Lake Oscawana
2017 Water Quality Assessment

Prepared for the Lake Oscawana Management Advisory Committee
Putnam Valley, New York

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Introduction

The Lake Oscawana 2017 in-lake 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. All regular sampling stations can be viewed in the watershed map in the Appendix of this document (Figure 26). During each visit six locations in the lake were surveyed for native and invasive aquatic plants. A map and descriptions of these sites are included in the Aquatic Plant Management section (p24) of this annual report. Survey sites were first established in 2016 and are used to compare presence, density, and growth of plants throughout the season. Aquatic plant data is also used to track harvester efforts and to study how grass carp affect plants in the lake.

In addition to sampling the seven main inlets, a thorough investigation of the watershed was performed in order to identify problematic areas in need of Low Impact Development (LID) stormwater management retrofits. Watershed work was conducted during rain events, but precipitation was not great enough to generate high volumes of rainwater runoff from roadways. Thus, only a handful of stormwater runoff samples were collected to be analyzed for nutrients. Water samples were collected to determine the effectiveness of the western shore "biofilter," which was recently updated. All watershed work was conducted as part of the plan to update the New York State Department of Environmental Conservation (DEC) Total Maximum Daily Load (TMDL) Implementation Plan. This Implementation Plan will be part of an updated overall Lake Management Plan. A draft of the updated Lake Management Plan should be published by December 2018.

This annual report reviews the 2017 data with respect to historical measurements and expands upon the more detailed analytical review presented in the 2016 monitoring report. This report also details the results of the monthly monitoring of aquatic plants and provides recommendations for future aquatic plant management. The following section outlines the monitoring components at Oscawana Lake and describes the general lake science terms that are frequently referenced in this report.

Description of Monitoring Components

Secchi Disk Transparency Depth

Secchi Disk

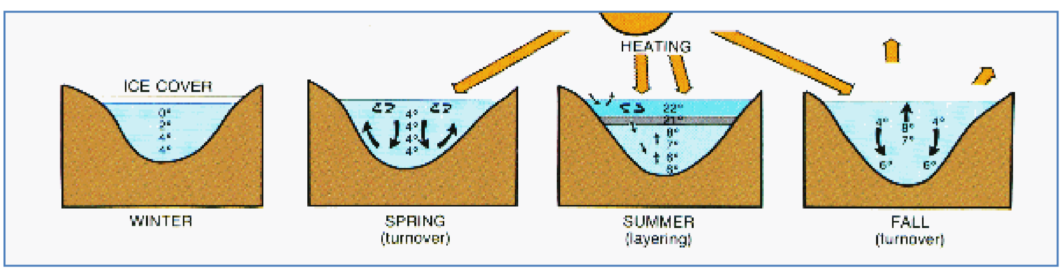
Water clarity was measured during each visit to the lake at three sampling sites. To do so, an 8-inch circular **Secchi disk** is attached to a measuring tape and lowered into the water on the shady side of the boat. Using a view scope to shade out light in one’s peripheral vision, the Secchi disk is 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. There are seasonal fluctuations in water clarity that NEAR tracks in relation to other limnological parameters such as plankton populations and nutrient levels.

Lake Profile Measurements

Temperature in lakes and ponds in the northeast will follow a seasonal pattern of warming and cooling. Following ice-melt 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. Combined, measurements at all 1-meter depth increments are referred to as a lake profile. Profile measurements change as the sun's rays penetrate into the water column. The water warms through the spring and summer, but the depth extent 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. The thermocline influences trends in dissolved oxygen. Cooling waters in the fall result in a weakening thermocline and eventually water "turn-over," or when the temperature once again becomes uniform from top to bottom, termed isothermal conditions.

The ***RTRM (Relative Thermal Resistance to Mixing)*** is a unit-less number that describes the difference in water density between each meter, with higher numbers indicating 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.

The picture below demonstrates the concept of lake temperature change throughout the season and how the lake responds with mixing regimes.



Picture credit: Pennsylvania Department of Environmental Protection

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 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 that 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 > 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.

Conductivity measures the quantity of dissolved ions in water that conduct electricity. Conductivity measurements were also taken at one-meter increments from surface to lake bottom at Station 1. Conductivity increases with dissolved salt content in the lake, which can be traced to either natural mineral sources or to human inputs from road salting and septic systems.

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 free-floating microscopic algae in the water column. Zooplankton are the microscopic animals that feed on phytoplankton. Plankton represent 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 data.

Stream Assessment

Stream samples are collected monthly from seven identified inlets to the Lake (p34). Stream samples are collected as grab samples and represent a baseflow 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.

Aquatic Plant Surveys

The aquatic plant surveys at Lake Oscawana in 2017 utilized six established transects located perpendicular to shore. These transects were first established in 2016 as a way to monitor change in plant biomass and dominance over the course of a season and long term trends. Transects were sampled on a monthly basis from spring through fall. A map of transect locations is included on page 24.

Executive Summary

- Lake Oscawana experienced above average water clarity in 2017. The seasonal average 2017 Secchi disk depth was 3.64 meters at Station 1. Water clarity was maintained around 4 meters from the end of July to mid September 2017, which is excellent for Oscawana during summer months.
- Peak anoxic boundary at all Stations was on 6/28/17. The worst depth of anoxic water was 5.9-meters at Station 1, 6.1-meters at Station 2, and 5.8-meters at Station 3. The long term goal for Stations 2 and 3 is to maintain greater than 5 milligrams/Liter (parts per million) of oxygen below 6.5 meters during summer months.
- Despite fully-oxygenated conditions in mid-April 2017, oxygen was lost beneath 7-meters at Station 1 by the end of May suggesting a high rate of oxygen loss. In order to better calculate this severe rate of oxygen loss future monitoring may involve two May sampling trips.
- Slight discrepancies in temperatures between sampling Stations throughout the season were noted and will be tracked again in 2018. Temperature differences may reveal sections of the lake where groundwater inflow is more pronounced.
- Relative thermal resistance to mixing was high during June through the end of August, but within normal levels based on historical data.
- Cyanobacteria (Harmful Blue-green Algae) phytoplankton were much lower in 2017 than in 2016. The highest cyanobacteria cell count in 2017 was only 7,000 cells/mL.
- There were more large-bodied Cladoceran zooplankton in 2017 than in 2016, which is good. Yet the lake still does not have sufficient populations of large Daphnia Cladocerans.
- In-lake Total Phosphorus (TP) was very low in August and September 2017, which may correspond to the very dry summer conditions and reduced watershed loading during this time. The highest surface TP was in October after fall turnover.
- Total Nitrogen (TN) seasonal patterns in surface and bottom waters indicated external (watershed source) loading.
- Aquatic plant survey results currently do not show any impacts of grass carp. Effects of weed harvesting were noted only in plant height in the water column; frequency remained similar throughout the season at all transects and density generally increased as summer progressed.
- Watershed sources of nutrient loading have been identified. Inlet 4 is a primary concern and potential area for localized groundwater nutrient contamination. Stormwater catch basins were mapped using GIS. More stormwater data will be collected in 2018 with the cooperation of resident volunteers.
- All watershed data will be incorporated into a Lake Management Plan to be completed with oversight from the NY DEC in order to update the TMDL Implementation Plan.
- Watershed soils and depth-to-bedrock data were acquired from the Natural Resources Conservation Service Web Soil Survey. Maps are included as separate pdf documents.

Water Quality 2017 Monitoring Results

Water Clarity

Overall the water quality in 2017 was good. The Secchi water clarity was measured during each visit at Stations 1, 2, & 3, with one exception in October where it was too windy to safely reach station three. All 2017 Secchi disk measurements are shown in **Figure 1**.

- Average 2017 Station 1 Secchi disk depth was 3.64 meters. From the end of July to mid September 2017 clarity was maintained around 4 meters, which is excellent for Oscawana during summer months (**Figure 1**).
- While the 2016 and 2015 averages of 3.2 and 3.5 meters, respectively, are similar to the 2017 average, only 2017 saw sustained good clarity throughout the summer.
- Long term historical average (1987-2017) = 3.1 meters
- 2017 water clarity remained above average for all sampling dates except 6/28/17
- Maximum 2017 Secchi disk depth = 5.1 meters (St.3, 7/31/17)
- Minimum 2017 Secchi disk depth = 2.35 meters (St.2, 10/31/17); compared to 2016 = 1.8 meters (St. 1; 9/27/16), and 2015 minimum = 2.0 meters (Station 1; 4/30/15)
- Long term water clarity trend shows slight clear-water phase from June to July, but very wide range in clarity from mid-July to mid-October since 1995 (**Figure 2**).

