Portage Lake

Lake Management Plan 2016

Prepared for Onekama Township, Portage Lake Watershed Forever & Invasive Species Committee

Submitted By:

BreAnne Grabill, Environmental Scientist

PLM Lake & Land Management Corp.

PO Box 424 · Evart, Michigan 49631
phone 800.382.4434 · fax 231.372.5900
www.plmcorp.net

TABLE OF CONTENTS

Lake Management Plan

Executive Summary

Portage Lake has been managed over the past eight years with goals of identifying and reducing the presence of exotic species throughout the Portage Lake watershed, tracking plant trends, improving water quality readings and protecting Portage Lake into the future. The following report breaks down the specifics of the previous management, the management of the 2016 season and the need for future management.

In 2016, just over 21 acres of EWM, Phragmites, Purple Loosestrife and Narrow lead cattails were controlled via chemical control methods. Extensive lake mapping, vegetation mapping and water quality testing was also performed. The abundance of healthy native plants in Portage Lake increases the long term stability of the lake. While some water quality parameters have maintained themselves with little change over the years, other parameters have shown some fluctuations. One of the most important parameter to test is Total Phosphorus and in 2015 and 2016, all lake and shoreline basin samples came back below recent years, showing a decline and a very positive outlook for Portage Lake. Some of these fluctuations in other parameters include showing that the tributaries around Portage Lake are bringing excess nutrients into the lake. This information is vital in determining the areas within Portage Lake that need to be focused on reducing nutrient loading to help reduce the productivity in Portage Lake. The ability of Portage Lake to produce algae and aquatic plants is directly related to the overall health and use of Portage Lake. While the main goal of the management is to protect the long term ecological health of the lake, it is also important to protect the recreational, aesthetical and financial aspects of the lake as well. All of these factors play into the management efforts on Portage Lake which need to be continued into next season.

Portage Lake was selected to be a sampling lake in PLM's DNR Grant study in 2015. PLM has partnered with Michigan Tech University in a 3-year study to genetically test milfoil plants to determine the plant response to various chemical herbicides. This exciting study is still underway but should assist with management decisions and the direction of the program in the future.

Introduction

Purpose of the Plan

This management plan documents management activities during 2016, examines current conditions in the lake, and provides management recommendations for 2017. The plan will detail an integrated approach to lake management including but not limited to exotic weed control, water quality monitoring and aquatic vegetation surveying.

Characteristics of the Lake

Portage Lake is a 2165-acre lake located in Onekama Township and the Village of Onekama, Manistee County, Michigan. Public access to the lake is provided by multiple access sties. A large portion of the shoreline has been developed and of that, a majority for single family year-round homes. A formal lake-use survey was not included in this study, but observations made while working on the lake indicate that the lake is used for fishing, boating (power & non-power), and swimming.

Portage Lake makes up 13.6% of the overall Portage Lake Watershed, which drains into Lake Michigan. Numerous other lakes and tributaries flow into Portage Lake, which has a man made channel into Lake Michigan on the west end. Portage Lake is a natural lake with two deep holes approximately 60' deep.

A few problems necessitating management of Portage Lake are: (1) exotic and invasive species, and (2) water quality concerns. The presence of multiple exotic species has required annual management of the aquatic and terrestrial plants within and around Portage Lake.

Establishment of weedy exotic aquatic plants, including Eurasian watermilfoil and curly leaf pondweed, exacerbates problems caused by aquatic vegetation in the lake. These weedy exotic plants grow to the surface and cause substantially more interference with recreation than native plants.

Management Goals for Portage Lake

- The primary goal of management in Portage Lake is to control and manage exotic plants, to allow recreational use of the lake and promote a healthy fishery. The exotic plant species, Eurasian watermilfoil and Phragmites, should be controlled throughout Portage Lake to the maximum extent possible. Native plants should be encouraged throughout the lake to promote an overall heahlty ecosystem. Genetic testing in Portage Lake has found that the Eurasian watermilfoil and Northern watermilfoil species have bred, forming a new genetic strand of milfoil commonly referred to as Hybrid milfoil. In reference to Portage Lake, Eurasian milfoil will be now referring to both EWM and Hyrbid milfoil as it all needs to be managed as an exotic, invasive species.

- Aquatic plant management should preserve species diversity and cover of native plants sufficient to provide habitat for fish and other aquatic organisms. Native plants should be managed to encourage the growth of plants that support the Portage Lake fishery (by creating structure and habitat) provided that they do not excessively interfere with recreational uses of the lake (e.g., swimming and fishing) in high-use areas. Where they must be managed, management techniques that reduce the stature of native plants without killing them (e.g., harvesting, contact herbicides) should be used whenever possible. Specific areas should be set aside where native plants will not be managed, to provide habitat for fish and other aquatic organisms. Muskgrass (*Chara*) should be allowed to grow throughout the lake, except in where it grows so tall as to interfere with boating and swimming.
- The species Starry stonewort, if found on the Portage Lake should be actively controlled and managed. Starry stonewort is in the same family as Muskgrass (Chara) but is considered to be an exotic invasive species. Starry stonewort, which looks very similar to the beneficial species Chara, is appearing in more and more lakes. Chara is a highly desired plant because it is typically low growing, keeps the water clear and can slow down the invasion of exotic weed species. Starry stonewort also forms dense mats, but

Starry stonewort

unlike chara, it can grow from 5 to 7 feet tall. Starry stonewort can be very detrimental to a lake's ecosystem and has the ability to kill off native plants and have a negative impact on a lake's fisheries.

- The aquatic invasive terrestrial plants, Purple loosestrife and Phragmities should be controlled along the shoreline and adjacent wetlands where present. Both species are exotic and have the ability to displace beneficial native vegetation. Purple loosestrife grows 2 -4 feet tall and is a vibrant magenta color. It is very aggressive and can quickly become the dominant wetland vegetaion. Phragmites (common reed) is a wetland grass that ranges in height from 6 to 15 feet tall. "Phrag" quickly becomes the dominant feature in aquatic ecosystems, aggressively invading shorelines, wetlands, and ditches. This plant creates dense "strands" - walls of weeds crowding out beneficial native wetland vegetation and indigenous waterfowl habitats. Spreading by fragmentation and an extensive root system, Phragmites ultimately out-competes native plant life for sun, water and nutrients.


Phragmites

- The terrestrial invasive plant, Japanese knotweed should be controlled throughout the Portage Lake Watershed. Japanese knotweed is a large, herbaceous perennial plant native to Eastern Asia. In North America the species has been classified as an invasive species. Japanese knotweed has hollow stems with distinct raised nodes that give it the appearance of bamboo, though it is not closely related. Reaching a maximum height of about 12' each growing season, it is typical to see much smaller plants in places where they sprout through cracks in the pavement or are repeatedly cut down. The invasive root system and strong growth can damage concrete foundations, buildings, roads, paving, retaining walls and architectural sites. It can also reduce the capacity of channels to carry water. It forms thick, dense colonies that completely crowd out any other herbaceous species. The success of the species has been partially attributed to its tolerance of a very wide range of soil types, pH and salinity. The plant is also resilient to cutting, vigorously resprouting from the roots. The most effective method of control is by herbicide application close to the flowering stage in late summer or autumn.

- Water quality efforts in Portage Lake should continue to be made to reduce external loading of nutrients. Proper watershed management techniques should be applied where possible and lake residents should be encouraged to practice "lake friendly" lawn maintenance.
- Outreach/education of the Portage Lake residents should continue in an attempt to communicate lake activities and management goals. The Portage Lake website should be maintained as a way to directly relay pertinent information along with annual meetings and newsletters.

Strategies for Achieving Lake Management Goals

Aquatic Plant Control Techniques

Areas of the lake that support vegetation will grow plants, despite intense efforts to remove them. Aquatic vegetation provides important benefits to a lake, including stabilizing sediments, providing habitat for fish and other aquatic organisms, and slowing the spread of exotic plant species. In general, native plants interfere less with recreation and other human activities than exotic species. The non-native plant species, Eurasian watermilfoil and curly leaf pondweed concentrate their biomass at the water surface where they strongly interfere with boating, swimming and other human activities. This growth form also allows exotic plants to displace native plants and form a monospecific (i.e., single species) plant community. The dense surface canopies of Eurasian watermilfoil and Curly leaf pondweed provide a lower quality habitat than that provided by a diverse community of native plants. Control of exotic plant species minimizes interference of plant growth with human activities and protects the native vegetation of the lake. The goal of environmentally responsible aquatic plant management, therefore, is not to remove all vegetation, but to control the types of plants that grow in the lake and the height of plants, to minimize interference with human activities.

It is important that control techniques meet the needs and expectations of lake users. Each technique has advantages and disadvantages. Many aquatic plants are relatively susceptible to some control measures but resistant to others. Too often, lake groups select a control technique before determining what their needs are.

Chemical control, or use of aquatic herbicides, is the most common strategy for controlling exotic plant species. Aquatic herbicides provide predictable results and there is a great deal of research and data regarding theses products. Many of the aquatic herbicides available can be used to selectively control exotic species with minimal or no impact on native species.

Mechanical harvesting is best suited for native plant species. Most native plant species have a higher tolerance to aquatic herbicides and require higher dosage rates (higher cost and reduced selectivity). Mechanical harvesting can be used to provide relief from native plant species if they are causing a recreational nuisance. Harvesting does not kill the plants, but simply reduces it's stature, leaving lower growth for fish habitat and sedimnet stabilization. Mechanical harvesting of Eurasain watermilfoil is not recommended as it will expedite its spread throughout a lake through fragmentation.

Biological control options for nuisance aquatic vegetation are limited. Grass carp, which indiscriminately devour aquatic vegetation, have been restricted in many states because of their nonselective grazing and fear they may escape into nonintended waters. The use of the milfoil weevil (Euhrychipsis lecontei) to control Eurasian watermilfoil has been implemented in many Michigan lakes. PLM Lake & Land Management Corp has many years of experience particapating in weevil stocking, evaluations and longterm observations related to their performance and sustainability. Although the milfoil weevils may impact EWM populations in certain situations, the use of this tool remains unpredictable.

Bacteria product formulations and application techiques has greatly improved in recent years. Granular bacteria products can be applied to specific shoreline areas to reduce organic muck that has acumulated over the years. As waterbodies age, organic sediment can build up due to excessive plant and algae growth. This process is called eutrohpication. Increasing native populations of bacteria can slow this process down. Reductions in the depth of muck may depend on many variables. Most importantly, the percent of sediment that is organic. The more organics in the sediment, the greater the potential for muck reduction via bacteria augmentation.

Aeration can be a beneficial tool to sustain ecological balance within an aquatic ecosystem. By maintaining sufficient oxygen levels throughout a waterbody, the entire eutrophication process can be slowed down, the health of the fishery can be maintained and overall water quality can be improved. The implementation of an aeration system to control rooted aquatic plant growth is not recommended. Rooted plants, such as Eurasian watermilfoil, will not be affected by aeration. Similar to the use of biological control, the impact of aeration on improving water quality and reducing organic sediment will vary greatly from site to site. Therefore, it is extremely important to thoroughly evaluate each site's conditions and expectations before implementing an aeration system.

Integrated Pest Management (IPM) approaches to aquatic plant control IPM emphasize spending more effort evaluating the problem, so that exactly the right control can be applied at just the right time to control the pest. IPM approaches minimize treatment costs and the use of chemicals. Lake Management planning ensures the most appropriate, cost-effective treatment for your lake. Planning is an essential phase of Integrated Pest Management and includes lake vegetation surveys, water quality evaluation and a detailed, written lake management plan. Having the plan in place helps lake users know what to expect from lake management. Survey results provide a permanent record of conditions in the lake and the impact of management practices.

Exotic Plant Management

Aquatic herbicides currently represent the most reliable, effective, selective means for controlling Eurasian watermilfoil. There are currently five systemic herbicides, 2,4-D (Navigate), 2,4-D amine (Sculpin G), triclopyr (Renovate 3 & OTF), 2,4-D/Triclopyr combination (Renovate Max G) and fluridone (Sonar or Avast), which can be used to achieve long-term, selective control of Eurasian watermilfoil. Systemic herbicides are capable of killing the entire plant. Several contact herbicides, including diquat (Reward or Solera) can also provide short-term control of Eurasian watermilfoil. These herbicides kill only the shoots of the plant, and plants regrow relatively rapidly from their unaffected below ground parts.

Systemic herbicides control Eurasian watermilfoil with little or no impact on most native plant species. Under ideal conditions, several consecutive annual applications of these herbicides can reduce Eurasian watermilfoil to maintenance (low) abundance, such that only relatively small spot treatments are required to keep it under control. For this strategy to succeed, it is necessary to treat most of the Eurasian watermilfoil in the lake each time.

Harvesting of Eurasian watermilfoil is not recommended. This plant spreads by fragmentation and regrows significantly more rapidly than most native plant species; thus continued harvesting of mixed plant beds typically leads to nearly complete domination of the aquatic vegetation by Eurasian watermilfoil.

Purple loosestrife can be selectively controlled through the use of triclopyr (Renovate). Purple loosestrife is an exotic species, which is out competing native vegetation, destroying valuable wetlands and animal habitat and expanding in density along Portage Lake. In past years our options to manage this nuisance weed has been extremely limited to prevention, manual removal or broad spectrum herbicide treatments, which not only killed the Purple Loosestrife but also the native vegetation remaining in the treatment areas. The biological control effort, beetles, have shown positive control measures and this method is also encouraged to continue into the future.

Phragmites, can be selectively controlled through the use of glyphosate or imazapyr (Habitat) herbicides. Phragmites is an exotic species, which can out compete native vegetation, destroying valuable wetlands and animal habitat.

Native Plant Management

Native plants should be controlled primarily by harvesting if required. Unlike Eurasian watermilfoil, most native plants do not regrow rapidly after harvesting, and a single harvest is often sufficient to control them for the entire summer. Normally low-growing species should not be controlled unless unusually fertile growing conditions allow them to grow tall in areas of high recreational use. Contact herbicides applied at higher rates can be effective at controlling native plants that are causing a nuisance close to shore, in between docks.

Algae Management

Not required at this time.

Monitoring

It is important to maintain a record of lake conditions and management activities. Vegetation surveys monitor types and locations of plants in the lake, providing information that is essential to the administration of efficient, cost-effective control measures. Vegetation surveys also document the success or failure of management actions and the amount of native vegetation being maintained in the lake. Water quality monitoring can identify trends in water quality before conditions deteriorate to the point where remediation is prohibitively expensive or impossible. Records of past conditions and management activities also help to keep management consistent despite changes in the membership of the organization. Records should include (at a minimum):

- Temperature, dissolved oxygen and Secchi disk depth should be measured in the lake at both deep hole basins. Temperature and dissolved oxygen profiles should be obtained in the deep hole, so as to monitor the timing and extent of oxygen depletion in the hypolimnion (i.e., bottom water).
- Total phosphorus and nitrates and ammonia should be measured in the surface and bottom water at least two times per season (spring and late summer) to monitor nutrient accumulation in the hypolimnion.
- Chlorophyll a sampling
- Tributary testing including flow and nutrient sampling
- Lake vegetation should be surveyed on an annual basis (late-spring and/or late summer/early fall) to document the results of plant management efforts and provide information necessary for planning future management.

Nutrient Loading Abatement

Lakeshore property owners should be encouraged to use phosphorus-free fertilizers on lawns and other areas that drain into Portage Lake or the adjacent wetlands. Lakeshore residents should also be encouraged to manage their waterside landscapes according to the recommendations outlined in publications on this topic available from the MSU Extension.

It is also important to remember that rooted plants derive most of their key nutrients from the sediments; thus they respond slowly, if at all, to reductions in nutrient loading. In fact, if reductions in nutrient loading lead to improved water clarity, the growth of rooted plants will probably increase.

If organic material (muck) accumulates to undesirable levels in shoreline areas, bacterial treatments should be considered as a way to alleviate the buildup. PLM MD (Muck Digestion) Pellets are a combination of natural beneficial bacteria, enzymes, and vitamins that stimulate the biological activity of the lake bottom. This stimulation allows the bacteria to feed on the organic sediment, therefore reducing the muck levels over time.

Prevention

Eurasian watermilfoil and curly leaf pondweed were possibly introduced to Portage Lake by plant fragments carried on boats and/or boat trailers. A variety of other troublesome exotic plants and animals that have been introduced to Portage Lake are also transported this way. Preventing their inadvertent introduction to Portage Lake can significantly lower the cost of future lake management. Education can be an effective preventative measure. Newsletter articles should alert lake residents to the threat from exotic nuisance plants and animals. Warning signs should be erected at any public boat access sites, if applicable, that encourage boaters to clean boats and trailers when launching or removing watercraft from the lake.

