Lake Oscawana Management Plan

Prepared for the Lake Oscawana Management Advisory Committee

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Report Outline

This document is a combination of three reports that together encompass an overall updated lake management plan for Lake Oscawana.

1. 0 Water Quality Monitoring - This section includes a detailed overview of water quality in 2018, as well certain trends and observations from historical data. The 2019 monitoring data is reviewed in a separate monitoring report to be published in early 2020.

2. 0 Watershed Based Management Plan – This section contains a detailed watershed assessment that goes beyond the existing 2008 Total Maximum Daily Load (TMDL) report for watershed phosphorus management. **This Watershed-Based Plan includes an update to the TMDL Implementation Plan** with a list of actionable measures to improve water quality, to submit to the New York Department of Environmental Conservation (NYDEC).

3.0 Aquatic Plant Management Plan - Aquatic plant management is inherently linked to water quality improvement, yet the specific NYDEC/EPA formats of both the Watershed Based Plan and the TMDL Implementation Plan Update do not allow for the inclusion of plant-specific components to an overall lake management plan. For that reason, this plant management plan became a report unto itself. This plant management section refers back to water quality data presented in the 2018 Water Quality Monitoring Section (1.0) and provides a framework for integrated improvements in plant management techniques at Lake Oscawana.

Table of Contents

List of Maps

List of Figures

List of Tables

1.0 Water Quality Monitoring Results

The Lake Oscawana 2018 water quality monitoring was conducted over seven visits from April to October. Monthly in-lake water quality measurements consisted of water clarity, temperature, dissolved oxygen, and conductivity. Zooplankton and phytoplankton samples were collected during each visit. Water samples were collected at three established in-lake stations, as well as the seven main inlets.

1.1 Description of Monitoring Components

* This section reiterates definitions from the monitoring components section of the 2017 Water Quality Monitoring Report.

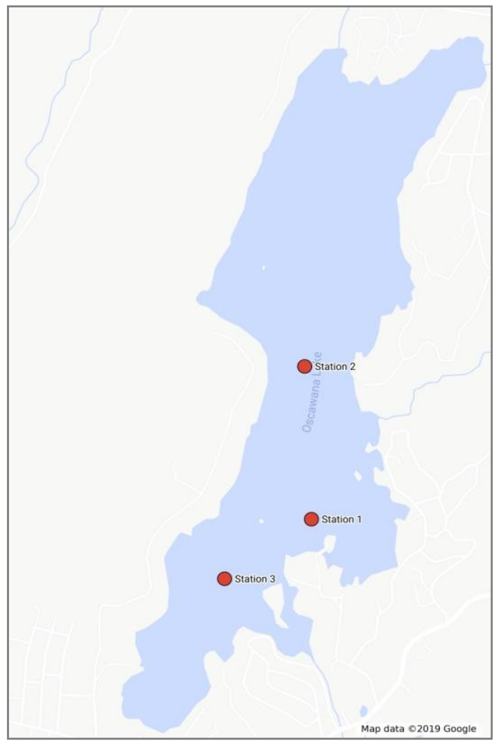
Lake Sampling Sites

Station 1: The "Deep Hole" is approximately 35-ft deep and is the primary water quality monitoring site.
(41.39063, -73.84836)

Station 2: The northern monitoring station is located in approximately 27-ft of water.
(41.39553, -73.84824)

Station 3: The southern station is also located in roughly 27-ft of water and represents water quality near some of the most populated and disturbed areas of the lake.
(41.38817, -73.85275)

All stations are too deep to support aquatic plant growth, and all stations lose oxygen from late spring to late summer. Monitoring data at three stations has proven critical in determining the sources and causes of nutrient pollution in the lake because the three sites differ substantially depending variable lake conditions.



Secchi Disk Transparency

Water clarity was measured during each visit to the lake at the three sampling sites. A **Secchi disk** is an 8-inch circular disk that is attached to a measuring tape. The disk is lowered into the water on the shady side of the boat, and using a view scope to shade out light in one's peripheral vision, the Secchi disk is lowered until it disappears from view in the water column. The average of the depth at which it is no longer visible and the depth at which it becomes visible again when lifted slightly, is recorded as the water transparency measurement. This Secchi value is dependent on light penetration, and is affected by phytoplankton and suspended sediments in the water column. Clearer waterbodies have greater Secchi transparency values.

Lake Profile Measurements

Temperature in lakes and ponds in the northeast follow a seasonal pattern of warming and cooling. In early spring, Lake Oscawana should be uniform in temperature from top to bottom. Temperature measurements are made at one-meter increments from the lake surface to the bottom at each sampling Station. This top-to-bottom measurement is referred to as a lake profile. Temperature profile measurements change as the sun's rays penetrate into the water column. The sun warms the surface water through the spring and summer, but the depth of this warming is dependent on the water clarity. Clearer water allows for greater sunlight penetration and deeper warming into the water column. The depth and development of a **thermocline**, or the zone of rapid temperature change, is dependent on water depth and clarity. Cooling temperatures in the fall result in a weakening thermocline and eventually lake "turn-over," or when the temperature once again becomes uniform from top to bottom.

The ***RTRM (Relative Thermal Resistance to Mixing)*** is a unit-less ratio that describes the difference in water density between each meter. Higher numbers indicate stronger thermal **stratification**. Stratification is the result of density differences as warming surface waters become less dense than cold deeper water. The RTRM is a relative number that distinguishes the intensity and depth of the thermocline. RTRMs describe how the lake is or is not mixing with respect to layers of water at specific depths. RTRMs also show when the lake becomes de-stratified as the result of temperature changes or excessive wind energy that can overcome thermal density boundaries.

Dissolved oxygen in a lake is essential to aquatic organisms. At the surface of the lake, the water is in direct contact with the air, and atmospheric oxygen is dissolved into the water as a result of diffusion. As water mixing takes place, the dissolved oxygen is circulated throughout the water column. Decomposition of rooted aquatic plants and algae requires dissolved oxygen (Biological Oxygen Demand) and can deplete the oxygen levels in the bottom waters below the thermocline. This phenomenon results in **anoxic** (<1mg/L) conditions in the deeper waters for much of the season at Lake Oscawana. It is critical to track the level of the **anoxic boundary**, or the depth of water at which dissolved oxygen is depleted. Anoxic water is not suitable for respiring organisms like fish and invertebrates.

The **percent oxygen saturation** is the percentage of dissolved oxygen at a given depth, relative to the water's capacity to hold oxygen, which is based on its temperature. For instance, 50% O_2 saturation means that the water contains only half of the dissolved oxygen that it is able to hold at its current temperature. In essence, anything less than 100% means that the biological oxygen demand, or rate at which oxygen is used up, is depleting the water of oxygen at a rate faster than it can be replenished. Any percentage greater than 100% is a result of excessive phytoplankton production of oxygen that causes the water to be supersaturated. The seasonal decline in oxygen saturation at all Stations is monitored as a rate over time.

Lake Nutrients Samples

Water samples were collected monthly from April to October at each monitoring Station. Sampling depths incorporated top, middle, and bottom depths. All samples were analyzed for total phosphorus, total nitrogen, ammonia nitrogen, and nitrate nitrogen. ***Phosphorus*** and ***Nitrogen*** are the two principal plant nutrients that drive aquatic plant and algae growth. Due to lake stratification, these nutrients are not present in the same quantities throughout the lake. Typically the bottom of the lake has more phosphorus and nitrogen as the summer progresses because bottom-sediments release nutrients when oxygen is depleted.

Phytoplankton/Zooplankton

Phytoplankton are microscopic “plants” that are freely suspended in the water column. Phytoplankton algae are photosynthetic and produce green pigments that color the lake water and make the water more turbid. Zooplankton are microscopic animals, also suspended in the water column, that feed on either phytoplankton and or other zooplankton. Photosynthesis of the phytoplankton in lakes represents the beginning of the lake food chain. Integrated phytoplankton samples were collected monthly using a 3-meter algae tube at Station 1, the deepest site. At the same time, zooplankton samples were collected using a fine-mesh tow net. Phytoplankton populations increase with higher nutrients and cause declines in water clarity. Zooplankton are influenced by predators such as small fish, and they regulate phytoplankton populations through their water column filtration capabilities. An understanding of lake plankton allows for a better interpretation of water quality and fisheries data.

Stream Assessment

Stream samples are collected monthly from seven identified inlets to the lake. Stream samples are collected as grab samples and represent a base flow value of nutrient inputs. Samples are collected only when the respective inlets are flowing, as some of the inlets run dry during the summer months.

1.2 Water Clarity Results

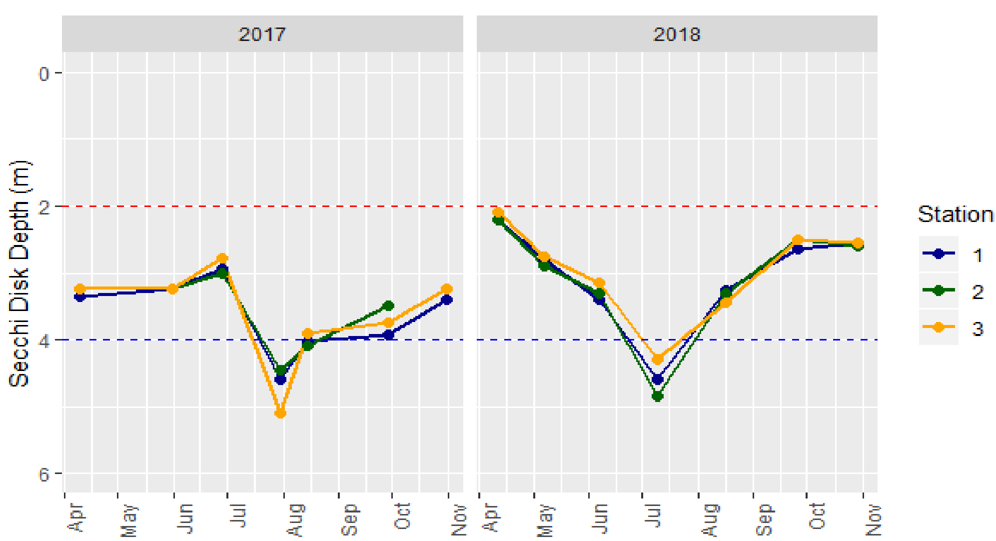
The Lake Oscawana water clarity was recorded monthly at Stations 1, 2, and 3. Clarity ranged from 2.1 to 4.85 meters with the worst clarity recorded in April at Station 3 and the best clarity readings across all stations measured on July 9th. The target water clarity for Lake Oscawana is greater than 3.0 meters for the entire season, with at least one month of clarity greater than 4.0 meters. Water clarity less than 2.0 meters is considered very poor. The average clarity across all sampling stations in the last six years is 3.21 meters. Clarity readings of 2018 were poorer in the spring and fall when the lake was more uniformly mixing due to spring and fall 'turn-over' conditions. When variability between stations is greater than +/- 0.2 meters on the same day, it can be expected that the clarity readings are not a result of user error and instead are indicative of variable local conditions that impact clarity in specific parts of the lake. In general, 2018 water clarity was good in June through August, but not good in other months. The annual patterns in water clarity over time show that mid-June through mid-July tend to have the best water clarity, while clarity in late summer varies dramatically.

Table 1: Water Clarity Results 2018 (Measured in Meters) Compared Averages

Month	2018 Date	Station 1	Station 2	Station 3	*Six Year Average*	*Long-term Average*
April	**4/11/18**	2.20	2.20	2.10	*2.84*	*2.75*
May	**5/7/18**	2.80	2.90	2.75	*3.14*	*3.02**
June	**6/7/18**	**<u>3.40</u>**	**<u>3.30</u>**	**<u>3.15</u>**	*3.40*	*3.63*
July	**7/9/18**	**<u>4.60</u>**	**<u>4.85</u>**	**<u>4.30</u>**	*3.85*	*3.73*
August	**8/17/18**	**<u>3.27</u>**	**<u>3.30</u>**	**<u>3.45</u>**	*3.28*	*3.19*
September	**9/26/18**	2.65	2.50	2.50	*2.74*	*2.59*
October	**10/29/18**	2.55	2.60	2.55	*2.69*	*2.95*

Bold & underlined = good clarity readings from 2018;

*Very few May readings prior to 2013



Points above the red dashed line at 2 meters represents very poor clarity readings.

Points below the blue dashed line at 4 meters represent good water clarity.

Figure 1: 2017 & 2018 Seasonal Variability in Water Clarity

1.3 Temperature and Dissolved Oxygen

Monthly temperature profiles (Figure 2) indicate fully mixed conditions in April but strongly stratified conditions by early May, lasting through the end of September. The late October temperature profile was once again uniform from top to bottom during fall fully mixed conditions. The thermocline was very strong from mid-May and began to erode by mid-September. Temperature profiles at Stations 2 and 3 followed similar trends. There was no indication of storm-induced deep-water mixing, and the thermocline range appears to extend all the way to 9 meters in summer months. The resistance to mixing (RTRM) is highest at around 4 to 5 meters at all stations, which should have prevented bottom-phosphorus from reaching the surface before fall turnover.

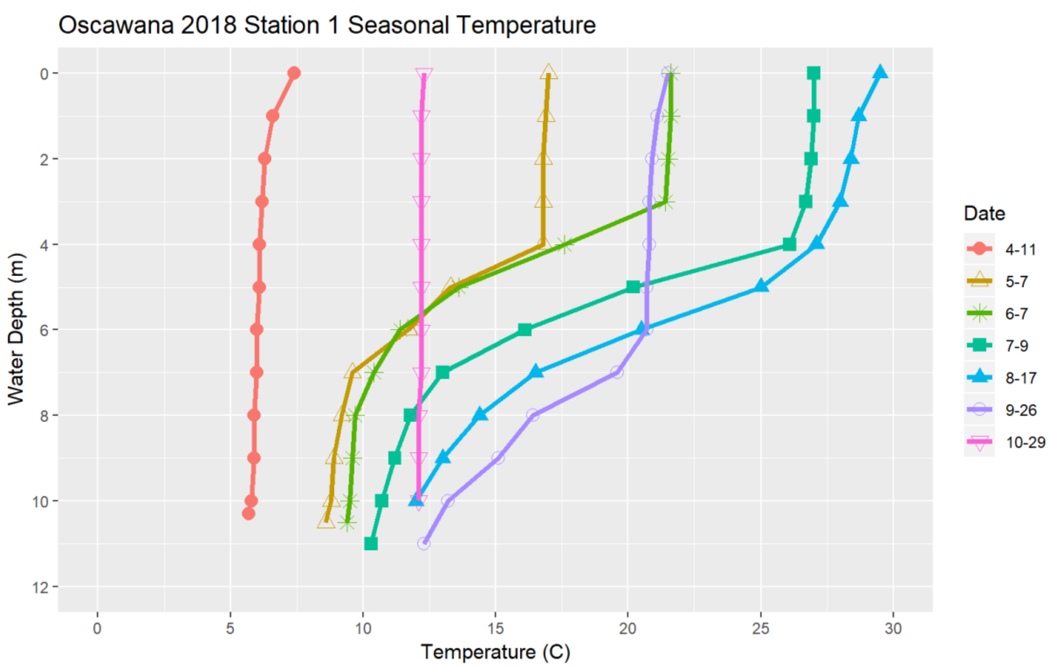


Figure 2: Station 1 Temperature Profiles 2018

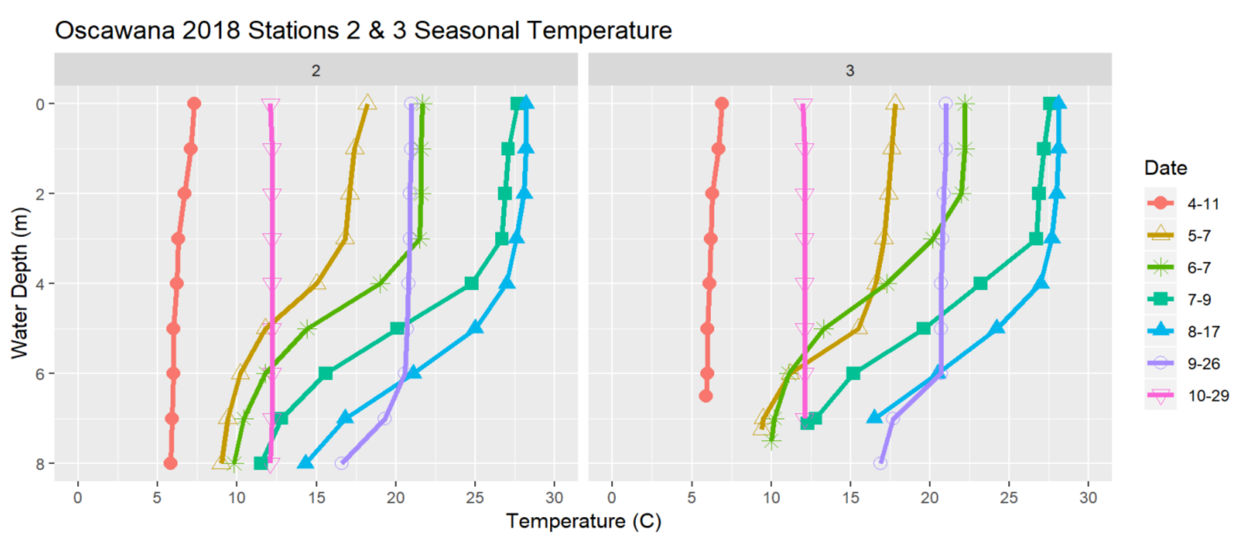


Figure 3: Stations 2 & 3 Temperature Profiles 2018

Figure 4 below depicts the measurements taken at Station 1, 2, and 3 at 1-meter increments from the surface to the lake bottom. The lake bottom is shallower at Stations 2 and 3, hence the measurements at those stations do not go as deep as at Station 1. Profiles are shown as the percent oxygen saturation, which takes into account the temperature of the water and it's relative ability to dissolve oxygen. Please refer back to Section 1.1 for a more detailed explanation of the significance of dissolved oxygen measurements.

The monthly profile measurements were similar to other years, but there was much more oxygen on May 7, 2018 than there was on the May 31st sampling date in 2017. Comparing the annual rate of dissolved oxygen loss is a way to measure improvements or decline in overall water quality through the years. Dissolved oxygen was the primary parameter in the initial development of "trophic" categories back in the 1930s, before knowledge of limiting nutrients became commonplace. The May visits in 2017 and 2018 demonstrate the severe loss of oxygen in bottom waters that occurs annually almost entirely in the month of May. The rapid rate of oxygen loss points towards an enormous sediment oxygen demand that is unlikely to be overcome with aeration or bottom-water oxygenation. This fact is one of the reasons why we have not recommended aeration as a feasible lake restoration technique. Another important thing to note is that the surface waters were supersaturated with oxygen in August. Super-saturation is notable because greater than 100% saturation is indicative of excessive phytoplankton production in the water column.

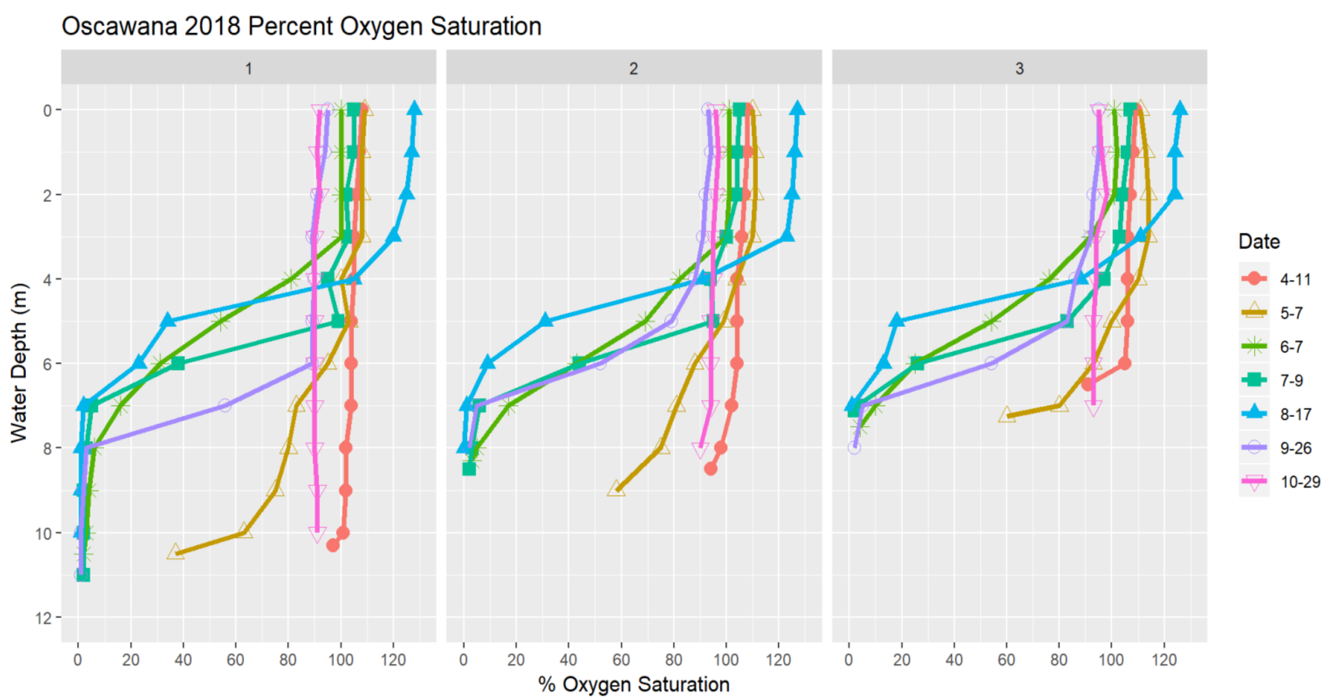


Figure 4: 2018 Percent Oxygen Saturation Profiles At Station 1, 2, & 3

Figure 5 compares the 2017 and 2018 anoxic boundaries at all three stations. Overall, there is no major change in the maximum height of the anoxic boundary. Since data collection began in the 1990s, the anoxic boundary annual maximum has hovered around 6 meters, which is indicated with a horizontal dashed line. In previous years, we had hypothesized that the height of the anoxic boundary at Stations 2 and 3 played an important role in the migration of bottom-water nutrients to the surface, fueling algae blooms because the thermal stratification at these two shallower stations was not as strong as at Station 1. Weaker thermal stratification at the two shallower stations could theoretically allow more bottom-water phosphorus to be mixed into the surface waters during periods of anoxia. However, the 2017 and 2018 dissolved oxygen profiles indicate that relatively good water clarity is possible in summer months despite anoxic water and associated internal loading of nutrients. This relationship will be tracked into the future.

