DRAFT Apple River Flowage Lake Management Plan

Polk County, Wisconsin
June 2013

Prepared By
Polk County Land and Water Resources Department
100 Polk County Plaza, Suite 120
Balsam Lake, WI 54810

Funded By
Apple River Flowage Protection and Rehabilitation District
Wisconsin Department of Natural Resources Lake Planning Grant

We would like to thank the following persons for their contributions to this project:

Derrick Carlson
Norval Doddridge
John Dressen
Peter Henry
Angie Johnson
Doug Johnson
Debi Lein
Dave Myers
Jeri Peterson
Roland Peterson
Dale Richardson
Billie Jo Schleusner
Dave Schleusner
Bob Strobush
Gale Tappe

Jordan Petchenik
Alex Smith
Pamela Toshner

Table of Contents

Purpose of the Study

Lakes are a product of the landscape they are situated in and of the actions that take place on the land which surrounds them. Due to this fact, lakes situated within feet of others can differ profoundly in the uses they support.

Factors such as lake size, lake depth, water sources to a lake, and geology all cause inherent differences in lake quality.

Additionally, humans, by changing the landscape, can bring about changes in a lake. This arises because rain and melting snow may eventually end up in lakes and streams through surface runoff or groundwater infiltration. Rain and melting snow entering a lake is not inherently problematic. However, water has the ability to carry nutrients, bacteria, sediments, and chemicals into a lake. These inputs can impact aquatic organisms such as insects, fish, and wildlife and—especially in the case of the nutrient phosphorus—fuel problematic algae blooms.

The landscape can be divided into watersheds and subwatersheds, which define the land area that drains into a particular lake, flowage, stream, or river. Watersheds that preserve native vegetation and minimize impervious surfaces (cement, concrete, and other materials that water can't permeate) are less likely to cause negative impacts on lakes, rivers, and streams.

Lake studies often examine the underlying factors that impact a lake's health, such as lake size, depth, water sources, and the land use in a lake's watershed. Many forms of data can be collected and analyzed to gauge a lake's health including: physical data (oxygen, temperature, etc.), chemical data (including nutrients such a phosphorus and nitrogen), biological data (algae and zooplankton), and land use within a lake's watershed.

Lakes can be classified based on their nutrient status and clarity levels. Three categories commonly used are: oligotrophic, mesotrophic, and eutrophic.

- ✓ Oligotrophic lakes are generally clear, deep, and free of weeds and large algae blooms.
- ✓ Mesotrophic lakes lie between oligotrophic and eutrophic lakes. They usually have good fisheries and occasional algae blooms.
- ✓ Eutrophic lakes are generally high in nutrients and support a large number of plant and animal populations. They are usually very productive and subject to frequent algae blooms. Lakes can also be hypereutrophic. Hypereutrophic lakes are characterized by dense algae and plant communities and can experience heavy algal blooms throughout the summer.

Lake studies often identify strengths, opportunities, challenges, and threats to a lake's health. These studies can identify practices already being implemented by watershed residents to improve water quality and areas providing benefits to a lake's ecosystem. Additionally, these studies often quantify practices or areas on the landscape that have the potential to negatively impact the health of a lake.

The end product of a lake study is a Lake Management Plan which identifies goals, objectives, and action items to either maintain or improve the health of a lake. These goals should be realistic based on inherent lake characteristics (lake size, depth, etc.) and should align with watershed residents' goals.

Included in this document are the data and conclusions drawn from a 2012 lake study completed by the Polk County Land and Water Resources Department. This study collected and analyzed the following data to aid in the creation of a Lake Management Plan for the Apple River Flowage:

- ✓ Lake resident opinions
- ✓ Lake level and precipitation data
- ✓ In lake physical and chemical data
- ✓ Algae and zooplankton data
- ✓ Lake sediment chemistry
- ✓ Shoreline land use results
- ✓ Tributary monitoring results
- ✓ Watershed and subwatershed land use

This study also included a number of educational opportunities for members of the Apple River Flowage District including:

- ✓ A pontoon classroom
- ✓ A shoreline restoration workshop
- ✓ A series of five meetings to review the data collected and develop a Lake Management Plan

Whenever possible, past lake studies completed on the Apple River Flowage are used as a baseline comparison for this study. A summary of previous lake studies can be found on page 21.

Executive Summary

Lake information

The Apple River Flowage is located in southeastern Polk County, Wisconsin in the Town of Lincoln and within the Amery city limits. The Apple River Flowage is a 604 acre impoundment with a mean depth of six feet and a maximum depth of eighteen feet.

There are two inflows to the Apple River Flowage: the Beaver Brook Inlet and the Apple River Inlet. The Beaver Brook Inlet originates in Barron County and flows through the Joel Flowage to the Apple River Flowage; and the Apple River Inlet originates from Staples Lake and flows through White Ash Lake to the Apple River Flowage. The Apple River Flowage has one outlet which is located at the Amery Dam and flows to the Black Brook Flowage.

The Apple River Flowage and many of its tributaries (Beaver Brook Inlet originating at the Joel Flowage, Apple River Inlet, and the Apple River Outlet) are designated as Areas of Special Natural Resource Interest through their identification as Natural Heritage Inventory Waters.

The drainage basin: lake area ratio (DB: LA) compares the size of a lake's watershed to the size of a lake. If a lake has a relatively large DB: LA then surface water inflow (containing nutrients and sediments) occurs from a large area of land relative to the area of the lake. The DB: LA ratio for the Apple River Flowage is approximately 175:1, which is quite large.

The total phosphorus criterion for the Apple River Flowage (classified as a stream based on a residence time of less than fourteen days) is 0.075 mg/L. In 2011, the Apple River Flowage was proposed for the 303(d) list of Impaired Waters for the pollutant total phosphorus and the resulting impairment of excess algae growth. As of January 2013, the Flowage had not yet been formally listed.

Survey results

Ninety-two members of the Apple River Flowage Protection and Rehabilitation District completed a survey regarding the flowage (41% response rate). In this survey concerns for the flowage were ranked. Invasive species ranked as the 1st concern for the flowage, followed by aquatic plants in 2nd, and algae blooms in 3rd.

Around a quarter of respondents described the water quality of the Apple River Flowage as either poor (36%) or fair (32%). Fewer respondents described the water quality as good (14%) and zero respondents described it as excellent. The majority of respondents felt that in the time since they have owned their property, the water quality has degraded. Zero respondents perceived that water quality has improved.

In general, more respondents felt that algae often or always negatively impact their enjoyment of the flowage as compared to never or rarely.

A third of respondents described the current amount of shoreline vegetation on the Apple River Flowage as just right (33%). Generally, more respondents felt there was too much shoreline vegetation as compared to not enough.

Although a combined 74% of respondents felt that shoreline buffers, rain gardens, and native plants are very important or somewhat important to water quality; nearly half (47%) of respondents are not interested in installing a shoreline buffer or rain garden on their property.

Respondents are making educated decisions when applying fertilizer to their property. Two thirds of respondents do not use fertilizer on their property (64%) and one third use zero phosphorus fertilizer (33%). Very few respondents use fertilizer but are unsure of its phosphorus content (5%), and zero respondents use fertilizer on their property that contains phosphorus.

Survey respondents were asked to choose all of the management practices they felt should be used to maintain or improve the water quality of the Apple River Flowage from a list of options. Over half of respondents felt that enhanced efforts to monitor for new populations of aquatic invasive species should be used to maintain or improve the water quality of the flowage (60%). Other management practices supported by many respondents include information and education opportunities (46%) and cost-sharing assistance for the installation of farmland conservation practices (41%).

Lake level and precipitation data

Seasonal precipitation totaled eighteen inches north of the 46 bridge and thirteen inches south of the 46 bridge. Shortly following precipitation events, water levels did increase in the flowage. The flowage is created by a dam within the city limits of Amery. Currently, the dam is used to maintain water levels on the flowage. Overall, water levels remained fairly constant over the sampling season.

Sampling procedure

Physical and chemical data were collected in-lake at two sites (Site 1, north and Site 2, south) on the Apple River Flowage from May 8th, 2012 through September 17th, 2012. Spring turnover samples were taken on April 3rd, 2012. Fall turnover samples were taken on October 15th, 2012.

Turnover

Turnover events in lakes occur two times a year in Wisconsin. At spring and fall turnover, the temperature and density of the water is constant from the top to the bottom. This uniformity in density allows a lake to completely mix. As a result, oxygen is brought to the bottom of a lake, and nutrients are re-suspended from the sediments.

As the sun's rays warm the surface waters in the spring, the water becomes less dense and remains at the surface. Warmer water is mixed deeper into the water column through wind and wave action. However, these forces can only mix water to a depth of approximately twenty to thirty feet. The Apple River Flowage, with a maximum depth of eighteen feet, remained well mixed over the sampling season.

In stratified lakes, warmer surface waters are prevented from mixing with cooler bottom waters. As a result, nutrients can actually become trapped in the bottom waters of a lake that stratifies. Additionally, because mixing is one of the main ways oxygen is distributed throughout a lake, lakes that stratify have the potential to have very low levels of oxygen in the bottom waters. The Apple River Flowage did not stratify in 2012.

Chemical data

The total phosphorus criterion for the Apple River Flowage is 0.075 mg/L. In 2012, the summer index period (July 15th – September 15th) average total phosphorus was 0.0895 mg/L at site one (north) and 0.0680 mg/L at site two (south). The total phosphorus criterion was exceeded at site one in 2012.

Nitrate/nitrite and ammonium are all inorganic forms of nitrogen which can be used by aquatic plants and algae. Inorganic nitrogen concentrations above 0.3 mg/L can support summer algae blooms in lakes. Average growing season (excludes turnover) inorganic nitrogen was 0.02 mg/L at site one (north) and 0.03 mg/L at site two (south). Inorganic nitrogen concentrations at both sites were well below the healthy limit.

The total nitrogen to total phosphorus ratio (TN: TP) is a calculation that depicts which nutrients limit algae growth in a lake. The total nitrogen to total phosphorus ratio for both sites (north and south) indicate a nitrogen limited state during the growing season, which is fairly uncommon in Wisconsin.

Physical data

A water quality standard for dissolved oxygen in warm water lakes and streams is set at 5 mg/L. This standard is based on the minimum amount of oxygen required by fish for survival and growth. Oxygen levels remained above 5 mg/L near the surface but dropped below this threshold in the bottom waters.

Secchi depth serves as a general indicator of water quality. The average growing season secchi depth was 5.5 feet at site one (north) and 4.5 feet at site two (south).

Chlorophyll *a* (an indicator of algae) seems to have the greatest impact on water clarity when levels exceed 0.03 mg/L. Lakes which appear clear generally have chlorophyll *a* levels less than 0.015 mg/L. With the exception of site two (south) on August 7th, 2012, chlorophyll *a* levels on the flowage were below 0.015 mg/L.

Trophic state index

Trophic State Index (TSI) data indicates that in 2012 the Apple River Flowage was mildly eutrophic to eutrophic. Eutrophic lakes are generally high in nutrients and support a large number of plant and animal populations. They are usually very productive and subject to frequent algae blooms.

Phytoplankton or Algae

At both sites the dominant algae division in May and June was Cryptophyta, or cryptomonads. By July, the algae community at both sites was dominated nearly equally by cryptomonads and Chlorophyta, or green algae. In August, the algae community at site one was dominated by cryptomonads and the algae community at site two was dominated by Cyanophyta, or blue green algae. In September, the algae community at site one shifted back to being green algae dominated and the algae community at site two shifted back to being dominated by cryptomonads.

Blue green algae were only present in August at site one and only present in August and September at site two. Their concentrations at these sampling dates were very low and well below the risk threshold for toxin production.

Zooplankton

The Apple River Flowage zooplankton were dominated by rotifers, which is characteristic of flowing waters. Some cladocera are present but almost no copepods, which is somewhat unusual even for a flowing system. Abundance appears to fluctuate with the likely drivers being water retention time (higher flows reducing populations) and temperature (increasing productivity).

Shoreline survey

The shoreline inventory shows that the greatest land use at the ordinary high water mark is natural (93%), followed by rip rap (5%), and lawn (2%). A characterization of the shoreline buffer composition (area upland thirty-five feet from the ordinary high water mark) shows that the greatest land use is natural (82%), followed by lawn (17%), and hard surfaces (1%).

Tributary monitoring

The Apple River Inlet is contributing the greatest amount of phosphorus to the Apple River Flowage (8,442 pounds on an annual basis). The Beaver Brook Inlet is contributing 2,580 pounds of phosphorus on an annual basis. Total phosphorus concentrations were elevated on the East branch of the Beaver Brook Inlet (0.2472 mg/L).

Site	Total Phosphorus (mg/L)	Discharge (L/s)	Instantaneous Load (mg/s)	Annual Load (lb/yr)
Fox Creek	0.0518	974.610	50.485	3,512.284
Apple River Inlet	0.0648	1,872.570	121.343	8,441.935
Apple River Outlet	0.0636	3,652.740	232.314	16,162.362
Beaver Brook Inlet	0.0836	443.520	37.078	2,579.577
Beaver Brook West	0.0586	125.496	7.354	511.631
Beaver Brook East	0.2472	60.048	14.844	1,032.704

Watershed land use and phosphorus loading

The area of land that drains towards a lake is called a watershed. Since the Apple River Flowage Watershed is so extensive in size and drains from many area lakes and rivers, a management area was established for the Apple River Flowage. Areas of land already included in lake management areas for other Polk County lakes (ie. Bone Lake, Balsam Lake, Blake Lake, White Ash Lake, etc.) were excluded from the management area.

The resulting management area is 37,125 acres in size. The largest land uses in the management area are row crop (32%) and forest (31%), with row crop contributing the greatest phosphorus load to the Flowage (74%).

Implementation plan

The following goals of the Implementation Plan for the Apple River Flowage were created through collaborative efforts and take into account current and past water quality data, a 2012 sociological survey regarding the needs of the Apple River Flowage Protection and Rehabilitation District members, and a series of four meetings by the Apple River Flowage Water Quality Committee.

Goal 1: Reduce excessive watershed nutrient inputs to the flowage to improve water quality

Goal 2: Minimize the release of nutrients from within the Apple River Flowage to improve water quality

Goal 3: Protect, maintain, and enhance fish and wildlife habitat

Goal:4 Maintain and enhance the natural beauty of the Apple River Flowage

Goal 5: Evaluate the progress of lake management efforts through monitoring and data collection

Goal 6: Provide information and education opportunities to residents and users

Goal 7: Develop partnerships with a diversity of people and organizations

Goal 8: Implement the Aquatic Plant Management Plan

Introduction to the Flowage

The Apple River Flowage (WBIC 2624200) is located in southeastern Polk County, Wisconsin in the Town of Lincoln and within the Amery city limits (Polk/T.33N.-R.16W./Sec.21,22,28,33 & T.33N.R.16W./Sec 9,10,15,16,22 & T.33, 34N.-R.16W./Sec 3,4,5,9,32,33).

The Apple River Flowage is located in the Upper Apple River Watershed which is part of the St. Croix River Basin. The Upper Apple River Watershed drains to the Apple River Flowage, which ultimately drains to the St. Croix River.

The Upper Apple River Watershed is the largest watershed in Polk County, totaling approximately 125,074 acres in size. Close to half of the watershed land use is forest and nearly a third is agriculture.

There are two inflows to the Apple River Flowage, the Beaver Brook Inlet and the Apple River Inlet. The Beaver Brook Inlet originates in Barron County and flows through the Joel Flowage to the Apple River Flowage; and the Apple River Inlet originates from Staples Lake and flows through White Ash Lake to the Apple River Flowage. The Apple River Flowage has one outlet which is located at the Amery Dam and flows to the Black Brook Flowage.

Although the soils of the Apple River watershed are mixed, the majority of the soils are Type B, or loamy to sandy soils.

There are two ramp public access sites and one carry in public access site on the flowage. One ramp site is located within the city of Amery on Birch Street and the second ramp site is located north of Amery at the end of River Shore Lane. The carry in site is adjacent to North Park, the city park. North Park and Michael Park/Riverfront Park (also known as Bobber Park) are both situated on the Apple River, providing public access and use opportunities. Both parks have public fishing piers and picnic table areas.

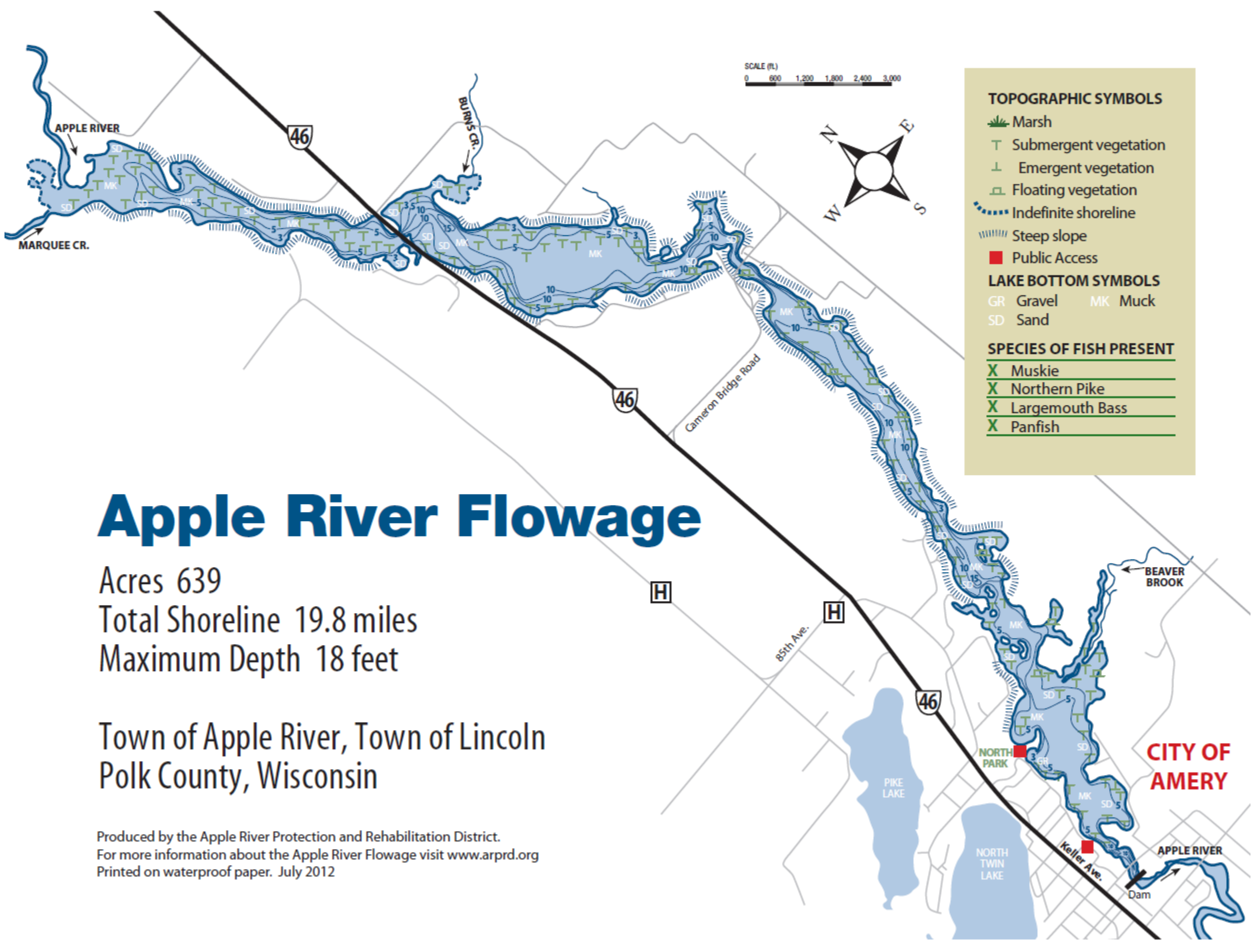
Harvesting for aquatic plants began on the flowage in early August 2012.

Flowage Characteristics

Information from: (Wisconsin Department of Natural Resources, 2012).

Apple River Flowage (WBIC: 2616100)
Area: 604 Acres
Maximum depth: 18 feet
Mean depth: 6 feet
Bottom: 40% sand, 10% gravel, 0% rock, and 50% muck
Hydrologic lake type: drainage
Total shoreline: 19.8 miles
Invasive species: Curly leaf pondweed

Self Help Monitoring Data has been collected on the Apple River Flowage at the deep hole annually since 1986. Secchi depth has been recorded since 1986 and chlorophyll *a*nd total phosphorus have been recorded since 1994. The Self Help Monitoring Data show that the Apple River Flowage is eutrophic.

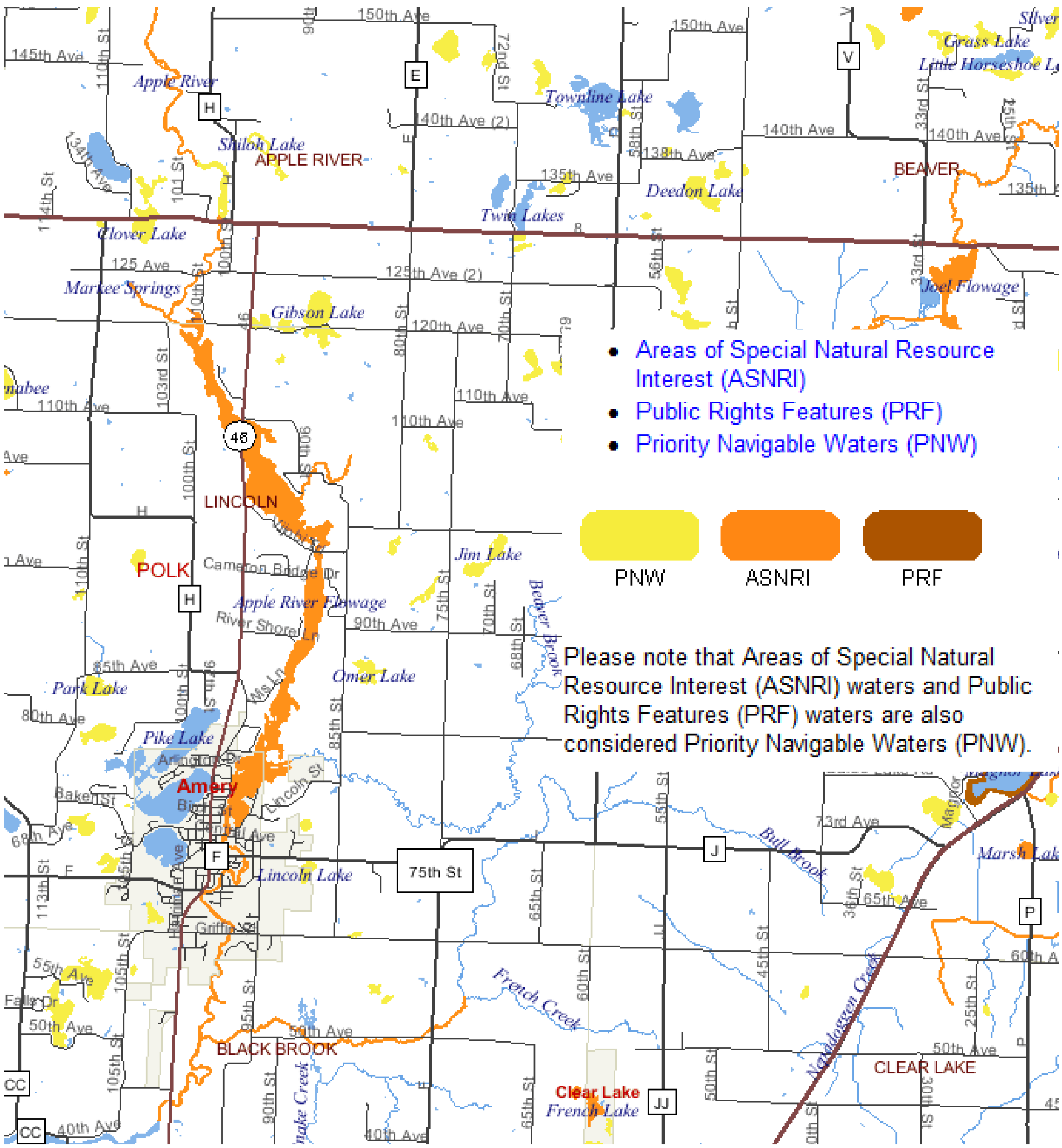


Designated Waters

Information from: (Wisconsin Department of Natural Resources, 2012).

A designated water is a waterbody with special designations that affect permit requirements.

The Apple River Flowage and many of its tributaries (Beaver Brook inlet originating at the Joel Flowage, the Apple River inlet, and the Apple River Outlet) are designated as Areas of Special Natural Resource Interest through their identification as Natural Heritage Inventory Waters. The Natural Heritage Inventory Program identifies waters or portions of waters inhabited by any endangered, threatened, special concern species, or unique ecological community indentified in the Natural heritage Inventory.



Habitat Areas

Information directly from: (Harmony Environmental and Endangered Resource Services, LLC, September 2011).

Naturally occurring native plants are extremely beneficial to the Apple River Flowage. They provide a diversity of habitats, help maintain water quality, sustain fish populations, and support common lakeshore wildlife such as loons and frogs.

Aquatic plants can improve water quality by absorbing phosphorus, nitrogen, and other nutrients from the water that could otherwise fuel nuisance algal growth. Some plants can even filter and break down pollutants. Plant roots and underground stems help to prevent re-suspension of nutrient-rich bottom sediments. In the flowage, this is particularly important.

Stands of emergent plants (whose stems protrude above the water surface) and floating plants help to blunt wave action and prevent erosion of the shoreline. The rush, reed, and rice populations around the flowage are particularly important for reducing erosion along the shoreline, but these populations are also vulnerable to nutrient loading and resultant algae growth. Dense wild rice is found near the Apple River Inlet north and west of the State Highway 46 Bridge, and scattered growth occurs in other areas.

Habitat created by aquatic plants provides food and shelter for both young and adult fish. Invertebrates living on or beneath plants are a primary food source for many species of fish. Other fish, such as bluegills, graze directly on the plants themselves. Plant beds in shallow water provide important spawning habitat for many fish species.

Plants offer food, shelter, and nesting material for waterfowl. Birds eat both the invertebrates that live on plants and the plants themselves.

A draft sensitive area study was completed by the Department of Natural Resources in the late 1990's/early 2000's and is included in the 2003 DNR/Polk County *Apple River Flowage Aquatic Plant Survey Report*. The sensitive area study is not included in DNR records, and it is not clear if results will be used for permitting in the flowage.

The Natural Heritage Inventory map of Polk County indicates occurrences of aquatic listed species in the sections where the flowage is located. A species list is available to the public only by town and range. The Apple River Flowage is located in the town of Lincoln (T33N, R16W). The Natural Heritage Inventory indicated two species of special concern in the Town of Lincoln: banded killifish (SC/N; no laws regulating use, possession, or harvesting) and bald eagle (SC/P; fully protected).

Fishery

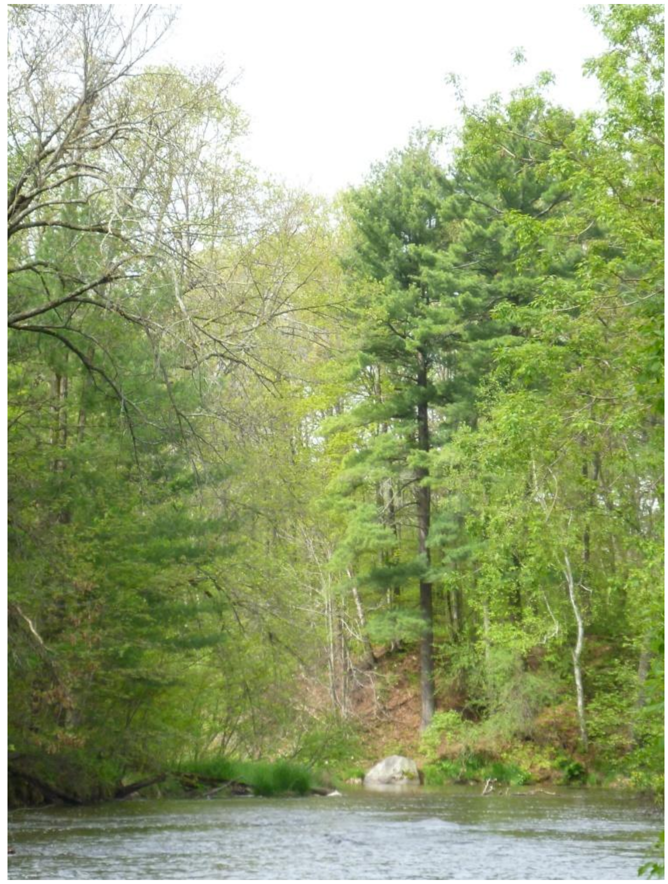
The Apple River Flowage fishery is comprised of muskie, northern pike, largemouth and smallmouth bass, and pan fish. Pan fish include blue gills, crappies, pumpkin seeds, and yellow perch. Muskies are in small numbers, but good sized muskies are harvested from the flowage. The flowage is an excellent largemouth bass fishery with quality fish harvested in good numbers (Harmony Environmental and Endangered Resource Services, LLC, September 2011).

The most recent fish survey on the Apple River Flowage occurred in May 2011. A shocking survey was completed in mid May targeting pan fish such as bass, blue gills, and crappie and a netting survey was completed in late May targeting muskie and walleye (Aaron Cole, Northern Region Fisheries Biologist, personal communication, 2013).

Lake Classification

Lake classification in Polk County is a relatively simple model that considers:

- ✓ lake surface area
- ✓ maximum depth
- ✓ lake type
- ✓ watershed area
- ✓ shoreline irregularity
- ✓ existing level of shoreline development



These parameters are then used to classify lakes as class one, class two, or class three lakes.

Class one lakes are large and highly developed.
Class two lakes are less developed and more sensitive to development pressure.
Class three lakes are usually small, have little or no development, and are very sensitive to development pressure.

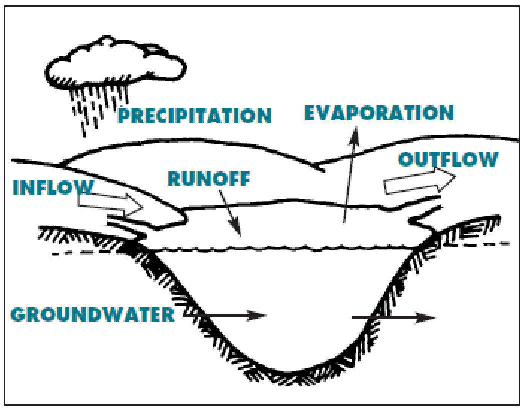
(Polk County Shoreland Protection Zoning Ordinance, Effective April 1, 2010).

The Apple River Flowage is classified as a class one lake (Polk County, Wisconsin Shoreland Property Owner Handbook A Guide to the Polk County Shoreland Protection Zoning Ordinance in Developing and Caring for Waterfront Property, October 2002).

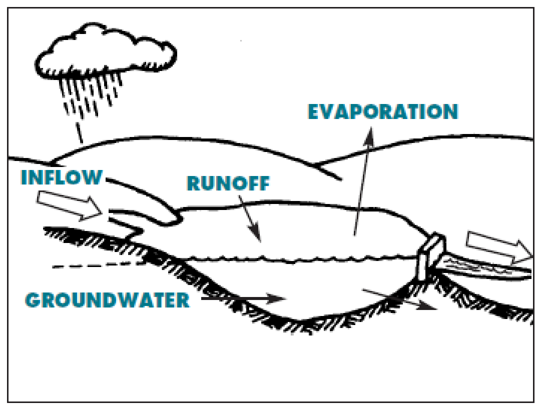
Lake Types

Lakes are commonly classified into four main types based on water source and type of outflow: seepage lakes, groundwater drainage lakes, drainage lakes, and impoundments.

The Apple River Flowage is a six mile impoundment that was created in 1888 by a dam located in the City of Amery (Office of Inland Lake Renewal Wisconsin Department of Natural Resources, 1979). An impoundment is a man-made lake that is formed when the flow of a stream or river is impeded. The restriction on the natural flow of water often results in the collection of soil and nutrients in impoundments. By definition all impoundments have outlet flows and are thus categorized as drainage lakes. The Wisconsin DNR has classified the Apple River Flowage as a drainage lake.



3. DRAINAGE LAKE—a lake fed by streams, groundwater, precipitation and runoff and drained by a stream.



4. IMPOUNDMENT—a manmade lake created by damming a stream. An impoundment is also drained by a stream.

Figure from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004)

The drainage basin: lake area ratio (DB: LA) compares the size of a lake's watershed to the size of a lake. If a lake has a relatively large DB: LA then surface water inflow (containing nutrients and sediments) occurs from a large area of land relative to the area of the lake (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

The DB: LA for the Apple River Flowage is approximately 175:1, which can be compared with a ratio of 2.5:1 for Pike Lake and a ratio of 1.3:1 for North Twin Lake (Harmony Environmental and Endangered Resource Services, LLC, September 2011). The DB: LA ratio for the Apple River Flowage is quite large, which indicates that the flowage receives nutrients and sediments from an extensive land base. Additionally, since the flowage is fairly shallow, the effects of nutrients and sediments are intensified.

The retention time is the average amount of time water remains in a body of water. In general, impoundments are characterized by short retention times. The retention time for the Apple River Flowage is estimated at around twelve days (Harmony Environmental and Endangered Resource Services, LLC, September 2011).

Impaired Waters

Wisconsin lakes, rivers, and streams are managed to determine if their conditions are meeting state and federal water quality standards. Water samples are collected through monitoring studies and results are compared to guidelines designed to evaluate conditions as compared to set standards. General assessments can place waters in four different categories: poor, fair, good, and excellent. The results of assessments can be used to determine which actions will ensure that water quality standards are being met (anti-degradation, maintenance, or restoration).

