monitoring performed to date has been helpful in evaluating baseline water quality conditions in Silver Lake and general trends in water quality. However, given the decline in several key water quality indicators in Silver Lake, it is recommended that the water quality monitoring program in Silver Lake be expanded to include monthly dissolved oxygen and bacteria sampling (May through August) tributary sampling, identification of dominant algal types in the lake, and measurements of lake chloride levels.

Appendix A
Silver Lake
Historical Water Quality Data

TABLE A1
SILVER LAKE
DEEP BASIN WATER QUALITY DATA, 1989-2010

Date	Sampling Station	Sample Depth (feet)	Temper-ature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]	pH (S.U.)[3]	Total Alkalinity (mg/L as $CaCO_3$)[4]
26-Apr-89	1	1	54.0	11.1	6	8.5	132
26-Apr-89	1	9	53.5	11.2	3	8.5	137
26-Apr-89	1	18	52.5	11.1	3	8.3	126
26-Apr-89	2	1	52.5	11.1	8	8.7	126
26-Apr-89	2	5	52.5	0.0	5		
26-Apr-89	2	10	52.0	10.8	4	8.4	134
26-Apr-89	2	15	52.0	0.0	3		
26-Apr-89	2	20	50.5	9.2	6	8.3	138
08-Jun-89	1	1	70.0	10.3	14	8.9	146
08-Jun-89	1	10	68.5	10.0	18	8.5	137
08-Jun-89	1	20	64.0	8.2	20	8.6	130
08-Jun-89	2	1	68.0	9.6	19	8.9	140
08-Jun-89	2	10	68.0	9.9	22	8.9	142
08-Jun-89	2	20	64.0	8.5	23	8.7	135
10-Jul-89	1	1	76.0	8.2	12	8.4	127
10-Jul-89	1	10	76.0	8.1	10	8.3	126
10-Jul-89	1	18	75.5	7.8	11	8.4	112
10-Jul-89	2	1	76.0	8.7	10	8.3	126
10-Jul-89	2	10	75.5	7.7	10	8.4	124
10-Jul-89	2	19	75.0	7.8	10	8.3	118
29-Aug-89	1	1	73.0	9.4	26		
29-Aug-89	1	10	72.0	8.8	28		
29-Aug-89	1	20	72.0	8.4	24		
29-Aug-89	2	1	72.5	9.1	24		
29-Aug-89	2	12	72.0	9.2	29		
29-Aug-89	2	18	71.5	8.0	25		
21-Jan-93	1	1	32.0	14.5	17		133
21-Jan-93	1	10	32.5	14.2	19		131
21-Jan-93	1	20	34.0	13.0	17		138

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.
3 S.U. = standard units.
4 mg/L $CaCO_3$ = micrograms per liter as calcium carbonate.

TABLE A1 (continued)
SILVER LAKE
DEEP BASIN WATER QUALITY DATA, 1989-2010

Date	Sampling Station	Sample Depth (feet)	Temper- ature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]	pH (S.U.)[3]	Total Alkalinity (mg/L as $CaCO_3$)[4]
05-May-93	1	1	53.0	11.0	17		109
05-May-93	1	10	53.0	11.0	19		110
05-May-93	1	20	53.0	10.9	17		106
27-Jul-93	1	1	73.0	9.1	15		128
27-Jul-93	1	10	73.0	8.6	10		127
27-Jul-93	1	20	73.0	6.5	17		131
26-Apr-94	1	1	54.0	9.8	8		109
26-Apr-94	1	10	54.0	9.9	12		130
26-Apr-94	1	21	52.5	9.8	24		130
22-Aug-94	1	1	72.0	8.3	22		110
22-Aug-94	1	10	70.0	8.0	22		126
22-Aug-94	1	20	70.0	8.0	25		137
11-Apr-95	1	1	41.0	12.2	29		
11-Apr-95	1	10	40.0	12.1	23		
11-Apr-95	1	20	40.0	12.0	15		
18-Aug-95	1	1	78.0	8.2	28		
18-Aug-95	1	10	78.0	8.2	30		
18-Aug-95	1	20	77.5	7.7	25		
18-Apr-96	1	1	47.0	11.8	20		
18-Apr-96	1	10	47.0	12.0	18		
18-Apr-96	1	20	46.5	12.2	17		
30-Jul-96	1	1	66.5	8.5	17		
30-Jul-96	1	10	67.0	8.5	19		
30-Jul-96	1	19	67.0	8.4	35		
29-Apr-97	1	1	48.0	10.7	80		
29-Apr-97	1	10	48.0	11.1	43		
29-Apr-97	1	20	48.0	10.8	20		

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.
3 S.U. = standard units.
4 mg/L $CaCO_3$ = micrograms per liter as calcium carbonate.

TABLE A1 (continued)
SILVER LAKE
DEEP BASIN WATER QUALITY DATA, 1989-2010

Date	Sampling Station	Sample Depth (feet)	Temper-ature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]	pH (S.U.)[3]	Total Alkalinity (mg/L as $CaCO_3$)[4]
01-Aug-97	1	1	75.0	8.0	20		
01-Aug-97	1	10	75.0	8.0	46		
01-Aug-97	1	20	75.0	8.0	13		
30-Mar-98	1	1	48.0	13.0	19		
30-Mar-98	1	10	48.0	12.2	30		
30-Mar-98	1	19	48.0	12.3	21		
20-Aug-98	1	1	75.0	8.6	15		
20-Aug-98	1	10	74.0	8.7	34		
20-Aug-98	1	20	73.5	8.7	37		
19-Apr-99	1	1	48.5	11.2	25		
19-Apr-99	1	10	48.5	12.3	19		
19-Apr-99	1	20	48.5	12.0	19		
12-Aug-99	1	1	75.0	10.0	35		
12-Aug-99	1	10	74.5	9.8	38		
12-Aug-99	1	20	73.0	9.5	31		
8-Apr-02	1	1	37.8	12.0	11		
8-Apr-02	1	10	37.8	12.0	13		
8-Apr-02	1	20	37.9	12.0	21		
29-Aug-02	1	1	74.5	8.9	48		
29-Aug-02	1	10	73.9	8.0	55		
29-Aug-02	1	20	73.8	7.7	46		
14-Apr-03	1	1	44.8	8.2	5		
14-Apr-03	1	10	44.6	8.1	13		
14-Apr-03	1	20	44.4	7.8	12		
26-Aug-03	1	1	75.7	7.1	48		
26-Aug-03	1	10	75.7	7.1	56		
26-Aug-03	1	20	75.7	7.2	60		

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.
3 S.U. = standard units.
4 mg/L $CaCO_3$ = micrograms per liter as calcium carbonate.