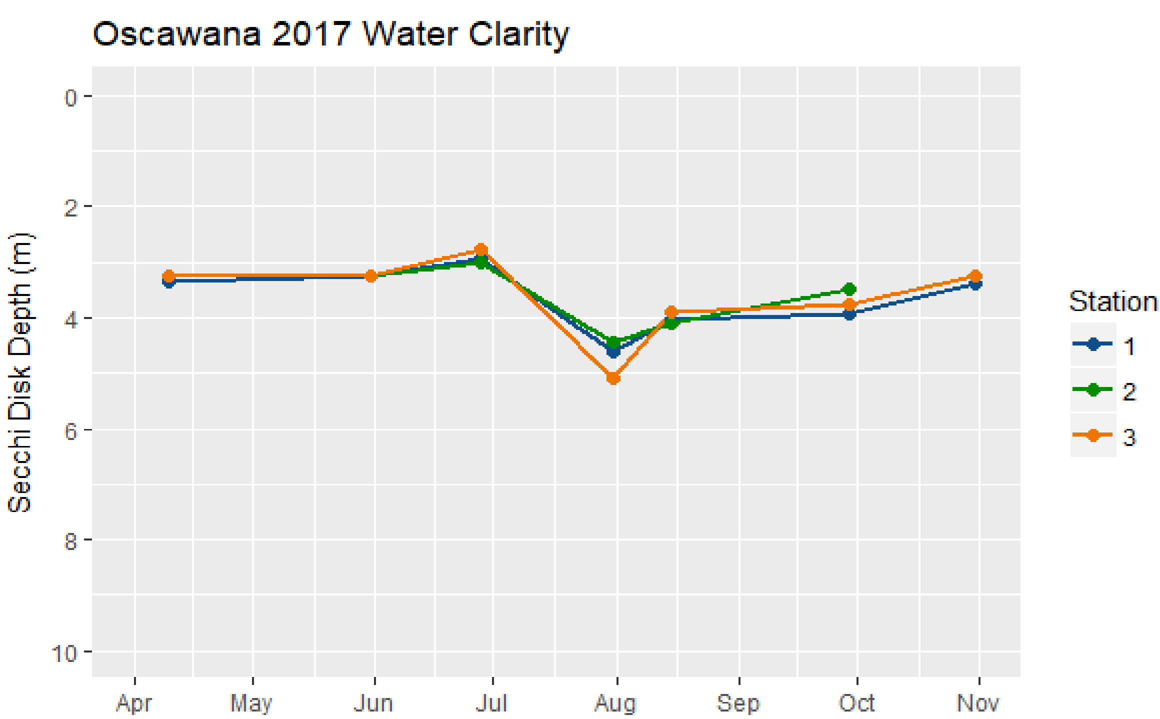


Figure 1: Secchi Water Clarity 2017 Season

Long term water clarity was analyzed on an overlapping seasonal time-scale (**Figure 2**) and it is apparent that there is less variation in water clarity through the years during the late May to mid June time period. This period coincides with a trend of increasing clarity from spring until the lake stratifies. Throughout the summer, however, water clarity has not been consistent over the years. Large ranges from greater than 5 meters to about 1.5 meters occur in late August. The 2017 summer clarities were better than average. The 2017 water clarity trends will be discussed in terms of nutrient loading in the following section.

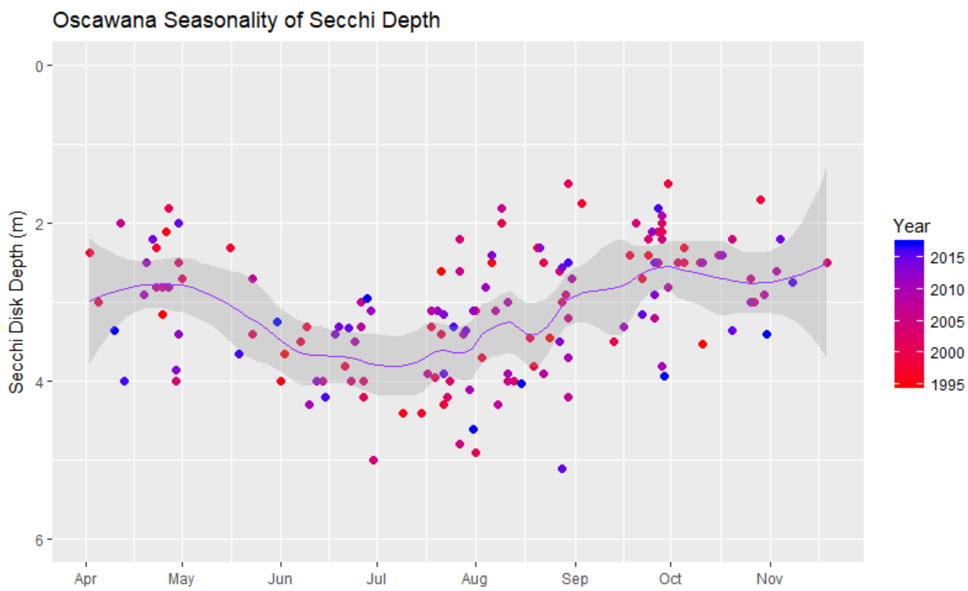


Figure 2: Seasonality of Water Clarity

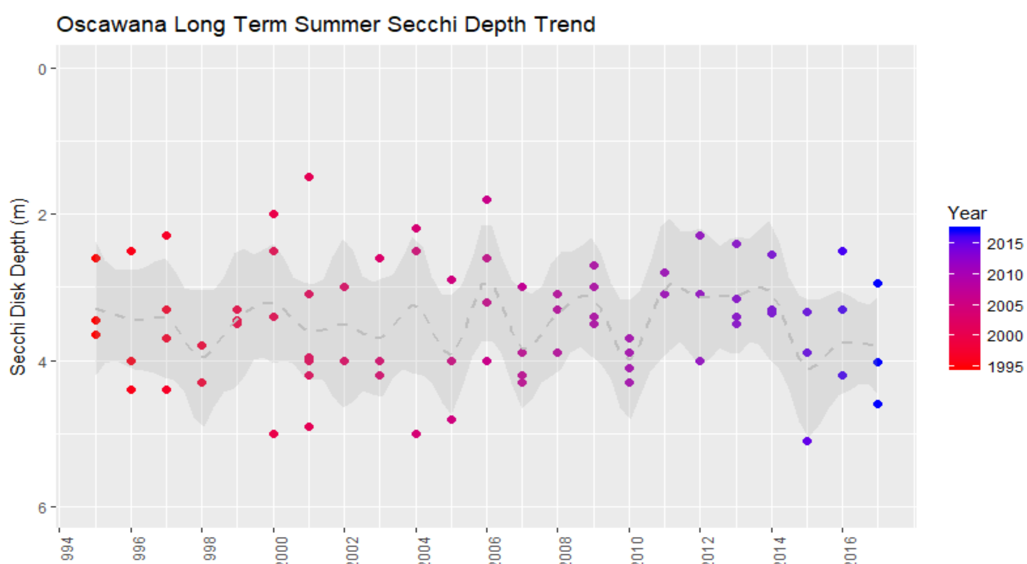


Figure 3: Long Term Summer Water Clarity

Figure 3 above simply displays the historical water clarity values from July and August each year. The historical summer data suggests no trends specifically in summer water clarity.

Temperature and Dissolved Oxygen

Temperature and dissolved oxygen were measured monthly at one-meter increments at each sampling station during 2017 (**Figures 4-5**). Based on the temperature and dissolved oxygen concentrations, the percent oxygen saturation and thermal resistance to mixing were calculated.

- Maximum height of anoxia at all Stations was on 6/28/17, where anoxic water reached 5.9-meters (19.3ft) at Station 1, 6.1-meters (20ft) at Station 2, and 5.8-meters (19ft) at Station 3.
- For comparison, the 2016 Station 1 anoxia maximum was 5.7-meters on 8/31/2016.
- Shallower depth numbers signify poorer anoxia conditions. A target goal for Lake Oscawana is to keep anoxia below 6.5 to 7-meters at Stations 2 and 3 during the summer.

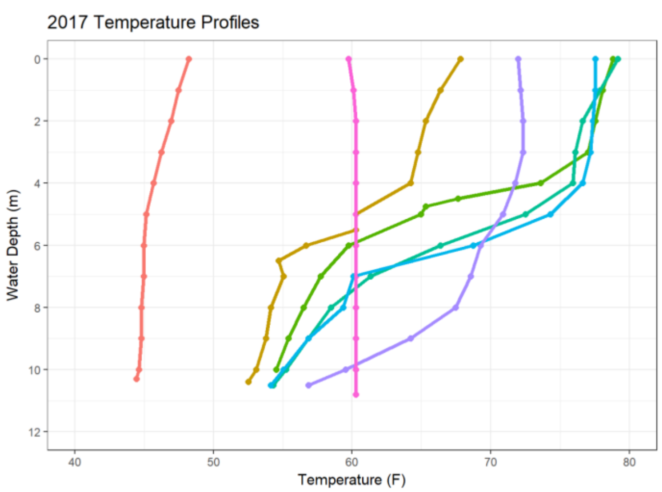


Figure 4: Station 1, Temperature Profiles 2017

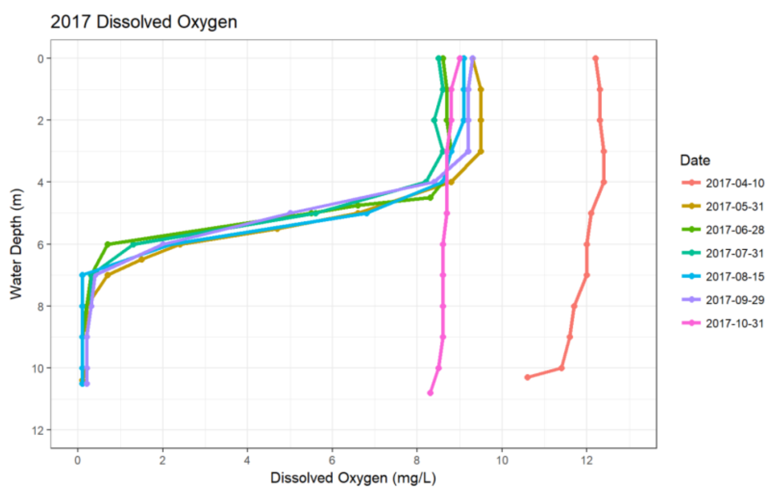


Figure 5: Station 1, Dissolved Oxygen Profiles 2017

Figure 5 displays the Station 1 dissolved oxygen profiles throughout 2017. The lake very quickly lost dissolved oxygen in deeper waters from April to May. Below, **Figures 6 & 7** demonstrate that anoxic boundary rose from the lake bottom and peaked at all stations in late July, which coincided with the poorest clarity of the season.