If a waterbody does not meet water quality standards it is placed on Wisconsin's Impaired Waters List under the Federal Clean Water Act, Section 303(d). Every two years the State of Wisconsin is required to submit list updates to the United States Environmental Protection Agency for approval.

Waterbodies can be listed as impaired based on pollutants such as total phosphorus, total suspended solids, and metals.

The total phosphorus criterion for the Apple River Flowage (classified as a stream based on a residence time of less than fourteen days) is 0.075 mg/L. In 2011, the Apple River Flowage was proposed for the 303(d) list of Impaired Waters for the pollutant total phosphorus and the resulting impairment of excess algae growth. As of January 2013, the Flowage had not yet been formally listed.

Water Quality in Impoundments

Impoundments are distinct from naturally formed lakes in terms of water quality. As a result, impoundments should not be expected to have the water quality of nearby lakes.

In general as compared to natural lakes, impoundments are characterized as having:

- ✓ higher nutrient concentrations
- ✓ lower water clarity
- ✓ poorer water quality

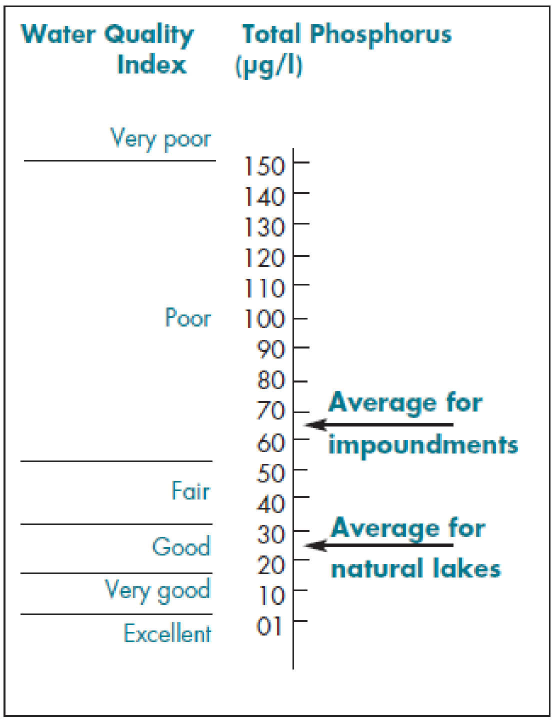


FIGURE 4. Total phosphorus concentrations for Wisconsin's natural lakes and impoundments. (*Adapted from Lillie and Mason, 1983.*)

Figure from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004)

Previous Lake Studies

Past studies that include the Apple River Flowage are:

- ✓ Office of Inland Lake Renewal Feasibility Study and Management Alternatives (1979)
- ✓ Polk County Land and Water Resources Department Apple River Association Development and I&E Project (2003)
- ✓ Harmony Environmental and Endangered Resources Services Aquatic Plant Management Plan (2011)

Office of Inland Lake Renewal Feasibility Study and Management Alternatives

The most recent water quality study completed for the Apple River Flowage was conducted by the Office of Inland Lake Renewal in 1979.

This study included surveys of:

- ✓ Soil loss
- ✓ Barnyard and feedlot locations
- ✓ In-lake sediment volume and accumulation rates
- ✓ Flow, nutrient, and sediment data at the Beaver Brook Inlet, Apple River Inlet, and Amery Dam Outlet
- ✓ In-lake physical and chemical data
- ✓ In-lake aquatic plant species and abundance

This study suggested that although high flow precipitation events may produce sediment erosion in the Beaver Brook basin, the problems are not serious. Additionally, the study suggested that feedlot runoff is not a major problem. The study suggested that considerable sediment has accumulated in the flowage since 1954. Sediment accumulation over the 1954-1977 timeframe has ranged from 16-25 inches across four sample sites.

Nutrients levels were found to be relatively low for an impoundment, although they were sufficient to fuel aquatic plant and algae growth. However, chlorophyll *a* values indicated that no algae blooms occurred.

Aquatic vegetation was found at 94% of the points sampled in June and 96% of the points sampled in August. The study also concluded that in recent years coontail and northern water milfoil have replaced more desirable species.

The management alternatives for the flowage suggested by this study include:

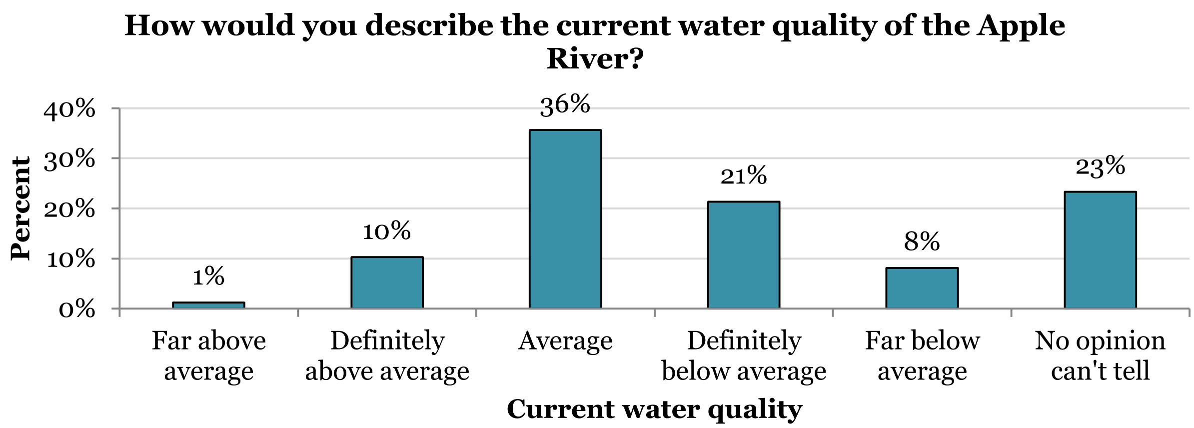
1. Sediment removal through dredging
2. Aquatic plant control through herbicides or harvesting
3. No action

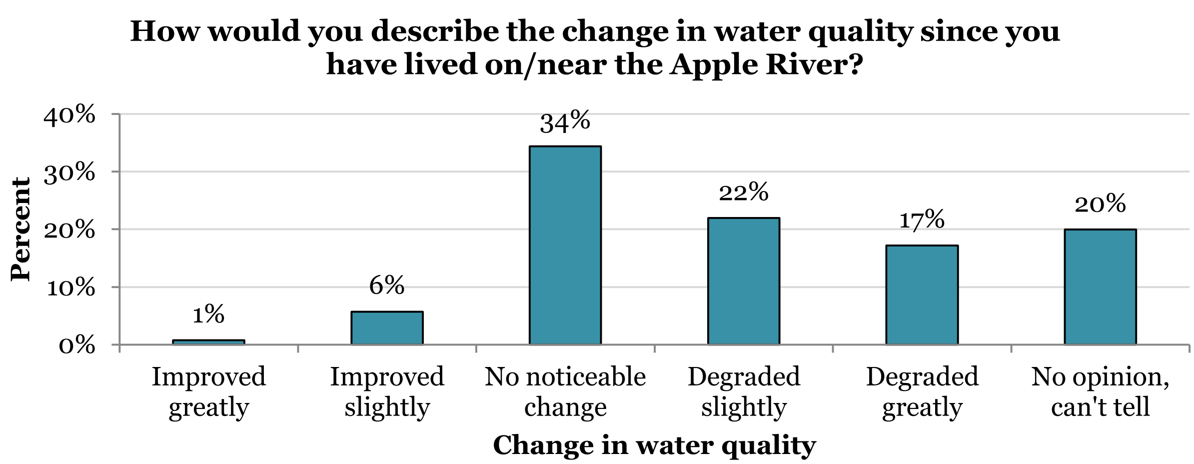
Polk County Land and Water Resources Department Apple River Association Development and I&E Project

The primary focus of this project was to increase public education and protect the water quality of the Apple River by creating the Apple River Association. The Association was established in 2001. This project also sponsored the mailing of a sociological survey in 2001 which was mailed to 1,958 landowners in the Apple River Watershed. Four hundred four surveys were returned for a response rate of 21%.

The top three concerns for the Apple River that emerged from this survey were pollution, development, and aquatic plants.

Over a third of respondents described the current water quality of the Apple River as average (36%). Combined more respondents described the current water quality of the Apple River as below average (29%) as compared to above average (11%). Survey participants were also asked to describe the change in water quality since they have lived on or near the river. Approximately a third of respondents described no noticeable change (34%). Combined, more respondents described a degradation in water quality (39%) as compared to an improvement (10%).





Harmony Environmental and Endangered Resources Services Aquatic Plant Management Plan

The most recent Aquatic Plant Management Plan for the Apple River Flowage was completed in 2011 by Harmony Environmental and Ecological Integrity Services.

In July 2010, an aquatic plant inventory was completed for the Apple River Flowage by Endangered Resource Services. This survey documented aquatic vegetation at 88% of the points sampled.

In June 2010, a bed mapping survey for curly leaf pondweed was completed by Endangered Resource Services. This survey documented curly leaf pondweed at 69% of the sample locations. Additionally, this survey classified areas of curly leaf pondweed by beds and areas of high density. The survey mapped thirteen beds totaling 345 acres and an additional 27 acres that were considered areas of high density.

To be considered a curly leaf bed two criteria had to be met: greater than 50% of the plants in an area had to be curly leaf pondweed and the curly leaf pondweed needed to have canopied at the surface or close enough to the surface to likely cause interference with normal boating traffic. Areas with high amounts of curly leaf pondweed that did not meet the density requirements, or were not canopied out, were considered high density curly leaf pondweed areas. These high density areas have the potential to form beds in the future.

The goals developed for the Apple River Flowage Aquatic Plant Management Plan include:

- ✓ Improve water quality on the Apple River Flowage and downstream on the Apple River
- ✓ Prevent the introduction of aquatic invasive species
- ✓ Maintain navigation for fishing, boating, and access to lake residences
- ✓ Maintain native aquatic plant functions
- ✓ Minimize environmental impacts of aquatic plant management

Lake District Resident Survey

A Wisconsin Department of Natural Resources approved sociological survey was mailed to two hundred twenty five residences of the Apple River Flowage Protection and Rehabilitation District in late June 2012. The survey was designed to gather information from residents concerning property ownership and use, land use, flowage use, concerns for the flowage, water quality, algae, shoreline vegetation, management practices for improvement of the flowage, wetlands, and website use.

Ninety two surveys were returned (41% response rate) and data was entered and analyzed. Ninety one percent of respondents own shoreline property on the Apple River Flowage; whereas the remaining 9% do not (n = 92). Respondents who did not own waterfront property were directed to skip questions to quantify shoreline habitat.

Property Ownership and Use

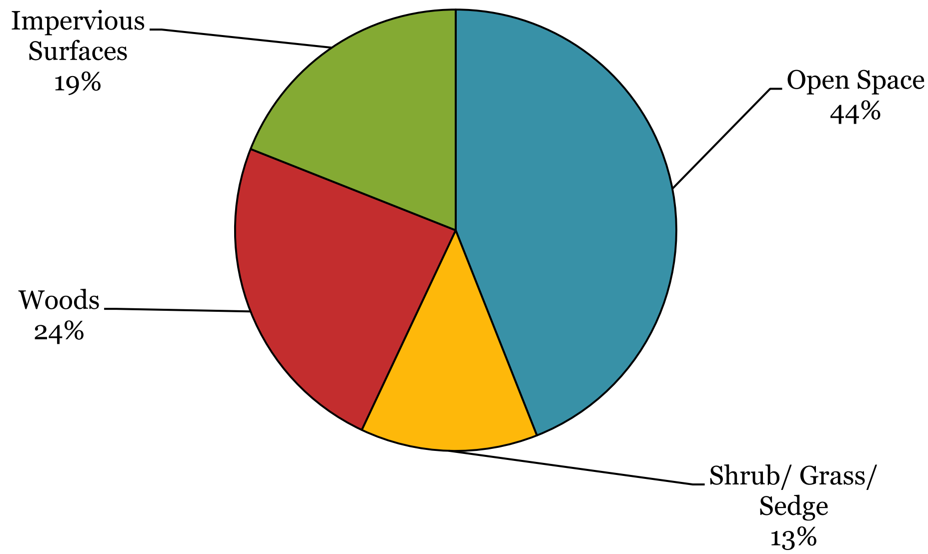
Respondents have owned property on or near the flowage for an average of 19 years (97%). The majority of residents use their property as a year round residence (59%) and close to a quarter of respondents use their property as a weekend, vacation, and/or holiday residence (21%). Fewer respondents use their property as a seasonal residents (continued occupancy for months at a time) (5%) and as a rental property (3%). Survey participants were also given the opportunity to specify how their property is used. A number of respondents own lots that do not currently have buildings (8%).

On average, respondents occupy their property for 237 days per year. At any given time an average of three people occupy each property.

Land Use

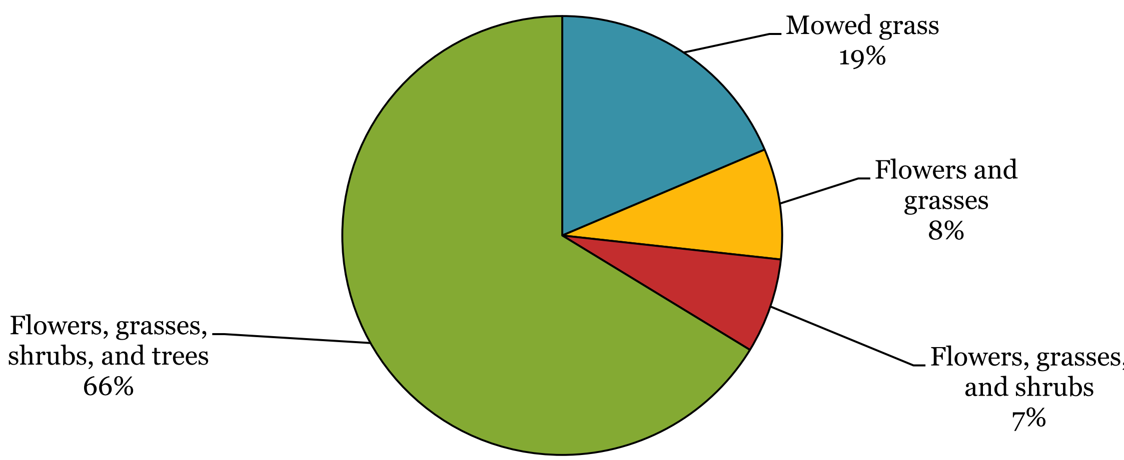
Survey respondents were asked to classify the amount of open space (lawns or mowed areas), shrub/grass/sedge community, woods, and impervious surfaces (buildings, driveways, sidewalks, patios, gravel paths and driveways) on their property to gauge land use in the area directly surrounding the Apple River Flowage. According to respondent classification an average of 44% of properties are occupied by open space, 24% by woods, 19% by impervious surfaces, and 13% by the shrub/grass/sedge community.

Please use estimated percentages to describe the amount of each land use on your property.



Respondents owning waterfront property were also asked to describe the first 35 feet of their shoreline (the area located directly adjacent to the flowage). The majority (66%) classified the first 35 feet of their shoreline as a mix of native flowers, grasses, shrubs, and trees. Nineteen percent classified the first 35 feet of their shoreline as mostly mowed grass, 8% as mostly native flowers and grasses, and 7% as a mix of native flowers, grasses, and shrubs.

Which best describes the first 35 feet of your shoreline (the area located directly adjacent to the lake)?



Flowage Use

Survey participants use the Apple River Flowage for a variety of recreational activities. Seventy one percent of respondents partake in fishing (any season); 52% partake in motorized water activities (PWC, boating, water skiing, tubing, jet skiing); 39% partake in non-motorized water activities (birding, canoeing, hiking, running); and 22% partake in swimming. Winter specific recreational activities were less frequent on the flowage. Eighteen percent of respondents partake in non-motorized winter activities (skiing, snowshoeing, ice skating) and 10% partake in motorized winter activities (ATV, snowmobile). Eight percent of survey participants do not participate in any of the activities described in the survey.

Respondents keep a total of 32 paddleboats/rowboats, 37 canoes/kayaks, 2 sailboats, 2 jet skis, 21 motorboats/pontoons (1-20 HP), 34 motorboats/pontoons (21-50HP), and 10 motorboats/pontoons (50+ HP).

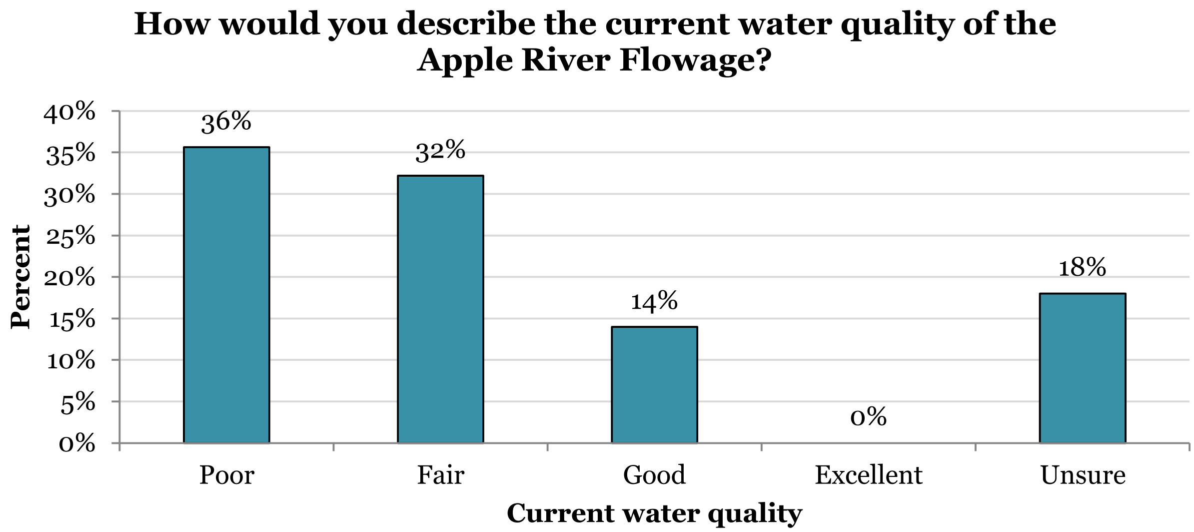
Concerns for the Apple River Flowage

Survey respondents were asked to rank their top three concerns for the Apple River Flowage. To analyze this data each concern that was ranked first received 3 points, each concern that was ranked second received 2 points, and each concern that was ranked third received 1 point. Total points were then added to determine the ranking of concerns for the flowage. Invasive species ranked as the 1st concern, followed by aquatic plants, and algae blooms.

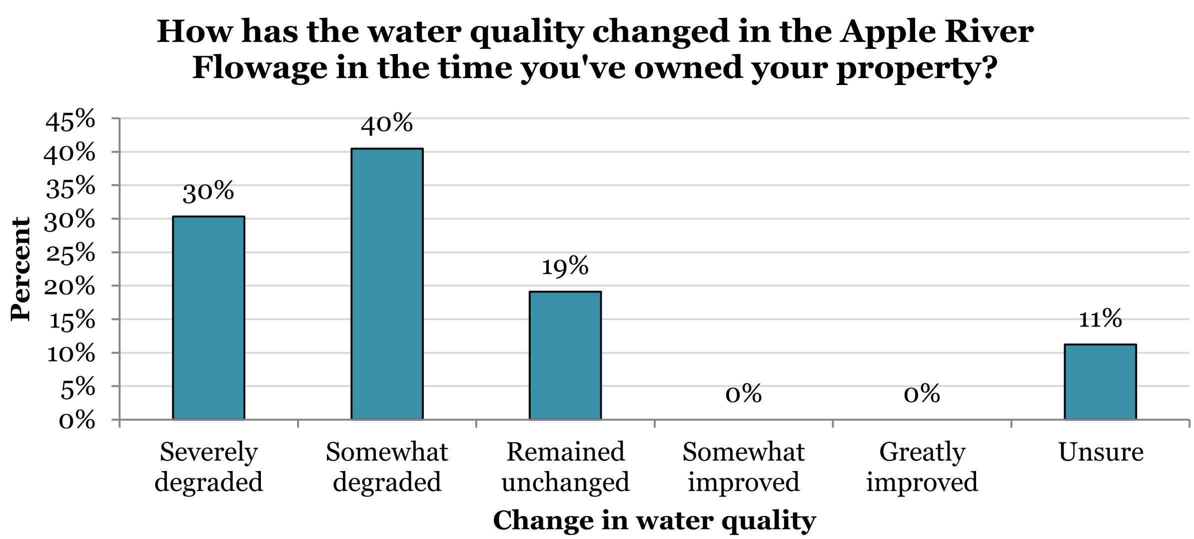
Concerns for the Apple River Flowage	Rank	Points
Invasive species (Eurasian water milfoil, zebra mussels, curly leaf, purple loosestrife)	1st	113
Aquatic plants (not including algae)	2nd	87
Algae blooms	3rd	63
Pollution (chemical inputs, septic systems, agriculture, erosion, storm water runoff)	4th	60
Property values and/or taxes	5th	50
Water clarity (visibility)	6th	39
Quality of fisheries	7th	29
Quality of life	8th	28
Water levels (loss of lake volume)	9th	24
Development (population density, loss of wildlife habitat)	10th	13
Water recreation safety (boat traffic, no wake zone)	11th	10
Other, please describe (geese, muskrats, sediment buildup, navigation)		10

Water Quality

Around a quarter of respondents described the water quality of the Apple River Flowage as either poor (36%) or fair (32%). Fewer respondents described the water quality as good (14%) and zero respondents described it as excellent. The remaining respondents were unsure how to describe the water quality of the flowage (18%).

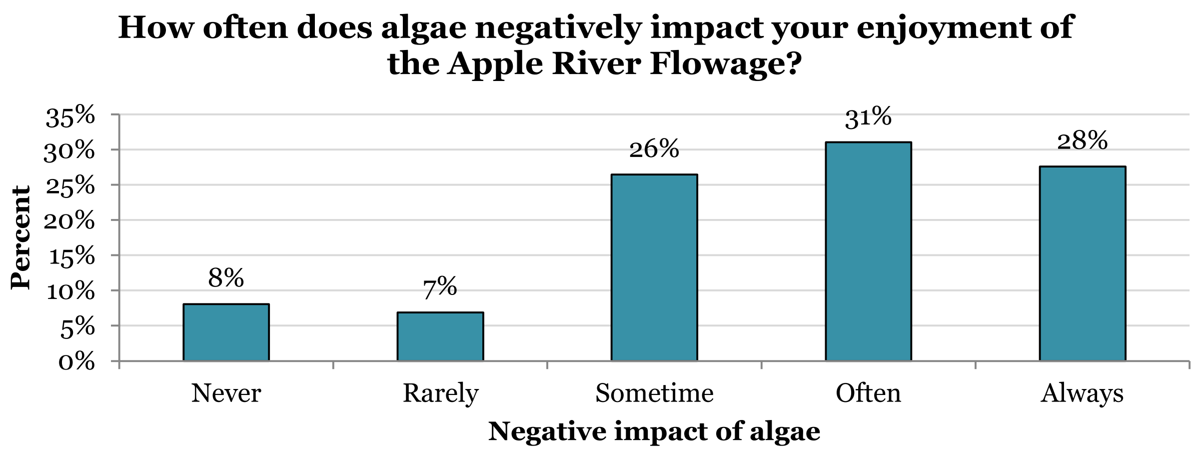


Survey participants were asked how the water quality has changed in the flowage in the time they have owned their property. Forty percent of respondents perceive that water quality has somewhat degraded and 30% perceive that water quality has severely degraded. Zero respondents perceive that water quality has either somewhat improved or greatly improved. Nineteen percent of respondents perceive that water quality has remained unchanged and 11% are unsure how water quality has changed.



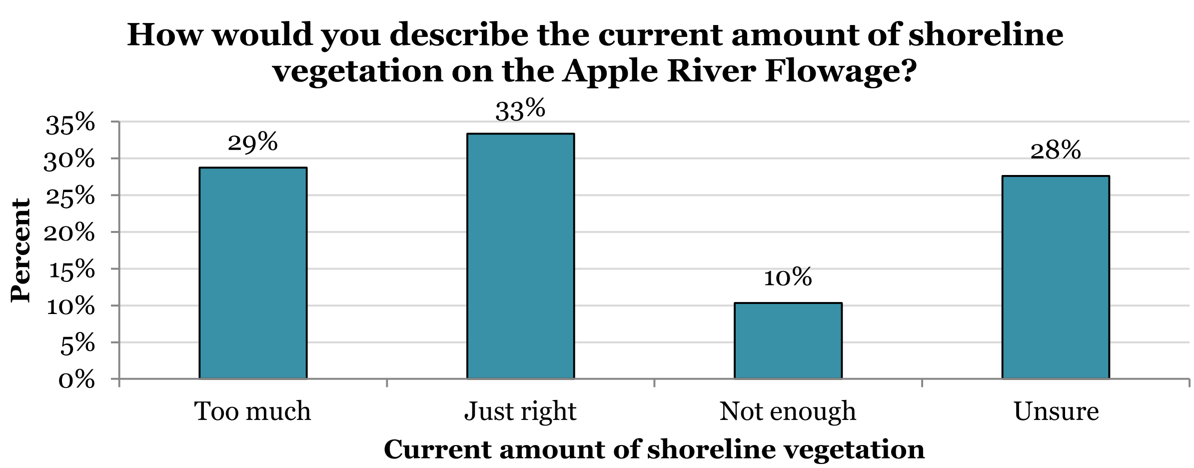
Algae

Over a quarter of respondents feel that algae always negatively impacts their enjoyment of the flowage (28%) and nearly a third of respondents feel that algae often negatively impacts their enjoyment of the flowage (31%). Approximately a quarter of respondents feel that algae sometimes negatively impact their enjoyment of the flowage (26%). Fewer respondents feel that algae rarely (7%) or never (8%) negatively impacts their enjoyment of the flowage.



Shoreline Vegetation

Survey participants were asked how they would describe the current amount of shoreline vegetation on the Apple River Flowage. Around a third of respondents described the amount of shoreline vegetation as either too much (29%) or just right (33%). A mere 10% of respondents described the amount of shoreline vegetation as not enough. The remaining 28% of respondents were unsure how to describe the current amount of shoreline vegetation.



Overall respondents recognize the importance of shoreline buffers, rain gardens, and native plants to the water quality of the flowage. Nearly half of respondents described shoreline buffers, rain gardens, and native plants as very important to the water quality of the flowage (47%) and over a quarter described shoreline buffers, rain gardens, and native plants as somewhat important to the water quality of the flowage (27%). Very few respondents described shoreline buffers, rain gardens, and native plants as not at all important (2%) and not too important (6%). The remaining 18% of respondents were unsure how to describe the importance of shoreline buffers, rain gardens, and native plants.

The results from this question suggest a possible educational need regarding the importance of shoreline buffers, rain gardens, and native plants to water quality.

Although a combined 74% of respondents felt that shoreline buffers, rain gardens, and native plants are very important or somewhat important to water quality, nearly half (47%) of respondents are not interested in installing a shoreline buffer or rain garden on their property. In contrast, 28% of respondents have already installed a shoreline buffer or rain garden and 12% are interested in installing a shoreline buffer or rain garden. The remainder of respondents (15%) were unsure of their interest in installing a shoreline buffer or rain garden.

Respondents are making educated decisions when applying fertilizer to their property. Nearly two thirds of respondents do not use fertilizer on their property (64%) and one third use zero phosphorus fertilizer (33%). Very few respondents use fertilizer but are unsure of its phosphorus content (5%), and zero respondents use fertilizer on their property that contains phosphorus.

Management Practices for Improvement

Survey respondents were asked to choose all of the management practices they felt should be used to maintain or improve the water quality of the Apple River Flowage from a list of seven options. Over half of respondents felt that enhanced efforts to monitor for new populations of aquatic invasive species should be used to maintain or improve the water quality of the flowage (60%).

Other management practices supported by many respondents include information and education opportunities (46%) and cost-sharing assistance for the installation of farmland conservation practices (41%).

Management practices to improve water quality	Percent
Enhanced efforts to monitor for new populations of aquatic invasive species	60%
Information and education opportunities	46%
Cost-sharing assistance for the installation of farmland conservation practices (nutrient management plans, contour strips, conservation tillage)	41%
Collection of sediment cores to provide information concerning historical lake conditions	38%
Establishment of slow-no-wake zones to protect aquatic plants and fisheries habitat	35%
Cost-sharing assistance for the installation of shoreline buffers and rain gardens	27%

Wetlands

Overall survey participants feel wetlands in the Apple River Flowage Watershed are important to the water quality of the flowage. Very few respondents described wetlands as not at all important (3%) or not too important (1%). Over half of respondents described wetlands as very important to the water quality of the flowage (52%) and close to a quarter described wetlands as somewhat important (21%). The remaining 22% of respondents were unsure how to describe the importance of wetlands to water quality on the flowage (n = 89). The results from this question suggest a possible educational need regarding the importance of wetlands to water quality.

Website Use

The Apple River Flowage Protection and Rehabilitation District maintains a website available at http://arprd.org. Over half of respondents never visit the website (59%) and an additional 20% of respondents rarely visit the website. Seventeen percent of respondents sometimes visit the website and 3% of respondents often visit the website.

Comparison of results to the 2001 survey

Although the 2001 survey was mailed to a much larger sample size (Apple River Watershed residents) as compared to the 2012 survey (Apple River Flowage Protection and Rehabilitation members) and was used to assess the Apple River rather than the Apple River Flowage, it may still be useful to analyze sharp differences or similarities across the two surveys.

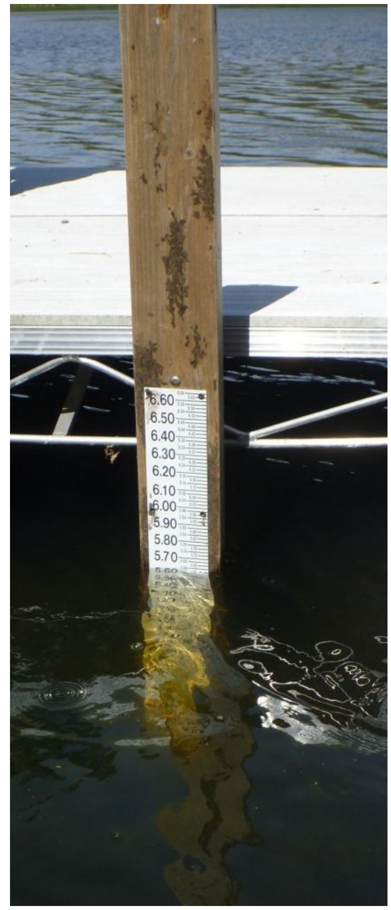
On both the Apple River survey in 2001 and the Apple River Flowage survey in 2012, survey responses for current water quality were clustered towards average and below average, or poor and fair. Additionally, changes in water quality for both surveys indicate responses that are clustered towards degradation as opposed to improvement.

Concerns cited by survey respondents for the Apple River in 2001 differ substantially from concerns for the Apple River Flowage in 2012. Top concerns in the 2001 survey were pollution followed by development and aquatic plants (weeds)[1]. In the 2012 survey for the Apple River Flowage the top concerns were invasive species, followed by aquatic plants, and algae.

Although aquatic plants rank high as concerns in both surveys, pollution and development were of greater concern for the Apple River in 2001, and invasive species and algae were of greater concern for the Apple River Flowage in 2012.

[1] Responses for the 2001 survey were re-ranked such that each concern that was ranked first received 3 points, each concern that was ranked 2nd received 2 points, and each concern that was ranked third received 1 point. Total points were then added to determine the ranking of concerns. Points for pollution totaled 688, points for development totaled 475, and points for aquatic plants (weeds) totaled 458.

Lake Level and Precipitation Monitoring



Lake water-level fluctuations are important to lake managers, lakeshore property owners, developers, and persons using lakes for recreation. Lake level fluctuations can have significant effects on lake water quality and usability. Although lake levels naturally change from year to year, extreme high or low levels can present problems such as restricted water access, flooding, shoreline and structure damage, and changes in riparian (near shore) vegetation.

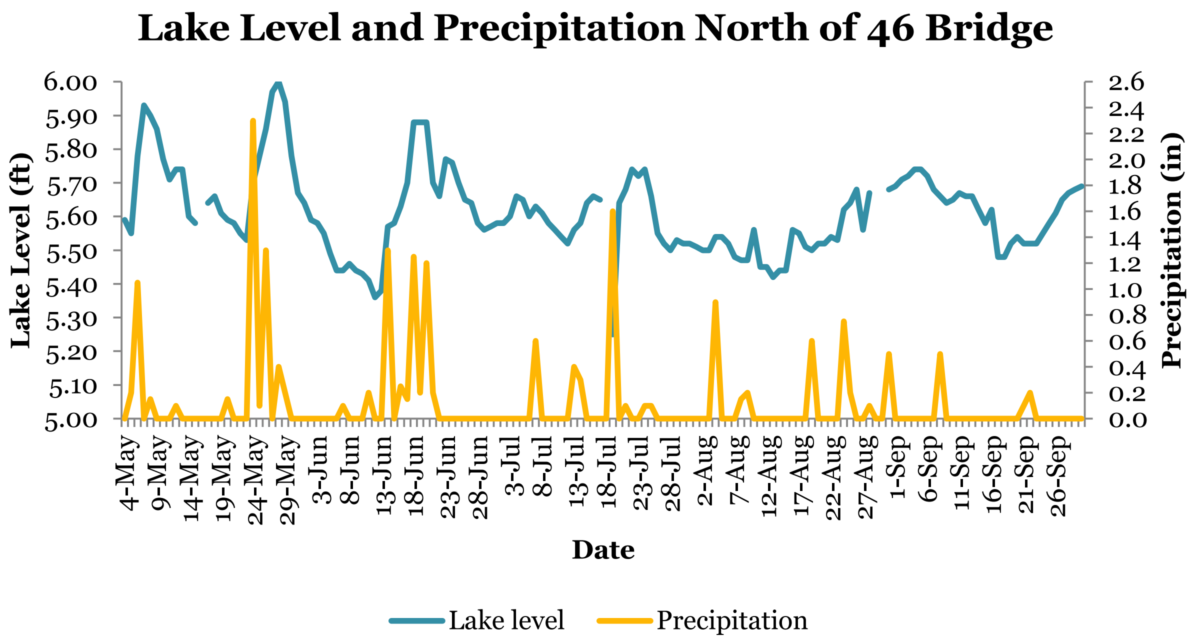
Records of lake water elevations can be very useful in understanding changes that may occur in lakes. While some lakes respond almost immediately to precipitation, other lakes do not reflect changes in precipitation until months later.