TABLE A1 (continued)
SILVER LAKE
DEEP BASIN WATER QUALITY DATA, 1989-2010

Date	Sampling Station	Sample Depth (feet)	Temper-ature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (µg/L)[2]	pH (S.U.)[3]	Total Alkalinity (mg/L as $CaCO_3$)[4]
6-Apr-04	1	1	43.5	10.4	<6		132
6-Apr-04	1	10	43.7	10.4	<6		
6-Apr-04	1	20	43.7	10.4	19		
7-Sep-04	1	1	71	7.8	25		
7-Sep-04	1	10	71	7.6	21		
7-Sep-04	1	20	71	7.3	34		
28-Apr-05	1	1	49	12.0	22		
28-Apr-05	1	10	49	11.6	20		
28-Apr-05	1	20	49	11.8	20		
31-Aug-05	1	1	74	8.4	23		
31-Aug-05	1	10	74	8.5	33		
31-Aug-05	1	20	73	7.5	26		
28-Apr-05	1	1	49	12.0	22		
28-Apr-05	1	10	49	11.6	20		
28-Apr-05	1	20	49	11.8	20		
31-Aug-05	1	1	74	8.4	23		
31-Aug-05	1	10	74	8.5	33		
31-Aug-05	1	20	73	7.5	26		
18-Apr-06	1	1	51	9.9	16		
18-Apr-06	1	10	51	10.0	21		
18-Apr-06	1	20	51	10.5	26		
6-Sep-06	1	1	73	9.6	31		
6-Sep-06	1	10	72	10.0	26		
6-Sep-06	1	20	72	5.8	35		

1 mg/L = milligrams per liter = parts per million.
2 µg/L = micrograms per liter = parts per billion.
3 S.U. = standard units.
4 mg/L $CaCO_3$ = micrograms per liter as calcium carbonate.

TABLE A1 (continued)
SILVER LAKE
DEEP BASIN WATER QUALITY DATA, 1989-2010

Date	Sampling Station	Sample Depth (feet)	Temper-ature (°F)	Dissolved Oxygen (mg/L)[1]	Total Phosphorus (μg/L)[2]	pH (S.U.)[3]	Total Alkalinity (mg/L as $CaCO_3$)[4]
24-Apr-07	1	1	51	12.0	63		
24-Apr-07	1	10	51	8.6	89		
24-Apr-07	1	20	50	11.0	76		
23-Aug-07	1	1	72	9.0	9		
23-Aug-07	1	10	72	9.3	12		
23-Aug-07	1	20	71	7.8	5		
22-Apr-08	1	1	55	11.8	16		
22-Apr-08	1	10	55	12.2	19		
22-Apr-08	1	20	51	12.0	12		
4-Aug-08	1	1	80	7.8	7		
4-Aug-08	1	10	78	8.0	26		
4-Aug-08	1	20	78	7.0	<5		
20-Apr-09	1	1	48	11.3	5		
20-Apr-09	1	10	48	11.2	<5		
20-Apr-09	1	20	48	11.7	12		
1-Sep-09	1	1	68	10.7	19		
1-Sep-09	1	10	67	10.0	10		
1-Sep-09	1	20	66	8.3	51		
5-Apr-10	1	1	51	10.7	24		
5-Apr-10	1	10	51	10.5	11		
5-Apr-10	1	19	50	10.3	8		
24-Aug-10	1	1	77	10.4	27		
24-Aug-10	1	10	77	8.2	<5		
24-Aug-10	1	20	76	8.1	60		

1 mg/L = milligrams per liter = parts per million.
2 μg/L = micrograms per liter = parts per billion.
3 S.U. = standard units.
4 mg/L $CaCO_3$ = micrograms per liter as calcium carbonate.

TABLE A2
SILVER LAKE
SURFACE WATER QUALITY DATA, 1989-2010

Date	Station	Secchi Transparency (feet)	Chlorophyll-*a* (µg/L)[1]
26-Apr-89	1	5.5	6
26-Apr-89	2	5.5	4
08-Jun-89	1	7.0	7
08-Jun-89	2	5.5	6
10-Jul-89	1	5.5	3
10-Jul-89	2	5.5	3
29-Aug-89	1	3.5	12
29-Aug-89	2	3.5	10
23-Jan-93	1		4
05-May-93	1	8.5	5
27-Jul-93	1	6.5	5
26-Apr-94	1	22.0	2
22-Aug-94	1	8.5	2
11-Apr-95	1	12.5	2
18-Aug-95	1	5.5	7
18-Apr-96	1	8.0	5
30-Jul-96	1	6.5	3
29-Apr-97	1	11.0	5
01-Aug-97	1	7.0	4
30-Mar-98	1	8.0	6
20-Aug-98	1	7.0	10
14-Apr-99	1	5.5	6
12-Aug-99	1	5.5	8
8-Apr-02	1	7.5	3
29-Aug-02	1	4.5	23
14-Apr-03	1	13.0	5
26-Aug-03	1	8.0	2
6-Apr-04	1	10.0	2
7-Sep-04	1	6.8	1
28-Apr-05	1	5.5	3
31-Aug-05	1	3.5	4

1 µg/L = micrograms per liter = parts per billion.

TABLE A2 (continued)
SILVER LAKE
SURFACE WATER QUALITY DATA, 1989-2010

Date	Station	Secchi Transparency (feet)	Chlorophyll-*a* (µg/L)[1]
18-Apr-06	1	6.5	0
6-Sep-06	1	6.5	3
24-Apr-07	1	4.5	2
23-Aug-07	1	6.5	1
17-Apr-08	1	5.0	2
4-Aug-08	1	5.5	2
20-Apr-09	1	8.5	2
1-Sep-09	1	4.0	3
5-Apr-10	1	8.0	3
24-Aug-10	1	2.5	9

1 µg/L = micrograms per liter = parts per billion.