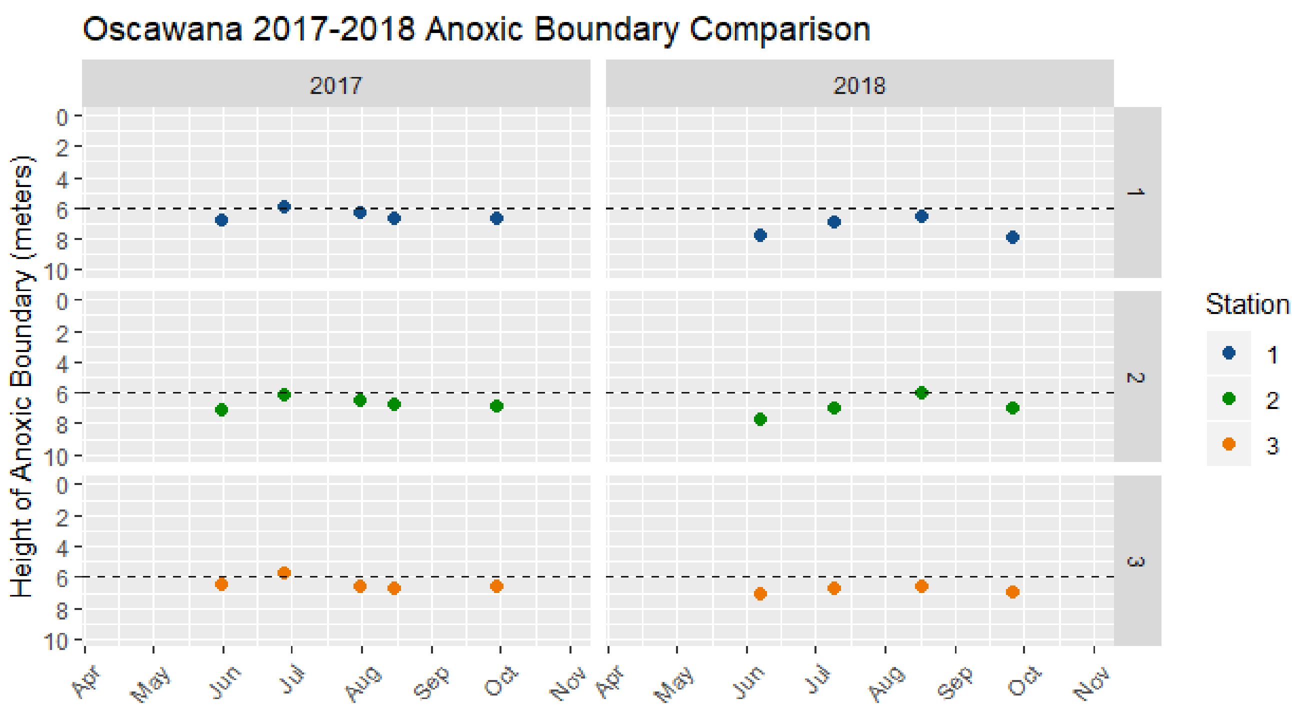


Figure 5: Anoxic Boundary 2017-2018

1.4 Phosphorus

On each visit, four water samples were taken at Station 1, the deepest point in the lake, at 1, 4, 6, and 9 meters. At Stations 2 and 3, samples were taken at 1 and 7 meters, serving as a top and bottom sample. All samples were analyzed for Total Phosphorus (TP). The goal for Lake Oscawana is to have surface (1-meter) TP be below 20 µg/L (ppb) for the entire season. The 2018 season, however saw TP increase in the surface waters at the time of fall turnover, which began in late September and completed by the October visit. Throughout late summer and fall, TP increased in the surface, most likely as a result of internal phosphorus loading from the bottom waters (9-meters). However bottom water TP was only severe in late August to September. Generally, internal loading in 2018 was worse than in 2017. There may be a connection between mechanical harvesting of aquatic plants and internal phosphorus loading; further discussion is included in the aquatic plant management section of this report.

TP values of 10 or less in the surface waters are considered very good water quality, yet TP values of 10 or less at Oscawana have been rare over the past six years. The tables below list TP values from the 2018 season. Figures 6A-B shows the surface TP data graphically for a visual comparison between the past two years (A) and the last five year mean (B). Figure 6C overlays the 2018 data on a chart showing all historical TP values since monitoring began in the late 1990s.

Table 2: Station 1 Total Phosphorus 2018

	Station 1			
Date	1-meter	4-meters	6-meters	9-meters
4/11/2018	14	23	10	18
5/7/2018	18	22	16	28
6/7/2018	10	14	16	23
7/9/2018	12	15	31	112
8/17/2018	17	30	32	261
9/26/2018	20	16	16	552
10/29/2018	22	15	19	23

Table 3: Station 2 & 3 Total Phosphorus 2018

	Station 2		Station 3	
Date	**1-meter**	**7-meters**	**1-meters**	**7-meters**
4/11/2018	8	19	19	21
5/7/2018	15	17	19	17
6/7/2018	8	21	16	18
7/9/2018	13	92	9	89
8/17/2018	17	50	18	122
9/26/2018	18	57	21	17
10/29/2018	21	23	23	29

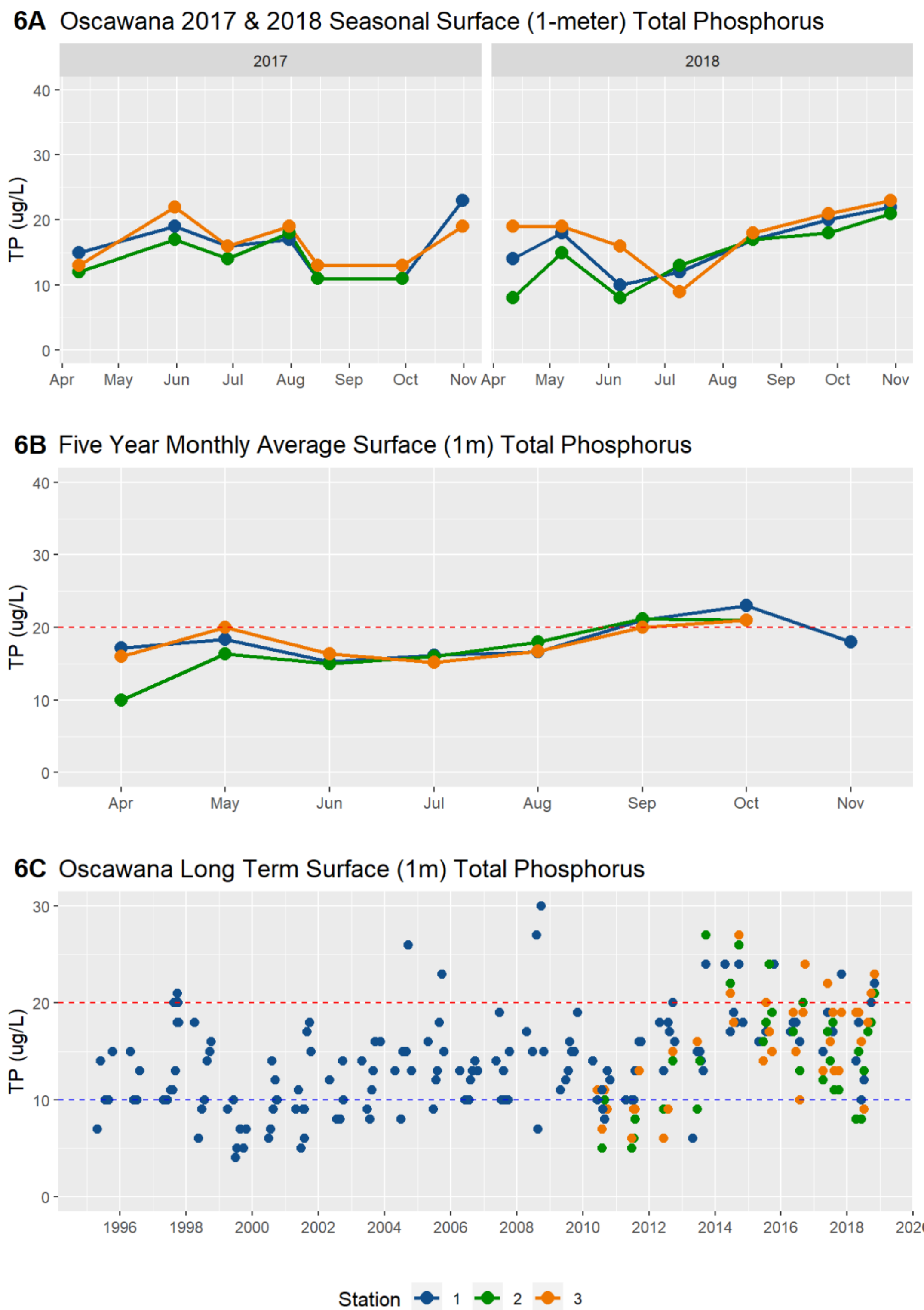


Figure 6: Surface Total Phosphorus- (A) 2017-2018, (B) Compared to Five Year Average*, (C) Long-Term Trend

*Note that the mean values for April and May at Stations 2 and 3 are skewed because we only have three years of spring phosphorus data at these locations. Prior to 2016, only Station 1 was monitored in spring months.

Figure 7 below depicts the bottom water (hypolimnetic) TP. Station 1 bottom samples are always collected at 9-meters, while bottom samples at Stations 2 and 3 are collected at only 7-meters because these secondary sites are somewhat shallower. It is critical to note the distinct variation in bottom water TP at Station 1 from year to year. The seasonal increase in TP concentration is dramatically high in some years and seemingly low in other years. As described in previous reports, some of this annual variation comes from vertical migration of bottom-water TP to the upper water column, but when corrected by lakewide volume, years 2010, 2011, 2012, and 2017 had considerably less internal loading; reasons for this phenomenon are uncertain but may be related to weed harvesting rates and septic system pumping.

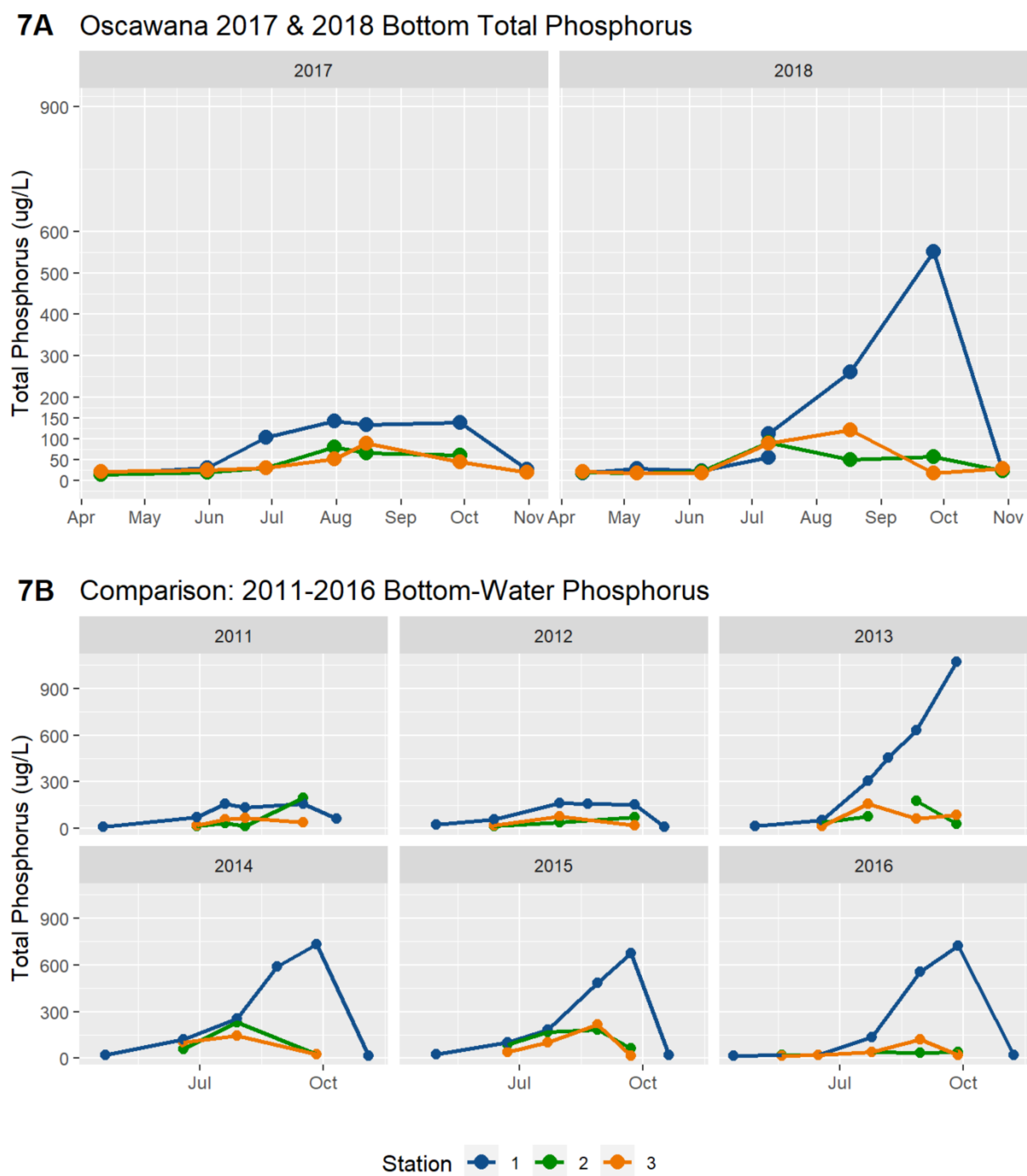


Figure 7: Trends in Seasonal Bottom Water Phosphorus (A) 2017-2018 & (B) 2011-2016

On July 9th, 2018 two extra samples were taken at Station 1, at 5 and 7-meters deep. The purpose of the extra samples was to measure the TP gradient from surface to bottom as another way to assess the impact of bottom water internal phosphorus loading on surface waters. Scientific literature suggests that a linear increase from bottom to surface waters indicates nutrient entrainment from bottom to surface. Yet the trend in July was more exponential than linear, suggesting that the thermocline effectively limited phosphorus at the bottom of Station 1 from migrating to surfaces waters. As expected, the trend is linear below 6-meters, which is the depth of the thermocline on the July sampling date. With reference to the seasonal increase in surface (1m) TP during the 2018 season, this vertical trend in summer TP demonstrates that surface increases are not entirely a result of internal loading phosphorus accumulation. Other sources of phosphorus, related to weed harvesting and watershed loading, also contribute to summer surface increases.

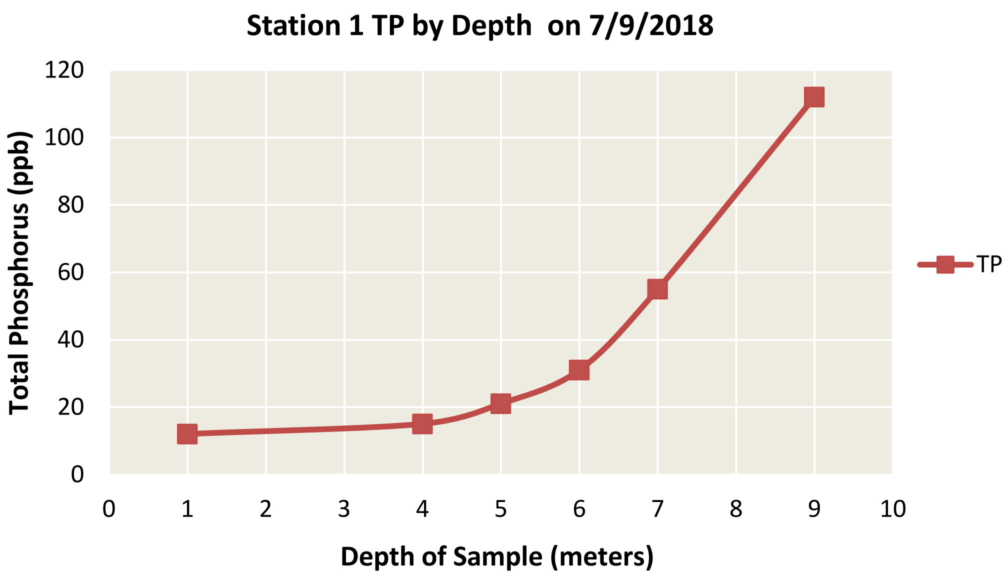


Figure 8: Total Phosphorus Extra Depths (July 9, 2018)

In order to better understand phosphorus in the water column, we also tested summer samples for dissolved phosphorus, which is a fraction of the total phosphorus that is small enough to pass through a 0.45 micron filter. Dissolved phosphorus is typically very close to the amount of ortho-phosphorus, or readily available phosphorus that algae can use immediately for growth. In a bottom-water internal loading situation, one can expect the dissolved phosphorus to increase at about the same rate as the total phosphorus. Dissolved phosphorus will usually make up a large fraction of the total phosphorus in the bottom-waters. However, that was not the case at Oscawana in 2018 (Figure 9). The 2018 season was the first year of testing dissolved phosphorus in bottom waters, so unfortunately there is no historical data for comparison.

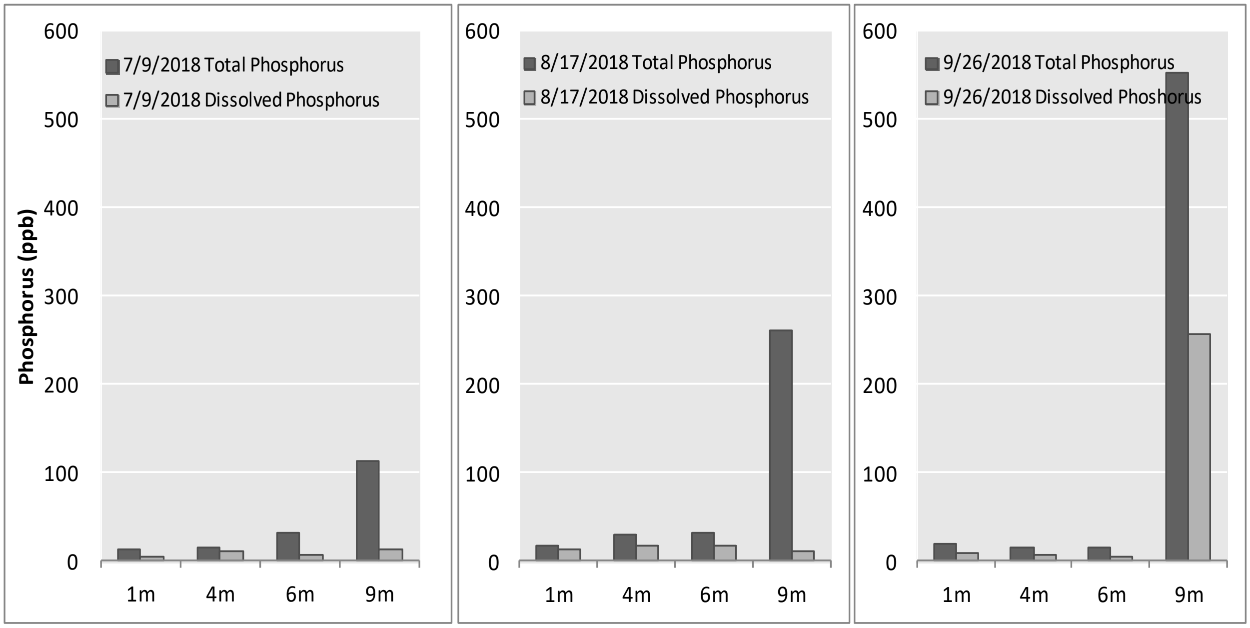


Figure 9: Dissolved Phosphorus of the Total July-September 2018

Figure 9 demonstrates that the increasing amount of bottom-water phosphorus is comprised of very little dissolved phosphorus through mid-August despite anoxic conditions and apparent release of dissolved P since early June. It isn't until late September when the true internal loading of dissolved phosphorus at 9 meters is seen. Even then, dissolved phosphorus constitutes less than half of the total. Again, this information will become critical in tracking potentially reduced internal loading with new weed management techniques designed to reduce sediment disturbances and particle re-suspension.

1.5 Nitrogen

All in-lake samples were also analyzed for Total Nitrogen (TN). TN values from the 2018 sampling season are shown in the tables and figures below. Overall, TN in surface waters were at satisfactory levels around 300 ug/L throughout the season. The goal for Oscawana is to have TN remain below 300 ug/L for the entire season. Tables 4 and 5 below show TN results from 2018. Please note that prior to 2018 there was no consistent TN data collected at Stations 2 and 3. For historic reference, Figure 10 compares the measured TN concentrations in surface waters from 2011-2018. Increased TN in bottom waters throughout summer months can be attributed to ammonia nitrogen, which leaches from anoxic sediments. Bottom water ammonia nitrogen concentrations are only measured at Station 1 and steadily increase throughout the season. Trends in ammonia over the past five years are shown in Figure 11.

Station 1 data revealed TN trends in the upper water column were not well aligned with trends in increasing bottom-derived ammonia nitrogen, which indicates an external source of nitrogen (compare annual Figure 10 to Figure 11 trends). This finding is similar to the internal phosphorus sources.

Table 4: Station 1 Total Nitrogen 2018

	Station 1			
Date	1-meter	4-meters	6-meters	9-meters
4/11/2018	320	311	308	297
5/7/2018	240	260	259	290
6/7/2018	298	309	243	320
7/9/2018	214	259	338	249
8/17/2018	311	353	446	653
9/26/2018	301	263	262	1429
10/29/2018	346	374	394	359

Table 5: Station 2 & 3 Total Nitrogen 2018

	Station 2		Station 3	
Date	1-meter	7-meters	1-meters	7-meters
4/11/2018	NSS	NSS	NSS	NSS
5/7/2018	NSS	NSS	NSS	NSS
6/7/2018	256	275	265	311
7/9/2018	256	667	253	467
8/17/2018	268	410	299	409
9/26/2018	234	409	266	244
10/29/2018	346	351	363	357

NSS=No sample sent

The information for surface TN in the tables is also displayed below in Figure 10. Stations 2 and 3 followed a very similar total nitrogen (TN) pattern throughout the season, while TN at Station 1 was more variable in the spring into summer. This drastic change in TN at Station 1 deserves further investigation, but again, it is likely driven by external nutrient inputs, as the lake had not yet accumulated bottom-water nitrogen from anoxic sediments and the trend is dramatically different from year to year. Accumulation of ammonia nitrogen from anoxic sediments throughout the season is shown in Figure 11. This internal bottom-water nitrogen trend is much more consistent seasonally.

