Photo courtesy of the Portage Lake Association. Photographer, Al Taylor.

Portage Lake

Lake Management Plan 2019

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

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Executive Summary

Portage Lake has been managed over the past decade with goals of identifying and reducing the presence of aquatic invasive species (AIS) throughout the Portage Lake watershed, tracking plant trends, improving water quality and protecting Portage Lake into the future. The following report breaks down the specifics of the previous, current and future management needs.

In 2019, just over 60 acres of Eurasian watermilfoil (EWM) and Phragmites (Phrag) were controlled via chemical control methods. When reviewing the management area for the last decade, at no time has more than nine percent of the lake received herbicide management and, in most years, it is far under three percent. This shows that the program has successfully removed and managed the exotic infestation population, while preserving much of the lake from exotic plant disturbance. Further, with over 92% of the lake not receiving any herbicide treatment, the native plant community has been left as natural as a lake will allow with adjusting water levels/depths, a constant changing environment and exotic species introductions. Extensive vegetation surveys and water quality testing is included in the management program annually, to allow a checks and balance over the program and ensure the long-term protection of the lake. The abundance of healthy native plants in Portage Lake increases the long-term stability of the lake, which has been found over the last decade. 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 parameters to test is Total Phosphorus (TP). After finding a decrease in TP in 2015 and 2016, and a general downward trend; in 2017 TP concentrations increased. Although levels were only enriched and not highly enriched, it was concerning. However, in the last few years, testing has shown a decrease in the overall nutrient levels in Portage Lake, indicating the slight rise in 2015 and 2016 was short lived. Additionally, no signs of internal loading were found in this year's sampling. Over the years, a few samplings have shown small peaks or elevated levels, but generally speaking; the lake trends are all positive. The Tributaries and Storm Drains around Portage Lake continue to show elevated nutrient levels and prove to be a point source for bringing excess nutrients into the lake. This information is vital in determining the areas within Portage Lake that need to be focused on to reduce 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 (nutrient base) of Portage Lake and its surrounding watershed. While the main goal of the management program 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 has been sampled numerous times in the past to review the genetic makeup of the milfoil or hybrid milfoil within the waterbody. All testing has continued to prove that the aggressive hybrid milfoil has outcompeted any Eurasian strand and will continue to require more rigorous management, when found. Additional research data will be provided as part of this LMP, if and when available from the Universities reviewing genetic data.

Introduction

Purpose of the Plan

This management plan documents management activities during 2019, examines current conditions in the lake, and provides management recommendations for 2020. 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 2110-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 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 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.

Starry stonewort

- 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.

- Narrow-leaf cattails, another terrestrial invasive species, which can often be confused with the Common cattail, are often found growing in marches, lakeshores, ponds, ditches, etc. Similar to other invasive species, Narrow-leaf cattails often form monocultures and outcompete other native species, leading to a concern for species habitat and often affecting recreational use of the area. Narrow-leaf cattail's leaves are about ½ inch wide, roughly half the width of the native broadleaf cattail. The stem is roughly 3-6' tall. The two species also hybridize, producing a cross that can exhibit characteristics of both species, though is often taller and more aggressive than either parent species and can be more difficult to identify. Management options include mowing, digging, grazing, water level manipulation, and chemical control.

- 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) and fluridone (Sonar or Avast), which can be used to achieve long-term, selective control of Eurasian watermilfoil. Additionally, a new product, ProcellaCOR, is now approved for use in Michigan and is designed to work on Eurasian and hybrid milfoil. 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, 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 2019

Water Quality

Water quality was evaluated on May 1, June 4, July 31, and October 1, 2019. The May sampling included storm drain and tributary testing. In June, deep hole testing and shoreline testing of Portage Lake occurred. The later July sampling for deep hole testing occurred (this was an additional sampling added into the program in 2015). During the last sampling, tributaries, shoreline and the deep hole basins were sampled. 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 shoreline sampling, the following occurred, (1) depth profile for water temperature and dissolved oxygen concentrations were measured at the surface, (2) samples for LakeCheck™ analysis were collected at the surface for numerous parameters, (3) chlorophyll and algae composition analysis was collected at the surface. During the Storm Drain sampling the following occurred at four 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 seven 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 one tributary and including testing multiple locations from the entrance at the lake, upstream. Parameters tested included Total Phosphorus, Nitrates and Alkalinity.

Weather Challenges of 2019

Michigan winters are usually quite different from year to year. While some are very cold and have high snowfall amounts, others are the opposite. The winter of 2019/2020 was very mild. When looking at the previous few winters, which were also rather mild, it brings some concern with how the lakes, specifically the plants, will respond the following summer. Weather patterns can have impacts well into the next few seasons, so when we have a mild Michigan winter, it is not helpful with controlling exotic species. Further, ice coverage came late and was not as thick as normal; leading to more sunlight penetration and ability for EWM to overwinter. Weather patterns throughout the summer also have impacts. Each

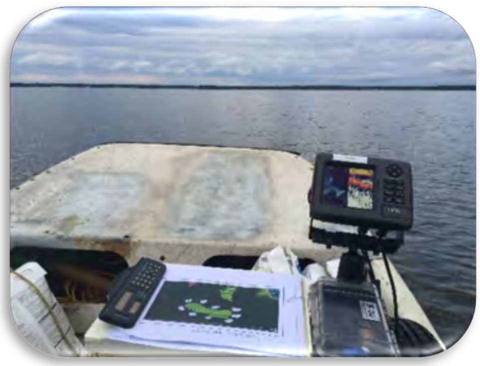
Eurasian watermilfoil

lake responds differently from the weather impact and as Portage Lake tends to be slow to grow in the spring, the longer, warmer falls may impact growth differently than smaller, inland lakes. Finally, weather patterns have brought unusually high-water levels to the Great Lakes, which in turn have had large impacts on Portage Lake. Changes in water levels will have impacts on a waterbody, both short and long term and do need to be taken into consideration when managing aquatic plants.

Exotic species tend to benefit from changes in weather conditions. In Portage Lake, little plant growth is evident early on into the growing season and it is not until mid-summer that diverse plant coverage is found. Weather patterns can have impacts on lakes and individual plant trends that may not be evident right way.

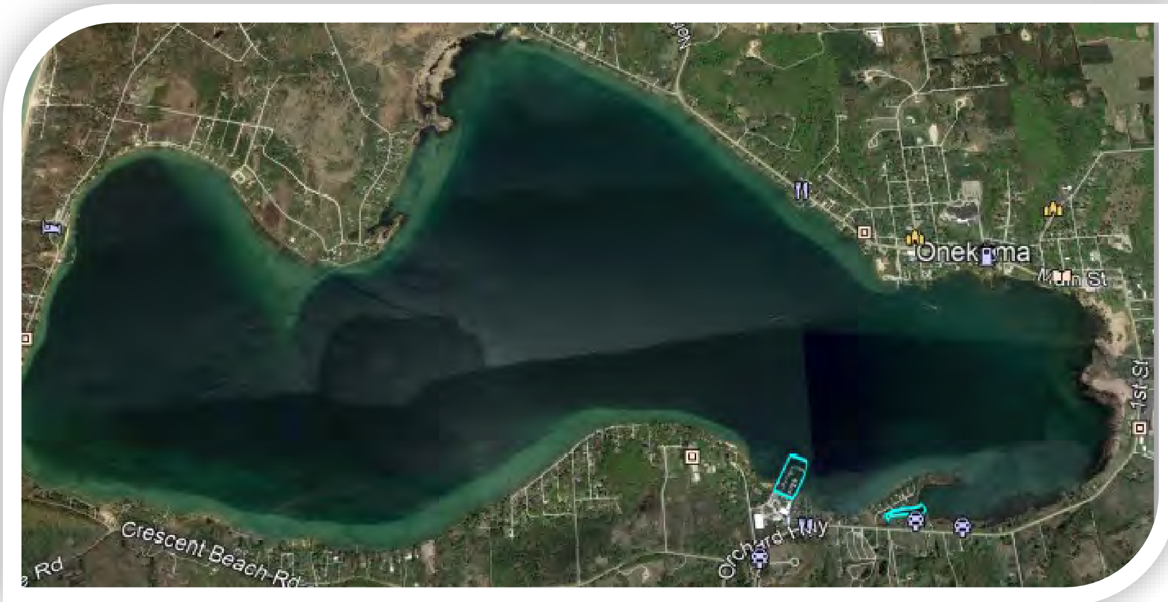
Aquatic Plant Control

Weed treatments were conducted in June and August to control Eurasian watermilfoil (EWM) in Portage Lake. Phragmites was also treated throughout 2019 around Portage Lake. The lake was closely monitored this year for any areas of exotic plant growth and treated accordingly.



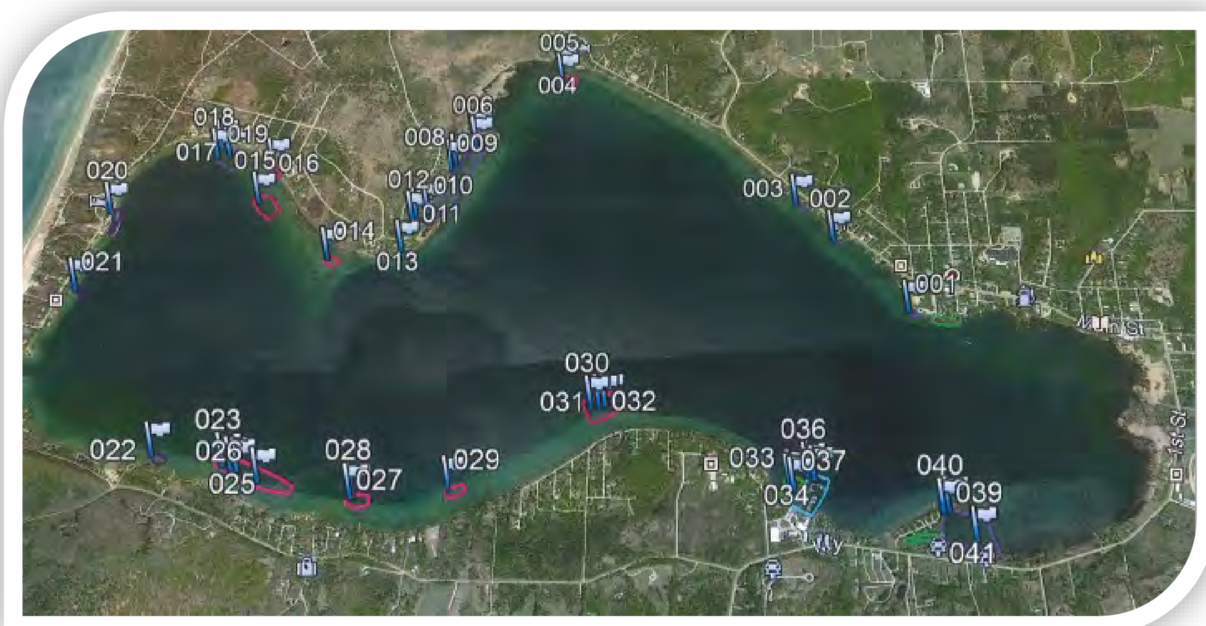
The management strategy for the control of Eurasian watermilfoil has been working, with substantial reductions in EWM treatments from when the initial treatments began. Although some years see some fluctuation, overall there is a downward trend. However, despite our efforts, EWM control is a constant 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 2019, as well as previous years for both EWM and Phragmites/Purple Loosestrife/Japanese knotweed Control.

Map 1: Portage Lake June 2019 Treatment Map



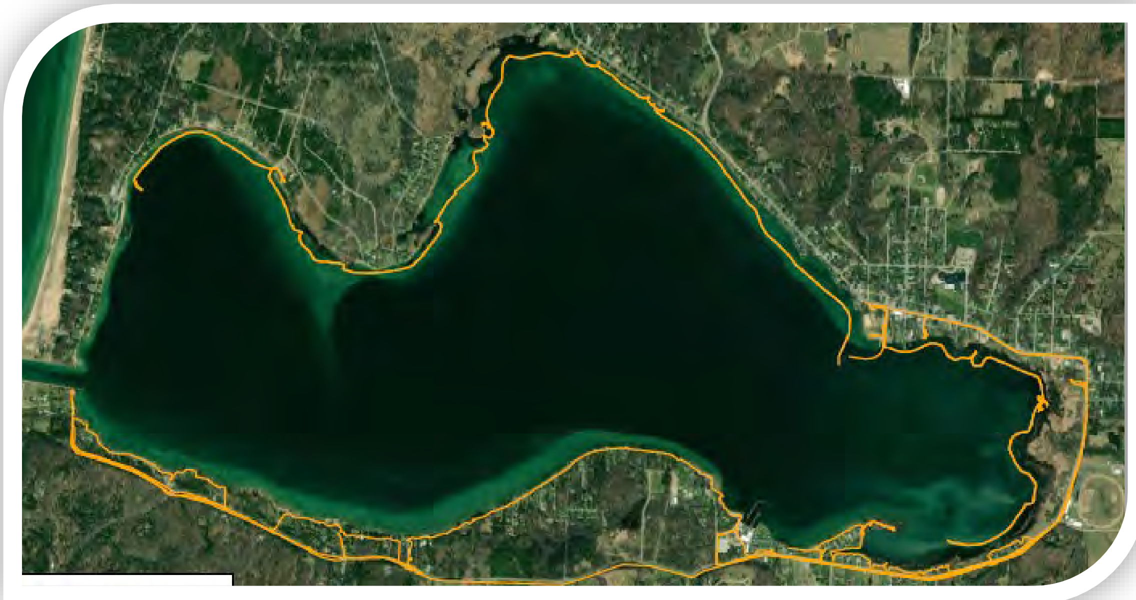
June 17, 2019 EWM and CLP Treatment, 6.3 acres Clipper at 200ppb

Map 2: Portage Lake August 2019 Treatment Map



August 15, 2019 EWM Treatment, 25.25 acres Renovate OTF (at 240lbs/acre), 20 acres Sculpin G (at 240lbs/acre), 4.5 acres Renovate 3 (at 4 gals/acre) and 4.2 acres ProcellaCOR.