TABLE A3
SILVER LAKE
BACTERIOLOGICAL SAMPLING DATA, 1989-2010

Date	Sample Location	*E. coli* Bacteria (per 100 mL)
27-Jun-89	East shore, 2000 feet north of outlet	10
27-Jun-89	East shore, 750 feet north of outlet	10
27-Jun-89	East shore, 1500 feet north of outlet	10
27-Jun-89	East shore, 2500 feet north of outlet	10
27-Jun-89	East shore, 1500 feet south of SP.	10
27-Jun-89	East shore, 1000 feet south of SP.	10
27-Jun-89	Near access	10
27-Jun-89	State Park (SP.)	10
27-Jun-89	East shore, 500 feet north of SP.	10
27-Jun-89	Near marina	10
27-Jun-89	West shore, 2000 feet north of outlet	10
27-Jun-89	East shore, 1000 feet north of outlet	10
27-Jun-89	East shore near Hunter Creek (HC)	10
27-Jun-89	Wetland near outlet	10
27-Jun-89	West shore, 5000 feet north of outlet	10
27-Jun-89	Northwest corner of lake	10
27-Jun-89	North shore, 300 feet east of dunes	10
27-Jun-89	North shore, 800 feet east of dunes	10
27-Jun-89	North shore, 1300 feet east of dunes	10
27-Jun-89	North shore, 500 feet north of Hunter Creek	10
10-Jul-89	North shore, 500 feet east of dunes	10
10-Jul-89	Southwest corner of lake	10
10-Jul-89	East shore, 500 feet north of SP.	10
10-Jul-89	North shore, 1500 feet east of dunes	10
10-Jul-89	North shore, 750 feet north of Hunter Creek	10
10-Jul-89	East shore, 100 feet north of Hunter Creek	10
10-Jul-89	Near Hunter Creek	80
10-Jul-89	North shore, 1000 feet east of dunes	10
10-Jul-89	Access site	10
10-Jul-89	East shore, 2000 feet south of SP.	10
10-Jul-89	East shore, 2000 feet north of outlet	10
10-Jul-89	East shore, 1500 feet north of outlet	10
10-Jul-89	Wetland near outlet	10
10-Jul-89	West shore, middle of dunes	10
10-Jul-89	North shore, near dune interface	10

TABLE A3 (continued)
SILVER LAKE
BACTERIOLOGICAL SAMPLING DATA, 1989-2010

Date	Sample Location	*E. coli* Bacteria (per 100 mL)
10-Jul-89	North shore, 2000 feet east of dunes	10
10-Jul-89	East shore, 500 feet north of outlet	10
10-Jul-89	Northwest corner of lake	10
10-Jul-89	Northwest corner of lake	10
10-Jul-89	North shore, 500 feet north of HC	10
29-Aug-89		10
29-Aug-89		10
29-Aug-89		10
29-Aug-89		10
29-Aug-89		10
29-Aug-89		20
29-Aug-89		10
29-Aug-89		10
29-Aug-89		10
29-Aug-89		70
27-Jul-93	North shore, 2000 feet east of dunes	10
27-Jul-93	East shore at SP.	10
27-Jul-93	East shore, 300 feet south of HC	10
27-Jul-93	Canal, southeast	21
27-Jul-93	Canal, northeast	440
27-Jul-93	Canal, northwest	136
27-Jul-93	East shore, 300 feet north of Hunter Creek	10
27-Jul-93	Northwest corner of lake	10
27-Jul-93	East shore, 2000 feet north of outlet	10
27-Jul-93	Canal, southwest	15
23-Aug-95	Canal	94
14-Aug-96	East shore near access	6
14-Aug-96	East shore, near hotel	6
14-Aug-96	Canal, northeast	23
14-Aug-96	North shore, 300 feet east of dunes	9
01-Aug-97	East shore, 200 feet north of outlet	0
01-Aug-97	East shore, 2,000 feet north of outlet	4
01-Aug-97	East shore, 2,000 feet south of State Park	4
01-Aug-97	East shore at State Park	8
01-Aug-97	East shore near hotel	6

TABLE A3 (continued)
SILVER LAKE
BACTERIOLOGICAL SAMPLING DATA, 1989-2010

Date	Sample Location	*E. coli* Bacteria (per 100 mL)
01-Aug-97	Canal, southwest	3
01-Aug-97	Canal, northwest	200
01-Aug-97	Canal, southeast	6
01-Aug-97	North shore, 2,000 feet east of dunes	30
01-Aug-97	North shore, 500 feet east of dunes	4
20-Aug-98	Wetland near outlet	0
20-Aug-98	800 feet east of outlet	2
20-Aug-98	2,100 feet east of outlet	2
20-Aug-98	3,600 feet east of outlet	5
20-Aug-98	State Park beach	3
20-Aug-98	Hotel	8
20-Aug-98	Canal, southeast	12
20-Aug-98	Canal, east	2
20-Aug-98	2,000 feet north of Hunter Creek	4
20-Aug-98	Near dune/cottage interface	8
12-Aug-99	Hotel	4
12-Aug-99	Canal off Hunter Creek	12
12-Aug-99	1,500 feet north of Hunter Creek	4
12-Aug-99	Extreme north end of lake near dune	4
12-Aug-99	700 feet east of outlet	8
12-Aug-99	2,500 feet east of outlet	4
12-Aug-99	2,500 feet west of State Park	4
12-Aug-99	State Park beach	4
12-Aug-99	Upper Silver Lake outlet	40
12-Aug-99	Silver Lake outlet	36
11-Jul-02	East shore, 2,000 feet north of State Park	2
11-Jul-02	East shore, in front of hotel	17
11-Jul-02	Hunter Creek canal, southwest	34
11-Jul-02	East shore, 2,500 feet north of Hunter Creek	2
11-Jul-02	North shore, 1,000 feet east of dunes	37
11-Jul-02	South shore, 500 feet east of outlet	5
11-Jul-02	South shore, 750 feet east of 118th Ave	10
11-Jul-02	East shore, 1,500 feet south of Wood rd.	3
11-Jul-02	East shore, 1,500 feet south of State Park	4
11-Jul-02	East shore, State Park beach	6