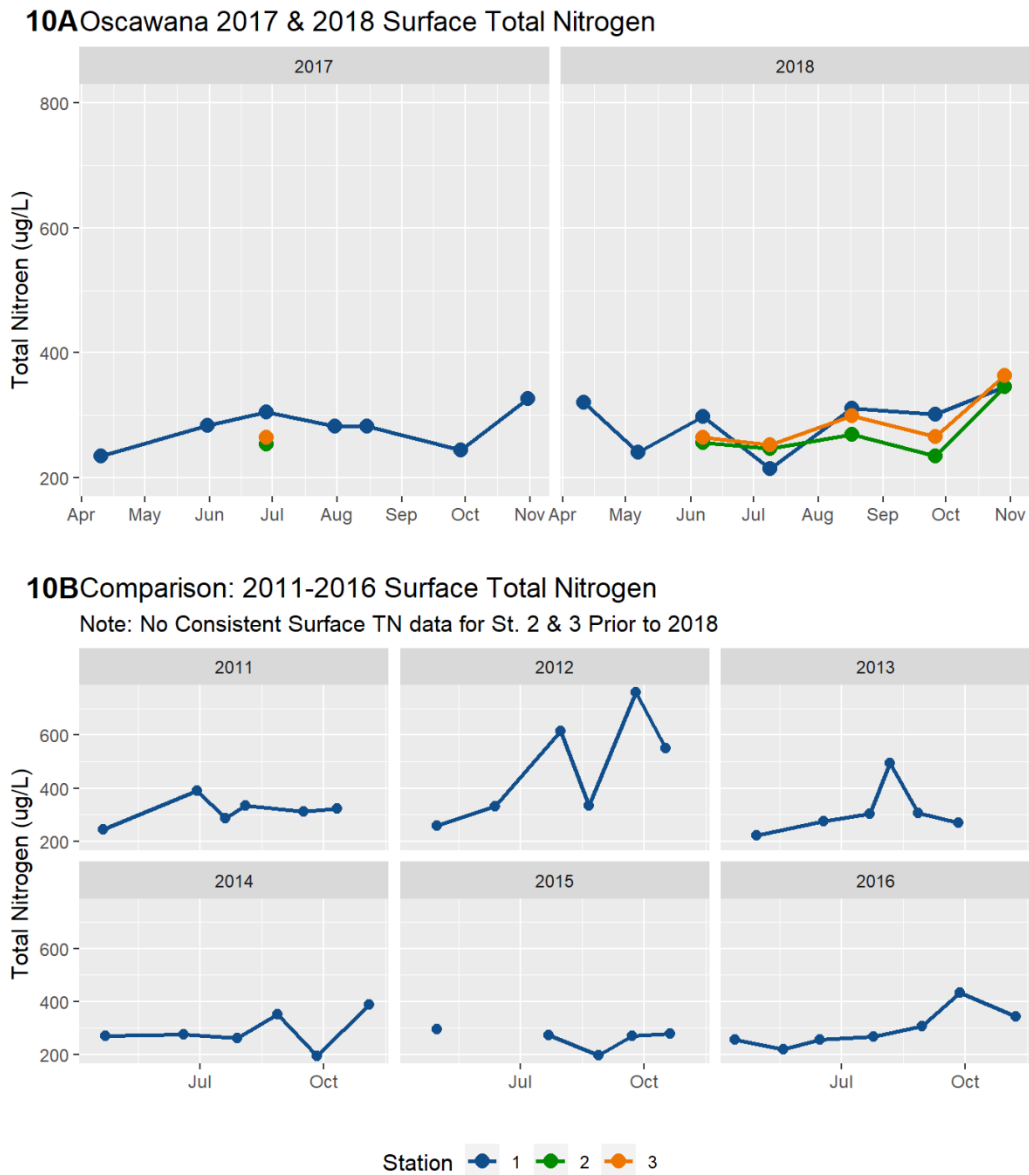


Figure 10: Surface Total Nitrogen 2017-2018 (A) and 2011-2016 (B)

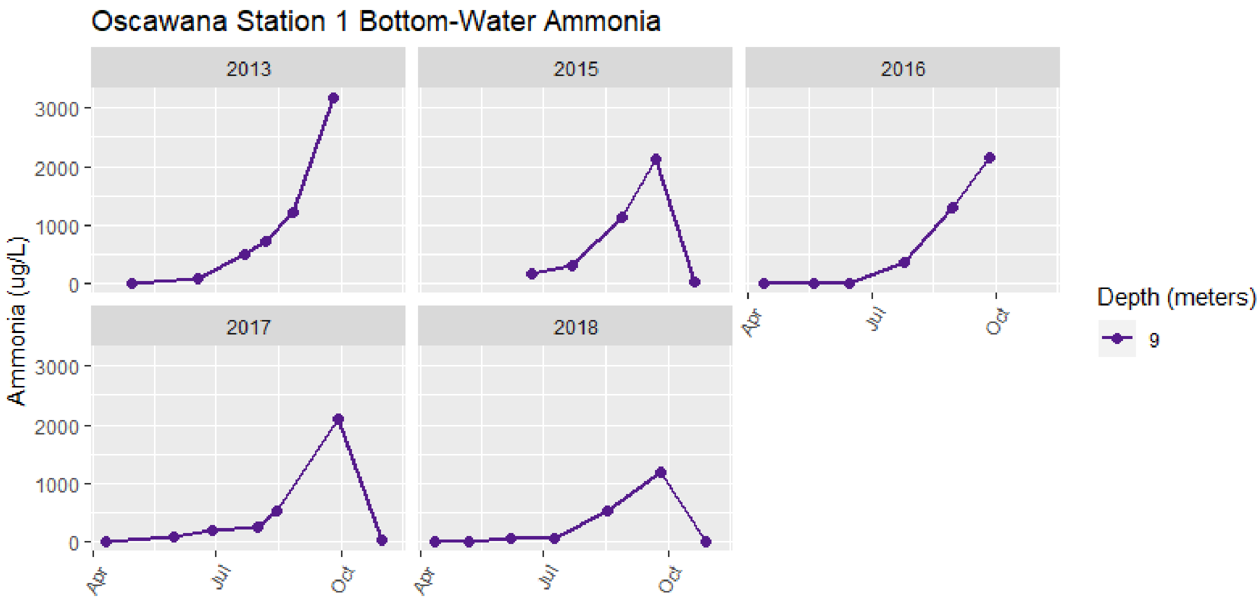


Figure 11: Bottom-Water Ammonia Accumulation at Station 1 (2013-2018)

Ammonia nitrogen was tested only on bottom-water samples from Station 1. There is no ammonia nitrogen data from 2014. Ammonia released from the anoxic bottom sediments in 2018 was similar to recent years, drastically increasing over the course of the summer. In comparing the surface TN to bottom-water ammonia in 2018, it is evident that the fall turnover caused an increase in surface nitrogen as bottom-water ammonia was mixed into the epilimnion late in the season. Yet as previously mentioned, surface ammonia nitrogen trends appear more externally driven and not wholly related to the bottom-water ammonia accumulations, which again suggests external sources of nutrient pollution.

1.6 Plankton Communities

Phytoplankton levels in 2018 ranged from approximately 17,000 to 23,000 cells per milliliter. These levels indicate overall good water quality conditions. Spring sampling did not record a substantial Diatom bloom, as has been documented in years past, yet spring water clarity was still poor. Poor water clarity seen in spring and fall 2018 can also be linked to suspended sediments in the water column, but suspended sediments have never been explicitly measured. The Oscawana phytoplankton assemblage becomes dominated by cyanobacteria, also referred to as harmful blue-green algae, during summer months. Yet cyanobacteria numbers have remained relatively low throughout the season. Cyanobacteria becomes a human health concern once a bloom reaches concentrations greater than 70,000 cells/mL.

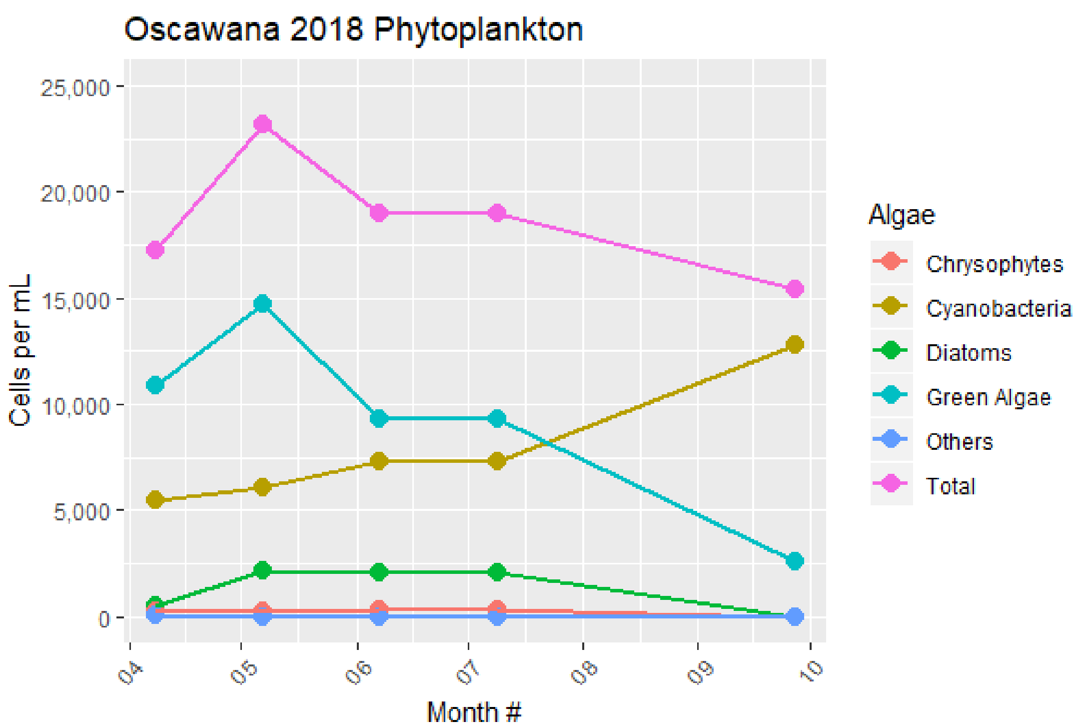


Figure 12: Phytoplankton Assemblage 2018

Zooplankton densities were dramatically different than previous years. The 2018 season captured two full growth and die-off cycles of Rotifers. Minimum and maximum Rotifer densities were very similar to 2017, but 2018 saw two cycles instead of one longer cycle as in 2017. In comparison to 2016, however, Rotifer numbers were much lower throughout the season. Maximum Rotifer densities of nearly 500 animals per liter in 2016 are potentially related to very low numbers of large-bodied zooplankton (large Copepods and Cladocerans). Large Copepods dominated the early 2018 summer 'clear water' phase instead of large-bodied Cladocerans, as was the case in 2017. As a whole, Cladoceran populations were very low and no large Daphnia were seen in 2017 samples. Yet the boom in Copepod populations to roughly 56 animals per liter was unprecedented for Oscawana. For comparison, maximum Cladocern populations in 2017 were approximately 25 animals per liter, which was more than double the 2016 numbers. After three years of not stocking Walleye, it seems like zooplankton populations are stable and large-bodied zooplankton have become more common. The 2019 fish population study will be very informative and provide more insight into the mechanisms that regulate zooplankton densities.

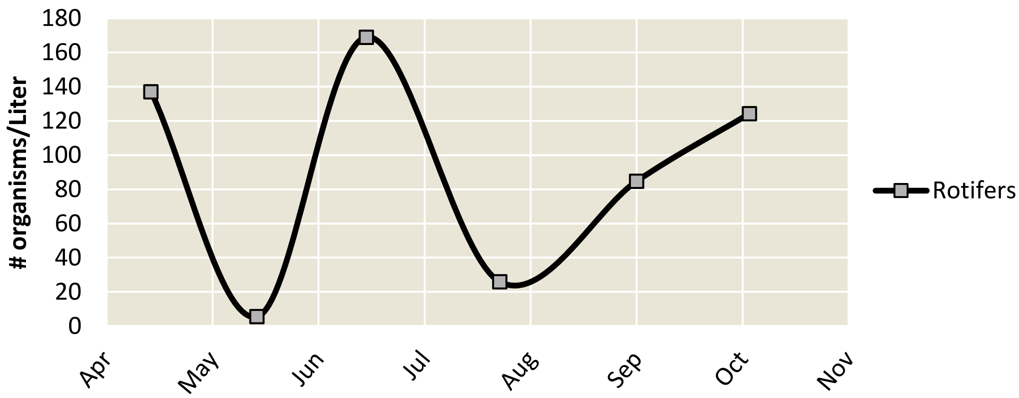


Figure 13: Rotifer Populations 2018

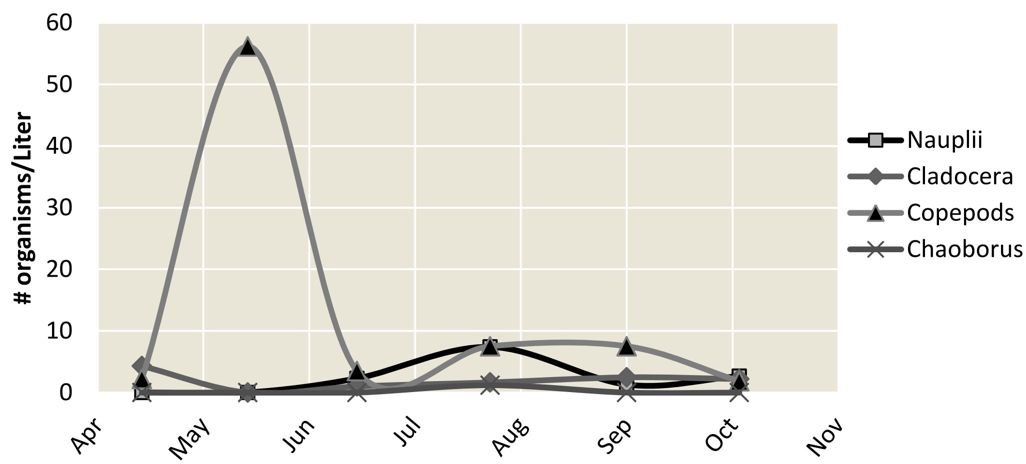


Figure 14: Other Zooplankton Populations 2018

1.7 Stream Monitoring

There are seven main inlets that correspond to seven watershed sub-basins. These inlets range greatly in their size and flow volumes but are monitored monthly throughout the season. Some streams become dry during peak summer months. Exact stream monitoring locations can be viewed in a Google maps document developed for resident communication purposes:

https://drive.google.com/open?id=1DWZIyj5XOGN3D8HQrhCB5I7EOh5VUrmx&usp=sharing

Streams 1 and 2 are the largest inlets to the lake and are mostly forested with low residential development. The concentrations in streams 1 and 2 should ideally remain below 12ppb of total phosphorus, since these streams represent relatively undisturbed landscapes that release low background concentrations of nutrients. From 1994 to 2018, the average seasonal concentrations of streams 1 and 2 have been increasing slightly. The 2010 to 2018 average concentrations for streams 1 and 2 are 17 and 22ppb, respectively (Table 6). Both of these concentrations are over the 12ppb threshold that is necessary to maintain good quality water entering the lake. While concentrations do change with the amount of water flow throughout the season, the averages still suggest that loading has increased in recent years, likely related to **stormwater runoff**, **eroding stream banks**, and **channelized wetlands**.

Table 6 - Change in Stream Phosphorus Over Time

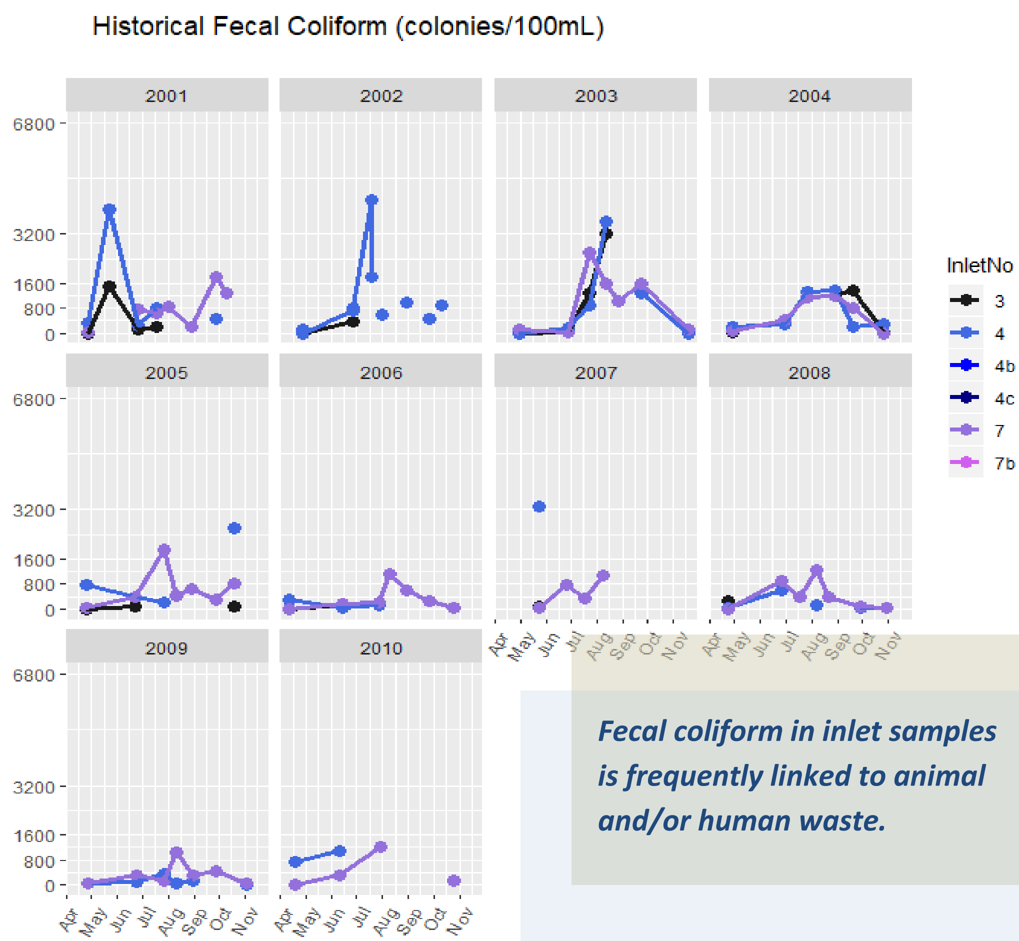
Main Inlets Total Phosphorus Concentration (parts per billion)

Excludes two stormwater sampling events with very high TP

Inlet #	1994-2000 AVG	2000-2010 AVG	2010-2018 AVG
1	12	16	17
2	17	16	22
3	27	13	39
4	153	146	126
5	18	15	16
6	20	15	18
7	17	19	39

Stream 3 has changed dramatically over the period of monitoring, making changes in concentration more difficult to compare. This inlet is a braided meandering stream that flows from residential areas, through a large wooded wetland to the lake. The exact channel of the stream is not static, and flow is diffuse across the wetlands before entering the channel closer to the lake. Sampling in 2018 demonstrated very high concentrations of nitrate nitrogen (1650ppb) seeping out of the wooded hillside in the upper part of the stream 3 subbasin. This is consistent with very high nitrate nitrogen concentrations measured directly at the forested area of stream 3 in 2016 and 2017, ranging from 612-1860ppb. For comparison, streams 1 and 2 nitrate nitrogen concentrations during that same time averaged less than 132ppb, which is more in line with natural background concentrations of forested and wetland areas (Kifner, 2017). Values in excess of 1000ppb of nitrate nitrogen indicate human or animal related pollution. Sources of high nitrate nitrogen can come from fertilizers, animal waste, and residential onsite wastewater systems.

Inlets 4 and 7 are also likely candidates for septic system impairment as they have historically been high in fecal coliform bacteria (Figure 15). The Health Department is aware of these high fecal coliform counts and circa 2003, at least one septic system was replaced near inlet 4. However, since that time, nutrients have remained elevated throughout the seasons. One round of Fecal coliform testing was conducted at inlets 4 and 7 in 2018. Results from September 29, 2018 found 120 and 270 fecal coliform colonies per 100mL sample at inlets 4 and 7, respectively. Further e. coli and fecal coliform testing occurred in 2019. The Health Department was made aware of bacteria and nitrate results. The very high nitrate nitrogen concentrations (**average 2014-2018 inlet 4 nitrate nitrogen = 1,398ppb**) indicates human sources of groundwater impairment. Of the total 20 samples that were taken at inlet 4 from 2014 to 2018, the top 30% all occurred in April and May, which is the period of high groundwater that may interfere with septic system functioning. Unfortunately there are no total nitrogen or ammonia nitrogen values to make better comparisons through the seasons. A discussion of possible remediation actions is included in Section 2.3. Detailed inlet nutrient results are included in the appendix of this report.



Fecal coliform in inlet samples is frequently linked to animal and/or human waste.

Figure 15 - Inlets Fecal Coliform Historical Data

Streams 5 and 6 also drain mostly forested sub-basins of the watershed. Stream 5 is located along the western shore of the lake and flows into a channelized wetland along West Shore Drive before reaching the lake. Stream 5 has historically had the lowest nutrient concentrations, mostly fluctuating between 10 and 25 ppb total phosphorus. Concentrations do not appear to have changed much over the last two decades. Despite draining a similar sub-basin size to Inlets 4 and 5, Inlet 6 typically does not flow during the summer months when drier conditions reduce groundwater baseflow. The following tables present inlet concentrations measured in 2018. Late June concentrations are elevated due to a rain event.

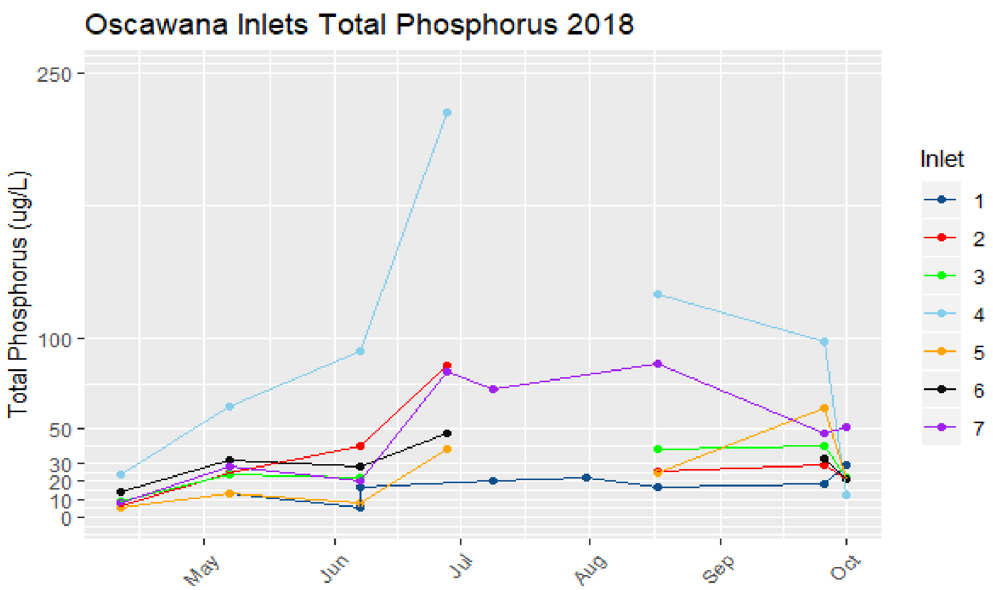


Figure 16: Inlets Total Phosphorus Concentrations 2018

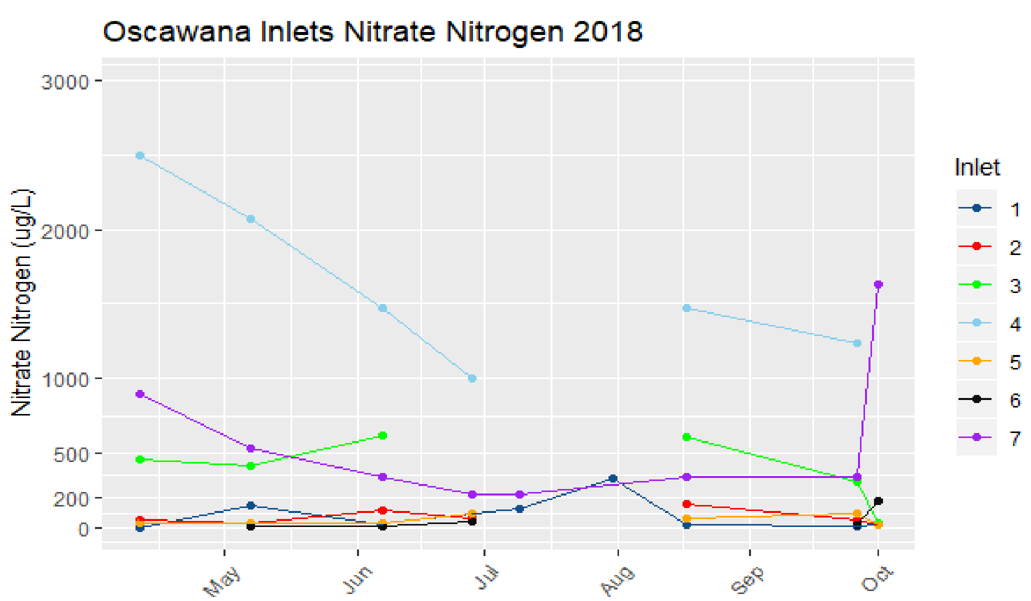


Figure 17: Inlets Nitrate Nitrogen Concentrations 2018

1.8 Updated Data Conclusions & Recommendations

Based on the 2018 water quality data results, we emphasize the importance of monitoring Inlets 4 and 7 for fecal coliform and E. Coli bacteria to match with high nutrient concentrations. The Public Health Department has requested bacteria samples and will not take action with just nitrogen and phosphorus concentrations alone. Inlets 4 and 7 represent water affected by densely populated sub-basins of the overall Oscawana watershed, and results from these streams point towards potential groundwater nutrient impairment from onsite wastewater.

Overall, total nitrogen values in the lake are much lower than values measured prior to 2010. As noted in previous reports, this fact may be related to increased septic system pumping, maintenance, and reconstruction in the watershed. Because soils readily leach nitrate nitrogen from septic leach fields, we expect lake nitrogen concentrations to decrease measurably due to onsite wastewater improvements over time, provided that new sources are not subsequently introduced. Similarly, this reduction in overall nitrogen in the lake could be related to a reduction in lawn fertilization for the same reasons. It should also be noted that onsite wastewater and fertilizer nitrogen in densely packed shoreline areas will fuel aquatic plant growth because aquatic plants take nearly all of their nutrients from the shallow sediments.

Hypolimnetic bottom-water phosphorus reached higher concentrations than in 2017. However, the maximum 2018 bottom-water phosphorus concentration was lower and the duration of elevated concentrations was shorter than 2016. The bottom-water dissolved phosphorus did not follow the same pattern as total phosphorus. Dissolved phosphorus did not appear to migrate into the upper water column at all. Because this is the first year measuring dissolved phosphorus at Oscawana, we cannot yet make any conclusive data interpretations, but initial results seem to suggest that the bottom derived phosphorus was not primarily available ortho-phosphorus.