Map 3: Portage Lake Terrestrial Treatment Map 2019



2019 Terrestrial Treatment Coverage Map

Table 1: Submersed Plant Treatment Quantities 2019-2009

		Product	Rate#/Acre	Acres	Total Acres
2019	16-Jun	Clipper	200ppb	6.3	60.25
	15- Aug	Renovate 3	4gals	4.5	
		Renovate OTF	240#	25.25	
		Sculpin G	240#	20	
		ProcellaCOR	45.6PDU	4.2	
2018	19- Jun	Clipper	200ppb	1.58	51.08
	15- Aug	Renovate OTF	200#	8	
		Renovate 3	4gals	4.5	
		Sculpin G	240#	33.5	
		ProcellaCOR	40PDU	3.5	
2017	14- Jun	Clipper	200ppb	1.58	67.68
	15- Aug	Renovate OTF	200#	14	
			240#	13	
		Renovate 3	4gals	5.6	
		Sculpin G	200#	4	
		Sculpin G	240#	29.5	
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, Narrow leaf cattails, Yellow iris, Purple loosestrife, Japanese knotweed) 2019-2009

Year	Product	Rate	Acres
2019	Glyphosate/Imazapyr	3%	6.6
2018	Glyphosate/Imazapyr	1.5,3%	0.2
2017	Glyphosate/Imazapyr	1-3%	0.15
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

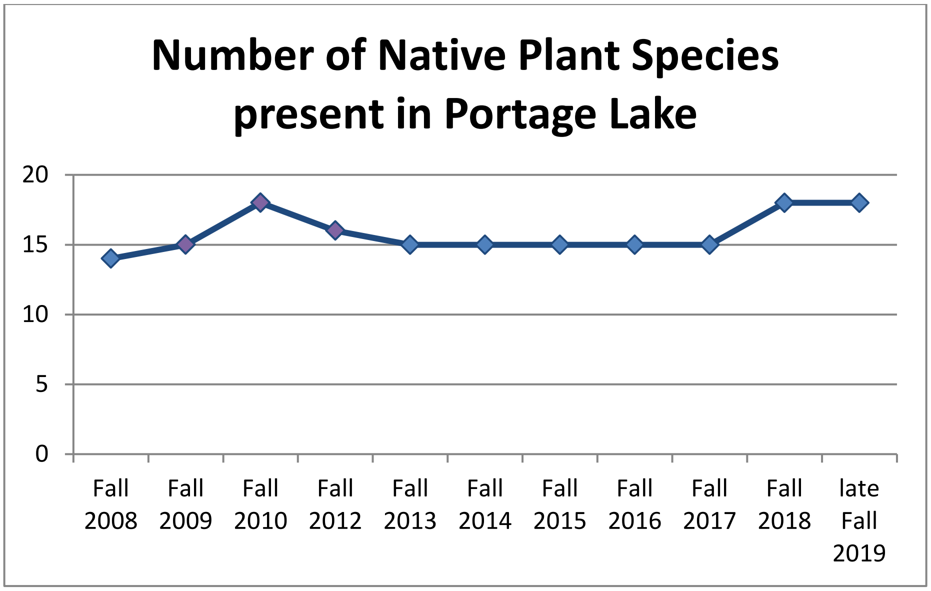
Surveys of the aquatic vegetation of the lake were conducted on June 4, 17; July 31; August 15, September 26, and October 4, 2019. Surveys of the lake were made frequently throughout the summer months for pre or post treatment evaluation, to collect water quality parameters, as well as to have additional 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 considers 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 using 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/early summer while the second is conducted in late summer or fall.

Table 3: Plant Species Found in Portage Lake –2019

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

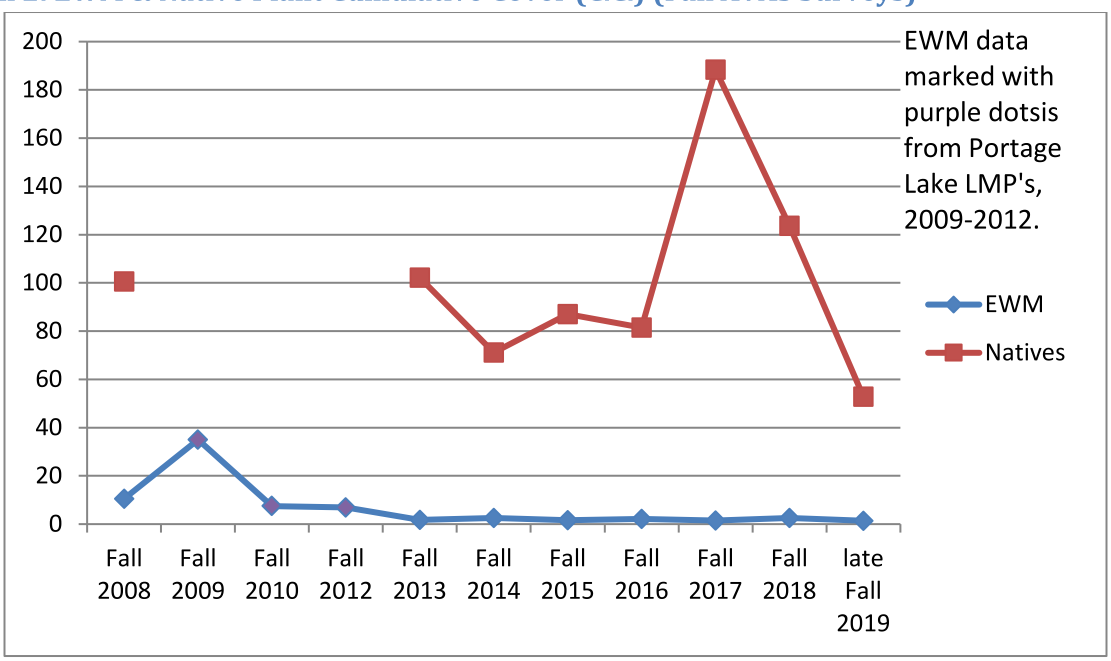
AVAS Code	Common Name	Scientific Name	% Cumulative Cover June 2019	% Cumulative Cover October 2019
	Submerged- Exotic			
1	Eurasian watermilfoil	*Myriophyllum spicatum*	1.72	1.40
2	Curlyleaf pondweed	*Potomageton crispus*	4.46	0.01
	Submerged- Native			
3	Muskgrass	*Chara*	22.95	17.06
4	Thinleaf pondweed	*Potomageton spp.*	11.10	1.55
5	Flatstem pondweed	*Potomageton zosteriformis*	5.49	1.73
6	Robbins pondweed	*Potomageton robbinsil*	0.00	0.15
7	Variable leaf pondweed	*Potomageton gramineus*	2.72	3.67
8	White stem pondweed	*Potomageton praelongus*	4.60	0.37
9	Richardsons pondweed	*Potomageton richardsonii*	9.07	1.90
10	Illinois pondweed	*Potomageton illinoensis*	14.62	1.22
11	Largeleaf pondweed	*Potomageton amplifolius*	5.03	1.26
15	Wild Celery	*Vallisneria Americana*	5.71	10.85
17	Northern milfoil	*Myriophyllum sibiricum*	0.00	0.05
20	Coontail	*Ceratophyllum demersum*	4.79	1.82
21	Elodea	*Elodea Canadensis*	6.24	0.31
22	Bladderwort	*Utricularia valgaris*	0.22	0.66
25	Naiad	*Najas flexilis*	6.67	9.23
27	Sago pondweed	*Potomageton pectinatus*	3.05	0.98
45	Variable leaf watermilfoil	*Myriophyllum heterophyllum*	2.28	0.02
	Emergent- Native			
30	Water lily	*Nymphaea odorata*	0.55	0.01
39	Cattail	*Typha spp.*	19.82	26.44*
40	Bulrush	*Scirpus spp.*	19.13	12.17
42	Swamp loosestrife	*Dianthera americana*	0.11	0.00
	Emergent - Exotic			
43	Purple loosestrife	*Lythrum salicaria*	0.00	0.01
44	Common reed	*Phragmites*	0.01	0.01*
	Total		**150.21**	**93.32**

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 (C.C.) (Fall AVAS Surveys)



This graph shows the cumulative coverage of EWM from 2008-2019 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 2019 survey found great diversity but lower density, likely contributed to the weather patterns and a cooler September than the previous few years when increases in plant growth were found. 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 this information was taken from the *Portage Lake Forever* website and used with permission of the board.

Current Conditions in the Lake

Aquatic Vegetation

Over the years, the presence of Eurasian watermilfoil and Curlyleaf 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 (Basin 1 and Basin 2), Shoreline Sites (3A, 3B, 3D), Tributaries (Glen Creek, McCormick Creek, Onekama Creek, Schimke Creek, Dunham Creek, Stream #9, Hansen Creek) and Storm Drains (#2, #5, #6, #7).

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 4: Portage Lake Water Quality Testing Locations

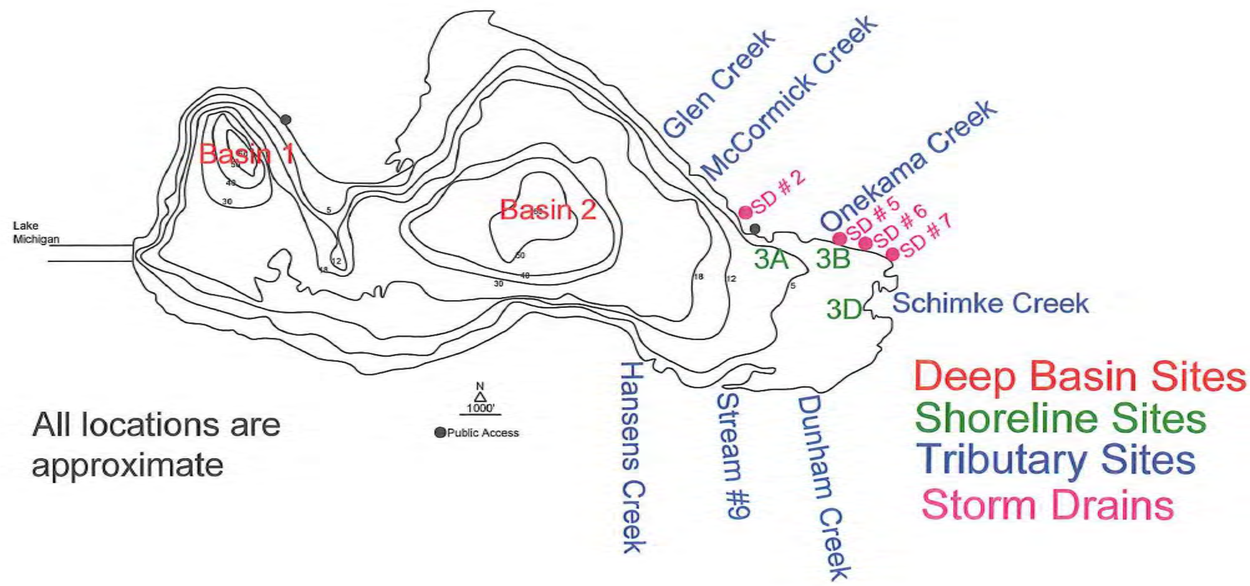


Table 4: Tributary Water Quality Portage Lake –2019 –rainy/65

5/1/2019	Temp (C)	D.O. (mg/L)	Conduct-ivity (uS/cm)	TDS (ug/L)	pH (S.U.)	TP (ug/L)	TKN (mg/L)	Nitrate (ug/L)	Amm-onia (mg/L)	Flow (Ft/sec)
Glenn	9.1	11.8	419	302	8.1	8	0.221	350	0.035	1
McCormick	9.8	11.12	444	338	8.1	17	0.049	767	0.056	1.7
Onekama*	8.8	10	398	293	8.4	13	0.327	1220	0.031	1.1
Schimke	9.9	10.8	423	268	8.3	19	0.203	911	0.015	1.4
Dunham	10.12	10.7	399	278	8.2	17	0.542	500	0.029	2
Hansen	8.7	9.8	412	301	7.9	14	0.054	605	0.015	0.8
Stream #9	9.7	10.2	334	239	7.8	17	0.516	605	0.134	0.9
10/1/2019	**Temp (C)**	**D.O. (mg/L)**	**Conduct-ivity (uS/cm)**	**TDS (ug/L)**	**pH (S.U.)**	**TP (ug/L)**	**TKN (mg/L)**	**Nitrate (ug/L)**	**Amm-onia (mg/L)**	**Flow (Ft/sec)**
Glenn	11.3	10.39	397	258	8.48	21	0.28	1380	0.015	1.2
McCormick	12.1	9.62	410	267	8.35	39	0.004	1080	0.170	1
Onekama	12	10	376	245	8.46	18	0.254	1240	0.015	1.4
Schimke	138	9.51	380	247	8.41	20	0.417	1110	0.015	1.2
Dunham	12.7	9.75	361	235	8.44	17	0.302	980	0.015	1.8
Hansen	14.5	8.9	392	255	8.27	10	0.522	710	0.015	1
Stream #9	16.2	8.77	340	222	8.27	28	1.12	650	0.019	1

Table 5: Deep Hole Basin 1 Portage Lake –2019 (Secchi Disc: June 12', August 19', Oct.13')

Basin 1 June 4 2019	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 (mg/L)	ALK (mg/L)	Chlor. A (ug/L)
s.	15.1	10.38	280.7	182	8.43	8	126.8	1.15	0.046	230	0.015	119	0.94
10'	15.1	10.41	280.8	183	8.41	-	132.1	1.11	-	-	-	-	-
20'	15.1	10.39	280.9	183	8.42	-	134.3	1.11	-	-	-	-	-
30'	11.7	11.57	273.8	178	8.34	8	137.8	0.98	0.384	230	0.029	126	0.3
40'	10.8	9.73	278.3	181	7.9	-	135.6	0.091	-	-	-	-	-
50'	10.5	9.43	277.1	179	7.92	-	133.8	0.88	-	-	-	-	-
60'	10.1	9.12	279.7	181	8.11	8	136.99	0.79	0.378	230	0.185	139	0.78
Basin1 Jul 31 2019	**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 (mg/L)**	**ALK (mg/L)**	**Chlor. A (ug/L)**
s.	22.9	9.01	274.9	179	8.72	8	150.1	1.1	0.975	230	0.064	107	0.31
10'	22.7	9.01	274.9	179	8.75	-	145.5	1.04	-	-	-	-	-
20'	27.6	8.93	275.1	179	8.75	-	144.4	1.04	-	-	-	-	-
30'	16.4	9.56	277.1	180	8.46	8	151.4	0.96	0.193	289	0.015	94	0.294
40'	12.5	9.13	281.2	183	8.22	-	159.6	0.78	-	-	-	-	-
50'	11.2	8.1	282.6	184	8.05	-	165.4	0.95	-	-	-	-	-
60'	10.9	5.84	287.5	187	7.87	8	171.5	0.37	0.574	368	0.113	98	0.32
Basin1 Oct 1 2019	**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 (mg/L)**	**ALK (mg/L)**	**Chlor. A (ug/L)**
s.	18.2	8.8	276.2	180	8.62	12	131	0.57	0.91	230	0.032	104	2.21
10'	18.2	8.79	276.2	180	8.63	-	138.7	0.65	-	-	-	-	-
20'	18.1	8.76	276.3	180	8.61	-	189.5	0.57	-	-	-	-	-
30'	18	8.7	276.4	180	8.59	13	189.8	0.66	0.453	230	0.021	115	1.92
40'	18	8.65	276.5	180	8.59	-	189.5	0.6	-	-	-	-	-
50'	18	8.6	276.6	180	8.57	-	190.2	0.36	-	-	-	-	-
60'	17.9	8.54	276.7	180	8.55	8	190.5	0.45	0.509	230	0.019	119	11.3

Table 6: Deep Hole Basin 2 Portage Lake –2019 (Secchi Disc: June 13', August 17', Oct. 15')