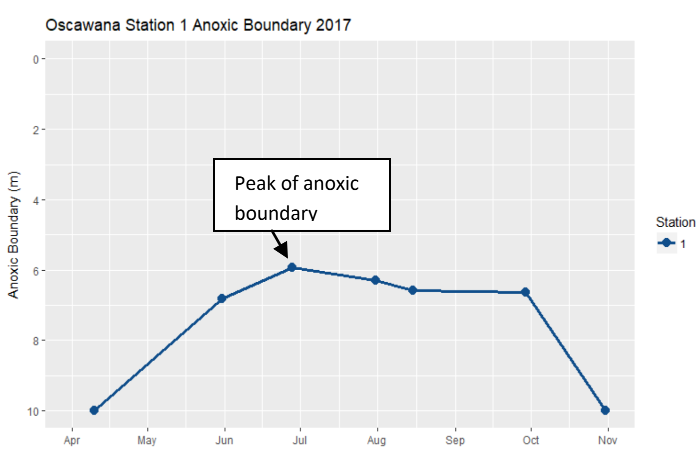


Figure 6: Station 1, 2017 Anoxic Boundary

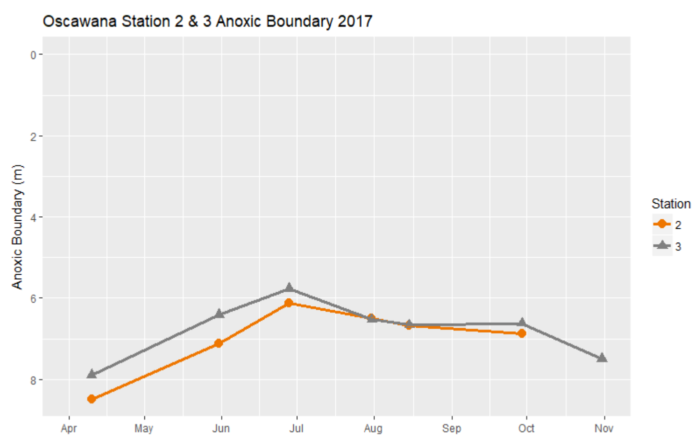
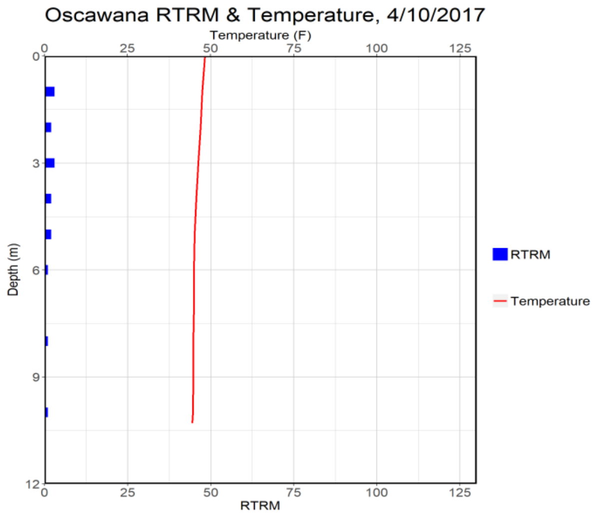
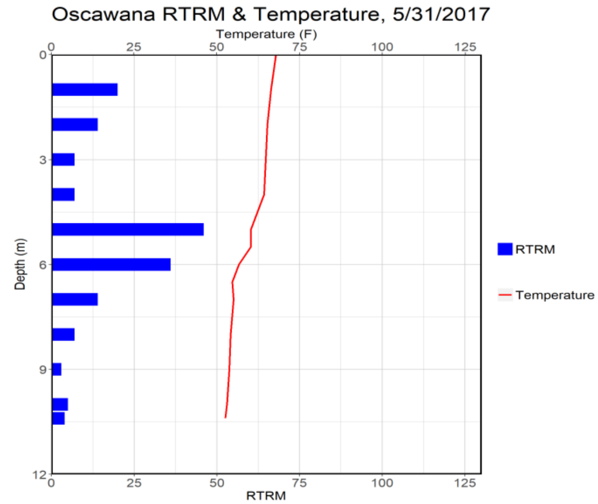
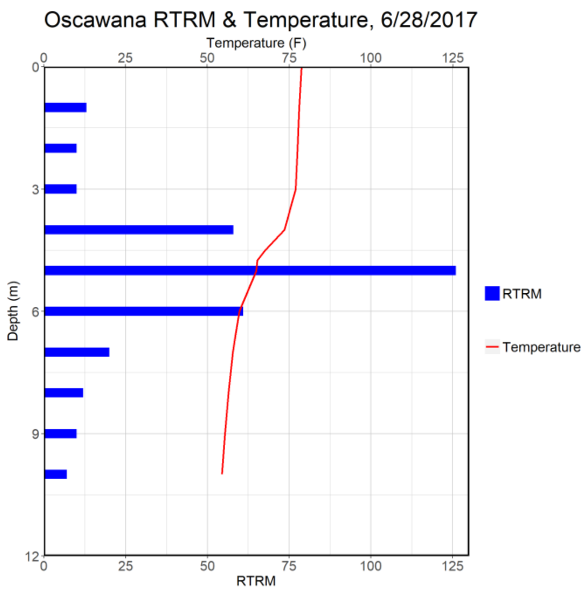


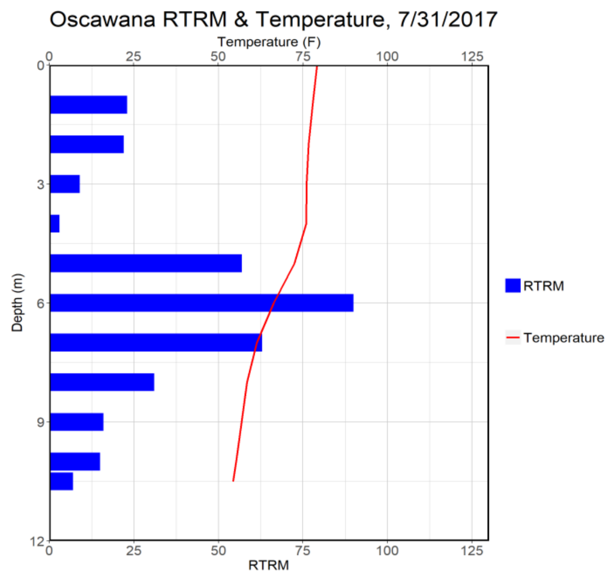
Figure 7: Station 2 & 3, 2017 Anoxic Boundary

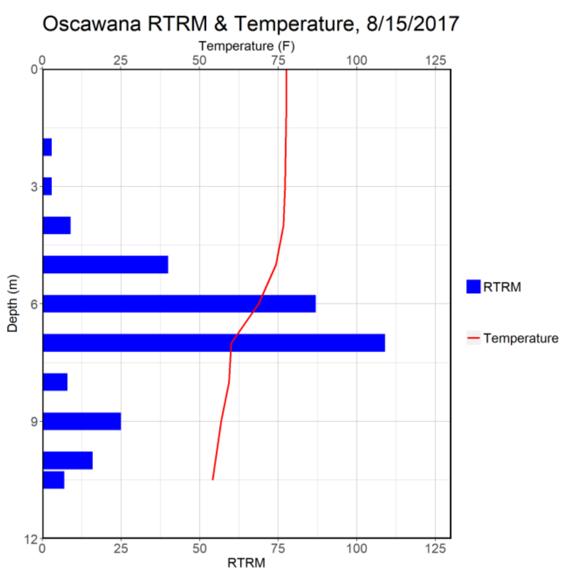
All temperature and Relative Resistance to Mixing (RTRM) graphs are shown below. To reiterate, RTRM is a unit-less number that describes the difference in water density between each meter, with higher numbers indicating stronger thermal stratification. RTRM becomes important when determining how bottom water nutrients are interacting with surface waters.

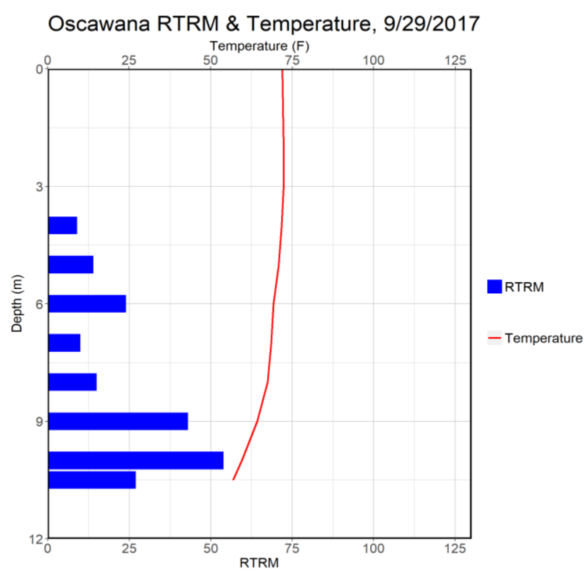

Oscawana RTRM & Temperature, 4/10/2017
Temperature (F)
Depth (m)
RTRM
RTRM
Temperature

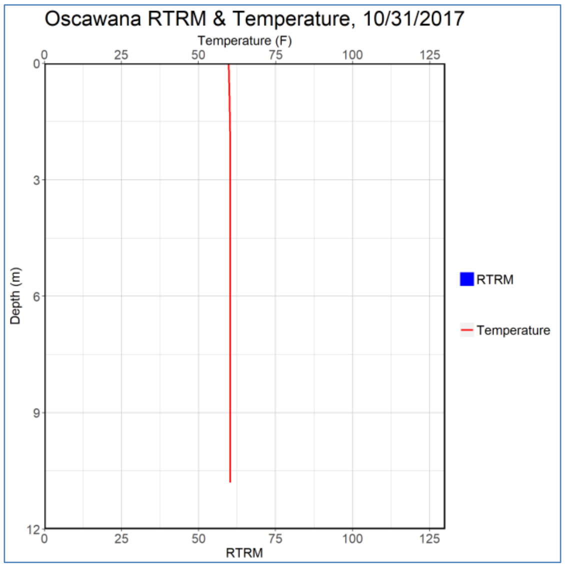

Oscawana RTRM & Temperature, 5/31/2017
Temperature (F)
Depth (m)
RTRM
RTRM
Temperature


Oscawana RTRM & Temperature, 6/28/2017
Temperature (F)
Depth (m)
RTRM
RTRM
Temperature


Oscawana RTRM & Temperature, 7/31/2017
Temperature (F)
Depth (m)
RTRM
RTRM
Temperature


Oscawana RTRM & Temperature, 8/15/2017
Temperature (F)
Depth (m)
RTRM
RTRM
Temperature


Oscawana RTRM & Temperature, 9/29/2017
Temperature (F)
Depth (m)
RTRM
RTRM
Temperature



Figures 8(a-f): RTRMs 2017

As expected, the maximum RTRM indicates a summer thermocline that varies in thickness between 4 to 7-meters depth. Our recent data analysis explored a potential connection between the placement of the thermocline, determined by the RTRM values, and the water clarity. In short, there is not conclusive data to support that phytoplankton concentration and dilution in the surface waters is dependent on the top of the thermocline, but we observed at least six instances in prior years where a reduction in the thickness of the thermocline increases water clarity. We will pay more attention to this phenomenon in future years.