Surface total phosphorus concentrations were very good in June, July, and to some extent August 2018. During these months, low phosphorus correlated with increased water clarity. Water clarity was not as good as in 2017, and the poorest clarity readings were during periods of full lake mixing in the spring and fall.

Algae populations in the lake were fairly stable throughout the season and there were no lake-wide cyanobacteria blooms observed, as have been seen in 2013-2016. Zooplankton populations appear to be becoming more complex over the past three years. There are greatly reduced numbers of Rotifers and increased numbers of large-bodied zooplankton in recent years. These results indicate that not stocking Walleye fish in the lake in the past three years has not had cascading negative impacts on zooplankton. The 2019 fisheries survey will provide more insight into these phenomena. Fisheries survey data will be published in early 2020.

Overall, inlet nutrient concentrations are problematic in densely populated areas. Recent nitrogen and fecal coliform measurements indicate potential septic nutrient pollution of inlets 3, 4, and 7. A more in-depth analysis of watershed and stream dynamics is included in the Watershed Management Plan (2.0).

2.0 Introduction to the Watershed Plan

Water quality data collected since 2008, the year since the last lake management plan was published, demonstrate that internal nutrient loading is not the primary driver of surface algae blooms and water clarity in all years. In-depth analysis of volumetrically calculated phosphorus mass suggests that internal phosphorus loading was suppressed in certain years. Similarly, there has been an overall reduction in lake-wide nitrogen over the past two decades, and there have been no significant correlations between surface nutrients and bottom-water nutrients, except during fall turnover when the lake should have uniform concentrations. This dataset points to external nutrient pollution sources that may have historically been overlooked.

Additionally, internal phosphorus loading has only three frequently practiced control options: Alum treatments, hypolimnetic oxygenation/aeration, and thermal destratification. Currently, Alum treatments are not generally permitted in the State of New York and these treatments are often cost prohibitive and variable in success. Hypolimnetic oxygenation, aeration, or thermal destratification all require an immense amount of energy, and the scientific literature is full of case studies where improper sizing or installation made algae problems worse. In any event, unaddressed external nutrient inputs will continue to minimize the effectiveness of internal nutrient control efforts. For these reasons, the Lake Oscawana Management Advisory Commission (LOMAC) has concluded that the most effective plan to improve the water quality of the lake is to minimize external sources of nutrients to the lake. This watershed management plan is the culmination of a complete watershed investigation and several stormwater monitoring events.

New York Water Quality Standards and Programs

The purpose of a Nine Element Watershed-Based Plan is to provide a list of actionable measures to reduce watershed nutrient loading to the lake. The ultimate goal of this plan is to improve Lake Oscawana's overall water quality in order to delist Oscawana from the New York State Impaired Waterbodies List (Clean Water Act, Section 303d) in future years.

The State of New York relies on a water quality standards **narrative** instead of numerical criteria:
https://www.dec.ny.gov/chemical/77704.html

> The narrative standard for phosphorus and nitrogen is: "*None in amounts that result in the growths of algae, weeds and slimes that will impair the waters for their best usages*."

Lake Oscawana is currently listed as a "4a" and "4c", meaning that the State of NY has taken the initial steps towards remediation in preparing the Total Maximum Daily Load (TMDL) report, but that the lake is still considered impaired based on the NY water quality standards. The NYS Department of Environmental Conservation (DEC) and Environmental Protection Agency (EPA) use these "4a" and "4c" classifications as a way to quantify and distinguish the many impaired waterbodies that do or do not yet have a TMDL.

Below, an explanation of categories of NYDEC Impaired Waterbodies that have been moved from the 303(d) list but are still considered "impaired." (https://www.dec.ny.gov/chemical/31290.html)

> **Impaired Waters NOT Included on the NYS Section 303(d) List**
>
> Not all impaired waters of the state are included on the Section 303(d) List. By definition, the List is limited to impaired waters that require development of a Total Maximum Daily Load (TMDL). A list of Other Impaired Waterbody Segments Not Listed (PDF, 83 KB) on the 303(d) List Because Development of a TMDL is Not Necessary is also available. The purpose of this supplemental list is to provide a more comprehensive inventory of waters that do not fully support designated uses and that are considered to be impaired. (NOTE: This list will be updated upon USEPA approval of the Proposed Final 2016 List.)
>
> There are three (3) categories of justification for not including an impaired waterbody on the Section 303(d) List:
>
> - Category 4a Waters - TMDL development is not necessary because a TMDL has already been established for the segment/pollutant.
> - Category 4b Waters - A TMDL is not necessary because other required control measures are expected to result in restoration in a reasonable period of time.
> - Category 4c Waters - A TMDL is not appropriate because the impairment is the result of pollution, rather than a pollutant that can be allocated through a TMDL.

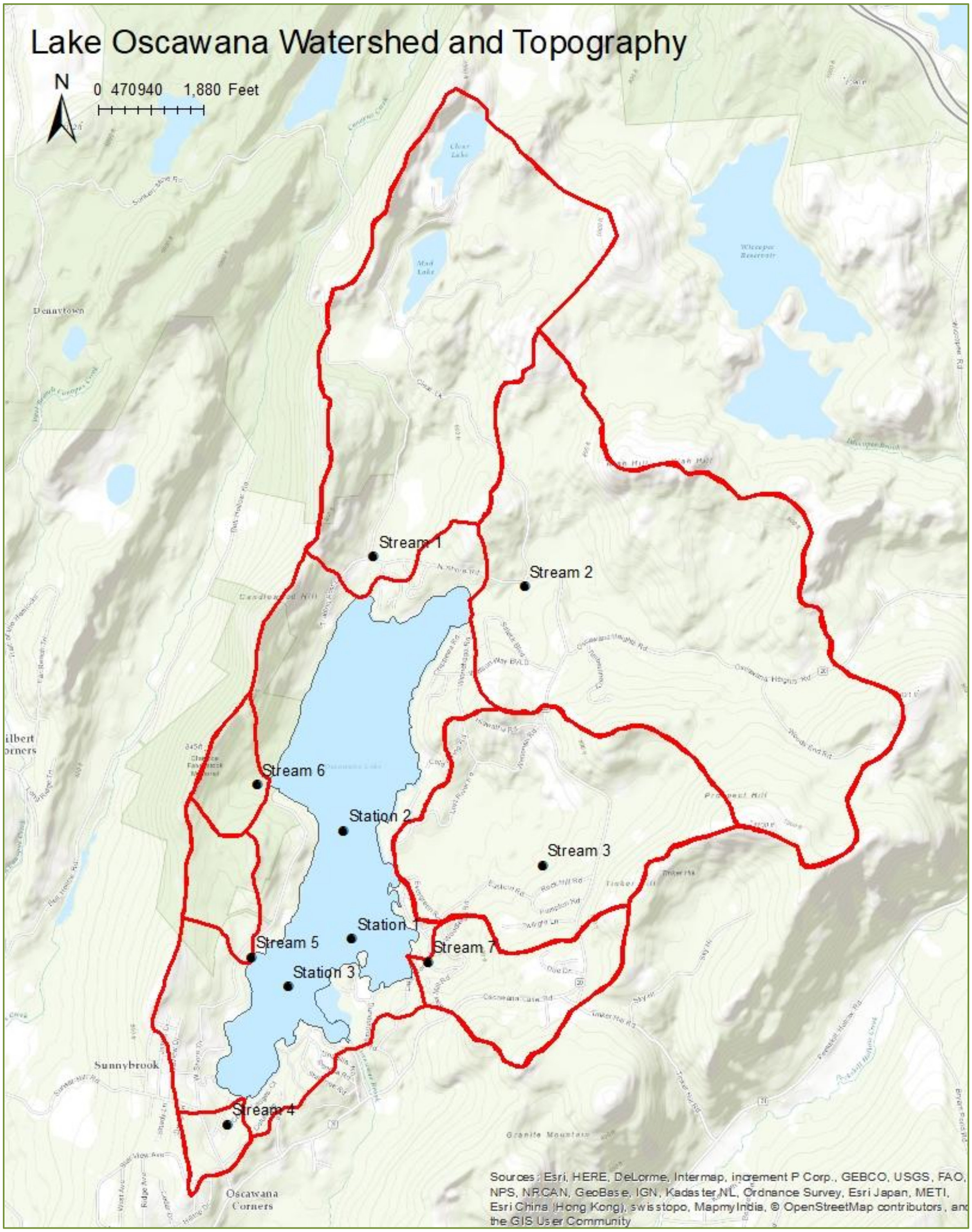
Nonpoint source pollution at Oscawana, as opposed to point sources, is a result of widespread collective nutrient pollution from a variety of small sources. Point sources such as an agricultural stream with very high phosphorus, or wastewater treatment plant effluent, are more easily controlled than disperse nonpoint sources of pollution. **The DEC lists that Oscawana is impaired due to: *onsite wastewater systems* and *urban* sources,** which means that the immediate watershed is overdeveloped, resulting in excess nutrients from wastewater, stormwater runoff, and disturbance of natural conditions.

While the 2008 TMDL for Lake Oscawana relied on modeling the potential sources of nutrient impairment, this watershed management plan is designed to be specific and is a result of much on-the-ground sampling and inspection that occurred over 2016-2018. This plan requires specific measures to track change and to ensure ongoing public education. For nonpoint source pollution, public education is a form of management. Nutrient reduction from diffuse sources increasingly relies on residents' property maintenance and personal responsibilities within a lake's watershed, including reductions of fertilizer use and proper septic maintenance or upgrades.

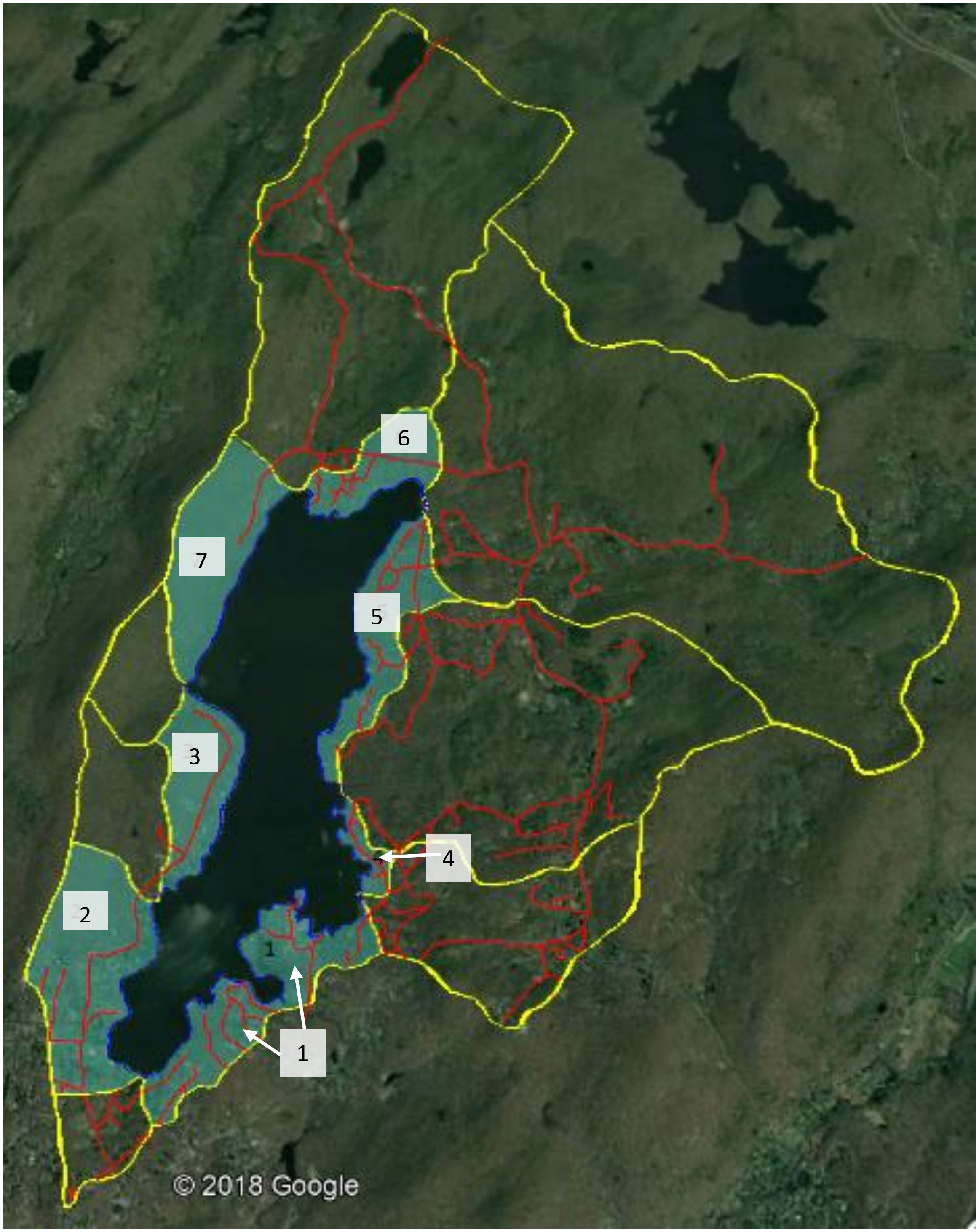
2.1 Identified Causes of Impairment and Pollution

As published in the Lake Oscawana TMDL, the watershed is approximately 80% forested and 15% developed (Cadmus Group, 2008). The watershed has seven sub-watersheds corresponding to seven historically sampled inlets (Map 1, pg 28. The remaining component of the watershed is considered direct-drainage, as water flow from these areas is not concentrated to a single stream. For the purposes of this plan, the direct-drainage area was split into another seven areas shaded light blue in Map 2, pg 29.

Map 1 Oscawana Watershed and Main Inlets/Sub-basins



Map 2 Direct Drainage Areas (#D1-D7)



Map 2, above, also demonstrates the measured linear feet of roadways in each of the sub-basins and seven direct-drainage areas (direct-drainage #D1-D7 shown shaded in blue, roadways in red).

Updated Watershed Sources of Impairment

Stream Inputs

The table below lists the annual average stream concentrations from the seven major inlet sites, as shown in Map 1, pg 28. Long-term average concentrations indicate that sub-basins 3, 4, and 7 are above the 20 ppb (µg/L) threshold that is known to stimulate algae blooms in the lake.

Table 7 - Stream Annual Mean Phosphorus

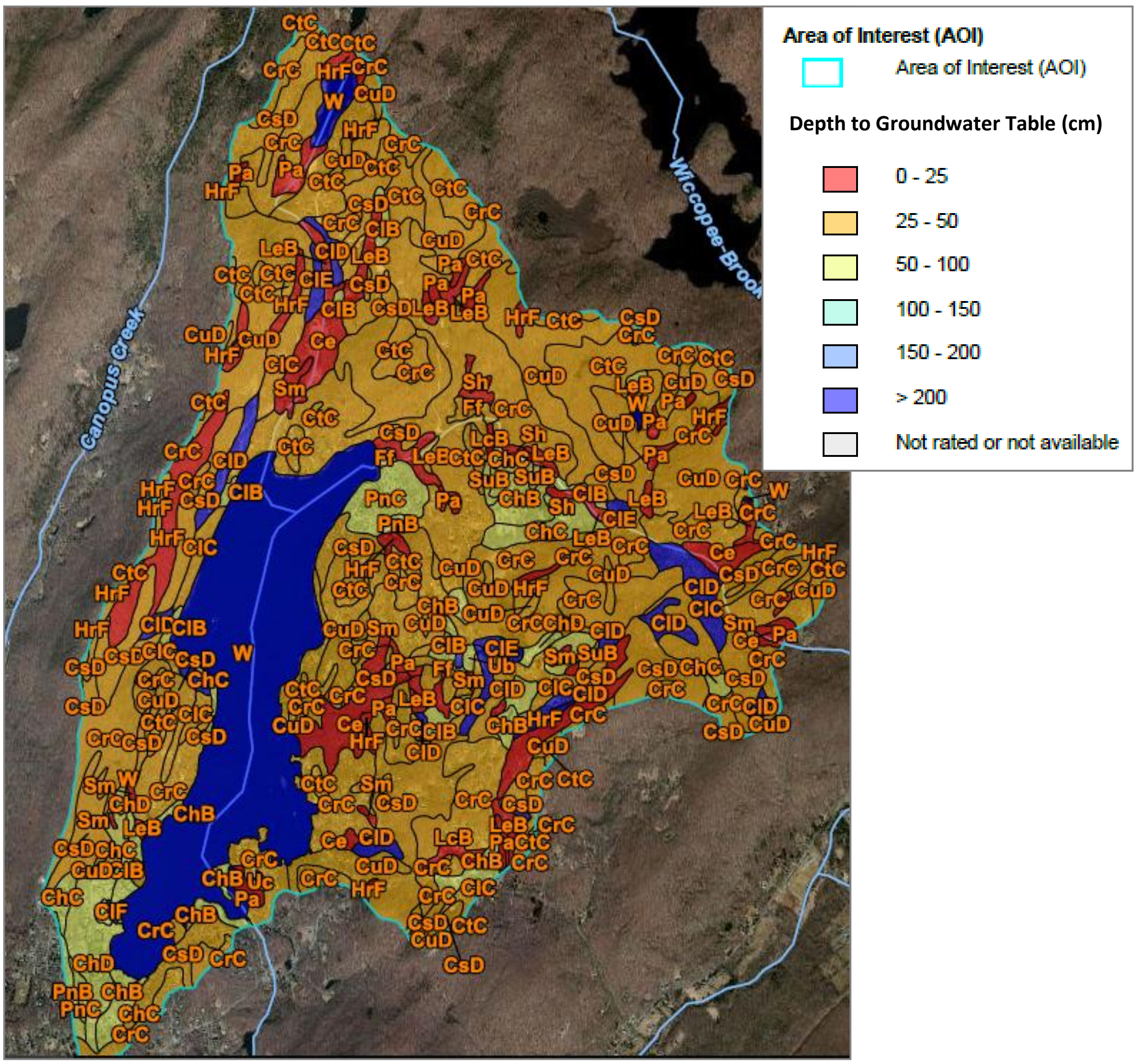
Annual Mean Total Phosphorus Concentration (ppb) at Main Inlets (based on monthly sampling from April-October)								
Year	**Inlet 1**	**Inlet 2**	**Inlet 3**	**Inlet 4**	**Inlet 5**	**Inlet 6**	**Inlet 7**	**AVG TP**
1994	12	17	70	287	32	27	18	**66.0**
1995	12	13	16	143	20	48	16	**38.2**
1996	13	15	19	81	14	13	18	**24.7**
1997	12	33		229	25		19	**63.5**
1998	11	13		112	14	7	18	**28.9**
1999	10		17	81	7	11	10	**22.7**
2000		12	15	138	17	15	20	**36.0**
2001	8	34	25	164	14	20	23	**41.0**
2002	8	10	10	190	17	6	9	**35.7**
2003	13	17	20	166	14	24	17	**38.9**
2004	12	14	15	122	18	23		**33.8**
2005	12	10	7	215	6	9	18	**39.6**
2006	19	12	8	195	19		28	**46.8**
2007	11	21	6	103			24	**33.0**
2008	16	19	8		17	11	17	**14.5**
2009	35	14	14	110	14	12	17	**30.9**
2010	22	13		55	10	13	16	**21.4**
2011	8	20	32	82	11	12	23	**26.7**
2012	36	13	22	81	13	19	27	**30.1**
2013	13	16	127	76	8	10	55	**43.4**
2014	13	49	9	236	13	14	79	**59.0**
2015	15	18	15	196	24	26	27	**45.8**
2016	17	17	51	113	17	20	39	**39.0**
2017	20	17	26	173	22	22	36	**44.9**
2018	14	33	27	120	25	31	49	**42.7**
LongTermAVG (ppb = mg/m3)	**15.1**	**18.8**	**25.3**	**144.4**	**16.2**	**17.7**	**25.9**	**37.6**
Approximate sub-basin area (acres)	**605**	**839**	**394**	**30**	**58**	**47**	**138**	

Primary sub-basins for nutrient reduction projects: 3, 4, & 7

Onsite Wastewater

The 2008 TMDL report for Oscawana estimated that 47% of the external phosphorus load to the lake was from onsite wastewater systems (The Cadmus Group, Inc., 2008). This section details the underlying concerns with nutrient leaching from onsite wastewater in shoreline areas.

The soils in the Oscawana watershed were determined using the Natural Resource Conservation Service Web Soil Survey Application. The majority of the watershed soils are classified as well drained, very rocky Charlton-Chatfield (CrC) and Chatfield-Charlton (CsD) complexes. The next most common soil types were Chatfield-Hollis-Rock outcrop rock complexes (CtC and CuD), which indicate the large areas of the watershed with exposed bedrock. The map image below displays the various soil types using their three letter code, as well as a color coding to indicate the soil types' depths to the groundwater table. Soil rating colors indicate the number of vertical centimeters to the groundwater table.



The important take-away from this map is that the majority of soils in the immediate shoreline area have a depth to groundwater of 25-50 cm (about 10-20 inches) and high amounts of bedrock. By current New York onsite wastewater standards, the majority of the lake's watershed soils are not suitable for onsite wastewater treatment**.** The NY Public Health Law, 201(1)(1) Wastewater Treatment Standards for Residential Onsite Systems Section 75-A.4 states that, "Highest groundwater level shall be at least two feet below the proposed trench bottom," meaning that a minimum of 24 inches of usable soil is required for conventional septic system leaching fields.

Current NY Treatment Standards for Residential Onsite Systems Section 75-A.4 states that, "Highest groundwater level shall be at least two feet below the proposed trench bottom," meaning that a minimum of 24 inches of usable soil is required for conventional septic system leaching fields.

Based on elevation, this shallow depth to groundwater becomes catastrophic in shoreline areas that sit near the lake elevation level. Water levels at Oscawana naturally fluctuate. When water levels are high, large sections of shoreline onsite wastewater systems can fail as their leaching systems are potentially flooded. At this point, not only do these systems become public health concerns for bacteria and virus transport, the inundated leaching fields also act as a flow through systems for unfiltered phosphorus and nitrogen to enter the lake. The map image below highlights the 2ft- above lake level contour line (512ft-elevation). All properties closer to the lake than the yellow line are vulnerable to septic failure and should be priorities for rebuilding with advanced onsite wastewater treatment methods. Abele and Wildwood coves are of primary concern and the image is zoomed to these areas. The State of New York has acknowledged such issues, and has provided Putnam County with grant funding for updates and repairs to private onsite wastewater systems. This grant program could serve as a financial incentive for the replacement of problematic septic systems in the Oscawana watershed.

Direct Drainage Watershed Contributions

Seven distinct direct drainage areas to the lake were identified and highlighted in blue in Map 2 (Direct Drainage areas 1-7, pg29). These areas are considered "direct drainage" because their topography is such that water does not flow to a single stream, and instead the inflow to the lake is very diffuse overland flow, groundwater flow, and roadway stormwater runoff. Table 8 below demonstrates the approximate linear footage of roads in each direct drainage area. Then, using the New York State Stormwater Management Design Manual Section 4.2 Water Quality Volume (WQv) calculations, the table then calculates the estimated road-only stormwater runoff per each direct drainage sub-basin. This equation does not take into account impermeable rooftops and driveways in each direct drainage area, but generally areas with more roads have more homes.

$$WQv = (P * Rv * A) / 12$$

where:

WQv = water quality volume (acre-feet) per inch of rain
P = % Rainfall Event
[P = 0.9 used only for calculating water holding-volume for detention basins, **1.0** used for this total quantification purpose]
Rv = 0.05 + 0.009(I), where I is the percent impervious cover (100% for roads only)
A = area in acres

Table 8 demonstrates that Direct Drainage areas 4 and 5 (Map2, pg29) are the most densely populated, with the ratio of acres to the number of property parcels being 3.04 and 1.75, respectively. The table also demonstrates that the largest stormwater runoff volumes from roadways in these areas comes from direct drainage area 1, 2 and 5. Please refer back to Map 2 for visualization.