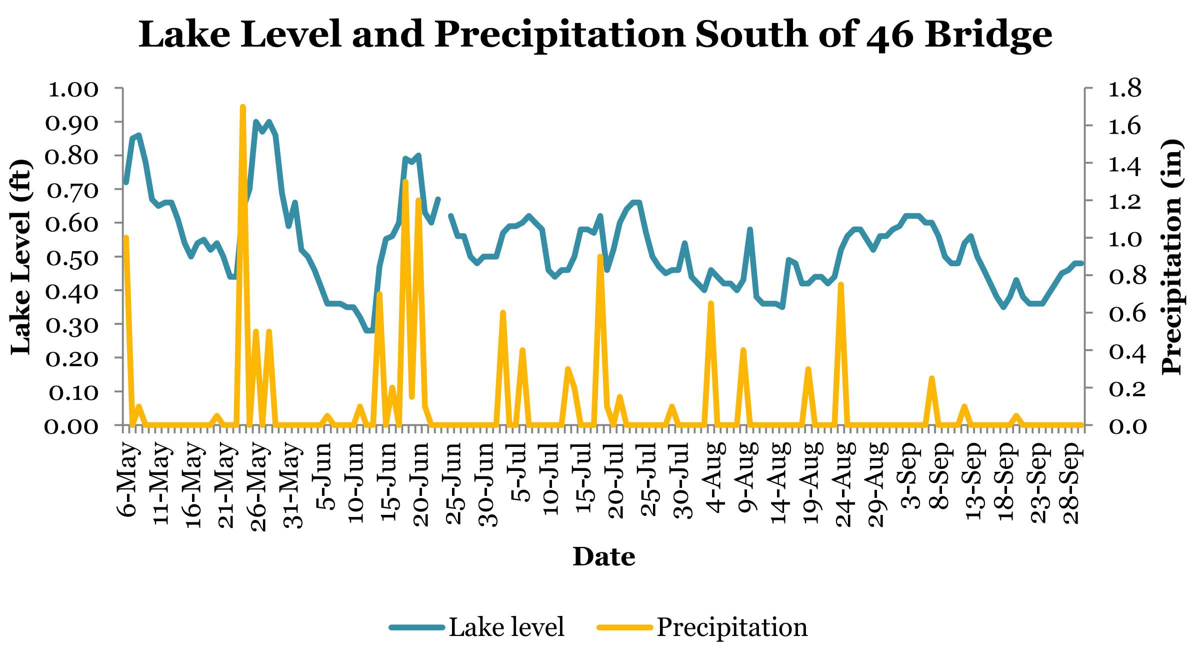
Volunteers monitored lake level and precipitation data for the Apple River Flowage in two locations: north and south of the 46 bridge. LWRD provided training to volunteers regarding data collection and installed staff and rain gauges at both sites. Staff gauges were set at an arbitrary height; therefore, lake levels are not comparable across the two sites at a specific point in time. However, the relative changes in lake level across the two sites are comparable.

Monitoring north of the 46 bridge began on May 4th, 2012 and monitoring south of the 46 bridge began on May 6th, 2012. Both sites were monitored through September 30th, 2012.

Seasonal precipitation totaled 18 inches north of the 46 bridge and 13 inches south of the 46 bridge. Shortly following precipitation events, water levels did increase in the flowage.

The flowage is created by a dam within the city limits of Amery. Currently, the dam is used to maintain water levels on the flowage. Water levels in the flowage changed by sixty-four-tenths of a foot north of the 46 bridge and sixty-two-tenths of a foot south of the bridge. Largely these changes are due to increased water levels after rainfall events. Overall, water levels remained fairly constant over the sampling season.


Lake Level and Precipitation North of 46 Bridge
Lake Level (ft)
Precipitation (in)
Date
Lake level
Precipitation


Lake Level and Precipitation South of 46 Bridge
Lake Level (ft)
Precipitation (in)
Date
Lake level
Precipitation

Chemical and Physical Data: Sampling Procedure

Chemical and physical data were collected in-lake at two sites (Site 1, North and Site 2, South) on the Apple River Flowage from May 8th, 2012 through September 17th, 2012. Spring turnover samples were taken on April 3rd, 2012. Fall turnover samples were taken on October 15th, 2012.

Two meter integrated samples were collected from the water column once a month during the growing season and at spring and fall turnover. Samples were analyzed at the Water and Environmental Analysis Lab (WEAL) at UW-Stevens Point for two types of phosphorus (total phosphorus and soluble reactive phosphorus), three types of nitrogen (nitrate/nitrite, ammonium, and total Kjeldahl nitrogen), chlorophyll *a*, chloride, and total suspended solids. Metals were analyzed for growing season samples and included: arsenic, calcium, copper, iron, potassium, magnesium, manganese, sodium, phosphorus, lead, zinc, and sulfate. In addition to these parameters, total hardness, calcium, sulfate, and sodium were analyzed at both turnover events.

Lake profile monitoring—which included dissolved oxygen, temperature, conductivity, pH, and secchi depth—was conducted bi-monthly during the growing season. Dissolved oxygen, temperature, and conductivity readings were recorded at every meter within the water column using a YSI 85 multi-parameter probe. pH readings were recorded at every meter within the water column using a YSI 60 pH meter. During the second sampling set in July, both YSI meters stopped working. Beginning with the August 6th sample, lake profile monitoring data was collected using an HI 9828 multi-parameter probe.

Secchi depth was recorded using a secchi disk, which is an eight inch diameter round disk with alternating black and white quadrants. To record secchi depth, the secchi disk was lowered into the flowage on the shady side of a boat until it just disappeared from sight. This depth was measured in feet and recorded as the secchi depth.

In most instances in this report, data is presented as an average over the **growing season**, which refers to data collected from May through September and excludes April and October turnover data. In some instances, data is averaged over the **summer index period**, which refers to data collected from July 15th through September 15th.

Lake Mixing and Stratification: Background Information

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

Water quality is greatly affected by the degree to which the water in a lake mixes. Within a lake, mixing is most directly impacted by the temperature-density relationship of water. When comparing why certain lakes mix differently than others, lake area, depth, shape, and position in the landscape become important factors to consider.

Water reaches its greatest density at 3.9°C (39°F) and becomes less dense as temperatures increase and decrease. Compared to other liquids, the temperature-density relationship of water is unusual: liquid water is denser than water in its solid form (ice). As a result, ice floats on liquid water.

When ice melts in the early spring, the temperature and density of the water will be constant from the top to the bottom of the lake. This uniformity in density allows a lake to completely mix. As a result, oxygen is brought to the bottom of a lake, and nutrients are re-suspended from the sediments. This event is termed **spring turnover**.

In spring 2012, ice out on the Apple River Flowage occurred approximately one month earlier than what is typical in Polk County. Since the grant start date was April 1st, spring turnover samples were not taken until April 3rd. However, due to early ice out, the spring turnover samples were likely taken after spring turnover occurred.

As the sun's rays warm the surface waters in the spring, the water becomes less dense and remains at the surface. Warmer water is mixed deeper into the water column through wind and wave action. However, these forces can only mix water to a depth of approximately twenty to thirty feet. Generally, in a shallow lake, the water may remain mixed all summer. However, a deeper lake usually experiences layering called **stratification**.

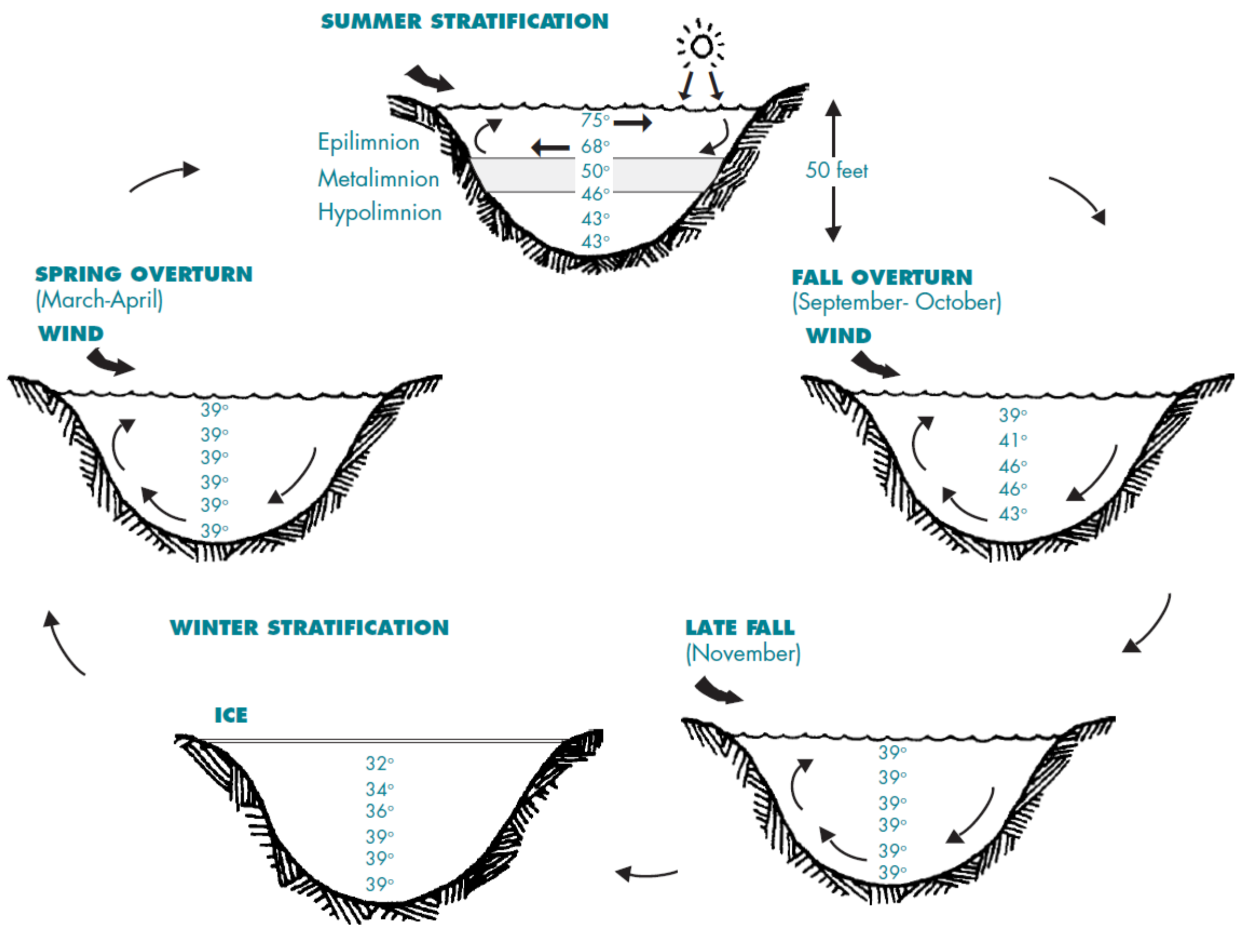
During the summer, lakes have the potential to divide into three distinct zones: the **epilimnion**, **thermocline** or **metalimnion**, and the **hypolimnion**. The epilimnion describes the warmer surface layer of a lake; whereas the hypolimnion describes the cooler bottom area of a lake. The thermocline, or metalimnion, describes the transition area between the warmer surface layer and the cooler bottom layer.

As surface waters cool in the fall, they become more dense and sink until the water temperature evens out from top to bottom. This process is called **fall turnover** and allows for a second mixing event to occur. Occasionally, algae blooms can occur at fall overturn when nutrients from the hypolimnion are made available throughout the water column.

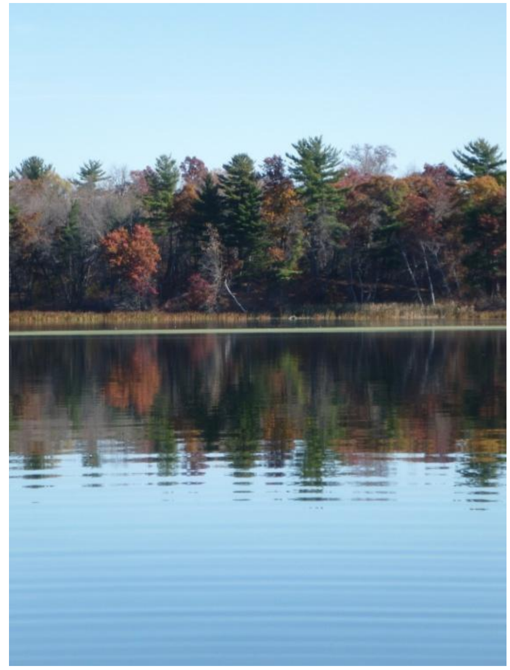
The variations in density arising from different water temperatures can prevent warmer water from mixing with cooler water. As a result, nutrients released from the sediments can become trapped in the hypolimnion of a lake that stratifies. Additionally, because mixing is one of the main ways oxygen is distributed throughout a lake, lakes that don't mix have the potential to have very low levels of oxygen in the hypolimnion.

The absence of oxygen in the hypolimnion can have adverse effects on fisheries. Species of cold water fishes, such as trout, require the cooler waters that result from stratification. Cold water holds more oxygen as compared to warm water. As a result, the cooler waters of the hypolimnion can provide a refuge for cold water fisheries in the summer as long as oxygen is present. Respiration by plants, animals, and bacteria is the primary means by which oxygen is removed from the hypolimnion. A large algae bloom can cause oxygen depletion in the hypolimnion as algae die, sink, and decay.

In the winter, stratification remains constant because ice cover prevents mixing by wind action.



Phosphorus



Phosphorus is an element present in lakes which is necessary for plant and algae growth. It occurs naturally in soil, rocks, and the atmosphere and can make its way into lakes through groundwater and soil erosion induced from construction site runoff or other human induced disturbances. Additional sources of phosphorus input into a lake can include fertilizer runoff from urban and agricultural settings and manure.

Phosphorus does not readily dissolve in water, instead it forms insoluble precipitates (particles) with calcium, iron, and aluminum. If oxygen is available in the hypolimnion, iron forms sediment particles that store phosphorus in the sediments. However, when lakes lose oxygen in the winter or when the hypolimnion becomes anoxic in the summer, these particles dissolve in the water. Strong wind action or turnover events can then re-distribute phosphorus throughout the water column.

While phosphorus is necessary for plant and animal growth, excessive amounts lead to an overabundance of growth which can decrease water clarity and lead to nutrient pollution in lakes. Phosphorus is present in lakes in several forms. This study measured two forms of phosphorus: total phosphorus and soluble reactive phosphorus.

Total phosphorus (TP) is a measure of all the phosphorus in a sample of water. In many cases total phosphorus is the preferred indicator of a lake's nutrient status because it remains more stable than other forms over an annual cycle.

Soluble reactive phosphorus (SRP) includes forms of phosphorus that are dissolved in the water and are readily available for uptake by algae and aquatic macrophytes (plants).

In lakes, a "healthy" limit of phosphorus is set at 0.02 mg/L total phosphorus and 0.01 mg/L soluble reactive phosphorus to prevent nuisance algae blooms. If a value is above the healthy limit it is more likely that a lake could support nuisance algae blooms. In impoundments, the limit is set at 0.03 mg/L total phosphorus. If a value is above the healthy limit it is more likely that a lake could support nuisance algae blooms.

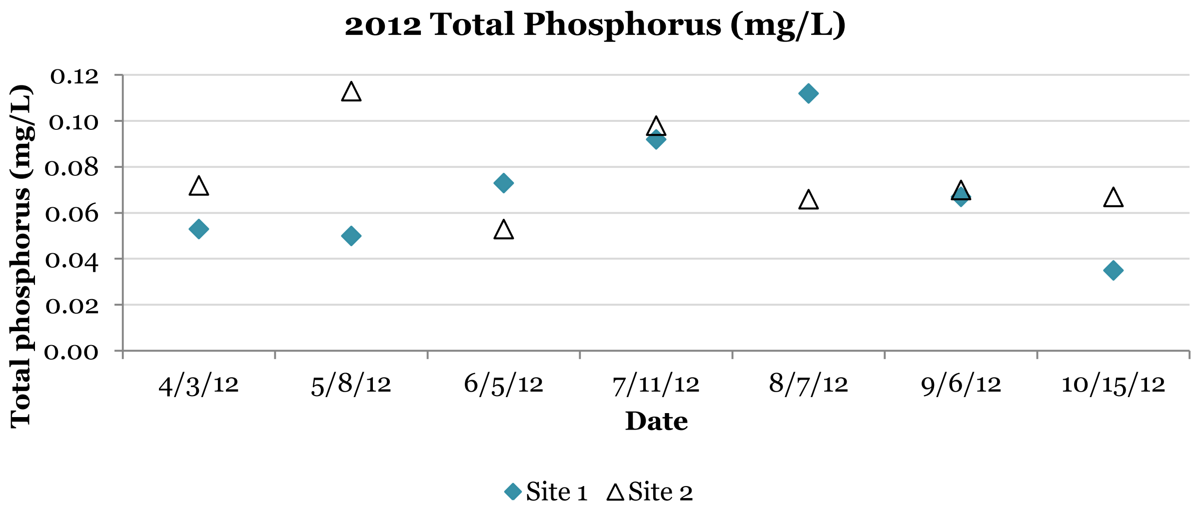
Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

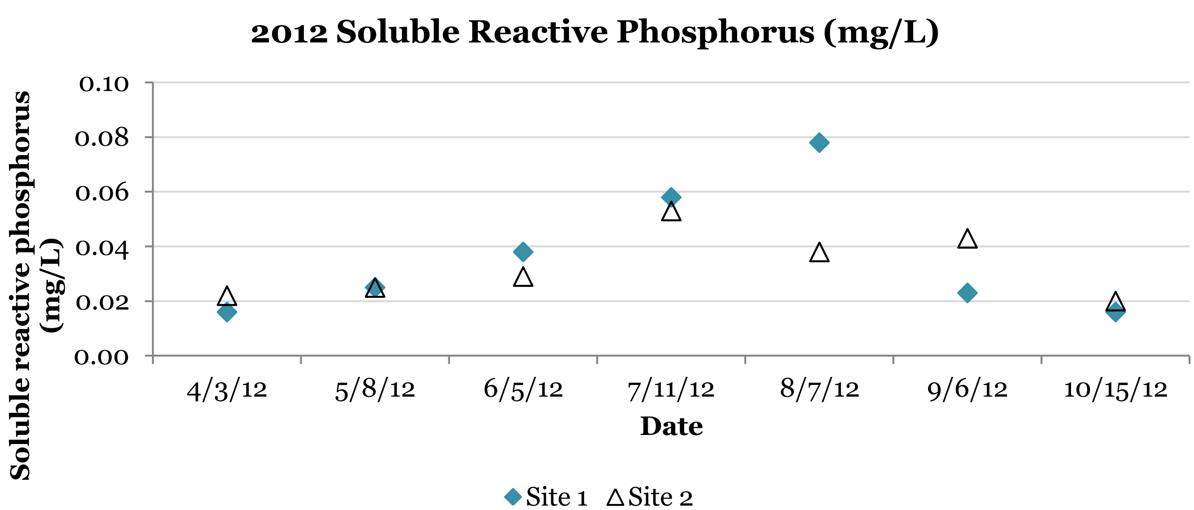
The total phosphorus criterion for the Apple River Flowage, as measured over the summer index period, is 0.075 mg/l.

The growing season average total phosphorus was 0.0788 mg/L at site one and 0.0800 mg/L at site two.

The summer index period average total phosphorus was 0.0895 mg/L at site one and 0.0680 mg/L at site two. The total phosphorus criterion was exceeded at site one in 2012.

The growing season average (excludes turnover) soluble reactive phosphorus was 0.0444 mg/L at site one 0.0376 mg/L at site two.





Nitrogen

Nitrogen, like phosphorus, is an element necessary for plant growth. Nitrogen sources in a lake can vary widely. Although nitrogen does not occur naturally in soil minerals, it is a major component of all plant and animal matter. The decomposition of plant and animal matter releases ammonia, which is converted to nitrate in the presence of oxygen. This reaction accelerates when water temperatures increase. Nitrogen can also be introduced to a lake through rainfall, in the form of nitrate and ammonium, and through groundwater in the form of nitrate.

In most instances, the amount of nitrogen in a lake corresponds to land use. Nitrogen can enter a lake from surface runoff or groundwater sources as a result of fertilization of lawns and agricultural fields, animal waste, or human waste from septic systems or sewage treatment plants. During spring and fall turnover events, nitrogen is recycled back into the water column, which can cause spikes in ammonia levels. Under low oxygen circumstances, nitrogen can be lost from a lake system through a process called denitrification. Under these conditions nitrate is converted to nitrogen gas. Additionally, nitrogen can be lost through permanent sedimentation.

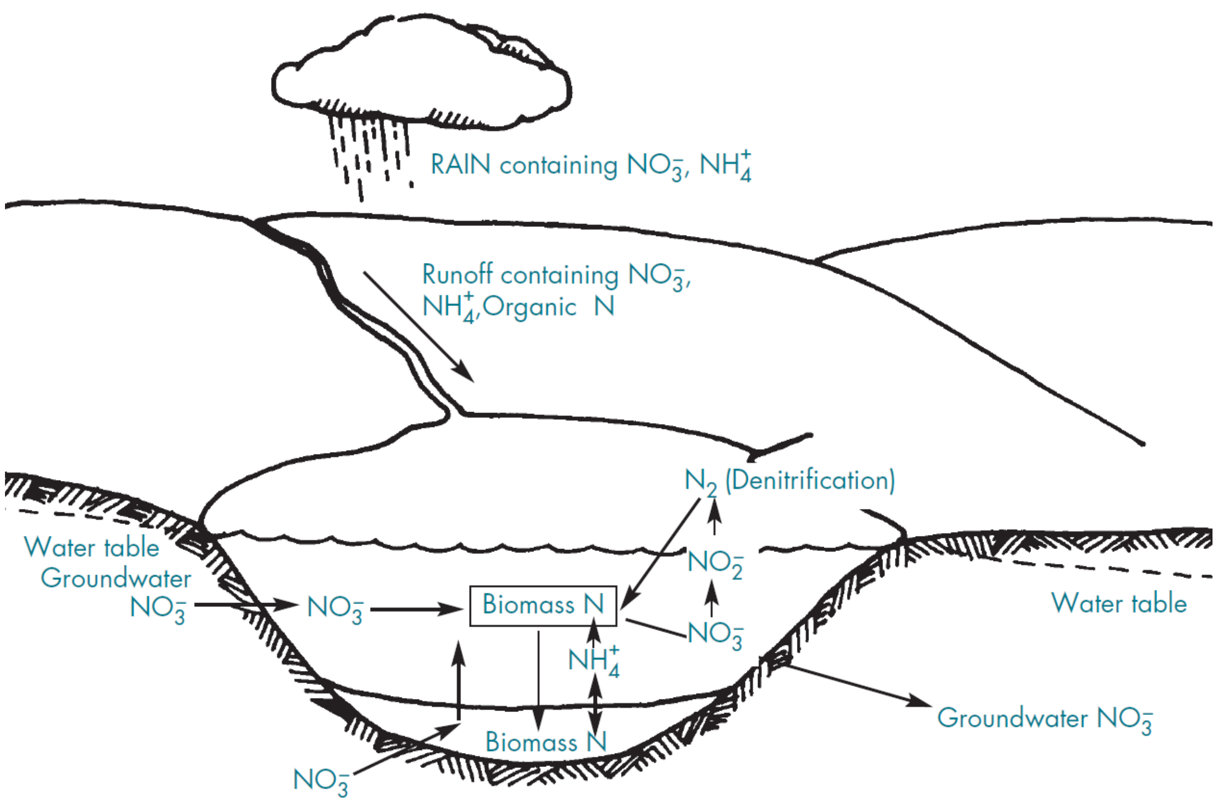


Figure from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

Nitrogen comprises the majority (78%) of the gases in the Earth's atmosphere. As with other gases, nitrogen is more soluble in cooler water as compared to warmer water. Nitrogen gas is not readily available to most aquatic plants, with the exception of blue green algae.

Similar to phosphorus, nitrogen is divided into many components. In this study nitrate/nitrite (NO_3 and NO_2), ammonium (NH_4), and total Kjeldahl nitrogen (TKN) were analyzed.

Nitrate/nitrite and ammonium are all inorganic forms of nitrogen which can be used by aquatic plants and algae. Inorganic nitrogen concentrations above 0.3 mg/L can support summer algae blooms in lakes.

Total Kjeldahl nitrogen (TKN) is a measure of organic nitrogen plus ammonium. By subtracting the ammonium concentration from TKN, the organic nitrogen concentration found in plants and algal material can be found.

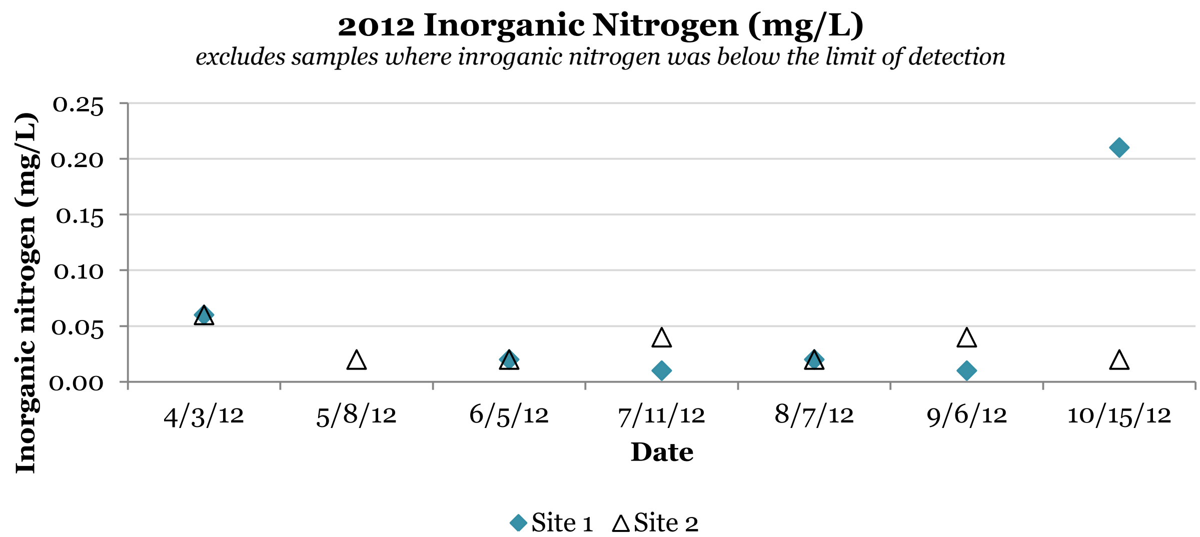
Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

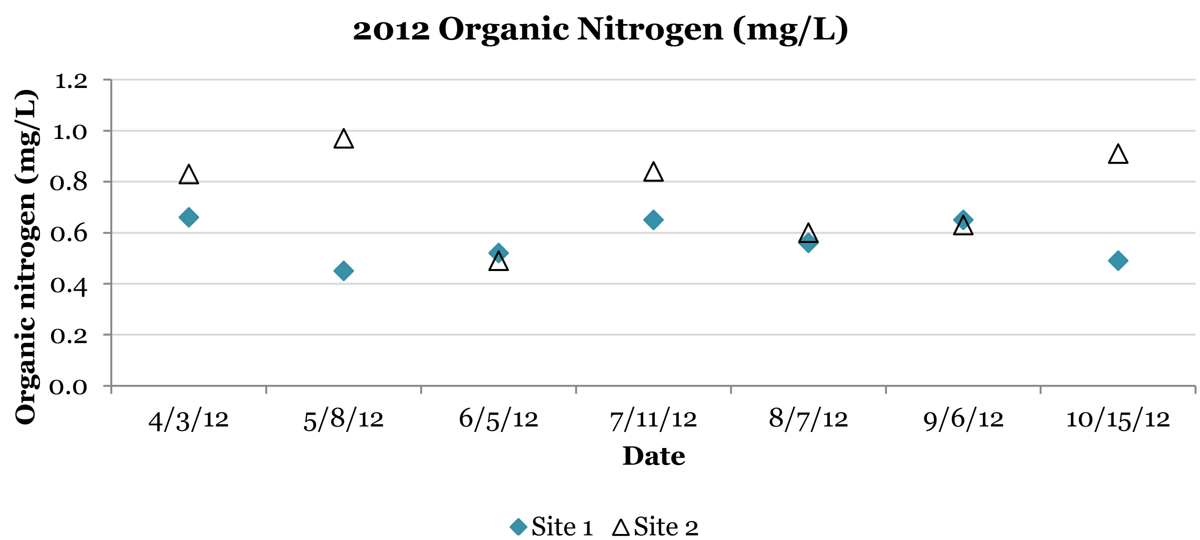
Average growing season (excludes turnover) inorganic nitrogen was 0.02 mg/L at site one and 0.03 mg/L at site two. Inorganic nitrogen concentrations at both sites were below the healthy limit which can support summer algae blooms in lakes. However, these healthy limit values are based on lakes versus impoundments.

Average growing season (excludes turnover) organic nitrogen was 0.566 mg/L at site one and 0.706 mg/L at site two.

At site one, nitrate/nitrite concentrations were below the limit of detection (0.1 mg/L) at all samples dates with the exception of spring and fall turnover. Additionally, at site one ammonium concentrations were below the limit of detection (0.01 mg/L) on May 8th. As a result, inorganic nitrogen concentrations were below the limit of detection on May 8th at site one.

At site two, nitrate/nitrite concentrations were below the limit of detection at all sample dates with the exception of spring turnover.


2012 Inorganic Nitrogen (mg/L)
excludes samples where inroganic nitrogen was below the limit of detection
Inorganic nitrogen (mg/L)
0.25
0.20
0.15
0.10
0.05
0.00
4/3/12
5/8/12
6/5/12
7/11/12
8/7/12
9/6/12
10/15/12
Date
Site 1
Site 2


2012 Organic Nitrogen (mg/L)
Organic nitrogen (mg/L)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4/3/12
5/8/12
6/5/12
7/11/12
8/7/12
9/6/12
10/15/12
Date
Site 1
Site 2

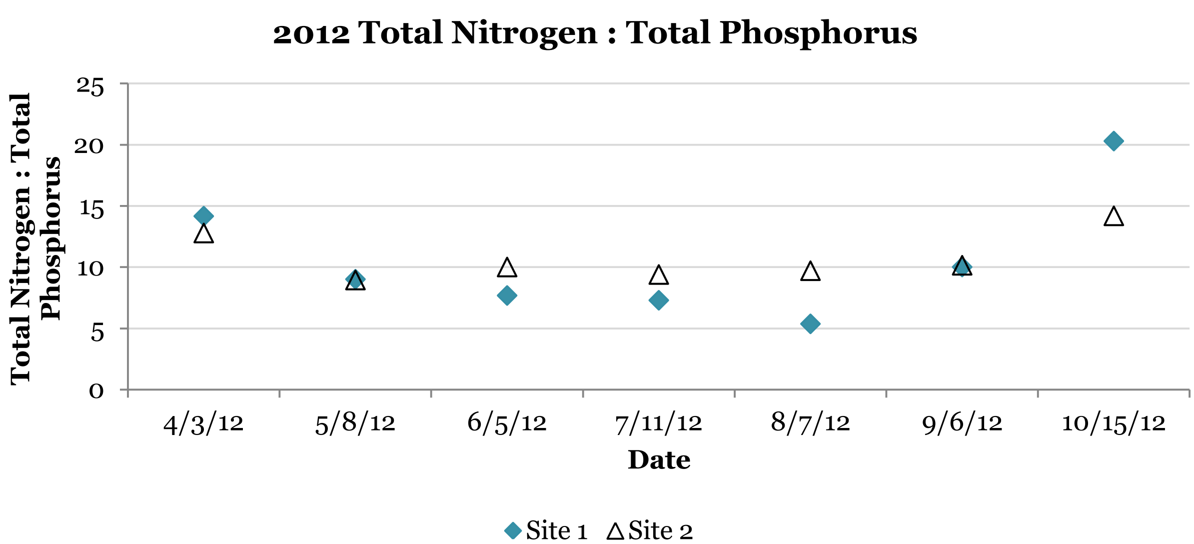
Total Nitrogen to Total Phosphorus Ratio

The total nitrogen to total phosphorus ratio (TN: TP) is a calculation that depicts which nutrient limits algae growth in a lake.