Basin 2 June 4 2019	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 (mg/L)	ALK (mg/L)	Chlor. A (ug/L)
s.	15.8	10.29	283.4	184	8.41	8	170.1	1.08	0.199	254	0.015	113	0.37
10'	15.8	10.29	283.4	184	8.34	-	177.9	1.09	-	-	-	-	-
20'	15.5	10.26	283.2	184	8.37	-	179	1.14	-	-	-	-	-
30'	14	10.36	280.7	182	8.28	8	182	1.08	1.38	230	0.015	137	1.1
40'	13.6	9.9	281.5	183	8.2	-	184.2	0.97	-	-	-	-	-
50'	13.1	8.25	283.6	184	8.05	-	191.7	4.34	-	-	-	-	-
60'	12.8	7.8	279.9	184	8.1	8	187.2	3.76	1.17	230	0.017	129	0.87

Basin2 Jul 31 2019	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 (mg/L)	ALK (mg/L)	Chlor. A (ug/L)
s.	23.5	9.22	274.5	178	8.81	8	149.7	1.03	0.72	252	0.033	119	0.294
10'	23.2	9.22	274.7	179	8.81	-	148.7	1.09	-	-	-	-	-
20'	23.1	9.12	274.8	179	8.79	-	148.9	1.1	-	-	-	-	-
30'	17.8	9.14	282.3	184	8.46	8	156.9	1.15	0.74	230	0.019	127	0.251
40'	15.1	9.12	286.6	186	8.2	-	162.7	1.05	-	-	-	-	-
50'	14.4	5.32	289.8	188	8.05	-	164.8	1.07	-	-	-	-	-
60'	14.2	3.45	297.7	150	7.93	8	167.9	0.89	0.359	275	0.077	131	0.1
Basin2 Oct 1 2019	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 (mg/L)	ALK (mg/L)	Chlor. A (ug/L)
s.	17.9	9.05	274.9	179	8.62	8	177.4	0.73	0.07	230	0.015	119	0.662
10'	17.8	9.02	275	179	8.64	-	176.8	0.6	-	-	-	-	-
20'	17.8	8.99	275.1	179	8.63	-	178.2	0.55	-	-	-	-	-
30'	17.7	8.96	275.1	179	8.62	8	179.2	0.75	0.611	230	0.015	121	18.5
40'	12.7	5.13	287.5	187	8.26	-	186.6	0.59	-	-	-	-	-
50'	11.2	1.67	295.4	192	8.01	-	189.2	0.29	-	-	-	-	-
60'	11	0.55	296.6	193	7.86	10	190.2	0.22	0.437	270	0.073	118	2.02

Table 7: Shoreline Sampling Portage Lake –2019

Jun5 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 (mg/L)	ALK (mg/L)	Chlor. A (ug/L)
A 8.5’	16.1	10.1	284.5	184	8.38	8	164.5	0.68	1.17	230	0.015	131	0.358
B 6’	16.5	9.92	307.9	200	8.31	8	178.5	0.47	0.708	230	0.016	158	4.86
D 8’	16.5	10.07	303.1	197	8.39	8	195.8	0.75	0.535	230	0.046	149	0.71
Jul 31 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 (mg/L)	ALK (mg/L)	Chlor. A (ug/L)
A 10’	24.3	9.3	277.3	180	8.8	8	138.6	0.87	0.402	230	0.047	92	0.32
B 10’	24.5	9.13	278.3	181	8.8	8	115.3	0.75	0.352	230	0.037	100	0.272
D 10’	24.2	9.46	280.3	182	8.8	8	110.7	0.67	0.394	230	0.047	107	0.897
Oct 1 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 (mg/L)	ALK (mg/L)	Chlor. A (ug/L)
A* 10’	17.9	8.82	276	179	8.64	8	169	0.7	0.021	230	0.021	108	1.37
B 10’	18	8.7	289.7	188	8.52	8	173.5	0.36	0.014	250	0.014	131	10.5
D* 10’	18.4	8.77	276.6	180	8.63	11	172.3	0.56	0.022	230	0.022	106	0.65

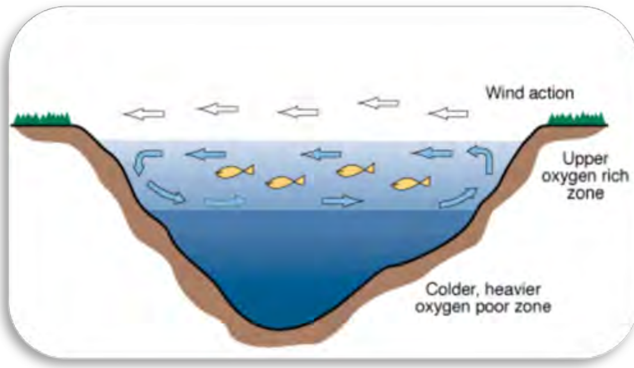
***End of summer samplings for shoreline sites included the standard site 3B, but A was moved to the small cove and D was moved to Portage Point Inn.**

Table 8: Storm Drain Sampling Portage Lake – May 1, 2019

	Temp (C)	D.O. (mg/L)	Cond. (uS/cm)	TDS (mg/L)	pH (S.U)	TP (ug/L)	Nitrate (ug/L)	Flow (Ft/sec)	Weather rainy,60
#2 Zosel Park	7.6	10.4	437.2	307	7.79	20	500	0.4	cloudy
#5 Fourth St	8.4	7.6	52.8	344	7.5	39	500	0.2	very turbid
#6 Third St	8	10.88	188.8	122	7.78	37	500	0.1	turbid
#7 First St.	8.4	7.66	117	761	7.39	23	1220	0.4	turbid

Temperature and Dissolved Oxygen Profiles

Depth profiles of temperature and dissolved oxygen indicate that on June 4 the lake was already stratified. The surface levels were above saturation, 10.38 mg/L at Basin 1 and 10.29 mg/L at Basin 2 with shoreline ranging from 9.92 to 10.1 mg/L. At this time, Portage Lake had adequate dissolved oxygen all the way down to 60' in depth (9.12 mg/L in Basin 1 and 7.8 mg/L in Basin 2). On June 5, the lake was thermally stratified, with a thermocline at approximately 30' in Basin 1 and 30' in Basin 2 – similar results in 2018. 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 1, four storm drains (table 9) and seven tributaries (table 4) were tested coming into Portage Lake. All sites were well oxygenated ranging from 7.6 to 11.8 mg/L, similar to previous years.

In late July, the lake was still strongly divided. The late July sampling was added into the program in 2015 and has been sampled since. Basin 1 was stratified and was almost anoxic at the bottom of the lake (void of oxygen). The thermocline in Basin 1 was 30', similar to most recent years. Oxygen levels stayed more consistent and didn't start declining until 60' and at that point the oxygen levels started a quick drop from 8.25 mg/L to 7.8 mg/L. This is up substantially from 2018 and 2017. The 2019 sampling showed more oxygen than the previous few years, which had shown a decline in trending oxygen levels. 3.0 mg/L is generally considered anoxic. In Basin 2, the surface waters had oxygen levels at 9.22 mg/L (similar to past years) and a thermocline at 30' (deeper than 2018). Oxygen levels were much improved in July 2019 compared to recent years, with the bottom waters above 3.0 mg/L. Basin 2 deep sample had a reading of 3.45 mg/L compared to 0.93 mg/L in 2018. More oxygen was present in the 30'-50' range than in the last few years as well, another positive sign.

During the fall, the lake was still stratified in Basin 2 but not Basin 1 during the sampling period. In years past, both mixing and no mixing has been found during this sampling period. The warmer September weather allowed a strong stratification to be found in 2018, much stronger than in the last few years. However, in 2019 only one Basin was not mixed. Basin 1 was not stratified and it was NOT anoxic below the thermocline (void of oxygen). DO levels ranged from 8.8 mg/L at the surface to 8.54 mg/L at the bottom, much higher than previous years. This is an excellent sign for the lake since 3.0 mg/L is generally considered anoxic. In Basin 2, which in many years has already mixed, had a thermocline during the sampling at 40'. Further, the oxygen was saturated from top to the thermocline and then was void of oxygen to the bottom. 9.05 mg/L at the surface, 5.13 mg/L in the thermocline and 0.55 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. The 2019 sampling shows good oxygen levels present in the hypolimnion, compared to previous years.

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 October as well as in the tributaries and shoreline sites. The pH in June ranged 7.9-8.11, in July from 7.87-8.81 and in October from 7.86 -8.64. The shoreline sampling was similar to the deep hole basins as was the tributary and storm drain sampling. This data is consistent with 2018 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 October in both Basin 1 and Basin 2. The average sampling between both basins in June was 127 mg/L with a range of 113-139 mg/L. The July samples were similar with an average of 112 mg/L with a range of 84-131 mg/L. The October samples were similar with an average of 116 mg/L with a range of 104-121 mg/L. All samplings show the lake to be considered "soft" with readings under 150 mg/L, a typical threshold of a hardwater lake. Overall, the 2019 readings on the lake are slighter lower than previous readings, but overall show consistent softwater 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 combined readings of TDS on Portage Lake ranged from June readings averaging 195 ug/L, July averages of 195 ug/L to September readings averaging 192 ug/L. (Shoreline samplings were very similar to deep basins). The tributary sampling was slightly higher, averaging 248 ug/L in May and 247 ug/L in October. 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 with the basin average of 280 uS/cm in May, 281 uS/cm in late July and 278 uS/cm in October. (uS/cm=microsiemens per centimeter). 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 404 uS/cm while October average is 278 uS/cm). Tributary readings are similar to past readings.

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 126 - 191 mV in the spring sampling to 144 - 171 mV in the late July sampling to 131 - 190 mV in the end of summer/fall sampling, indicating oxidized conditions. Tributaries and shoreline samples had similar results and these are similar readings to past samplings.

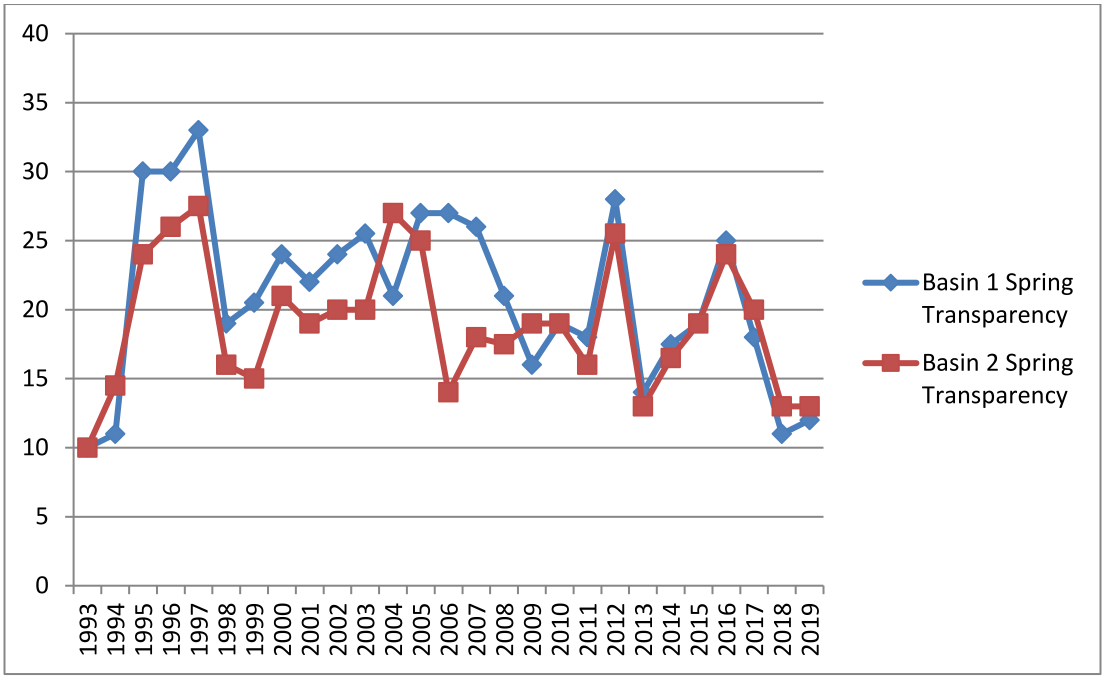
Turbidity

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 ranged from 0.79 – 4.34 (at the bottom) NTU's in June to 0.78 - 1.1 NTU's in late July to 0.22 - 0.75 NTU's in October. Shoreline sampling ranged from 0.47 - 0.75 NTU's in June, 0.67 - 0.87 NTU's in late July and 0.36-0.7 NTU's in October. 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.

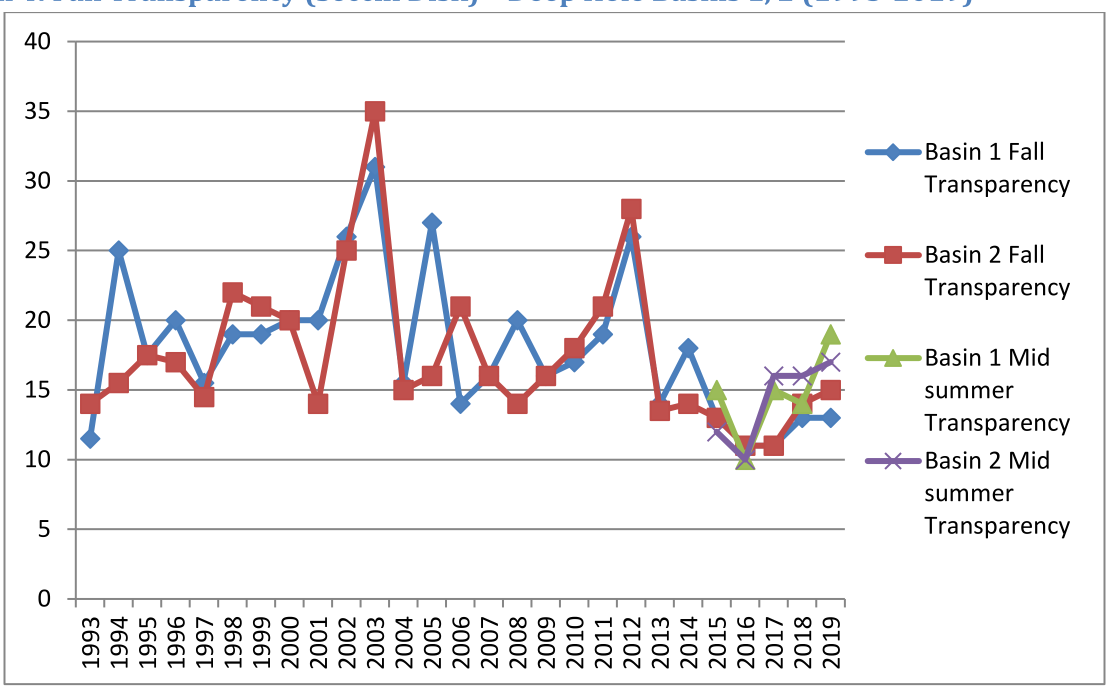
Secchi Disk Depth

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 12' while Basin 2 was 13'. Clarity improved with the Secchi disk depth of 19' in late July in Basin 1 and 17' in Basin 2 and was at 13' in Basin 1 and Basin 2 was at 15' in October. Water clarity can fluctuate from week to week depending on several environmental factors such as rain fall & algal production. Basin 2 may likely be more affected by the fetch of the lake, therefore would likely have a lower Secchi disk reading, which is not evident each year. These clarity readings show that sunlight is available for plant and algae throughout a good portion 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 October samplings.