Phytoplankton and Zooplankton

Overall phytoplankton populations in Oscawana in 2017 were very good. The total cells/milliliter (mL) did not rise above 16,000, which is about half of the 2016 maximum. The 2016 cyanobacteria populations rose steadily in August and September up to 25,000 cells/mL, but this rise in cyanobacteria did not occur in 2017. The cyanobacteria *Anabeana* made up most of the total cell fraction in summer 2016, but was substantially lower in 2017. Similar to prior years, Diatoms were most frequent early in the season, with populations highest during April to May, and declining throughout October. Sometimes lakes have a second Diatom bloom during fall turnover, but this did not occur in either 2016 or 2017 at Oscawana. Phytoplankton trends are displayed in **Figure 9** below.

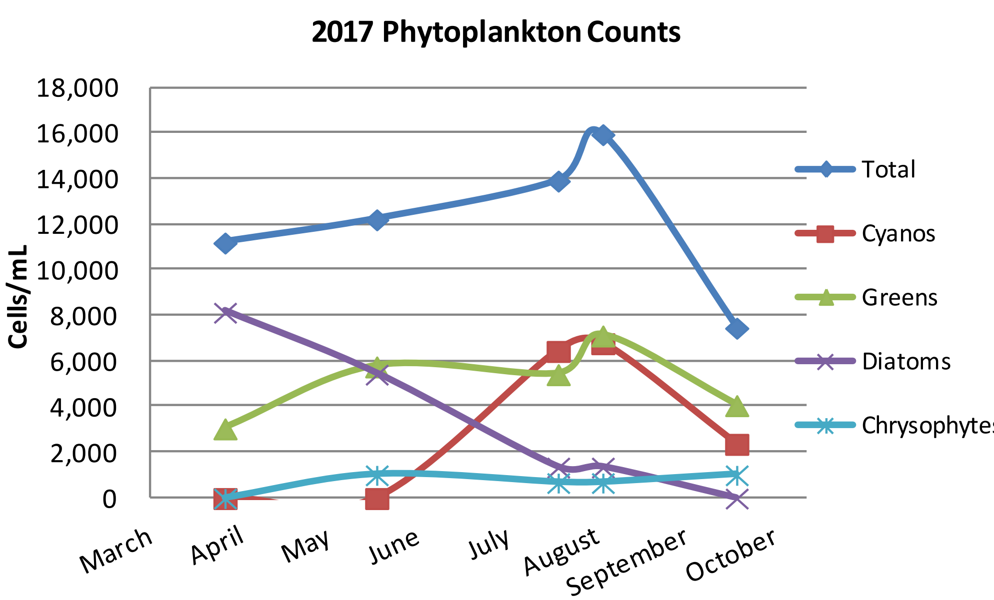


Figure 9: 2017 Phytoplankton Trends

In 2017, there were more Cladocerans overall than in 2016, but their populations fluctuated greatly throughout the season. The maximum number of Cladocerans occurred in June at approximately 24 per Liter. Of the total number of Cladocerans identified in May and June, approximately 30% of them were medium-large at 0.8-1.2mm in length. By late July, Cladoceran populations came crashing down to about 3 organisms per Liter. This seasonal trend, however, is common in clear-water lakes. As part of an ongoing effort to increase the populations of Large-bodied Cladocerans, the Lake Oscawana Management Advisory Committee (LOMAC) previously stocked Walleye fish. Walleye are at the top of the lake food chain and eat smaller fish. The goal of increasing Walleye populations is to reduce the smaller fish populations that voraciously feed on zooplankton. However, LOMAC ceased stocking Walleye two years ago so 2017 changes are not likely reflective of this effort.

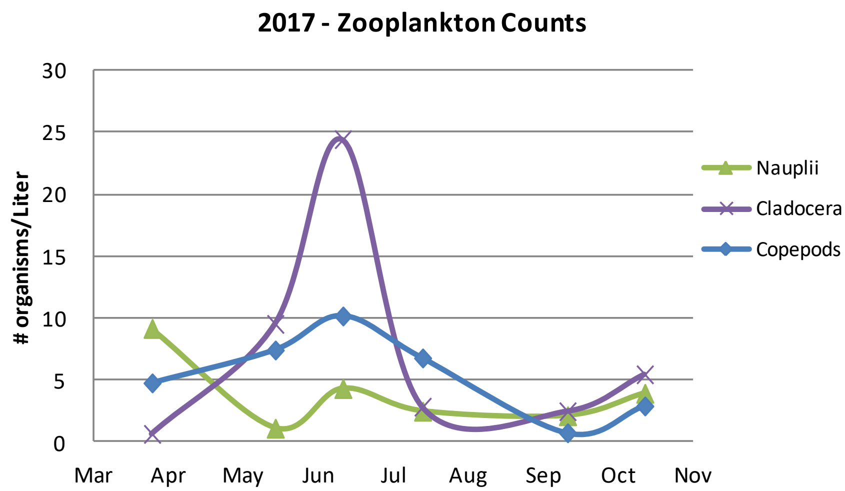


Figure 10: Zooplankton Populations 2017

The zooplankton population at the Lake was again dominated by Rotifers, yet the general populations were generally lower than in 2016. This decrease may be due to somewhat of a difference in the counting methods, but the general trend was similar to 2016. Populations were indicative of boom and bust growth cycles (**Figure 11**) where the Rotifer count crashed in May and June, reaching a maximum during September before falling off again in October.

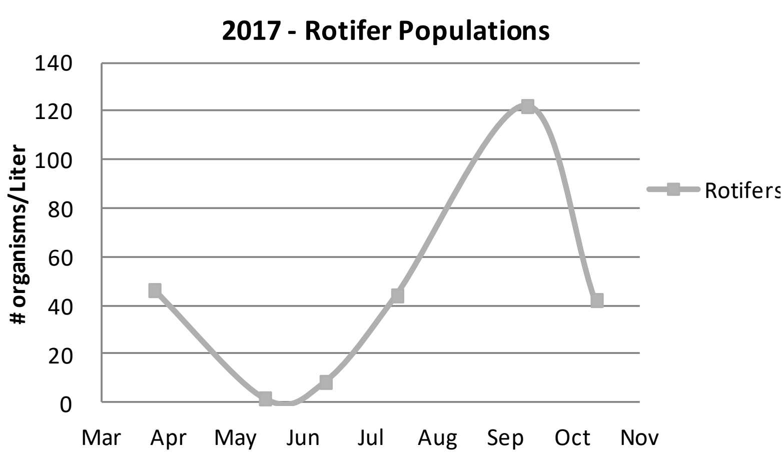


Figure 11: Zooplankton Rotifer Populations

Total Phosphorus

In-lake phosphorus was tracked at all three Stations (**Map 1**). Four monthly samples were taken at Station 1, while at least two monthly samples were collected at Stations 2 and 3. Total Phosphorus (TP) results from the main sampling depths are shown in **Table 1** (Station 1) and **Table 2** (Stations 2 & 3).

- TP in the surface waters ranged from 11-23 μ-grams/Liter (parts per billion) at Station 1. The highest surface TP was in October after fall turnover.
- On May 31st, 2017, Station 3 had higher TP than both Station 1 & 2.
- Bottom water TP remained below 150 ppb for the entire season, which is significantly lower than concentrations seen in many prior years.
- Internal loading is still a problem but was much less than usual - more on par with levels seen in 2010 and 2011.

Table 1: Station 1 Total Phosphorus (TP) 2017

Date	1-meter	4-meters	6-meters	9-meters	*Average*
4/10	15	15	16	16	*16*
5/31	19	20	17	30	*22*
6/28	16	21	29	104	*43*
7/31	17	18	22	143	*50*
8/15	11	22	23	135	*48*
9/29	11	10	25	139	*46*
10/31	23	26	24	27	*25*

Map 1: In-Lake Water Quality Sampling Stations

Table 2: Station 2 & 3 Total Phosphorus (TP) 2017

Date	1 meter	7 meters	Average
Station 2			
4/10	12	14	*13*
5/31	17	19	*18*
6/28	14	31	*23*
7/31	18	81	*50*
8/15	11	67	*39*
9/29	11	61	*36*
10/31	*NA*	*NA*	*NA*
Station 3	**1 meter**	**7 meters**	**Average**
4/10	13	21	*17*
5/31	22	25	*24*
6/28	16	30	*23*
7/31	19	51	*35*
8/15	13	89	*51*
9/29	13	44	*29*
10/31	19	19	*19*

In 2017 the hypolimnetic (bottom-water) TP followed a similar trend at all Stations throughout the season, but as usual the internal phosphorus load from Station 1 was higher than at the shallower Stations 2 and 3 (**Figure 12**). Internal loading became apparent by the May 31st sampling visit and then drastically increased by the end of June. In August and September, the internal load did not appear to have much influence on the surface waters at any sampling station; likely a result of strong thermal resistance to mixing at these times. **Figure 13** demonstrates that years 2010 and 2017 both have low internal loading and bottom TP concentrations throughout the season, while many years in-between those time periods have high TP and worsened internal loading.