Table 8 - Direct Drainage Roadway Stormwater Runoff Volumes

Direct Drainage Areas	RdLinearFt	Sq.Ft of Rd	Acres of Rd	Rv	WQv (acre-ft)	WQv (cu.ft)	Total Area Acreage	RdFt/Acre	#Parcels	Ratio Ac:#parcels
1	9753	243825	5.60	0.95	0.443	19,303	72.7	134	46	0.63
2	6172	154300	3.54	0.95	0.280	12,215	90.6	68	73	0.81
3	3619	90475	2.08	0.95	0.164	7,163	52.5	69	52	0.99
4	2412	60300	1.38	0.95	0.110	4,774	11.5	210	35	3.04
5	6451	161275	3.70	0.95	0.293	12,768	65	99	114	1.75
6	4144	103600	2.38	0.95	0.188	8,202	45.9	90	42	0.92
7	1441	36025	0.83	0.95	0.065	2,852	81.9	18	6.5	0.08

Town Progress Since 2008 Reports

The initial TMDL and Lake Management Reports recommended a 'Septic Management Plan' as well as a detailed investigation of geologic and soil restrictions. Based on conversations with the Town of Putnam Valley Engineer and Wetlands Inspector, they are acutely aware of the difficulties the landscape presents for soil-based wastewater and stormwater treatment. There has not been significant development in the watershed in the last ten years, but any new onsite wastewater treatment systems installed were based on current NY technical codes for conventional and advanced types of systems.

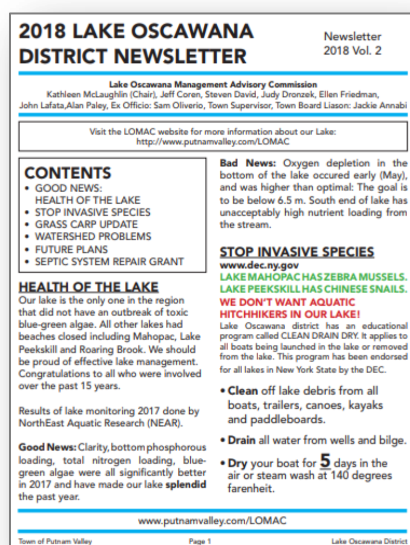
In February 2010, the Town of Putnam Valley adopted a local ordinance for Lake Oscawana, which required mandatory septic pumping for waterfront lots within twelve months of the code adoption. General consensus among Town officials was that this first year of septic pumping, for homes within 100-ft of the lake, was very successful, but that the second round of pumping for homes within 200-ft of the lake was not adequately enforced in 2011. **The ordinance aimed to enforce regular septic pumping of waterfront and nearby lots on a three year basis.**

Based on conversations with the Town Supervisor, the code enforcement office was able to more effectively enforce septic pumping in the watershed in 2017 and 2018. The records of pumping are intermixed with Town building code records, but the Municipal Separate Storm Sewer System (MS4) Annual Reports to the State of New York estimate that less than 1% of the septic systems in Putnam Valley were inspected and pumped between 2011-2015. The MS4 reports estimate that approximately 20% of systems were inspected and/or pumped in both 2016 and 2017 (refer to supplemental reference materials).

The most recent updates to septic improvements came in late 2018, when the Putnam County Health Department announced a reimbursement grant program for septic system repairs for residences within 250 feet from the lake. The excerpt below, from the LOMAC September 2018 District Newsletter, advertised this county program in hope that eligible residents will voluntarily elect to update their systems. As the first local septic reimbursement opportunity, success of the program will be dependent on resident notification, education, and voluntary enrollment. There may be a second round of funding but this is not yet certain. This program continued into 2019.

LO residents may receive a grant from the County Health Department if you live within 250 feet from the lake
If you live 250 feet from the lake and need repair of your septic system, you can receive up to $10,000 (50% match of the cost). You will receive a letter from the health department if you are eligible.

https://www.putnamvalley.com/wp-content/uploads/2018/10/Newsletter_Pages_9-18.pdf



2018 LAKE OSCAWANA DISTRICT NEWSLETTER

Newsletter
2018 Vol. 2

Lake Oscawana Management Advisory Commission
Kathleen McLaughlin (Chair), Jeff Coren, Steven David, Judy Dronzek, Ellen Friedman, John Lafata,Alan Paley, Ex Officio: Sam Oliverio, Town Supervisor, Town Board Liason: Jackie Annabi

Visit the LOMAC website for more information about our Lake:
http://www.putnamvalley.com/LOMAC

CONTENTS
- GOOD NEWS: HEALTH OF THE LAKE
- STOP INVASIVE SPECIES
- GRASS CARP UPDATE
- WATERSHED PROBLEMS
- FUTURE PLANS
- SEPTIC SYSTEM REPAIR GRANT

HEALTH OF THE LAKE

Our lake is the only one in the region that did not have an outbreak of toxic blue-green algae. All other lakes had beaches closed including Mahopac, Lake Peekskill and Roaring Brook. We should be proud of effective lake management. Congratulations to all who were involved over the past 15 years.

Results of lake monitoring 2017 done by NorthEast Aquatic Research (NEAR).

Good News: Clarity, bottom phosphorous loading, total nitrogen loading, blue-green algae were all significantly better in 2017 and have made our lake **splendid** the past year.

Bad News: Oxygen depletion in the bottom of the lake occured early (May), and was higher than optimal: The goal is to be below 6.5 m. South end of lake has unacceptably high nutrient loading from the stream.

STOP INVASIVE SPECIES
www.dec.ny.gov
LAKE MAHOPAC HAS ZEBRA MUSSELS.
LAKE PEEKSKILL HAS CHINESE SNAILS.
WE DON'T WANT AQUATIC HITCHHIKERS IN OUR LAKE!

Lake Oscawana district has an educational program called CLEAN DRAIN DRY. It applies to all boats being launched in the lake or removed from the lake. This program has been endorsed for all lakes in New York State by the DEC.

- **Clean** off lake debris from all boats, trailers, canoes, kayaks and paddleboards.
- **Drain** all water from wells and bilge.
- **Dry** your boat for 5 days in the air or steam wash at 140 degrees farenheit.

www.putnamvalley.com/LOMAC

Town of Putnam Valley Page 1 Lake Oscawana District

The Town has also made progress in curbing watershed stormwater runoff through a number of grant-funded water quality improvement projects. In coordination with the Town Engineer, a number Fabco sediment and phosphorus filters were installed in catch basins annually since 2010. However, the phosphorus-specific filters capture mostly sand and organic material, and it is not yet possible to adequately measure the mass of phosphorus reduction per filter over time. Ortho-phosphate specific filters are still used at catch basins that are closest to the lake, but if left uncleaned after major rains, these filters prevent rapid waterflow into catchbasins, decreasing the volume capacity once filled with debris. As part of budget balances, the Town has refined a list of priority catch basins that should utilize phosphorus filters.

2.2 Estimated Pollutant Load Reductions

Historical Pollutant Load Modeling

Two initial nutrient loading models were applied to Oscawana Lake in 2008. The results from both the Cadmus Group Total Maximum Daily Load (TMDL) and the Princeton Hydro report are compared below against an updated Lake Loading Response Model (LLRM), which is a spread-sheet model initially developed by the University of New Hampshire and modified by Dr. Ken Wagner in 2009. Both models were run using nutrient runoff coefficients based on land cover and water volume.

Table 9: Phosphorus Load Model Results Compared

Performed by:	Total Estimated Annual P Load	Modeled Watershed P Load	Internal P Load	Surface Runoff P Load	Septic Systems P Load
Camus Group, 2008	663 lbs (300.7 kg)*	663 lbs (300.7 kg)	Not Calculated*	228 lbs (103.4 kg)	313 lbs (142 kg)
Princeton Hydro, 2008	**2,170.8 lbs (984.5 kg)**	835.2 lbs (378.8 kg)	1,247.4 lbs (565.7 kg)	428 lbs (194.1 kg)	407.3 lbs (184.7 kg)
Northeast Aquatic, 2018	**1,490 lbs (678 kg)**	960 lbs (436 kg)	467 lbs (212 kg)	560 lbs (254 kg)	400 lbs (182 kg)

* TMDL did not include internal P loading estimate and represents only external loading.

What is important to note is that the TMDL was only concerned with the watershed inputs and did not consider the internal phosphorus loading impacts to lake eutrophication. While the Princeton Hydro report did include an estimate for internal phosphorus loading, we believe this estimate is too high. Updated water quality data shows that internal phosphorus loading is not consistent from year to year. The Princeton Hydro report used an internal phosphorus flux rate of 6.0 mg/m^2/day for anoxic sediments. Yet in a modeling analysis of actual hypolimnetic Oscawana data, the actual flux rate appears to hit a maximum of 3.0 mg/m^2/day for sediments in the 7-meter depth range in peak summer conditions. For deeper sediments, this flux rate was measured to be an average of **less than 3.3**

mg/m²/day from June to September. It is important to note that areas of the lake do not accumulate sediment and organic material uniformly, thus the recycling of nutrients will also vary across the lake bottom, which is why we chose to differentiate between flux rates in the deep-hole and in the widespread 7-meter depth range. Using these measured concentrations and flux rates, we estimated that the anoxic sediments released only 288 kilograms of phosphorus per year from 2013-2016, which were years of strong internal loading. The fraction of this measured internal load that was entrained into the surface waters to fuel algae blooms is much less due to strong thermal resistance to mixing across the thermocline. The LLRM model confirms these calculations with a similar estimate of just 212 kgs of phosphorus per year of internal loading.

Furthermore, recent analysis of phosphorus data supports that reductions in internal phosphorus loading are possible without direct control via aeration or alum, and instead by controlling external anthropogenic nutrient sources. Details are discussed in the following section.

Modeling In-Lake Phosphorus to Predict Feasible Mass Reductions

For the purposes of this watershed plan, we calculated an estimate of total in-lake phosphorus mass based on TP concentrations measured throughout the past two decades. This model allows for a data-based comparison of apparent phosphorus loading with the actual quantity of phosphorus observed in the entire lake. This model includes data from all water quality sampling events since the early 1990s to 2018. One-foot depth contours and respective surface acreages were transformed into metric units to align with water quality sampling depths. Monthly sampling depths from 1,4,6,7, & 9 meter TP concentrations were multiplied by their respective volumetric units of water (TP in micrograms/Liter * Liters of water per horizontal layer of water = TP mass). The table below demonstrates the layers of water and associated volumes used in modeling internal phosphorus mass in the lake.

Table 10: Water Volumes of Lake Layers

Depth (meters)	SUM Ac-ft	Cubic Meters	Liters
0.0-3.0	3502.88	4,320,735	4,319,053,602
3.1-5.8	2275.18	2,806,387	2,805,295,192
5.9-7.0	518.60	639,688	639,439,525
7.1-8.5	342.30	422,226	422,061,743
8.6-10.7	14.42	17,791	17,784,419
SUM Total Lake	**6,653**	**8,206,828**	**8,203,634,481**

The resulting long term in-lake TP mass (kilograms) is displayed below in Figure 18. As can be seen, phosphorus mass in the lake varies significantly throughout the years and during the season. Actual TP values per date are included in the Appendix. The graph in the Appendix demonstrates a period of reduced in-lake phosphorus mass from 2009 to 2012, followed by a sharp increase in 2013 and a subsequent season-wide decrease in 2017 and 2018. Years 2010 and 2017 were the lowest in-lake phosphorus mass on record since the late 1990s. The 2017 Lake Monitoring Report discussed this phenomenon and how the periods of nutrient reductions coincide with both septic ordinances/pumping and reduced mechanical weed harvesting loads.

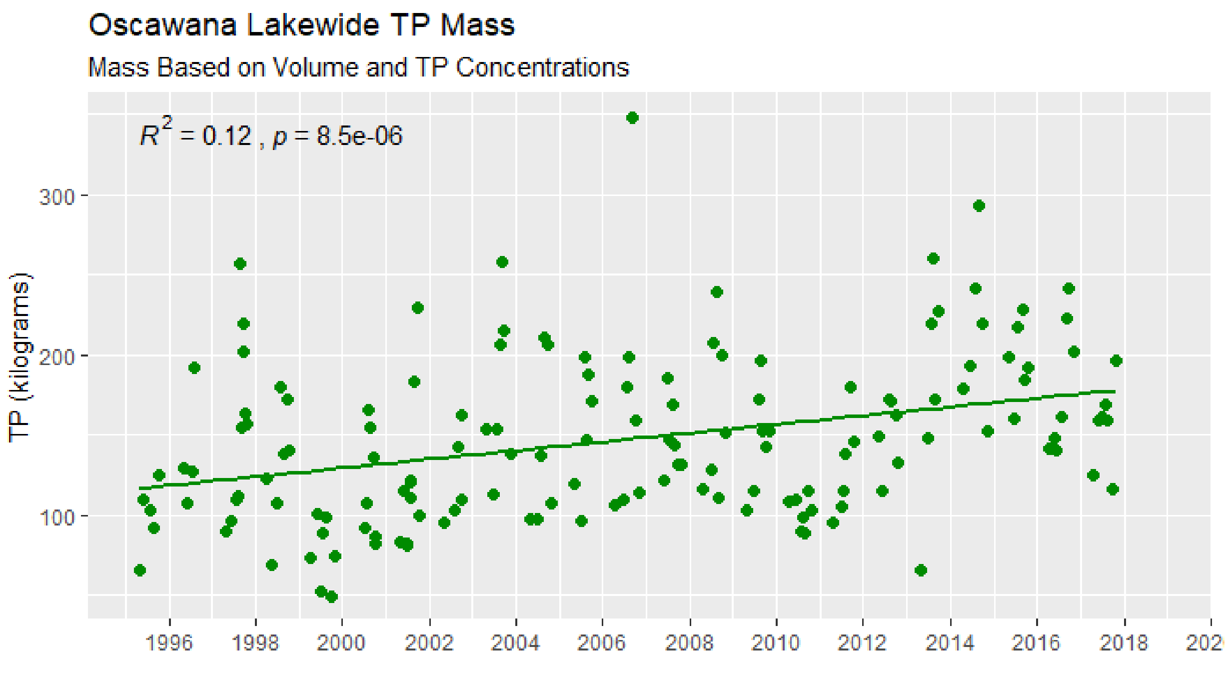


Figure 18: Long Term Lake Phosphorus Mass

External Reductions to Facilitate Internal Reductions

The historical in-lake total phosphorus mass is the foundation to understanding internal loading. Phosphorus mass was further divided and analyzed on a seasonal basis. Figure 19 below demonstrates the seasonal changes in lake phosphorus mass from 1994 to 2018. The horizontal dashed line serves as a **target threshold for Lake Oscawana of 130 kilograms of phosphorus**, which is the quantity of phosphorus present in the lake during most years in early spring. Years where phosphorus mass remained below this threshold for the entire season are outlined (boxed) in navy blue. Readers should also note that the pattern of seasonal phosphorus mass in the lake is not uniform from year to year. There are years where mass loading appears to be higher than others, indicating that suppression of internal loading is possible.

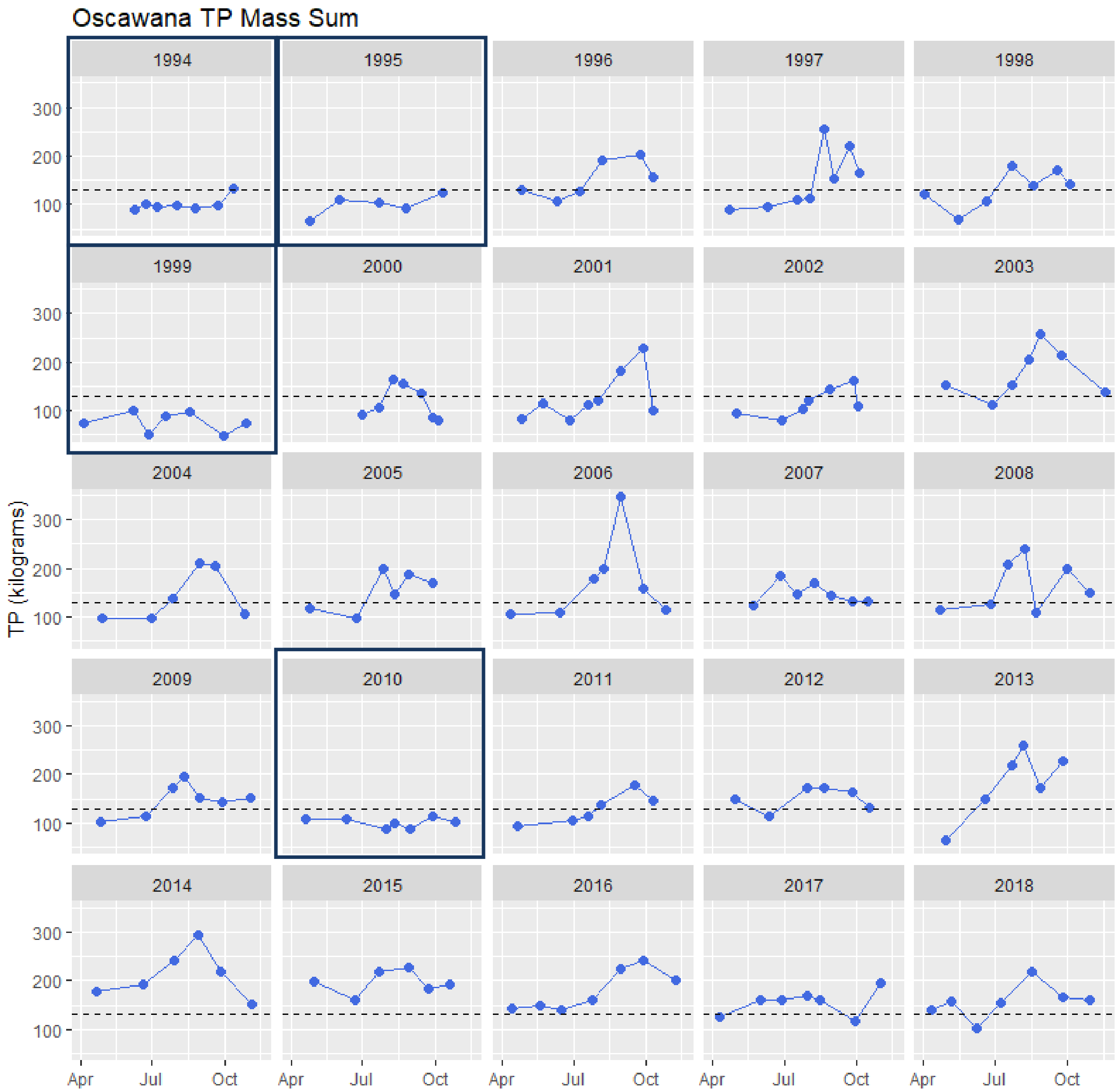


Figure 19: Seasonal Lake Phosphorus Mass by Year

When phosphorus inputs from the watershed are reduced, the lake should respond with suppressed internal loading (Jeppesen, 2005).

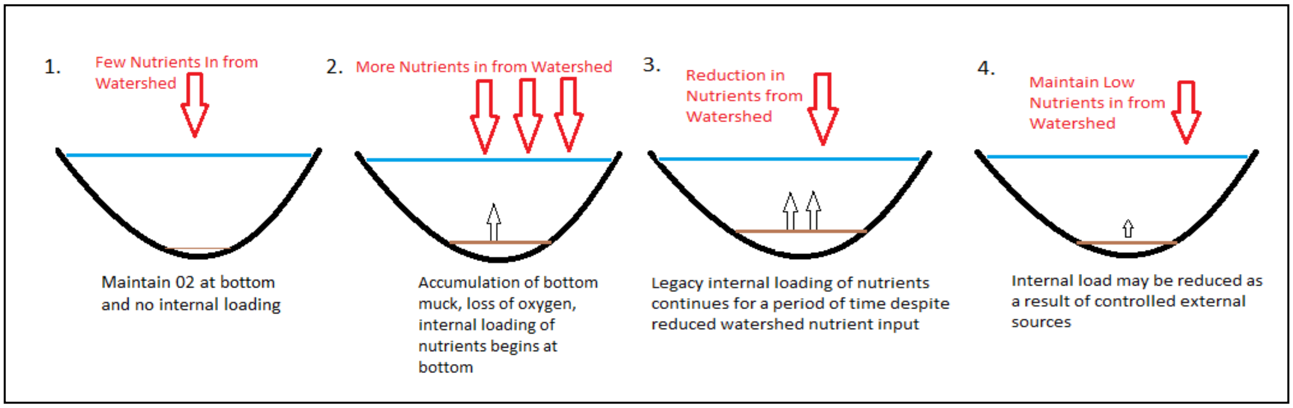


Figure 20: Internal Loading Suppression Diagrams

Modified from Gertrud Nurnberg 2017 Internal Loading Workshop at North American Lake Management Society.

As previously mentioned, 2010 and 2017 overall low phosphorus masses coincide with the periods of septic system pumping of shoreline properties. New findings also suggest that disturbing shallow sediments during annual weed harvesting efforts negatively impacts water quality by increasing phosphorus mass in the water column.

Weed harvesting records of the last decade were tracked by the harvester operators on their respective payment time-sheets. The harvesters record the number of hours, approximate area of weed harvesting, and the number of daily "loads," which is roughly the number of times the harvester becomes full with plant and organic material and has to off-load. Though the "loads" metric is not an ideal way to track the amount of weed harvesting in past years, this was the only information on record. Only seven years of harvesting data has been recovered since 2009, yet a statistically significant correlation was found between the number of harvested loads and total in-lake phosphorus mass (r^2 = 0.6435, p-value = 0.029). This correlation is prompting new conversations about weed control, which are discussed further in Section 3.0.

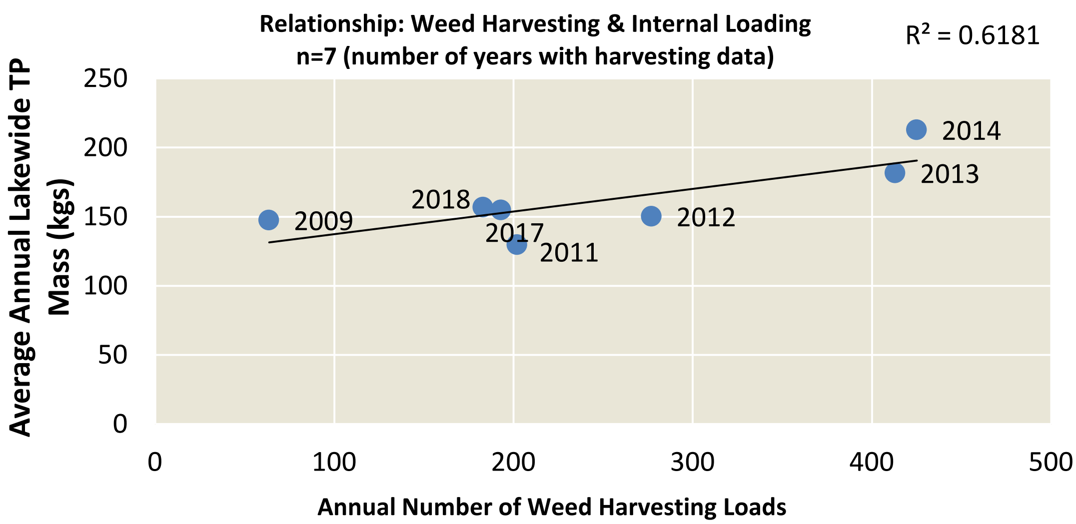


Figure 21: Weed Harvesting Loads vs. Phosphorus Mass

Based on nutrient monitoring it is apparent that there were years with much less internal loading than others. Similarly the surface nitrogen concentrations have been steadily declining since 2004, which may be attributed to onsite wastewater improvements over time. Nitrate nitrogen readily leaches to the groundwater table and impairs downstream water quality by increasing plant and algae growth. If onsite wastewater systems were being updated and more adequately maintained, there would be significantly less nitrogen entering the lake. This trend, as demonstrated in the figure below, would be more apparent than phosphorus changes because phosphorus accumulates in aerated sediments for long periods of time. The very high outliers of nitrogen on this graph are not explainable at this time and may either have been related to concentrated surface cyanobacteria blooms or laboratory error.