TABLE A3 (continued)
SILVER LAKE
BACTERIOLOGICAL SAMPLING DATA, 1989-2010

Date	Sample Location	*E. coli* Bacteria (per 100 mL)
8-Jul-04	1	96
8-Jul-04	2	517
8-Jul-04	3	28
8-Jul-04	4	15
8-Jul-04	5	2
8-Jul-04	6	15
8-Jul-04	7	1
8-Jul-04	8	3
8-Jul-04	9	2
8-Jul-04	10	4
7-Sep-04	1	<1
7-Sep-04	2	1
7-Sep-04	3	3
7-Sep-04	4	2
7-Sep-04	5	2
7-Sep-04	6	<1
7-Sep-04	7	1
7-Sep-04	8	<1
7-Sep-04	9	1
7-Sep-04	10	<1
8-Sep-05	1	4
8-Sep-05	2	20
8-Sep-05	3	7
8-Sep-05	4	1
8-Sep-05	5	2
8-Sep-05	6	276
8-Sep-05	7	27
8-Sep-05	8	19
8-Sep-05	9	126
8-Sep-05	10	88
8-Sep-05	11	8
8-Sep-05	12	3

TABLE A3 (continued)
SILVER LAKE
BACTERIOLOGICAL SAMPLING DATA, 1989-2010

Date	Sample Location	*E. coli* Bacteria (per 100 mL)
6-Sep-06	1	40
6-Sep-06	2	8
6-Sep-06	3	3
6-Sep-06	4	6
6-Sep-06	5	1
6-Sep-06	6	2
6-Sep-06	7	5
6-Sep-06	8	8
6-Sep-06	9	8
6-Sep-06	10	10
7-Jun-07	1	5
7-Jun-07	2	770
7-Jun-07	3	23
7-Jun-07	4	2
23-Aug-07	1	47
23-Aug-07	2	13
23-Aug-07	3	32
23-Aug-07	4	7
23-Aug-07	5	28
23-Aug-07	6	38
23-Aug-07	7	79
23-Aug-07	8	38
23-Aug-07	9	816
23-Aug-07	10	152
10-Jul-09	1	1
10-Jul-09	2	6
10-Jul-09	3	1
10-Jul-09	4	9
10-Jul-09	5	5
10-Jul-09	6	20
10-Jul-09	7	167
10-Jul-09	8	14
10-Jul-09	9	4
10-Jul-09	10	10

TABLE A3 (continued)
SILVER LAKE
BACTERIOLOGICAL SAMPLING DATA, 1989-2010

Date	Sample Location	*E. coli* Bacteria (per 100 mL)
24-Aug-10	1	10
24-Aug-10	2	194
24-Aug-10	3	2
24-Aug-10	4	7
24-Aug-10	5	13
24-Aug-10	6	7

Appendix B

Watershed Management:

What Every Riparian Should Know and Do

Watershed Management – What Every Riparian Property Owner Should Know and Do

By Tony Groves

Water Resources Practice Leader, Progressive AE

This is the first of a two-part article about watershed management. The focus of this article is on riparian property owners and specific things waterfront property owners should know and do to protect lakes and streams. The second article, that will appear in the next issue of the The Michigan Riparian, will be entitled *Watershed Management – What Every Government Official Should Know*. The second article will look at watershed management from a governmental perspective and focus on watershed planning and water resource protection policy.

What is a Watershed?

A watershed is the land area that drains to a lake or stream. A watershed boundary is typically defined by examining a topographic map that shows the land elevation around a particular lake or stream. Once a watershed boundary has been identified, soils, land cover, drainage patterns and a variety of other features can be evaluated. Watersheds are essentially large catchment basins that convey everything to the lowest point – a lake or stream.

The Importance of Watershed Management

Water quality is often a reflection of the watershed. Lakes and streams with highly urbanized watersheds tend to be of poorer quality than lakes and streams in less developed watersheds. There is often a tendency to view a problem in a lake or stream with no regard for the watershed. For example, excessive plant growth is often cited as a problem in lakes, and millions of dollars are spent annually for aquatic plant control. Yet, in some instances, the increase in plant growth is merely a symptom of another problem, such as fertilizer runoff from the watershed. Until the watershed problem is addressed, the symptom will persist.

Watershed management is especially important in the shoreland areas immediately adjacent to lakes and streams. All too often, trees, shrubs, and brush are cleared from the shoreline. Natural vegetation is then replaced with turf grass and a sea wall is installed. Many riparian spend considerable time and effort removing logs, sticks, rocks, and other natural "debris" from their shorelines not realizing that all the things that have been removed are habitat for plants and animals. There is a whole food web that exists within a natural shoreline. When the habitat is cleared, the food web falls apart.

It has long been recognized that logs, sticks, and other woody structure in river systems provide habitat for a variety of aquatic insects. These insects are the foundation of the food chain and are essential to sustaining a healthy fishery. Recent research indicates that same holds true for lakes. For a riparian property owner, these are extremely important findings and underscore the need to properly manage shoreland property.

Impacts of Shoreland Development

Several recent studies have examined the impact of shoreland development. The recurring conclusion of these studies is that excessive development of shorelands is adversely impacting the quality of our lakes and streams.

A recent national assessment found that poor shoreline habitat was the biggest problem facing the nation's lakes.[1] Further, the national assessment found that lakes with poor shoreline habitat were three times more likely to be in poor biological condition.

In one Wisconsin study, runoff from lawn areas was compared to runoff from undeveloped wooded areas.[2] This study found that the amount of water that runs off a lawn was generally 10 or more times greater than runoff from an undeveloped wooded site. As a result of the increased rate of runoff, the phosphorus and nitrogen transported from the lawn was 10 to 100 times greater than the amount transported from the undeveloped wooded site. The same study found nitrate and phosphorus levels in groundwater under lawns was 3 to 4 times higher than groundwater under wooded sites. The researchers concluded that nutrients from lawns can leach to the water table and ultimately the lake, even if surface runoff itself does not reach the lake.