Lakes are considered nitrogen limited, or sensitive to the amount of nitrogen inputs, when TN: TP ratios are less than 10. Only about 10% of Wisconsin lakes are limited by nitrogen. In contrast, lakes are considered phosphorus limited, or sensitive to the amount of phosphorus inputs into a lake, when the TN: TP ratio is above 15. Lakes with values between 10 and 15 are considered transitional. In transitional lakes it is impossible to determine which nutrient, either nitrogen or phosphorus, is limiting algae growth.

Total nitrogen is found by adding NO_3+NO_2+TKN. As previously mentioned, nitrate/nitrite concentrations were below the limit of detection on all sample dates at site one, with the exception of spring and fall turnover, and on all sample dates at site two with the exception of spring turnover. As a result, total nitrogen is largely reflective of TKN.

The total nitrogen to total phosphorus ratio for both sites indicate a nitrogen limited state during the growing season. During spring turnover at both sites and during fall turnover at site two, the ratio indicates a transitional state. During fall turnover at site one, the ratio indicates a phosphorus limited state.



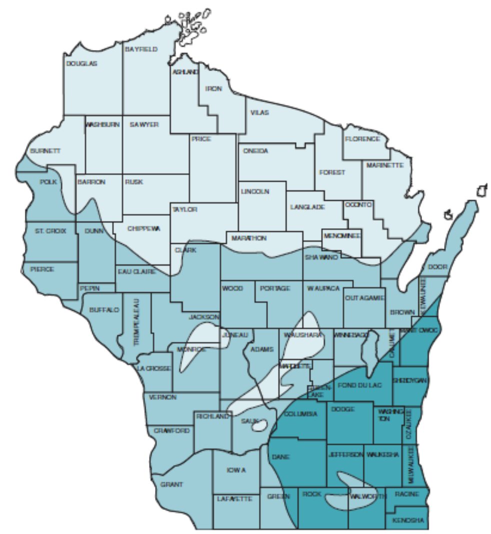
Chloride

Although chloride does not directly negatively impact plants, algae, or aquatic organisms, elevated levels of chloride in a lake can indicate possible water pollution.

With the exception of limestone deposits, chloride is uncommon in Wisconsin soils, rocks, and minerals. Background levels of chloride are generally found in small quantities in nearly every Wisconsin lake and can be introduced to waterways through rainwater.

The watershed for the Apple River Flowage is located in an area where chloride concentrations can be expected to range from greater than three up to ten mg/L.

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).



CHLORIDE CONCENTRATIONS (mg/l)

>10 | >3 - 10 | <3

FIGURE 7. Generalized distribution gradients of chloride in the surface waters of Wisconsin lakes. (*Adapted from Lillie and Mason, 1983.*)

Chloride concentrations range from 4.2 mg/L up to 6.7 mg/L at site one and from 4.3 mg/L up to 7.3 mg/L at site two. Average growing season (excludes turnover) chloride concentrations were 5.1 mg/L at site one and 5.2 mg/L at site two.

Sulfate

Sulfate concentrations in lakes are most directly related to the types of minerals found in the watershed and to acid rain. Sulfur compounds released into the atmosphere by coal burning facilities can enter lakes via rainfall. In general, sulfate concentrations are higher in the southeastern portion of the state where mineral sources of sulfate and acid rain are more common.

In Polk County, sulfate concentrations are generally less than 10 mg/L.

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

Sulfate concentrations ranged from 2.6 mg/L up to 6.4 mg/L at site one and from 2.6 mg/L up to 7.5 mg/L at site two

Average growing season sulfate concentrations were 5.0 mg/L at site one and 5.5 mg/L at site two.

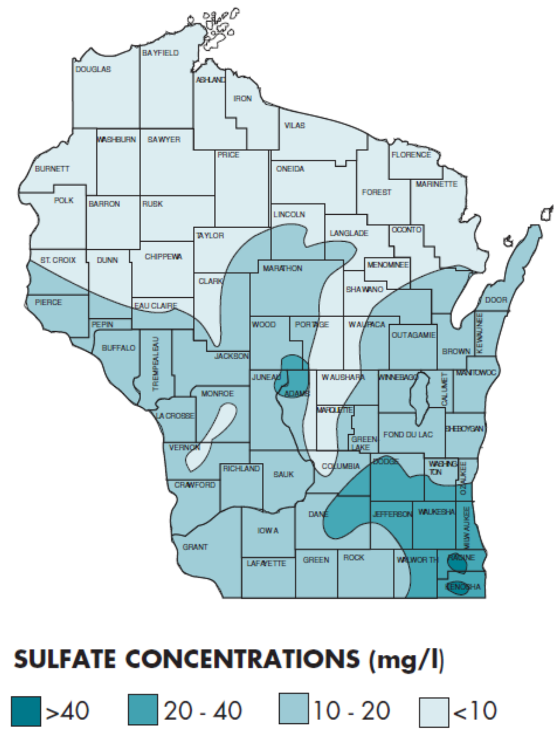
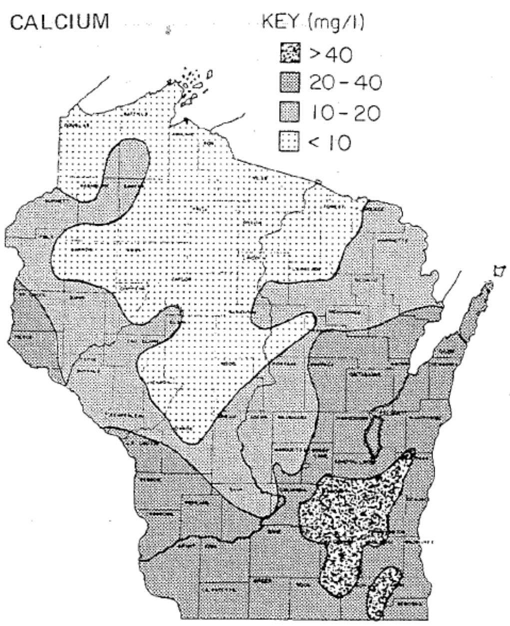


FIGURE 8. Generalized distribution gradients of sulfate in the surface waters of Wisconsin lakes. (*Adapted from Lillie and Mason, 1983.*)

Calcium and Magnesium

Calcium and magnesium concentrations in Wisconsin lakes are closely related to the bedrock geology of the landscape, with highest concentrations found in areas with limestone and dolomite deposits. In Polk County, calcium concentrations typically range from 10-20 mg/L and magnesium concentrations are typically less than 10 mg/L (Lillie, 1983). Calcium concentrations were elevated as compared to the average for Polk County lakes and magnesium concentrations were at the maximum range for Polk County lakes.



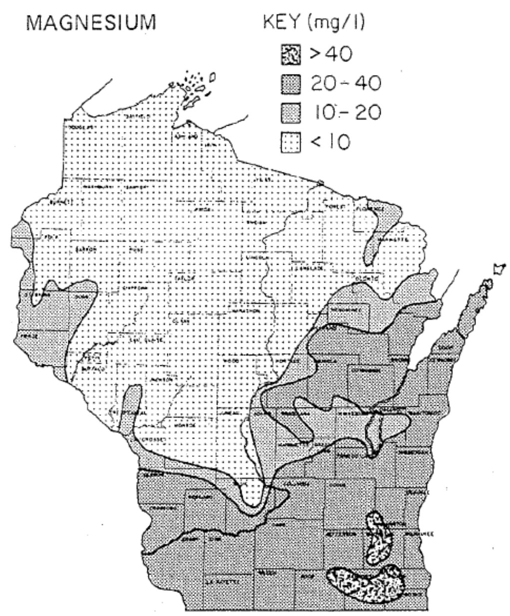


Figure from: (Lillie, 1983).

	Site 1	Site 2
Average Calcium (mg/L)	**30.7**	**29.9**
Minimum Calcium (mg/L)	26.6	24.0
Maximum Calcium (mg/L)	34.4	34.4

	Site 1	Site 2
Average Magnesium (mg/L)	**10.9**	**11.1**
Minimum Magnesium (mg/L)	8.6	8.7
Maximum Magnesium (mg/L)	12.9	12.6

Total Suspended Solids

Total suspended solids (TSS) quantify the amount of inorganic matter that is floating in the water column. Wind, waves, boats, and even some fish species can stir up sediments from the lake bottom re-suspending them in the water column. Fine sediments, especially clay, can remain suspended in the water column for weeks. These particles scatter light and decrease water transparency.

Total suspended solids were below the limit of detection (2 mg/L) at site one on June 5th and September 6th.

Dissolved Oxygen

Oxygen is required by all aquatic organisms for survival. The amount of oxygen dissolved in water depends on water temperature, the amount of wind mixing that brings water into contact with the atmosphere, the biological activity that consumes or produces oxygen within a lake, and the composition of groundwater and surface water entering a lake.

In a process called photosynthesis, plants use carbon dioxide, water, and the sun's energy to produce simple sugars and oxygen. Chlorophyll, the pigment in plants that captures the light energy necessary for photosynthesis, is the site where oxygen is produced. Since photosynthesis requires light, the oxygen producing process only occurs during the daylight hours and only at depths where sunlight can penetrate.

Plants and animals also use oxygen in a process called respiration. During respiration, sugar and oxygen are used by plants and animals to produce carbon dioxide and water.

Temperature °C	Temperature °F	Oxygen solubility (mg/L)
0	32	15
5	41	13
10	50	11
15	59	10
20	68	9
25	77	8

Cold water is able to hold more oxygen as compared to warm water. However, although temperatures are coolest in the deepest part of a lake, these waters often do not contain the most oxygen. This arises because in the deepest parts of lakes, oxygen producing photosynthesis is not occurring, mixing is unable to introduce oxygen, and the only reaction occurring is oxygen consuming respiration. Therefore, it is not uncommon for oxygen depletion to occur in the hypolimnion.

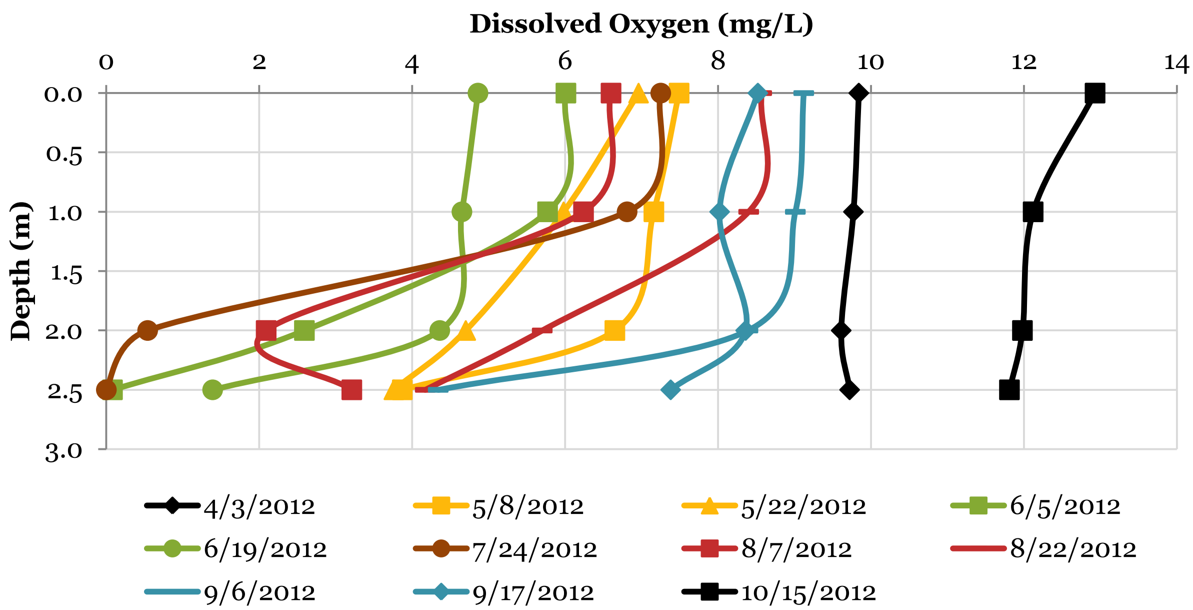
During the sunlight hours, when photosynthesis is occurring, dissolved oxygen levels at a lake's surface may exceed the oxygen solubility values. Conversely, at night or early in the morning (when photosynthesis is not occurring), the dissolved oxygen values can be expected to be lower.

A water quality standard for dissolved oxygen in warm water lakes and streams is set at 5 mg/L. This standard is based on the minimum amount of oxygen required by fish for survival and growth. For cold water lakes supporting trout, the standard is set even higher at 7 mg/L.

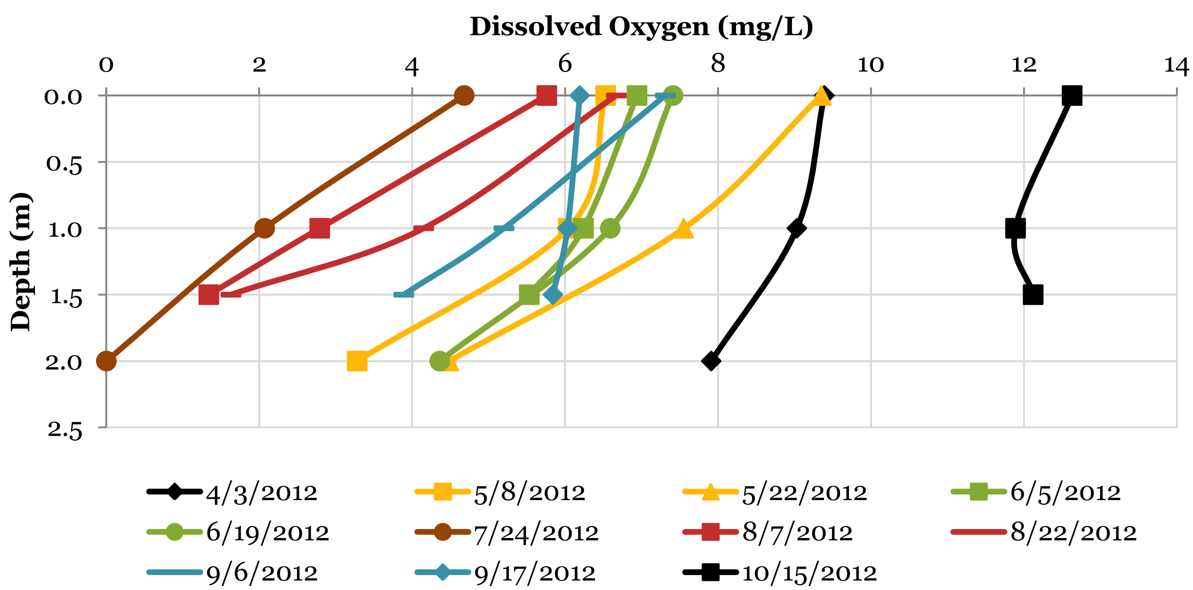
Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

The upper waters of the Apple River Flowage remained well oxygenated throughout the majority of the summer. Near bottom, dissolved oxygen levels were lowest in June and July at site one and lowest in July and August at site 2. At site one, where water depths were 2.5 meters, the first meter of the water column remained well oxygenated. At site two, where water depths were 2 meters, oxygen levels dropped substantially by the first meter. This likely arose from the increased abundance of plants at this site.

2012 Site 1 Dissolved Oxygen (mg/L)

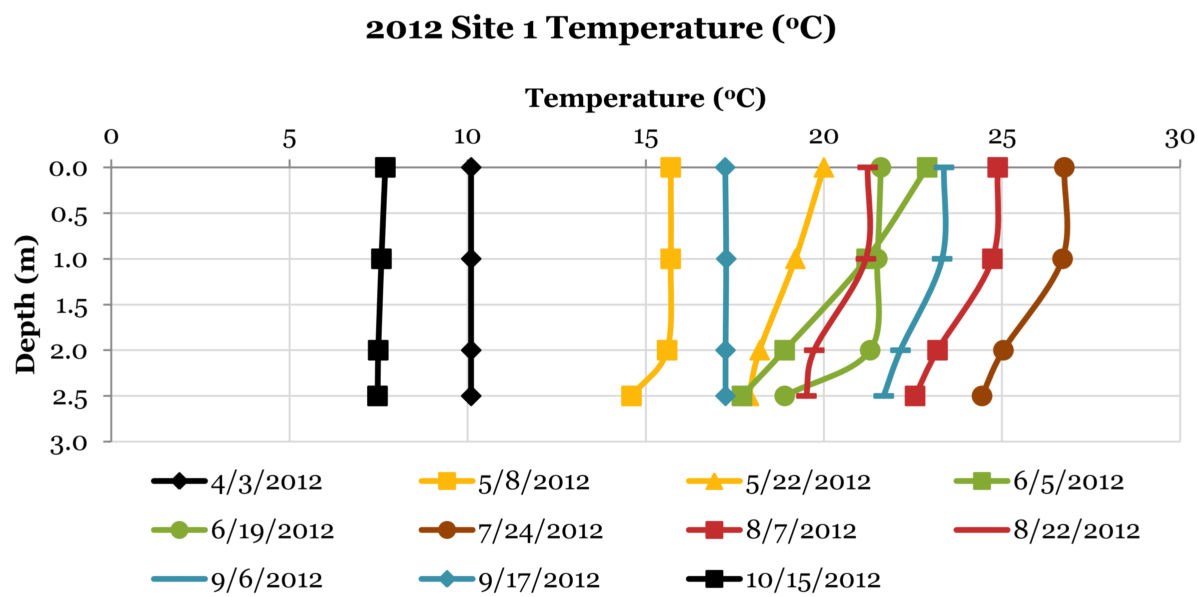


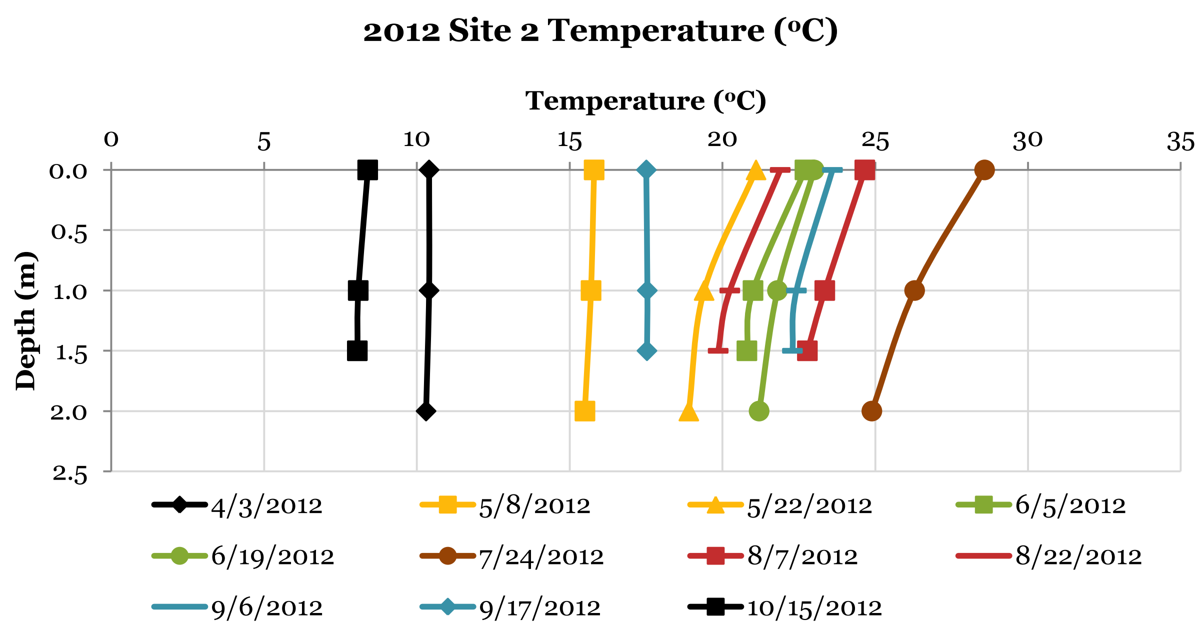
2012 Site 2 Dissolved Oxygen (mg/L)



Temperature

The Apple River Flowage reached its warmest surface temperature (26.8 °C at site one and 28.6 °C at site two) on July 24th. By examining the temperature profile it is clear that in 2012 the Apple River Flowage did not stratify, or develop density dependent differences that create distinct layers in the water column.





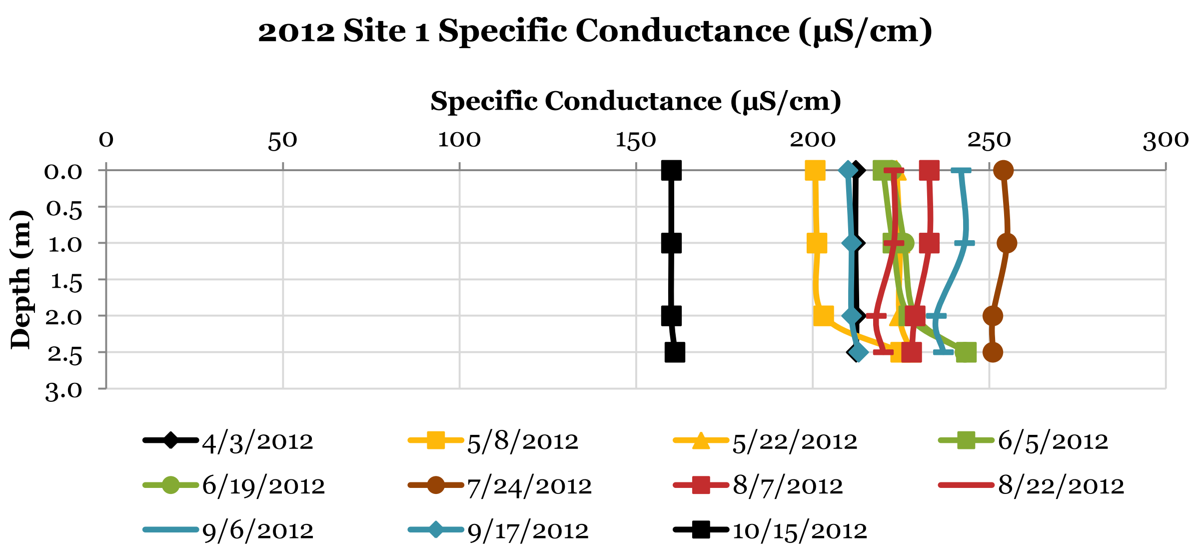
Conductivity (Specific Conductance)

Conductivity is the measure of the ability of water to conduct an electrical current and serves as an indicator of the concentration of total dissolved inorganic chemicals in the water. Since conductivity is temperature related, reported values are normalized at 25°C and termed specific conductance. Specific conductance increases as the concentration of dissolved minerals in a lake increase.

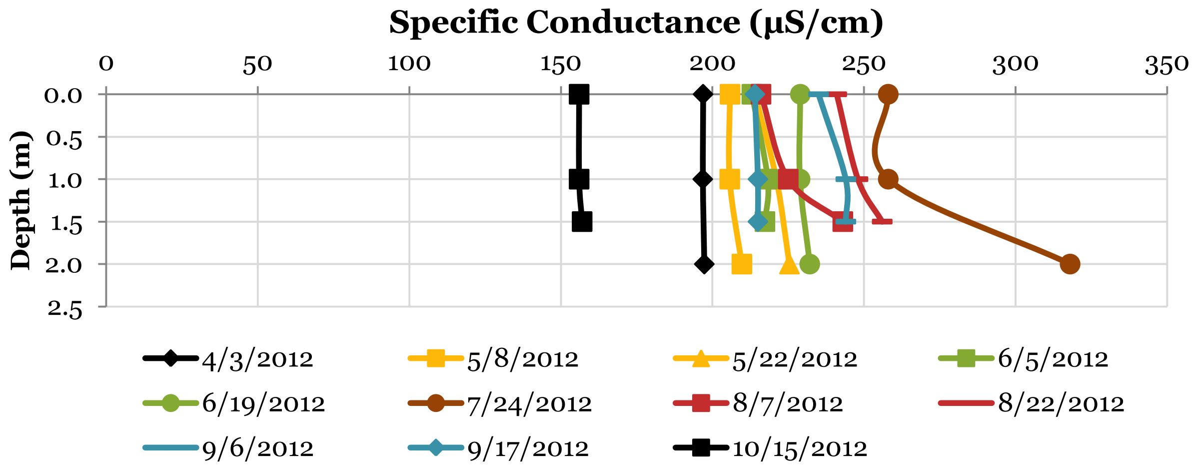
Specific conductance values are typically two times the water hardness. Hardness is the quantity of cations with more than one positive charge, primarily calcium and magnesium. Soluble minerals, especially limestone, in a lakes watershed impact the value for hardness. A categorization of hardness indicates that the Apple River Flowage is moderately hard (between 61-120 mg/L).

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

In general, conductivity values fell between 200-250 µS/cm at both sites on the Apple River Flowage. Conductivity values were the highest on July 24th, 2012 and the lowest at fall turnover (October 15th, 2012).



2012 Site 2 Specific Conductance (µS/cm)



pH

An indicator of acidity, pH is the negative logarithm of the hydrogen ion (H+) concentration. Lower pH waters have more hydrogen ions and are more acidic, and high pH waters have less hydrogen ions and are less acidic.

A pH value of seven is considered neutral. Values less than seven indicate acidic conditions; whereas, values greater than seven indicate alkaline conditions. A single pH unit change represents a tenfold change in the concentration of hydrogen ions. As a result, a lake with a pH value of eight is ten times less acidic than a lake with a pH value of seven.

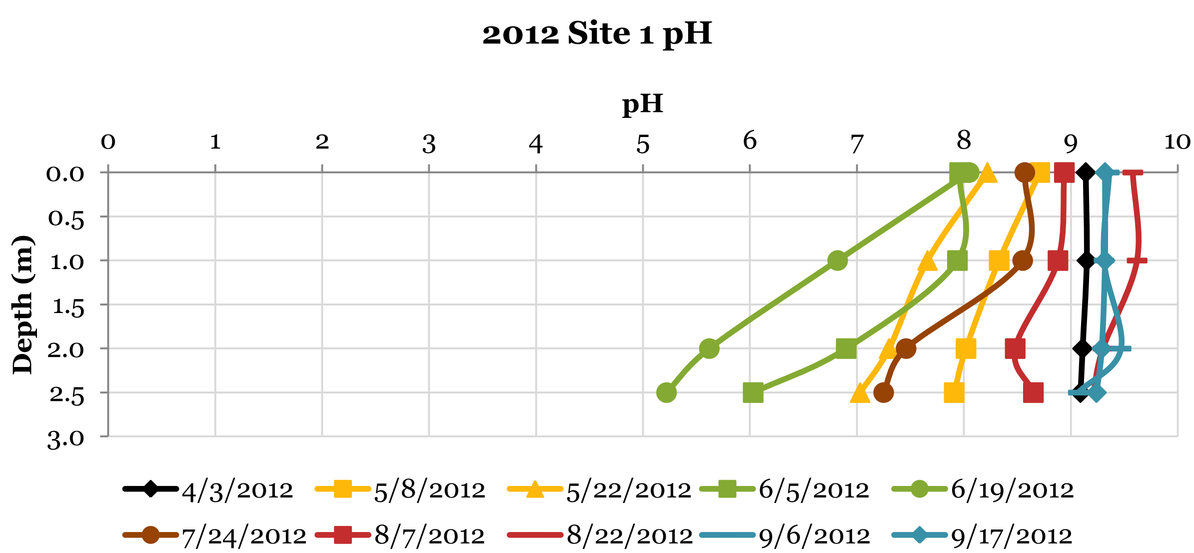
Across Wisconsin lakes, pH values can range from 4.5 (acid bog lakes) to 8.4 (hard water, marl lakes).

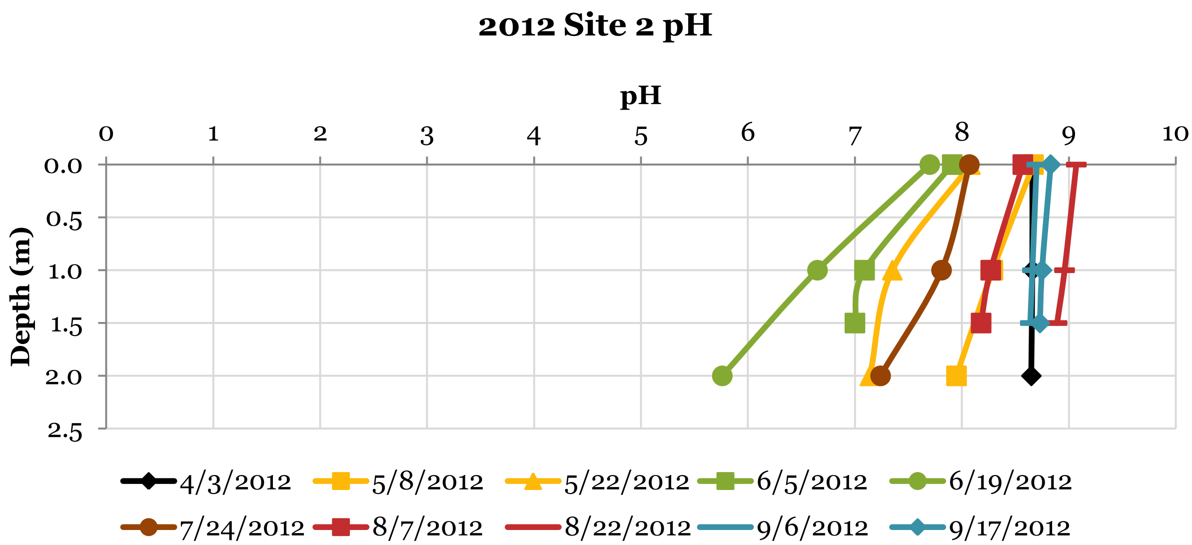
Through the removal of CO_2 from the water column, photosynthesis has the effect of increasing pH. As a result, pH generally increases during the day and decreases at night. Under conditions such as high temperature, high nutrients, and dense algae blooms, pH levels can increase.

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

April, May, and June data were collected using a YSI 60 pH meter; whereas, July, August, and September data were collected with a HI 9828 multi-parameter probe.

In general, at any given sampling date, the pH was greater at the surface of the flowage as compared to the bottom of the flowage. In general, pH was the lowest in May and June and the greatest in August and September.




2012 Site 2 pH
pH
0
1
2
3
4
5
6
7
8
9
10
0.0
0.5
1.0
1.5
2.0
2.5
Depth (m)
4/3/2012
5/8/2012
5/22/2012
6/5/2012
6/19/2012
7/24/2012
8/7/2012
8/22/2012
9/6/2012
9/17/2012

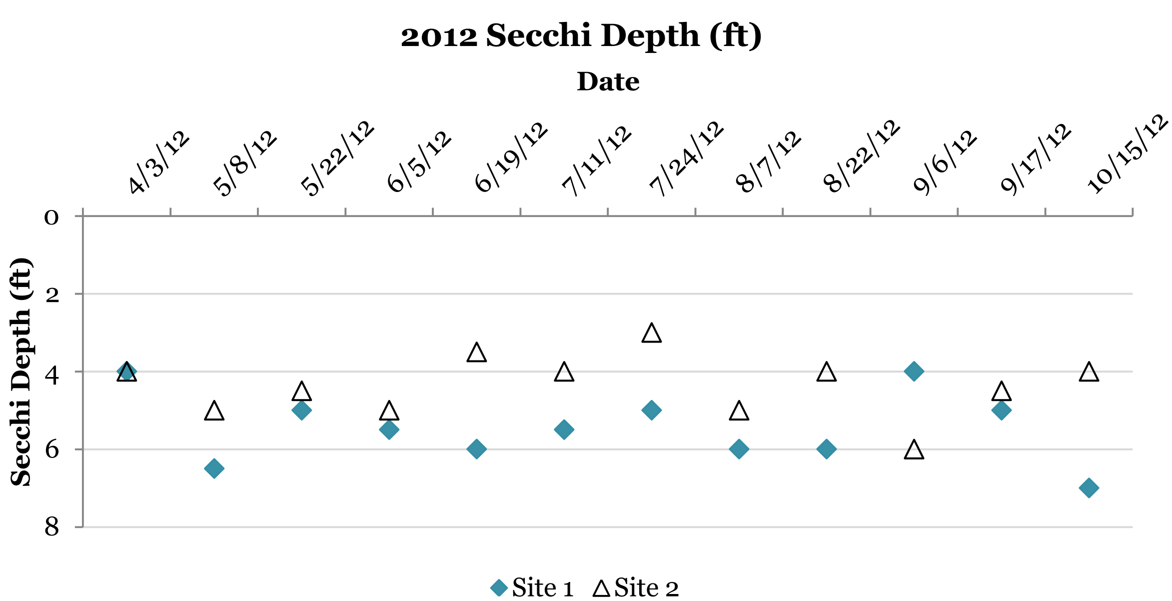
Secchi Depth

The depth to which light can penetrate into lakes is affected by suspended particles, dissolved pigments, and absorbance by water. Often, the ability of light to penetrate the water column is determined by the abundance of algae or other photosynthetic organisms in a lake.