Graph 3: Spring Transparency (Secchi Disk) – Deep Hole Basins 1, 2 (1993-2019)



Graph 4: Fall Transparency (Secchi Disk) – Deep Hole Basins 1, 2 (1993-2019)



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, 8 μg/L at the lake surface, and 8 μg/L at thermocline depth and 8 μg/L in the bottom water. The June shoreline readings from sites 3A was 8 μg/L, 3B was 8 μg/L and

3D 8 μg/L. The tributary TP readings in May ranged from 8-19 μg/L (decreased from 2018). Storm Drain TP May readings were from 20-39 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 past years, showing a slight trend down. The tributaries and storm drains were similar to the past, more elevated than the basins.

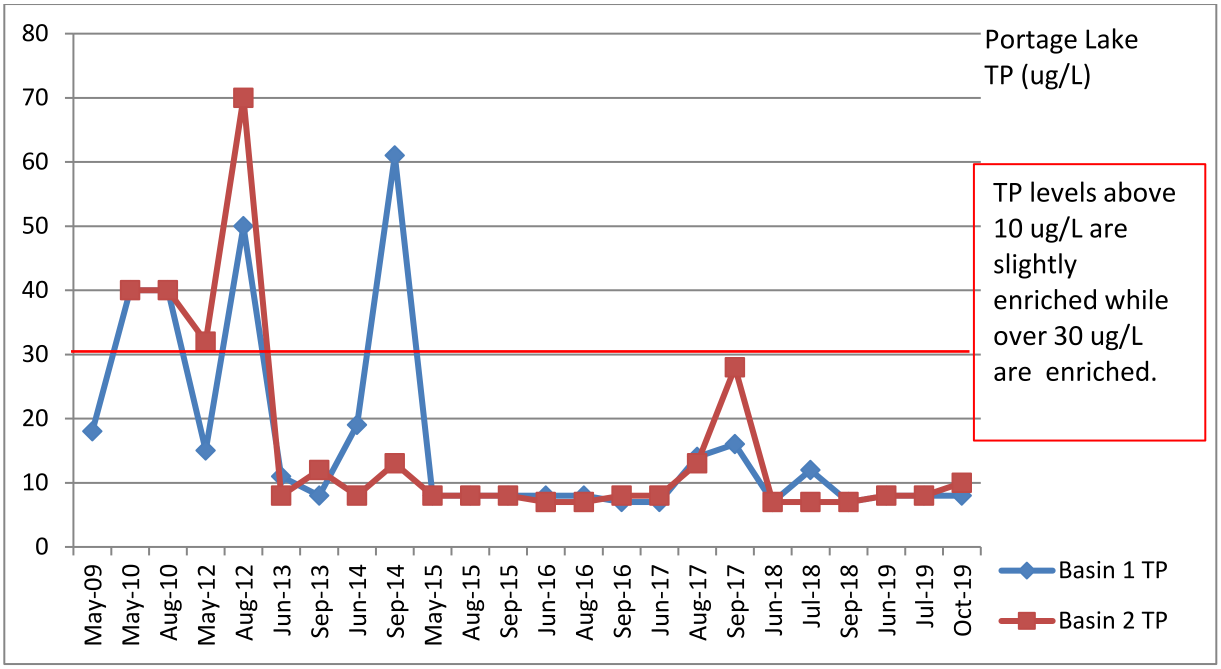
Late July Total Phosphorus concentrations were: Basin 1: 8 μg/L at the surface, 8 μg/L in the thermocline and 8 μg/L at bottom while Basin 2: 8 μg/L at the surface, 8 μg/L in the thermocline and 8 μg/L at bottom. No increases from the June testing and readings are still well below levels of concern.

End of summer Total Phosphorus concentrations were: Basin 1 12 μg/L at the surface, 13 μg/L at 30' and 8 μg/L at bottom while Basin 2; 8 μg/L at the surface, 8 μg/L in the thermocline and 10 μg/L at bottom. All of these results are similar to 2018. In 2017, levels were increased from 2016, so this is an excellent sign for Portage Lake that both 2018 and 2019 levels are down overall. Note: The levels are still under the 30 μg/L level, which we hope to avoid. In years past, Tributary sampling showed Stream #9 was generally the highest of the reading; however, in 2016 McCormick showed the higher reading, and in 2018, McCormick was still high compared to the other Tributaries. In 2019, the tributaries were similar in the spring and more polluted in the end of summer. The tributary samplings showed higher levels of TP compared to the basins, with numerous results considered slightly elevated-to-elevated. Additional tributary upstream testing was again done with the end of summer sampling and findings were slightly elevated, but not as large of a concern as some years.

The end of summer readings show that overall, slightly higher phosphorus concentrations are found in the tributaries and that internal loading was not a large contributing factor to TP in 2018 or 2019. The 2019 data shows the TP has decreased slightly in both Basins, similar to what was found in 2018, and still well below historical 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, the last few years of data has shown a declining trend.

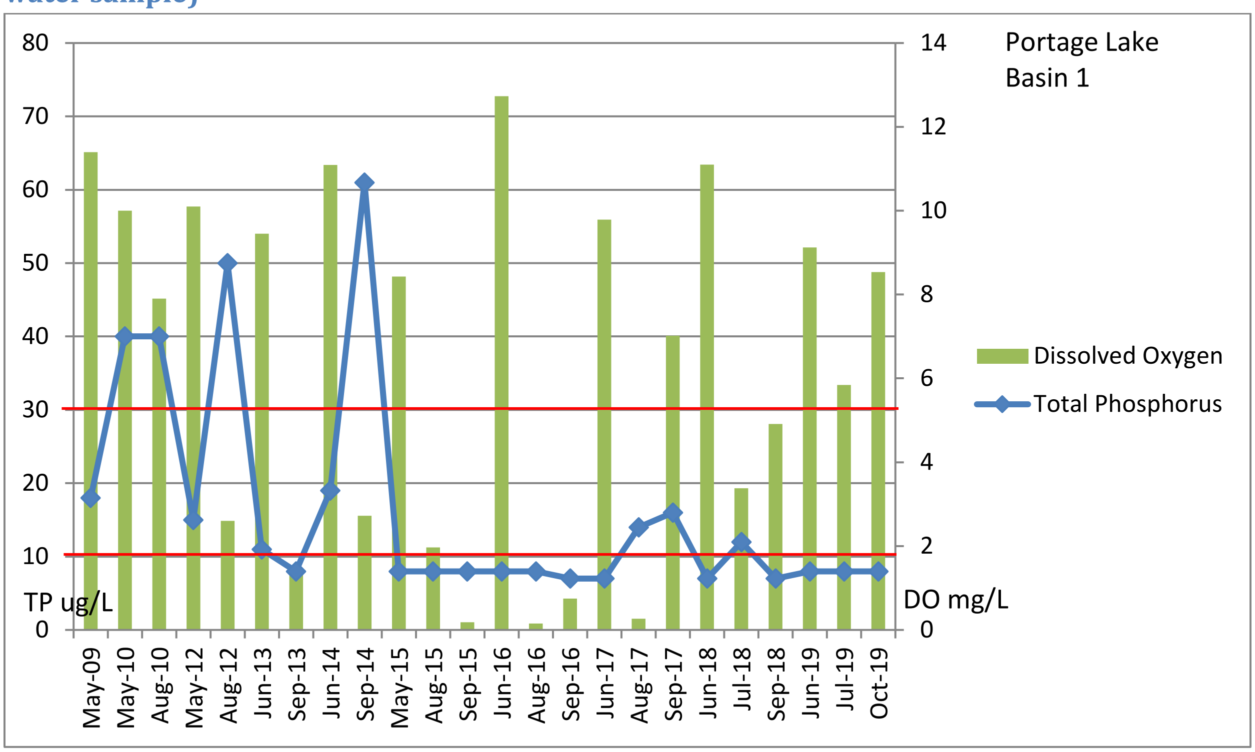
See below graphs of TP concentrations from 2019. Basin 1 and 2 are graphed using data previously collected on Portage Lake (via various sources, provided to PLM via the Portage Lake Watershed Forever website with permission from the committee).

Graph 5: Total Phosphorus – Deep Hole Basins 1, 2 (2009-2019) (deep water sample)



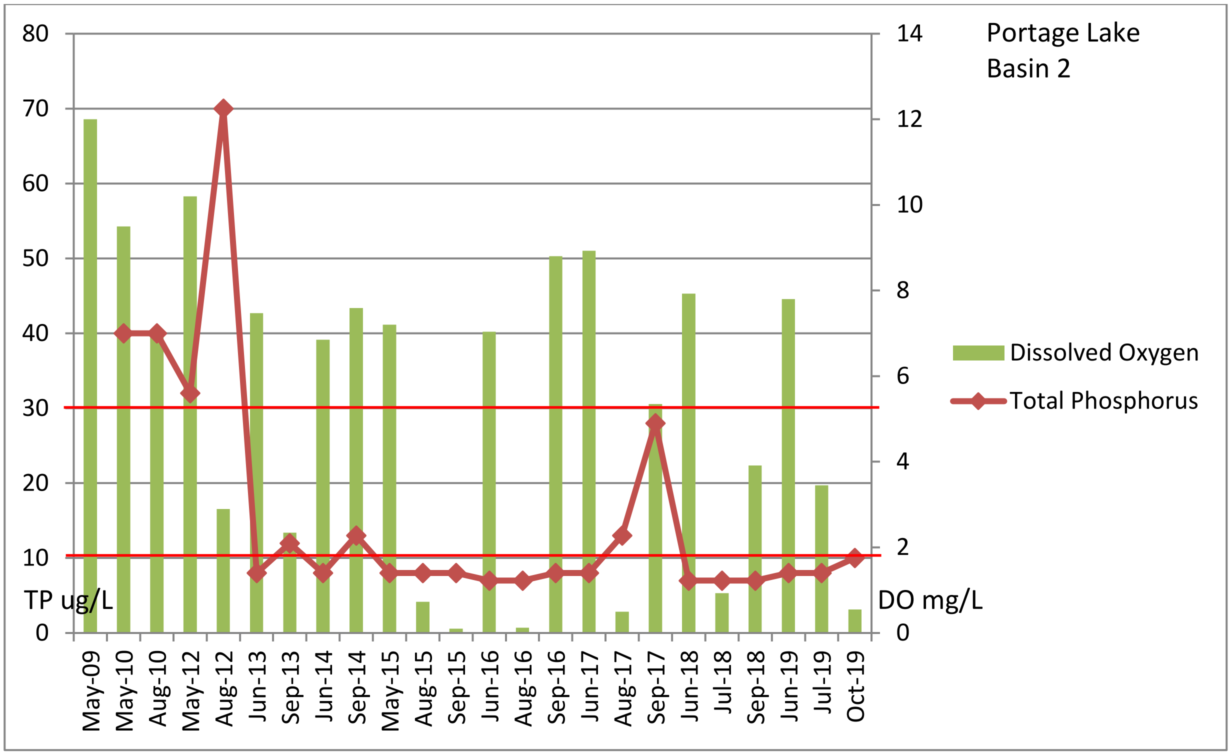
There have been a few spikes in TP over time, an overall decrease in 2013 and a large spike in Basin 1 in 2014, likely an outlier based on 2015 and 2016 results. Basin 2, which has been higher in TP, had the same results in 2015 and 2016, showing a declining trend in overall TP in Portage Lake. The 2017 results, although show a trend up, are far below data collected from 2009-2012. In 2018 and 2019, TP concentrations have declined, showing a downward trend for 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, (2009-2018) (deep water sample)



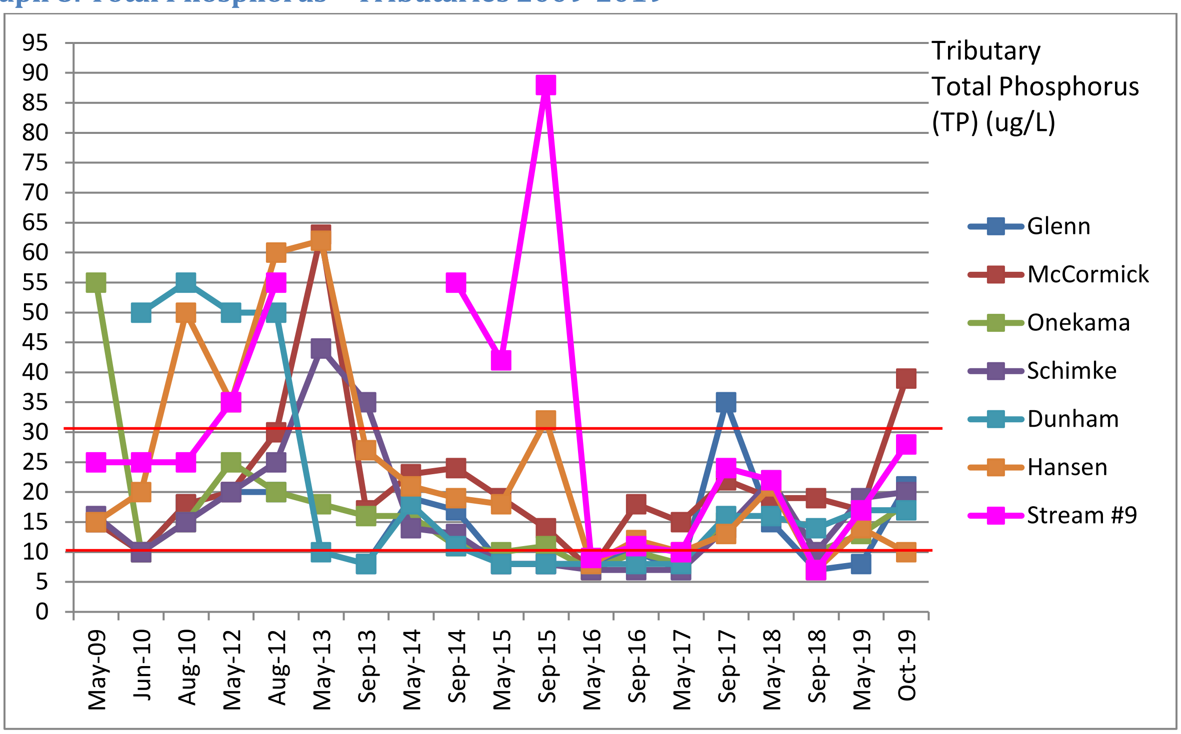
Internal loading can take place when dissolved oxygen levels decrease. In 2018 and 2019, DO levels throughout the summer were better, than some past years, and low-level TP concentrations were found. There is no indication of internal loading taking place.