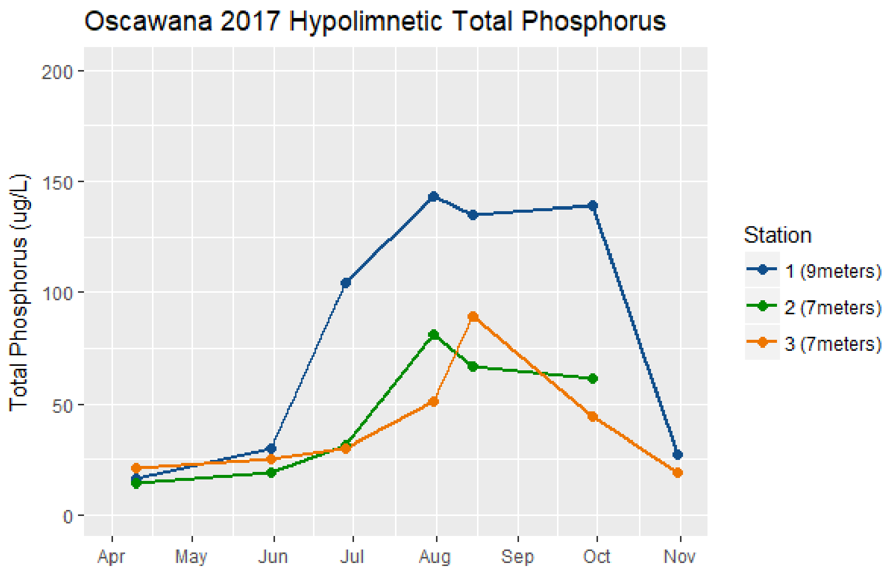


Figure 12: Seasonal Hypolimnetic Total Phosphorus 2017

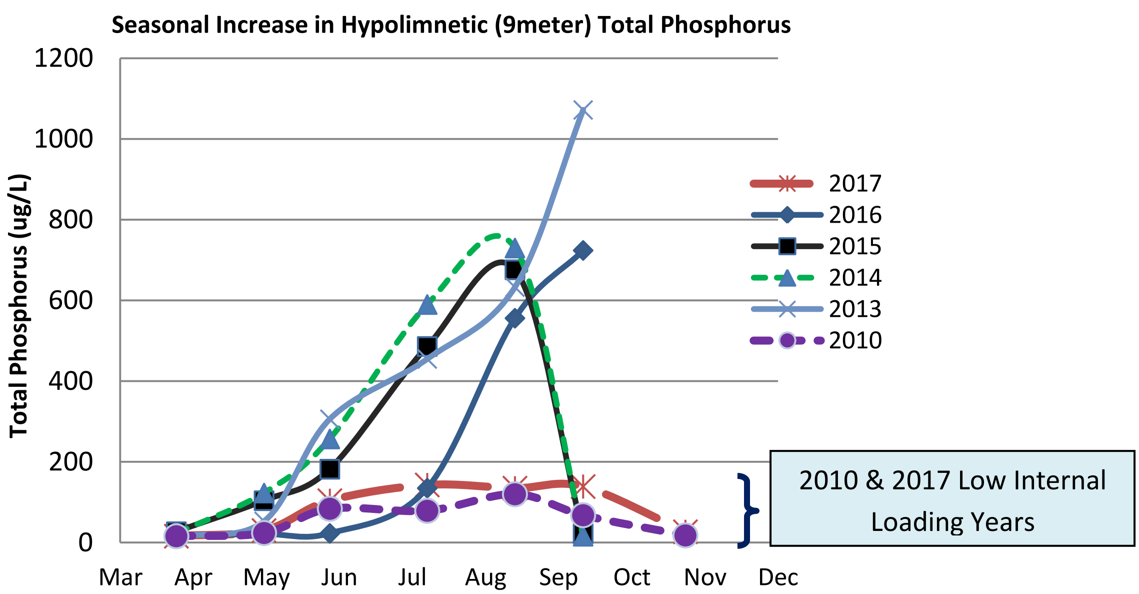


Figure 13: Seasonal Increase in Hypolimnetic TP by Year

Long term 1-meter TP trends at Lake Oscawana are displayed in **Figure 14** below. The lower threshold, marked by a horizontal blue dashed line, marks 10 µg/L. Concentrations below this line are considered very good for Oscawana. As one can see from the figure, surface TP concentrations below 10 µg/L were frequent during 1996 to 2006, but did not occur from 2006-2009. Year 2010 had many low concentrations, but the general trend appears to be of increasing surface TP concentrations. Very few sampling dates after 2010 had concentrations less than 15 µg/L. The upper threshold of 20 µg/L is denoted by the red dashed line. This line indicates the surface concentrations that make cyanobacteria blooms more likely.

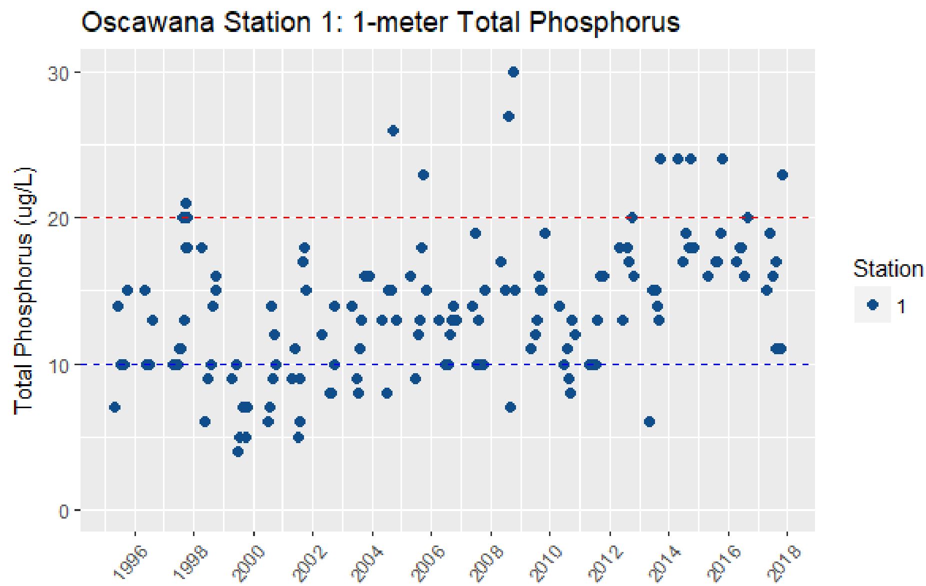


Figure 14: Long Term TP 1-meter Concentrations at Station 1

In order to better track the impacts of internal phosphorus load from bottom sediments, it is necessary to calculate the mass of Total Phosphorus. This is estimated by multiplying the measured concentration by the respective volume of water at each sampling depth (**Table 3**). In this way, a researcher is able to see the transfers of phosphorus from bottom to top of the water.

Table 3: Volumetric Water Layers by Depth (meters)

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

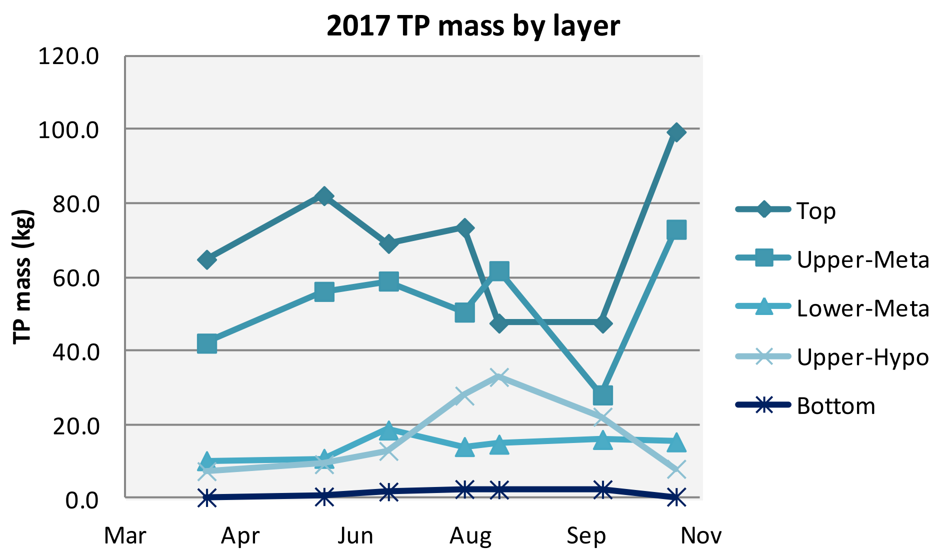
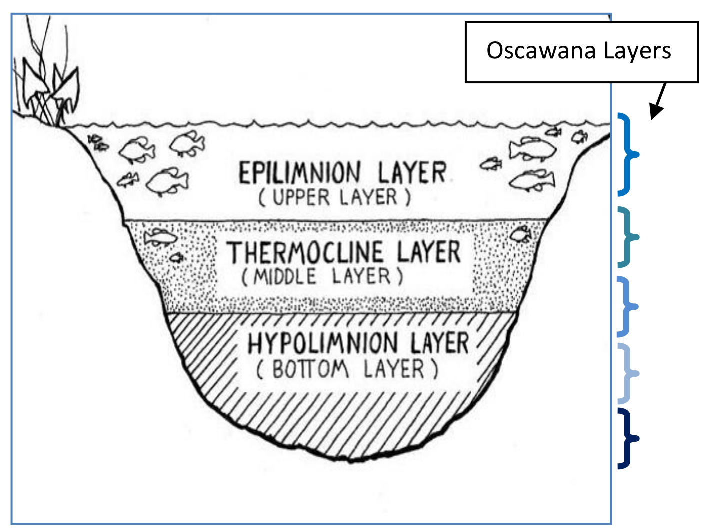


Figure 15: 2017 Total Phosphorus Mass In Each Layer of Water

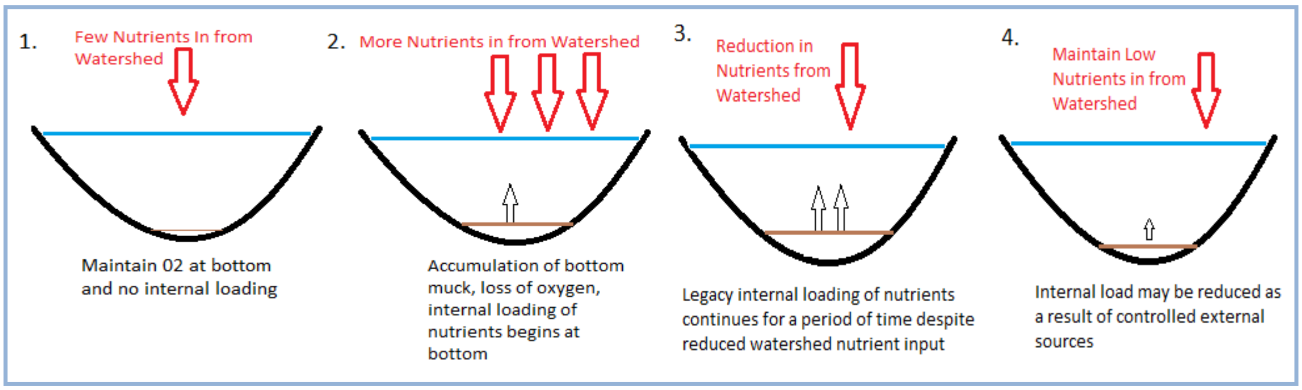
Figure 15 demonstrates that although the bottom phosphorus numbers are the highest, the bottom waters make up little of the total in-lake phosphorus mass. This is due to the very small area of the lake that is deeper than 7-meters. From the figure, one can see approximately a 30 kilogram increase in the combined Top and Upper-metalimnion layers (surface waters) from April to the end of May while there was no increase in bottom water mass during this time. There was also already a moderately strong thermal boundary (50 RTRM) suggesting that bottom-water TP release did not cause this early season spike in nutrients. Groundwater inputs during this time of the year would be highest and would occur in the shallow lake surface waters. Similarly, this spring surface water trend is not consistent throughout the years. If it were due to early season oxygen loss and internal loading, we would expect it to be more consistent. Therefore we expect this spring pulse of nutrients to be controllable via watershed improvements and septic system updates.