Lake Management Activities Conducted in 2016

Water Quality

Water quality was evaluated on May 4, June 8, July 11, August 23, September 28 and October 5, 2016. The May sampling included Storm Drain and tributary testing. In June, deep hole testing and shoreline testing of Portage Lake occurred. The July testing was for Ecoli. In August, deep hole testing occurred (this was an additional sampling added into the program in 2015). During September, tributaries, shoreline and the deep hole basins were sampled. The October sampling include additional tributary testing upstream. During the deep hole sampling the following occurred, (1) a depth profile of water temperature and dissolved oxygen concentrations were measured at ten feet intervals at both Deep Hole Basins and the Secchi disk depth was measured, (2) samples for LakeCheck™ analysis were collected from the deep holes of the lake (surface, bottom and every 10' between) for numerous parameters, (3) chlorophyll and algal composition analysis was collected from surface, mid thermocline and bottom samples. During the Storm Drain sampling the following occurred at 4 designated drains, (1) Flow testing, (2) surface reading of temperature and dissolved oxygen (3) samples for LakeCheck™ analysis were collected. During the tributary testing, the following occurred at 7 designated tributaries, (1) surface reading for temperature and dissolved oxygen, (2) samples for LakeCheck™ analysis were collected and (3) flow was determined. LakeCheck measures at the various sites included some or all of the following parameters: Conductivity, Total Dissolved Solids, pH, Conductivity, Total Phosphorus, Oxidative Reduction Potential (ORP), Alkalinity, Ammonia, Nitrates and Total Kjeldahl Nitrogen. The additional tributary testing included sampling at 4 tributaries and including testing multiple locations from the entrance at the lake, upstream. Parameters tested included Total Phosphorus, Nitrates and TSS.

Weather Challenges of 2016

Eurasian watermilfoil

Unlike previous winters which had been extremely cold with an above average snow fall, the 2015/2016 winter has above average. Snow was late to come, lakes froze over later than normal and ice left in a hurry. Without a deep, hard freeze, many lakes do not slow production the same way they would on a cold winter. The summer brought warm temperatures, great for residents enjoying the water, but bringing difficulties to plant management programs. Each lake responds differently from the weather impacts. Each year the weather will causes changes within Portage Lake. Some years it may lower plant production while other years may lead to increase plant growth and elevated water quality numbers. Exotic species tend to benefit from changes in weather conditions. In Portage Lake, little plant growth was evident early on into the growing season and it wasn't until mid summer that diverse plant coverage was found. Weather patterns can have impacts on lakes and individual plant trends that may not be evident right way, but months or years later.

Aquatic Plant/Algae Control

Weed treatments were conducted in June and August to control Eurasian watermilfoil (EWM) in Portage Lake. Phragmites, Purple Loosestrife and Japanese knotweed were also treated throughout 2016 around Portage Lake. The lake was closely monitored this year for any areas of exotic plant growth and treated accordingly.

The management strategy for the control of Eurasian watermilfoil has been working, with fewer acres of milfoil treated in 2016 than in 2015, 2014, 2013 or 2012. However, despite our efforts, EWM control is a constant battle that is heightened with hybrid watermilfoil. The presence of Hybrid watermilfoil supports the conclusion that milfoil treatments will continue to be required annually. A reflection of proper/successful management is a good fishery, which has been verified through the terrific fishing reports on the lake. Although fewer acres of milfoil treatment were required, the recommended application rates have increased, which uses up the budget more quickly. The Phragmites Treatment Program has been very effective. After the initial treatment of 83 acres, the follow up years have required just a small treatment in proportion to the initial application. The below maps and table show a breakdown of the treatments in Portage Lake in 2016, as well as previous years for both EWM and Phragmites/Purple Loosestrife/Japanese knotweed Control.

Map 1: Portage Lake June 2016 Treatment Map

June 27, 2016 EWM and CLP Treatment, 1.5 acres Clipper at 200ppb

Map 2: Portage Lake August 2016 Treatment Map

August 2,3 2016 EWM Treatment, 13.1 acres Renovate OTF (at 200 and 240lbs/acre) (purple on map), 5 acres Sculpin G (at 240lbs/acre) (yellow on map), 2 acres Renovate 3 (at 4 gals/acre) (red on map).

Map 3: Portage Lake Terrestrial Treatment Map 2016

Map 4: Portage Lake Biobase Vegetation Map – pre treatment

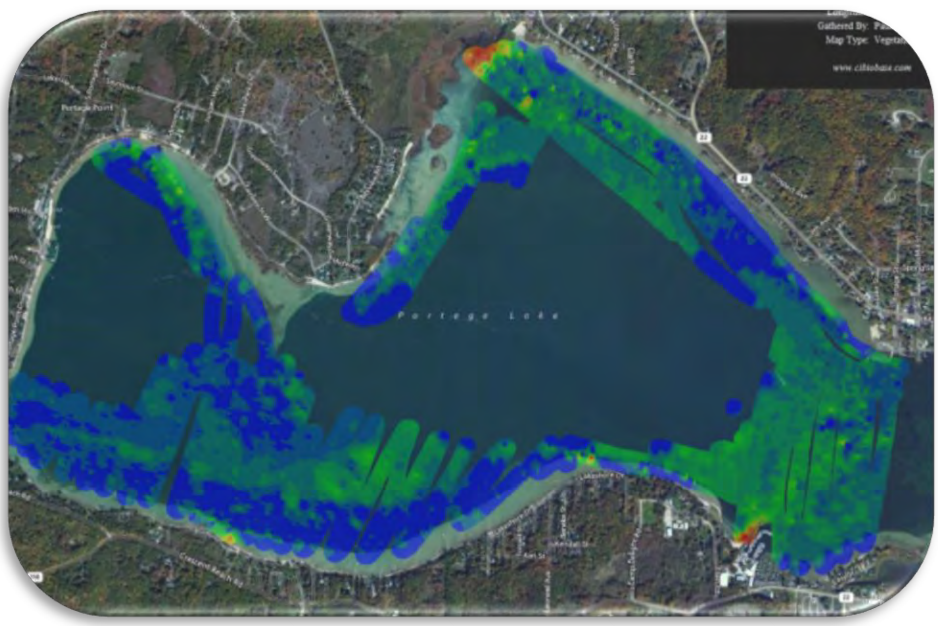


Table 1: Submersed Plant Treatment Quantities 2016-2009

		Product	Rate#/Acre	Acres	Total Acres
2016	27-Jun	Clipper	200ppb	1.25	21.35
	2-Aug	Renovate OTF	200#	6.6	
		Renovate OTF	240#	3.5	
	3-Aug	Renovate OTF	200#	3	
		Renovate 3	4gals	2	
		Sculpin G	240#	5	
2015	6-Jun	Clipper	200ppb	1.25	79.35
	28-Jul	Renovate OTF	200#	4	

		Renovate OTF	240#	3.8	
		Sculpin G	200#	4	
		Sculpin G	240#	66.3	
2014	6-Jun	Renovate OTF	200#	1.5	176.05*
	29-Jul	Renovate OTF	200	.8	
		Renovate Max LZR	120#	95	
		Sculpin G	200#	10	
		Clipper	200ppb	1.25	
	8-Sep	Sculpin G	160#	23	
		Sculpin G	200#	12.5	
		Sculpin G	240#	6	
		Renovate Max LZR	160#	26	
2013	24,27 -Jun	Renovate OTF	160#	5	129.75
		Renovate Max G	160#	39	
		Sculpin G	160#	74.5	
	8-Aug	Sculpin G	160#	10	
		Clipper	200ppb	1.25	
2012	9-Jul	Renovate OTF	120#	10	145
		Renovate Max G	160#	55	
	24-Jul	Renovate OTF	120#	5	
		Renovate Max G	120#	40	
		Sculpin G (2,4-D)	160#	35	
2011	27-Jul	Renovate OTF	120#	22	22
2010	29-Jun	Renovate OTF	120#	5	86
		Navigate 2,4-D	100#	17	
	27-Sep	Renovate OTF	120#	14	
		Navigate 2,4-D	120#	50	
2009	15-Sep	Renovate OTF	120#	~41.5	161.5
		Navigate 2,4-D	100#	120	

*Some Re-Treatment in 2014 due to in-adequate dieback of treatment beds.

Table 2: Terrestrial Treatment Summary (Phragmites, Purple Loosestrife, Japanese knotweed) 2016-2009

Year	Product	Rate	Acres
2016	Glyphosate/Imazapyr	1-3%	0.48
2015	Glyphosate/Imazapyr Triclopyr	1-3%	4
2014	Glyphosate/Imazapyr	4%	6.2
2013	Glyphosate/Imazapyr	2%	7.9
2012	Glyphosate/Imazapyr	2%	13.5
2011	Glyphosate/Imazapyr	2%	7
2010	Glyphosate/Imazapyr	2%	10
2009	Glyphosate/Imazapyr	2%	83

Planning/Evaluation

Surveys of the aquatic vegetation of the lake were conducted on June 8, June 24, July 27, August 23, and September 28, 2016. Additional surveys of the lake were made frequently throughout the summer months for pre or post treatment evaluation, to collect water quality parameters, as well as to have additional survey data available for management purposes. Vegetation surveys determine the locations of target and non-target plant species. The results of the surveys are used to determine the most appropriate management strategy. The vegetation surveys also document the success of the prescribed management program. An AVAS survey is the State of Michigan's method for conducting a complete aquatic vegetation survey. The Aquatic Vegetation Assessment Site (AVAS) survey divides the parts of the lake capable of growing plants (littoral zone) into subareas and records the cover of each aquatic plant found in each "site". This method of surveying takes into account not only the types of plant species present in the lake but also the densities of those species. AVAS surveys are also an excellent way to track plant species trends over time. A goal of invasive plant management is to have native plants increase while exotic plants decrease over time. The success of this goal can be illustrated through the use of the AVAS data collected over several years. Since different native plants grow at varying times throughout the season it is important to evaluate the lake multiple times to account for *all* species in the lake. The first evaluation is conducted in the spring and is used to determine areas that will require treatment or management. The second survey is conducted in late summer or fall and is used to determine management success.

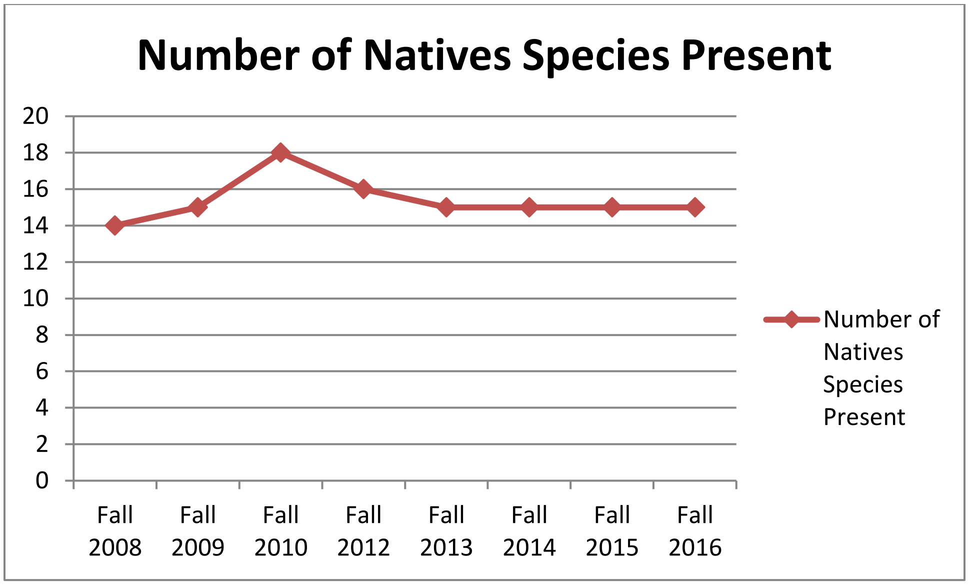
Table 3: Plant Species Found in Portage Lake –2016

*** Based from boat survey, not as precise as a walking shoreline survey**

AVAS Code	Common Name	Scientific Name	% Cumulative Cover June 2016	% Cumulative Cover September 2016
	Submerged- Exotic			
1	Eurasian watermilfoil	*Myriophyllum spicatum*	3.22	2.13
2	Curlyleaf pondweed	*Potomageton crispus*	1.75	0.13
	Submerged- Native			
3	Muskgrass	*Chara*	14.46	14.58
4	Thinleaf pondweed	*Potomageton spp.*	4.93	0.99
5	Flatstem pondweed	*Potomageton zosteriformis*	2.74	2.26
6	Robbins pondweed	*Potomageton robbinsil*	0.11	0 .00
7	Variable leaf pondweed	*Potomageton gramineus*	0.80	1.39
8	White stem pondweed	*Potomageton praelongus*	0.00	0.00
9	Richardsons pondweed	*Potomageton richardsonii*	4.36	9.21
10	Illinois pondweed	*Potomageton illinoensis*	4.26	8.07
11	Largeleaf pondweed	*Potomageton amplifolius*	0.89	2.09
15	Wild Celery	*Vallisneria Americana*	6.75	17.64
17	Northern milfoil	*Myriophyllum sibiricum*	0.01	2.14
20	Coontail	*Ceratophyllum demersum*	1.64	6.42
21	Elodea	*Elodea Canadensis*	1.20	3.39
22	Bladderwort	*Utricularia valgaris*	0.02	0.00
25	Naiad	*Najas flexilis*	5.16	5.16
27	Sago pondweed	*Potomageton pectinatus*	3.62	7.71
28	Nitella	*Nitella flexilis*	0.00	0.00
	Emergent- Native			
30	Water lily	*Nymphaea odorata*	0.00	0.11
39	Cattail	*Typha spp.*	20.46	20.33
40	Bulrush	*Scirpus spp.*	16.68	18.03
42	Swamp loosestrife	*Dianthera americana*	0.00	0.22
	Emergent - Exotic			
43	Purple loosestrife	*Lythrum salicaria*	0.00	0000

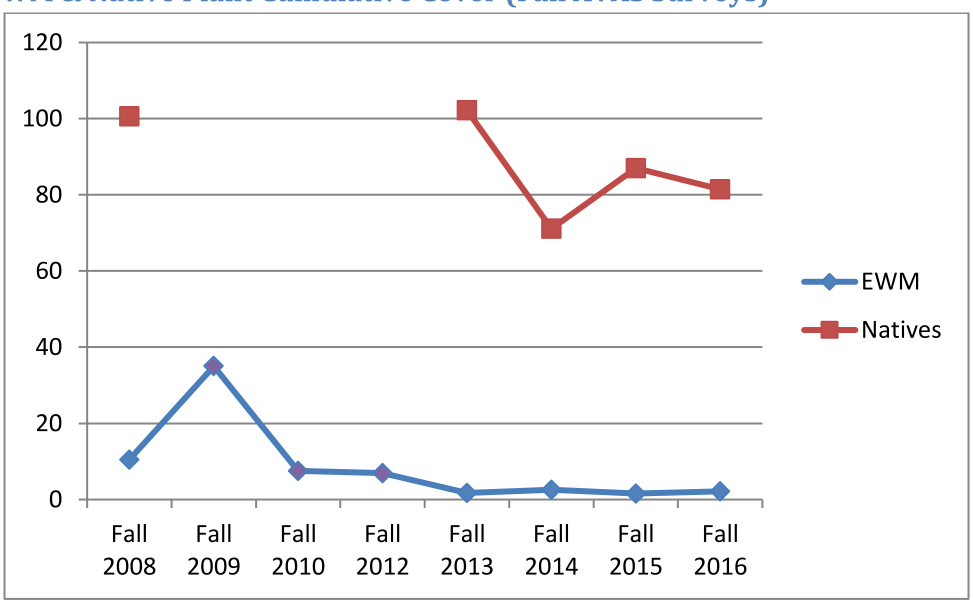
44	Common reed	*Phragmites*	0.00	1.04*
	Total		**93.07**	**123.33**

Graph 1: Native Plant Diversity (Fall AVAS Surveys)



This graph shows the diversity of native plants found in Portage Lake. Portage Lake has excellent native plant diversity and this has been maintained throughout managing the exotic species.

Graph 2: EWM & Native Plant Cumulative Cover (Fall AVAS Surveys)



This graph shows the cumulative coverage of EWM from 2008-2016 as well as the overall cumulative coverage of all native plants in Portage Lake. The overall decline in the presence of EWM from the start of the management program shows the success of the treatments and that the population is currently being maintained at very low levels. The native plant population will naturally vary from year to year based on weather, water depth and many other factors; but has been maintained during the treatment of EWM. Please note that the EWM data marked with purple dots was data collected from another firm and not by PLM. This information was taken from the *Portage Lake Forever* website and used with permission of the board.