In a study of the impact of increased development around Higgins Lake in Roscommon County, researchers found that the concentration of phosphorus in near-shore waters was about 1.5 times higher than the concentration found in the deep lake basins, and E. coli bacteria levels in groundwater increased in concentration as building density exceeded 0.40 buildings per acre.[3] Septic systems were cited as the most likely source for increased phosphorus in near-shore lake water and groundwater.

Why the Fuss about Phosphorus?

Phosphorus is the nutrient that most often stimulates the excessive growth of aquatic plants and algae, leading to a number of problems collectively known as eutrophication. Once in a lake, a pound of phosphorus can generate hundreds of pounds of aquatic vegetation. Lawn fertilizers and septic seepage are primary sources of phosphorus.

Cultural eutrophication (accelerated lake aging) was recently implicated as a cause of amphibian disease, limb deformities, and mortality.[4] In this study, increased nitrogen and phosphorus enrichment was linked to the emergence and production of an infectious parasite. Eutrophication promoted amphibian disease by increasing the density of infected snail hosts and by enhancing per-snail production of the infectious parasites which, in turn, infected amphibian larvae. Given that cultural eutrophication is often linked to increased shoreland development, this study could have broad significance.

In a study of 14 lakes in the Upper Peninsula of Michigan and northern Wisconsin, bluegill growth rates were significantly reduced as the intensity of lakeshore residential development increased.[5] The loss of near-shore habitat, specifically

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woody debris such as dead trees, was cited as a possible explanation for the decline in growth rate. The results of this study suggest that the development of lakeshores that results in the alteration of shoreline and near-shore habitat may reduce the capacity of lakes to maintain productive fish populations.

In a study of 40 Vermont Lakes, near-shore habitat in developed and natural shoreline areas was compared.[6] At each site a number of components were measured including shoreline tree cover, shading, the amount and type of woody structure, leaf material, sediment type, and the presence of damselflies and dragonflies. The difference between the developed and natural sites was substantial. Developed areas had less tree cover, less shading (and warmer water), less woody structure, less leaf material, and fewer damselflies and dragonflies (a.k.a. fish food). The conclusion of this study was that although the conversion of natural shorelines to lawns may appear harmless to humans, the physical, chemical, and biological characteristics of near-shore areas are radically changed by this activity. As this change occurs, plants and animals that depend on this near-shore habitat for survival will eventually disappear.

A study of 28 lakes in the Pacific Northwest and a literature review of 24 North American lakes found shoreline development can have direct impact on aquatic habitats, food webs, and ultimately fish.[7] In this study, dramatic declines in terrestrial insects were observed in fish diets as shoreline development density increased. The terrestrial insects provided much greater sustenance to fish than openwater and bottom-dwelling prey. The data from this study indicated a clear link between shoreline development, riparian vegetation, and the prevalence of terrestrial insects in fish diets, and indicated shoreland development can alter food webs. This report concluded that one important step that can be taken to preserve the function of lake food webs is to retain riparian vegetation along shorelines.

What to Know and Do

While the recurring conclusion of recent studies is that shoreland development is altering the quality of our lakes, the take-home message is that these impacts can be minimized. Riparians can make a difference, a big difference! The question is, will the difference be good or bad? Shorelands must be thought of as a shared resource between land and water. To maintain healthy lakes and fisheries, the vegetation and woody structure along the shoreline and in near-shore areas of lakes must be preserved.

What You Can Do

- Maintain a natural landscape with natural vegetation
- Leave or maintain a vegetation buffer (i.e., a greenbelt) strip along the shore
- Do not install lawns on slopes that drain to the lake
- Do not add fertilizer to lakeshore lawns
- Limit the amount of impervious area on your property such as sidewalks and driveways
- Reduce erosion
- Enhance infiltration of runoff from rooftops, driveways, and other impervious areas
- Do not remove woody vegetation from nearshore areas
- Install rain gardens to enhance runoff infiltration

Modified from: Evaluating the Effects of Nearshore Development on Wisconsin Lakes. U.S. Geological Survey. Fact Sheet 2006-3033.

The illustrations on the following pages demonstrate things you can do to protect your lake. Remember, while the individual impacts of shoreland alterations may appear subtle, the collective impact is profound. Shoreland disruption must become the exception rather than the rule.

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[2] U.S. Geological Survey 2006. Evaluating the effects of nearshore development on Wisconsin lakes. Fact Sheet 2006-3033.