Graph 7: Total Phosphorus & Dissolved Oxygen – Deep Hole Basin 2, (2009-2019) (deep water sample)



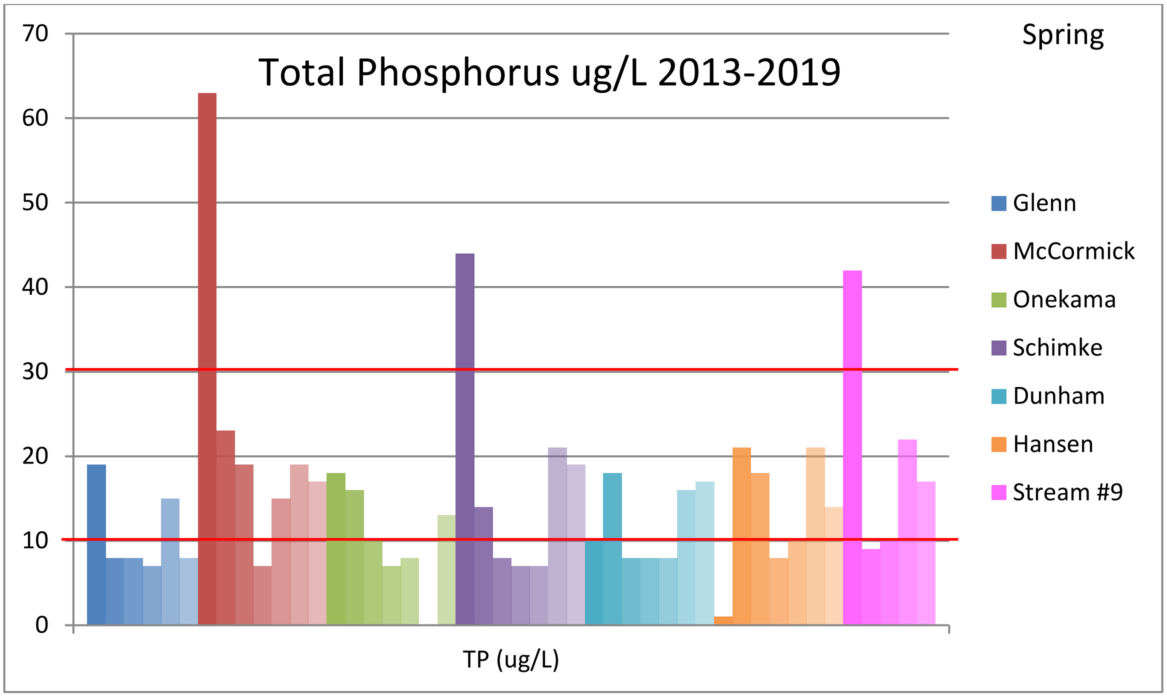
DO levels had decreased for a few years, and in 2017, TP levels had increased. However, in 2018 and 2019, generally the DO is better and the TP is down. There is no indication of internal loading in Basin 2.

Graph 8: Total Phosphorus – Tributaries 2009-2019



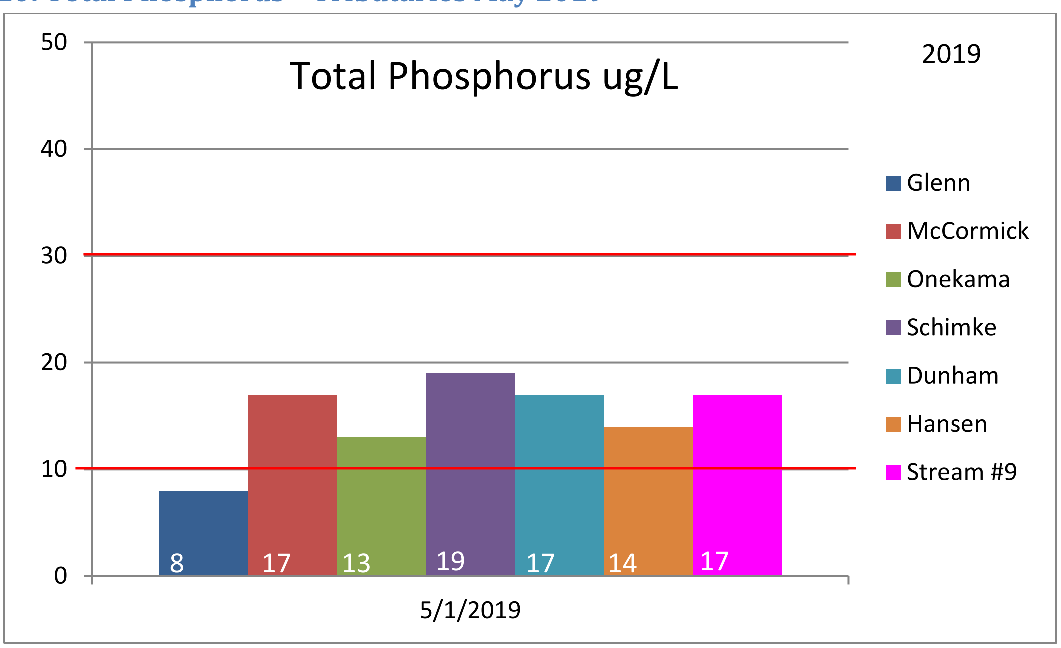
As the graph illustrates, there are fluctuations between the creeks over time. See below graphs to show the 2019 comparisons between the creeks. Glenn Creek May 2013 sample was removed from this graph as an extreme outlier, likely from a contaminated sample. Stream#9 was not sampled in 2013.

Graph 9: Total Phosphorus – Tributaries 2013-2019



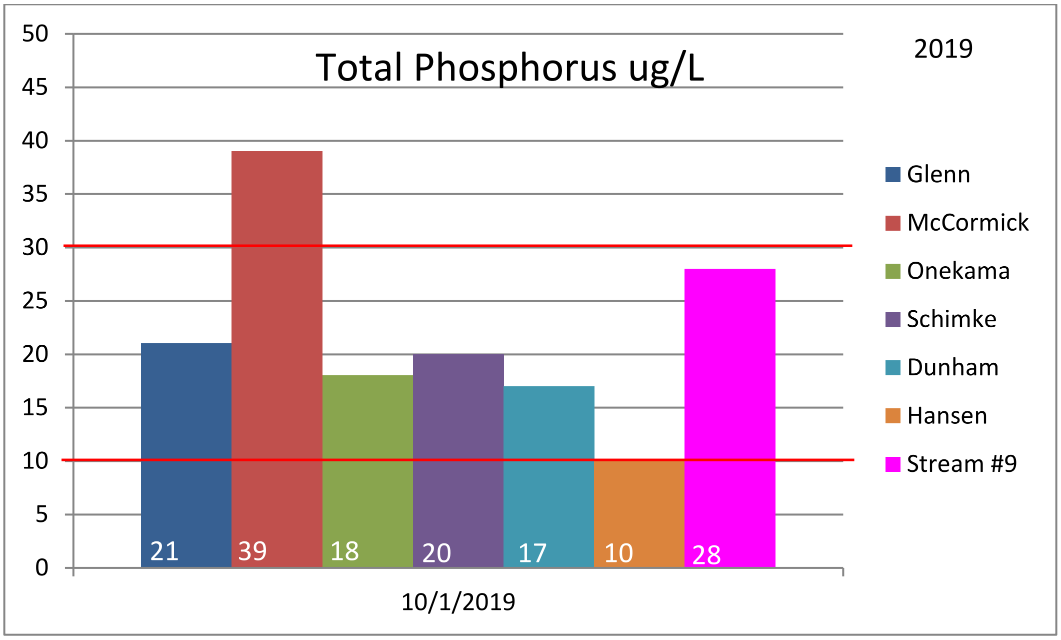
As the graph illustrates, there are fluctuations between the creeks over time. See below graphs to show the 2019 comparisons between the creeks. Glenn Creek May 2013 sample was removed from this graph as an extreme outlier, likely from a contaminated sample. Stream #9 was not sampled in 2013.

Graph 10: Total Phosphorus – Tributaries May 2019



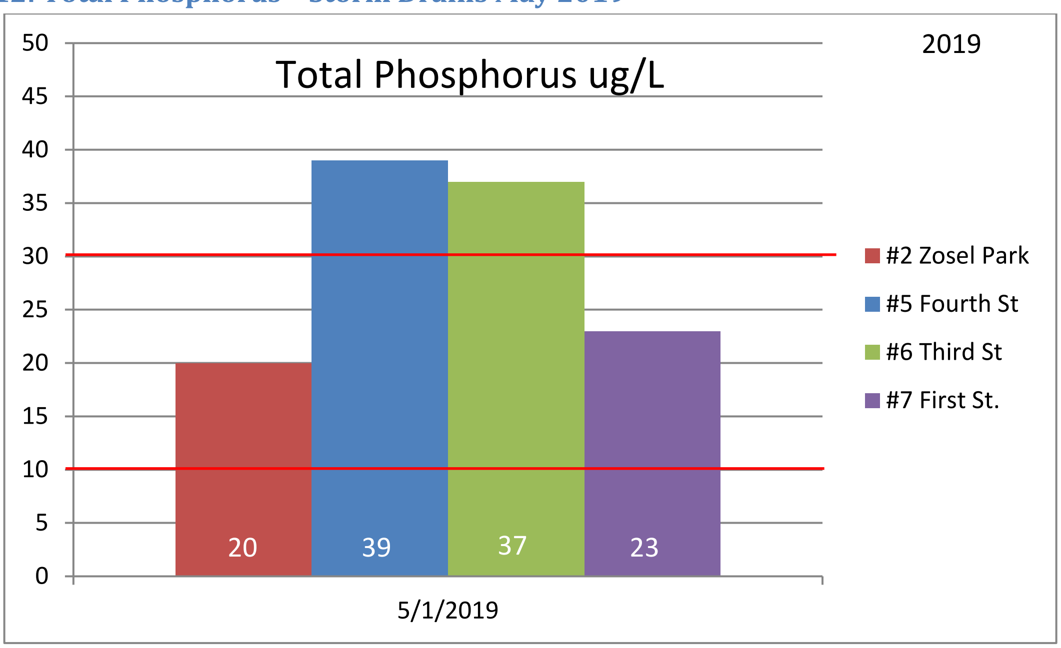
As the graph illustrates, very little fluctuation between the TP in the different creeks entering Portage Lake was found in 2019. In years past, concentrations have ranged more and been more enriched.

Graph 11: Total Phosphorus – Tributaries End of Summer 2019



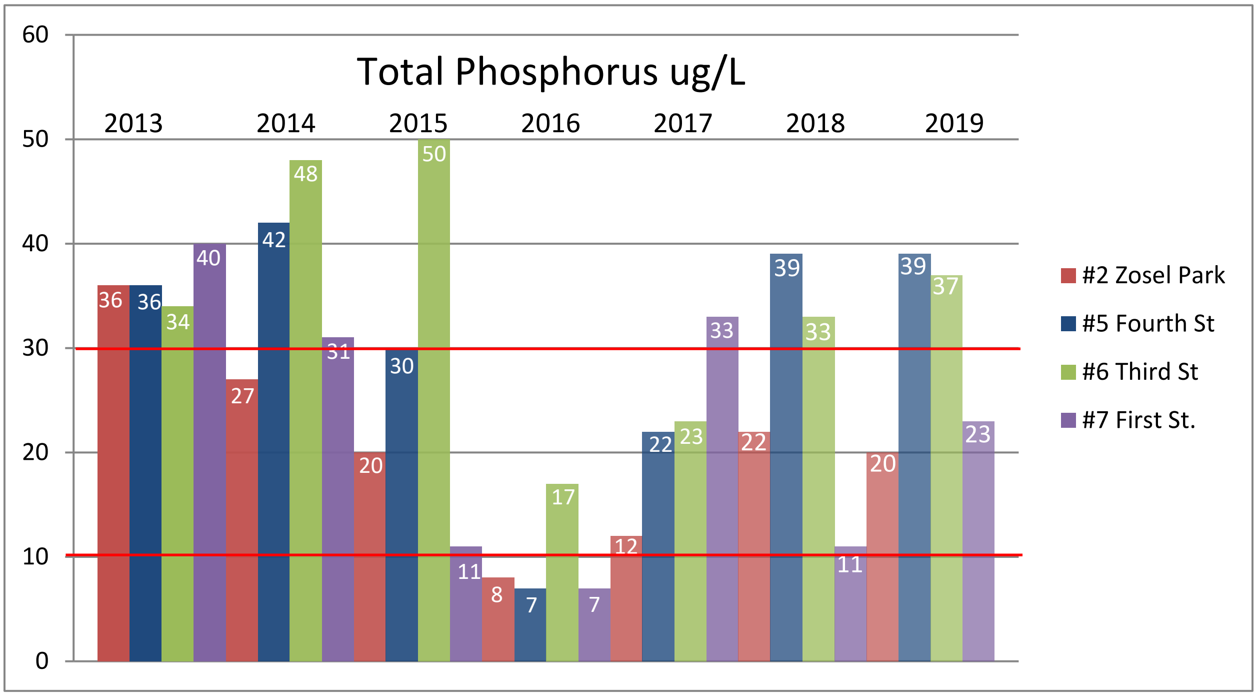
As the graph illustrates, there is fluctuation between the TP in the different creeks entering Portage Lake and overall, the samples were increased from the spring sampling.

Graph 12: Total Phosphorus – Storm Drains May 2019



As the graph illustrates, there is a fluctuation between the TP in the different storm drains around Portage Lake and overall, the samples are higher than last year.

Graph 13: Total Phosphorus – Storm Drains May 2013 - 2019

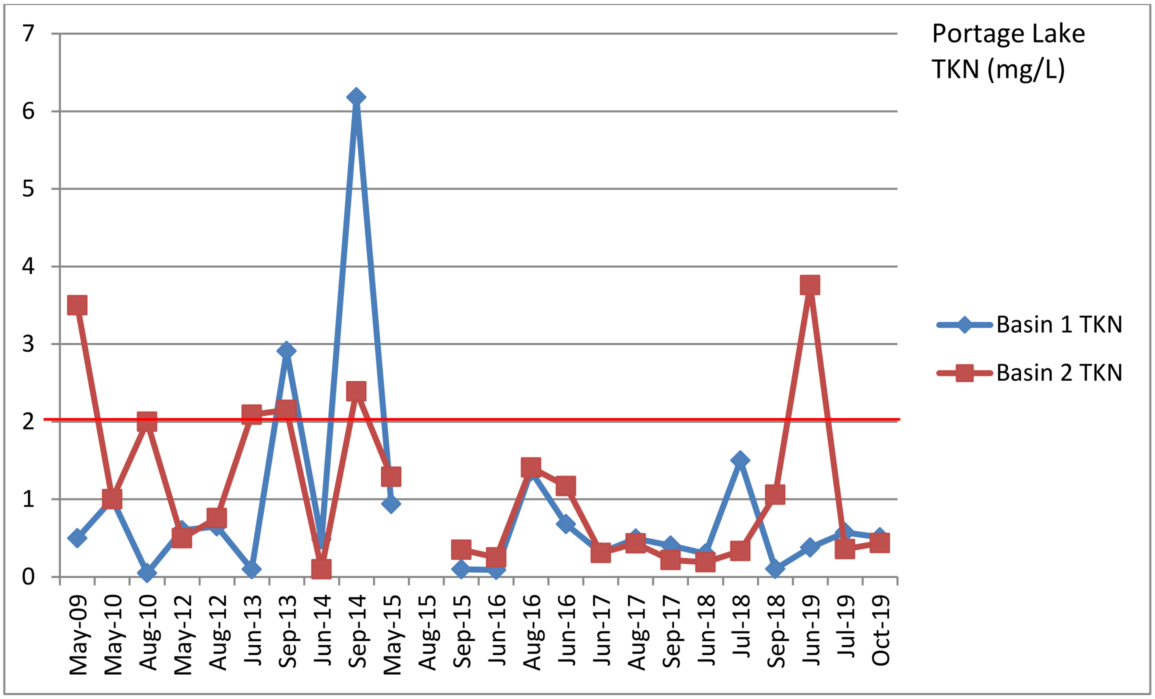


As the graph illustrates, there is variance between the TP in the different storm drains entering Portage Lake and most of the TP concentrations are considered enriched. These sites are a key introduction point of Phosphorus into Portage Lake. In general, drains have decreased in 2016, with increases in 2017, 2018 and 2019.