Genetic Testing/Sampling on Portage Lake

Previous sampling on Portage Lake as shown that hybrid milfoil is present. Portage Lake was sampled twice in 2015 as part of PLM's participation in a grant program to sample and test milfoil plants for genetic analysis and herbicide sensitivity. More information on the grant study below:

From PLM's Spring 2015 PLM News Newsletter: "Recently the State of Michigan developed a "Michigan Invasive Species Grant

Program" to be implemented in 2015 and is intended to be ongoing. Over 4 million dollars has been awarded to 20 different initiatives related to invasive plant management. Although all of these projects have relevant goals, PLM Lake & Land Management Corp (PLM) understands the urgencies to utilize science to ensure balance of our aquatic ecosystems. Under the direction of Dr. Casey Huckins, Michigan Technological University (MTU), in partnership with Many Waters LLC., SePRO Corporation and PLM Lake & Land Management Corp; a grant application was submitted and approved for $332,000. Although not every waterbody that we currently manage is directly involved in this project, PLM cliental representation is found throughout Michigan. To oversimplify; milfoil plant samples will be collected from over 15 different water bodies during the 2015 season. Samples will be sent to MTU for genetic analysis (providing specific hybrid genotypes of milfoil). Samples will also be sent to SePRO Corporation to simultaneously determine herbicide sensitivity of each hybrid type. Ultimately we plan to verify the specific genotype of milfoil and determine how we can effectively control it. If we do not determine an effective prescription for the control of certain genotypes of milfoil, we could potentially end up with a tolerance issue or select for herbicide resistant hybrid strains. For nearly a decade PLM has proactively implemented management protocols that rotate different types of herbicides at higher rates to reduce tolerance and resistance potential, stay tuned. There are several other "multifaceted" objectives within this proposal."

Year 2 of this study is complete and no official updates are available currently.

Current Conditions in the Lake

Aquatic Vegetation

Over the years the presence of Eurasian watermilfoil and curly leaf pondweed undoubtedly reduced native plant diversity in the lake. Curlyleaf pondweed, although aggressive, naturally dies out mid season and the increase in native plants after that die off is evident when looking at the early and late season surveys. Native plants currently have a good diversity and density in the lake.

Native plant diversity will continue to be promoted in the lake. The native plant species in Portage Lake benefit the lake, performing such functions as stabilizing sediments and providing habitat for fish and other aquatic organisms. In general, native species cause few problems, compared with those caused by exotic plants. Plant diversity is key to maintaining and improving the overall ecological balance of Portage Lake.

All of the plants listed in Table 3 are native North American species except Eurasian watermilfoil, Curlyleaf pondweed, Purple Loosestrife and Phragmites. These plants are non-indigenous aquatic nuisance species, i.e., plants from other places. These exotic plants cause considerably more problems than most native species. Eurasian watermilfoil can attain nuisance levels of growth at almost any time of year, whereas curly leaf pondweed completes its lifecycle and drops out of the water column by approximately the Fourth of July.

The native plant species benefit the lake, performing such functions as stabilizing sediments and providing habitat for fish and aquatic organisms. In general, native species cause few problems, compared with those caused by exotic plants. Three species commonly found in Portage Lake:

Coontail

Sago pondweed

Wild Celery

Water Quality Monitoring

Water quality monitoring is a critical part of lake management. Water quality monitoring provides an ongoing record of conditions in a waterbody. Changes in water quality can indicate threats from sources such as failed or inadequate septic systems, agricultural and lawn runoff, burgeoning development and erosion from construction site. Prompt identification of threats to water quality makes it possible to remedy them before irreversible harm has been done. Riparian's enjoyment of the water resource and the value of their property depend on maintaining water quality. The following tables break down the parameters tested in the different locations in Portage Lake including the Deep Hole Basins, shoreline sites, Tributaries and Storm Drains.

The graphs and tables below contain historical water quality data on Portage Lake that has been collected from numerous parties other than PLM. All information was made available to PLM via the Invasive Species Committee, on behalf of the Portage Lake Watershed Forever and Onekama Township and used with permission.

Map 5: Portage Lake Water Quality Testing Locations

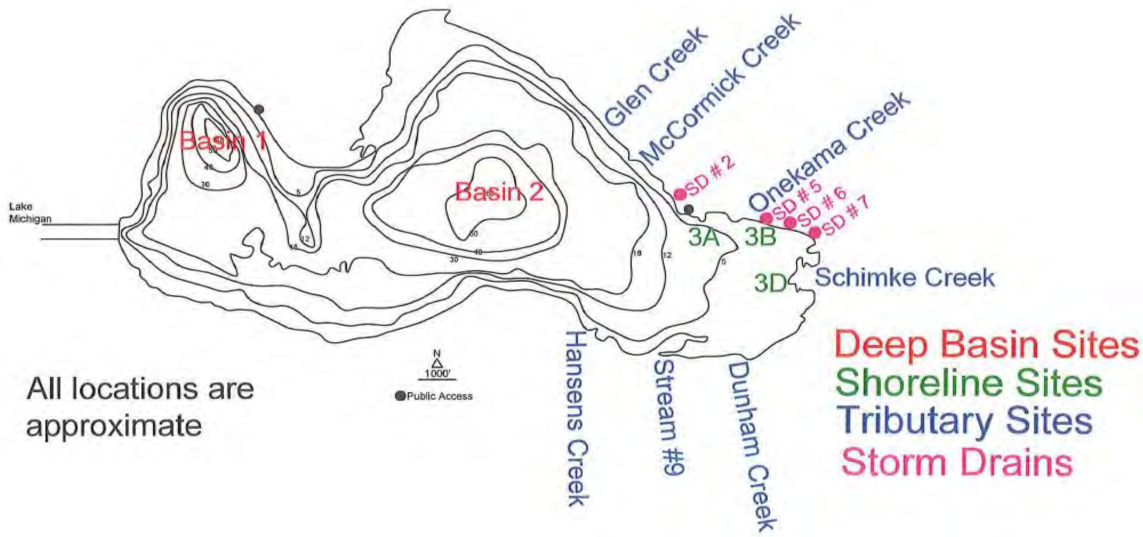


Table 4: Tributary Water Quality Portage Lake –2016 –cloudy/sprinkles/60

5/4/2016	Temp (C)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (ug/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Nitrate (ug/L)	Amm-onia (ug/L)	Flow (Ft/sec)
Glenn	8.44	11.02	296	281	8.2	8	212	1.1	0.59	1310	15	1.2
McCormick	8.74	11.48	277	261	8.2	7	207	1.6	0.48	620	15	1.2
Onekama	8.25	11.52	279	266	8.34	7	223	1	0.48	1160	14	1.4
Schimke	8.09	11.59	267	257	8.28	7	209	1.1	0.66	900	15	2.3
Dunham	8.26	11.22	260	253	8.28	8	227	0.66	0.41	850	14	1.9
Hansen	8.18	10.41	309	296	8.11	8	207	2	0.55	700	15	0.04
Stream #9	9.42	10.6	241	233	8.15	9	219	1.7	1.27	520	15	0.08
9/28/2016	Temp (C)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (ug/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Nitrate (ug/L)	Amm-onia (ug/L)	Flow (Ft/sec)
Glenn	10.23	10.12	308	279	8.36	10	260	3.6	0.1	1370	10	1.8
McCormick	11.62	7.6	33	289	8.11	18	268	2.6	0.11	840	10	1.8
Onekama	10.43	9.88	302	272	8.396	10	270	3.1	0.71	1300	10	1.4
Schimke	11.77	9.67	309	269	8.29	7	261	5.2	0.09	1180	10	0.2
Dunham	12.25	8.96	190	249	8.53	8	258	1.4	0.18	1200	10	1.8
Hansen	13.19	7.51	382	320	8.16	12	262	3.4	0.2	840	10	0.2
Stream #9	13.53	7.72	293	246	8.24	11	261	11	0.22	700	10	0.2

Table 5: Deep Hole Basin 1 Portage Lake –2016

(Secchi Disc: June 20', August 10', Sept.11')

Basin 1 June 8 2016	Temp (C)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (ug/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Nitrate (ug/L)	Amm-onia (ug/L)	ALK (mg/L)	Chlor. A (ug/L)
s.	17.44	10.14	265	201	8.44	8	207	0.69	0.32	210	13	117	0
10'	17.43	10.22	265	201	8.43	-	205	0.78	-	-	-	-	-
20'	17.43	10.13	264	201	8.4	-	208	0.67	-	-	-	-	-
30'	12.81	13.19	229	195	8.34	8	206	0.74	0.09	210	18	124	0.199
40'	11.87	13.35	224	194	8.32	-	207	0.83	-	-	-	-	-
50'	11.38	12.6	223	196	8.23	-	200	0.9	-	-	-	-	-
60'	11.35	12.73	224	195	8.31	8	205	0.79	0.09	210	15	118	0
Basin1 Aug23 2016	Temp (C)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (ug/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Nitrate (ug/L)	Amm-onia (ug/L)	ALK (mg/L)	Chlor. A (ug/L)
s.	23.26	8.27	286	192	8.71	7	313	1.9	1.06	210	13	109	0.801
10'	23.24	8.58	286	192	8.71	-	388	1.8	-	-	-	-	-
20'	23.18	8.62	285	192	8.68	-	352	2.6	-	-	-	-	-
30'	17.31	2.74	274	209	7.76	8	302	1.1	0.44	210	91	130	8.01
40'	13.5	0.2	257	215	7.58	-	299	1.9	-	-	-	-	-
50'	12.95	0.15	256	216	7.58	-	285	2.5	-	-	-	-	-
60'	12.89	0.15	257	217	7.59	8	303	3	1.36	210	332	125	5.51
Basin1 Sep28 2016	Temp (C)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (ug/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Nitrate (ug/L)	Amm-onia (ug/L)	ALK (mg/L)	Chlor. A (ug/L)
s.	17.53	8.17	257	195	8.47	8	279	1.9	0.09	250	64	119	1.56
10'	17.53	8.42	257	195	8.46	-	275	2	-	-	-	-	-
20'	17.53	8.59	257	195	8.46	-	280	1.4	-	-	-	-	-
30'	17.42	8.61	257	195	8.43	7	274	1.3	0.27	210	50	116	0.841
40'	11.72	3.5	231	202	7.65	-	238	0.97	-	-	-	-	-
50'	11.56	1.5	234	205	7.57	-	338	1.3	-	-	-	-	-
60'	11.48	0.75	237	208	7.72	7	349	3.9	0.68	230	538	123	0.343

Table 6: Deep Hole Basin 2 Portage Lake –2016 (Secchi Disc: June 24', August 10', Sept. 11')

Basin 2 June 8 2016	Temp (C)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (ug/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Nitrate (ug/L)	Amm-onia (ug/L)	ALK (mg/L)	Chlor. A (ug/L)
s.	18.28	9.77	270	201	8.54	7	207	0.7	0.18	210	18	118	0
10'	18.27	9.8	270	201	8.52	-	200	0.96	-	-	-	-	-
20'	18.25	9.97	270	201	8.51	-	202	0.9	-	-	-	-	-
30'	16.53	10.85	258	200	8.4	8	288	1.1	0.56	210	19	120	0.273
40'	13.86	11.3	243	201	8.31	-	288	1.1	-	-	-	-	-
50'	13.43	10.19	243	203	8.21	-	228	0.81	-	-	-	-	-
60'	13.36	7.04	244	203	7.66	7	210	0.7	0.25	210	19	111	0.239
Basin2 Aug23 2016	Temp (C)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (ug/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Nitrate (ug/L)	Amm-onia (ug/L)	ALK (mg/L)	Chlor. A (ug/L)
s.	23.67	8.63	287	191	8.78	7	277	2.1	0.8	210	9	106	0.374
10'	23.67	8.9	287	191	8.76	-	285	2	-	-	-	-	-
20'	23.67	8.67	287	191	8.77	-	267	2.1	-	-	-	-	-
30'	21.3	3.04	283	205	7.94	7	343	1.2	3.13	210	91	120	3.9
40'	16.16	0.17	276	216	7.63	-	438	3	-	-	-	-	-
50'	15.48	0.13	273	217	7.58	-	399	3.4	-	-	-	-	-
60'	15.34	0.12	279	223	7.42	7	341	2.4	1.41	210	321	136	7.57
Basin2 Sep28 2016	Temp (C)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (ug/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Nitrate (ug/L)	Amm-onia (ug/L)	ALK (mg/L)	Chlor. A (ug/L)
s.	18.07	7.84	261	196	8.54	8	262	2.1	0.42	210	49	116	1.57
10'	18.08	8.2	261	196	8.53	-	263	2	-	-	-	-	-
20'	18.08	8.41	261	196	8.53	-	264	2.5	-	-	-	-	-
30'	18.08	8.63	261	196	8.5	7	265	1.8	1.01	210	42	117	1.87
40'	17.41	8.63	260	196	8.45	-	269	1.9	-	-	-	-	-
50'	17.21	8.8	257	196	8.43	-	271	2.8	-	-	-	-	-
60'	17.1	8.8	272	209	7.63	8	278	3.5	1.17	210	43	128	0.824

Table 7: Shoreline Sampling Portage Lake –2016

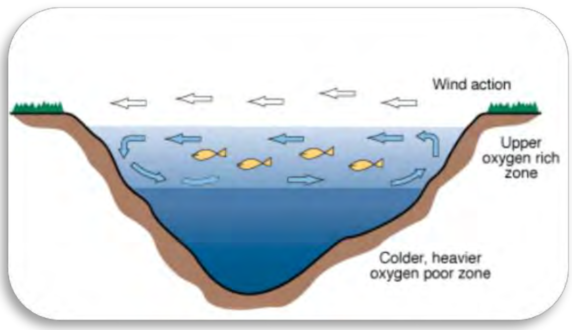
Jun4 Secchi	Temp (C)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (ug/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Nitrate (ug/L)	Amm-onia (ug/L)	ALK (mg/L)	Chlor. A (ug/L)
A 9'	17.86	9.76	275	207	8.43	8	213	1	0.14	210	31	117	*0.272*
B 7'	17.53	9.95	278	211	8.42	7	210	0.96	2.59	210	26	135	*0*
D **4.8'**	17.14	10.57	277	212	8.51	7	209	1.4	0.4	210	18	137	*0.295*
Sep28 Secchi	Temp (C)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (ug/L)	pH (S.U.)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Nitrate (ug/L)	Amm-onia (ug/L)	ALK (mg/L)	Chlor. A (ug/L)
A 7'	16.03	8.17	253	198	8.39	10	270	2.4	0.29	270	40	117	0
B **6'**	15.55	7.92	250	199	8.47	8	262	1.8	0.22	210	57	116	0.561
D 5'	15.98	7.89	250	197	8.44	7	267	2.2	0.13	210	34	125	0.47

Table 8: Storm Drain Sampling Portage Lake – May 4, 2016

	Temp (C)	D.O. (mg/L)	Cond. (uS/cm)	TDS (mg/L)	pH (S.U)	TP (ug/L)	ORP (mV)	Turb. (NTU)	TKN (mg/L)	Nitrate (ug/L)	Flow (Ft/sec)	Weather no rain
#2 Zosel Park	9.52	18.25	429	396	8.43	8	233	1.4	1.72	520	0	Clear, sprinkles
#5 Fourth St	9.88	11.66	399	366	7.91	*7*	*229*	*0.98*	*1.05*	*410*	*0.2*	Clear, sprinkles
#6 Third St	9.51	11.83	159	145	7.97	17	241	1.2	0.8	740	0.2	Clear, no rain
#7 First St.	10.77	4.56	279	249	7.59	7	278	0.72	1.45	200	0.6	clear, no rain

Temperature and Dissolved Oxygen Profiles

Depth profiles of temperature and dissolved oxygen indicate that on June 8 the lake was already stratified. The surface levels were above saturation, 10.14 mg/L at Basin 1 and 9.77 mg/L at Basin 2 with shoreline ranging from 9.76 to 10.57 mg/L. At this time, Portage Lake had adequate dissolved oxygen all the way down to 60' in depth (12.73 mg/L in Basin 1 and 7.04 mg/L in Basin 2). On June 8 the lake was thermally stratified, with a thermocline at approximately 30' - slightly deeper than during a similar time in June of 2014 and 2015. The epilimnion (i.e., water above the thermocline) was well oxygenated, with oxygen concentrations at adequate levels to support a healthy fishery. Conditions in the hypolimnion (i.e., water below the thermocline) were also oxygenated.



On May 4, four storm drains and seven tributaries were tested coming into Portage Lake. All sites were well oxygenated ranging from 7.51 to 11.83 mg/L, except one site Storm Drain #7 at First St. The oxygen level here was low, which was a similar reading as in 2015. In 2014, there was no flow reported at the sampling at this site and in 2015, only light flow. In 2016, flow was slightly more. Strom Drain #5 and #6 had very little flow. This sampling was performed post an overnight rain event and some light rain was coming down during the sampling.