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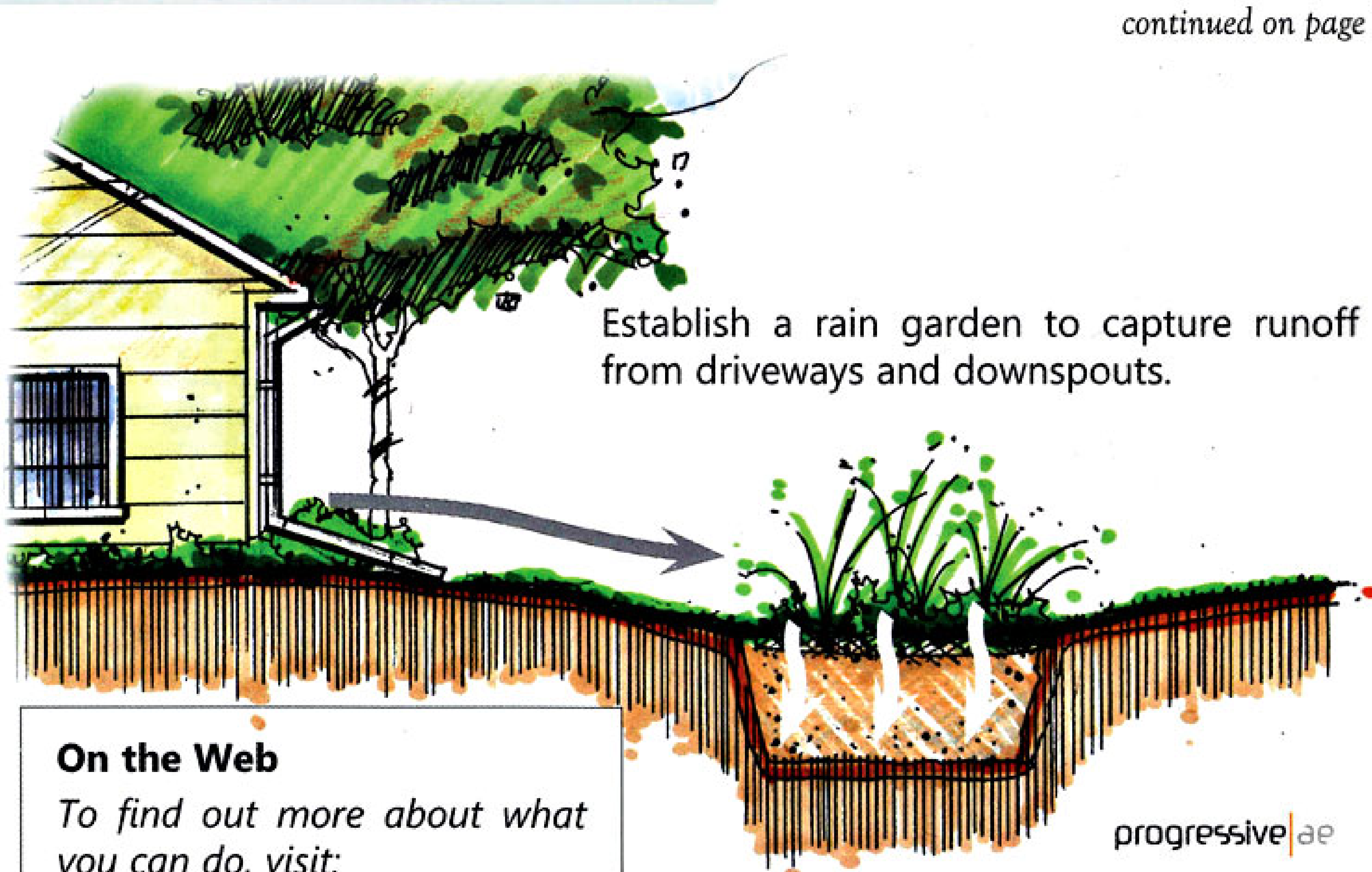

On the Web

To find out more about what you can do, visit:

www.raingardens.org

www.shoreline.msu.edu

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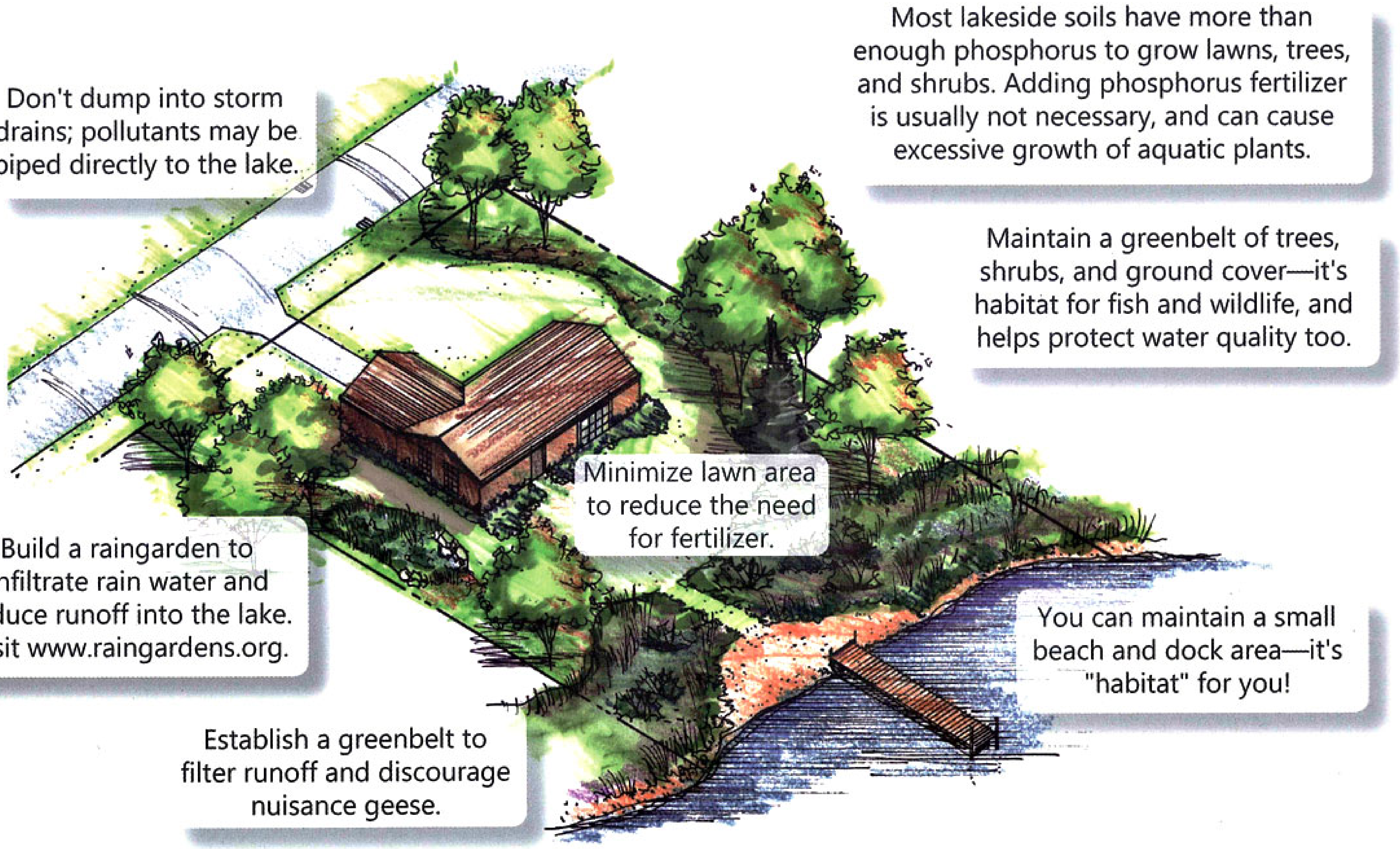
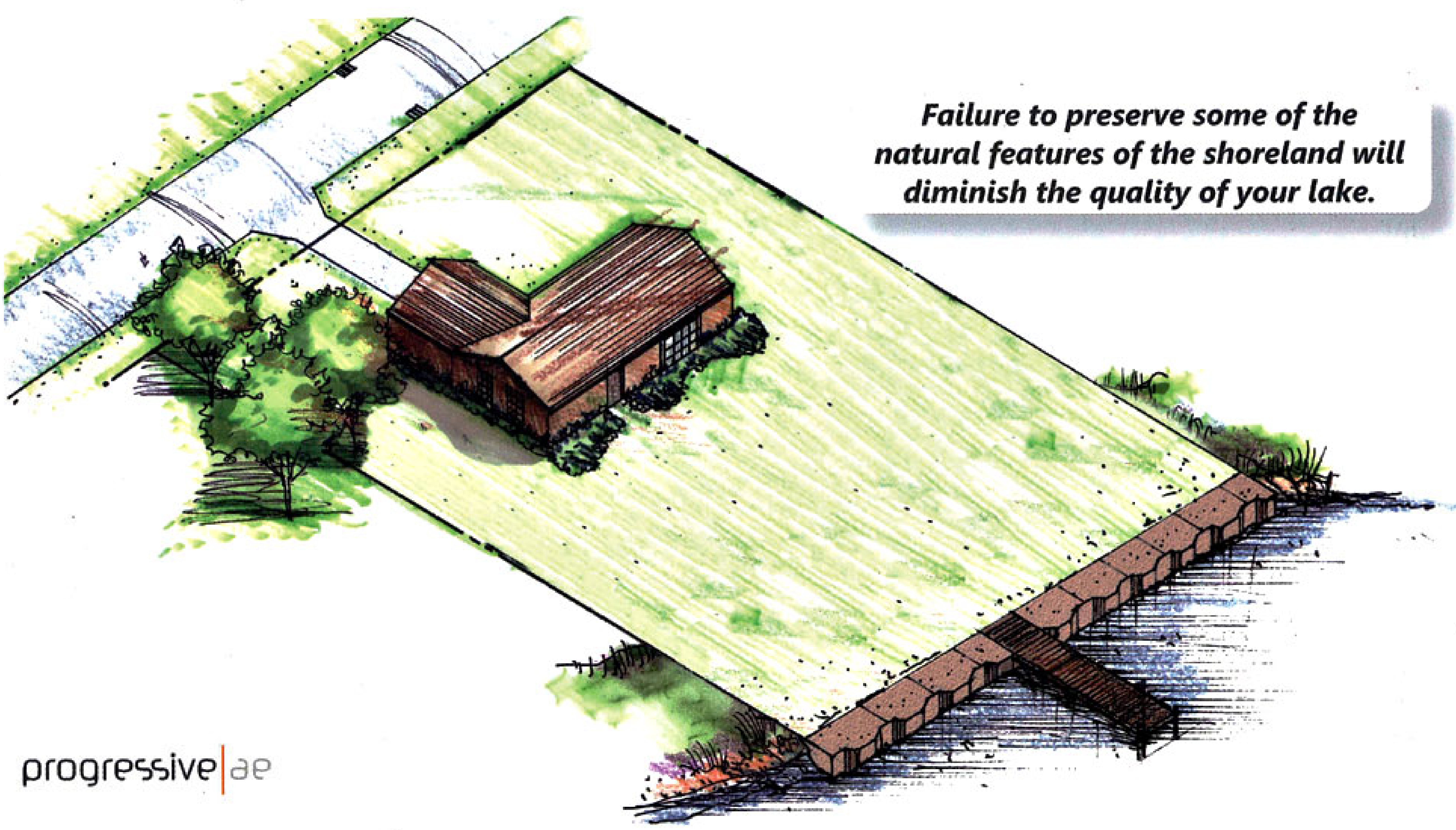
Caring for Your Shoreland

Your shoreland can be maintained to provide beach and boat access for you while maintaining habitat for fish and wildlife.