Total Kjeldahl Nitrogen (TKN)

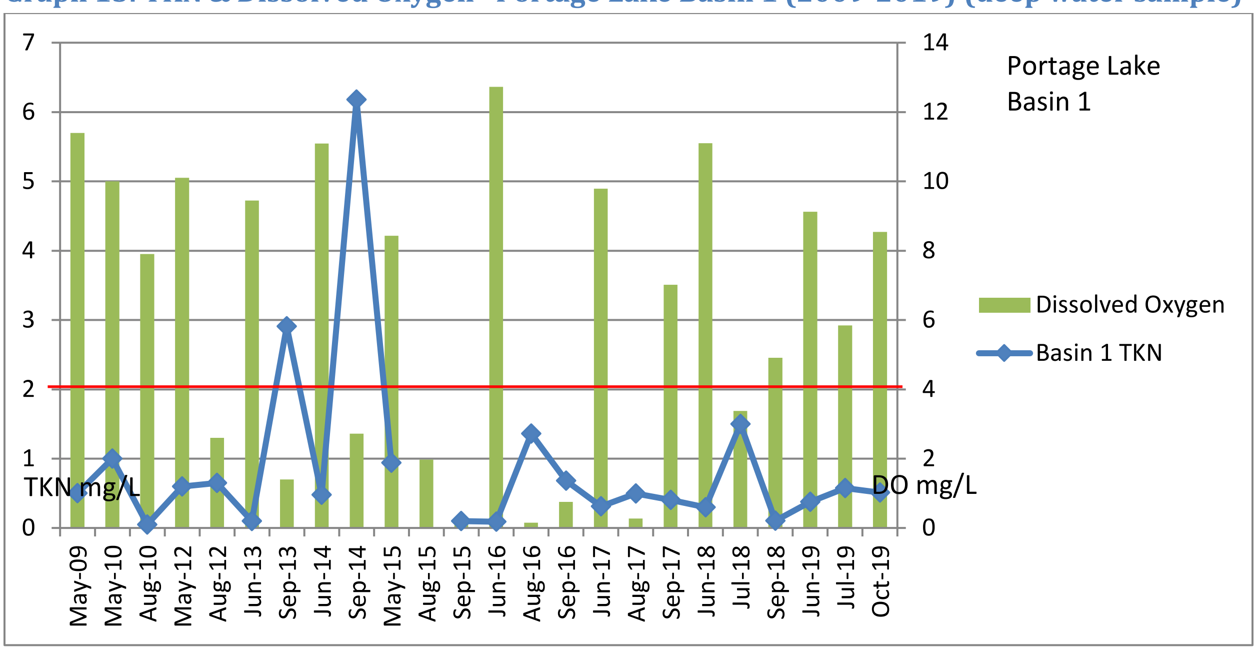
TKN measures the total organic amount of nitrogen (nitrate and nitrite) and ammonia in the water. Nitrogen is the plant nutrient (i.e. fertilizer) most likely to control the amount of rooted plant growth in lakes and ponds. Most Midwestern lakes have more nitrogen and more rooted plant growth than is 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 0.19 mg/L to 1.38 mg/L, in late July from 0.139 mg/L to 0.975 mg/L and in October from 0.07 mg/L – 0.91 mg/L between both basins. The tributaries and storm drains showed lower levels than past years as well. The tributaries samples ranged from 0.04 mg/L- 0.5 mg/L in May and from 0.004 mg/L – 1.12 mg/L in September.

Graph 14: TKN – Portage Lake Basins 1, 2 (2009-2019) (deep water sample)



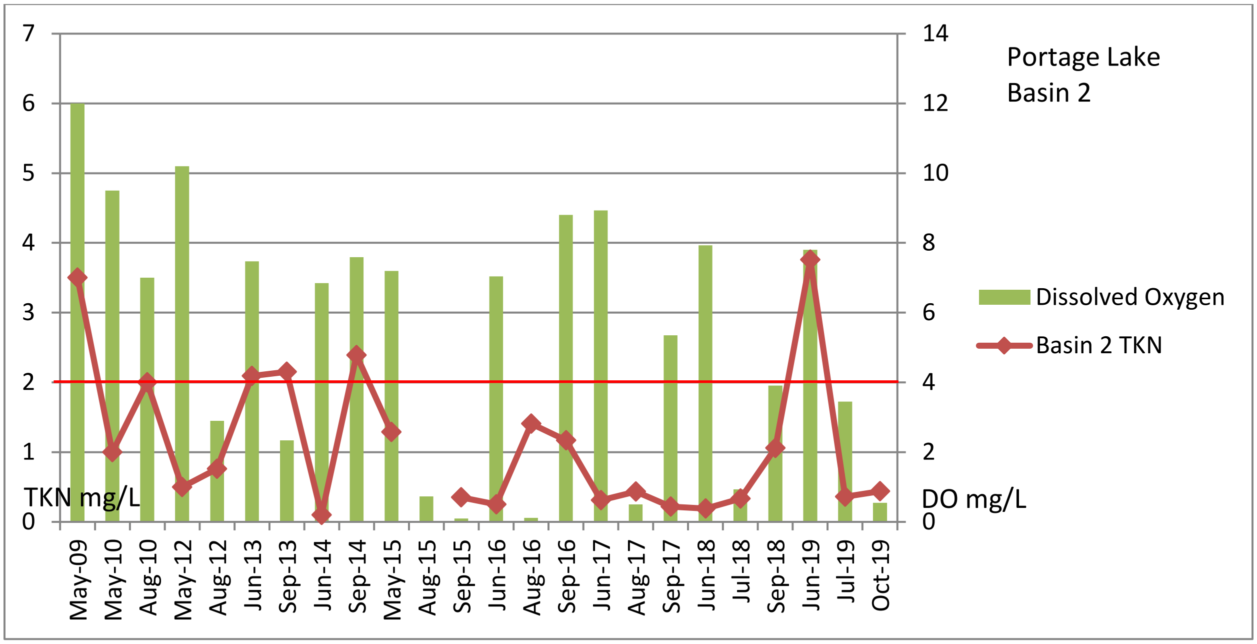
As the graph illustrates, the TKN concentrations on Portage Lake have fluctuated some in recent years and spiked in August 2014. A large spike (or outlier) in August 2015 is not graphed (readings of 12 and 47 mg/L), as additional samplings have found that to be an outlier and not a trend for Portage Lake.

Graph 15: TKN & Dissolved Oxygen– Portage Lake Basin 1 (2009-2019) (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. In 2016-2018 samplings show low TKN levels regardless of DO levels, indicating no internal loading taking place. In 2019. DO levels were better than recent years and TKN was overall low, another excellent sign and indicating no internal loading.

Graph 16: TKN & Dissolved Oxygen– Portage Lake Basin, 2 (2009-2019) (deep water sample)



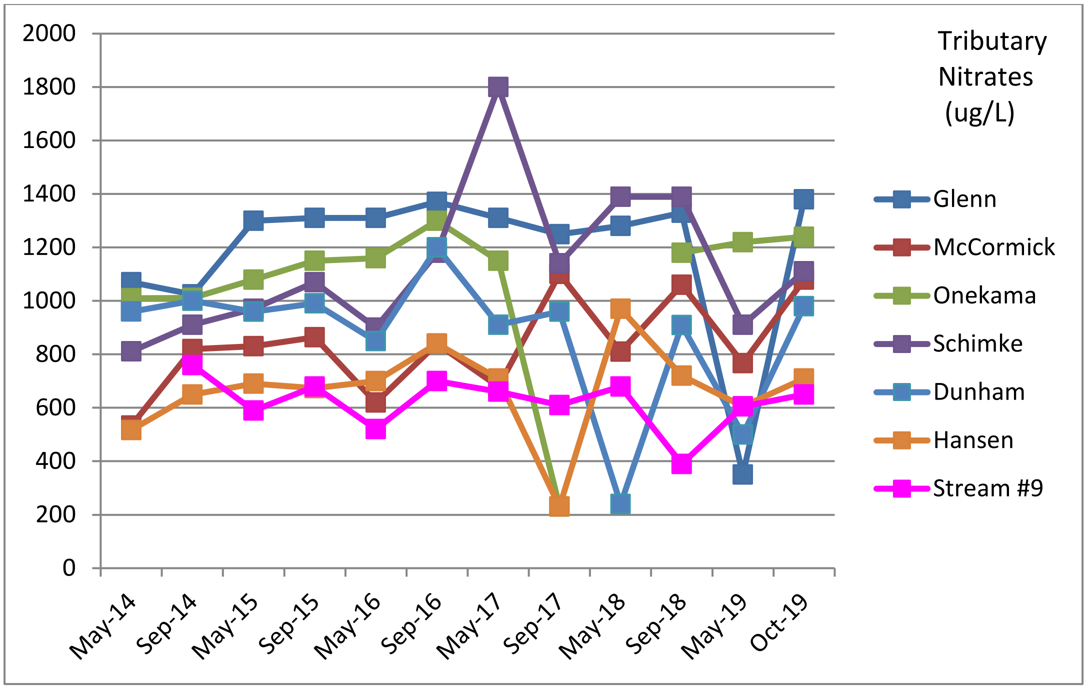
Basin 2 has followed a similar pattern to Basin 1 and as no indication of TKN increasing with decreased DO levels, indicating no internal loading.

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 ranged from 230 µg N/L to 254 µg N/L. The late July readings ranged from 230 µg N/L to 368 µg N/L and October concentrations of nitrates ranged from 230 µg N/L to 270 µg N/L in both basins throughout the water column. Nitrates in the tributaries ranged from 350 µg N/ to 1220 µg N/L in the spring and from 650 µg N/ to 1380 µg N/L in October, which are slight increases. The Strom Drains ranged from 500 µg N/L to 1220 µg N/L, classifying as 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. Based on the higher levels of nitrates observed in inlets (Tributaries and Storm Drains) in May and October, 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.

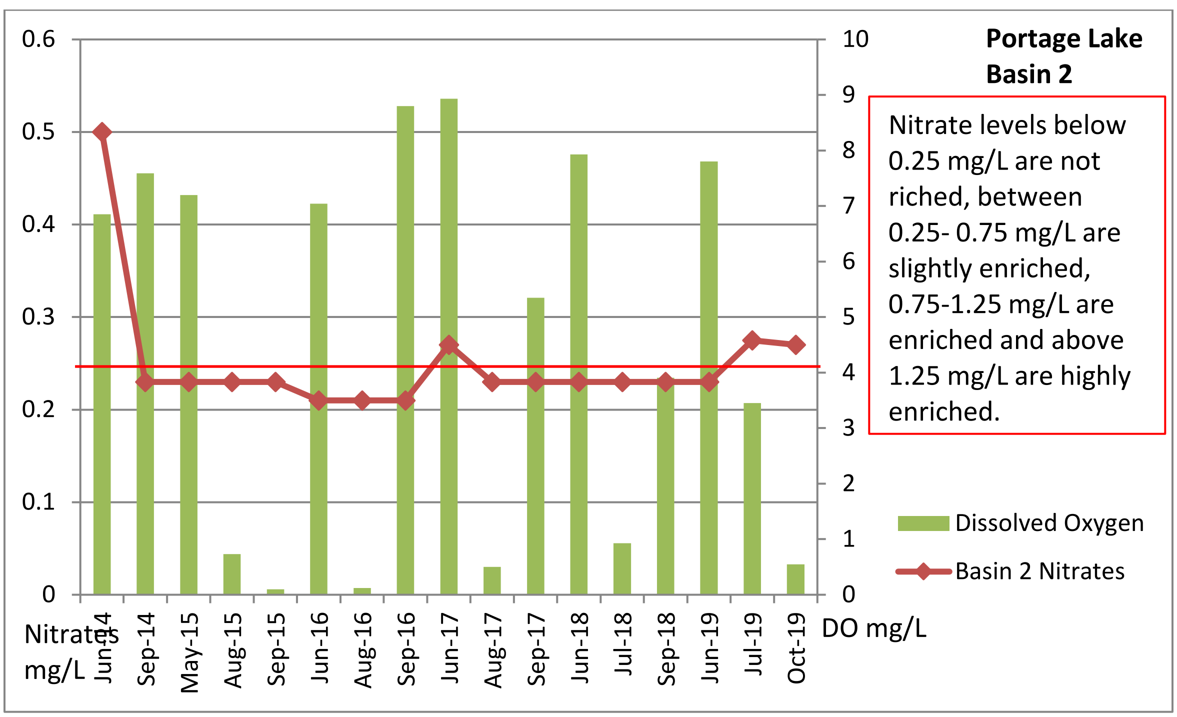
These samples show that the lake (at the time of sampling) may be Phosphorus limited. Phosphorus limited lakes tend to have a TN:TP >15. In 2019 the average TN was 248 ug/L in the basins and the TP 8.6 ug/L, giving a TN:TP of 28. In 2018 the average TN was 242 ug/L in the basins and the TP 8.4 ug/L, giving a TN:TP of 28. Both readings indicate Phosphorus may be the limiting nutrient. This is common in most lakes in this geographical area.