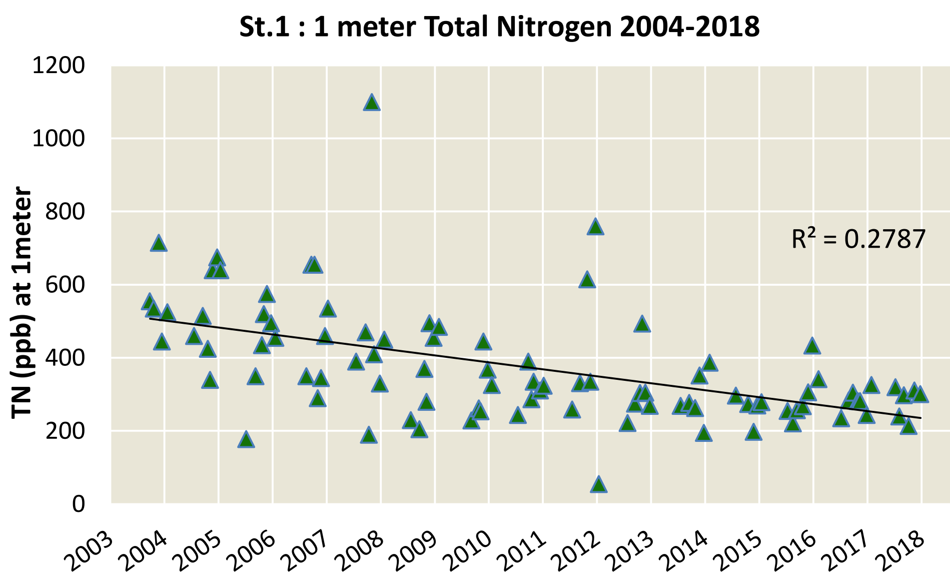


Figure 22: Historical Nitrogen Concentration Trend

With this new internal loading information, a Watershed Based Plan to reduce external sources, as well as a less disruptive weed management plan are critical to maintaining lower phosphorus in Lake Oscawana in years to come.

2.3 Nonpoint Source Pollution Management Measures

Critical Areas Requiring Nonpoint Management Measures

This section outlines critical areas requiring nonpoint source pollution management measures. Proposed stormwater projects are based on utilizing natural soil conditions and the landscape to infiltrate stormwater in a way that is as cost effective as possible. The goals of stormwater Best Management Practices (BMPs) are to minimize runoff, slow water velocity, de-channelize water flow, and infiltrate water into vegetated soils whenever possible.

The following Critical Areas for watershed BMPs are listed in order of priority based on overall nutrient threats to the lake:

1. Lee Ave Inlet
2. Winnebego / Chippewa Road
3. Community Place & Hilltop Park
4. Inlet 7 at Lakefront Road
5. Investigate Potential Illicit Discharges (3 identified sites)
6. West Shore Drive Catch Basin Retrofit / Infiltration Easement (2 parts)
7. West Shore Drive Primary Erosion Project
8. West Shore Drive Small Erosion and Infiltration Projects (4 sites in order of priority)
9. Cayuga Road
10. Sunken Mine Road
11. Unadilla and Seneca Drive
12. Lee Ave Lake Access Path
13. West Shore Biofiler
14. Test Lawns Soil Nutrients / Property Fertilizer Use

Low Elevation Shoreline Septic Systems constitute their own High Priority and are not included in the list.

1. Lee Ave Inlet

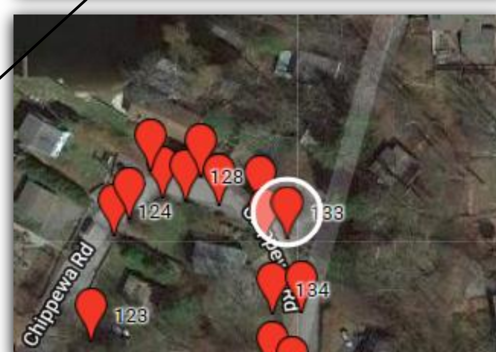
The Inlet 4 samples are collected at the road on the northern side of Lee Ave. This area is notorious for very high nutrient concentrations and frequently tests positive for fecal coliform bacteria. The aerial image shows that water that is sampled comes directly from an upstream private pond (white arrow), which is frequently full of algae. From the road you can see pipes on private property which appear to drain the front lawn into a private pond. The pond then flows under Lee Ave to the lake through a concrete channel on a wooded parcel. It is very likely that upstream septic systems are contributing to a plume of groundwater pollution in the immediate area of Inlet 4. By late December 2018, the health department has been made aware, but no action has been taken. E. coli bacteria testing was also performed in 2019 based on recommendations from the health department.

LOMAC has expressed continued interest in acquiring a portion of the parcel downstream of the private pond (outlined in white) and utilizing it to address the high nutrient concentrations present in this area. However, **the first step should be to ensure proper functioning of all upstream septic systems in this area** and to work with the local health department. Purchasing the property for a stream restoration project or stormwater management project will not fix the issues of upstream wastewater impairment. Only after addressing nearby onsite wastewater issues can the downstream parcel be used for a **stream de-channelization project** and potential installation of **tiered "level spreaders."** Any de-channelization project aimed at infiltrating water must aim to maintain prominent existing vegetation and trees. **Estimated costs: $ TBD** (project not defined prior to Health Department inspections).

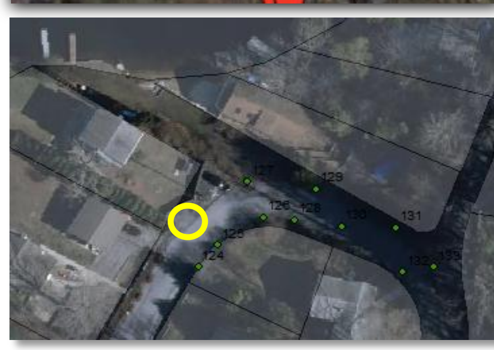
2. Winnebego / Chippewa Road

The curve of Chippewa Road is very steep and water flows into a series of catch basins down Winnebego and around the corner of Chippewa, towards the lake. All catch basins on this Winnebego-Chippewa stretch of road were full of debris on all site visits. Catch basin filters were not visible but may have been present under the debris. Again, this **whole street should be maintained with the phosphorus filter inserts and prioritized for catch basin cleaning**.

Waypoint 133 marks a catch basin next to a privately owned lot with an open grassy area that could serve as a bio-retention stormwater infiltration basin for small storms (area traced with yellow-dashed line). Additionally, this catch basin would need to be retrofitted with a particle separator unit connected to the bio-retention cell with an overflow mechanism for large storm events. **Estimated cost $25,000**.



The Town must check the extent of the road easement at this location. The **bottom of the hill is also a Town access site** with a catch basin (Right: WPT#127 circled in yellow) that could be converted to a holding wetland or infiltrative area depending on soil infiltration rates. Local soils are surveyed as well-drained Paxton fine sandy loam, but test pits must be dug prior to stormwater design. **Estimated stormwater improvement costs $30,000.**



Additionally, all catch basins on Chippewa, Sioux, and Winnebago Road were full of debris, which gets caught above the filter inserts and may prevent proper functioning of the catch basins. On most recent visits in 2018 and 2019, many of these catch basins were flooded and the filters were in need of repair. This whole area is a priority for specialty phosphorus filters. Yet with large amounts of flooding and water stagnation on the corner of Chippewa and Sioux, the Town should consider this a priority for complete roadway reconstruction with innovative stormwater practices in mind. **Estimated costs > $50,000.**

3. Community Place & Hilltop Park

Erosion of Community Place road and large volumes of water flow to two catch basins at the end of Community at the intersection of West Shore Drive - marked as white star. Water then flows under the road and into the Hilltop Park swales / catch basin system. There are a series of failing silt fences in Hilltop Park and very high concentrations of nutrients in groundwater seepage. **High groundwater nutrients are likely related to septic leaching** from uphill systems; the yellow star indicates seepage flow and sampling point where **Nitrate nitrogen = 4,930ppb (4.9mg/L) and Total Phosphorus = 139ppb.** We recommend testing this site for fecal coliform in 2019 and notifying the local health department if bacteria tests are positive. The Town should also clean the catch basins in Hilltop Park and either replace failing silt fence, or install a more permanent barrier to protect against slope erosion caused by groundwater seepage. **Estimated costs: $300** for additional bacteria and nutrient testing. **Follow up with Health Department.**

Photos of Community Place and seepage location at Hilltop Park




4. Inlet 7 at Lakefront Road

Monitoring at Inlet 7 at the intersection of Lakefront Road suggests that there may be multiple septic systems in this immediate area that are not functioning properly and are leaching high nutrients to the downstream wetland and lake. Fecal coliform tested at this location in 2018 were 270 colonies per 100 mL. Further 2019 E. coli testing revealed **3700 E. coli** colonies per 100mL, which is very high and invoked Public Health Department involvement.
Estimated costs: $300 further bacteria and nutrient testing per year.
Follow up with Health Department.

5. Investigate Potential Illicit Discharges

In the area of 59 West Shore Drive (WPT #24 in GoogleMaps GPS file-shared with LOMAC), there is a small white pipe that comes out of a retaining wall. At the time of inspection this pipe and area smelled of sewage. Further investigation is need to ensure that this drainage pipe is not leaking septic effluent into the nearby catch basin during storm events and high groundwater periods. **Estimated costs: $No Cost**

Similarly, there is another suspected illicit discharge near 51 Lee Ave (WPT #54 in GPS file). This unknown white pipe also requires inspection and potential elimination. **$NC**

An unknown corrugated pipe was also documented as draining into catch basins located at 129 West Shore Drive (WPT #8 and #9). This pipe may be related to groundwater routing to protect roadways, but groundwater should not be draining to the stormwater system and this area needs further inspection as well. **$NC**

6. West Shore Drive Catch Basin Retrofit / Infiltration Easement

Across from 110 West Shore Drive (GPS WPT#3) there is a catch basin that should be retrofitted to overflow to an infiltration easement on vacant residential property. The property is privately owned, however, so there must be a form of public-private partnership for this retrofit (Tax ID-62.13-1-77). This same infiltration easement could be used to reroute catch basin stormwater flow from the area of 27 West Shore Drive (GPS WPT#4).

Estimated costs: $15,000 for physical retrofit work. Potential costs for public-private cooperation unknown.

7. West Shore Drive Primary Erosion Project

The northern section of West Shore Drive has consistent roadside erosion. During seasonal spring high-groundwater conditions, water frequently seeps out of the hillside and across the road, which can damage roads during freeze/thaw events and cause flooding and erosion. Potential solutions include proper under-road drainage to the forested area across the street. The Town could also install small tiered water storage system on western side of road to prevent flooding and erosion. **Estimated costs: $ 20,000+**

However, a primary source of this erosion comes from a private driveway just uphill (153 West Shore Drive). Encouraging the property owner to work with LOMAC to install trench drains - example areas indicated with stars - to flow into a small rain garden at the corner of the property would prevent much erosion. The trench drain could be easily cleaned by the highway department at the time of annual catch basin cleaning. An example of a type of trench drain and rain garden is shown in the third photo. **Estimate costs: $ 3,000**

Photo 3 Credit: https://s-media-cache-ak0.pinimg.com/originals/44/61/7a/44617a40b9ad8c540f00bc6a8c47acd7.jpg.

8. West Shore Drive Small Erosion and Infiltration Projects

Potential spot for roadside curbing to minimize erosion. Located near 146-148 West Shore Drive. **Estimated costs: $5,000**

Rain garden infiltration at the top of a private driveway located at 160-162 West Shore Drive. This location could also use pervious interlocking pavers to infiltrate stormwater from both directions of uphill flow. **Estimated costs: $12,000**, though prices may be much lower if privately funded.

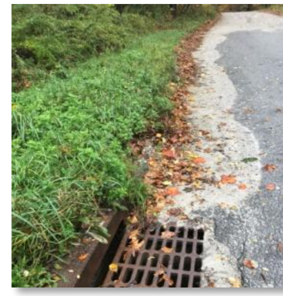
Small rain garden site around private mailbox area at 116 West Shore Drive to limit street stormwater runoff. A rain garden could be installed privately for minimal costs **(estimated $800**), but costs would be higher if the Town were to incorporate highway and/or engineering personnel to perform the work.

The hillside at 218 West Shore Drive needs to be stabilized to prevent further erosion and runoff. This area is very close to where the road becomes private. The hillside stabilization should utilize native shrub planting with roots that can thrive in shallow bedrock conditions present in the area. **Estimated costs: $500** for plants and labor.

9. Cayuga Road

Clean and maintain the catch basins on lower Cayuga Road near Abele Park. On multiple visits the catch basins in this area were completely full of debris and unable to hold substantial volumes of water. **To be performed by Town Highway Department, $TBD.**

10. Sunken Mine Road



Sunken Mine Road intersection with North Shore Road: visible road erosion and runoff flows into stormdrain. Drain needs sediment filter to prevent road runoff from entering this Inlet 1 stream. **Estimated costs: < $500.** Paving this road was not considered due to the seasonal usage.

11. Unadilla and Seneca Drive

There are no catch basins on this street, and the corner intersection is subject to stormwater sheet flow down Seneca Drive to the lake. Reduce water volume that makes its way to the steep slope of lower Seneca by installing infiltrating catch basins in the upper road areas, if possible. Feasibility will depend on presence of suitable soils and depth to bedrock. Maintain sheet flow in lower section of road, which minimizes roadside erosion and reduces water velocity. **Estimated costs: $TBD - Follow up with Highway Department for project feasibility.**

12. Lee Ave Lake Access Path

This area is a low point where stormwater accumulates and flows down the footpath. Some Lee Ave stormwater may be directed to a small rain garden at this location, which would be placed on existing Town property. **Estimated costs: $4,000**

13. West Shore Biofiler

The West Shore biofilter is included in this list in order to explain the functioning and to ensure proper maintenance in years to come. The biofilter, which is adjacent to Inlet 5, serves as a stormwater retention pool and wetland filtration system. Residents were long under the misunderstanding that the biofilter was intended to purify the Inlet 5 water, however, the primary function of the biofilter is to receive stormwater from West Shore Road. Stormwater runoff enters a culvert and mixes with the Inlet 5 water during high-flow periods, spilling into the biofilter. Testing at the biofilter in 2018 revealed that there was no major decrease in nitrogen or phosphorus from the inlet compared to the outlet of the biofilter. Samples were taken at four sites. The first sampling site was a groundwater seepage point from the West Shore drive hillside across the road from the biofilter. Sites 2-4 are indicated on the images below and nutrient test results are shown in Table 11.

Table 11: West Shore Biofilter Test Results

Sample ID	Description	Date	Nitrate	TN	TP
February 2018					
1	Groundwater seepage at road	2/27/18	1060	1326	199
2	Culvert flowing into biofilter plunge pool	2/27/18	103	140	10
3	Biofilter plunge pool outlet	2/27/18	119	167	9
4	Biofilter outflow from wetland to lake	2/27/18	87	169	16
April 2018					
2	Biofilter pool inlet	4/11/18	NS	327	3
3	Biofilter pool outlet	4/11/18	NS	247	24

* All nutrient concentrations are in parts per billion (µg/L). NS = Not Sampled.

Results and field investigations at the biofilter indicate that the groundwater levels are too high for the filter to adequately hold stormwater in the settling basin and that only very large sand and gravel particles will settle in the pool. The pool is also was frequently cooler than the Inlet 5 temperature, meaning that the biofilter is filled with groundwater, not just stagnant storm water. During the summer months the water level in the pool was lower, and there was little to no outflow during summer inspections. At present, no further maintenance to the biofilter plunge pool is recommended because the pool component is not the major nutrient filtration section of the biofilter. Instead, the adjacent wetland that receives flow from the plunge pool should be monitored to prevent water channelization. Stormwater should be spread out over the entire wetland area.

14. Test Lawns Soil Nutrients / Property Fertilizer Use

Despite a ban on phosphorus fertilizer in the Oscawana watershed, nitrogen fertilizers are also bad for lake water quality, and most lawns are over-fertilized by both homeowners and professional lawn care servicemen. Homeowners should test their soils before any nitrogen fertilization to determine adequate quantities for soil health and to limit migration of nitrate through soils to the lake. Seasonal group sampling can be arranged if needed, but residents may also send samples to the Cornell Cooperative Extension laboratory. Sample costs are usually under **$25 per sample**.

Septic System Management Program

The septic system pump-out ordinance is a great step towards homeowner accountability for onsite wastewater nutrients. However, the septic system upgrade and repair grant program is a better opportunity to improve nutrient conditions at the lake. Simply pumping very old systems will not prevent excessive long-term nutrient loading to soils, especially soils that are too close to the groundwater table. For reasons already stated, all septic systems within the yellow contour line that represents 2ft above typical lake water level are vulnerable to hydraulic failure and flushing of nutrients during high groundwater periods. Abele Cove and Wildwood Knolls have the most concentrated number of homes at this elevation and are primary concerns for septic upgrades and pumping. In order to better understand this impact, **lake level monitoring gauge should be installed** in an area where lake managers have access to regularly document the levels.

The entire world is facing new water quality challenges related to old onsite wastewater infrastructure. There is expanding scientific research to support that septic systems may only retain phosphorus in aerated soils if they have at least 3ft of soil above the groundwater table (Lombardo, 2006). Similarly, some research points to limited abilities of soils to retain phosphorus over 20 years (Robertson, 1998 & 2008). The lifetime of septic leach fields at Oscawana are frequently more than double that time span.

The Town of Putnam Valley and LOMAC should continue to communicate with the Putnam County Health Department. Homeowners should view updates to their onsite wastewater systems as an investment in their property and the lake. The Putnam County Health Department septic-update grant program was a great opportunity for Oscawana homeowners within 250 feet of the lake shore. There may be additional regional funding opportunities in the future that allow homeowners to take advantage of advanced nutrient removal technologies newly permitted in NY. The Town should also prioritize ongoing septic pump-outs and inspections. Records of inspections, pump-outs, and system updates should be made easily accessible and available to LOMAC. In concert with the Public Health Department, future inspections of watershed homes could also include a questionnaire about leach field and soil conditions to gather better data on which systems may need updates and potential innovative designs permitted for the reduction of nutrients.

Watershed BMPs and Expected Load Reductions

In order for the Town to move forward with the watershed Critical Areas improvement projects outlined in this management plan, the following section presents a description of various stormwater soil-filtering methods and their respective capacities to reduce nutrient loading. Stormwater Best Management Practices (BMPs) include careful construction of appropriate technologies given the site slope and soil conditions. Detailed reduction percentages are derived from a series of scientific publications, including a review of stormwater treatment methods conducted by the EPA (Jiang et al. 2015, Barret et al. 2004, U.S. EPA 2008, Young et al. 1996). **Proposed stormwater improvement updates will need to be planned based on the local soils, site area, and topography - creative Low Impact Designs (LID) are encouraged.**

Dry Detention Basins

Dry detention basins are designed to store and infiltrate storm-water runoff in a level, vegetated depression. Based on available scientific literature, nutrient reduction is variable but Total Phosphorus reductions are up to 30%. Dry detention reduces Total Nitrogen by up to 50%[1]. The variation in nutrient decrease is attributed to differing soil characteristics and is also dependent on the design of the dry detention system. Improper grading will prevent even dispersal of rainwater and reduce pollutant reduction. If water is allowed to pool for long periods of time, phosphorus may be released from the sediments as biologically available ortho-phosphorus. This can occur if the filtration bed becomes clogged over time with very fine sediment and organic particles; which is minimized by an adequately maintained forebay (smaller detention prior to full dry detention area). This type of stormwater BMP is frequently used along sides of highways or apartment complexes. Proper design and construction are critical and pollution control can be further increased by manipulating underlying fill.

Photo 1 Dry Detention Basin (https://sustainablestormwater.org)

Wet Detention Ponds

Wet storm-water detention ponds are designed to let particles settle out, thereby reducing TSS up to 94%. However, if the pond is not designed and sized correctly it will merely act as a flow through system with no containment. Inadequately designed wet detention ponds may also have the inflow and outflow too close together, negating any particulate-holding ability. On average, nitrogen concentration reductions for these types of ponds are around 9-32%. Wet detention ponds are not designed to retain phosphorus and are typically only used to hold very large volumes of water to prevent flooding. For these types of systems, phosphorus reductions are around 5%, yet some research suggests that

[1] Estimates based on many peer-reviewed publications and also in agreement with the MA Stormwater Handbook.

orthoreactive-phosphate concentrations in effluent may increase to greater than influent concentrations as a result of sediment release from standing water. We have observed this increase in stormwater ponds in Connecticut. It is important to note that simply retaining suspended solids (TSS) does not reduce phosphorus by equivalent levels. These systems are not recommended in the Oscawana watershed.

Constructed Wetlands ("Bio-filter")

Constructed wetlands are similar to wet detention ponds: they are permanently flooded, but these wetland areas are designed to be shallow and well-vegetated. Storm-water nutrients in constructed wetland systems are partially used by plants, primarily nitrogen. Robust woody wetland plants use and store nutrients before they reach the Lake. Constructed wetlands create wildlife habitat and are aesthetically pleasing.

Ongoing research suggests that initial phosphorus reduction of constructed wetlands can be as high as 60%, but as nutrients saturate the system over 10-20 years, retention capacity declines (Mitcsh et al. 2000). It will be critical to monitor the effectiveness of the Oscawana bio-filter as it matures in age. Like all forms of storm-water treatment, an understanding of the underlying sediment is critical to initial design, maintenance, and lasting efficiency.

Bio-retention / Rain Gardens

Though the term 'rain garden' is frequently used across multiple types of stormwater filtration systems, these types of systems are more correctly referred to as bio-retention systems. The goal of rain gardens is to infiltrate storm-water onsite in a shallow depression. Rain gardens will pool with water during heavy rains, but water should fully infiltrate into the underlying soils within one to two days.

Rain gardens are excellent at reducing the overall water volume entering a lake system as road runoff or through underground culverts. Rain gardens are best used on small scales and are a good thing for homeowners to invest in to reduce runoff from their own properties. Depending upon the design, rain gardens are capable of reducing sediments and nutrients. Increased phosphorus retention is possible with the use of additional iron and aluminum oxides in the subsoil. The Town may want to explore ways to provide incentives and guidance to homeowners within the Oscawana watershed to direct driveway runoff into small personal rain gardens.

Porous Pavement

Porous pavement systems are designed to infiltrate storm-water and reduce overland runoff during heavy rain. Typical sidewalks, parking lots, and roadways are built using impervious materials that do not allow rainwater to penetrate into the underlying soils. Porous pavement is made of either cement or asphalt. The material

Photo 2 UCONN Center for Land Use Education and Research Pervious Pavement Demonstration

is constructed with tiny holes that allow water to filter through and infiltrate onsite rather than being directed into storm drains.

Flow reduction studies determined that permeable interlocking concrete and porous pavement with an underlying gravel sub-base reduce overland runoff and allow soils to naturally filter phosphorus. However, permeability relies on the void spaces in the pavement material and can be easily clogged if not maintained. Porous pavement should not be sanded during winter months and biennial vacuuming may be necessary. No consistent nutrient reduction percentages were found in the literature, but phosphorus is naturally retained to a high degree in infiltrating aerobic soils.

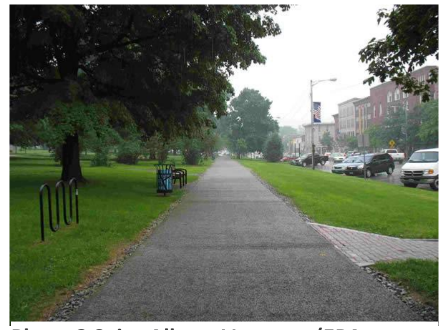


Photo 3 Saint Albans Vermont (EPA https://www.epa.gov/soakuptherain/soak-rain-permeable-pavement)

Interlocking Pavers & Pea-Gravel

Interlocking pavers filled with pea-sized crushed gravel (Photo 4), have been installed in several locations in the Oscawana watershed as a follow-up to the initial TMDL and lake management plan published in 2008. This type of infiltration is good for walkways, lightly-used parking lots, and driveways. Again these types of pavers require specific maintenance and are subject to clogging if sanded or salted during winter months. This type, as well as many other similar interlocking pea-gravel pavers are not suitable for roadways and heavy vehicle traffic areas, though they are encouraged for personal driveways which mostly serve stationary vehicles.