In August, the lake was still strongly divided. An August sampling was added into the program in 2015. Basin 1 was stratified and was anoxic at the bottom of the lake (void of oxygen). The thermocline in Basin 1 was 30' (whereas in 2015 it was at 40') and at that point the oxygen levels started a quick drop from 8.62 mg/L to 2.74 mg/L, ending at 0.15 mg/L at the bottom; anoxic water. This numbers are slightly lower than in 2015 and 2014 September sampling. 3.0 mg/L is generally considered anoxic. In Basin 2, the surface waters had oxygen levels at 8.63 mg/L (similar to 2015) and a thermocline at 30', when oxygen levels dropped from 8.67 mg/L to 0.12 mg/L at the bottom (similar to 2015)

In September, it appeared that the lake was still partially stratified during the sampling period. In years past, both mixing and no mixing has been found during the September sampling. Basin 1 was stratified at 40' and was anoxic below the thermocline (void of oxygen) with oxygen levels started a quick drop from 8.61 mg/L at 30' to 0.78 mg/L at the bottom; anoxic water. These numbers are slightly better than during the August sampling. 3.0 mg/L is generally considered anoxic. In Basin 2, like in some previous years the surface waters had already mixed and no definite thermocline was found; (in 2015 the basin was still divided) and dissolved oxygen levels were 8.84 mg/L at the surface and 8.27 mg/L at the bottom.

Substantial oxygen demand leads to rapid deoxygenation of the hypolimnion upon thermal stratification in the spring and oxygen concentrations are frequently decreased in bottom waters during the summer.

Depletion of oxygen beneath the thermocline during the summer is a common symptom of eutrophication, and often leads to elevated internal nutrient loading as the result of the release of phosphorus from hypolimnetic sediments. However, Total Phosphorus testing the last two years has shown little phosphorus being released from the bottom sediments during peak summer months when oxygen is low.

pH

pH describes the balance between acids and bases in the water. Neutral values of pH are desirable. Low pH values typically result either from the growth of bog vegetation (such as peat moss), acid precipitation ("acid rain"), or acid runoff (as in acid mine drainage). Excessive growth of certain plants and algae can raise pH values. A majority of Michigan lakes have pH values in the 7-9 range. Portage Lake pH was recorded in Basin 1 and Basin 2 in the June, August and September as well as in the tributaries and shoreline sites. The pH in June ranged 7.66-8.54, in August from 7.42-8.78 and in September from 7.63 -8.54. The shoreline sampling was similar to the deep hole basins as was the tributary and storm drain sampling. This data is consistent with 2015 data as well as previous samplings.

Total Alkalinity

Alkalinity, in addition to pH, measures the amount of dissolved bases and the balance of acids and bases in the water. Alkalinity specifically measures the concentration of carbonates and bicarbonates in the water. These compounds and other ions associated with them can make water "hard". High alkalinity lakes are hardwater lakes, while low alkalinity lakes are softwater lakes. Different kinds of plants, algae and other aquatic organisms live in hardwater versus softwater. Alkalinity is a basic characteristic of water and is neither inherently good nor bad. Total Alkalinity was measured in June, August and September in both Basin 1 and Basin 2. The average sampling between both basins in June was 118 mg/L with a range of 111-124 mg/L. The August samples were similar with an average of 121 mg/L with a range of 106-136 mg/L. The September samples were similar with an average of 120 mg/L with a range of 116-128 mg/L. All samplings show the lake to be considered "soft" with readings under 150 mg/L, a typical threshold of a hardwater lake. The 2015 September readings on the lake are slighter lower than previous readings, but in 2016, the readings were close to previous readings and overall show rather consistent data for Portage Lake.

Conductivity and Total Dissolved Solids

Conductivity and Total Dissolved Solids (TDS) measure the total amount of material dissolved in the water. Higher values indicate potentially rich, more productive water, whereas lower values indicate potentially clean, less productive water. (If nutrient pollution is occurring, the total phosphorus concentration is a much better indicator of potential productivity.) The readings of TDS on Portage Lake ranged from June readings averaging 199.5 ug/L, August averages of 205 ug/L to September readings averaging 198 ug/L. (Shoreline samplings were very similar to deep basins). The tributary sampling was only slightly higher. Overall, these averages classify the overall TDS of Portage Lake as Low Dissolved material. The conductivity readings on Portage Lake are slightly higher than the TDS readings and overall the spring readings (average 249 uS/cm) were similar to the September readings (average 254 uS/cm) (uS/cm=microsiemens per centimeter). The August averages were slightly higher (277 uS/cm), but not significantly. Higher levels can likely be due to runoff which is also supported by the slightly higher conductivity readings from the Tributaries (May average Conductivity reading is 275 uS/cm while September average is 316 uS/cm). Tributary readings are similar to 2015. The tributary Conductivity readings are almost considered high dissolved salts (material). All of lake data Conductivity numbers are similar to past data collected.

Oxidative Reduction Potential (ORP)

The oxidative reduction potential of a lake measures the ability of the water to serve as potential oxidizers and indicates the degree of reductants present within the water (the ability to gain or lose electrons). The reduction potential measurement has proven useful as an analytical tool in monitoring changes in a system rather than determining their absolute value. Like pH, the redox potential represents an intensity factor. It does not characterize the capacity of the system for oxidation or reduction; in much the same way that pH does not characterize the buffering capacity. Generally speaking, higher ORP values, the healthier the lake. As a lake stratifies and oxygen levels decrease towards the bottom of the lake, ORP values will decrease even in a healthy lake due to the lack of oxygen. This is because there are many bacteria working in the sediments to decompose the material and they use up the available oxygen. ORP is measured in addition to pH and dissolved oxygen as it can provide additional information of the water quality and degree of pollution, if present. High ORP values indicate high levels of oxygen in the water and that bacteria that decompose the dead matter can work more effectively. The deep basins ranged from 200-288 mV in the spring sampling to 277-438mV in August to 238-349 mV in September, indicating oxidized conditions. Tributaries and shoreline samples had similar results and these are similar readings to past samplings.

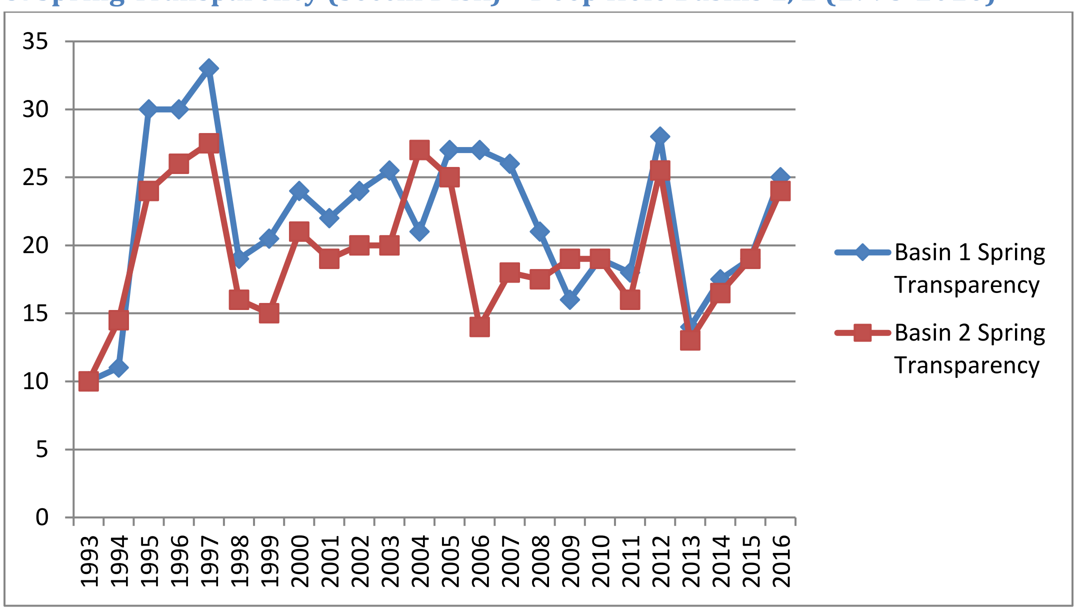
Turbidity

Turbidity is a measure of the clarity of the water, specifically from the presence of suspended particles in the water. Turbidity will typically increase as the suspended particles in the water increase, lowering clarity of the water. Turbidity may be caused by a variety of factors from the bottom sediments, erosion, algae production, and runoff and possibly from fish species such as carp. Suspended particles can capture heat from the sun raising water temperature as well (often witnessed in shallow waters). Turbidity readings on Portage Lake averaged 0.83 NTU's in June to 2.07 NTU's in August to 2.09 NTU's in September with similar readings throughout the water column. Shoreline sampling averaged was 1.12 NTU's in June and 2.13 NTU's in September while the tributaries average was overall higher, which would be expected in a shallow, flowing system (1.3 NTU's average in May and 4.3 NTU's in September). During the September sampling, Stream #9 had a high reading of 11NTU's, which has been the only elevated reading found. It had been raining during the sampling event. Generally, more mixing occurs in shallow water, closer to the substrate. The World Health Organization (WHO) requires drinking water be less than 5 NTU's, but recreational water can be significantly higher. Overall, the turbidity readings on Portage Lake are within safe drinking water standards and overall show that clarity should be very good on the lake.

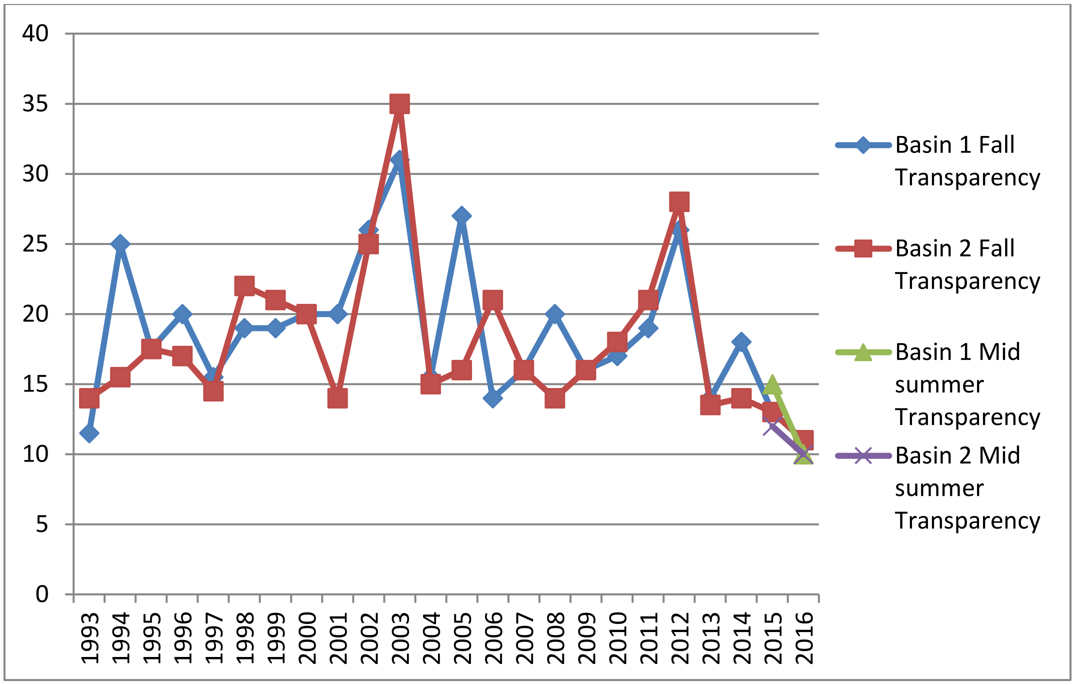
Secchi Disk Depth

The Secchi disk depth is another measure of water clarity, determined by measuring the depth to which a black and white disk can be seen from the surface. (Larger numbers represent greater water clarity.) In June, Basin 1 was 25 feet while Basin 2 was 24' (slightly higher than 2015 recordings). Basin 2 is likely more impacted by the fetch of the lake, therefore would likely have a lower Secchi disk reading, which has been seen in the past, but not during the June 2016 sampling, but was witnessed in later season sampling. Clarity declined with the Secchi disk depth of 10' in August in Basin 1 and 10' in Basin 2 (slightly lower than in 2015) and was at 11' in Basin 1 and Basin 2 was at 11' in September. Water clarity can fluctuate from week to week depending on several environmental factors such as rain fall & algal production. These clarity readings show that sunlight will be available for plant and algae throughout the good portions of the lake. The shoreline sampling sites had very good clarity, with all readings reaching the bottom of the lake in both the June and September samplings.

Graph 3: Spring Transparency (Secchi Disk) – Deep Hole Basins 1, 2 (1993-2016)



Graph 4: Fall Transparency (Secchi Disk) – Deep Hole Basins 1, 2 (1993-2016)



Total Phosphorus

Total phosphorus measures the total amount of phosphorus in the water. Phosphorus is an important plant nutrient (i.e., fertilizer) and the nutrient most likely to limit algal growth. Phosphorus levels are not only related to internal loading of nutrients but also from external sources. Elevated phosphorus inputs to lakes caused by human activities are a major cause of cultural eutrophication. Total phosphorus concentrations in June in Basin 1 were 8 μg/L at the lake surface, and 8 μg/L at thermocline depth and 8 μg/L in the bottom water. In Basin 2, 7 μg/L at the lake surface, and 8 μg/L at thermocline depth and 7 μg/L in the bottom water. The June shoreline readings from sites 3A, 3B and 3D ranged from 7-8μg/L. The tributary TP readings in May ranged from 7-9 μg/L. Storm Drain TP May readings were from 7-17 μg/L. Readings above 10μg/L are considered slightly enriched while readings over 30 μg/L are considered enriched. In the past, higher TP readings have been found coming from the tributaries and storm drains. Overall, the spring samplings on the lake have stayed similar to 2015 readings, which had decreased slightly from previous years. The tributaries and storm drains had reduced spring sampling readings compared to previous years.

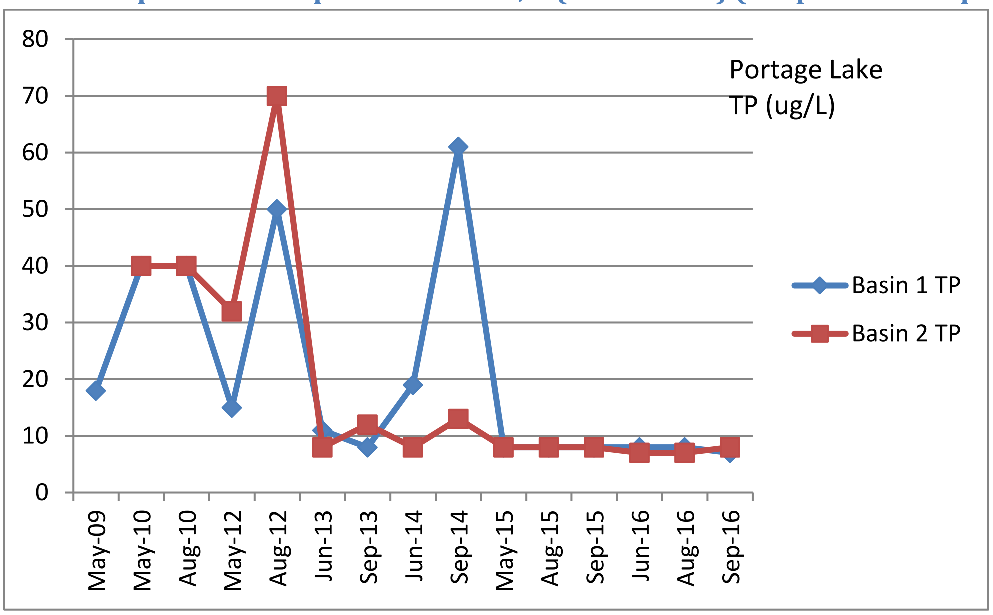
August Total Phosphorus concentrations were: Basin 1: 7 μg/L at the surface, 8 μg/L in the thermocline and 8 μg/L at bottom while Basin2: 7 μg/L at the surface, 7 μg/L in the thermocline and 7 μg/L at bottom. Surprisingly, no increase in these sampling results from June testing and these are similar readings to that of 2015, which are slightly lower than historical averages.