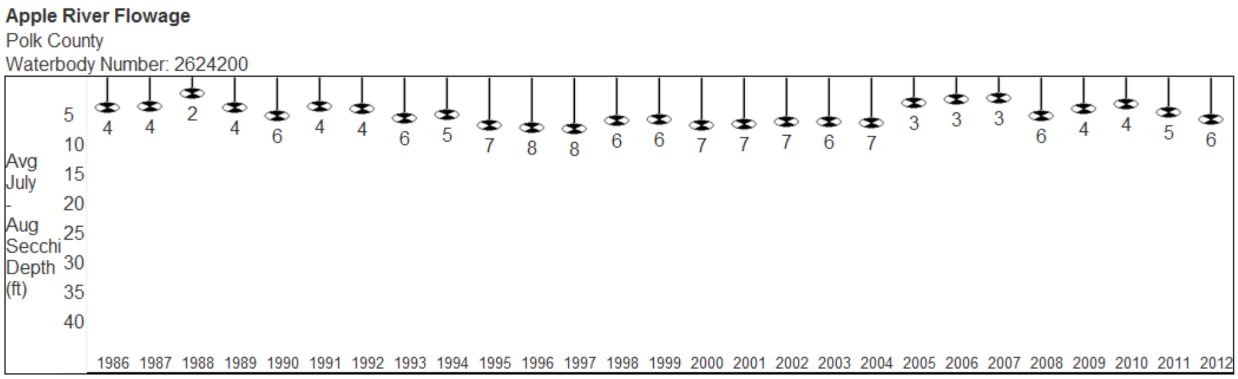
One method of measuring light penetration is with a secchi disk. A secchi disk is an eight inch diameter round disk with alternating black and white quadrants that is used to provide a rough estimate of water clarity. The depth at which the secchi disk is just visible is defined as the secchi depth. A greater secchi depth indicates greater water clarity.

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

The average growing season secchi depth was greater at site one (5.5 feet) as compared to site two (4.5 feet). A similar trend is evident when averaging the secchi depths over the summer index period. Average summer index period secchi depth was greater at site one (5.3 feet) as compared to site two (4.5 feet). Water depth at site one was approximately two feet greater that water depth at site two. Additionally, plants were much more abundant at site two. The plant community at site two was dominated by curly leaf pondweed in the spring and coon tail in the summer. In many instances, secchi depth at site two was limited by the plant canopy versus the clarity of the water.



The Wisconsin Department of Natural Resources provides historic secchi depth averages for the months of July and August only. This data exists for the Apple River Flowage deep hole from 1986 through the present year. Site one north and site two south are distinct from the deep hole site.



Past secchi averages in feet (July and August only).

Chlorophyll *a*

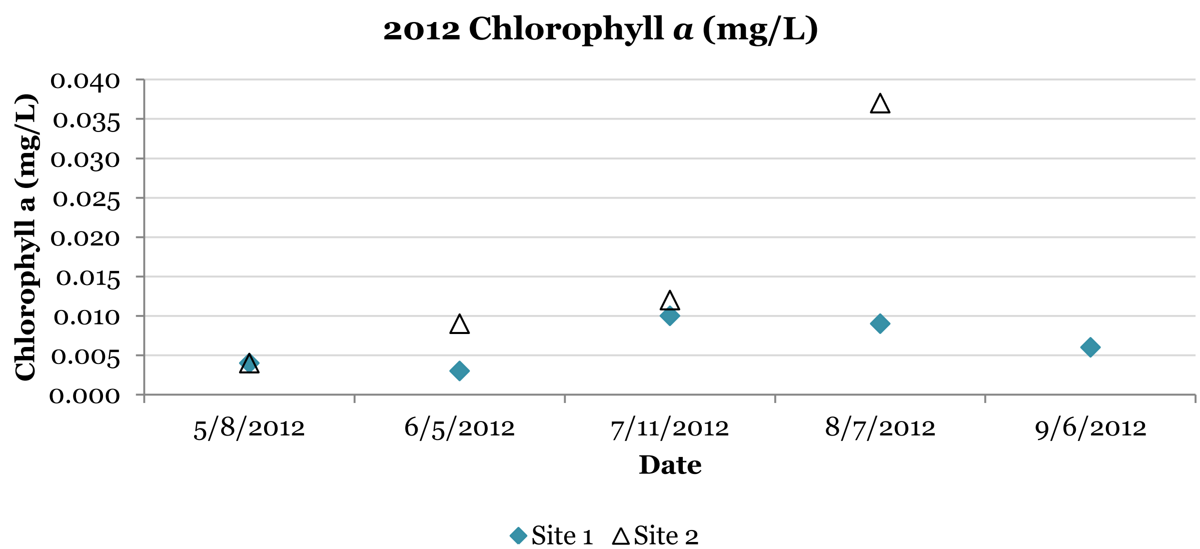
Chlorophyll *a* is a pigment in plants and algae that is necessary for photosynthesis and is an indicator of water quality in a lake. Chlorophyll *a* gives a general indication of the amount of algae growth in a lake, with greater values for chlorophyll *a* indicating greater amounts of algae. However, since chlorophyll *a* is present in sources other than algae— such as decaying plants— it does not serve as a direct indicator of algae biomass.

Chlorophyll *a* seems to have the greatest impact on water clarity when levels exceed 0.03 mg/L. Lakes which appear clear generally have chlorophyll *a* levels less than 0.015 mg/L.

Information summarized from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

With the exception of site two on August 7th, 2012, chlorophyll *a* levels on the flowage were below 0.015 mg/L.

The growing season average chlorophyll *a* was 0.0064 mg/L at site one and 0.0155 mg/L at site two. The summer index average chlorophyll *a* was 0.0075 mg/L at site one and 0.037 mg/L at site two. However, since the September chlorophyll *a* sample for site two was dropped at the lab, the summer index average at site two represents only one sample date.



Trophic State Index

Lakes are divided into three categories based on their trophic states: oligotrophic, eutrophic, and mesotrophic. These categories reflect a lake's nutrient and clarity level and serve as an indicator of water quality. Each category is designed to serve as an overall interpretation of a lake's primary productivity.

Oligotrophic lakes are generally clear, deep, and free of weeds and large algae blooms. These types of lakes are often poor in nutrients and are therefore unable to support large populations of fish. However, oligotrophic lakes can develop a food chain capable of supporting a desirable population of large game fish.

Eutrophic lakes are generally high in nutrients and support a large number of plant and animal populations. They are usually very productive and subject to frequent algae blooms. Eutrophic lakes often support large fish populations, but are susceptible to oxygen depletion.

Mesotrophic lakes lie between oligotrophic and eutrophic lakes. They usually have good fisheries and occasional algae blooms.

All lakes experience a natural aging process which causes a change from an oligotrophic to a eutrophic state. Human influences which introduce nutrients into a lake (agriculture, lawn fertilizers, and septic systems) can accelerate the process by which lakes age and become eutrophic.

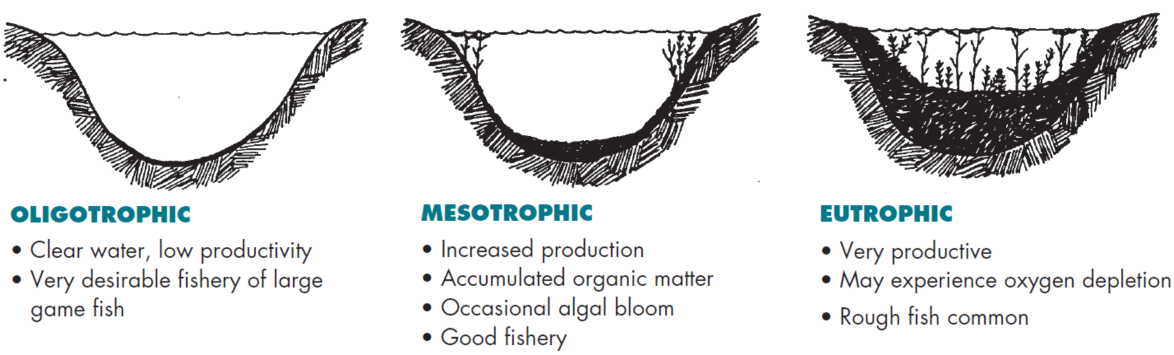


Figure from: (Byron Shaw, Christine Mechenich, and Lowell Klessig, 2004).

A common method of determining a lake's trophic state is to compare total phosphorus concentration (important for algae growth), chlorophyll *a* concentration (an indicator of the amount of algae present), and secchi disk readings (an indicator of water clarity). Although many factors influence these relationships, the link between phosphorus concentration, chlorophyll *a* concentration, and secchi disk readings is the basis of comparison for the Trophic State Index (TSI).

TSI is determined using a mathematic formula and ranges from 0 to 110. Lakes with the lowest numbers are oligotrophic and lakes with the highest values are eutrophic.

Three equations for summer index period TSI were examined for site one and site two on the Apple River Flowage. Phosphorus and chlorophyll *a* data were averaged from August 7th and September 6th. On September 6th, the sample for chlorophyll *a* was dropped by the Water and Environmental Analysis Lab. As a result, TSI chlorophyll is calculated using the single sample collected on August 7th. Secchi depth data were averaged from July 24th, August 7th, August 22nd, and September 6th.

TSI (P) = 14.42 * Ln [TP] + 4.15 (where TP is in µg/L)
TSI (C) = 30.6 + 9.81 Ln [Chlor-a] (where the chlorophyll *a* is in µg/L)
TSI (S) = 60-14.41 * Ln [Secchi] (where the secchi depth is in meters)

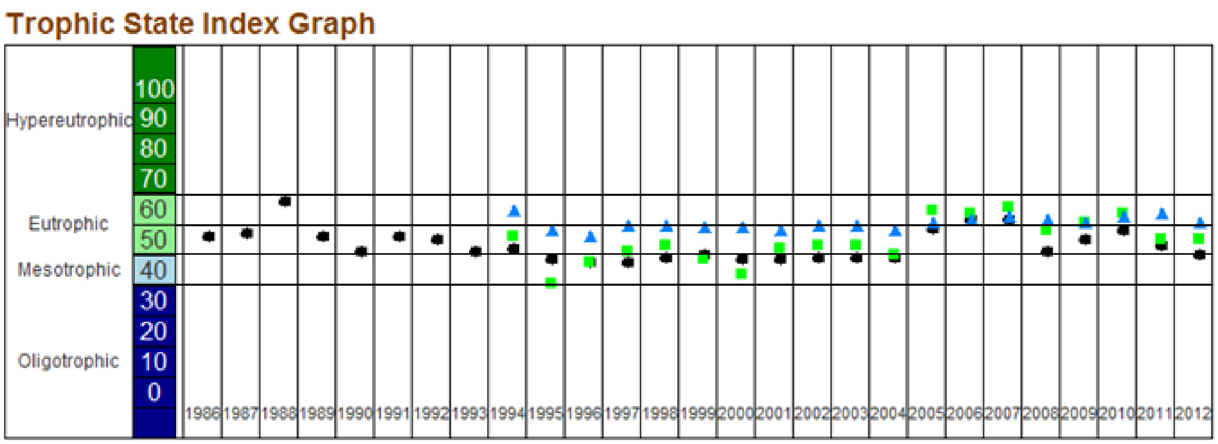
<u>Apple River Flowage Site 1</u>
Average summer index period TSI (total phosphorus) = 68.96
Average summer index period TSI (chlorophyll *a*) = 50.37
Average summer index period TSI (secchi depth) = 53.09
Average summer index period TSI = 57.47 = mildly eutrophic

<u>Apple River Flowage Site 2</u>
Average summer index period TSI (total phosphorus) = 65.00
Average summer index period TSI (chlorophyll *a*) = 66.02
Average summer index period TSI (secchi depth) = 55.45
Average summer index period TSI = 62.16 = eutrophic

TSI	General Description
<30	Oligotrophic; clear water, high dissolved oxygen throughout the year/lake
30-40	Oligotrophic; clear water, possible periods of oxygen depletion in the lower depths of the lake
40-50	Mesotrophic; moderately clear water, increasing chance of anoxia near the bottom of the lake in summer, fully acceptable for all recreation/aesthetic uses
50-60	Mildly eutrophic; decreased water clarity, anoxic near the bottom, may have macrophyte problem; warm-water fisheries only
60-70	Eutrophic; blue-green algae dominance, scums possible, prolific aquatic plant growth. Full body recreation may be decreased
70-80	Hypereutrophic; heavy algal blooms possible throughout the summer, dense algae and macrophytes
>80	Algal scums, summer fish kills, few aquatic plants due to algal shading, rough fish dominate

Monitoring the TSI of a lake gives stakeholders a method by which to gauge lake productivity over time. Fortunately, complete TSI secchi data exists for the Apple River Flowage Deep Hole from 1986 through 2012. Additionally, complete TSI phosphorus and chlorophyll *a* data exists for the Apple River Flowage Deep Hole from 1994-2012.

The majority of the historic TSI data for chlorophyll *a* and total phosphorus fall between 50 and 70; whereas, the majority of TSI data for secchi fall between 40 and 60.



Monitoring Station: Apple River Flowage - Deep Hole, Polk County
Past Summer (July-August) Trophic State Index (TSI) averages.

• = Secchi ■ = Chlorophyll ▲ = Total Phosphorus

Phytoplankton

Algae, also called phytoplankton, are microscopic plants that convert sunlight and nutrients into biomass. They can live on bottom sediments and substrate, in the water column, and on plants and leaves. Algae are the primary producers in an aquatic ecosystem and can vary in form (filamentous, colonial, unicellular, etc). Zooplankton, are small aquatic organisms that feed on algae. The size and shape of algae determine which types of zooplankton—if any—can consume them.

Algae have short life cycles. As a result, changes in water quality are often reflected by changes in the algal community within a few days or weeks. The number and types of algae in a waterbody can provide useful information for environmental monitoring programs, impairment assessments, and the identification of best management strategies.

The types of algae in a lake will change over the course of a year. Typically, there is less algae in winter and spring because of ice cover and cold temperatures. As a lake warms up and sunlight increases, algae communities begin to increase. Their short life span quickly cycles the nutrients in a lake and affects nutrient dynamics.

The types of algae present in a lake are influenced by environmental factors like climate, phosphorus, nitrogen, silica and other nutrient content, carbon dioxide, grazing, substrate, and other factors in the lake. When high levels of nutrients are available, blue green algae often become predominant.

Chlorophyll *a* is a pigment in plants and algae that is necessary for photosynthesis. Chlorophyll *a* gives a general indication of the amount of algae growth in the water column; however, it is not directly correlated with algae biomass. To obtain accurate algae data, composite samples from a two meter water column were collected monthly, preserved with glutaraldehyde, placed on ice, and sent to the State Lab of Hygiene for identification and enumeration of algae species.

Algae were identified to genus, and a relative concentration and natural unit count was made to describe the algae community throughout the growing season. This method of sampling also allows the identification of any species of concern which might be present.

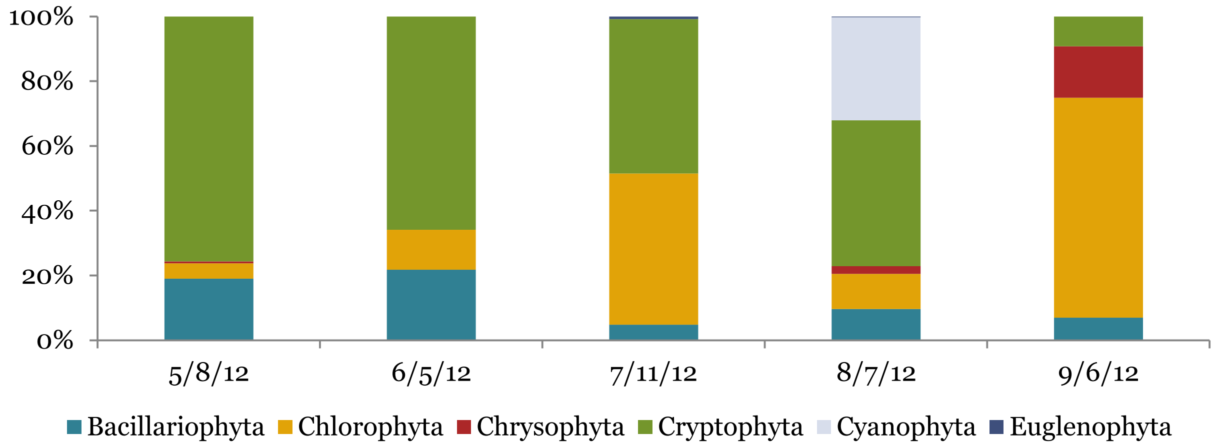
There are 12 divisions of algae found in typical lakes of Wisconsin. Six divisions were found in the Apple River Flowage.

Algal Division	Common Name	Characteristics
Bacillariophyta	Diatoms	Have a siliceous frustule that makes up the external covering. Sensitive to chloride, pH, color, and total phosphorus (TP) in water. As TP increases, see a decrease in diatoms. Generally larger in size. Tend to be highly present in spring and late spring. Can be benthic or planktonic.
Chlorophyta	Green algae	Have a true starch and provide high nutritional value to consumers. Can be filamentous and intermingle with macrophytes.
Chrysophyta	Golden brown algae	Organisms which bear two unequal flagella. A genus of single-celled algae in which the cells are ovoid. Contain chlorophyll a, c_1 and c_2, generally masked by abundant accessory pigment, fucoxanthin, imparting distinctive golden color to cells.
Cryptophyta	Cryptomonads	Have a true starch. Planktonic. Bloom forming, are not known to produce any toxins and are used to feed small zooplankton. Cryptomonads frequently dominate the phytoplankton assemblages of the Great Lakes.
Cyanophyta	Blue green algae	Prevail in nutrient-rich standing waters. Blooms can be toxic to zooplankton, fish, livestock, and humans. Can be unicellular, colonial, planktonic, or filamentous. Can live on almost any substrate. More prevalent in late to mid-summer.
Euglenophyta	Euglenoids	One of the best-know groups of flagellates, commonly found in freshwater that is rich in organic materials. Most are unicellular.

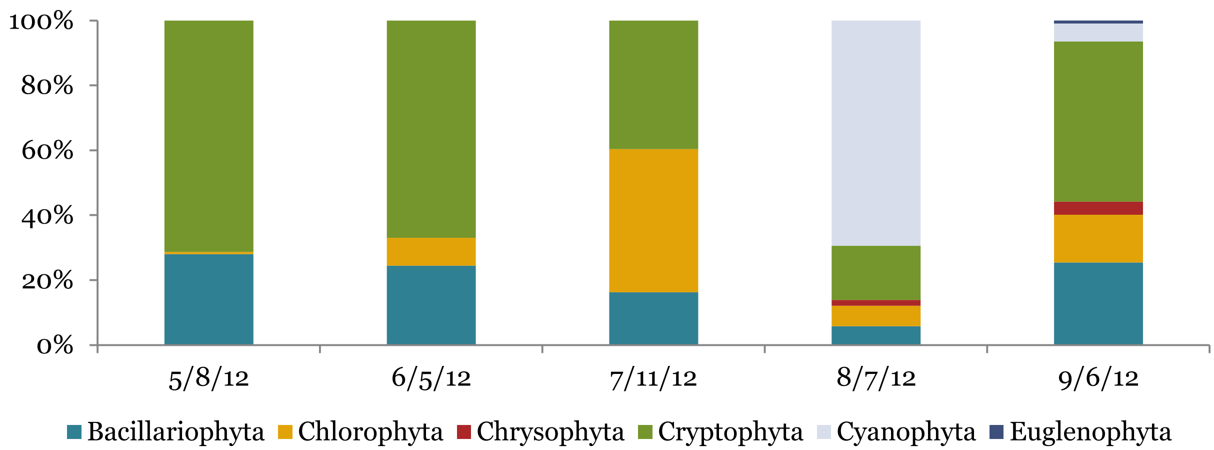
At both sites the dominant algae division in May and June was Cryptophyta, or cryptomonads. By July, the algae community at both sites was dominated nearly equally by cryptomonads and Chlorophyta, or green algae. In August, the algae community at site one was dominated by cryptomonads and the algae community at site two was dominated by Cyanophyta, or blue green algae. In September, the algae community at site one shifted back to being green algae dominated and the algae community at site two shifted back to being dominated by cryptomonads.

Across the entire sampling season Euglenophyta, or euglenoids, made up less than 1% of the algae community at both sites.

2012 Apple River Flowage Site 1 Algae Division (% of community)



2012 Apple River Flowage Site 2 Algae Community (% of community)



Blue green algae have been around for billions of years and typically bloom during the summer months. However, blue-green algae blooms become more frequent as a result of increased nutrient concentrations.

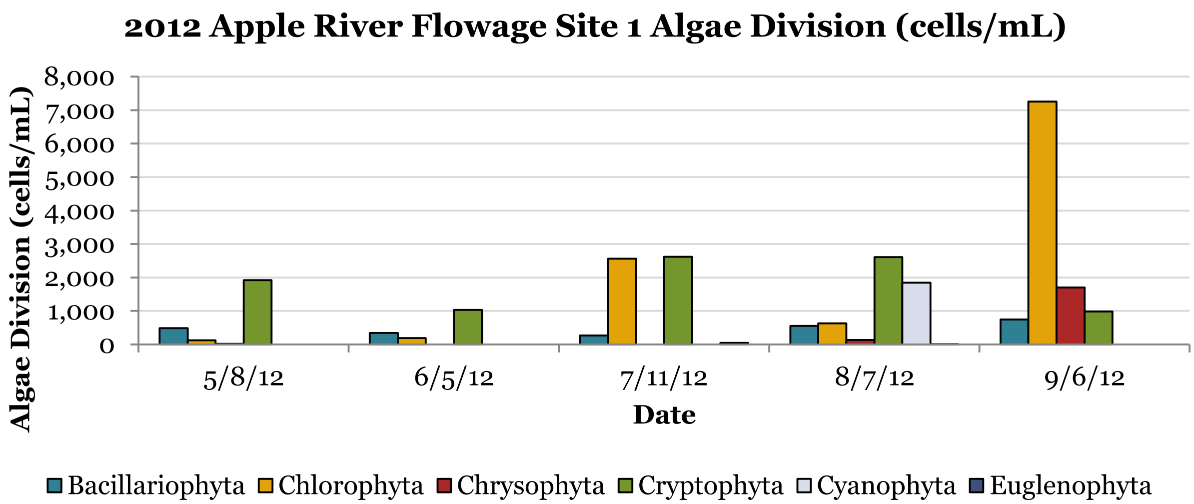
In addition to the negative aesthetics posed by algae, blue green algae are of specific concern because of their ability to produce toxins, that when ingested or inhaled, can cause short and long term health effects. Effects range from tingling, burning, numbness, drowsiness, and dermatitis to liver or respiratory failure possibly leading to death.

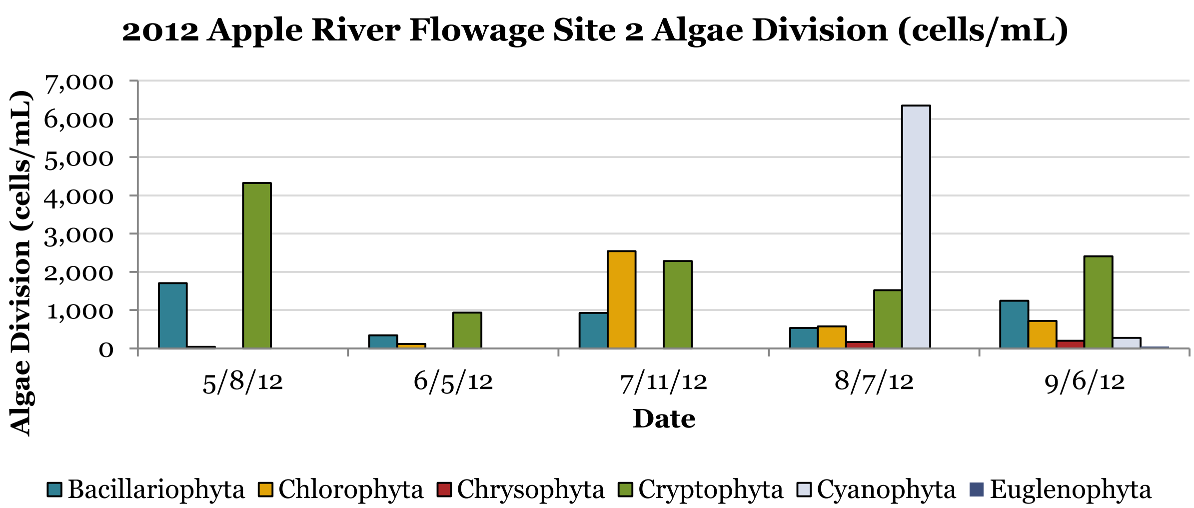
It is not know which environmental conditions cause the production of cyanotoxins, but scientists have found that when blue green algae is present at concentrations over 100,000 cells/mL toxin production is more likely to occur.

Federal guidelines for cyanobacterial cell densities and chlorophyll *a* concentrations do not exist. The Wisconsin Harmful Algal Bloom (HAB) Surveillance Program uses guidelines of the World Health Organization to determine risks from cyanobacteria:

Cyanobacterial cell density (cells/mL)	Chlorophyll *a* (mg/L)	Risk
Less than 20,000	Less than 0.01	Low
20,000 to 100,000	0.01 to 0.05	Moderate
Greater than 100,000	Greater than 0.05	High

Blue green algae were only present in August at site one and only present in August and September at site two. Their concentrations at these sampling dates were very low and well below the risk threshold for toxin production.





Zooplankton

Zooplankton are small aquatic animals that feed on algae and are eaten by fish. They are divided into three main components: rotifers, copepods, and cladocerans.

Rotifers eat algae, other zooplankton, and sometimes each other. Due to their small size, rotifers are not capable of significantly reducing algal biomass although they are able to shift the algae community to favor larger species.

Copepods feed on algae and other plankton. They are eaten by larger plankton and are preyed heavily upon by pan fish, minnows, and the fry of larger fish.

Cladocerans are filter feeders that play an important part in the food web. Species of cladocerans (particularly Daphnia) are well known for their ability to reduce algal biomass and help maintain clear water in lake ecosystems.

Zooplankton are often overlooked as a component of aquatic systems, but their role in a lake is extremely important. Lake systems are valued primarily for water clarity, fishing, or other recreation, all of which are strongly linked to water quality and ecosystem health. Zooplankton are the primary link between the “bottom up” processes and “top down” processes of the lake ecosystem.

“Bottom up” processes include factors such as increased nutrients, which can cause noxious algal blooms. Zooplankton have the ability to mediate algae blooms by heavy grazing. Conversely, shifts in algal composition, which can be caused by increased nutrients, can change the composition of the zooplankton community. If the composition shifts to favor smaller species of zooplankton, for example, algal blooms can be intensified, planktivorous fish can become stressed, and the development of fry can be negatively impacted.

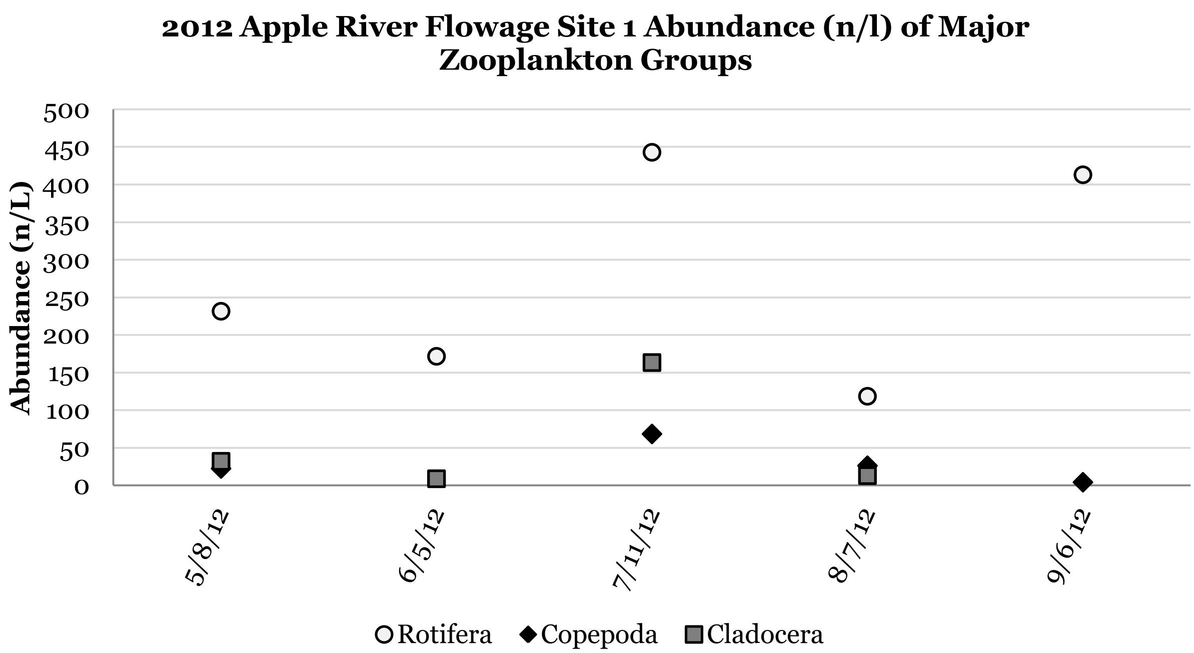
“Top down” processes include factors such as increased fish predation. Increases in planktivorous fishes (pan fish) can dramatically reduce zooplankton populations and lead to algal blooms. In some lakes, biomanipulation is utilized to manage this effect and improve water clarity. Piscivorous fish (fish that eat other fish) are used to reduce planktivorous fish. This in turn increases zooplankton populations and ultimately reduces algae populations.

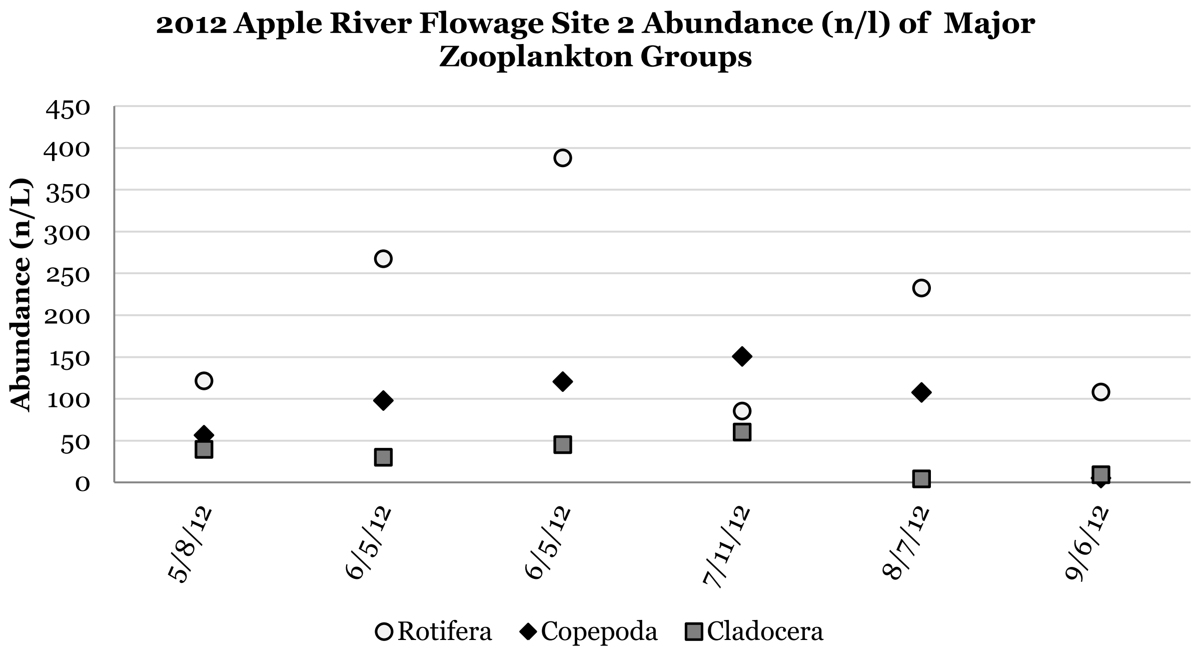
Changes in the aquatic plant community and shoreland habitat can impact zooplankton populations. This occurs especially in shallow lakes where zooplankton are more likely to have the ability to migrate horizontally to avoid predation from fish and other invertebrates. In general, a diverse shoreland habitat (substrate, plant species, and woody debris) will support a diverse zooplankton community.

Composite samples from a two meter water column were collected monthly, preserved with denatured ethanol, placed on ice, and sent to the Northland College for identification and enumeration of zooplankton species. This analysis shows the abundance of the major zooplankton groups—cladocera, copepoda, and rotifer—in the Apple River Flowage.

Composite samples from a two meter water column were collected monthly, preserved with denatured ethanol, placed on ice, and sent to the Northland College for identification and enumeration of zooplankton species. This analysis shows the abundance of the major zooplankton groups: cladocera, copepoda, and rotifer in the Apple River Flowage.

The Apple River Flowage zooplankton were dominated by rotifers, which is characteristic of flowing waters. Some cladocera are present but almost no copepods, which is somewhat unusual even for a flowing system. Abundance appears to fluctuate with the likely drivers being water retention time (higher flows reducing populations) and temperature (increasing productivity) (Lafroncois, 2013).




2012 Apple River Flowage Site 2 Abundance (n/l) of Major Zooplankton Groups
Abundance (n/L)
450
400
350
300
250
200
150
100
50
0
5/8/12
6/5/12
6/5/12
7/11/12
8/7/12
9/6/12
Rotifera
Copepoda
Cladocera

Lake Sediments

On August 22nd, 2012 a Petite Ponar® Grab Sampler was used to sample the surface sediments at site one and site two on the Apple River Flowage. Samples were analyzed by the University of Wisconsin-Madison Soil Testing Laboratories for total nitrogen, phosphorus, potassium, calcium magnesium, sulfur, zinc, boron, manganese, iron, copper, aluminum, and sodium.

In shallow lakes and reservoirs there is intense interaction of the water sediment interface; understanding the sediment water-interactions is therefore crucial to understanding the nutrient dynamics of shallow lakes such as the Apple River Flowage (Scheffer, 1998). This is the reason for the following analysis, which could have many implications for management actions.