Photo 4 Oscawana watershed interlocking pavers filled with pea-gravel

Vegetated Swales

A dry vegetated swale is a depression in the land alongside impervious surfaces, such as roadways and sidewalks. Dry swales are designed to slow water movement down steep hills via graded check dams, and to completely infiltrate the runoff. They should not be a zone of standing water. Infiltration capacity may be enhanced by manipulating the underlying sediments with aluminum and iron oxides, but dry swales need to be engineered and constructed based on the estimated water load that they would be expected to handle. Recent studies have suggested that total phosphorus and nitrogen reductions are near 30% for well-designed swales, but that a poorly designed system that creates standing water may actually increase dissolved P significantly.

Wet vegetated swales are typically used alongside highways and very large roadway systems. Wet swales are similar to constructed wetlands and rely on plants to use nitrogen. Most swales need overflow and under-drainage systems to connect back to the MS4.

Wetlands Restoration

The process of wetlands restoration can mean various things depending on the end goals of a project. Natural wetlands can be both sinks and sources of nutrients depending on their condition, relative age, and time of year. Wetlands restoration aimed at nutrient reduction often entails de-channelization of water flow while minimizing erosion. Wetlands disturbances can result in concentrated water flow patterns instead of diffuse flow across the entire wetland area. Diffuse flow allows for greater contact time of the water with the soils and the wetland plants for better nutrient uptake. De-channelization also minimizes erosion which will greatly reduce phosphorus inputs through streams. This type of wetland restoration would be appropriate at streams 1 and 2 to maximize the nutrient retention abilities of the existing wetlands despite high flow conditions.

Household Rainwater Harvest Systems

Rainwater harvesting systems, commonly known as rain barrels, are a way for individual homeowners to reduce the quantity of stormwater runoff from their own properties. This is also a great way to partner with local businesses and to create a local market for sustainable home products. Further discussion about rain harvest systems and runoff reduction is included in Section 2.5.

Street Sweeping and Catch Basin Cleaning Schedule

The Town should prioritize catch basin cleaning and limit winter sanding in direct drainage basins 1, 4, and 5. MS4 reports recorded nearly 3,000 cubic yards of sands and debris being removed from Putnam Valley catch basins in some years. The Highway Department should move to a digital record of catch basin cleaning instead of paper records. Paper records are not useful in tracking long-term updates in the watershed because they cannot be used as a searchable database. As part of this watershed plan, the records of 2016-2017 catch basin cleaning was tabulated in excel for Town records. Additional years should be entered and maintained by the Town Stormwater Coordinator. The Highway Department should also learn to utilize the Geographic Information System (GIS) maps of catch basins, at least utilizing the free Google Maps program and catch-based layer file created as part of this watershed management plan. The high-accuracy digital maps of the MS4 are supposedly GIS layer files possessed by the Town Wetlands Inspector and Town Engineer. We were not able to access these files and instead created the aforementioned GIS layer file of most catch basins in the Oscawana watershed. This file was presented to LOMAC through Google Maps.

2.4 Technical and Financial Assistance

State: New York Department of Environmental Conservation

- Water Quality Improvement Grants & Invasive Species Grants
- Update to TMDL implementation plan (approve list of watershed management projects)

County: Putnam Health Department

- Cyanobacteria (Harmful Algae Bloom) testing and beach closures
- Septic System Repair Funding
- Public Education for Onsite Wastewater BMPs

Putnam County Soil & Water Conservation District

- Stormwater education for public officials and residents

Town: MS4 Coordinator

- Additional stormwater education for residents
- Ensure that projects in the Oscawana watershed that satisfy MS4 requirements overlap with Oscawana Lake management Plan identified sources of impairment

Building Department

- Keep records of all onsite wastewater improvements and pumping records in Oscawana watershed - make records easily available to LOMAC
- Investigate potential illicit discharges found during NEAR's watershed investigation

Highway Department

- Continue to clean and maintain catch basins, sediment and phosphorus filters
- Keep digital excel-based log of catch basin cleanings to track long term improvements
- Should funding become available, implement watershed improvements suggested for Town roads and catch basins

Town Engineer & Wetlands Inspector

- Work with NEAR and LOMAC to design future Oscawana stormwater improvements

Lake Oscawana Management Advisory Commission (LOMAC)

- Oversee all management and monitoring activities for Lake Oscawana and surrounding watershed
- Serve as primary grant applicant and public outreach organization
- Continue educational public newsletters
- Oversee rain barrel program initiation
- Engage and communicate with local organizations:
    - Lake Oscawana Civic Association
    - Hilltop Community District
    - Abele Park District
    - Wildwood Knolls District
    - Smaller Homeowner Associations

2.5 Public Information and Education

Educating within Town Government

There needs to be ongoing communication between LOMAC and the Town Highway Supervisor, Town Consulting Engineer, Town Building Inspector, and Town Municipal Separate Stormwater System (MS4) Coordinator.

Because Lake Oscawana is within the upper watershed of the Hudson River in New York City, the efforts to fulfill annual regulated MS4 requirements should coincide with efforts specific to Lake Oscawana. Records of any stormwater improvements to Town roads within the Oscawana watershed should be tabulated over time and available in a lake-specific folder in Town Hall. This folder should include the Highway Department records of catch basin cleaning, notes, and filter type information.

Proposed Putnam Valley Rain Barrel Program

To benefit all lakes in the Town, an effort should be made to encourage residents to install rainwater catchment systems. A rain barrel program is an easy way to partner with a local business to promote sustainable options for homeowners in the watershed. LOMAC may be able to work with a local business to have them sell rain barrels to homeowners within the watershed as a way to reduce the quantity of water that inundates the Town storm drains and culverts. As roof gutters frequently drain to driveways on onto the public roads, every home that installs a rainwater catchment system will count towards a reduction in the quantity of water reaching Lake Oscawana through unfiltered stormwater culverts.

During a 1-inch rainfall, a 1,200sq.ft. home generates approximately 750 gallons of rainwater that runs off. If you multiple that rough estimate by the approximate number of homes within the Oscawana watershed, approximately 558 houses (Cadmus Group, 2008), that quantity of water then becomes nearly half a million gallons per inch of rainfall that could be slowly attenuated in soils instead of travelling across the streets, picking up contaminants, and entering the lake via stormwater culverts. That scale range increases further when you factor in the average 47-inches of rain that Putnam County receives on an annual basis. Rain barrels serve as a "grass-roots" community movement towards improved watershed management and are easily quantifiable through a Town sponsored and community-run program.

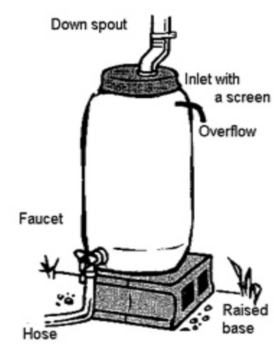


Image courtesy of Berkeley, CA, Office of Energy and Sustainable Development

Lake Presentations Video Log on Town Website

So far the annual public presentations have been successful in engaging and educating the community about lake management. These public presentations present an opportunity for residents to ask a variety of questions about aquatic plants, water quality, and stormwater. The presentation style of public outreach is usually effective in communicating complicated scientific concepts, and can summarize the annual monitoring concepts. The Town video log is critical to preserving this information for residents to watch if they were unable to attend the meeting in person.

2.6 Project Schedule and Implementation Milestones

Action Plan

- Utilize New York government grant programs for clean water and septic system replacement.
- Use Section 2.3 of this report to prioritize future watershed improvement projects. At least one project per year should be completed.
- Use BMP information in Section 2.3 to work with Town Engineer and NEAR to choose appropriate methods for stormwater control depending on site conditions.
- Establish education and community rain barrel programs, and encourage septic replacement opportunities.
- Rethink plant management efforts to prioritize water quality and phosphorus reduction.
- LOMAC leads NYDEC grant writing efforts in 2019 based on information in this report.

Useful links and information about NY funding opportunities:

Watershed Project Implementation Programs

New York supports watershed project implementation to protect and restore waters of the state primarily through two state funding sources: the New York Environmental Protection Fund (EPF) and the Clean Water State Revolving Fund (CWSRF). These watershed projects include best management practices (BMPs), land acquisition and other actions which serve to control or reduce the impact of nonpoint source pollution or pollutants on waters of the state. These state funds support four principal nonpoint source watershed project implementation programs including:

- Agricultural Nonpoint Source Program (Ag-NPS; from the EPF)
- Water Quality Improvement Program - Non-Agricultural NPS (WQIP; from the EPF)
- Clean Water State Revolving Fund (CWSRF) base program and Green Innovation Grant Program (GIGP) (from the CWSRF)
- Local Waterfront Revitalization Program (LWRP; from the EPF)

https://www.dec.ny.gov/docs/water_pdf/2014npsmgt.pdf

Septic System Replacement Program

Governor Andrew M. Cuomo announced a comprehensive $75 million program to improve water quality through the targeted replacement of aging septic systems in communities across New York (*an offsite link to the Governor's press release is in the "Links Leaving DEC's Website" section on the right side of this page*). Through a collaboration between the State Departments of Environmental Conservation and Health, and the Environmental Facilities Corporation, the state will support the new program in 31 counties with $15 million during its first year. Through this program, the state will provide funds to counties to reimburse eligible property owners for a portion of the cost of replacing failing septic systems and installing more environmentally effective systems.

https://www.dec.ny.gov/about/661.html

2.7 Indicators to Measure Change in Water Quality

This Watershed Management Plan would not be complete without defined ways to track improvements in water quality related to watershed improvements. The following section details measurable metrics to track success.

Spring Phosphorus Concentrations and Lake Loading

Spring Total Phosphorus (TP) content in a lake corresponds to watershed nutrient loading (Sawyer, 1947). Water quality sampling during late March to early April "ice-out" conditions will be used to estimate reductions in watershed phosphorus loading using four well-known simple models (Dillon & Rigler, 1975; Vollenweider, 1975; Chapra, 1975; Jones & Bachmann, 1976).

Table 12: Spring Phosphorus Metrics

Predicted Annual TP load (kgs)	Current Loading	Target Load
Loading Model	Spring TP @ 15ug/L	*Spring TP @ 12ug/L*
Kirchner and Dillon 1975	325	*260*
Chapra 1975	444	*355*
Vollenweider 1975	328	*262*
Jones and Bachmann 1976	183	*147*
Average	***320***	***256***

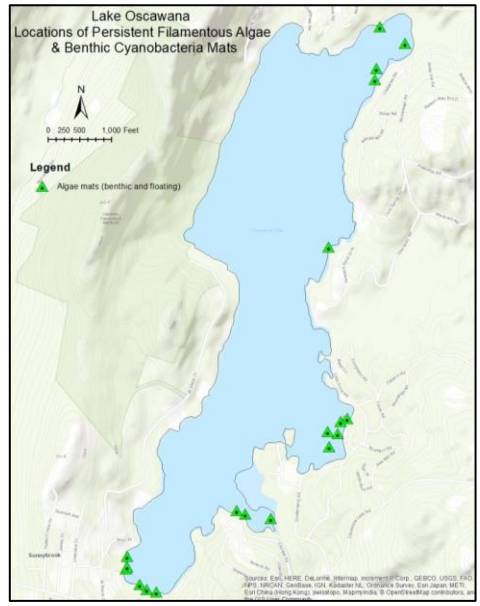
Potential reduction in lake TP annual loading = 64 kgs (20% total load reduction)

Seasonal In-Lake Phosphorus Mass

Use the range of in-lake volumetrically calculated phosphorus mass to quantify relative sources of nutrients over the course of a season.

Visible Algae

There are currently multiple areas around the lake with persistent floating rafts of filamentous algae (Chlorophyta) and/or thick benthic cyanobacteria mats. Algae is frequently a direct indication of localized nutrient input in the shoreline areas. It is not surprising that filamentous algae locations coincide with densely populated shorelines.



The quantity of filamentous algae in shoreline areas is expected to decline with continued reductions in lawn fertilizing, as well as proper septic system pumping and maintenance. Tracking filamentous algae patches around the lake will be done in concert with future aquatic plant surveys.

Stream Inlet Concentrations

Continue monitoring all seven major Inlets for Total Phosphorus, Nitrate Nitrogen and fecal coliform bacteria. Measure E. coli at Inlets 4 and 7 in future years, and use concentrations to track septic system and watershed improvements.

2.8 Tracking Effectiveness of Plan Implementation

Record Keeping of Plan Implementation Measures

- Number of Rain Barrels Installed in Watershed
- Number of Stormwater Management Measures (new vs. routine maintenance)
- Catch Basin Cleaning Digital Records
- Septic Pump-out Records
- Onsite Wastewater System Update Records
- Aquatic Plant Harvesting Records (GPS and number of loads recorded on time sheets)

3.0 Aquatic Plant Management Plan

3.1 Plant Management Efforts to Date

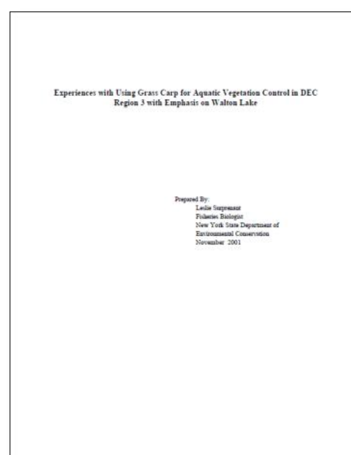
Mechanical weed harvesting has been the primary control measure for the invasive aquatic species Eurasian milfoil (*Myriophyllum spicatum*). The exact starting date of harvesting is not well-documented, but mechanical removal of Eurasian milfoil began at some point in the 1980s. Since the late 1990s, Northeast Aquatic Research has advised residents that weed harvesting has the potential to spread the invasive species because of the large number of plant fragments, yet at this time, residents were opposed to herbicide treatments. With the advent of easy GPS surveying, more accurate mapping of aquatic plants began in 2008. Since that time, Eurasian milfoil has expanded its depth range and is now frequently found growing in 15-18ft deep. For comparison, the 2003 survey indicated that the maximum depth range of the plant was just 12.5ft, and the 2013 maximum depth of plant growth was recorded as 15ft. <u>With the slightly increased depth range in recent years, Eurasian milfoil has spread to cover at least 64-acres of the lake in 2018</u>, and the invasive plant is now found growing densely in most shoreline areas. The 2008 survey indicated just 30-acres of total Eurasian milfoil coverage, which suggests that the plant's coverage has nearly doubled over the last decade.

With this rapid increase in coverage, residents decided that mechanical harvesting should be supplemented by stocking sterile triploid Grass Carp (*Ctenopharyngodon idella*), an herbivorous fish that has been used in other lakes to reduce Eurasian milfoil. Initial grass carp stocking took place in 2016 and was permitted and performed by the NY DEC Fisheries Department. The DEC calculated appropriate stocking rates based on previous case studies in NY and the number of vegetated acres in Lake Oscawana. There has been no additional stocking since 2016.

Important Considerations

Grass Carp

Lake Oscawana was not initially understocked with grass carp. The state purposefully limited the number of grass carp stocked in Oscawana after multiple cases of overstocking at nearby lakes such as Lake Mahopac or Walton Lake. These two lakes were two of the first NY lakes to be stocked with triploid grass carp for vegetation control back in 1994 and 1987, respectively. The relative success of grass carp control of aquatic plants is evaluated in a NY DEC Fisheries Department publication from 2001 (Surprenant et al.). Though understated in the report, it is evident that the high initial stocking rates in Lake Mahopac and Walton Lake decimated plant populations and increased macro-algae in shoreline areas.


Experiences with Using Grass Carp for Aquatic Vegetation Control in DEC Region 3 with Emphasis on Walton Lake

Prepared By:
Leslie Surprenant
Fisheries Biologist
New York State Department of
Environmental Conservation
November 2001

DEC Fisheries Biologists have referenced this report to conclude minimal impacts of grass carp on overall lake water quality, yet upon reading the report it is clear that there was never enough water quality data to study negative impacts. Only seven Secchi disk readings were reported over five years, in four case studies. The report also ignores apparent cyanobacteria blooms in Lakes Innisfree, Mahopac, Peekskill, and Long Pond. While grass carp remain a viable plant management technique, Oscawana residents should continue to approach additional grass carp stocking with caution, as there is no effective way to remove the fish once they are stocked. There is also no way to control what and where the fish will eat, often leading to reductions in native plant populations prior to invasive species reductions. Future plant management recommendations regarding grass carp are included in Section 3.4.

Mechanical Harvesting

Mechanical weed harvesting involves the cutting and ripping of aquatic plant stems at a certain depth beneath the surface. The mechanical harvester used at Lake Oscawana is capable of cutting plant stems to approximately 3ft below the surface. While the harvester is able to clear paths in milfoil beds that would otherwise grow to the surface, the milfoil will always re-grow from cut stems. Presumably, cutting stems also has a similar effect to pruning garden plants: allowing the plants to grow fuller and more dense.

In the last two years, increased scrutiny in the operation and whereabouts of the mechanical harvester have prompted two main concerns. The first concern is that when the harvester operates in dense plant beds, the fragmentation of milfoil is so much that the harvester operator must then spend many hours cleaning up the mess of floating plant stems. The second photo on the right was captured in Wildwood Knolls Cove and represents one of many large floating fragment rafts seen throughout the lake. A review of the plant harvesting logs from the 2018 season showed that approximately 10% of the harvesting loads were skimming floating fragments. And because it takes longer to collect a full load from just skimming fragments, it's expected that the time percentage dedicated to cleanup is much higher.

The second main concern with mechanical harvesting is that the harvester disturbs too much sediment when operating in shallow coves, specifically Abele Cove and the inner shoreline areas of Wildwood

Knolls. Excessive turbidity was documented trailing behind the harvesting machine. A plume of suspended sediment was also observed drifting via wind movement out of Abele Cove and across the southern portion of the lake. The sediment plume was great enough to reduce water clarity at the south monitoring station, (St. 3) closest to Abele Cove, by about a foot in comparison to the middle lake station (St. 1). While much of the sediment will settle out quickly, we expect that there has been an ongoing movement of sediment from the shallow zones to the deep water zones of the lake, which would contribute to internal loading. This suspicion led us to examine the relationship between mechanical weed harvesting and internal loading.

As previously mentioned in earlier sections of this overall report, we found a strong statistical correlation between the seasonal average in-lake phosphorus mass and the number of annual 'loads' of harvesting. The correlation between maximum bottom-water phosphorus concentrations and annual 'loads' was also strong.

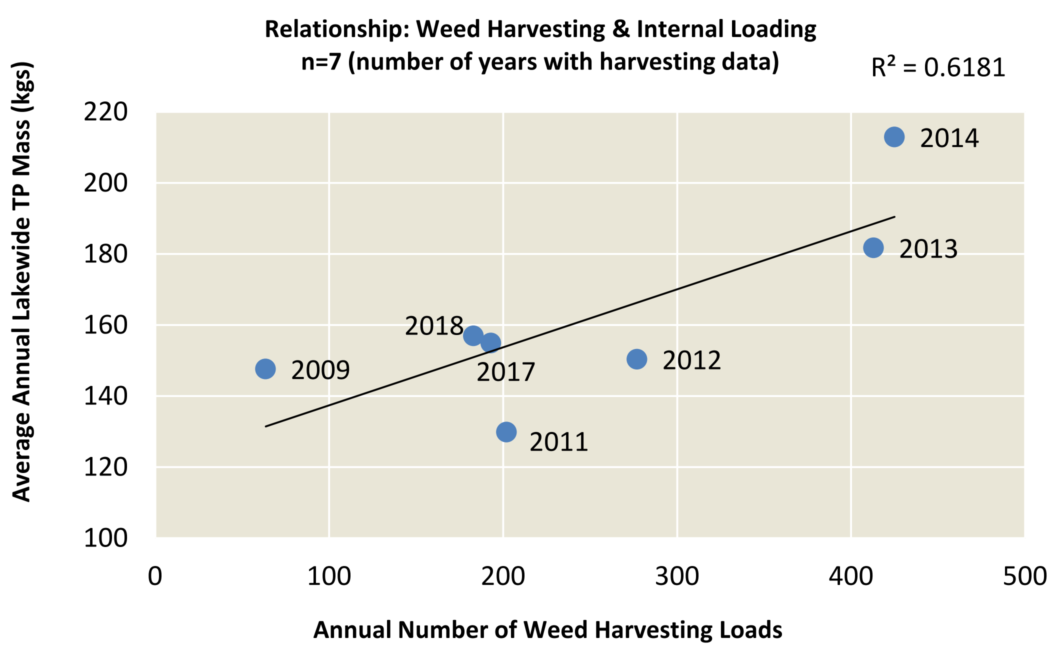


Figure 23: Weed Harvesting vs. Total Phosphorus Mass

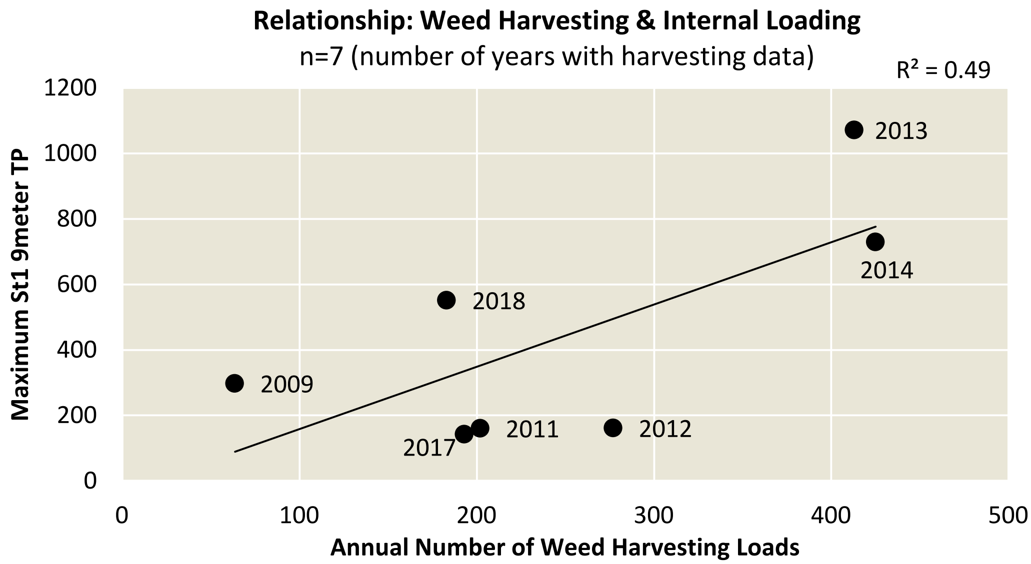


Figure 24: Weed Harvesting vs. Maximum Bottom Phosphorus (Metric of Internal Loading)

While a statistical correlation does not equate to causation, the fact that mechanical harvesting repeatedly disturbs sediment in shallow areas supports this relationship to internal phosphorus loading. For that reason <u>we suggest limiting plant harvesting in very shallow areas around the lake</u>. There are many other methods of area-specific plant control that would prove more effective in controlling the plants, and with much less repeated sediment disturbance. Detailed plant management options are included in the following sections.

3.3 Aquatic Plant Survey Results

Over the past four years, we have conducted two different types of aquatic plant surveys. Each type has a unique utility relevant to monitoring and plant management. The first type of survey is a transect survey, where plant sampling waypoints are arranged perpendicular to shore at various locations around the lake (Figure 25). This type of survey was first performed in 2016 as a way to study the long term impacts of Grass carp stocking on invasive and native plant species. In 2017, the established six transects were visited monthly during the growing season to observe plant species succession, growth, and in some areas impacts of weed harvesting. The transect data from 2017 serve as baseline information to compare long-term impacts of grass carp on native and invasive species. The following table was included in the 2017 report and demonstrates the seasonal progression of plants along all transect waypoints throughout the 2017 summer.