September Total Phosphorus concentrations were: Basin 1 8 μg/L at the surface, 7 μg/L in the thermocline and 7 μg/L at bottom while Basin 2 8 μg/L at the surface, 7 μg/L in the thermocline and 8 μg/L at bottom. All of these results are LOWER than in 2014 and similar to 2015. In September 2014, the reading of 61 μg/L which was a significant change from 2013 and considered highly enriched, appears to be an outlier based on 2015 and 2016 results and is not showing an increasing trend. The shoreline readings from sites 3A(10 μg/L), 3B(8 μg/L) and 3D(7 μg/L) while the tributaries overall ranged from 7 μg/L to 18 μg/L. In years past, Stream #9 was the highest of the readings, but in 2016 McCormick showed the higher reading at 18 μg/L, which is still lower than the normal highly elevated readings found at Stream #9. Additional tributary testing done in October did find elevated phosphorus levels. The

September readings show that overall, slightly higher phosphorus concentrations are found in the tributaries and that internal loading was not a contributing factor to TP in 2016 or 2015. The 2016 data shows the TP has decreased in both Basins, which was also found in 2015, after a slight increase in 2014 and after a drop in the 2013 data. Past data has shown that Basin 2 is routinely higher in concentrations than Basin 1, which is expected due to the fetch and potential lack of oxygen of Portage Lake; however, is currently showing similar concentrations to Basin 1.

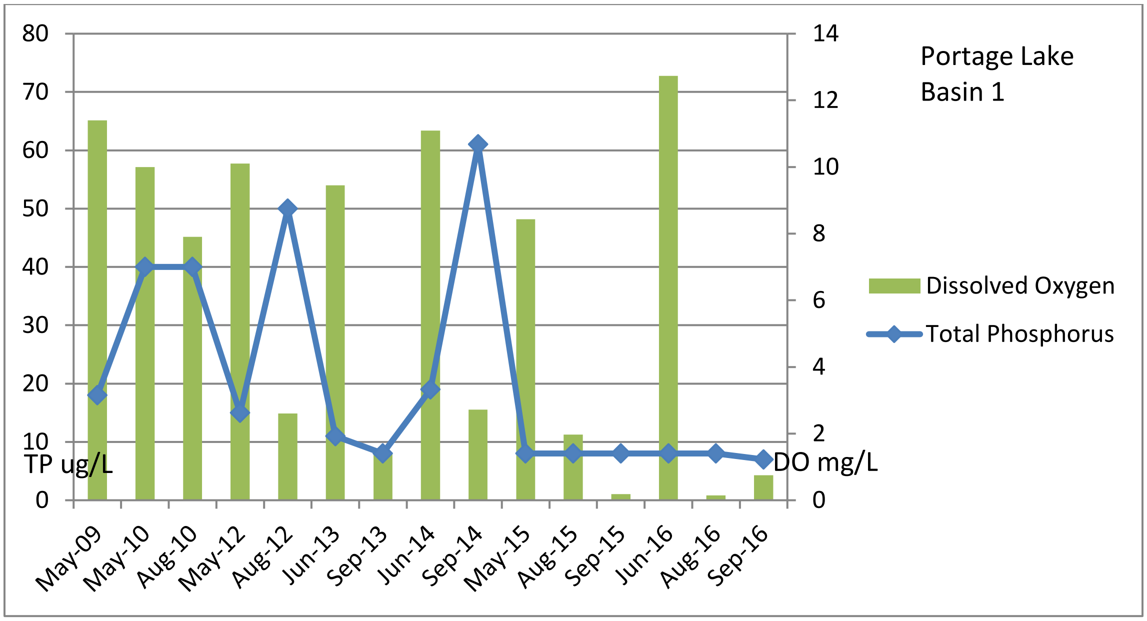
See below graphs of TP concentrations from 2016. Basin 1 and 2 are graphed using data previously collected on Portage Lake (via various sources, provided to PLM via the Portage Lake Watershed Forever website with permission from the committee).

Graph 5: Total Phosphorus – Deep Hole Basins 1, 2 (2009-2016) (deep water sample)



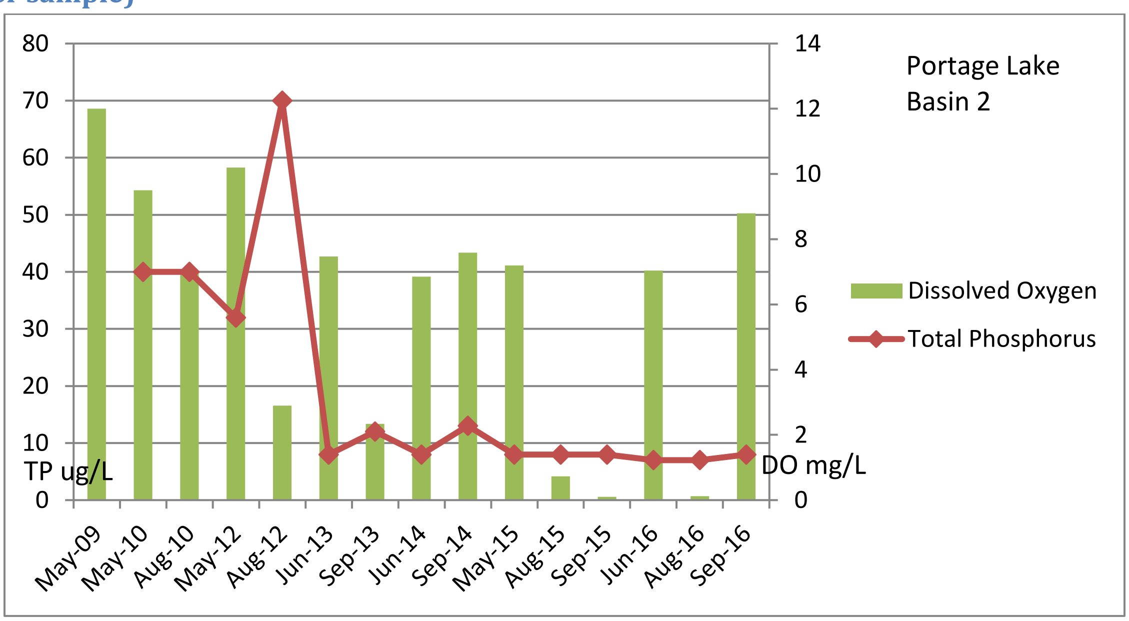
As the graph illustrates, there have been a few spikes in the TP concentrations over time, an overall decrease in 2013 and a large spike in Basin 1 in 2014, which is showing to be an outlier based on 2015 and 2016 results. Basin 2 which has been higher in TP than Basin 1 had the same results in 2015 and 2016, showing a DECLINING trend in overall TP in Portage Lake! Note: Basin 2 May 2009 sample is not graphed as the reading of 340 ug/L is an extreme outlier and not reflective of the overall lake results.

Graph 6: Total Phosphorus & Dissolved Oxygen – Deep Hole Basin 1, (2009-2016) (deep water sample)



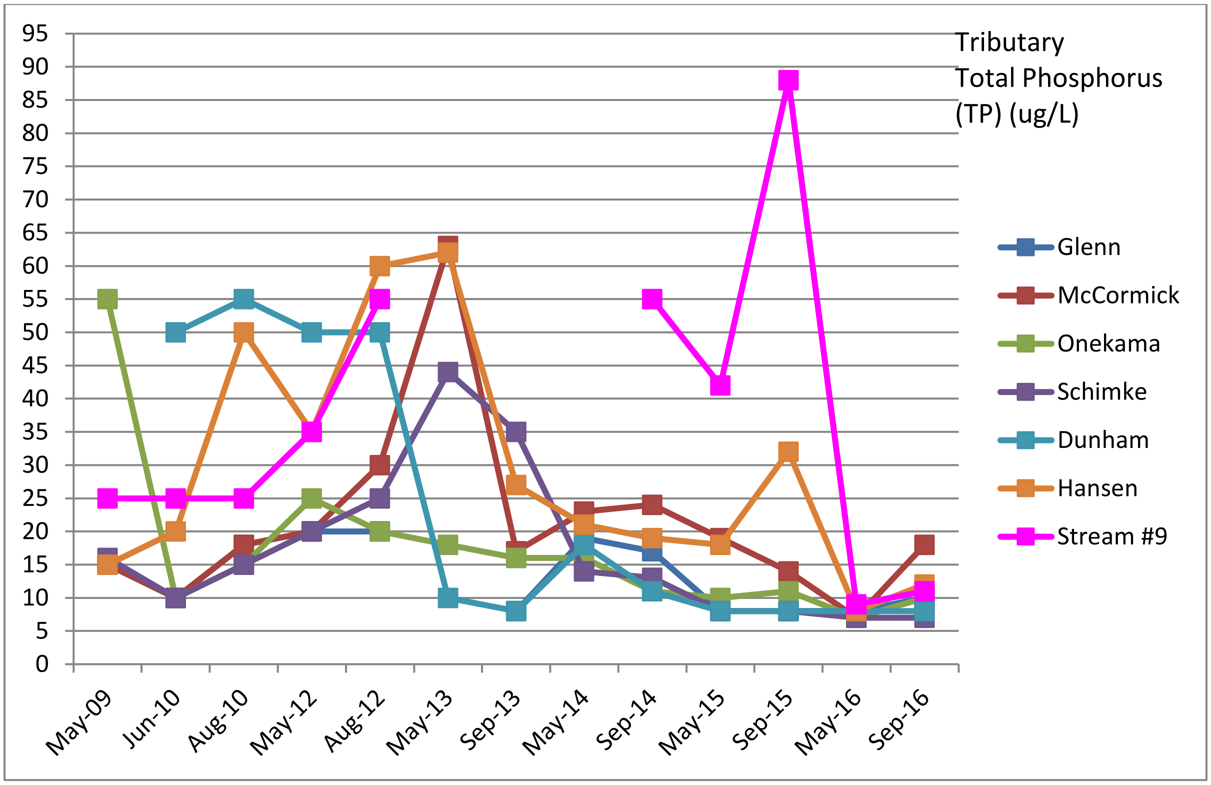
Internal loading can take place when dissolved oxygen levels decrease. 2015 and 2016 results show decreased DO levels, which again can cause internal loading, but no evidence of any increases in TP concentrations are found. Over the last few years, even when DO has dropped in more recent history to low levels, an increase in TP is not seen. This is a very positive sign for Portage Lake.

Graph 7: Total Phosphorus & Dissolved Oxygen – Deep Hole Basin 2, (2009-2016) (deep water sample)



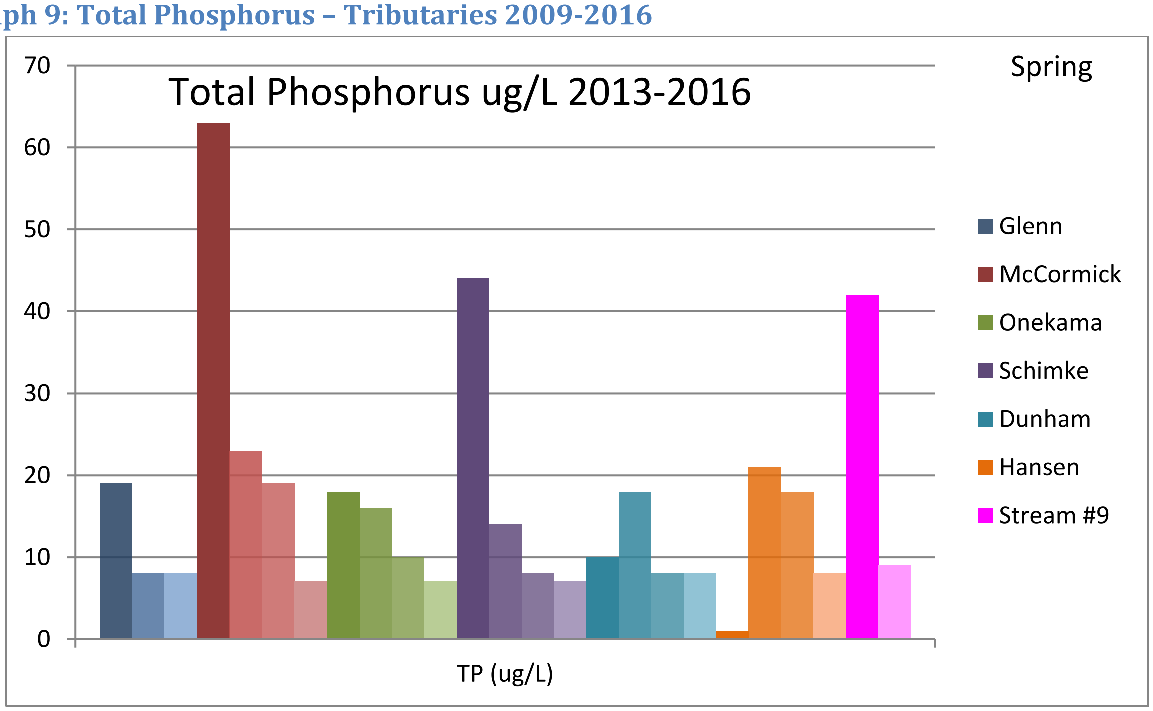
DO levels have decreased the last few years, and overall TP levels have decreased significantly. Internal loading does not appear to be a large contributing factor to TP concentrations currently.

Graph 8: Total Phosphorus – Tributaries 2009-2016



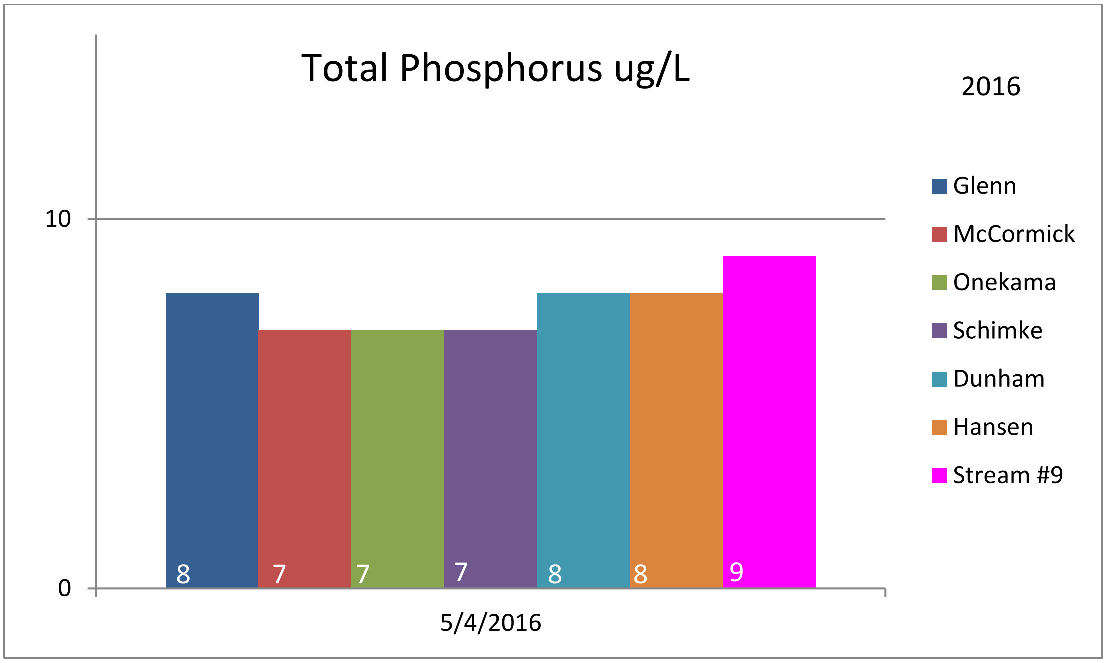
As the graph illustrates, there are fluctuations between the creeks over time. See below graphs to show the 2016 comparisons between the creeks. Glenn Creek May 2013 sample was removed from this graph as an extreme outlier, likely from a contaminated sample. Stream#9 was not sampled in 2013 but is currently showing the highest TP concentrations among the Tributaries with highly enriched readings in both 2014 and 2015. 2016 data was much lower across all tributaries than previous samplings.