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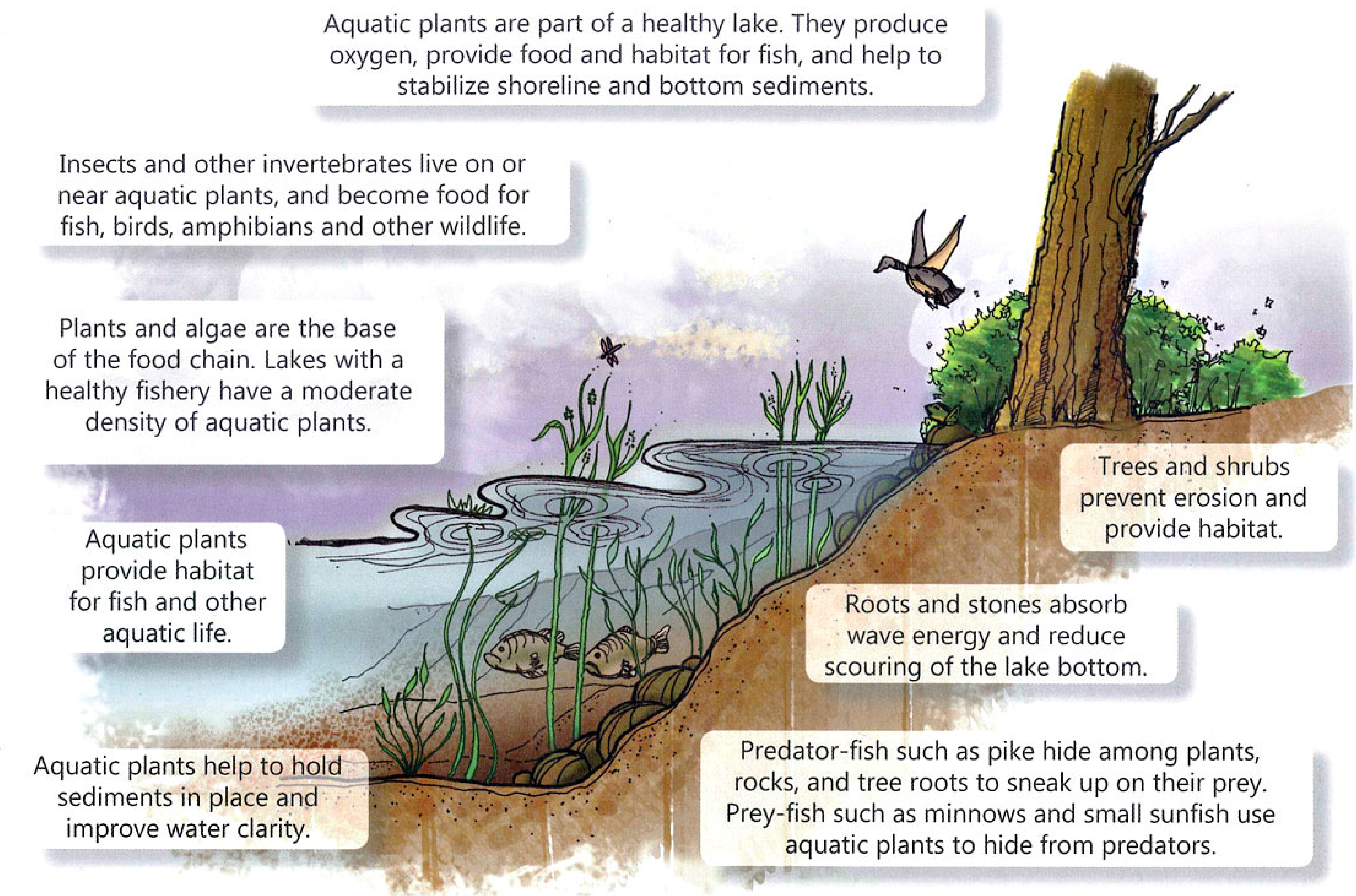

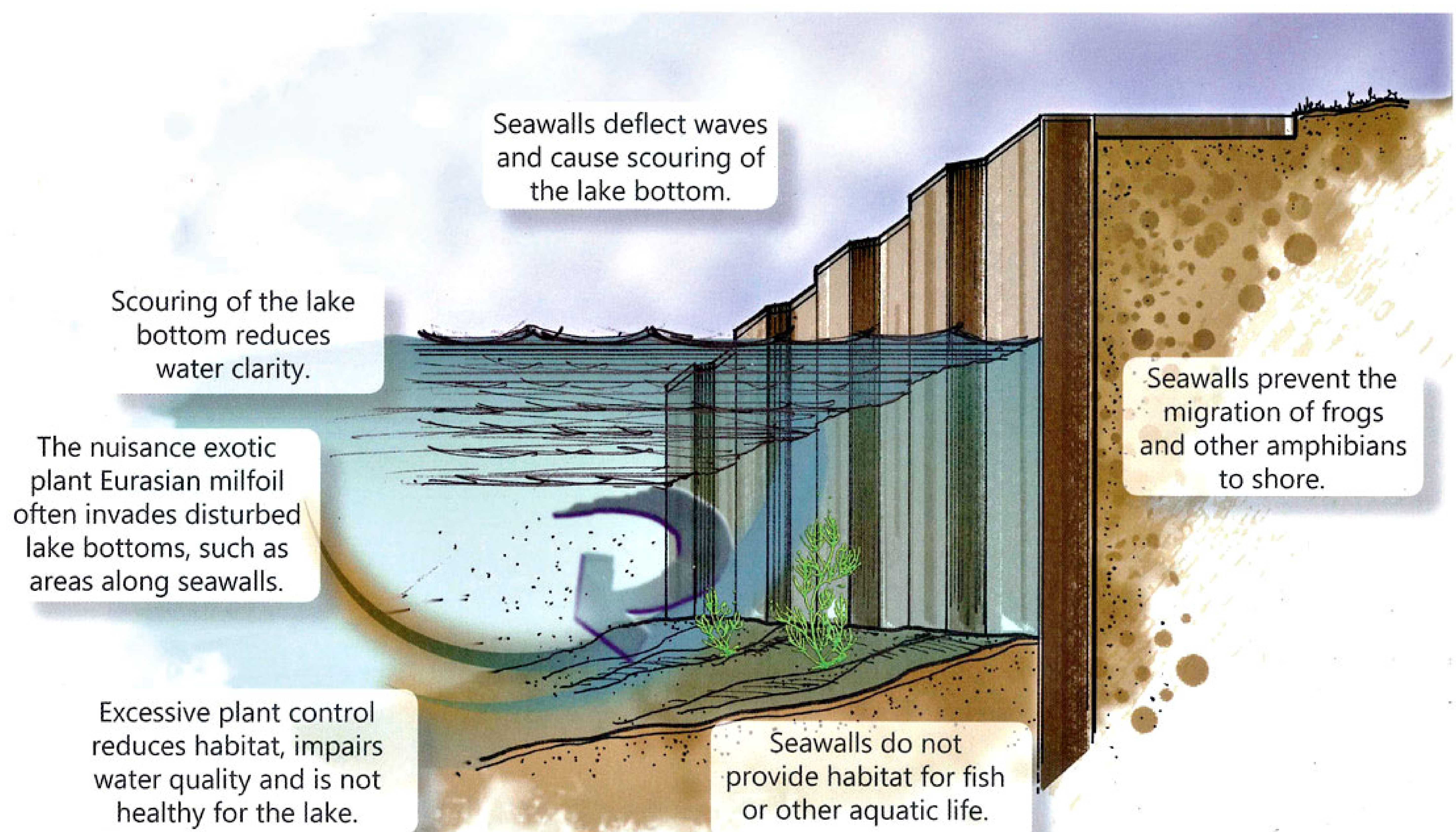

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U.S. Environmental Protection Agency (USEPA). 2009. National Lakes Assessment: A Collaborative Survey of the Nation's Lakes. EPA 841-R-09-001. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, D.C.