Graph 17: Nitrates– Portage Lake Tributaries

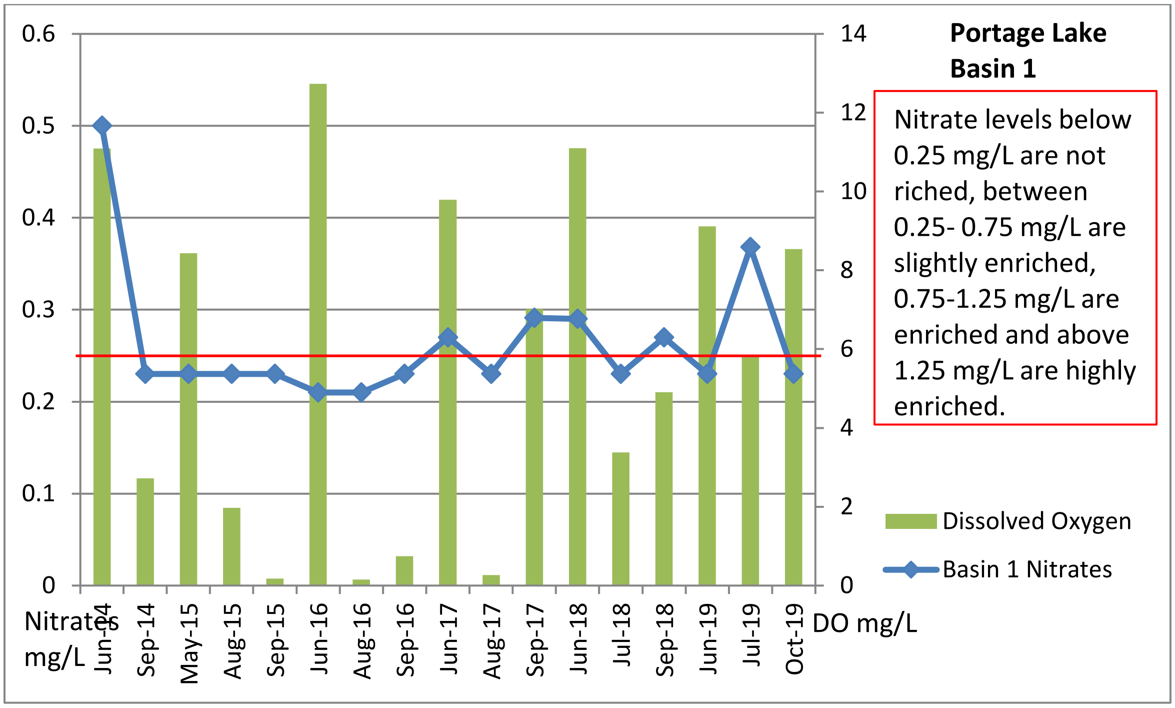


As the graph illustrates, the nitrate concentrations in the Portage Lake Tributaries range from slightly enriched to enriched to highly enriched. It is recommended to continue testing.

Graph 18: Portage Lake Nitrates Basin, 2(2014-2019) (deep water sample)



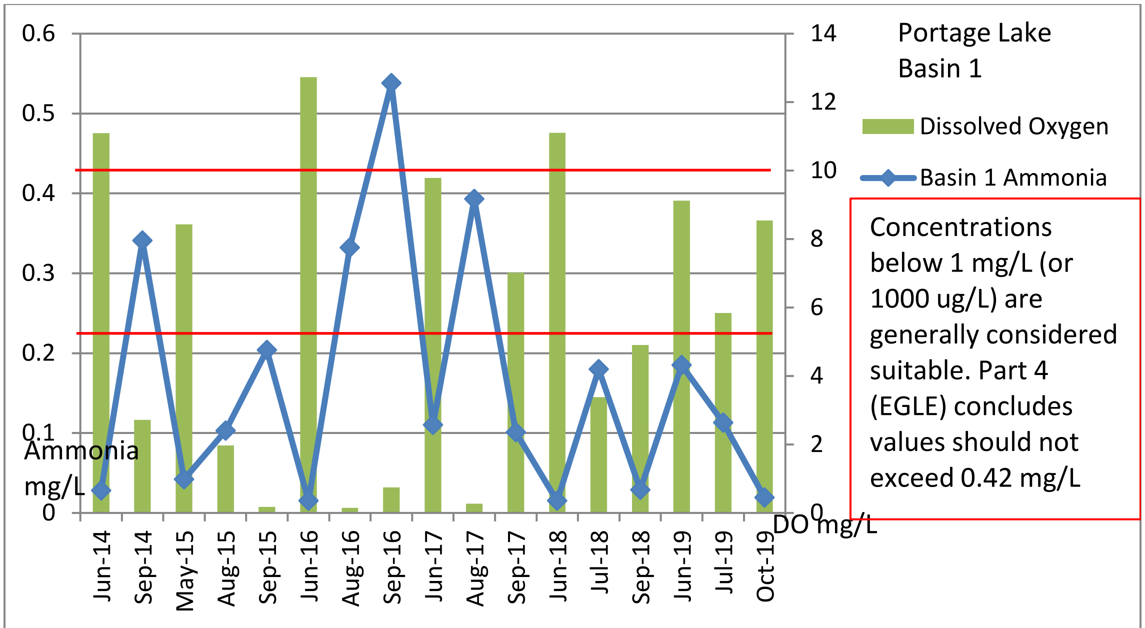
Graph 19: Portage Lake Nitrates Basin, 1(2014-2019) (deep water sample)



Ammonia

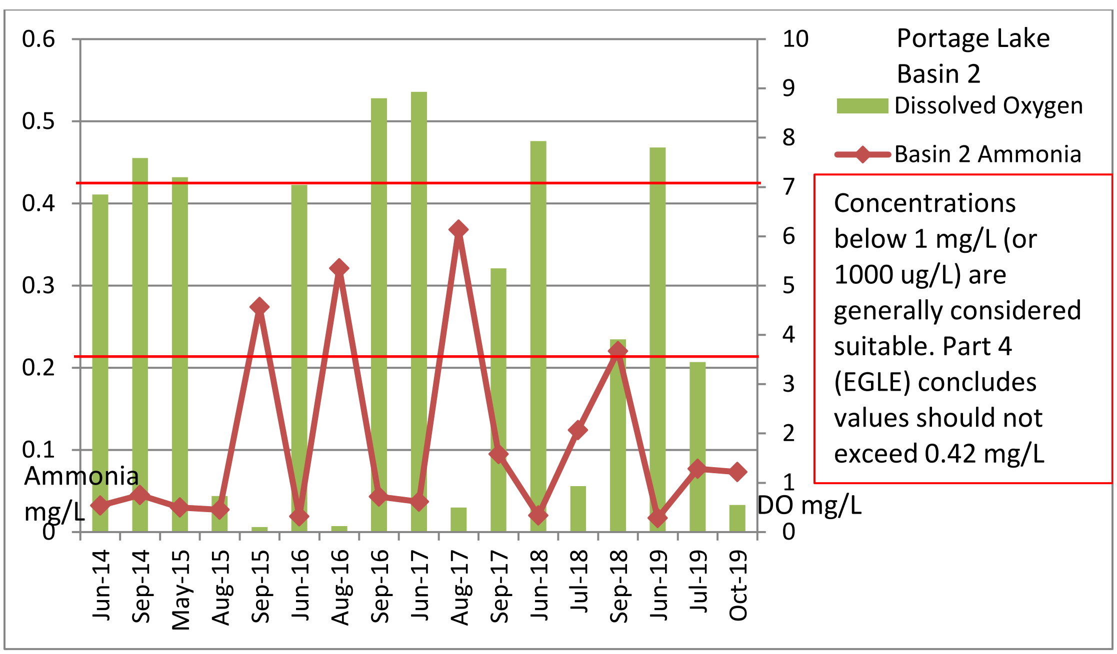
Ammonia is a form of nitrogen found in organic materials, sewage, and many fertilizers. It is the first form of nitrogen released when organic matter decays. Also, when ammonia degrades it consumes oxygen, which worsens already existing anaerobic conditions. However, ammonia can be used by most aquatic 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 1 mg/L (or 1000 ug/L) are generally considered suitable for healthy fisheries; however, Ammonia concentrations can have impacts on aquatic organisms at lower levels. It is important to review all ammonia concentrations based on the specific lake type, temperature, pH and dissolved oxygen. Michigan EGLE includes standards in part 4 (Water Resources Protection, Water Quality Standards) that ammonia shouldn't exceeded the Aquatic Maximum Value (AMV) threshold of 0.21 mg/L (210 ug/L) in which they feel negative impacts can occur in aquatic communities. Further, the Final Acute Value (FAV) shouldn't exceed a concentration of 0.42 mg/L (or 420 ug/L) where short term exposure can lead to negative impacts on aquatic organisms. Ammonia concentrations usually do not become elevated until water is void of oxygen and the nitrates are converted. Therefore, concentrations of Ammonia do not become elevated until anaerobic conditions are present, typically mid-summer. The concentration of ammonia at the Basin 1 in June was 0.015 mg/L (or 15ug/L) at the surface and 0.185 mg/L (185 ug/L) at the bottom while in Basin 2 it was 0.015 mg/L (or 15 ug/L) at the surface and 0.017 mg/L (or 17 ug/L) at the bottom. In late July, the concentrations were 0.064 mg/L at the surface and 0.113 mg/L at the bottom in Basin 1 and 0.033 mg/L at the surface and 0.077 mg/L at the bottom in Basin 2. The October concentrations were 0.032 mg/L at the surface and 0.019 mg/L at the bottom in Basin 1 and 0.015 mg/L at the surface and 0.073 mg/L at the bottom in Basin 2. All readings are well within range for a healthy fishery. The shoreline areas ranged from 0.014 mg/L – 0.047 mg/L throughout the summer, all considered very low. As oxygen is not an issue here, this is expected. The tributaries had similar levels of ammonia as the lake throughout the season. Ammonia concentrations ranged from 0.015 mg/L to 0.170 mg/L (with an average of 0.041 mg/L) in the tributaries.

Graph 20: Ammonia– Portage Lake Basin, 1 (2014-2019) (deep water sample)



As the graph illustrates, the ammonia concentrations in the Portage Lake Basin 1 are elevated when DO levels decline (i.e. in 2016); which is expected in anaerobic conditions. Although some thresholds have concentration spikes elevated on Portage Lake, the general review of the Ammonia trend is low. When spikes have been seen, internal loading of ammonia was likely.

Graph 21: Ammonia– Portage Lake Basin, 2 (2014-2019) (deep water sample)

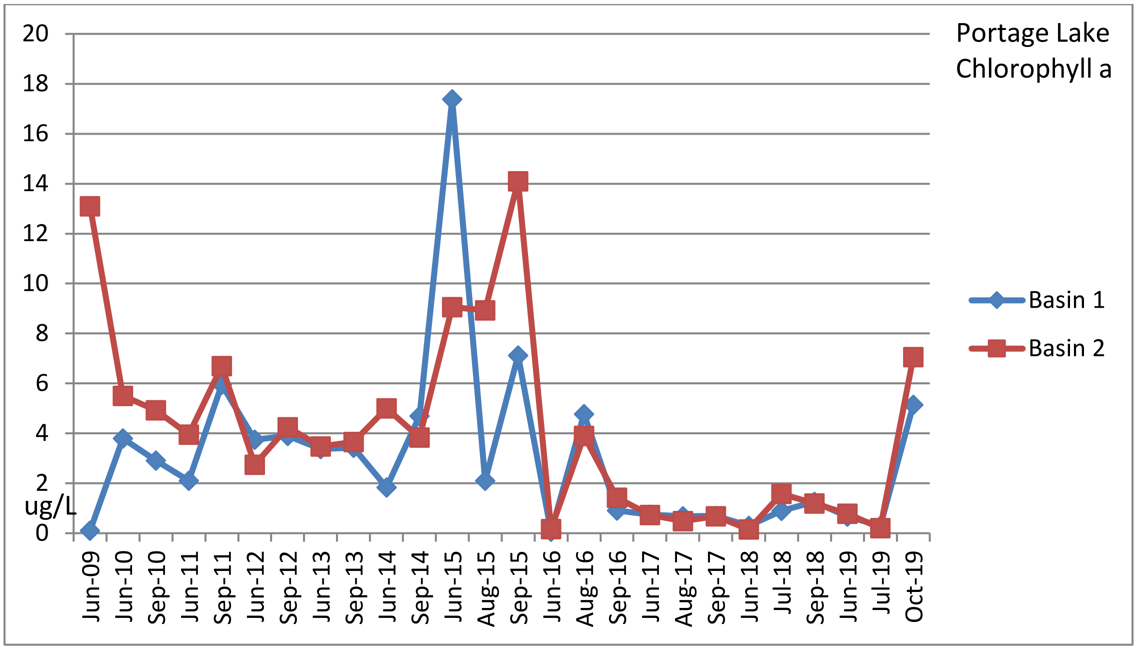


Basin 2 follows Basin 1 with spikes in Ammonia concentrations when DO levels drop.

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 0.1 ug/L to 0.31 µg/L indicating low plankton populations. Shoreline samplings sites (3A, 3B, 3D) averaged 1.97 ug/L. Chlorophyll in the Deep Basins ranged from 0.1 ug/L – 0.32 ug/L in late July. In October, Chlorophyll ranged from 0.662 ug/L to 18.5 ug/L. The shoreline sites averaged 0.49 ug/L in late July and 12.5 ug/L in September. A higher level, in shallow, warmer waters is common as the warmer water can be a breeding ground for plankton. Overall, chlorophyll levels have varied some in recent years.

Graph 22: Chlorophyll a– Portage Lake Deep Basins



Chlorophyll a sampling has declined over the last few years with some spikes, likely weather related. End of summer 2019 samplings showed some spikes. Additional monitoring is recommended.

Algae and Zooplankton Composition

Algal composition testing was performed at both deep Basins as well as the shoreline testing sites in June, late July and September. The June testing showed the majority genera present included (presented as most abundant to least abundant); Cyanophyta (blue green algae)*: Microcystis sp.*, Bacillariophyta (diatoms): *Cyclotella sp., Asterionella sp., Fragilaria sp., Tabellaria sp.;* Chlorophyta (green algae): *Chlamydomonas sp., Scendesmus sp., Spirogyra sp., Pediastrum sp.* The July sampling found Bacillariophyta (diatoms): *Fragilaria sp., Cyclotella sp.;* Chlorophyta (green algae): *Pediastrum sp., Chlorella sp., Gloecystis sp., Ulothrix sp.;* Euglenophyta, specifically *Trachelomonas sp.;* Cyanophyta (blue green algae), specifically *Microcystis sp*., The September sampling found Cyanophyta (blue green algae), specifically *Microcystis sp*., *Gloeotrichia sp.*, the most abundant species and genera of phytoplankton followed by Chlorophyta (green algae): *Pediastrum sp., Chlorella sp.;* Bacillariophyta (diatoms): *Fragilaria sp.*. 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. High overall zooplankton populations were found during the June and July samplings, which hasn't been noted on previous lab reports.

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.

In the last decade, E.Coli monitoring has become a priority for the watershed in order to ensure healthy, clean water for the area's residents and visitors. E.Coli data has been collected throughout the watershed by various entities including District 10 Heath Department, Onekama Village, Onekama Township and PLM Lake & Land Management. Between 2009 and 2018, 264 composite samples were collected around Portage Lake and its tributaries. Only two of these samples exceeded partial body contact and four exceeded total body contact criteria. All samples that exceeded these water quality standards were collected in Schimke Creek and Stream #9.

In the year 2018, the scope of the E.Coli monitoring expanded to include road end beaches and tributary streams. A total of three samples at 10 sites were collected six times between June and August, five of which were dry weather events and one which took place during a rain event. As previously mentioned, Schimke Creek and Stream #9 had elevated E.Coli levels over the total body contact criteria and are under further inspection.