The **Appendix** includes a series of annual in-lake phosphorus mass graphs, each year similar to Figure 15, but with different TP trends. There are years where there is a clear transfer of bottom-water phosphorus mass into the surface waters, and there are years where this transfer does not seem to occur. Also, the Upper hypolimnion layer only periodically affects the mass of phosphorus in the lower metalimnion, meaning that internal loading is not consistent over the years and should be controllable to some extent given proper watershed nutrient controls.



Picture 1: Lake Layers Diagram

Keep in mind that internal loading is related to external nutrient loading. The diagram below (**Picture 2**) depicts the watershed-internal loading relationship. As less nutrients enter the lake from the surrounding watershed, over time the internal load should also be reduced. However, this response is different at every lake.



Picture 2: External & Internal Loading Diagram

Figure 16 is the total in-lake TP mass over the years. The goal for Lake Oscawana is to have under 125 kilograms of TP in the lake during the entire season, which is what occurred in 2010 and should therefore be repeatable given continued watershed nutrient management. 2017 was very close to these low levels.

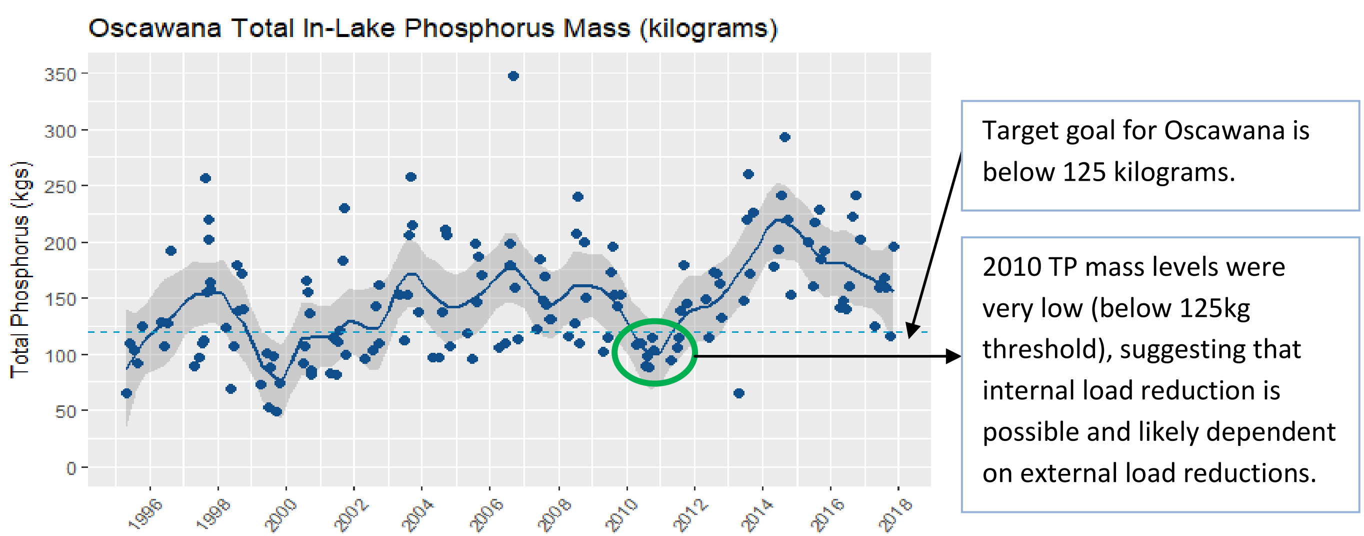


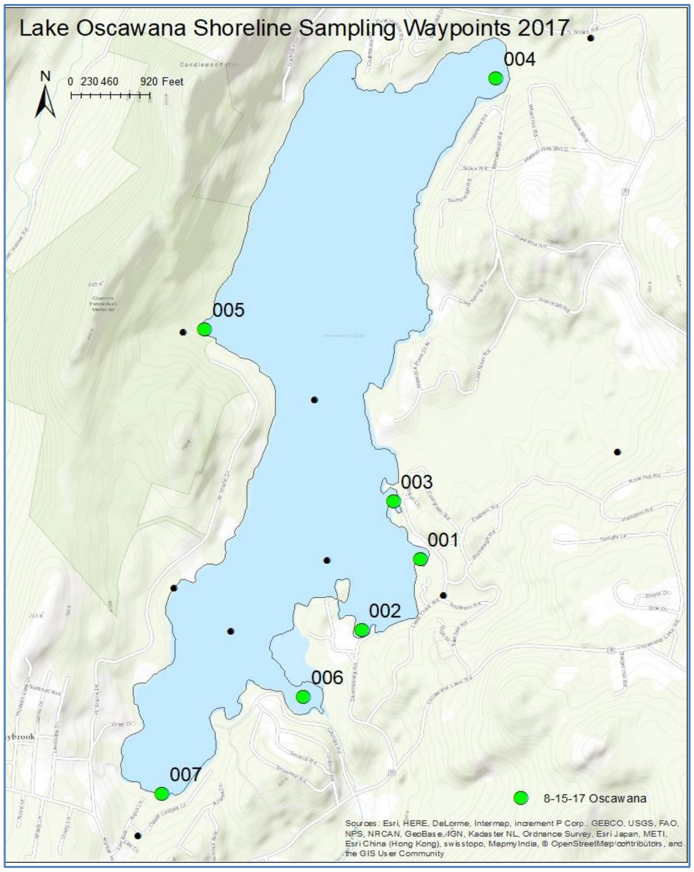
Figure 16: Historical Total TP Mass

In the 2012 Oscawana monitoring report, we recommended testing for phosphorus in shallow shoreline areas around the lake. This process could determine if shoreline concentrations of nutrients were consistent with, or higher than, Stations 1, 2, & 3, which are in open water. If concentrations at shoreline areas prove higher than in-lake concentrations it would be indicative of watershed nutrient loading. In 2017, we conducted a round of perimeter sampling in mid August. Sampling locations are identified in **Map 2**, and results are displayed in **Table 4**.

Table 4: Near-shore Lake Water Nutrient Testing Results 2017

Near-shore TP Sampling Sites	Date	TP(ppb)
Oscawana 001	8/15	10
Oscawana 002	8/15	12
Oscawana 003	8/15	11
Oscawana 004	8/15	13
Oscawana 005	8/15	8
Oscawana 006	8/15	16
Oscawana 007	8/15	10

Map 2: 2017 Shoreline Lake Samples (0.5-meters deep)



The results show that there is a definite difference between shoreline concentrations around the lake. The sample taken from location 005 was very low (8ppb) in TP. This location is below a well-forested area and this sample indicates low nutrient groundwater entering the lake at waypoint 005.

At waypoint 006, however, the TP concentration was 16ppb, double that of the previous sampling point. This region is very low lying and has thick accumulations of organic muck. This area is susceptible to septic system failures and high nutrients. Because this area is located near the Oscawana outlets, it is expected that high nutrient inputs at this site will not impact the lake as much as they could at far end. Yet, this type of sampling deserves more attention in the future.

August sampling may have been too dry to determine the full extent of shoreline groundwater nutrient loading because late summer months are very dry. Conditions in 2017 were especially dry.

We recommend repeating this shoreline nutrient testing in June of 2018 and 2019, when groundwater levels are expected to be higher. We also recommend testing these locations for Total Nitrogen, or Nitrate nitrogen, as septic systems contribute very high amounts of nitrogen in shoreline areas.

Nitrogen

Nitrogen in Lake Oscawana has generally been decreasing since the early 2000s (**Figure 17**). Despite some peaks in 1-meter TN during summer, the trend is statistically significant. There is a very wide range in surface Total Nitrogen (TN) throughout the season in some years.

- Concentrations of TN in surface waters should always be below 600 µg/L (ppb).
- The water quality target for Oscawana is below 300 µg/L TN in surface waters.
- No long-term trends were identified between Ammonia nitrogen and water clarity, a stronger relationship exists with TP and water clarity.
- Ammonia nitrogen accumulates in the bottom waters every year, with some ammonia reaching the surface waters. The seasonal ammonia trends at Station 1 at the 1, 4, & 6 meter depths were very similar, but did not follow bottom-water ammonia trends in August. Bottom-water ammonia was somewhat mixed into the surface during fall turnover (**Figure 18a-b**).
- Total Nitrogen trends did not follow ammonia trends, indicating a watershed source of nitrogen throughout the season.
- Total Nitrogen trends in surface layers (1-6 meters depth) decreased in August to September, during the period of good water clarity and similarly reduced phosphorus in surface waters. August to September was the only time period during 2017 where TN appeared to follow the same trend at 1, 4, & 6-meter water depths. This period could also be related to reduced watershed loading during the dry late summer period (**Figure 18c-d**).