	Total Nitrogen	**Phosphorus**	**Potassium**	**Calcium**	**Magnesium**	**Sulfur**
Site 1 N	8,600	1,500	1,400	16,200	3,300	4,100
Site 2 S	8,300	1,800	1,300	20,500	2,900	6,000

	Zinc	**Boron**	**Manganese**	**Iron**	**Copper**	**Aluminum**	**Sodium**
Site 1 N	54.44	8.12	769.57	53,359.20	21.12	11,092.40	127.20
Site 2 S	49.31	6.83	1,310.96	32,024.30	21.78	11,899.20	157.90

Copper is an essential trace element that tends to accumulate in sediments and can be toxic to aquatic life at elevated concentrations (United States Environmental Protection Agency, June 2008).

A study completed by MacDonald et al. (2000) developed consensus based numerical sediment quality guidelines for metals in freshwater ecosystems. This study provides guidelines for metals in freshwater ecosystems that reflect threshold effect concentrations (TECs, i.e., below which harmful effects are unlikely to be observed) and probable effect concentrations (PECs, i.e., above which harmful effects are likely to be observed). The consensus based TEC for copper is 31.6 mg/kg and the consensus based PEC for copper is 149 mg/kg.

Sediment copper concentrations were 21.12 mg/kg at site one and 21.78 mg/kg at site two. These concentrations are well below the consensus based TEC for copper, or the concentration below which harmful effects are unlikely to be observed.

Zinc is an additional essential trace element that can be toxic to aquatic life at elevated concentrations. The consensus based TEC for zinc is 121 mg/kg and the consensus based probable effect concentration for zinc is 315 mg/kg.

Sediment zinc concentrations were 54.44 mg/kg at site one and 49.31 mg/kg at site two. These concentrations are well below the consensus based TEC for zinc, or the concentration below which harmful effects are unlikely to be observed.

Nitrogen occurs in lakes and reservoirs in many different forms: dissolved nitrogen (N_2), a large number of organic compounds, ammonia (NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-). Sources of nitrogen include precipitation, nitrogen fixation in the water and sediment (in eutrophic lakes and reservoirs this can account for >80% of the N input), and inputs from the watershed. Losses occur by outflow, reduction of nitrate to nitrogen gas (which escapes to the atmosphere), and permanent sedimentation loss of organic and inorganic nitrogen compounds (Wetzel, 2001).

Ammonia is a common end product of the decomposition of organic matter. In the sediment of healthy lakes, a large portion of NH_4^+ is adsorbed on sediment particles. However, as the lake or reservoir becomes anoxic the ability of sediment to adsorb ammonia is greatly reduced. In this situation a large release of NH_4^+ occurs. Nitrate (NO_3^-) is also reduced to nitrite (NO_2^-) in the anaerobic sediments of eutrophic lakes and reservoirs.

However, rooted aquatic macrophytes are capable of absorbing large amounts of nitrogen from the sediment and can immobilize it by storing it in their root and foliage, in some cases to the point of reducing NO_3-N below detectable limits (Wetzel, 2001). This illustrates the importance of a healthy aquatic plant community. Healthy aquatic plant communities can be a primary storage site for nitrogen and their senescing tissues become a very important component of nutrient burial and assimilation into the sediment. The total nitrogen content was analyzed on the Apple River Flowage, so the different nitrogen species, are not known.

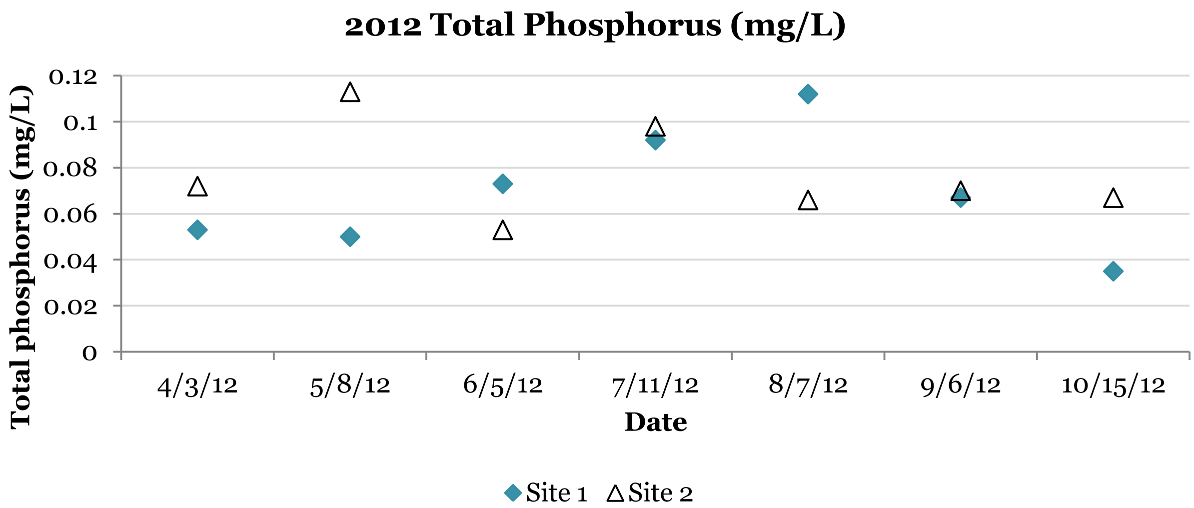
In contrast to nitrogen, which has many forms in lakes, the most significant form of inorganic phosphorus is orthophosphate (PO_4^{3-}). Because of the fundamental importance of phosphorus as a nutrient, a lot of emphasis has been placed on its evaluation in lake and reservoir systems. Four operational categories are commonly evaluated: (1) soluble reactive phosphorus, (2) soluble unreactive phosphorus, (3) particulate reactive phosphorus, and (4) particulate unreactive phosphorus (Wetzel, 2001). Often times, analysis is done for total phosphorus (TP).

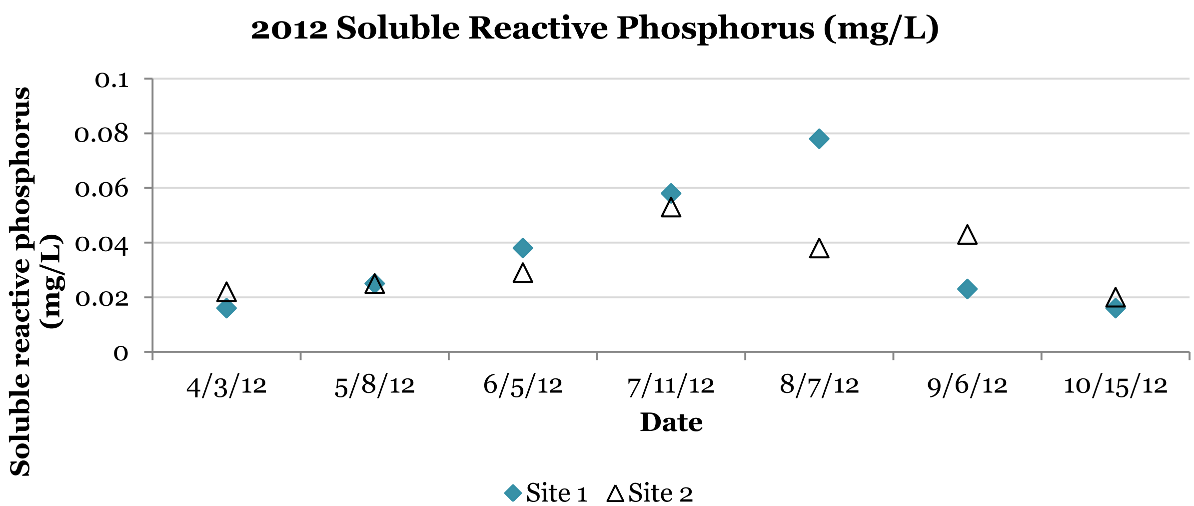
A substantial part of the available phosphorus in shallow lakes and reservoirs, such as the Apple River Flowage, is in the sediment. Release of phosphorus from the sediment into the water depends on the composition of the sediment and the concentration of the phosphorus in the water column; but varies strongly on the conditions at the sediment water interface (Scheffer, 1998) (Kaiserli, A., Voutsa, D., and Samara, C., 2002) (Gonsiorczyk, T., Casper, P., and Koschel, R., 1998).

Phosphorus in the sediments of lakes is often phosphorus precipitated with clays, aluminum, and iron compounds. Work on Wisconsin lake sediments and the Great Lakes, indicate that phosphorus in the sediments was predominately apatites (phosphate minerals), organic phosphorus, and orthophosphate bonded to iron compounds. However, as the oxygen content near the sediment declines there is a release of phosphorus, iron, and manganese to the water column (Wetzel, 2001).

The concentrations of phosphorus in the water tend to correlate well with the ratio between phosphorus and iron concentrations (P:Fe) in the sediment. It has been found where the P:Fe ratio is lower than 1: 10, the correlation with lake water becomes weak (Scheffer, 1998). The ratio in the north basin is approximately 1:36 while the ratio in the south basin is 1:18 indicating a strong correlation between the sediment phosphorus pool and the water column phosphorus concentration. The mobilization of recently deposited phosphorus seems to be the driving force of phosphorus release in eutrophic lakes and reservoirs (Gonsiorczyk, T., Casper, P., and Koschel, R., 1998). However, there is a limited amount of knowledge of the mechanisms behind internal loading in shallow waters (Sondergaard, M., Jensen, J.P., Jeppesen, E., 2001).

Water samples analyzed from the water column interface do indeed show an increase in phosphorus during the open water season (especially the north basin), indicating an internal release of phosphorus (sites were shallow enough that the entire water column was able to be sampled with a composite sampler).





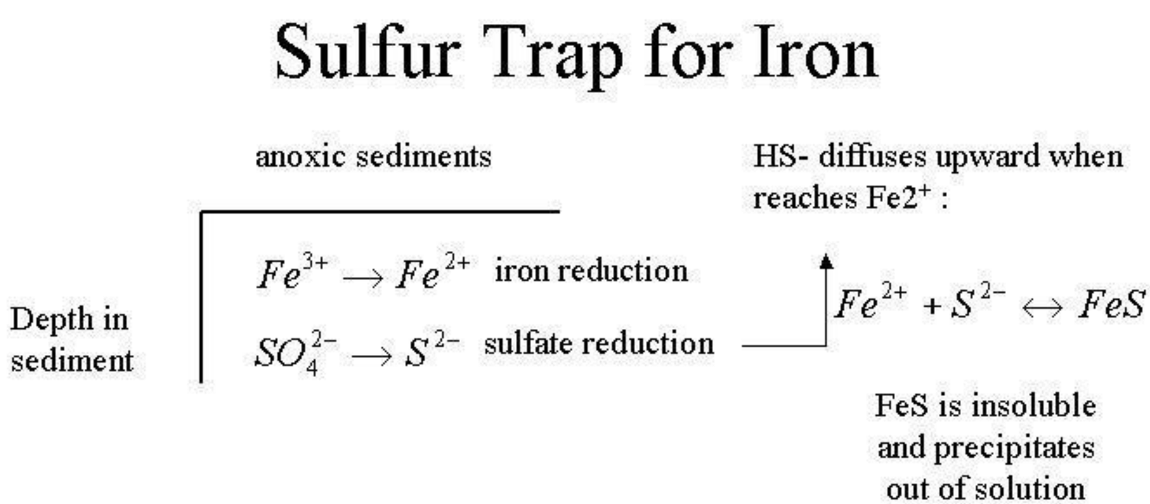
This internal phosphorus loading may delay the recovery of a lake once the external phosphorus loading sources are reduced; therefore it is important that the fraction of available phosphorus (iron and manganese bound) is evaluated for predicting internal phosphorus loading. The major factors controlling phosphorus release are dissolved oxygen, nitrates, sulfates, and pH (Kaiserli, A., Voutsa, D., and Samara, C., 2002). The University of Wisconsin Soil and Plant Analysis Lab uses the Bray-Kurtz method which analyzes plant available phosphorus, this fraction is considered to be the potentially mobile pool of phosphorus and is available to algae. However the residence time of the water in the Apple River Flowage is so short this should become less of a factor especially as native rooted aquatic macrophytes become more prevalent in the Apple River Flowage.

Concentrations of nutrient binding elements, such as iron, depend greatly on the redox potential of the sediment. A redox reaction is the flow of electrons between an oxidized and reduced state (for example iron moving from Fe^{3+} to Fe^{2+} and vice versa) the state of these elements is very important for the ability to bind to nutrients, particularly phosphorus.

There are many similarities in the behavior of iron and manganese, so they can be discussed together, although much more is known about the cycling of iron. There is also a very strong interaction between iron and sulfur. The fluxes of iron and magnesium reflect the variations in physical chemistry at the sediment water interface (Wetzel, 2001).

Iron is a very important micronutrient in aquatic systems. It is essential for aquatic organisms in many ways including: electron transport in oxidation-reduction systems of photosynthesis and respiration, it can be responsible for enzyme activation, and an oxygen carrier in nitrogen fixation.

Iron exists in solution in two different forms; either ferrous (Fe^{2+}) or ferric (Fe^{3+}). The amounts of iron in solution in lakes and the rate of oxidation of Fe^{2+} to Fe^{3+} in oxygenated water are dependent on pH, reduction potential, and temperature. Ferrous iron tends to be more soluble than ferric. Under anaerobic conditions with low redox potential, in productive lakes and reservoirs such as the flowage, bacteria often reduce sulfate to sulfide which decreases the concentration of Fe^{2+} through the formation of insoluble FeS (iron sulfide). This, iron sulfide formation can reduce the abundance of Fe compounds that can complex to phosphorus and promote release of phosphorus from the sediment (Wetzel, 2001). If enough FeS precipitates you can remove enough iron to get iron poor water making phosphorus more available for algae uptake. This is sometimes called the Sulfur Trap.



Iron bonds (complexes) with many organic compounds (e.g. detritus), which greatly alters its solubility and availability to organisms. Under anoxic conditions in the surface sediment and overlying water these complexes are reduced and phosphorus is released, with the release rate from sediments doubling g if the sediments are disturbed (though activities such as power boating for example) (Wetzel). Aquatic plants become especially important in productive waters such as the Apple River Flowage. Oxygen loss from the roots oxidized iron and the iron deposition can result in appreciable retention of iron and consequently phosphorus in the vegetated sediments (Wetzel, 2001) (Sondergaard, M., Jensen, J.P., Jeppesen, E., 2001).

Manganese is responsible for many cellular activities in organisms (i.e. electron transport reactions) and enzyme activation. Manganese (Mn) occurs in several states. Mn^{3+} is unstable under normal conditions in water and Mn^{4+} is insoluble at most pH values that would be found in natural lakes. As with ferrous iron, Mn^{2+} occurs at low redox potentials and pH. Manganese also reacts relatively rapidly with other anions and precipitates to the sediment. Unlike iron, whose concentrations can be controlled by precipitation of FeS, manganese is usually under-saturated so MnS (manganous sulfide) is usually not precipitated. Even so, MnS is much more soluble and formation of MnS has little effect on the Mn^{2+} concentrations (Wetzel, 2001).

Sulfur is utilized by all living organisms in both inorganic and organic forms. Sources of sulfur compounds to natural waters include solubilization from rock, fertilizers, precipitation, and dry deposition. Most (about 90%) of the total sulfur content in lake basins is found in the organic matter of mineral soil. Therefore much of the loading of sulfur compounds to lakes and reservoirs is in the form of sulfate and soluble organic sulfur compounds (Wetzel, 2001).

The cycling of sulfur entails the different sulfur chemical species under various conditions, the biotic influences, and sulfur transport within the lake or reservoir. The predominant form of sulfur in water is sulfate; nearly all assimilation of sulfur is as sulfate.

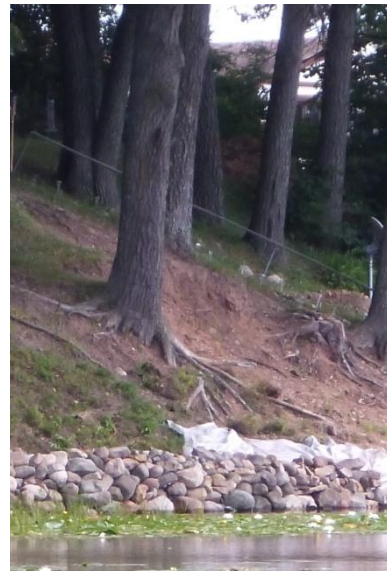
Sulfur that reacts with metals to form metal sulfides are extremely insoluble, so when Fe^{+2} is released from the sediment, it reacts vigorously with S to form FeS. Because the FeS is so insoluble the iron is not available to bind with phosphorus (Wetzel, 2001).

All data collected and modeling indicates that the internal loading component of the nutrient budget is present and could be significant. The senescence (dying back) of *Potamogeton crispus* (CLP) contributes, but likely the main release mechanism is the release of phosphorus bound to iron because of changes in redox potential at the sediment water interface due to shading by *Ceratophyllum demersum* (coontail) and a variety of duckweeds and sediment re-suspension.

Establishment of a robust, rooted aquatic macrophyte community could reduce the internal load if the macrophyte community extended deep enough. Radial oxygen loss from plant root tissues can maintain iron-bound phosphorus in the surrounding sediment. The epiphytic and epipelic algae associated within macrophyte stands utilize phosphorus from the water column, released from the sediment, and excreted by the macrophytes themselves. In addition, plants and algae that can use bicarbonate as a carbon source for photosynthesis can create free calcium ions (Ca) that can co-precipitate phosphorus with calcite. This can be an important self-cleaning mechanism in eutrophic lakes and reservoirs that can lead to the permanent burial of P within the sediments (Gonsiorczyk, T., Casper, P., and Koschel, R., 1998).

Because of the importance of the sediment phosphorus pool in almost all lakes and reservoirs further study of sediment release is warranted. *In situ* sediment release rates could be measured with benthic flux chambers over a series of years in several locations to accurately calculate actual phosphorus release from the sediment, this process can also be done in a lab using sediment cores. In addition, sediment cores should be considered. Species of phosphorus can be fractioned using sequential extractions (Engstrom, D.R., and Wright, H.E., 1984), and water column phosphorus can be reconstructed along with aquatic macrophyte community, soft algae (pigments), and chironomid (dissolved oxygen) reconstructions.

Land Use and Water Quality



Information summarized from: (D.D. MacDonald, C.G. Ingersoll, and T.A. Berger, 2000) and (Lynn Markham and Ross Dudzik, 2012).

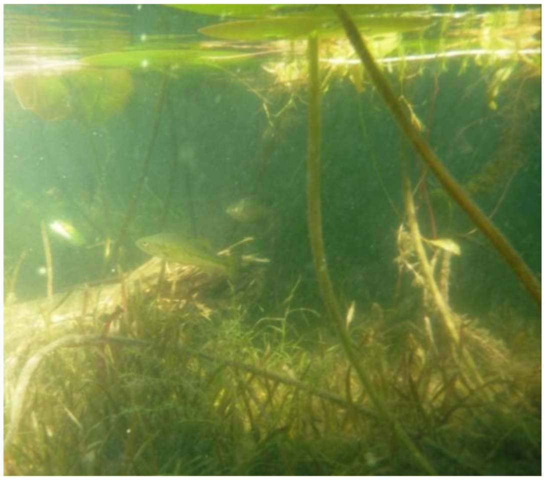
The health of our water resources depends largely on the decisions that landowners make on their properties. When waterfront lots are developed, a shift from native plants and trees to impervious surfaces and lawn often occurs. Impervious surfaces are defined as hard, man-made surfaces that make it impossible for rain to infiltrate into the ground. Examples of impervious surfaces include rooftops, paved driveways, and concrete patios.

By making it impossible for rainwater to infiltrate into the soil, impervious surfaces increase the amount of rainwater that washes over the soil surface and feeds directly into lakes and streams. This rainwater runoff can carry pollutants such as sediment, lawn fertilizers, and car oils directly into a lake. Native vegetation can slow the speed of rainwater, giving it time to soak into the soil where it is filtered by soil microbes. Median surface runoff estimates from wooded areas are an order of magnitude less than those from lawn areas.

In extreme precipitation events erosion and gullies can result, causing loss of property as soil is carried to the lake. The signs of erosion are unattractive and can cause decreases in property values. Additionally, sediment can have negative impacts on aquatic life. For example, fish eggs will die when covered with sediment, and sediment influxes to a lake can cause decreases in water clarity making it difficult for predator fish species to locate food.

Increases in impervious surfaces can also cause other negative impacts to fisheries. A study of 164 Wisconsin lakes conducted in 2008 found that the amount of impervious surfaces surrounding lakes can cause shifts in fisheries species assemblages. Certain species such as smallmouth and rock bass, blackchin and blacknose shiners, and mottled sculpin become less common with increasing amounts of impervious surfaces. Many of the smaller species affected are an essential food source for common game fish species such as walleye, northern pike, and smallmouth bass.

Increases in impervious surfaces and lawns cause a loss of habitat for birds and other wildlife. Over ninety percent of all lake life is born, raised, and fed in the area where land and water meet. Overdeveloped shorelines remove critical habitat which species such as loons, frogs, songbirds, ducks, otters, and mink depend on. Impervious surfaces and lawns can be thought of as biological desserts which lack food and shelter for birds and wildlife. Additionally, nuisance species such as Canada geese favor lawns over taller native grasses and flowers. Lawns provide geese with a ready food source (grass) and a sense of security from predators (open views).



Additionally, fish species depend on the area where land and water meet for spawning. The removal of coarse woody habitat, or trees and braches that fall into a lake, causes decreases in fisheries habitat.

Lawns in and of themselves are not particularly harmful and can provide an area for families to recreate. However, problems arise when lawns are not properly maintained, over-fertilized, located in areas important to wildlife habitat, or located on steep slopes.

Common lawn species, such as Kentucky bluegrass, are often dependent on chemical fertilizers and require mowing. Excess chemical fertilizers are washed directly into the adjacent water during precipitation events. The phosphorus and other nutrients in fertilizers, which produce lush vegetative growth on land, are the same nutrients which fuel algae blooms and decrease water clarity in a lake. Additionally, since common lawn species have very shallow root systems, when lawns are located on steep slopes, the impacts of erosion can be intensified.

Avoiding establishing lawns on steep slopes and at the water land-interface can provide direct positive impacts on lake water quality. The creation of a buffer zone of native grasses, wildflowers, shrubs, and trees where the land meets the water can provide numerous benefits for water quality and restore valuable bird and wildlife habitat.

In Polk County, all new constructions on lakeshore properties require that a shoreland protection area be in place. A shoreland protection area is required to be 35 feet in depth as measured from the ordinary high water mark, which is defined as the point on the bank or shore up to which the water leaves a distinct mark (erosion, change in vegetation, etc.).

These rules are in place largely to protect water quality and also provide benefits in terms of natural beauty, and bird and wildlife viewing opportunities. Additionally, shoreline protection areas allow for a 30 foot maximum viewing corridor (or 30% of the width of the lot, whichever is less), which can be established as lawn (Polk County, Wisconsin Shoreland Property Owner Handbook A Guide to the Polk County Shoreland Protection Zoning Ordinance in Developing and Caring for Waterfront Property, October 2002) and (Polk County Shoreland Protection Zoning Ordinance, Effective April 1, 2010).

Shoreline Inventory

On Monday, September 10th five resident volunteers were trained by Polk County Land and Water Resources Department staff to conduct a shoreline inventory for the Apple River Flowage. The shoreline inventory followed the protocol first developed for Bone Lake by Harmony Environmental (Harmony Environmental, Polk County Land and Water Resources Department, and Ecological Integrity Services, 2009).

Prior to the inventory, the linear feet of shoreline and the area of the shoreline buffer at each parcel were estimated using the Polk County Interactive GIS Map available online at: http://polkcowi.wgxtreme.com/.

Land use for each parcel was categorized for the shoreline (linear feet at the ordinary high water mark) and for the shoreline buffer area (area upland thirty-five feet from the ordinary high water mark). Additionally, the presence or absence of coarse woody habitat was determined at each parcel.

The shoreline (linear feet) was categorized as:

- ✓ Rip rap
- ✓ Structure
- ✓ Lawn
- ✓ Sand
- ✓ Natural

The shoreline buffer area (square feet) was categorized as:

- ✓ Hard surface
- ✓ Landscaping
- ✓ Lawn
- ✓ Bare soil
- ✓ Natural

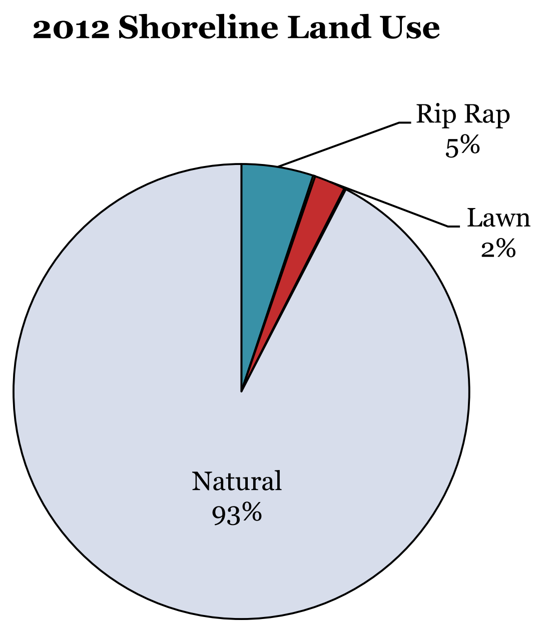
A total of 19.42 linear miles of shoreline and 0.13 square miles of buffer areas were categorized by volunteers beginning on September 10th through September 21st, 2012.

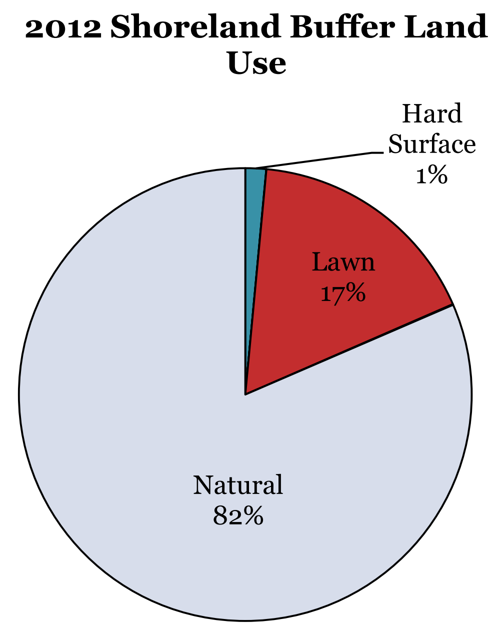
A characterization of the Apple River Flowage shoreline (linear area directly adjacent to the water) shows that the greatest land use is natural (93%), followed by rip rap (5%), lawn (2%), structure (0.15%), and sand (0.12%).

A characterization of the Apple River Flowage shoreline buffer area (area 35 feet upwards from the water) shows that the greatest land use is natural (82%), followed by lawn (17%), hard surface (1%), bare soil (0.05%) and landscaping (0.01%).

In comparison to the shoreline inventory, the shoreline buffer inventory showed a greater proportion of lawn. The large amount of natural area preserved along the shoreline and within the buffer area should be maintained for the extensive water quality benefits these areas provide.

Coarse woody habitat was present at 107 parcels on the Apple River Flowage.


2012 Shoreline Land Use
Rip Rap
5%
Lawn
2%
Natural
93%


2012 Shoreland Buffer Land Use
Hard Surface
1%
Lawn
17%
Natural
82%

Tributaries

Data was collected on six of the tributaries of the Apple River Flowage: Beaver Brook (two sites, east and west), Beaver Brook Inlet, Fox Creek, Apple River Inlet, and Apple River Outlet. Fox Creek ultimately enters the flowage through the Apple River Inlet; and Beaver Brook east and west ultimately enter the flowage through the Beaver Brook Inlet.

Flow data was collected bi-weekly at each tributary with a March McBirney Flo-Mate ™ velocity flowmeter. At each foot interval across each of the tributaries, depth (ft) and velocity (m/s) were measured. Grab samples were collected once monthly on each tributary. Samples were analyzed at WEAL for total suspended solids, nitrate/nitrite, ammonium, total Kjeldahl nitrogen, total phosphorus, soluble reactive phosphorus, and chloride.

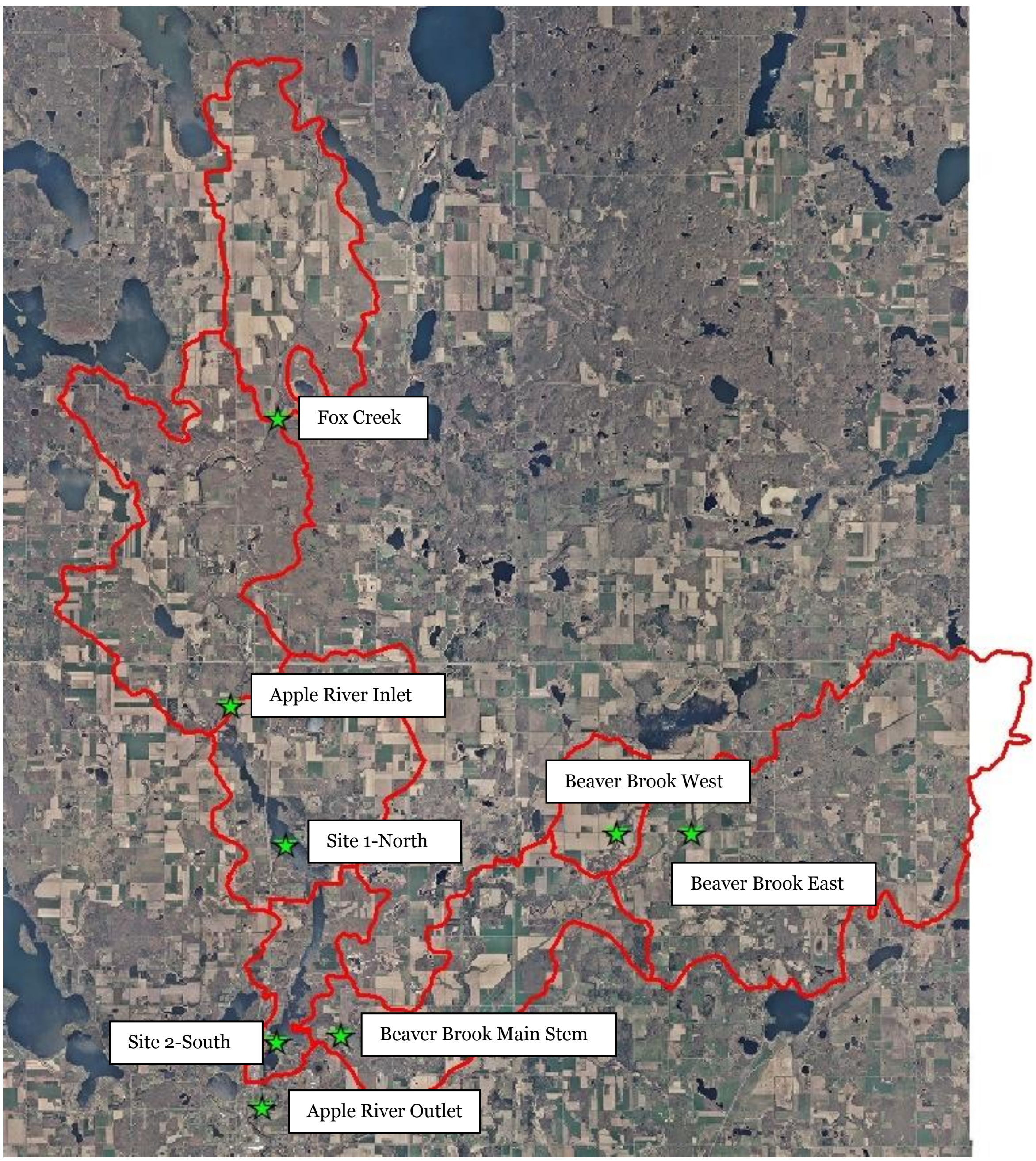
The phosphorus data collected is specific to date and location and can be used to theoretically determine how much phosphorus is entering the flowage through tributaries. Values for phosphorus influxes are established by multiplying the phosphorus concentration at a specific location by the volume of water that moves through a specific location, or the discharge in cubic feet per second. To determine the average instantaneous load of phosphorus (in mg/s), the average phosphorus concentration is multiplied by the average seasonal discharge. Units are then converted and expressed as lb/yr.

The analysis of this data allows for areas of highest phosphorus loading to be identified. Once areas of highest phosphorus loading are identified, the land use and geology of these areas can be investigated for their total phosphorus contribution and best management recommendations can be made.

The Apple River Inlet is contributing the greatest amount of phosphorus to the Apple River Flowage (8,442 pounds on an annual basis). The Beaver Brook Inlet is contributing 2,580 pounds of phosphorus on an annual basis. Phosphorus leaving the Apple River Flowage via the Outlet totals 16,162 pounds on an annual basis.

Total phosphorus concentrations were elevated on the East branch of the Beaver Brook Inlet (0.2472 mg/L).