Graph 9: Total Phosphorus – Tributaries 2009-2016



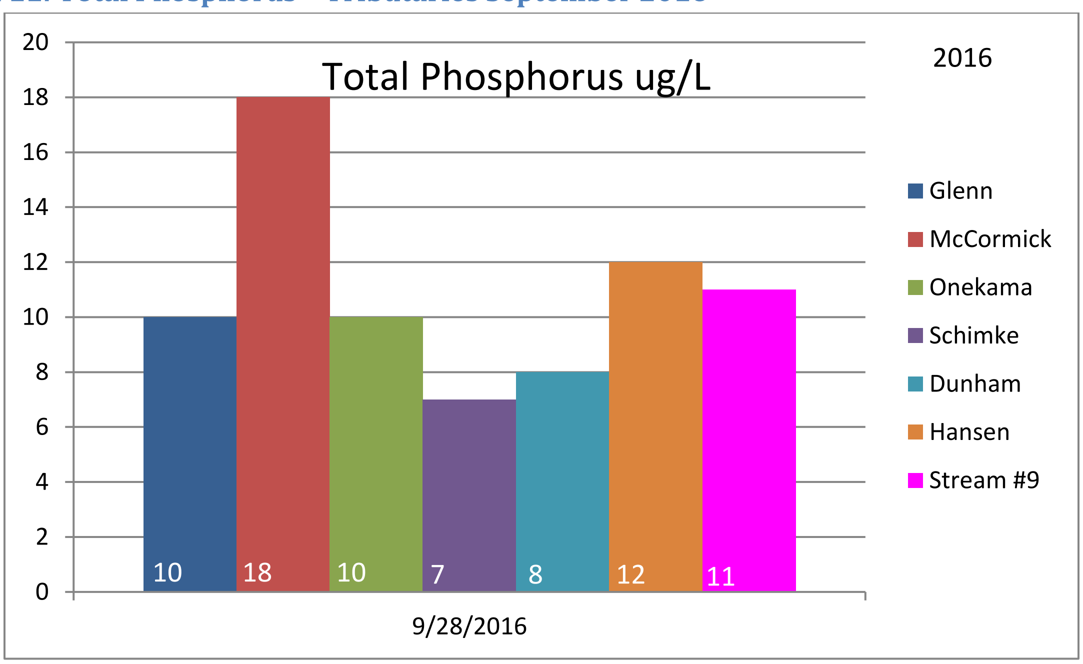
As the graph illustrates, there are fluctuations between the creeks over time. See below graphs to show the 2016 comparisons between the creeks. Glenn Creek May 2013 sample was removed from this graph as an extreme outlier, likely from a contaminated sample. Stream #9 was not sampled in 2013 but is currently showing the highest TP concentrations among the Tributaries.

Graph 10: Total Phosphorus – Tributaries May 2016



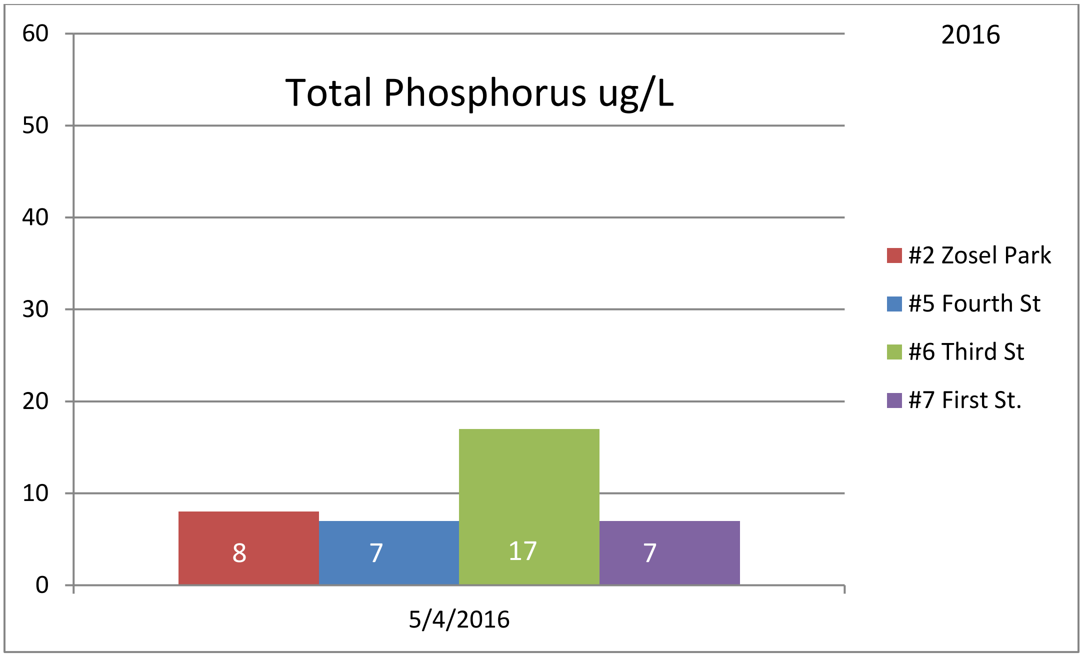
As the graph illustrates, very little fluctuation between the TP in the different creeks entering Portage Lake was found in 2016. In years past, concentrations have ranged more and been more enriched.

Graph 11: Total Phosphorus – Tributaries September 2016



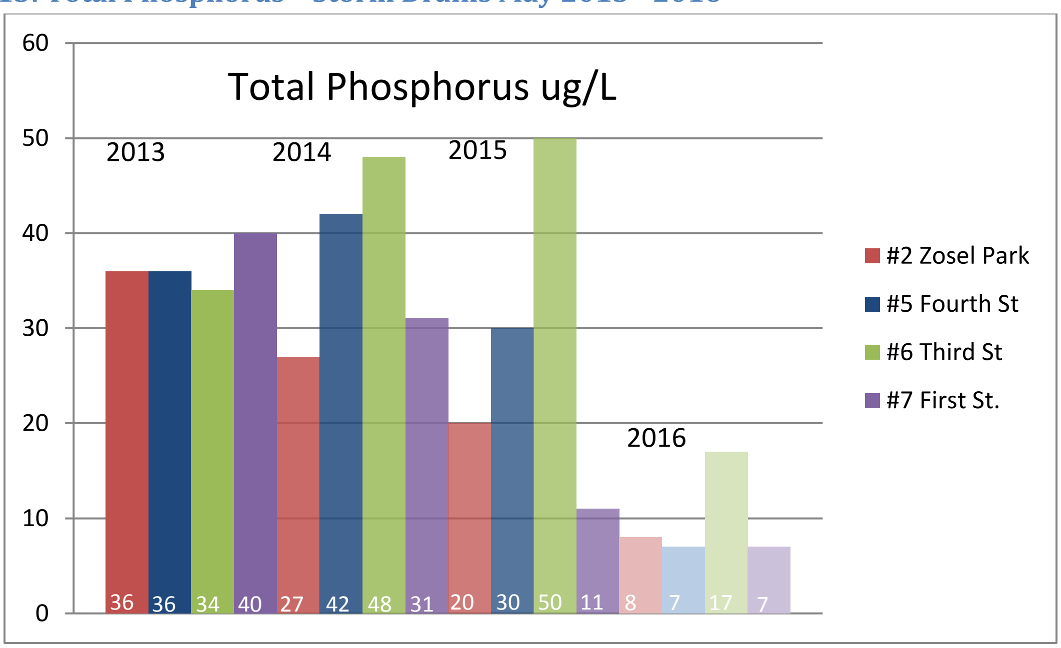
As the graph illustrates, there is a slight fluctuation between the TP in the different creeks entering Portage Lake and overall, the samples are less than 2015 and 2014. Note: Concentrations <10 are considered very low, not enriched.

Graph 12: Total Phosphorus – Storm Drains May 2016



As the graph illustrates, there is a slight fluctuation between the TP in the different storm drains around Portage Lake and overall, the samples are less than 2015 and 2014. Note: Concentrations <10 are considered very low, not enriched.

Graph 13: Total Phosphorus – Storm Drains May 2013 - 2016

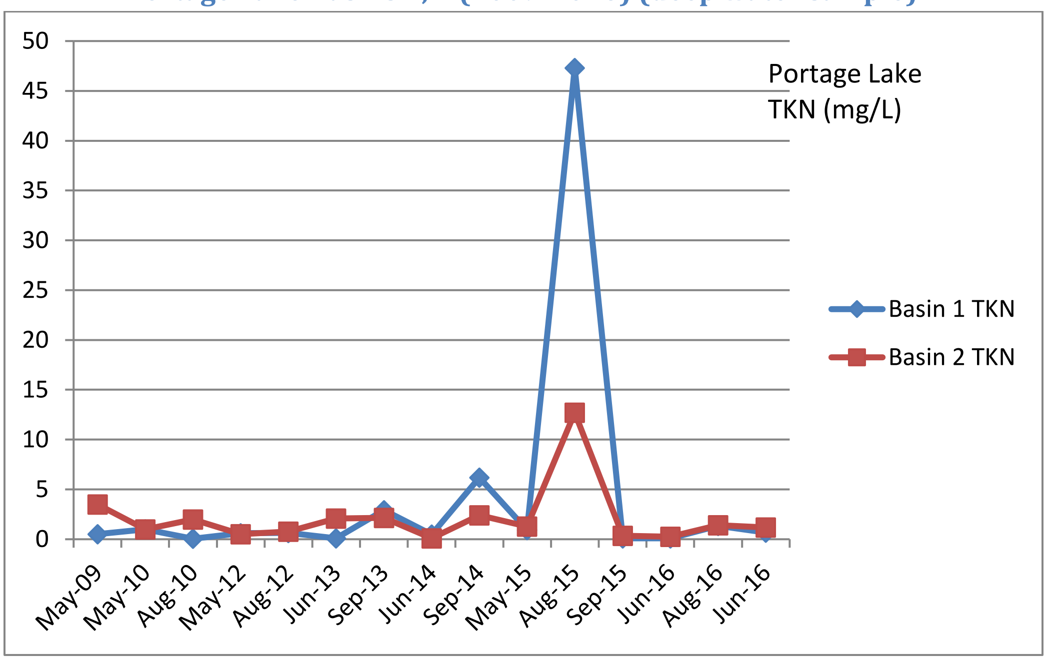


As the graph illustrates, there is variance between the TP in the different storm drains entering Portage Lake yet all the TP concentrations are considered enriched. These sites are a key introduction point of Phosphorus into Portage Lake. Over the last four years, Third St Drain is more elevated than the rest of the locations. In general, drains have decreased and the average has decreased over time.

Total Kjeldahl Nitrogen (TKN)

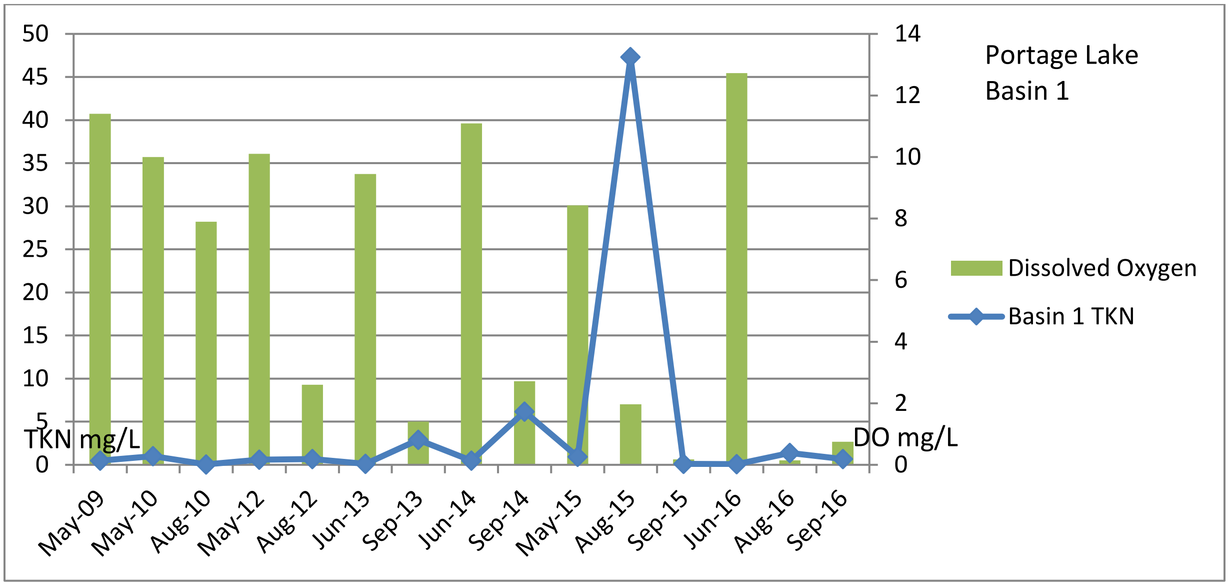
TKN measures the total organic amount of nitrogen (nitrate and nitrite) and ammonia in the water. Nitrogen is the plant nutrient (i.e. fertilizer) most likely to control the amount of rooted plant growth in lakes and ponds. Most Midwestern lakes have more nitrogen and more rooted plant growth than is desirable, so lower values are generally considered better. The major sources of nitrogen in lakes are from agriculture (animal waste, fertilizer) and atmospheric emissions (fossil fuel). Lakes with a TKN value of 0.66 mg/L or less are typically classified as oligotrophic lakes (having fewer nutrients, less productivity). Lakes with TKN values above 1.88 mg/L may be classified as eutrophic (highly productive and nutrient rich). Nitrates do not accumulate very much in the bottom waters during the summer because when nitrate is void of oxygen it turns into ammonia. Therefore, ammonia testing is an excellent way to determine internal loading of nitrogen. The TKN readings on Portage Lake at Basins 1 and 2 in June ranged from 0.09 mg/L to 0.56 mg/L, in August from 0.8 mg/L to 3.13 mg/L and in September from 0.9 mg/L - 1.17 mg/L between both basins. These readings are slightly lower than in 2015. The tributaries and storm drains showed lower levels than past years as well. The tributaries samples ranged from 0.41 mg/L- 1.27 mg/L in May to 0.09 mg/L -0.71 mg/L in September while the Storm Drains ranged from 0.8 mg/L - 1.72 mg/L in May. TKN readings decreased in 2016 from levels that had increased in 2015 and continuing to test this parameter is recommended.

Graph 14: TKN – Portage Lake Basins 1, 2 (2009-2016) (deep water sample)



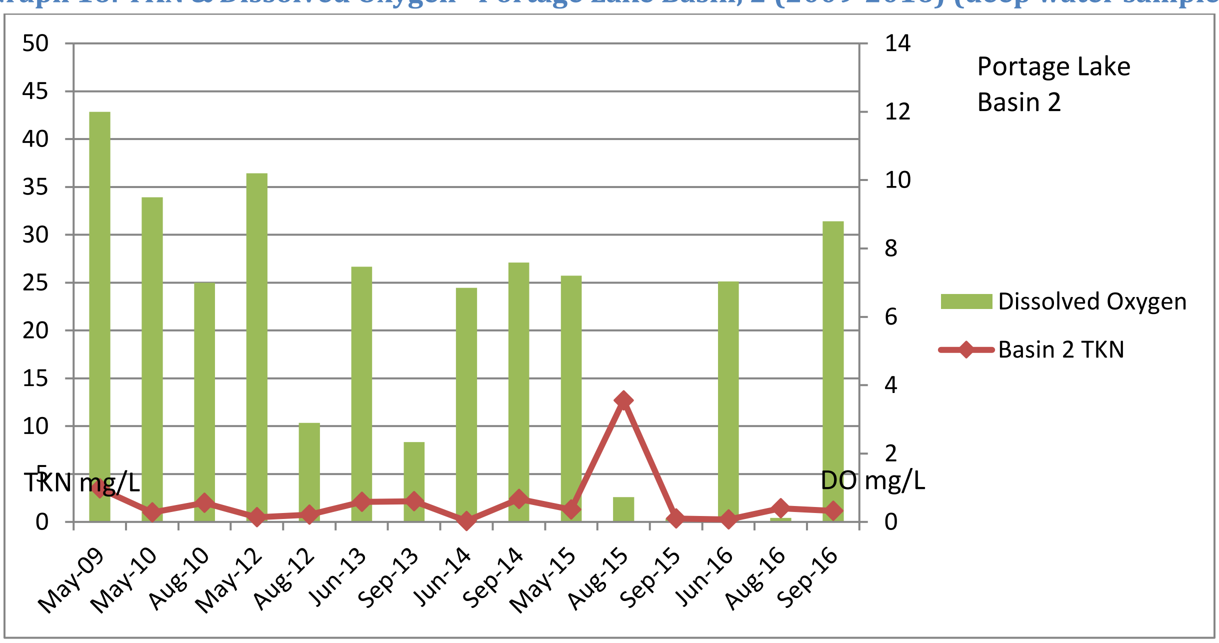
As the graph illustrates, the TKN concentrations on Portage Lake have fluctuated over the last few years, with a spike in August 2014 and a large spike in August 2015, but have returned to lower, less enriched levels in all of the 2016 readings.

Graph 15: TKN & Dissolved Oxygen– Portage Lake Basin 1 (2009-2016) (deep water sample)



Historically, comparing TKN and DO shows that as the DO levels decrease, TKN increase, indicating that internal loading is likely taking place. However, in 2015, low DO levels correlate with low TKN levels in September, but not August. 2016 samplings show low TKN levels regards to DO levels, indicating no internal loading taking place.