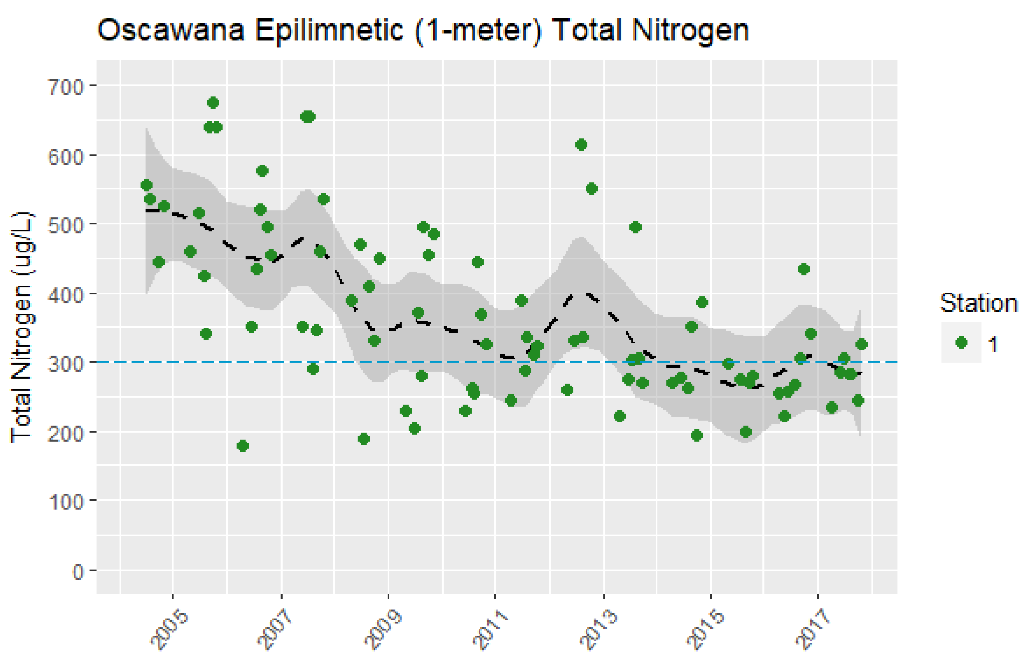


Figure 17: Surface (1-meter) Total Nitrogen Long Term Trend

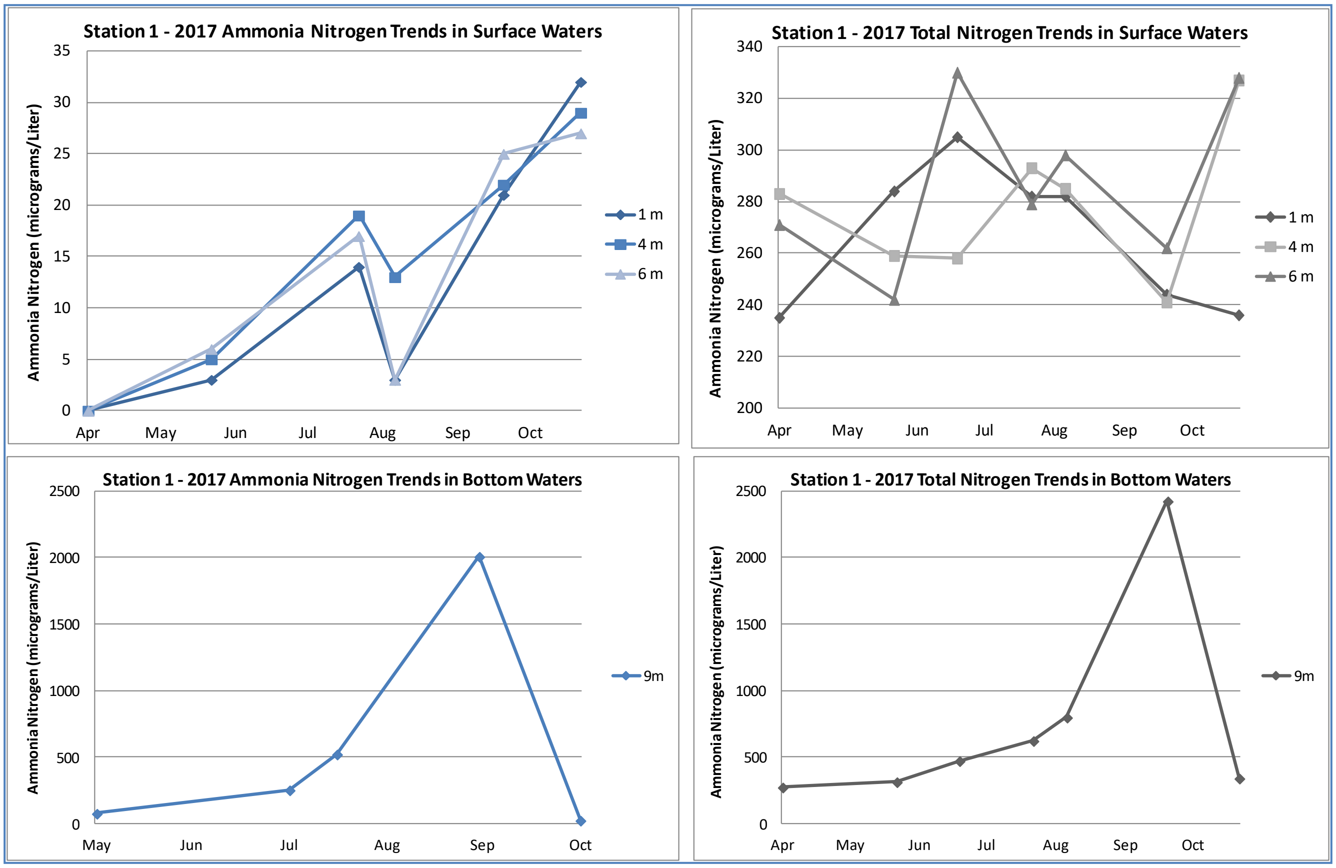
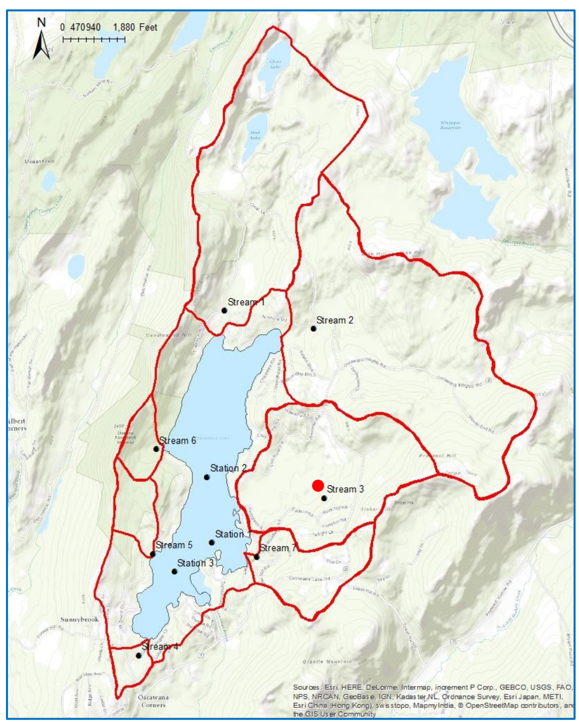


Figure 18a-d: Ammonia and Total Nitrogen 2017 Trends (Station 1)

Map 3: Inlet Locations



Stream Monitoring Results

Stream monitoring was conducted at the seven lake inlets from April to October. All inlets were flowing in April and early spring, but as the season progressed Streams 3, 5, 6, and occasionally 1 and 7 were reduced to immeasurable flow. At this point the water entering the lake is mostly groundwater. Stream 2 was always flowing, as it drains the largest amount of land and is the primary inlet to the lake; though flow conditions were drastically reduced from July to October.

A second tributary of Inlet 3 was located in 2017 (red dot, **Map 3**). This new sampling point is located on private property and we must get permission for sampling from the homeowner in future years. All Total Phosphorus 2017 inlet results are displayed in **Figure 19**.

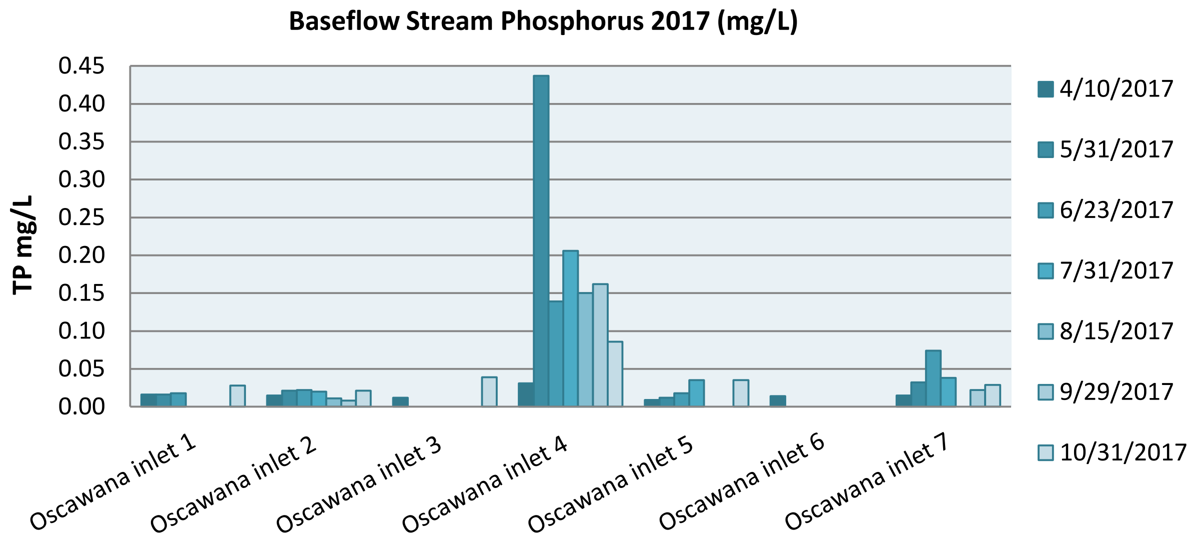


Figure 19: 2017 Baseflow Stream Total Phosphorus (note that concentrations are in mg/L, where 0.10mg/L = 100µg/L)

Overall the 2017 inlet results are very similar to years past in that Inlet numbers 4 and 7 are consistently high. Inlet 4 has a very small watershed and the surface water we collect throughout the dry periods of the season are indicative of groundwater contamination. There is a private pond upstream of Inlet 4 that is full of filamentous algae. This property should be inspected for septic system failure. If no localized failure is detected, then the contamination can be seen as a result of all surrounding onsite wastewater leaching fields, which is a known problem in the Oscawana watershed. While not shown on the above graph, Inlet 4 sampling on February (28th) 2018 revealed 6.110mg/L of Total Nitrogen (6110 µg/L), which is indicative of severe groundwater pollution during winter months, potentially at levels endangering any shallow drinking water wells in the nearby area.