Site	Total Phosphorus (mg/L)	Discharge (L/s)	Instantaneous Load (mg/s)	Annual Load (lb/yr)
Fox Creek	0.0518	974.610	50.485	3,512.284
Apple River Inlet	0.0648	1,872.570	121.343	8,441.935
Apple River Outlet	0.0636	3,652.740	232.314	16,162.362
Beaver Brook Main Stem	0.0836	443.520	37.078	2,579.577
Beaver Brook West	0.0586	125.496	7.354	511.631
Beaver Brook East	0.2472	60.048	14.844	1,032.704



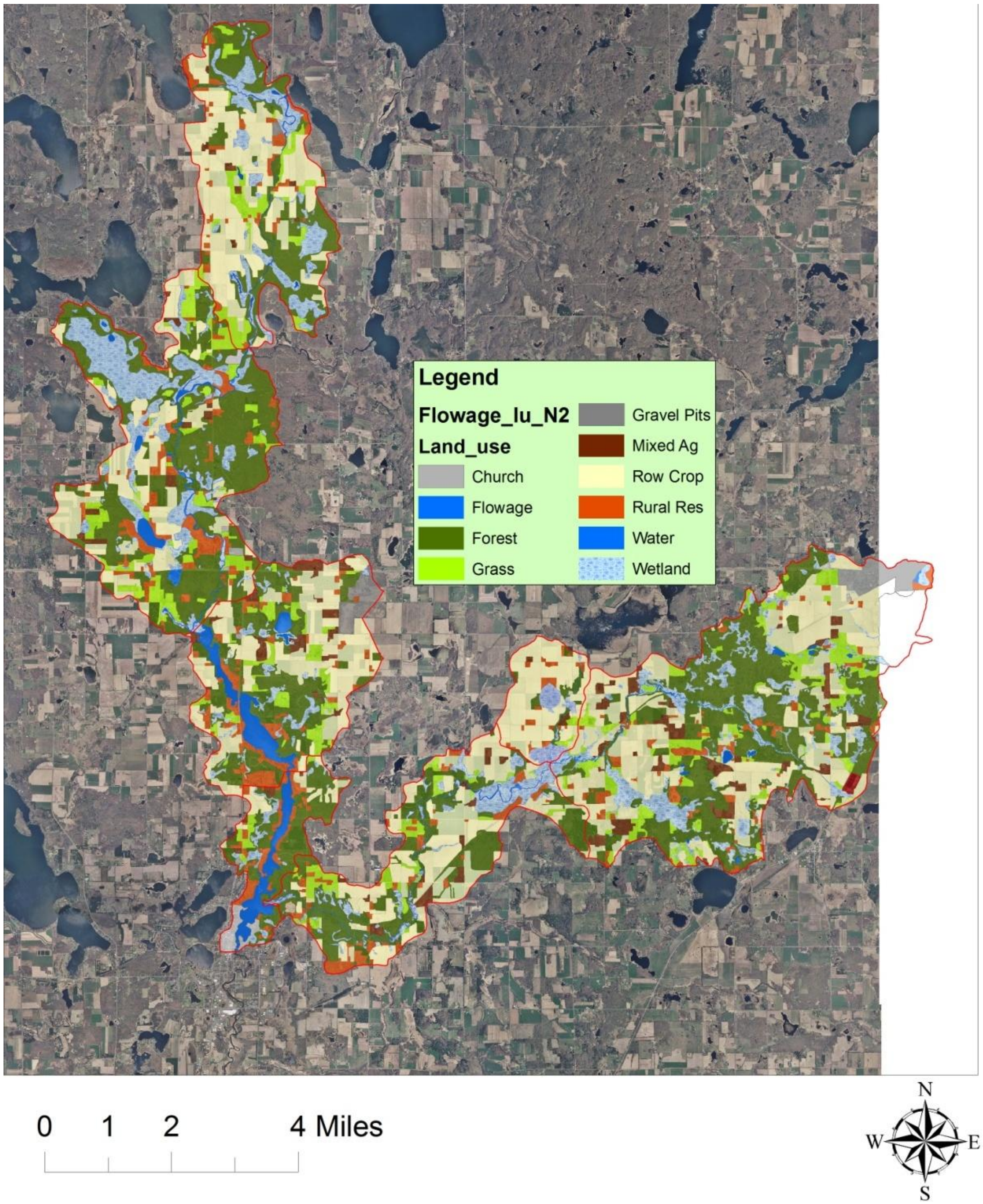
Land Use and Nutrient Loading in the Apple River Flowage Watershed

The area of land that drains towards a lake is called a watershed. Since the Apple River Flowage Watershed is so extensive in size and drains from many area lakes and rivers, a management area was established for the Apple River Flowage. Areas of land already included in lake management areas for other Polk County lakes (ie. Bone Lake, Balsam Lake, Blake Lake, White Ash Lake, etc.) were excluded from the management area.

The resulting management area is 37,125 acres in size. The largest land uses in the management area are row crop (32%) and forest (31%), with row crop contributing the greatest phosphorus load to the Flowage (74%).

The Wisconsin Lakes Modeling Suite (WiLMS) was used to model current conditions for the Apple River Flowage, verify monitoring, and estimate land use nutrient loading for the watershed. Phosphorus is the key parameter in the modeling scenarios used in WiLMS because it is the limiting nutrient for algae growth in most waterbodies.

Land Use	Total Acres	Percent Acres	Total Load (lb P/year)	Percent Load (lb P/year)
Flowage	633	2%	169	1%
Forest	11594	31%	926	7%
Grass	1182	3%	315	2%
Gravel Pits	242	1%	0	0%
Mixed Ag	1139	3%	810	6%
Pasture/Grass	1766	5%	471	3%
Row Crop	11718	32%	10430	74%
Rural Residential	2472	7%	220	2%
Wastewater treatment	37	0%	15	0%
Water	502	1%	121	1%
Wetland	4802	13%	429	3%
Unmapped	503	1%	0	0%
City/Village	494	1%	260	2%
Miscellaneous	40	0%	18	0%


Legend
Flowage_lu_N2
Land_use
Church
Flowage
Forest
Grass
Gravel Pits
Mixed Ag
Row Crop
Rural Res
Water
Wetland
0 1 2 4 Miles
N
W
E
S

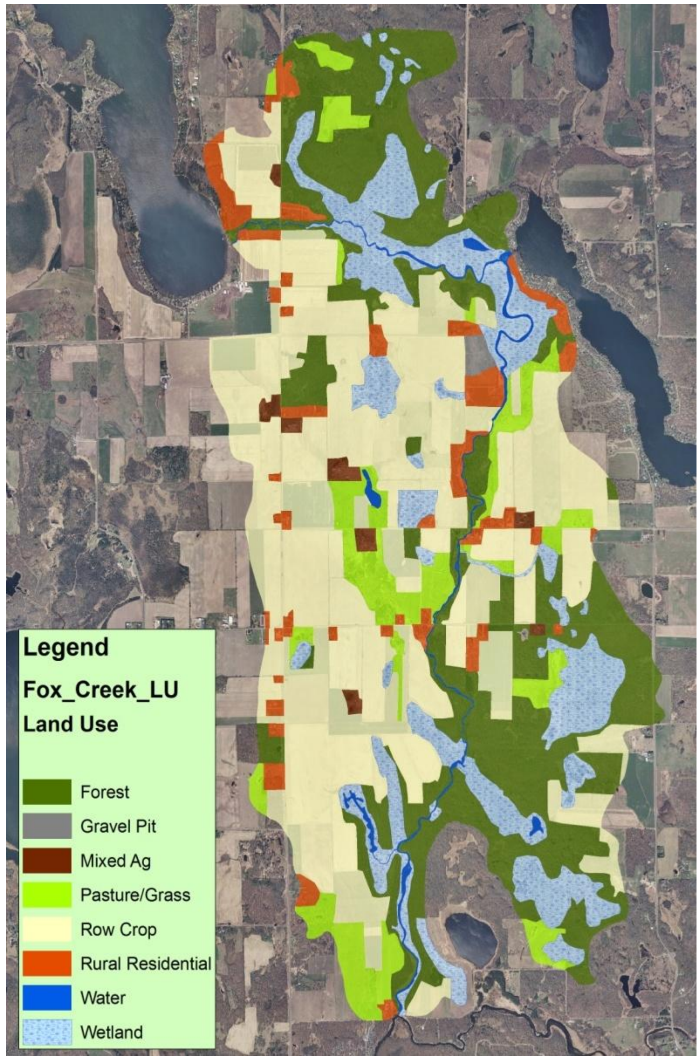
Land Use and Nutrient Loading in the Apple River Flowage Subwatersheds

Fox Creek Subwatershed

The Fox Creek Subwatershed is 5,136 acres in size.

The largest land use in the Fox Creek Watershed is row crop (42%) followed by forest (26%).

The largest contributor of phosphorus is row crop (84%).



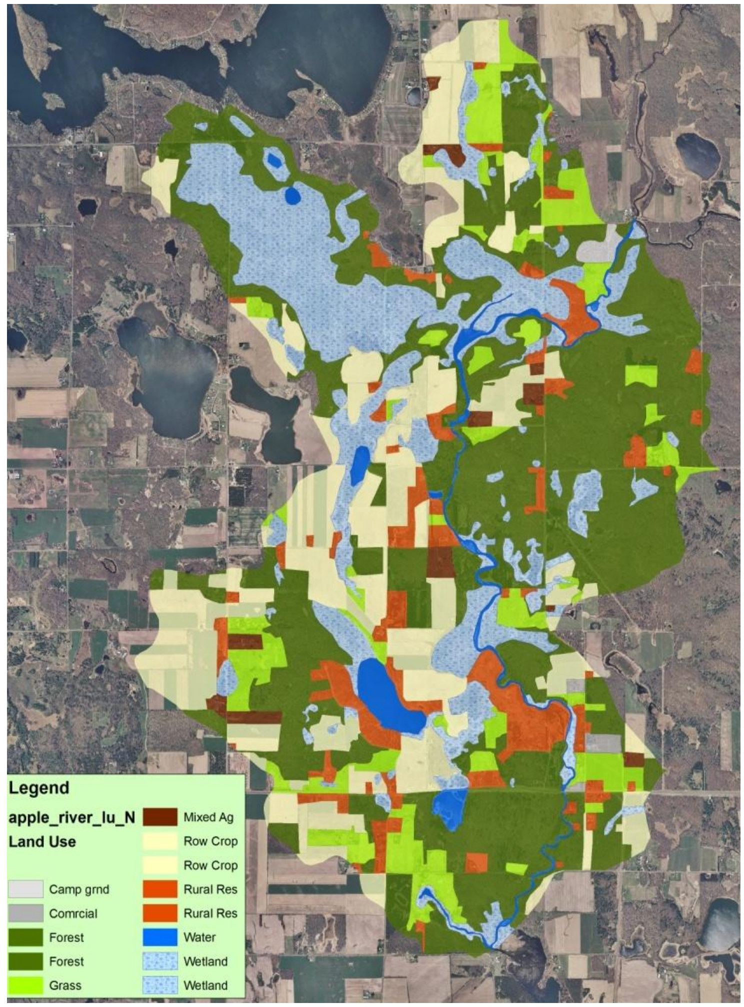
Land Use	Total Acres	Percent Acres	Total loading (lb P/year)	Percent Loading (lb P/year)
Forest	1356	26%	108	5%
Gravel Pit	17	0%	0	0%
Mixed Ag	54	1%	37	2%
Pasture/Grass	425	8%	114	5%
Row Crop	2175	42%	1936	84%
Rural Residential	270	5%	24	1%
Water	66	1%	18	1%
Wetland	773	15%	68	3%

Apple River Flowage Inlet Subwatershed

The Apple River Flowage Inlet Watershed is 7,965 acres in size.

The largest land use in the Apple River Flowage Inlet Subwatershed is forest (40%), followed by row crop (20%), and wetland (19%).

The largest contributor of phosphorus is row crop (63%).



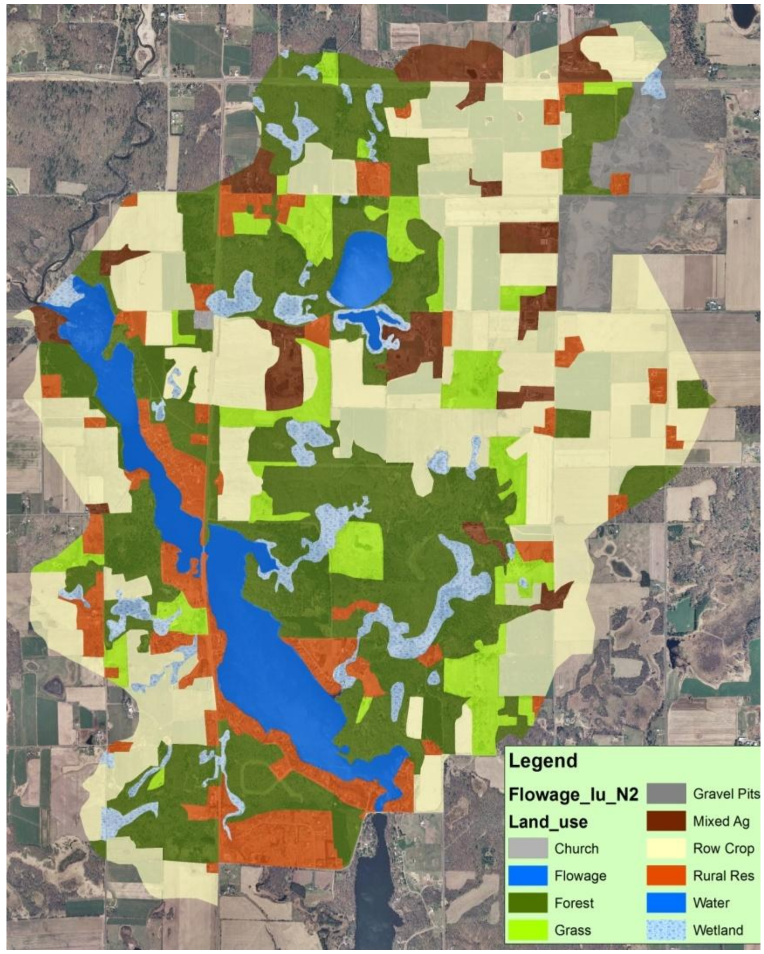
Land Use	Total Acres	Percent Acres	Total loading (lb P/year)	Percent Loading (lb P/year)
Campground	26	0%	11	0%
Commercial	27	0%	37	2%
Forest	3175	40%	255	11%
Grass	725	9%	194	9%
Mixed Ag	110	1%	79	4%
Row Crop	1584	20%	1410	63%
Rural Residential	595	7%	53	2%
Water	215	3%	57	3%
Wetland	1508	19%	134	6%

Site 1 North Subwatershed

The Site 1 North Subwatershed is 5130 acres in size.

The largest land use in the Site 1 North Subwatershed is row crop (33%), followed by forest (28%).

The largest contributor of phosphorus is row crop (74%).



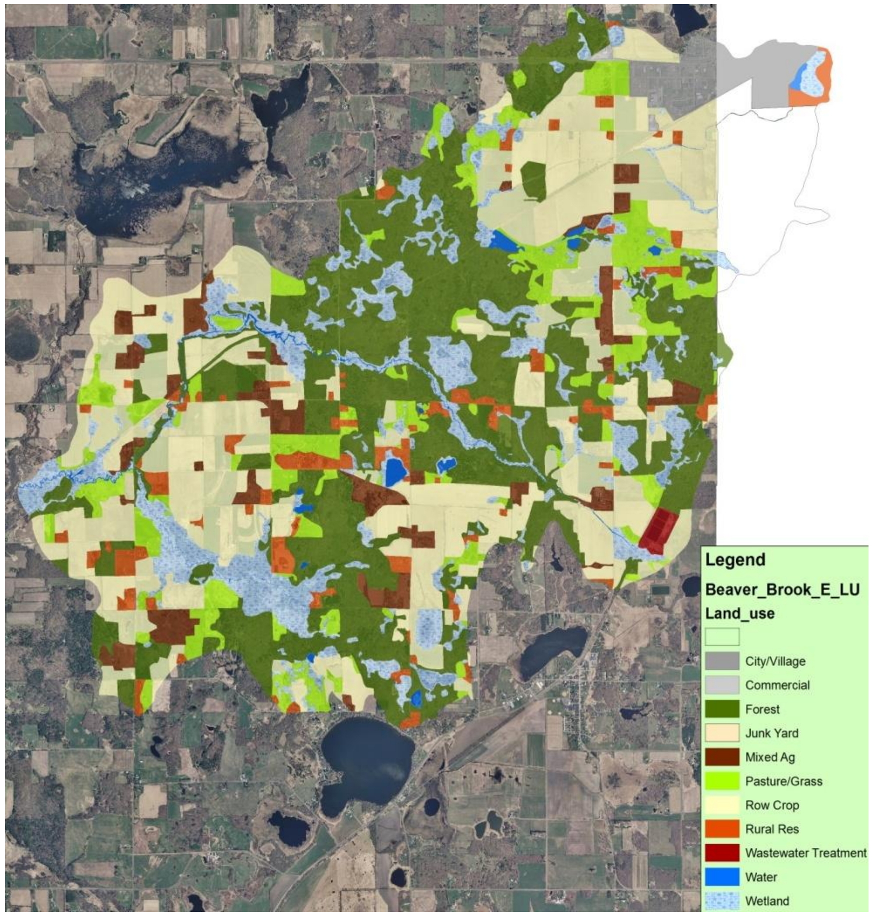
Land Use	Total Acres	Percent Acres	Total loading (lb P/year)	Percent Loading (lb P/year)
Church	4	0%	2	0%
Flowage	334	7%	90	4%
Forest	1439	28%	114	6%
Grass	364	7%	97	5%
Gravel Pits	225	4%	0	0%
Mixed Ag	254	5%	180	9%
Row Crop	1718	33%	1529	74%
Rural Residential	476	9%	42	2%
Water	53	1%	0	0%
Wetland	261	5%	24	1%

Beaver Brook East Subwatershed

The Beaver Brook East Subwatershed is 11,134 acres in size.

The largest land uses in the Beaver Brook East Subwatershed are forest (30%) and row crop (30%).

The largest contributor of phosphorus is row crop (70%).



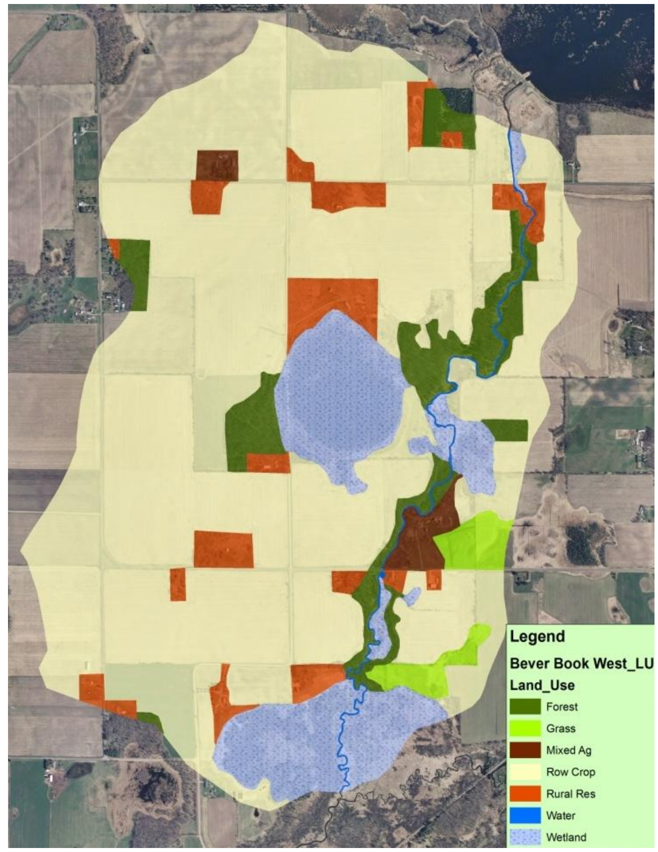
Land Use	Acres	Percent Acres	Total loading (lb P/year)	Percent Loading (lb P/year)
	503	5%	0	0%
City/Village	308	3%	136	3%
Commercial	15	0%	20	0%
Forest	3351	30%	268	6%
Junk Yard	6	0%	2	0%
Mixed Ag	526	5%	374	9%
Pasture/Grass	1016	9%	271	6%
Row Crop	3395	30%	3023	70%
Rural Residential	453	4%	40	1%
Wastewater Treatment	37	0%	15	0%
Water	98	1%	26	1%
Wetland	1427	13%	128	3%

Beaver Brook West Subwatershed

The Beaver Brook West Subwatershed is 1,345 acres in size.

The largest land use in the Beaver Brook West Subwatershed is row crop (70%).

The largest contributor of phosphorus is row crop (94%).



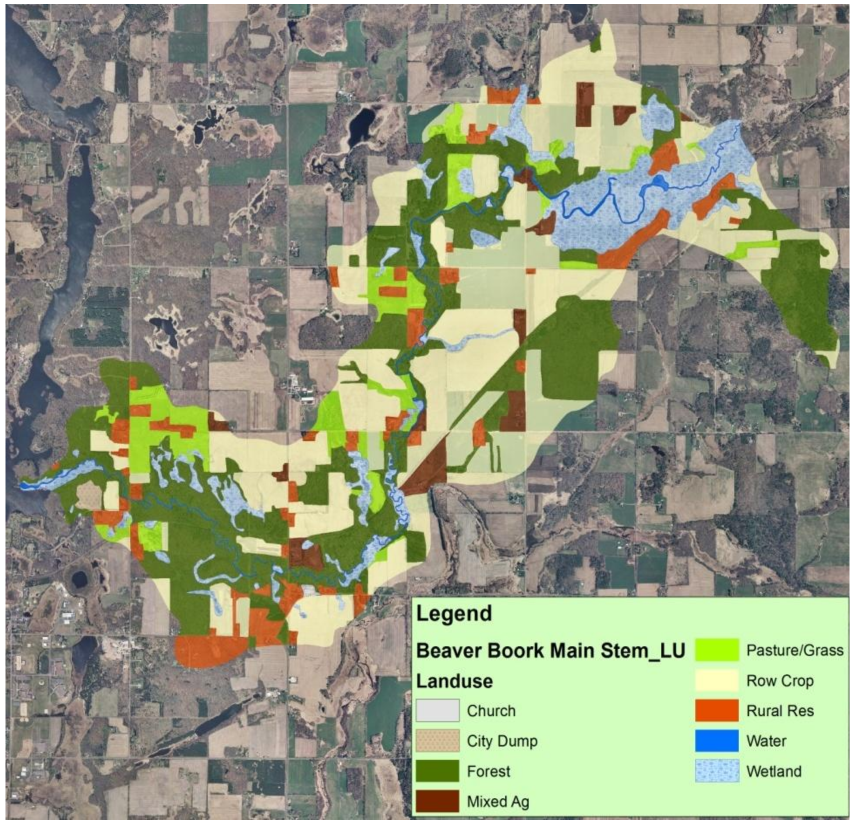
Land Use	Total Acres	Percent Acres	Total loading (lb P/year)	Percent Loading (lb P/year)
Forest	93	7%	7	1%
Grass	28	2%	7	1%
Mixed Ag	21	2%	15	2%
Row Crop	936	70%	834	94%
Rural Res	89	7%	9	1%
Water	8	1%	2	0%
Wetland	171	13%	15	2%

Beaver Brook Main Stem Subwatershed

The Beaver Brook Main Stem Subwatershed is 4,630 acres in size.

The largest land use in the Beaver Brook Main Stem Subwatershed is row crop (37%), followed by forest (32%).

The largest contributor of phosphorus is row crop (79%).



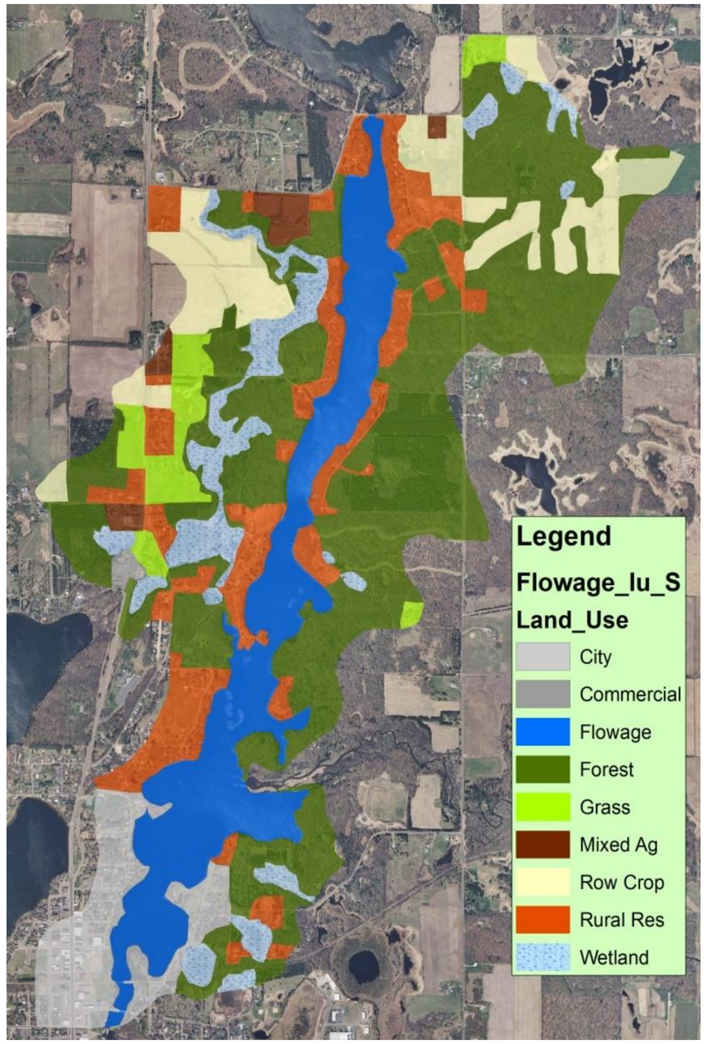
Land Use	Total Acres	Percent Acres	Total loading (lb P/year)	Percent Loading (lb P/year)
Church	4	0%	2	0%
City Dump	16	0%	2	0%
Forest	1461	32%	117	6%
Mixed Ag	145	3%	103	5%
Pasture/Grass	325	7%	86	4%
Row Crop	1730	37%	1540	79%
Rural Residential	348	8%	31	2%
Water	62	1%	18	1%
Wetland	538	12%	48	2%

Site 2 South Subwatershed

The Site 2 South Subwatershed is 1,785 acres in size.

The largest land use in the Site 2 South Subwatershed is forest (40%), followed by the flowage itself (17%), and rural residential (14%).

The largest contributor of phosphorus is row crop (37%), followed by the flowage itself (18%), the city of Amery (13%), and forest (13%).

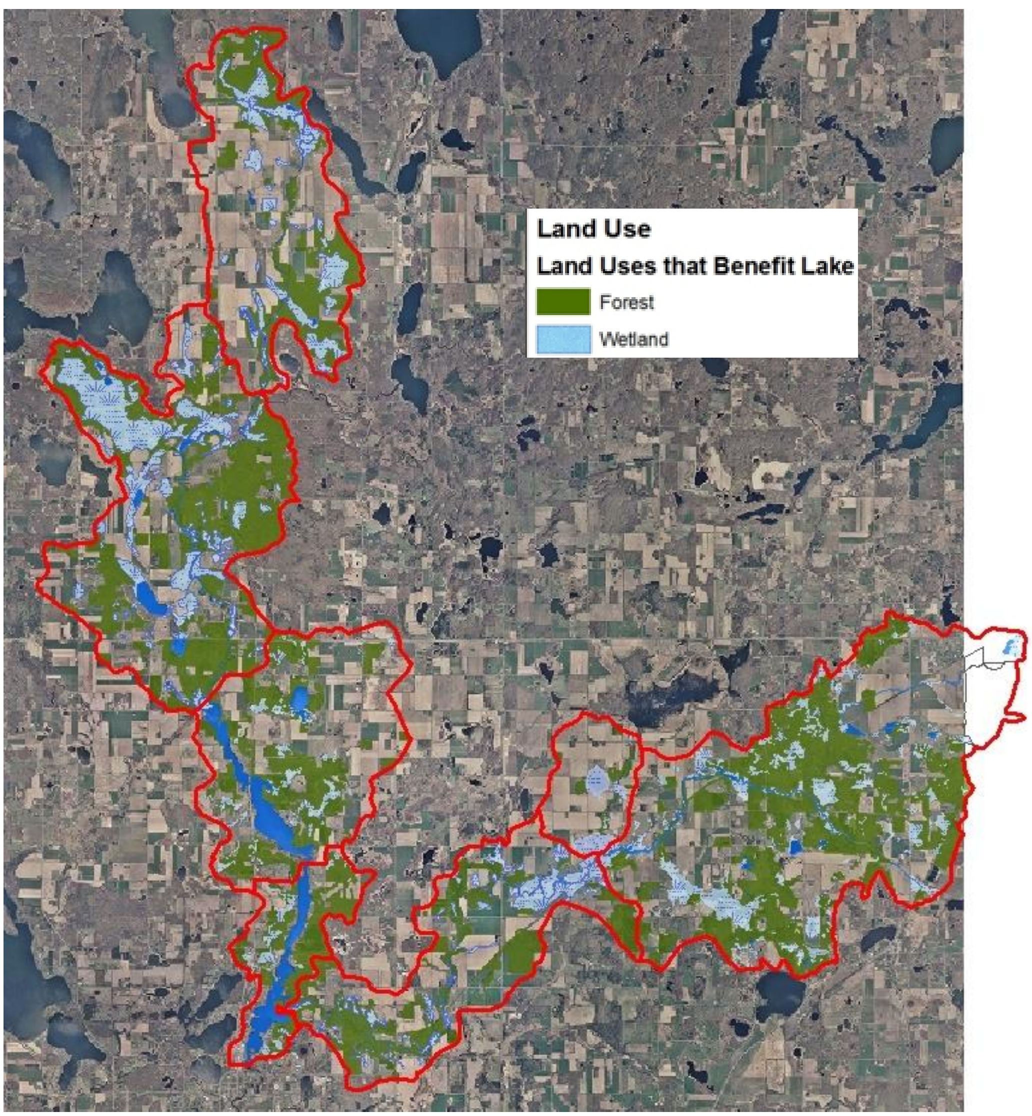


Land Use	Total Acres	Percent Acres	Total loading (lb P/year)	Percent Loading (lb P/year)
City	122	7%	55	13%
Commercial	6	0%	9	2%
Flowage	299	17%	79	18%
Forest	719	40%	57	13%
Grass	65	4%	18	4%
Mixed Ag	29	2%	20	5%
Row Crop	178	10%	158	37%
Rural Residential	242	14%	22	5%
Wetland	124	7%	11	3%

Areas Providing Water Quality Benefits to the Apple River Flowage

Natural areas such as forests and wetlands allow for more infiltration of precipitation when compared with row cropped fields and developed residential sites containing lawns, rooftops, sidewalks, and driveways. This occurs because dense vegetation lessens the impact of raindrops on the soil surface, thereby reducing erosion and allowing for greater infiltration of water. Additionally, wetlands provide extensive benefits through their ability to filter nutrients and allow sediments to settle out before reaching lakes and rivers.

Forests make up the second largest land use in the Apple River Flowage Watershed Management Area (31%) and wetlands make up the third largest land use (13%). The wetlands and forests of the Apple River Flowage Watershed Management Area should be considered sensitive areas and preserved for the benefits they provide to the flowage.



Watershed and Reservoir Modeling

The Wisconsin Lake Modeling Suite (WiLMS) was used to model current conditions and nutrient reductions for the north and south basins of the Apple River Flowage, verify monitoring, and estimate in-lake nutrient loading. Phosphorous is the key parameter in the modeling scenarios used in WiLMS because it is the limiting nutrient for algal growth in most lakes and reservoirs.

Based on average evaporation, precipitation, and runoff coefficients for Polk County soils and land use, the annual non-point source load was calculated to be 5,443.6 pounds of phosphorous for north basin. The measured load from Fox Creek and the Apple River entering the north basin was 8441.9 pounds of phosphorus or 80.1% of the external load. For the south basin the non-point source load was calculated to be 821.0 pounds of phosphorus per year and the outflow of the north basin into the south basin was calculated to be 7,712 pounds of phosphorus or 71.9% of the load. The measured load from Beaver Brook entering the south basin was 2,574.0 pounds of phosphorus per year.

Sub-watersheds were also modeled to estimate the total loading per acre as was reported in the Land Use and Nutrient Loading in the Apple River Flowage Subwatersheds section of this report.

Because the Apple River Flowage is a large, flowing system methods employed to model the internal loading from bottom sediments did not prove useful. The areal phosphorus loading was manipulated to come close to an actual number for the impact internal loading has on the Apple River Flowage. Areal loading is the amount of phosphorus entering the lake in milligrams per meter squared of lake surface area per year. Doing this, the north basin was calculated to have an internal load of 2,637 pounds of phosphorus per year; while the south basin was calculated to have an internal load of 2,690 pounds of phosphorus per year. Both of those calculations amount to about 25% of the total load which is reasonable for a system such as the flowage. Consideration of additional studies quantifying internal loading from bottom sediment is strongly encouraged.

The Nurnberg total phosphorus model takes internal loading into account:

$$\left(P = \frac{L_{Ext}}{q_s}(1-R) + \frac{L_{Int}}{q_s};\ \text{where } R = \frac{15}{18+q_s}\right)$$ [2]

This model predicts that the mixed lake total phosphorus concentration would be 59 μg/l in the north basin and 52 μg/l in the south basin. These estimates are low compared to the actual measured total phosphorus in both basins. There are obvious ecological and biogeochemical processes that affect measurable nutrient levels in lakes (such as sediment

[2] P is the predicted mixed lake total phosphorus concentration, L_{ext} is external areal loading, L_{int} is areal internal loading, qs is areal water loading or surface overflow rate, z is the lakes mean depth, and R is the Fraction of inflow total phosphorus retained in the lake.

REDOX potential) that simply can't be modeled and need to be measured and studied before assumptions can be made about the impact of sediments and internal loading on the nutrient cycle.

The model that was used to more accurately estimate the mixed lake water column total phosphorus concentration was the Canfield-Bachmann 1981 Artificial Lake Model which is calculated by:

$$\mathrm{P} = \frac{0.8L}{z(0.0942L/z)^{0.639} + p}.$$ [3]

The model was calibrated with available data for both the north and south basins.