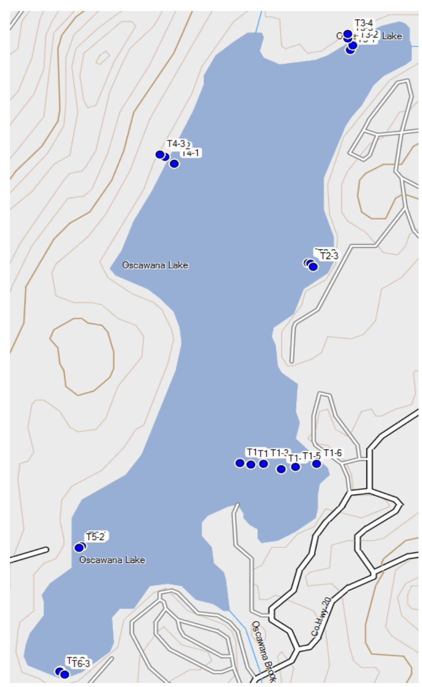


Figure 25: Plant Survey Transects

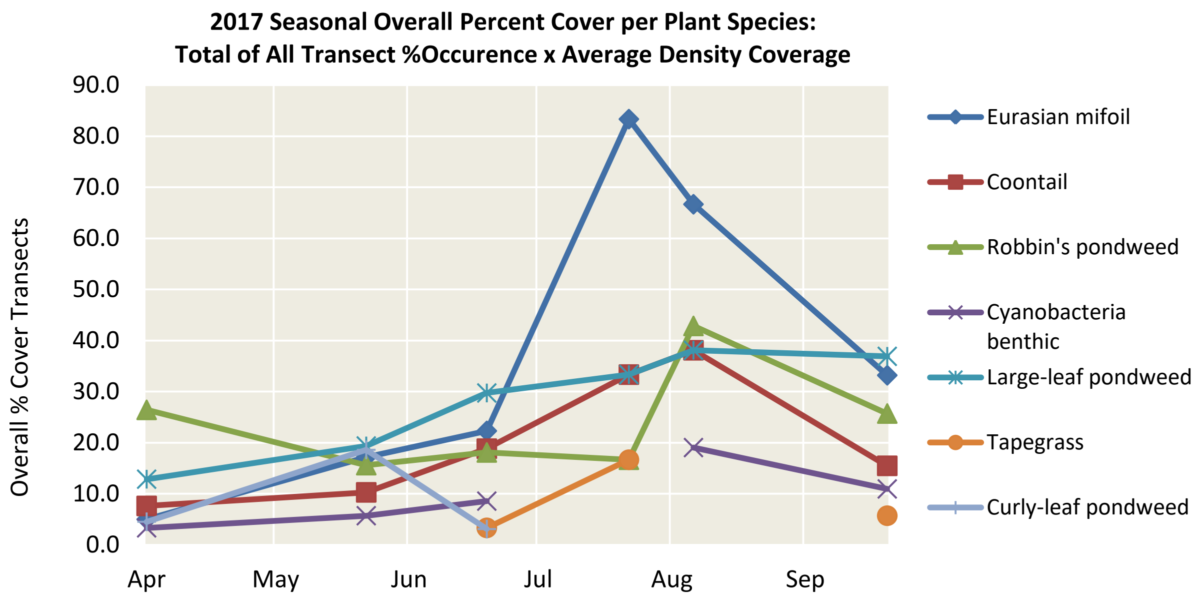


Figure 26: Seasonal Plant Coverage at Transects 2017

The second type is a full-lake survey where the primary purpose is to map the exact range, extent, and density of all aquatic plants in the lake. This is the traditional survey method used in surveys prior to 2016. The goal of this type of survey is to map the number of acres of invasive Eurasian milfoil and to establish the depth ranges and potential expansion of nuisance aquatic plant beds.

During the 2018 season, the traditional type of survey was conducted over two days on June 7th and 12th. This date was chosen because both invasive Eurasian milfoil and Curly leaf pondweed are growing during this time. If a survey is conducted in peak summer, the invasive Curly-leaf pondweed will have already senesced, as it is typically an early season nuisance aquatic plant. Approximately 64 acres of Eurasian milfoil were found in 2018. Based on waypoint data, Eurasian milfoil was present at nearly 70% of the total 264 waypoints made during this survey and was found growing at approximately 60% density. As indicated in the 2017 seasonal progression data, density of Eurasian milfoil is expected to increase into July and August. For this reason, the full-lake 2019 survey should be conducted in late July or early August.

Table 13 demonstrates all of the species found during the 2018 survey and the percent frequency, or how often they were found at survey waypoints. It is important to notice that just three species dominate the plant assemblage: Invasive Eurasian milfoil (*Myriophyllum spicatum*), native Large-leaf pondweed (*Potamogeton amplifolius*), and White water-lily (*Nymphaea odorata*). Another important thing to note is that only six submersed aquatic plant species were found in the lake in 2018. Of those six, only four are native species. Overall the species diversity in Oscawana is very low.

Table 14 compares the results of the 2015 and 2018 full-lake surveys. The same plants dominated in both years and there was not much change in Eurasian milfoil (*Myriophyllum spicatum*) or White water-lily (*Nymphaea odorata*). However, there was a small decrease in overall percent, which factors in the average density at which the plants grow around the lake, in Eurasian milfoil. It is also clear that Large-leaf pondweed was growing more densely in 2018 than in 2015, which could be a result of somewhat improved water clarity. There was also much less Tapegrass and Robbin's pondweed for some reason in 2018. These species' decrease may be related to grass carp herbivory. The 2019 season will document any further changes that could be a result of grass carp or harvesting.

Table 13: 2018 Aquatic Plant Survey Results

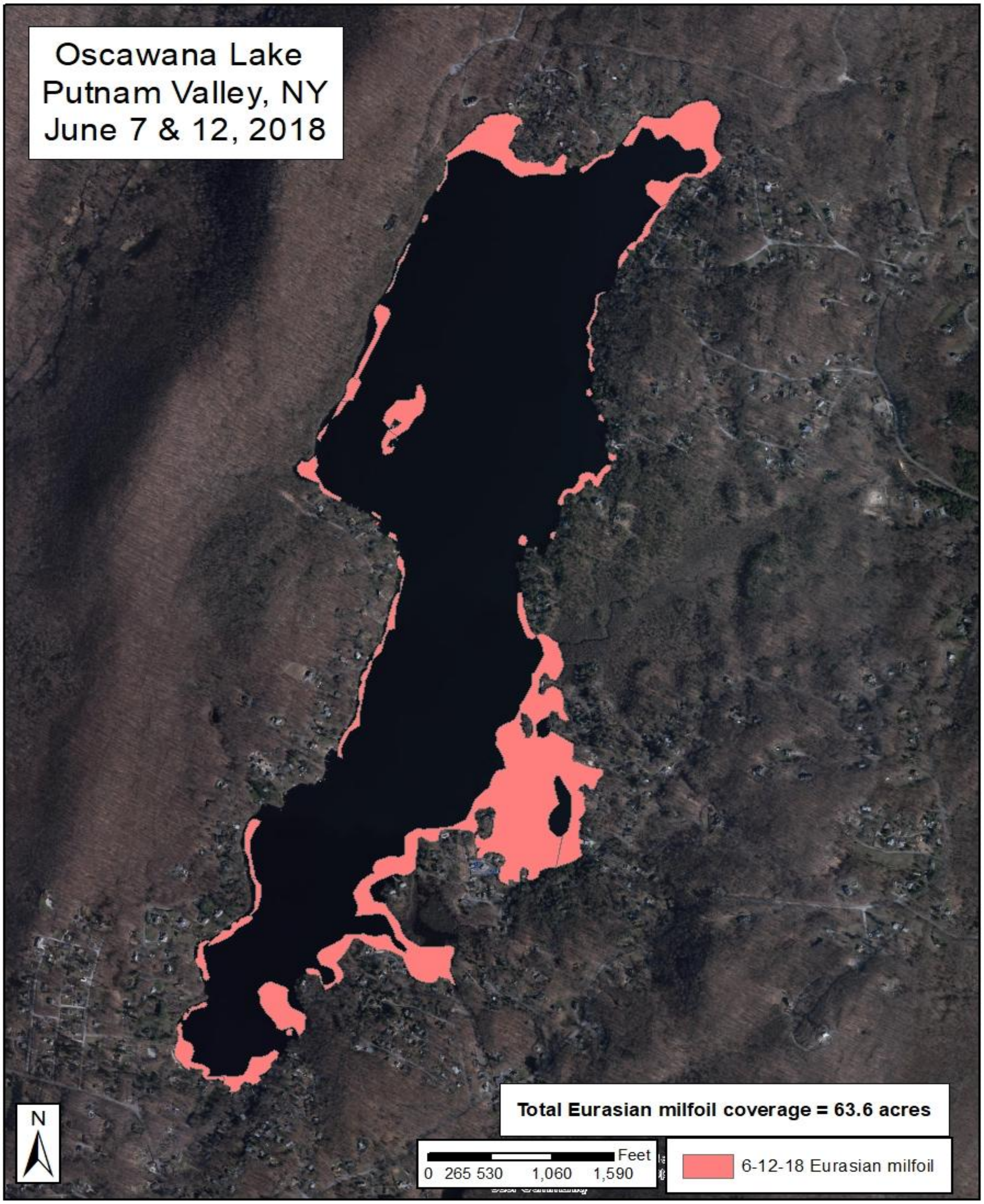
2018 Species List	Scientific Name	Percent Frequency	Type
Eurasian milfoil	*Myriophyllum spicatum*	69	Submersed / Invasive
Large-leaf pondweed	*Potamogeton amplifolius*	41	Submersed with some floating leaves
White water-lily	*Nymphaea odorata*	17	Floating leaf species
Nothing present	NA	11	NA
Curly-leaf pondweed	*Potamogeton crispus*	9	Submersed / Invasive
Coontail	*Ceratophyllum demersum*	8	Submersed
Robbin's pondweed	*Potamogeton robbinsii*	6	Submersed
Tapegrass	*Vallisneria americana*	6	Submersed
Filamentous algae	NA	5	NA
Yellow water-lily	*Nuphar variegata*	2	Floating leaf species
Pickerel weed	*Pontederia cordata*	1	Shoreline species

Table 14: 2015 and 2018 Plant Survey Comparison

Date	July 22nd	June 12th	July 22nd	June 12th	July 22nd	June 12th
Year	**2015**	**2018**	**2015**	**2018**	**2015**	**2018**
Species Name	**Count**	**Count**	**% Frequency**	**% Frequency**	**Overall %**	**Overall %**
Eurasian milfoil	191	183	86	69	49	41
White water-lily	53	45	24	17	13	10
Coontail	15	20	7	8	1	3
Large-leaf pondweed	108	108	49	41	10	30
Robbin's pondweed	50	17	23	6	17	5
Tapegrass	29	15	13	6	11	2
Filamentous algae	13	13	6	5	6	2

The total Eurasian milfoil coverage map is included on the following page. Based on the 2018 survey, impacts of grass carp are inconclusive. The main areas that appeared to have less Eurasian milfoil in 2018 as compared to 2015 was the Abele Cove channel, which had clearly just been mechanically harvested prior to our survey.

Map 3: 2018 Eurasian Milfoil Coverage



Based on the apparent relationship between mechanical harvesting and worsened internal loading, LOMAC should focus plant management efforts in shallow coves to avoid continued disturbance and re-suspension of shallow sediments that then migrate in a wind-driven plume across the lake. There are multiple plant control options worth exploring.

3.4 New Plant Management Techniques & Recommendations

Herbicide Spot Treatments

In Abele Cove, where shallow nutrient-rich sediments are easily disturbed by the weed harvester, mechanical harvesting should be minimized. Better Eurasian milfoil control may be achieved by using aquatic herbicides. If an herbicide treatment is to be performed, it should be conducted during a period of low water levels so that appropriate concentrations can be achieved close to the spillway. The cove totals about 6 acres, not including the areas of dense Water-lily coverage. A test case herbicide treatment using ProcellaCOR or SONAR can target Eurasian milfoil. SONAR has been approved for use in New York for decades, yet ProcellaCOR is a new product that was approved in 2018. ProcellaCOR herbicide is considered a faster-acting product perfect for small coves like Abele near an outflow. SONAR is considered a systemic herbicide and takes much longer to impact milfoil plants, but there is typically more years of control.

A 6 acre treatment is considered very small and can serve as a test case to determine if herbicide use is appropriate in lieu of mechanical harvesting. The treatment should cost in the range of $6,000 and should offer two years of Eurasian milfoil control for ProcellaCOR and 2-3+ years of control if SONAR is used. LOMAC should gauge public opinion of herbicide use at Oscawana.

Image 1: Abele Cove 2015 Aerial View (latest GoogleEarth image)

While aquatic herbicides remain controversial in society, they are incredibly effective and frequently used in New York and the USA. People may flinch at the use of aquatic herbicides because they fear unintended consequences of chemical use in the environment. These fears are not unfounded, but residents are often surprised to realize that aquatic herbicides are in fact the most well-regulated and most widely researched methods of aquatic plant control. Because all herbicide products must be first approved by the EPA, there is continuous rigorous testing and evaluations conducted on the implications of herbicide use on human health and the environment. If the same level of testing and research were to be done on other non-chemical forms of plant management techniques, surely many unintended consequences would be illuminated. For instance, 'bio-control' using non-native fish or insects has in many cases been proven to permanently alter ecosystem food webs. Similarly, the mechanical harvesting at Lake Oscawana is now assumed to be increasing internal phosphorus loading.

The NYDEC requires a permit for aquatic herbicide treatments. Only licensed personnel may apply aquatic herbicides. Permits frequently require pre- and post-treatment plant surveys to evaluate the impact of the herbicide on native and invasive species. It is also common for the NYDEC to require testing of herbicide levels in the lake and at the outlet. Permits are valid for one year. If residents and the Town of Putnam Valley are open to the possibility of using an aquatic herbicide to control Eurasian milfoil in certain coves around the lake, we recommend first trying either the herbicide SONAR or ProcellaCOR. Both herbicides have nearby NY case studies that demonstrate their proven effectiveness against milfoil.

Image 2: Potential Locations for Test Herbicide Treatments

<u>Additional areas recommended for spot herbicide treatments in the next five years are Wildwood Knolls and the Northwestern Cove</u>. A treatment in Wildwood Knolls would be about 18 acres and likely cost around $16,000. A treatment in the Northwestern Cove would cover roughly 1 acre and run about under $1,000-$3,000, depending on if other areas were treated on the same day. This small of an area, however, is not suited for SONAR due to the difficulties of maintaining an appropriate concentration. Fast-acting ProcellaCOR would be more appropriate at the Northwestern Cove section.

The southern and northeastern coves were not chosen as locations for aquatic herbicide treatments because the northeastern cove has a substantial population of native Large-leaf pondweed that should not be treated, and the southern cove has milfoil growing in very deep water, which is harder to control with herbicides than in shallow coves.

Further conversations will be necessary between NEAR, residents, and LOMAC if an herbicide treatment will be considered in 2019 or 2020. We recommend trying an herbicide treatment in Abele Cove first and waiting to evaluate further impacts of Grass Carp in Wildwood Knolls and the Northwestern Cove before attempting any treatments.

Benthic Barriers & Diver Hand Harvesting for Small Beach Areas

Image 3: Beach Benthic Barrier Potential Site, Southern Cove

In the southern cove, at the Hilltop Beach area, it is possible to use seasonal benthic barriers combined with diver hand harvesting. Because the beach has coarse sandy sediments, that are not rich in nutrients to fuel very dense Eurasian milfoil growth (compared to Abele Cove and Wildwood Knoll sediments), SCUBA divers should be able to lay down benthic barriers in the swim area and periodically hand-clear new Eurasian milfoil growth on the edges of the barrier. Barriers are only appropriate in water less than 8ft deep because of the difficulty in maintaining them. Barriers must also be removed every season and may require local permits. There are specific types of benthic barriers with holes and gas vents to allow passage of sediment air bubble buildup from decomposition. Barriers must also be appropriately weighted down with steel rebar rods so they do not move or become raised and billowy. Image 3 shows a potential area for benthic barrier coverage that does not exceed 1,500 square feet. Benthic barriers are also suitable for other small beach areas around the lake provided that they are coordinated through LOMAC and properly inspected by NEAR. Refraining from mechanical harvesting in areas with benthic barriers, will prevent excess siltation over the barriers. **Estimated cost is $1,500-$4,000 per 1,000 sq. ft., depending on the type of barrier material used.** Materials to consider: Aqua-screen, vented landscape fabric, Muck-Mat Pro rigid barrier.

Grass Carp

Annual aquatic plant surveys are recommended to evaluate the ongoing impact of Grass Carp on native and invasive aquatic plants. The main difficulty with Grass Carp is that it is impossible to control where, what, and how much the carp eat. It is well documented in the scientific literature that Grass carp prefer most native plant species rather than invasive Eurasian milfoil, meaning submerged native plants may be consumed prior to any visible milfoil reductions. LOMAC should maintain the low stocking rates as previously recommended by the NYDEC to avoid the complete elimination of native vegetation and the potential for a catastrophic shift to algae dominance in shallow areas. <u>Because Grass Carp like quiet areas with minimal human contact, it is expected that the primary areas where people desire milfoil</u>

control will not be the favored feeding areas of the carp. The 2019 fisheries survey will provide insight into Grass Carp population dynamics in the lake, and the survey transects will continue to evaluate long-term successes of Grass Carp around the lake. As stated in the herbicide treatment section, we recommend another year of evaluating Grass Carp impacts in major shoreline areas prior to submitting for any additional carp permits. An additional small stocking of Grass Carp is only appropriate if mechanical harvesting is limited in the future, and any future stocking deserves careful consideration and follow-up monitoring.

Plant Management Summary

All plant management techniques require trial and error, as well as ongoing evaluation and adjustments. Mechanical harvesting has been practiced at Lake Oscawana for nearly three decades, and although it may temporarily relieve densely packed areas of milfoil, it is harsh on water quality and has caused the spread of milfoil to the entire shoreline due to fragmentation.

Grass Carp have been present in the lake for four seasons and there has not been an appreciable decline in density or range of Eurasian milfoil. Native Large-leaf pondweed appeared to grow more densely in 2018 than in 2015. The 2019 survey results indicate that the carp have been feeding on plants in the shallow northern basin and have cleared very small shallow-water areas. Based on other grass carp case studies, we expect grass carp to first reduce the density of Eurasian milfoil, instead of eliminating it in certain areas. The fish reached adult sizes in 2019 and subsequent surveys will continue to evaluate the effectiveness.

Again, we recommend a test case spot herbicide treatment in Abele Cove if residents agree that would be appropriate in the next few years. Mechanical harvesting in Abele Cove appears to be negatively impacting the overall water quality of the lake and we hope to see lower phosphorus concentrations and better clarity with lessened harvesting in shallow areas. The mechanical weed harvester will continue to serve as the primary plant control method in 2019-2020, but harvesting Abele Cove should not be permitted unless absolutely necessary. The mechanical harvester is also in need of continued repairs in 2020, which presents a window of opportunity for LOMAC to explore alternative plant management options.

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Raw Inlet Concentration Data 2016- 2018

TP = Total Phosphorus, NOX = Nitrate + nitrite nitrogen

Lake	Year	Date	Inlet	TP	NOX
Oscawana	2016	4/13/2016	1	10	
Oscawana	2016	4/13/2016	2	13	
Oscawana	2016	4/13/2016	3	20	
Oscawana	2016	4/13/2016	4	54	
Oscawana	2016	4/13/2016	5	17	
Oscawana	2016	4/13/2016	6	19	
Oscawana	2016	4/13/2016	7	17	
Oscawana	2016	5/12/2016	1	23	
Oscawana	2016	5/12/2016	2	18	
Oscawana	2016	5/12/2016	3	82	
Oscawana	2016	5/12/2016	4	13	
Oscawana	2016	5/12/2016	5	20	
Oscawana	2016	5/12/2016	6	20	
Oscawana	2016	6/15/2016	2	16	
Oscawana	2016	6/15/2016	5	15	
Oscawana	2016	6/15/2016	7	18	
Oscawana	2016	8/30/2016	2	18	
Oscawana	2016	8/30/2016	4	272	
Oscawana	2016	8/30/2016	7	85	
Oscawana	2016	9/27/2016	2	32	
Oscawana	2016	9/27/2016	7	60	
Oscawana	2016	11/8/2016	2	7	
Oscawana	2016	11/8/2016	7	13	
Oscawana	2017	4/10/2017	1	16	
Oscawana	2017	4/10/2017	2	15	
Oscawana	2017	4/10/2017	3	12	
Oscawana	2017	4/10/2017	4	31	
Oscawana	2017	4/10/2017	5	9	
Oscawana	2017	4/10/2017	6	14	
Oscawana	2017	4/10/2017	7	15	
Oscawana	2017	5/31/2017	1	16	
Oscawana	2017	5/31/2017	2	21	
Oscawana	2017	5/31/2017	4	437	
Oscawana	2017	5/31/2017	5	12	
Oscawana	2017	5/31/2017	7	32	
Oscawana	2017	6/23/2017	1	18	
Oscawana	2017	6/23/2017	2	22	

Oscawana	2017	6/23/2017	4	139	
Oscawana	2017	6/23/2017	5	18	
Oscawana	2017	6/23/2017	7	74	
Oscawana	2017	7/31/2017	2	20	
Oscawana	2017	7/31/2017	4	206	
Oscawana	2017	7/31/2017	5	35	
Oscawana	2017	7/31/2017	7	38	
Oscawana	2017	8/15/2017	2	11	
Oscawana	2017	8/15/2017	4	150	
Oscawana	2017	9/29/2017	2	8	
Oscawana	2017	9/29/2017	4	162	
Oscawana	2017	9/29/2017	7	22	
Oscawana	2017	10/31/2017	1	28	
Oscawana	2017	10/31/2017	2	21	
Oscawana	2017	10/31/2017	3	39	
Oscawana	2017	10/31/2017	4	86	
Oscawana	2017	10/31/2017	5	35	
Oscawana	2017	10/31/2017	6	29	
Oscawana	2018	4/11/2018	1	5	3
Oscawana	2018	4/11/2018	2	6	54
Oscawana	2018	4/11/2018	3	9	455
Oscawana	2018	4/11/2018	4	24	2500
Oscawana	2018	4/11/2018	5	5	32
Oscawana	2018	4/11/2018	6	14	
Oscawana	2018	4/11/2018	7	8	894
Oscawana	2018	5/7/2018	1	13	144
Oscawana	2018	5/7/2018	2	25	33
Oscawana	2018	5/7/2018	3	24	416
Oscawana	2018	5/7/2018	4	62	2070
Oscawana	2018	5/7/2018	5	13	28
Oscawana	2018	5/7/2018	6	32	7
Oscawana	2018	5/7/2018	7	28	531
Oscawana	2018	6/7/2018	1	5	22
Oscawana	2018	6/7/2018	2	40	114
Oscawana	2018	6/7/2018	3	22	622
Oscawana	2018	6/7/2018	4	93	1467
Oscawana	2018	6/7/2018	5	8	32
Oscawana	2018	6/7/2018	6	28	9
Oscawana	2018	6/7/2018	7	20	340
Oscawana	2018	6/28/2018	1	17	32
Oscawana	2018	6/28/2018	2	85	67

Oscawana	2018	6/28/2018	4	228	1000
Oscawana	2018	6/28/2018	5	38	93
Oscawana	2018	6/28/2018	6	47	39
Oscawana	2018	6/28/2018	7	82	219
Oscawana	2018	7/9/2018	1	20	124
Oscawana	2018	7/9/2018	7	72	224
Oscawana	2018	7/31/2018	1	22	329
Oscawana	2018	8/17/2018	1	17	23
Oscawana	2018	8/17/2018	2	26	160
Oscawana	2018	8/17/2018	3	38	607
Oscawana	2018	8/17/2018	4	125	1475
Oscawana	2018	8/17/2018	5	25	65
Oscawana	2018	8/17/2018	7	86	342
Oscawana	2018	9/26/2018	1	19	10
Oscawana	2018	9/26/2018	2	29	52
Oscawana	2018	9/26/2018	3	40	309
Oscawana	2018	9/26/2018	4	99	1233
Oscawana	2018	9/26/2018	5	61	99
Oscawana	2018	9/26/2018	6	33	17
Oscawana	2018	9/26/2018	7	47	345
Oscawana	2018	10/1/2018	1	29	19
Oscawana	2018	10/1/2018	2	21	18
Oscawana	2018	10/1/2018	3	22	29
Oscawana	2018	10/1/2018	4	12	
Oscawana	2018	10/1/2018	5	21	19
Oscawana	2018	10/1/2018	6	21	184
Oscawana	2018	10/1/2018	7	51	1630