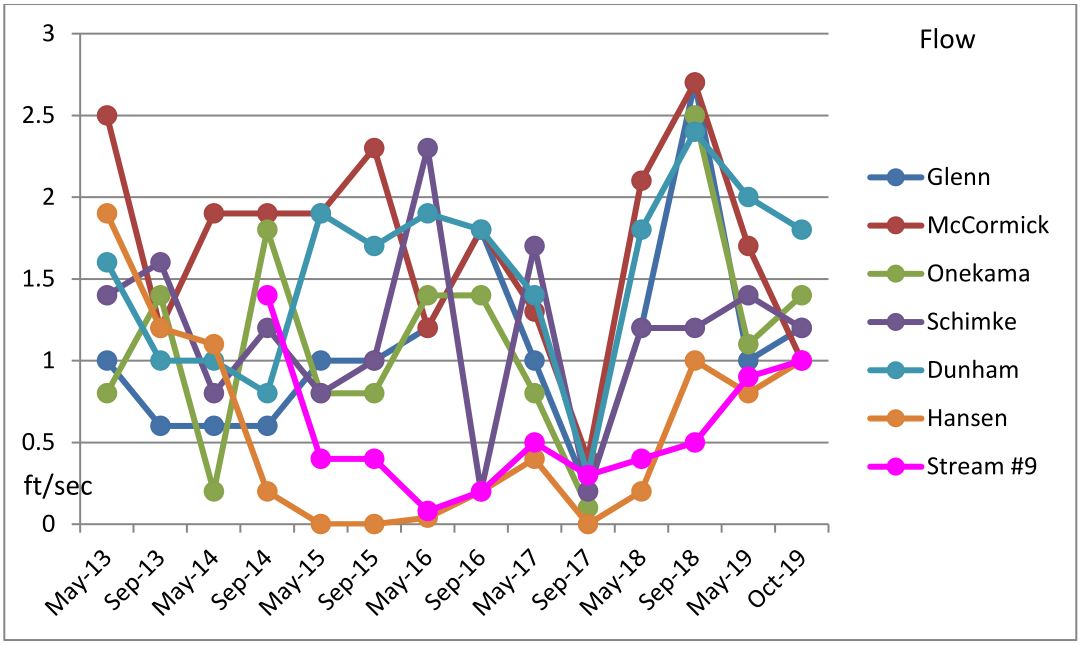
The majority of the sample sites in the Portage Lake watershed that have been monitored for E.Coli have had consistently low concentrations meaning that in the context of E.Coli, water quality is high and public health risk is low.

2019 monitoring found no elevated sampling in the July sampling, which tested numerous locations including Portage Point Inn, Swimming beaches, Camps, and inlet areas. An additional sampling was done during the year end sampling and those results all low as well, including sites Portage Point Inn, access, Schimke Creek and the Marina.

Tributary Flow and Phosphorus

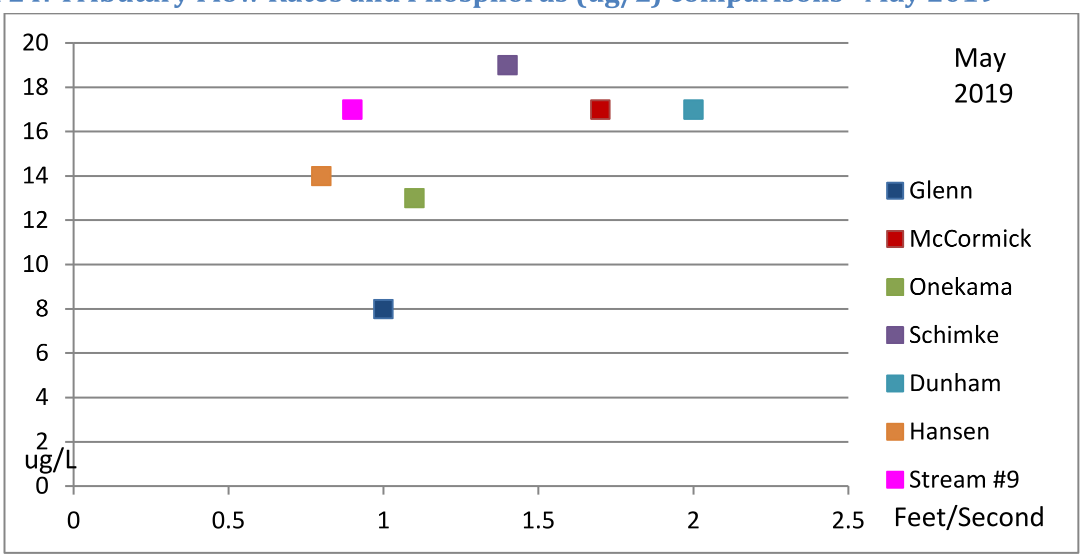
Flow rate data was determined, using a digital flow meter, at the seven tributaries studied in May and in October 2019. Flow ranged from 0.8 feet/second – 2.0 feet/second in the May sampling and from 1.0 feet/second – 1.8 feet/second in October. Unlike some previous years, Dunham Creek was the fast flowing in 2019. 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 23: Tributary Flow Rates –May and September 2013-2019



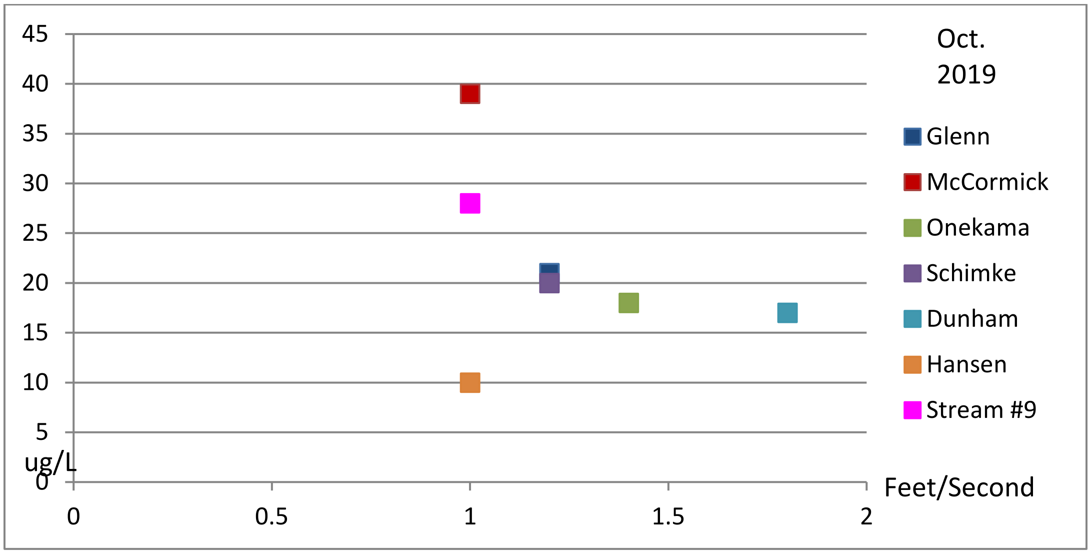
Historically, the graph illustrates that there is a decline in flow rate at the end of the summer versus the beginning of the summer. Typically, higher flows in spring will increase nutrient inputs in the spring and they decrease in the fall. This is standardly due to snow melt and spring rain. Generally speaking, the flow in 2019 had a smaller range and overall higher average. This likely correlated with high water levels in the watershed.

Graph 24: Tributary Flow Rates and Phosphorus (ug/L) comparisons –May 2019



In years past, the graph has illustrated a correlation between flow and TP. The greater the flow, the higher the Total Phosphorus. (This correlation has historically been strong.) In 2018, the TP concentrations were all elevated, regardless to flow and in 2019, TP levels were high and the average flow amount the tributaries was higher than previous years.

Graph 25: Tributary Flow Rates and Phosphorus (ug/L) comparisons –October 2019



End of summer readings found similarly elevated TP readings and a higher average of flow. The correlation doesn't seem as strong in 2019, but is still present and likely impacted with the amount of water present in the watershed.

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. 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.

Of the data collected, most locations came up somewhat enriched, with the largest concern being Stream #9. Because Stream #9 was the largest concern in 2016, it was selected for upstream testing in 2017, 2018 and 2019.

Of the four locations sampled on Stream #9, all samples came back lower than 2016 and 2017 results, a positive sign. Additional sampling needs to be collected to determine if a downward trend is occurring or if it was a seasonal response.

Map 5: Portage Lake Upstream Tributary testing locations

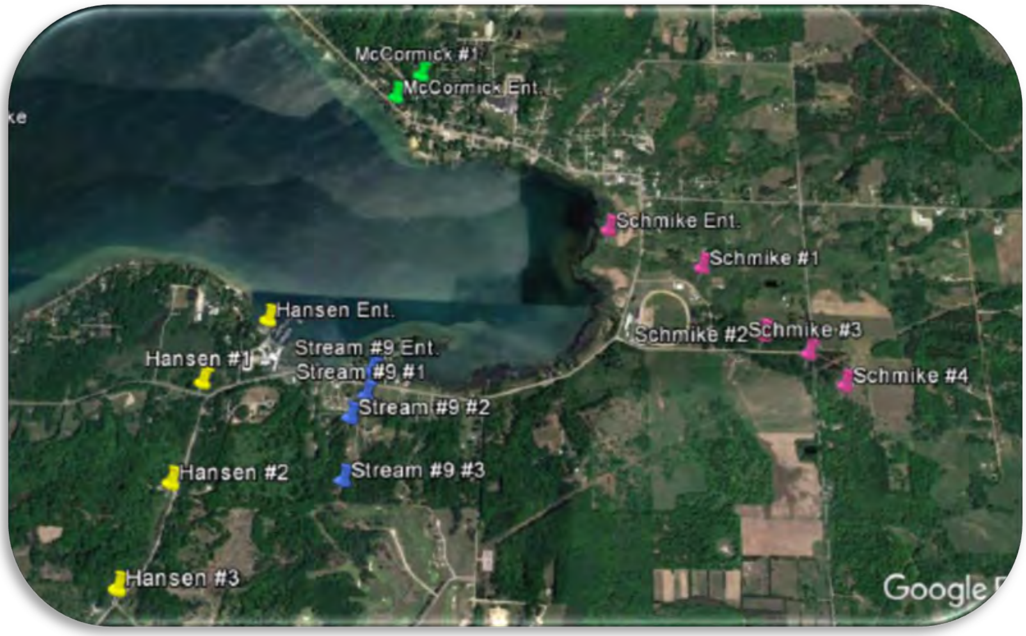
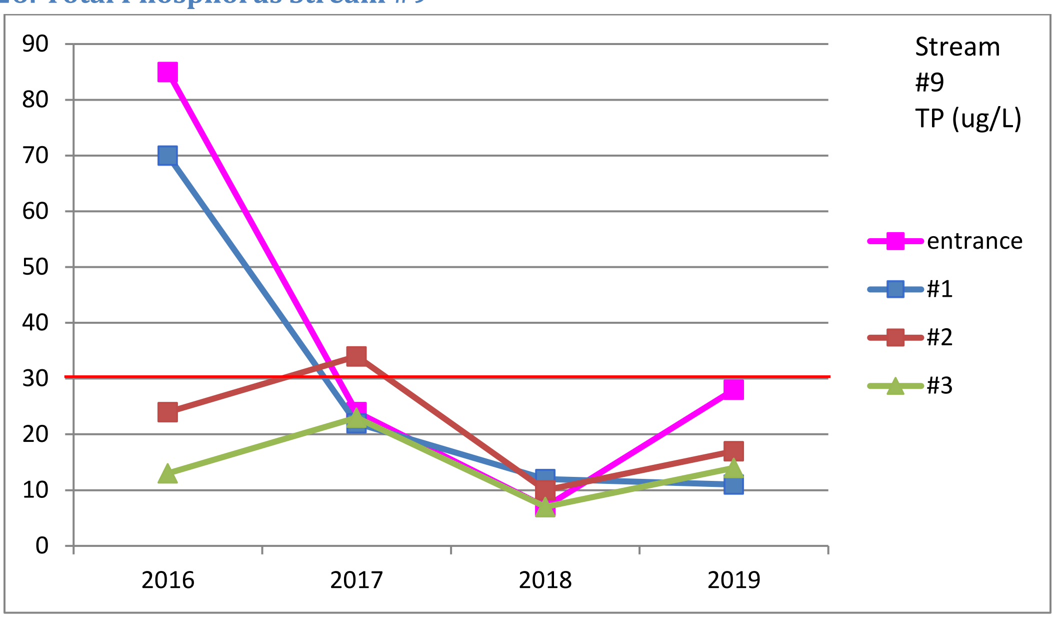


Table 9: Upstream Tributary Testing 2019

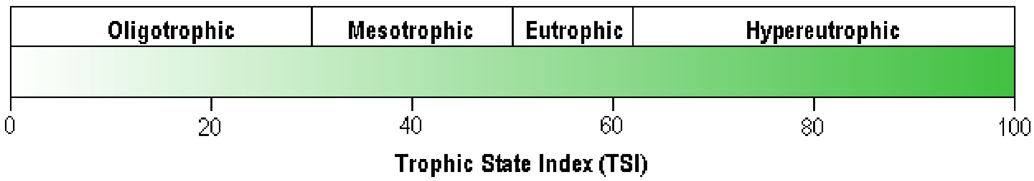
	10/1/2019	Total Phosphorus	Nitrates
Stream #9	Entrance	28	650
	#1	11	863
	#2	17	700
	#3	14	636

Graph 26: Total Phosphorus Stream #9



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 21 and 42, in late July between 19 and 40 and in October between 27 and 40 (Table 12). In general, these values rate Portage Lake as oligotrophic to mesotrophic. 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.

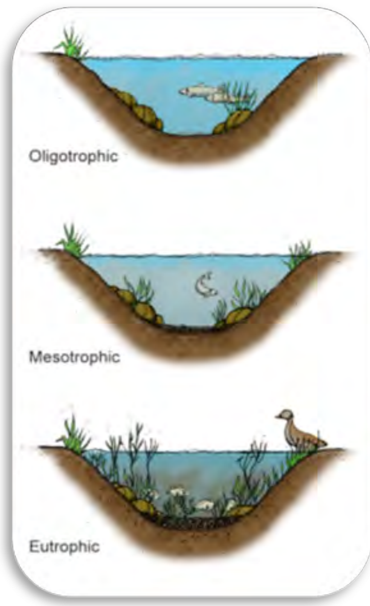


Table 10: 2019 Trophic State Index (TSI) Values

Site	Secchi Depth	Total Phosphorus	Chlorophyll a
Basin 1 – June	42	30	30
Basin 2 – June	40	30	21
Basin 1- Aug	35	30	19
Basin 2- Aug	36	30	19
Basin 1 – Oct	40	36	38
Basin 2 – Oct	38	30	27

2019 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. 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 2020

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 2020 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.

A new herbicide, ProcellaCOR, was used on Portage Lake in 2018 and successful controlled the milfoil present. These areas will be re-elevated in 2019, but this product should be incorporated into the program as much as positive. ProcellaCOR has systemic like capabilities, while using low application rates and potentially allowing for multiple season control.

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 11: Proposed 2020 Budget Portage Lake

Proposed/ Estimated Budget	2020
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 2020:

- 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