Graph 16: TKN & Dissolved Oxygen– Portage Lake Basin, 2 (2009-2016) (deep water sample)



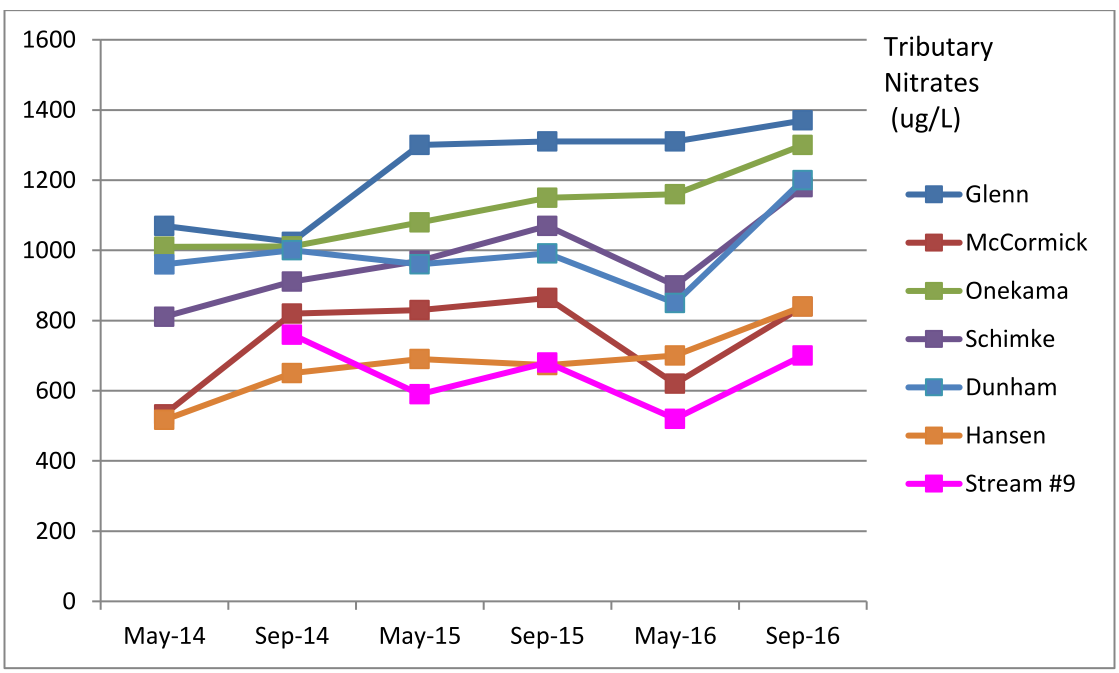
Similar 2015 results as in Basin 1 and 2016 data show no internal loading of TKN despite DO concentrations.

Nitrates

Nitrates measure the total amount of in-organic nitrogen in the water. Again, nitrogen is an important plant nutrient (i.e., fertilizer) and the nutrient most likely to limit the growth of rooted plants. Most Midwestern lakes have more nitrogen and more rooted plant growth than is desirable, so lower values are generally considered better. Nitrate levels under 250 µg N/L are considered not enriched while readings between 250-750 μg N/L are slightly enriched, readings from 750-1250 μg N/L are enriched and readings over 1250 μg N/L are highly enriched. The June concentrations of nitrates in Basin 1 and 2 were 210 μg N/L throughout the water column. The August and September concentrations of nitrates were 210μg N/L in both basins throughout the water column expect for one reading at 250μg N/L in Basin 1 at the surface in September. Both Basin results are down slightly from 2015 which were down from readings in 2014. Nitrates in the tributaries ranged from 620 μg N/ to 1310 μg N/L in the spring and from 700 μg N/ to 1370 μg N/L in September, which is up slightly from 2015 which were up slightly from 2014. The Strom Drains had slightly lower readings than the tributaries, classifying as slightly enriched with two drains enriched. Nitrates are typically higher in the spring when the water is colder because the bacteria needed to digest the nitrates are not as productive in cooler temperatures. Nitrates will often decrease over the spring and were slightly less in the lake by the end of the summer. Nitrate levels remained low throughout the rest of the season with an overall lake average of 210 μg N/L. Based on the higher levels of nitrates observed in inlets (Tributaries) in May and September, loading of the lake appears to be mainly from external sources. External sources for nitrate pollution are agricultural practices (manure, fertilizer), animal feedlots, urban runoff and municipal wastewater runoff. Based on the location of Portage Lake and the makeup of the surrounding watershed, nitrate enrichment is most likely coming from agricultural practices that have leached into the groundwater and animal feedlots. Nitrates did not accumulate very much in the bottom waters during the summer. The nitrates did not accumulate because when nitrate is void of oxygen it turns into ammonia. Therefore, ammonia testing is a better way to determine internal loading of nitrogen.

These samples show that the lake (at the time of sampling) may be Phosphorus limited. Phosphorus limited lakes tend to have a TN:TP >15. In 2016 the average TN was 210 ug/L in the basins and the TP <10 ug/L, giving a TN:TP of 21, indicating Phosphorus may be the limiting nutrient. This is common in most lakes in this geographical area.

Graph 17: Nitrates– Portage Lake Tributaries



As the graph illustrates, the nitrate concentrations in the Portage Lake Tributaries range from slightly enriched to enriched to highly enriched in 2015 and 2016. Additional testing recommended.

Ammonia

Ammonia is a form of nitrogen found in organic materials, sewage, and many fertilizers. It is the first form of nitrogen released when organic matter decays. Also, when ammonia degrades it consumes oxygen, which worsens already existing anaerobic conditions. However, ammonia can be used by most aquatic plants and is therefore an important nutrient. When oxygen is present in a lake ecosystem, ammonia will convert to nitrates. Ammonia is toxic to fish at relatively low concentrations in pH-neutral or alkaline water. In fish, ammonia affects hatching and growth rates, and can cause changes in tissues of gills, the liver and the kidneys. Ammonia concentrations below 1000 ug/L are considered suitable for healthy fisheries. Ammonia concentrations usually do not become elevated until water is void of oxygen and the nitrates are converted. Therefore, concentrations of Ammonia did not become elevated until anaerobic conditions are present, typically mid summer. The concentration of ammonia at the Basin 1 in June was 13 ug/L at the surface and 15 ug/L at the bottom while in Basin 2 it was 13 ug/L at the surface and 332 ug/L at the bottom. In August the concentrations were 18 ug/L at the surface and 19 ug/L at the bottom in Basin 1 and 9 ug/L at the surface and 321 ug/L at the bottom in Basin 2. The September concentrations were 64 ug/L at the surface and 538 ug/L at the bottom in Basin 1 and 49 ug/L at the surface and 43 ug/L at the bottom in Basin 2. The hypolimnion (deep water) concentrations observed in September are well within range for a healthy fishery. The tributaries had similar levels of ammonia as the lake throughout the season. Ammonia concentrations ranged from 10 ug/L to 15 ug/L in the tributaries. Storm drain levels were similar as well.

Chlorophyll

Chlorophyll measures the amount of plankton (green plant) in the water. Some plankton or algal growth is essential to support the growth of other organisms (e.g., fish) in the lake, but human activities and natural eutrophication often lead to excessive algal growth; thus, lower concentrations of chlorophyll are usually considered desirable. Chlorophyll concentrations in Portage Lake Deep Basins in June ranged from 0 ug/L to 0.2733 μg/L indicating low plankton populations. Shoreline samplings sites (3A, 3B, 3D) averaged 0.189 ug/L, which is much lower than in 2015 and more in line with 2014 and previous readings. Chlorophyll in the Deep Basins ranged from 0.374 ug/L - 8.01 ug/L in August with an average 7.36 μg/L. In September, Chlorophyll ranged from 0.343 ug/L to 1.87 ug/L. The shoreline sites averaged 0.34 ug/L, which was a decrease from previous results. A higher level, in shallow, warmer waters is common as the warmer water can be a breeding ground for plankton. Overall, chlorophyll levels, which had increased in 2015, have lowered again, similar to historical data for Portage Lake. This should continue to be monitored to determine if it is trending up or a sampling result of the growing season of 2015 and 2016.

Algae and Zooplankton Composition

Algal composition testing was performed at both deep Basins as well as the shoreline testing sites in June, August and September. The June testing showed the majority genera present included (presented as most abundant to least abundant); Chlorophyta (green algae): *Pediastrum sp., Chlorella sp.;* Cyanophyta (blue green algae): Microsystis sp., Lyngbya sp.; Bacillariophyta (diatoms): *Fragilaria sp.* The August and September sampling showed that the similar species in the genera were present with Cyanophyta (blue green algae), specifically *Microcystis sp*., the most abundant species and genera of phytoplankton followed by Chlorophyta (green algae): *Ulothix sp., Pediastrum sp., Chlorella sp.;* Bacillariophyta (diatoms): *Fragilaria sp.* Overall, concentrations were low. Some blue green algae, including *Microcystis sp*., can produce toxins. These toxins are normally released when the algae near the end of the life cycle and often occur for short phases during a growing season, often times towards the end of the season after the water temperatures and nutrient loading have reached a high. Further, blue green algae are not consumed by Zebra mussels, so if Zebra mussels are present in a lake ecosystem, it is likely to have lower green algae populations and higher blue green algae, as the Zebra Mussels will filter the green algae out of the water column and leave the blue green algae alone. The levels of blue green algae are not high enough to warrant a concern at this time. The blue green algae "scum" that forms on the lake surface when densities are extremely high should be avoided if that were to occur, but the densities in Portage Lake are not high enough to cause a bloom at this point. The zooplankton communities were also identified while looking at the phytoplankton and numerous species of zooplankton were documented including; *Cladocera sp. (Daphnia).*, *Rotifer sp.*, *Brachiopoda sp.*, and *Copepods sp*. Diverse and present phytoplankton is required to have a healthy zooplankton community as the base of the food chain.

Fecal Indicator Bacteria (E. Coli)

Fecal Indicator Bacteria (E. Coli) measurements count the number of live fecal indicator bacteria in the sample. These bacteria are considered reliable indicators of fecal contamination when they are found in a pond or lake, it is very likely that the water is being contaminated by animal feces. Contamination can potentially be derived from a number of sources, including failed septic systems, agriculture runoff, or waterfowl or wildlife droppings. E. Coli was tested in Portage Lake in July of 2016. Four locations of concern were tested in the lake including the beach, hotel area, Marina and camp. All samples came back very low.

Table 9: E. Coli Results in Portage Lake –2016

	E. Coli (CFU/100mL)	Total Coliforms (CFU/100mL)	Notes
Beach/Park	4	3700	Water meets bacteriological standards for safe swimming
Marina	4	1400	Water meets bacteriological standards for safe swimming
Portage Pt. Inn	4	300	Water meets bacteriological standards for safe swimming
Covenant Camp	4	700	Water meets bacteriological standards for safe swimming

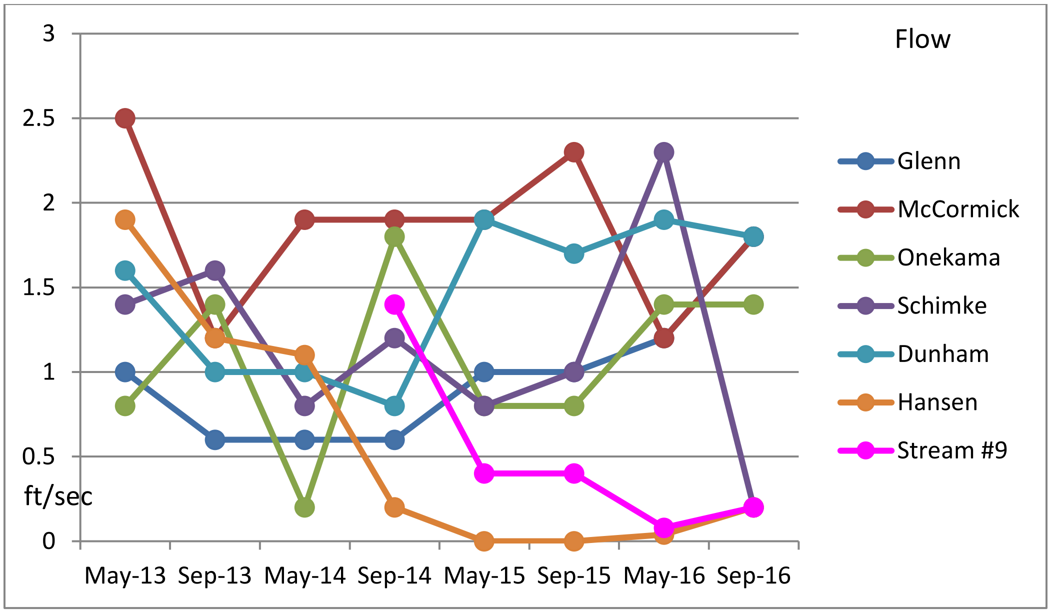
Bacterial counts are expressed as the number of Colony Forming Units per 100 milliliters (CFU/100mL).

For full body contact recreation (including swimming) counts of E. coli should not exceed 130 (CFU/100mL) as a monthly geometric mean of at least five samples per the State of Michigan standard, or single samples should not exceed 298 (CFU/100mL) [235 CFU/100mL in a designated bathing beach area] per Federal (EPA) guidelines. **Current recreational water quality standards do not rely on Total Coliform counts.**

Tributary Flow and Phosphorus

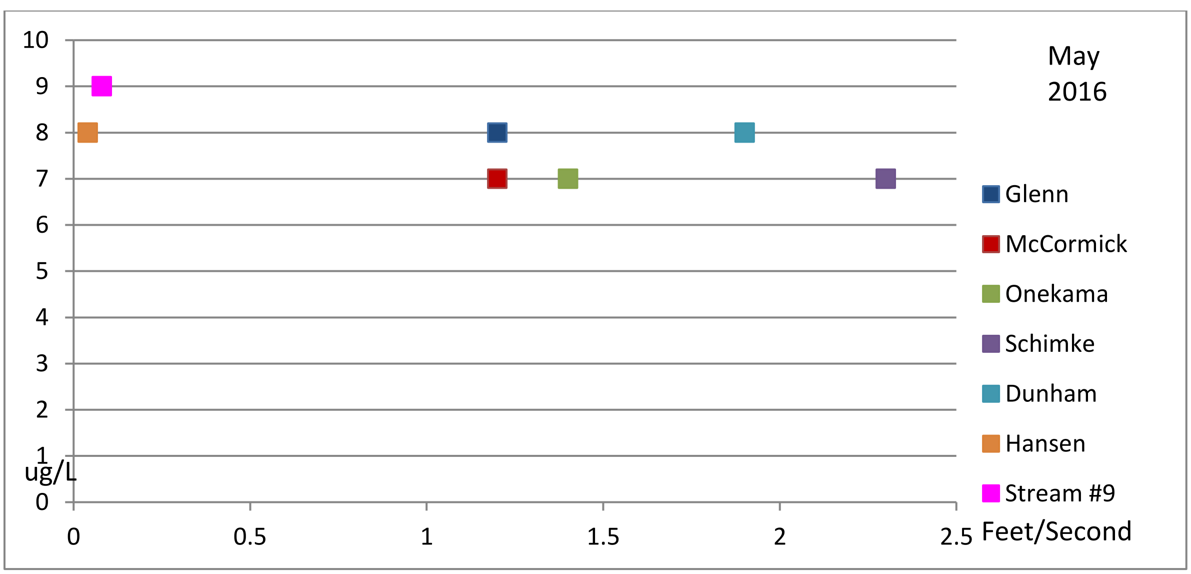
Flow rate data was determined, using a digital flow meter, at the seven tributaries studied in 2016 in May and seven tributaries in September 2016. Flow ranged from 0.04 feet/second - 2.3 feet/second in the May sampling and from 0.2 feet/second - 1.8 feet/second in September with Schimke being the fastest in May and McCormick, Glenn and Dunham Creeks being the fastest in September. Unlike in 2015, Hanson Creek was flowing at both sampling. The rates of flow varied from each creek and the basic chemistry varied as well. Nutrients coming in from the creeks are a concern as it is a transport from the watershed into Portage Lake. Total Phosphorus is graphed below along with flow to see how the flow and TP are connected.