The model estimated the north basin water column total phosphorus concentration as 74.74 µg/l, which was close to the actual annual measured average of 78.8 µg/l. A 15% reduction in the external areal load to the basin reduces phosphorus to 68.26 µg/l, a 25% reduction reduces phosphorus to 63.72 µg/l, a 32% reduction reduces phosphorus to 60.42 µg/l, and a 40% reduction reduces phosphorus to 56.54 µg/l.

The model also estimated the south basin water column total phosphorus concentration to be 74.74 µg/l, which also close to the actual annual measured average of 80.0 µg/l. A 15% reduction in the external areal load to the lake reduces phosphorus to 68.60 µg/l, a 25%% reduction reduces phosphorus to 64.72 µg/l, a 32% reduction reduces phosphorus to 61.77 µg/l, and a 40% reduction reduces phosphorus to 58.31 µg/l.

Using the available in situ and modeled data it is possible to predict reductions in chlorophyll *a* concentrations and total primary productivity within the water column by using the equation

$$\left[\overline{chl.a}\right] = 0.55\{[P]_i/(1+\sqrt{T_w}\}^{0.76}$$

for estimating the annual average chlorophyll a concentrations and

$$\sum C(gm^{-2}yr^{-1}) = \left[\frac{\{[P]_i/(1+\sqrt{T_w}\}^{0.76}}{0.3 + 0.011\{[P]_i/(1+\sqrt{T_w}\}^{0.76}}\right]$$ [4]

to correlate the relationship of total primary productivity with chlorophyll *a*. This equation is based on average chlorophyll concentrations and light extinction resulting from turbidity and dissolved organic substances (Wetzel, 2001).

---

[3] P is the predicted mixed lake total phosphorus concentration, L is areal loading, z is the lakes mean depth, and p is the lakes flushing rate.

[4] $\left[\overline{chl.a}\right]$ is the average annual concentration of chlorophyll a, $[P]_i$ is the average inflow concentration of total phosphorus, T_w is the lake hydraulic retention time, and $\sum C(gm^{-2}yr^{-1})$ is the sum of grams of carbon per meter squared of lake area per year produced during photosynthesis.

Using these equations it was predicted that the north basin would have an annual chlorophyll *a* concentration of 46.24 µg/l under current conditions, 40.87 µg/l with a 15% external load reduction, 37.16 µg/l with a 25% reduction, 34.49 µg/l with a 32% reduction, and 31.36 µg/l with a 40% reduction. All numbers are much higher than the 6.4 µg/l average measured in 2012; however, the model does predict a decline in chlorophyll *a* at all levels watershed nutrient reduction.

Similar results were found in primary productivity with the model predicting 462.91 C ($gm^{-2}yr^{-1}$) under current conditions, 446.99 C ($gm^{-2}yr^{-1}$) with a 15% reduction, 434.11 C ($gm^{-2}yr^{-1}$) with a 25% reduction, 423.69 C ($gm^{-2}yr^{-1}$) with a 32% reduction and 410.02 C ($gm^{-2}yr^{-1}$) with a 40% reduction in phosphorus.

The same equations showed that under current conditions the south basin would have an annual chlorophyll a concentration of 56.13 µg/l under current conditions. With a 15% external load reduction the south basin would have a chlorophyll concentration of 49.61 µg/l, 45.11 µg/l with a 25% external load reduction, 41.87 µg/l with a 32% reduction, and 38.07 µg/l with a 40% reduction. These values are still higher than the 15.5 µg/l measured in 2012, but still show a 12% reduction in chlorophyll *a* even at the lowest reduction level.

Total primary productivity went from 486.35 C ($gm^{-2}yr^{-1}$) under current conditions to 471.73 C ($gm^{-2}yr^{-1}$) with a 15% reduction, 459.85 C ($gm^{-2}yr^{-1}$) with a 25% reduction, 450.20 C ($gm^{-2}yr^{-1}$) with a 32% reduction and 437.43 C ($gm^{-2}yr^{-1}$) with a 40% reduction in phosphorus.

Models are generally an over simplification of natural phenomenon; however, they can be useful to guide lake and reservoir management because they can be used to predict many different scenarios. The models employed do show reductions in water column total phosphorus concentrations, chlorophyll *a* concentrations, and total primary productivity.

However, to enhance current understanding of these lakes' ecosystems and guide future management decisions a clear understanding of the Apple River Flowage current and past ecosystem functions needs to be achieved. Current aquatic macrophyte surveys should be coupled with continuous water column monitoring. Additionally, a detailed study of in situ sediment nutrient release and REDOX conditions should be seriously considered to adequately quantify internal loading and paleolimnological techniques should be employed to understand past water quality and ecosystem change and refine goals as needed.

Nutrient Budget Summary: Apple River North Basin

Modeling was used to estimate an annual phosphorus budget for both the North and South Basins of the Apple River Flowage for external (watershed) and internal (in-lake) sources of phosphorus.

Non-point source load estimated from WiLMS: <u>6,614 pounds phosphorus/year</u>

Divided by land use:

- ✓ Row crop: 4,875 pounds
- ✓ Forest: 477 pounds
- ✓ Mixed agriculture: 297 pounds
- ✓ Grass: 290 pounds
- ✓ Wetland: 227 pounds
- ✓ Rural residential: 119 pounds
- ✓ Pasture/grass: 114 pounds
- ✓ Precipitation to flowage surface: 90 pounds
- ✓ Water: 75 pounds
- ✓ Commercial: 37 pounds
- ✓ Campground: 11 pounds
- ✓ Church: 2 pounds

Tributary load calculated using field collected phosphorus data: <u>8,442 pounds phosphorus/year</u>

- ✓ Fox Creek: 3,512 pounds
- ✓ Apple River Inlet: 8,442 pounds

Internal load (load from sediments/dead or decaying matter): <u>2,637 pounds phosphorus/year</u>

Modeling was used to predict changes in water quality that would result from a 15%, 25%, 32%, and 40% reduction in external sources of phosphorus to the North Basin.

Modeling predicts that current water column phosphorus (with no reductions in internal or external loading) would be 0.07474 mg/L with a TSI(Phosphorus) of 66.3, which is close to the actual measured growing season average of 0.07888 mg/L with a TSI(Phosphorus) of 67.1.

Water column and TSI Phosphorus were estimated for each reduction.

Reduction	Water column phosphorus (mg/L)	TSI (Phosphorus)
15%	0.06826	65.0
25%	0.06372	64.0
32%	0.06042	63.3
40%	0.05654	62.3

Nutrient Budget Summary: Apple River South Basin

Modeling was used to estimate an annual phosphorus budget for both the North and South Basins of the Apple River Flowage for external (watershed) and internal (in-lake) sources of phosphorus.

Non-point source load estimated from WiLMS: <u>7,567 pounds phosphorus/year</u>

Divided by land use:

- ✓ Row crop: 5,555 pounds
- ✓ Mixed agriculture: 513 pounds
- ✓ Forest: 449 pounds
- ✓ Pasture/grass: 356 pounds
- ✓ Wetland: 202 pounds
- ✓ City/Village: 193 pounds
- ✓ Rural residential: 101 pounds
- ✓ Precipitation to flowage surface: 79 pounds
- ✓ Water: 46 pounds
- ✓ Commercial: 29 pounds
- ✓ Grass: 24 pounds
- ✓ Wastewater: 15 pounds
- ✓ Church: 2 pounds
- ✓ Junk yard: 2 pounds

Tributary load calculated using field collected phosphorus data: <u>2,580 pounds phosphorus/year</u>

- ✓ Beaver Brook Main Stem: 2,580 pounds
- ✓ Beaver Brook West: 512 pounds
- ✓ Beaver Brook East: 1,033 pounds

Internal load (load from sediments/dead or decaying matter): <u>2,690 pounds phosphorus/year</u>

Point source load from North Basin: <u>7,712 pounds phosphorus/year</u>

Tributary load leaving the South Basin using field collected phosphorus data: <u>16,162 pounds phosphorus/year</u>

Modeling was used to predict changes in water quality that would result from a 15%, 25%, 32%, and 40% reduction in external sources of phosphorus to the South Basin.

Modeling predicts that current water column phosphorus (with no reductions in internal or external loading) would be 0.07474 mg/L with a TSI(Phosphorus) of 66.3, which is close to the actual measured growing season average of 0.0800 mg/L with a TSI(Phosphorus) of 67.3.

Water column and TSI Phosphorus were estimated for each reduction.

Reduction	Water column phosphorus (mg/L)	TSI (Phosphorus)
15%	0.06860	65.1
25%	0.06472	64.2
32%	0.06177	63.6
40%	0.05831	62.7

Pontoon Classrooms

On September 12th, 2012 a pontoon classroom was held for members of the Apple River Flowage Protection and Rehabilitation District. The classroom was attended by five members.

At the pontoon classrooms, participants were given the chance to collect physical and chemical data, zooplankton samples, and algae samples. Data was explained and participants had the opportunity to see zooplankton and filter chlorophyll *a* samples. Plants were collected with a rake and shown to participants during a conversation regarding the benefits of aquatic plants and how to identify invasive species. Participants were given the chance to ask any questions they had regarding water quality. Tributary sampling was also discussed.

The pontoon classroom was promoted through the District newsletter and District Annual Meeting.

Shoreline Restoration Workshop

Polk County Ordinances

Comprehensive Land Use Planning

The Polk County Comprehensive Land Use Plan was adopted in 2009. The plan includes an analysis of population, economy, housing, transportation, recreation, and land use trends. It also reports the physical features of Polk County. The purpose of the land use plan is to provide general guidance to achieve the desired future development of the county and direction for development decisions. The lakes classification outlines restriction on development according to lake features. Plan information is available online at http://www.co.polk.wi.us/landinfo/PlanningCompPlan.asp

Town, City and Village Comprehensive Plans are available at: http://www.co.polk.wi.us/landinfo/PlanningCompPlans.asp

Smart growth is a state mandated planning requirement to guide land use decisions and facilitate communication between municipalities. Wisconsin's Comprehensive Planning Law (Statute 66.1001, Wis. Stats.) was passed as part of the 1999 Budget Act. The law requires that if a local government engages in zoning, subdivision regulations, or official mapping, those local land use regulations must be consistent with that unit of local government's comprehensive plan beginning on January 1, 2010. The law defines a comprehensive plan as having at least the following nine elements:

- ✓ Issues and opportunities
- ✓ Housing
- ✓ Transportation
- ✓ Utilities and community facilities
- ✓ Agricultural, natural, and cultural resources
- ✓ Economic development
- ✓ Intergovernmental cooperation
- ✓ Land use
- ✓ Implementation
- ✓ Polk County added "Energy and Sustainability"

Polk County Comprehensive Land Use Ordinance

The Polk County Comprehensive Land Use Ordinance, more commonly known as the Zoning Ordinance, is currently being updated due to the passage of the Comprehensive Plan. 17 of Polk County's 24 Towns have adopted county zoning, including: the Towns of Alden, Apple River, Beaver, Black Brook, Clam Falls, Clayton, Clear Lake, Eureka, Georgetown, Johnstown, Lincoln, Lorain, Luck, McKinley, Milltown, Osceola, and West Sweden. The Towns of Farmington, Garfield, and St Croix Falls have adopted Town Zoning and the Towns of Balsam Lake, Bone Lake, Laketown, and Sterling have no town or county zoning other than the state-mandated shoreland zoning. Land use regulations in the zoning ordinance include building height requirements, lot sizes, permitted uses, and setbacks among other provisions. The current Comprehensive Zoning Ordinance is available at: http://www.co.polk.wi.us/landinfo/pdfs/Ordinances/ComprehensiveLandUse.pdf

Shoreland Protection Zoning Ordinance

The State of Wisconsin's Administrative Rule NR115 dictates that counties must regulate lands within 1,000 feet of a lake, pond or flowage and 300 feet of a river or stream. The Shoreland Protection Zoning Ordinance is also currently being rewritten due to the Comprehensive Plan and the State of Wisconsin passing a new version of NR 115 in 2010. Polk County passed an update of the current Shoreland Ordinance in 2002 and again in 2008. These updates put in place standards for impervious surfaces, a phosphorus fertilizer ban for shoreland property, and lakes classification and setback standards. The current ordinance is available online at:
http://www.co.polk.wi.us/landinfo/pdfs/Ordinances/ShorelandOrdinance.pdf

Updates to the Shoreland Protection Ordinance and the Comprehensive Land Use Ordinance will be completed in 2013. The old and new version of the ordinances will be available at: http://www.co.polk.wi.us/landinfo/ordinances.asp

Subdivision Ordinance

The subdivision ordinance, adopted in 1996 and updated in 2005, requires a recorded certified survey map for any parcel less than 19 acres. The ordinance requires most new plats to incorporate storm water management practices with no net increase in runoff from development. The ordinance is available online at:
http://www.co.polk.wi.us/landinfo/PDFs/Ordinances/Subdivision%20Ordinance%202005-07-01.pdf

Animal Waste

The Polk County Manure and Water Quality Management Ordinance was revised in January 2000. A policy manual established minimum standards and specifications for animal waste storage facilities, feedlots, degraded pastures, and active livestock operations greater than 300 animal units for livestock producers regulated by the ordinances. The Land and Water Resource Department's objective was to have countywide compliance with the ordinance by 2006. The ordinance is available online at:
http://www.co.polk.wi.us/landwater/MANUR21A.htm.

Storm Water and Erosion Control

The ordinance, passed in December 2005, establishes planning and permitting requirements for erosion control on disturbed sites greater than 3,000 square feet, where more than 400 cubic yards of material is cut or filled, or where channels are used for 300 feet more of utility installation (with some exceptions). Storm water plans and implementation of best management practices are required for subdivisions, survey plats, and roads where more than ½ acre of impervious surface will result. The Polk County Land and Water Resources Department administers the ordinance. The ordinance is a local mechanism to implement the Wisconsin Non-agricultural Runoff Performance Standards found in NR 151.

WI Non-Agricultural Performance Standards (NR 151)

Construction Sites >1 acre – must control 80% of sediment load from sites

Storm water management plans (>1 acre)
- Total Suspended Solids
- Peak Discharge Rate
- Infiltration
- Buffers around water

Developed urban areas (>1000 persons/square mile)
- Public education
- Yard waste management
- Nutrient management
- Reduction of suspended solids

Amended Illegal Transport of Aquatic Plants and Invasive Animals

The purpose of this ordinance, passed in June 2011, is to prevent the spread of aquatic invasive species in Polk County and surrounding water bodies by prohibiting the transport of boats, trailer, personal watercraft, and equipment if aquatic invasive plants or invasive animals are attached.

Polk County Land and Water Resources Management Plan

The Polk County Land and Water Resources Management Plan describes the strategy the Land and Water Resources Department (LWRD) will employ from 2010-2018 to address agriculture and non-agriculture runoff management, stormwater discharge, shoreline management, soil conservation, invasive species and other environmental degradation that affects the natural resources of Polk County. The plan specifies how the LWRD will implement NR 151 (Runoff Management). It involves identifying critical sites, offering cost-share and other programs, identifying BMP's monitoring and evaluating projects for compliance, conducting enforcement activities, tracking progress, and providing information and education.

Polk County has local shoreland protection, zoning, subdivision, animal waste, and non-metallic mining ordinances. Enforcing these rules and assisting other agencies with programs are part of LWRD's ongoing activities. Other activities to implement the NR 151 Standards include information and education strategies, write nutrient management plans, provide technical assistance to landowners and lakeshore owners, perform lake studies, collaborate with other agencies, work on a rivers classification system, set up demonstration sites of proper BMP's, control invasive species, and revise ordinances to offer better protection of resources.

WI Agricultural Performance Standards (NR 151)

For farmers who grow agricultural crops

- ✓ Meet "T" on cropped fields
- ✓ Starting in 2005 for high priority areas such as impaired or exceptional waters, and 2008 for all other areas, follow a nutrient management plan designed to limit entry of nutrients into waters of the state

For farmers who raise, feed, or house livestock

- ✓ No direct runoff from feedlots or stored manure into state waters
- ✓ No unlimited livestock access to waters of the state where high concentrations of animals prevent the maintenance of adequate or self sustaining sod cover
- ✓ Starting in 2005 for high priority areas, and 2008 for all other areas, follow a nutrient management plan when applying or contracting to apply manure to limit entry of nutrients into waters of the state

For farmers who have or plan to build a manure storage structure

- ✓ Maintain a structure to prevent overflow, leakage, and structural failure
- ✓ Repair or upgrade a failing or leaking structure that poses an imminent health threat or violates groundwater standards
- ✓ Close a structure according to accepted standards
- ✓ Meet technical standards for a newly constructed or substantially-altered structure

For farmers with land in a water quality management area (defined as 300 feet from a stream, or 1,000 feet from a lake or areas susceptible to groundwater contamination)

- ✓ Do not stack manure in unconfined piles
- ✓ Divert clean water away from feedlots, manure storage areas, and barnyards located within this area

Lake Management Plan

Lake Management Plans help protect water bodies by encouraging partnerships between concerned citizens, lakeshore residents, watershed residents, agency staff, and diverse organizations. Lake Management Plans identify concerns of importance and set realistic goals, objectives, and action items to address identified concerns. Additionally, Lake Management Plans identify roles and responsibilities for meeting each goal and provide a timeline for implementation.

Lake Management Plans are living documents that are under constant review and adjustment depending on the condition of a lake, available funding, level of volunteer commitments, and the needs of lake stakeholders.

The implementation plan presented below was created through collaborative efforts and takes current and past water quality data, a 2012 sociological survey regarding the needs of The Apple River Flowage Protection and Rehabilitation members, and a series of four meetings by the Apple River Flowage Water Quality Committee.

Vision

We envision the Apple River Flowage as a healthy body of water with appropriate nutrient levels which supports human recreational uses and a diverse population of fish, wildlife, and native plants.

Guiding Principles

Lake management decisions are driven by what is best for the resource based on information that includes the ever evolving nature of lake management.

Communication regarding lake management needs to be easy to understand, concise, and frequent.

<u>Goal 1:</u> Reduce excessive watershed nutrient inputs to the flowage to improve water quality

Watershed nutrient inputs come from the land mass that drains to the Apple River Flowage. The watershed for the Apple River Flowage is 175 times larger than the flowage itself. As a comparison, the watershed for Pike Lake is 2.5 times larger than the lake itself and the watershed for North Twin Lake is 1.3 times larger than the lake itself.

The watershed management area for this study is 37,125 acres in size and spans from Balsam Lake, to Turtle Lake, Clayton, and Amery.

Means to accomplish this goal:

1. Reduce phosphorus loading from watershed sources by at least 15% (2,128 pounds)
   *A 15% reduction in phosphorus loading should remove the Apple River Flowage from the federal 303(d) list of Impaired Waters

2. Engage watershed residents and users in reducing nutrients and sediments to improve water quality

- Identify and contact residents and users to explain options for reducing nutrients and sediments
- Recognize residents and users that have taken steps to reduce watershed nutrient inputs and improve nutrient management
- Partner with the City of Amery to install stormwater practices

3. Support installation of best management practices, or practices which reduce runoff to the flowage

- Provide technical assistance and cost sharing (incentives) for the installation of best management practices including but not limited to:
    - Shoreline buffers
    - Rain gardens
    - Nutrient management
    - Soil testing on farm fields
    - Evaluation of septic systems
    - Water diversions
    - Sediment ponds
    - Stormwater practices
    - Stream and creek buffers
    - Shoreline erosion practices

- Consider purchase of highly erodible/ecologically sensitive land if option arises

Goal 2: Minimize the release of nutrients from within the Apple River Flowage to improve water quality

Nutrients are trapped in lake sediments and plants. If these nutrients are released back into the water column (through sediment disturbance or plant die back) they are made available to further increase plant or algae growth. This process is called internal loading.

Means to accomplish this goal:

1. Engage watershed residents and users in reducing internal loading

- Identify and contact residents and users to explain options for reducing internal loading

2. Support practices that reduce internal loading

- Support harvesting of curly-leaf pondweed, which removes nutrients from the flowage
- Increase awareness of slow-no-wake zones to minimize disturbance of sediments
- Consider aeration in developed stagnant bays
- Work with the County to develop a plan to install culverts on the 46 bridge when the bridge is redone

<u>Goal 3:</u> Protect, maintain, and enhance fish and wildlife habitat

Means to accomplish this goal:

1. Maintain desirable levels of game fish in the flowage

- Assess opportunities to improve fish habitat (i.e. woody habitat)
- Communicate with WDNR and Tribes to make informed decisions and encourage assessment and management of fish
- Continue work to maintain desirable levels of game fish
- Install fish structures to increase woody habitat based on expert recommendations
- Consider monetarily supporting fish stocking based on expert recommendations
- Develop a plan to take into account the potential for higher boat traffic associated with increased game fish (ie. boat wash, increased slow-no-wake)

2. Increase understanding of options for attracting desirable birds, waterfowl, and wildlife to property

- Identify and contact residents and users with educational information

3. Enhance wildlife habitat

- Provide technical assistance and incentives to encourage restoration of shoreline buffer zones

Goal:4 Maintain and enhance the natural beauty of the Apple River Flowage

Means to accomplish this goal:

1. Promote the preservation and restoration of natural vegetation along the Apple River Flowage shoreline

- Provide technical assistance and incentives to encourage restoration of shoreline buffer zones

2. Maintain undeveloped natural areas where feasible

- Consider conservation easements to preserve undeveloped lands
- Consider property acquisition to preserve undeveloped, priority, or degraded lands

3. Enhance natural beauty of developed areas

- Organize an annual clean-up date to remove old docks and garbage

4. Create areas for public use

- Consider installation of public fishing piers
- Consider creation of public parks with walking trails

Goal 5: Evaluate the progress of lake management efforts through monitoring and data collection

Means to accomplish this goal:

1. Continue current data collection efforts

- Ensure that a Citizen Lake Monitoring volunteer system is in place for each year

2. Expand data collection efforts

- Implement tributary sampling to track reductions in watershed nutrients
- Consider sediment cores to gather historical data (100-200 years)
- Implement a study to assess the impacts of harvesting
- Consider a study to determine phosphorus release from curly-leaf pondweed die off
- Determine feasibility of dredging and drawdown to address sediments
  *Note a drawdown typically reduces sediment by 1/3
- Work with the City to develop a plan if the dam fails or requires maintenance
  *If a drawdown needs to occur it could be used as an opportunity to reduce sediment or manage aquatic invasive species
- Repeat the 2012 water quality study in five years

<u>Goal 6:</u> Provide information and education opportunities to residents and users

Means to accomplish this goal:

1. Utilize various methods of communication:

- Website
- Social media such as Facebook and QR codes
- Emails
- Geo-caching
- Newsletters
- Press releases
- Regularly scheduled workshops

2. Topics to communicate:

- Water quality
- Opportunities for technical assistance and cost sharing of projects
- District projects
- District events
- Recognition of partners

<u>Goal 7:</u> Develop partnerships with a diversity of people and organizations

Means to accomplish this goal:

1. Develop a relationship with a diversity of groups

- City of Amery
- Apple River Association
- WDNR
- Tribe
- Polk County LWRD
- Polk County Association of Lakes and Rivers
- Lake Districts and organizations within the Upper Apple River Watershed
- Watershed residents
- Amery School District
- Youth groups
- Sportsman's Clubs

2. Attend area meetings held by partners

3. Invite partners to Apple River Flowage District Meetings

4. Consider the formation of a Watershed Council

5. Create and maintain a directory of key contacts

<u>Goal 8:</u> Implement the Aquatic Plant Management Plan

Means to accomplish this goal:

1. Improve water quality on the Apple River Flowage and downstream on the Apple River
2. Prevent the introduction of aquatic invasive species
3. Maintain navigation for fishing, boating, and access to lake residences
4. Maintain native aquatic plant functions
5. Minimize environmental impacts of aquatic plant management

Goal 1: Reduce excessive watershed nutrient inputs to the flowage to improve water quality

Action	Timeline	$ Estimate	Volunteer Hours	Partners	Funding Sources
Identify and contact residents and users to explain options for reducing nutrients and sediments	2013, ongoing			ARPRD Board LWRD	
Recognize residents and users that have taken steps to reduce watershed nutrient inputs and improve nutrient management	As projects are implemented			ARPRD Board	
Partner with the City of Amery to install stormwater practices	3-5 years			ARPRD Board City of Amery	WDNR Urban Nonpoint Source and Stormwater Management Grant
Provide technical assistance and cost sharing (incentives) for the installation of best management practices including but not limited to: shoreline buffers, rain gardens, nutrient management, soil testing on farm fields, evaluation of septic systems, water diversions, sediment ponds, stormwater practices, stream and creek buffers, and shoreline erosion practices	2015 or if funding available			ARPRD Board LWRD Consultant	WDNR Lake Protection Grant
Consider purchase of highly erodible/ecologically sensitive land if option arises	If available funding			ARPRD Board	WDNR Lake Protection Grant

<u>Goal 2:</u> Minimize the release of nutrients from within the Apple River Flowage to improve water quality

Action	Timeline	$ Estimate	Volunteer Hours	Partners	Funding Sources
Identify and contact residents and users to explain options for reducing internal loading	2013, ongoing			ARPRD Board	
Support harvesting of curly-leaf pondweed, which removes nutrients from the flowage	Ongoing			ARPRD Board	
Increase awareness of slow-no-wake zones to minimize disturbance of sediments	As needed			ARPRD Board	
Consider aeration in developed stagnant bays (determine costs)	2013			ARPRD Board Amery Economic Development	
Work with the County to develop a plan to install culverts on the 46 bridge when the bridge is redone	Ongoing			ARPRD Board Polk County	

<u>Goal 3:</u> Protect, maintain, and enhance fish and wildlife habitat

Action	Timeline	$ Estimate	Volunteer Hours	Partners	Funding Sources
Assess opportunities to improve fish habitat (i.e. woody habitat)	Ongoing			WDNR Tribe	
Communicate with WDNR and Tribes to make informed decisions and encourage assessment and management of fish	Ongoing			ARPRD Board WDNR Tribe	
Continue work to maintain desirable levels of game fish	Ongoing			ARPRD Board	
Install fish structures to increase woody habitat based on expert recommendations	TBD			ARPRD Board WDNR	
Consider monetarily supporting fish stocking based on expert recommendations	TBD			ARPRD Board	
Develop a plan to take into account the potential for higher boat traffic associated with increased game fish (ie. boat wash, increased slow-no-wake)	As needed			ARPRD Board	
Identify and contact residents and users with educational information	2013, ongoing			ARPRD Board	
Provide technical assistance and incentives to encourage restoration of shoreline buffer zones	2015			ARPRD Board LWRD Consultant	WDNR Lake Protection Grant

<u>Goal 4:</u> Maintain and enhance the natural beauty of the Apple River Flowage

Action	**Timeline**	**$ Estimate**	**Volunteer Hours**	**Partners**	**Funding Sources**
Provide technical assistance and incentives to encourage restoration of shoreline buffer zones	2015 or if funding available			ARPRD Board LWRD Consultant	WDNR Lake Protection Grant
Consider conservation easements to preserve undeveloped lands	If available funding			ARPRD Board	WDNR Lake Protection Grant
Consider property acquisition to preserve undeveloped, priority, or degraded lands	If available funding			ARPRD Board	WDNR Lake Protection Grant
Organize an annual clean-up date to remove old docks and garbage	2013, ongoing			ARPRD Board Apple River Association	
Consider installation of public fishing piers	TBD			ARPRD Board City of Amery	
Consider creation of public parks with walking trails	TBD			ARPRD Board City of Amery Town of Lincoln	

<u>Goal 5:</u> Evaluate the progress of lake management efforts through monitoring and data collection

Action	Timeline	$ Estimate	Volunteer Hours	Partners	Funding Sources
Ensure that a Citizen Lake Monitoring volunteer system is in place for each year	2013, ongoing	$100/year	20-40	ARPRD Board Volunteer	WDNR Citizen Lake Monitoring Network
Implement tributary sampling to track reductions in watershed nutrients	Inlet/outlet every year or as practices implemented	$81/sample		ARPRD Board Volunteer LWRD Consultant Tribe	WDNR Lake Planning Grant or Protection Grant
Consider sediment cores to gather historical data (100-200 years)	5-10 years	$12-30,000		ARPRD Board LWRD Consultant	WDNR Lake Planning Grant
Implement a study to assess the impacts of harvesting	2014			ARPRD Board LWRD Consultant Tribe	WDNR AIS Grant or Planning Grant
Consider a study to determine phosphorus release from curly-leaf pondweed die off	2014			ARPRD Board LWRD Consultant Tribe	WDNR AIS Grant or Planning Grant
Determine feasibility of dredging and drawdown to address sediments	5-10 years			ARPRD Board LWRD Consultant	
Work with the City to develop a plan if the dam fails or requires maintenance	Ongoing			ARPRD Board City of Amery	
Repeat the 2012 water quality study in five years	5 years			ARPRD Board LWRD Consultant	WDNR Lake Planning Grant

Goal 6: **Provide information and education opportunities to residents and users**

Action	Timeline	$ Estimate	Volunteer Hours	Partners	Funding Sources
Website	Ongoing			ARPD Board	
Social media such as Facebook and QR codes	2014, ongoing			Task Force	
Emails	Ongoing			ARPD Board	
Geo-caching	3-5 years			Task Force	
Newsletters	Ongoing			ARPD Board LWRD	
Press releases	Ongoing			ARPD Board LWRD	
Regularly scheduled workshops	3-5 years			ARPD Board LWRD Area partners	

<u>Goal 7:</u> Develop partnerships with a diversity of people and organizations

Action	Timeline	$ Estimate	Volunteer Hours	Partners	Funding Sources
Develop a relationship with a diversity of groups	Ongoing	$25 PCALR membership		ARPD Board Area partners	
Attend area meetings held by partners	Ongoing			ARPD Board Area partners	
Invite partners to Apple River Flowage District Meetings	2013, ongoing			ARPD Board Area partners	
Consider the formation of a Watershed Council	3-5 years			ARPD Board Area partners	McKnight Joyce Foundation WDNR
Create and maintain a directory of key contacts	2013, ongoing			ARPD Board	

Works Cited

Byron Shaw, Christine Mechenich, and Lowell Klessig. (2004). *Understanding Lake Data (G3582)*. UW-Extension.

Carlson, R. E. (March 1977. Volume 22(2)). A Trophic State Index for lakes. *Limnology and Oceanography* , 361-369.

Carrol L. Henderson, Carolyn J. Dindorf, and Fred J. Rozumalski. (n.d.). *Lakescaping For Wildlife and Water Quality*. St. Paul: Minnesota's Bookstore, part of the State of Minnesota Department of Administration Print Communication Division.

D.D. MacDonald, C.G. Ingersoll, and T.A. Berger. (2000). Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. *Archives of Environmental Contaminiation and Toxicology, 39*, 20-31.

Dodson, S. (2005). *Introduction to Limnology*. New York: McGraw-Hill.

Engstrom, D.R., and Wright, H.E. (1984). *Chemical Stratigraphy of Lake Sediments as a Record of Environmental*. (E. a. Haworth, Ed.) Leicester: Leicester University Press.

Gonsiorczyk, T., Casper, P., and Koschel, R. (1998). Phosphorus-Binding Forms in the Sediment of an Oligotrophic and an Eutrophic Hardwater Lake of the Baltic Lake District (Germany). *Wat. Sci. Tech., 37*(3), 51-58.

Harmony Environmental and Endangered Resource Services, LLC. (September 2011). *Aquatic Plant Management Plan Apple River Flowage Polk County, Wisconsin* .

Harmony Environmental, Polk County Land and Water Resources Department, and Ecological Integrity Services. (2009). *Bone Lake Comprehensive Lake Management Plan*.

Kaiserli, A., Voutsa, D., and Samara, C. (2002). Phosphorus Fractionation in Lake Sediments--Lakes Vovi and Koronia, N. Greece. *Chemosphere, 46*, 1147-1155.

Lafroncois, T. (2013). *Zooplankton of the Apple River Flowage, Big Lake, Church Pine Lake, Long Lake and Wind Lake of Polk County, WI, 2012*.

Lillie, R. A. (1983). Limnological Characteristics of Wisconsin lakes. Madison: Department of Natural Resources.

Lynn Markham and Ross Dudzik. (2012). Impervious Surfaces How They Impact Fish, Wildlife and Waterfront Property Values. University of Wisconsin Department of Natural Resources, University of Wisconsin Extension, and University of Wisconsin Extension Center for Land Use Education.

Office of Inland Lake Renewal Wisconsin Department of Natural Resources. (1979). *Apple River Flowage Polk County Results Feasibility Study Results; Management Alternatives*.

Polk County Land and Water Resources Department. (December 2003). *Apple River Association Development and I&E Project*.

Polk County Shoreland Protection Zoning Ordinance. (Effective April 1, 2010).

Polk County, Wisconsin Shoreland Property Owner Handbook A Guide to the Polk County Shoreland Protection Zoning Ordinance in Developing and Caring for Waterfront Property. (October 2002).

Scheffer, M. (1998). *Ecology of Shallow Lakes*. London: Chapman & Hall.

Sondergaard, M., Jensen, J.P., Jeppesen, E. (2001). Retention and internal loading of phosphorus in Shallow, Eutrophic Lakes. *The Scientific World, 1*, 427-442.

United States Environmental Protection Agency. (June 2008). *Copper Facts*.

Wetzel, R. G. (2001). *Limnology Lake and River Ecosystems Third Edition*. San Diego, California: Academic Press.

Wisconsin Department of Natural Resources. (2012). *Apple River Flowage*.

Wisconsin Department of Natural Resources. (2013, February). *Imparied Waters*.