Graph 18: Tributary Flow Rates –May and September 2013-2016



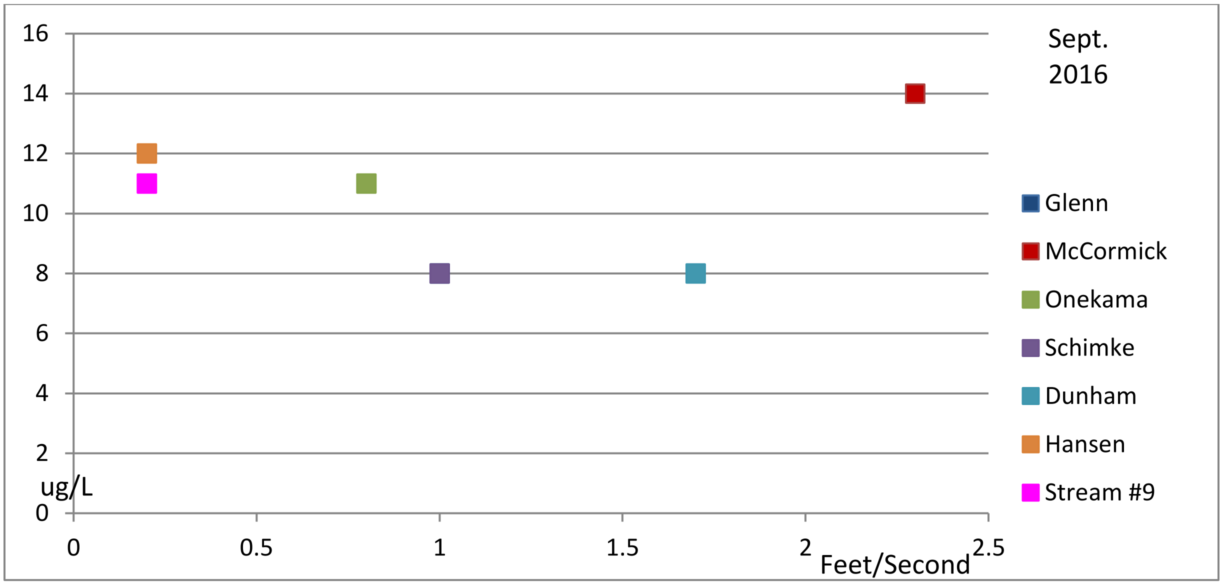
Historically, the graph illustrates that there is a decline in flow rate at the end of the summer versus the beginning of the summer. However, in 2015 and 2016, the rates are more consistent throughout the year, with an increase at McCormick Creek two years in a row. Typically, higher flows in spring will increase nutrient inputs in the spring and they decrease in the fall; however, if rates don't decrease, inputs are likely to not decrease as well.

Graph 19: Tributary Flow Rates and Phosphorus (ug/L) comparisons –May 2016



In years past, the graph has illustrated a correlation between flow and TP. The greater the flow, the higher the Total Phosphorus. (Exceptions: Stream #9 is highly nutrient enriched.). This correlation has historically been strong. In 2016, the TP concentrations are generally low across all tributaries, showing a smaller correlation.

Graph 20: Tributary Flow Rates and Phosphorus (ug/L) comparisons –September 2016



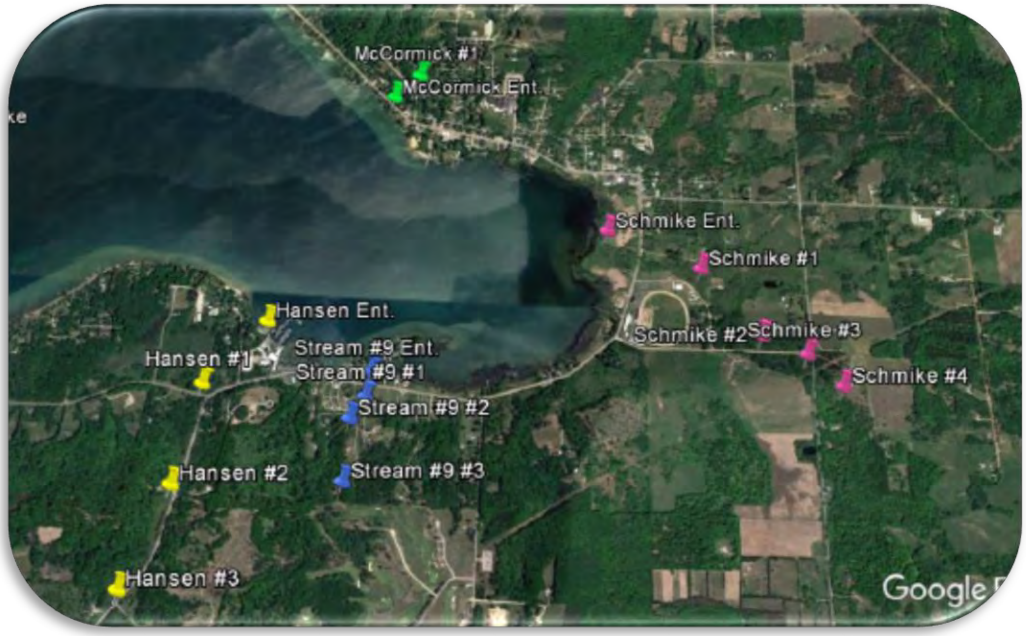
Similar to the observation in the Spring of 2016, TP concentrations have decreased substantially and less of a correction is seen in 2016, unlike in previous years.

Additional Tributary/Upstream testing

Tributary testing was expanded in 2016 to include testing four creeks upstream to determine if there were any point source locations determined or pinpointed. Determining any area of concern would allow future work to reduce nutrient loading into the lake be done. Using best management practices throughout the entire watershed, but especially on the creeks leading directly into the lake are essential. Determining if there is a location within the first few miles of the creek off of the lake that has elevated nutrient levels would allow future focus to be determined.

Based on historical data of nutrient levels from the tributaries, four creeks were selected to have additional testing done. Those creeks include: McCormick, Schimke, Hansen and Stream #9. Each creek was tested on 9/28/2016 at the entrance to the lake as part of the current program (flow and nutrients were tested). Each creek was again tested on 10/5/2016, just after a rain event. During this test, each creek was also tested upstream at locations that were determined upon walking up the creek. Upon walking upstream, visual observations were made for any concerns including but not limited to drain tiles, erosions, buffers, invasive, flow issues, sources of nutrient inputs, etc. Based on observations the following locations were selected as potential sources of nutrient inputs: culverts, wetlands, location of golf course, farming field, houses, roads, etc.

Map 6: Portage Lake Upstream Tributary testing locations

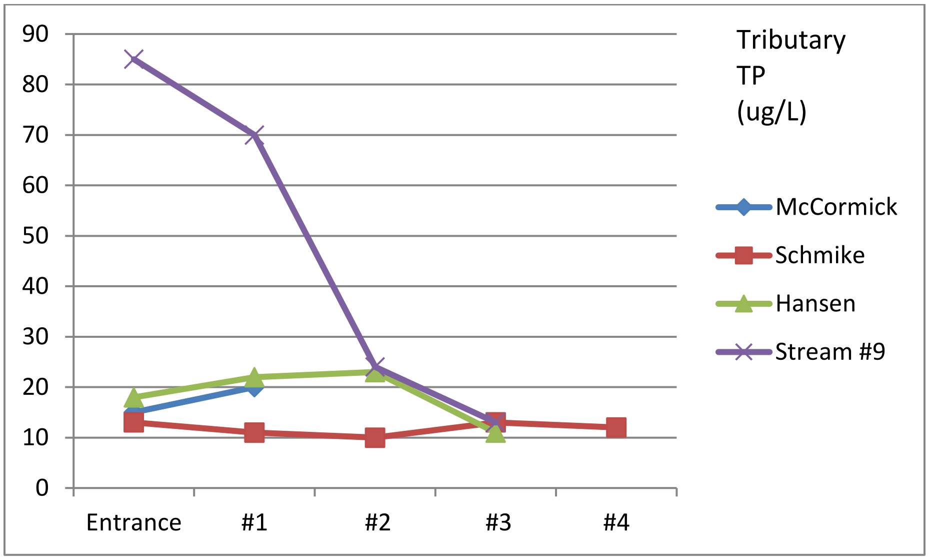


Of the data collected, most locations came up somewhat enriched, with the largest concern being Stream #9. Of the four locations sampled on Stream #9, the two large areas of concern were at the entrance to the lake as the first sampling south of the lake (South side of culvert, north end of wetland). It was noted that there was a hole in the culvert and if working properly, the water level could be much higher. The entrance sample came back highly nutrient enriched, with high TSS levels as well. TSS (total suspended solids) was tested as a determination of water clarity. Low TSS levels (under 20 mg/L is typically clear water while levels over 40 mg/L are cloudy and over 150 mg/L would be considered dirty). Stream #9 was sampled throughout the year (May and September) and although this location has been classified as highly enriched in previous years, it did not come back highly enriched in 2016. The other 2016 samplings actually came back lower than average for this stream. This is indicative that it is highly impacted with flow and rain events. It also shows that the area more near the golf course is less saturated with Phosphorus, but it does increase before it enters the lake.

Table 10: Upstream Tributary Testing 2016

	10/5/2016	Total Phosphorus	Nitrates	Total Sus. Solids
McCormick	Entrance	15	940	47
	#1	20	1400	176
Schimke	Entrance	13	1200	37
	#1	11	1120	96
	#2	10	1580	46
	#3	13	1610	100
	#4	12	1580	37
Hansen	Entrance	18	940	46
	#1	22	1020	51
	#2	23	1330	104
	#3	11	2290	122
Stream #9	Entrance	85	590	92
	#1	70	760	122
	#2	24	730	114
	#3	13	540	82

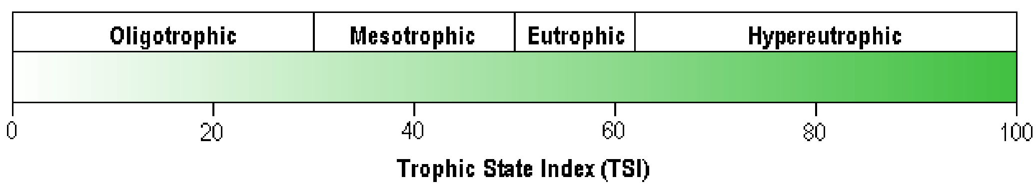
Graph 21: Additional Upstream Tributary Testing–October 2016

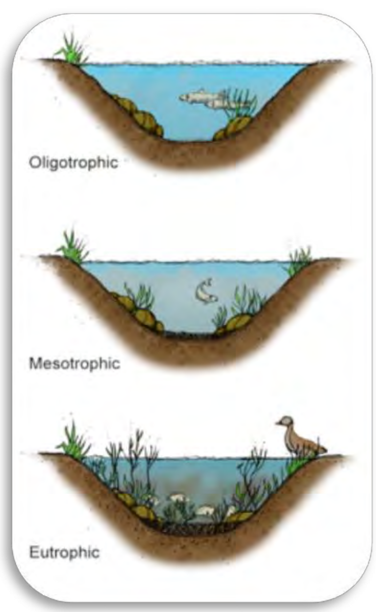


Of the streams tested, Stream #9 indicates high levels of TP. The other streams are elevated, but not as high. Readings over 10 ug/L are considered enriched.

Evaluation of Trophic Status

Carlson's Trophic State Index (TSI) is used to measure the trophic state of individual lakes. Lakes are ranked from 1 to 100 based on Secchi disc depth, Total phosphorus concentrations and/or Chlorophyll a levels. Based on that ranking, the TSI is determined. This chart gives the approximate classification for each category.





Portage Lake's June data yielded values between 15 and 31 (much lower than in 2015), in August between 28 and 46 and in September between 30 and 43 (Table 10). In general, these values rate Portage Lake as oligotrophic to mesotrophic. The Chlorophyll A samplings yielded higher results in 2015 but not in 2016 and overall readings correlate more similarly in 2016, similar to historical data. Characteristics associated with oligotrophic to meso- oligotrophic lakes are low nutrient levels, clear water and low productivity. High dissolved oxygen levels typically occur and survival of cold water fish is possible. Mesotrophic lakes tend to have moderate nutrient levels, clear water and moderate productivity. Rooted plants are abundant and the lake can still support a cold water fishery. As the picture to the right shows, eutrophic lakes (not Portage Lake at this time, but given for comparison) have high nutrient levels, turbid water, algae blooms are likely and sometimes severe. Plants are abundant and dissolved oxygen is often depleted from bottom waters, restricting fish populations to warm water species.

Table 11: 2016 Trophic State Index (TSI) Values

Site	Secchi Depth	Total Phosphorus	Chlorophyll a
Basin 1 - June	31	30	15
Basin 2 - June	31	28	17
Basin 1- Aug	44	30	46
Basin 2- Aug	44	28	44
Basin 1 - Sept	43	28	30
Basin 2 - Sept	43	30	34

2016 Water Quality Concerns/Recommendations

Current water quality problems in Portage Lake can result from nutrient loading from the watershed and nutrient rich bottom sediments in the lake. Please note that the overall nutrient levels in Portage Lake are still relativity low compared to most Michigan waterbodies. The last two years of data has shown an overall decline in the nutrient levels in the lake. Reductions in external nutrient loads may eventually reduce internally generated water quality problems, though improvements will require that dramatic reductions in external loading be sustained for long periods of time. Even if sufficient loading reductions are achieved, many years will be required before improvement is evident. In order to manage external nutrient inputs, it would be necessary to develop and implement a watershed management plan for the Portage Lake watershed. Watershed activities and public awareness using good management practices in the watershed will have long term positive improvements in the lake. This could be one cause of the decrease in nutrient levels in the lake.

Management Recommendations for 2017

Management options are dependent on many factors, including but not limited to, species abundance (density), species richness, species location and many lake characteristics. Whenever an exotic species is found within an aquatic environment, action needs to be taken to prevent long term ecological damage as well as recreational and aesthetic loss that will take place.

Submersed Aquatic Plants

The 2017 aquatic plant management program should detect and treat any areas where Eurasian watermilfoil or hybrid watermilfoil are present in addition to any other invasive, exotic species.

Any areas of Eurasian watermilfoil should be promptly treated using herbicides. Treatments with the herbicides, Triclopyr and/or 2,4-D, in localized treatment areas to slow the spread of Eurasian watermilfoil, when found should be conducted. The herbicides Triclopyr and 2,4-D, control Eurasian watermilfoil with little or no impact on most native plant species. Since they are selective, systemic herbicides, they can actually kill Eurasian watermilfoil plants. Under ideal conditions, several consecutive annual applications of Renovate or 2,4-D can reduce Eurasian watermilfoil to a maintenance (low) abundance. For this strategy to succeed, it is necessary to treat all the Eurasian watermilfoil in the lake each time they are applied. Michigan regulation restricting 2,4-D use in the vicinity of drinking water wells may result in the inability to apply 2,4-D near the shoreline of the lake.

Triclopyr is a systemic herbicide with selectivity very similar to 2,4-D. Triclopyr is not subject to the well setback restrictions that currently affect 2,4-D. Therefore, triclopyr can be used to control Eurasian watermilfoil in near shore areas. A combination of both systemic herbicides in Portage Lake could greatly reduce the growing Eurasian watermilfoil problem.

Several contact herbicides, including diquat, can also provide short-term control of Eurasian watermilfoil. These herbicides kill only the shoots of the plant, and plants regrow relatively rapidly from their unaffected belowground parts.

Nuisance native plant management can also be incorporated into a lake management program with conventional herbicide treatments if needed. Native plant treatments are completed using only contact herbicides in beach areas. Contact herbicides will not target the root system of the plant.

Emergent Vegetation Management

Purple loosestrife and Phragmites should continue to be addressed around the perimeter of the lake to prevent the further spread of these exotic species. The systemic herbicides, Glyphosate and Imazapyr, are effective at controlling Phragmites while Renovate 3 is effective in controlling Purple Loosestrife. Since they are systemic herbicide, the root system of the plant will be killed not just the foliage. Further, Purple Loosestrife should continue biological control measures as well. In addition, any other invasive terrestrial plants including but not limited to Japanese knotweed, honey suckle, garlic mustard and autumn olive should be targeted for control.

Monitoring

Aquatic vegetation and water quality should continue to be monitored to document the condition of the lake and to provide warning of any changes in the condition of the lake that need to be addressed by additional lake management activities.

Proposed Budget

The following budget is proposed based on previous requirement on Portage Lake and the budget is limited to the management and treatment of Portage Lake. If additional costs are required in the maintenance of the SAD or from outside factors, they may not be included in this budget. Please also note that as additional data becomes available from the Grant Study and application rates increase, the budget may have to be adjusted long term to account for genetically changing plants.

Table 12: Proposed 2017 Budget Portage Lake

Proposed/ Estimated Budget	2017
Emergent Control	5,000
EWM Control	54,500
Permit	1,500
Lake Management	15,000
Contingency Funds	7,600
Total	83,600

The Recommended Management Schedule for 2017:

- A spring and Fall vegetation survey (to evaluate conditions in the lake).
- Herbicide Treatment for exotics as required
- Pre and post treatment surveys as required, in addition to a mid-summer survey
- Extensive water quality monitoring throughout season
- Late summer/fall Phragmites treatment