The long term average concentrations at each inlet location are compared to 2017 values in **Figure 20** below. All long term inlet concentration data is displayed graphically in the **Appendix**.

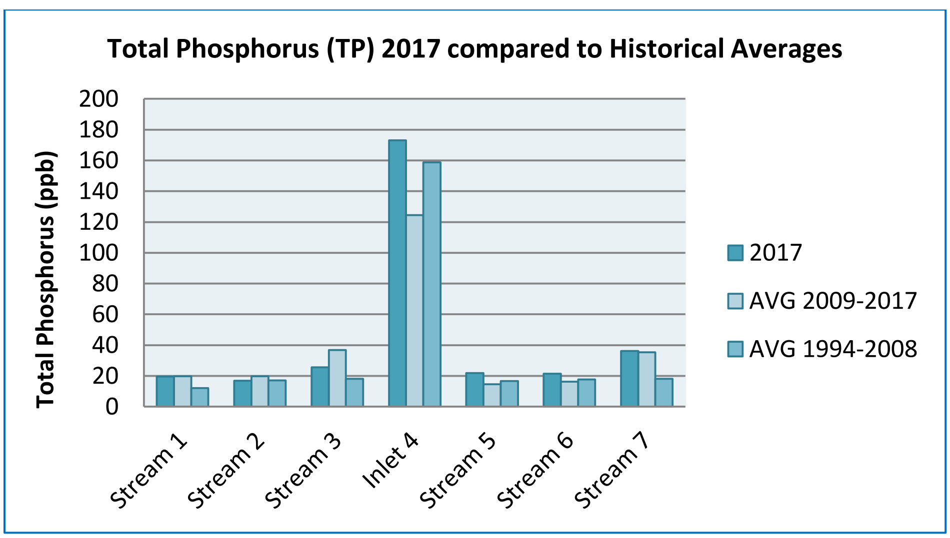
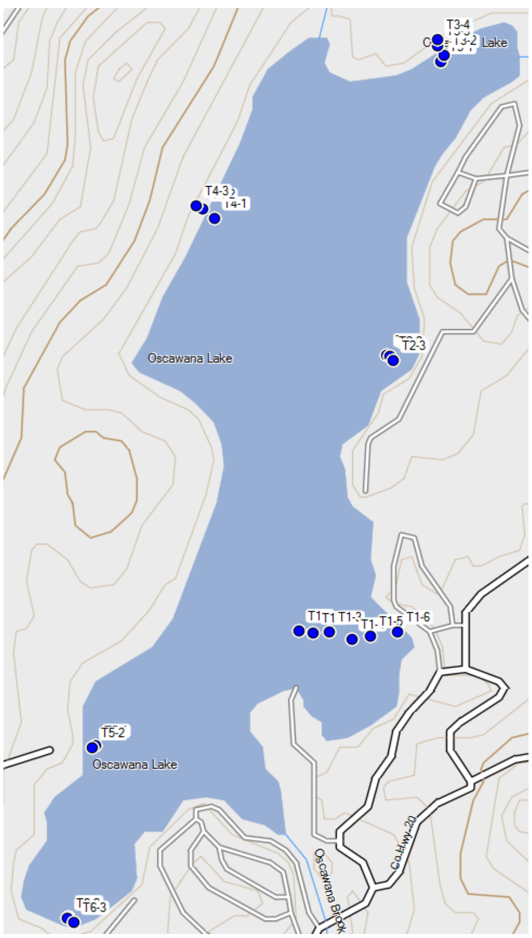


Figure 20: Inlet TP ppb (equivalent to µg/L)

Aquatic Plant Management

The aquatic plant surveying in 2017 consisted of monthly transects. The aim of the transect survey was to determine if the weed harvester had any visible affect on Eurasian milfoil frequency and density during the course of a season. The transect surveying was established in 2016 and will also serve as a way to track the long-term effects of grass carp. While an entire littoral zone survey is a good way to track overall lake wide abundance of aquatic plants, including invasive Eurasian milfoil, the transects serve as a statistically significant way to study changes over time in localized areas of the lake. No full aquatic plant survey was conducted in 2017, but there will be one in summer 2018. The six transect locations and descriptions are provided below (**Map 4**).

Map 4: Aquatic Plant Survey Transect Waypoints



T1 (6 waypoints) is located at a very wide section of the littoral zone in a cove that is heavily infested with Eurasian milfoil. This is an area where the weed harvester is known to work.
T2 (3 waypoints) is located along the rocky northeastern edge of the lake in an area with a narrower littoral zone.
T3 (4 waypoints) is located at the north end of the lake in a mixture of a large bed of *Pot. amplifolius* and E. milfoil. Inner waypoints are not inside swim area but are close to a resident's boat-house. Very mucky sediments with some rocks.
T4 (3 waypoints) along northwestern shore, not located by any houses. Narrow littoral zone, rocky, sharp drop-off to deeper water.
T5 (2 waypoints) is in a very sandy shallow area along southwestern shore. Ability to sample affected by water level.
T6 (3 waypoints) located in shallow water at the south end of lake. Very close to outfall pipe, walled shoreline, very mucky sediments.

Monthly survey results from all transects are summarized below in **Figure 21**, where each line on the graph represents a different species. The figure displays the overall percentage of the transect data, which is a factor of the frequency and the average percent density at each waypoint where a particular species was found. The seasonal progression is clear, specifically for Eurasian milfoil. In comparison to 2016, the overall percentage at the transect waypoints was much higher for Eurasian milfoil in 2017 than in late 2016.

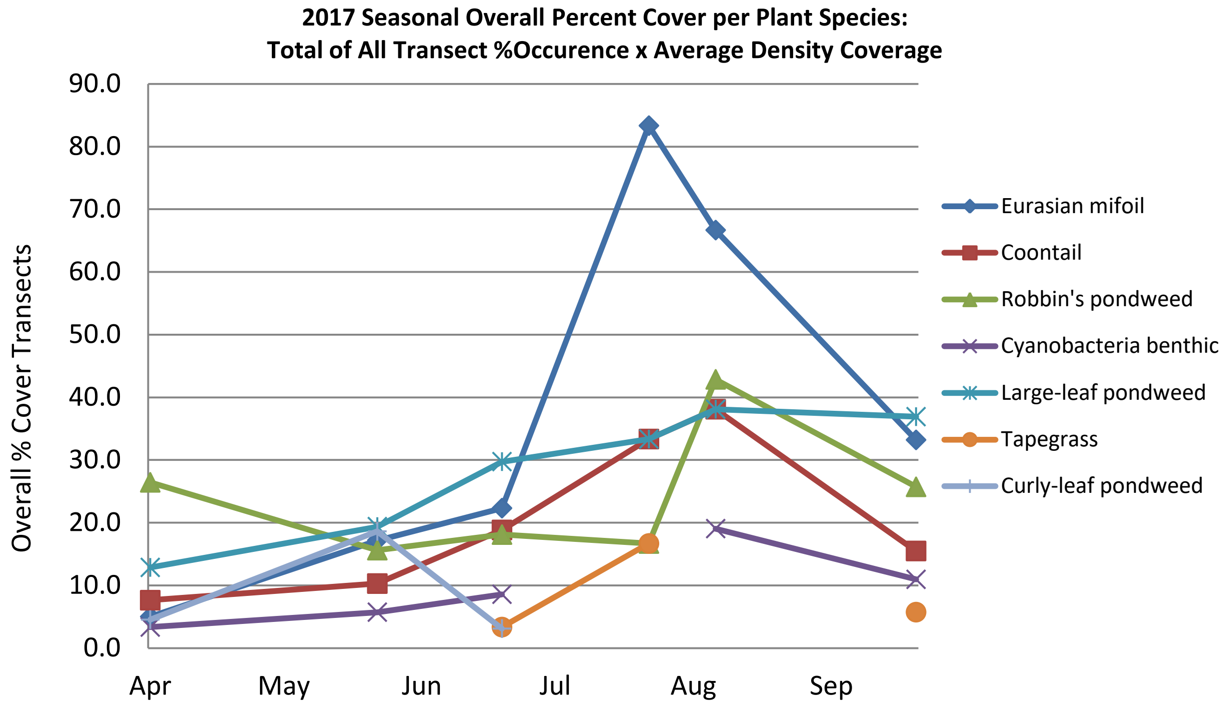


Figure 21: Seasonal Transect Aquatic Plant Survey Data

The Lake Oscawana Management Advisory Committee (LOMAC) is in the process of purchasing either a GPS or other tracking device in order to track where the harvester works during the season. The purpose of a tracking device is two-fold. First, the water quality data raises questions about the impacts of harvesting on water clarity and sediment re-suspension in certain areas. This could also be related to internal loading from decaying aquatic plants or particulate organic matter, which is disturbed by harvesting. Second, there needs to be a systematic way to evaluate how effective the harvesting is at reducing Eurasian milfoil biomass. Harvesting tracker and load data can then be compared to aquatic plant survey results. Tracker data will also be useful in evaluating grass carp impacts on the aquatic plant community over time.

As in years past, the weed harvester time sheet logs should include a section where the harvester operator records the number of daily loads as well as the general locations where the harvester worked that day. The GPS will keep track of the actual time spent harvesting in each specific area, but it is good to have the operator record general locations and loads as they have previously. LOMAC board members should be responsible for entering the harvester operator logs and tallying the number of loads per week into an excel spreadsheet.

Watershed Investigation

In 2017, additional inspection and sampling was conducted in the Oscawana watershed. There was initially some confusion as to whether the lake was still considered "Impaired" by the State of New York DEC. To clarify, Oscawana is listed as a "4a" and "4c" lake, meaning that it is still considered impaired based on the NYS Water Quality Standards, but that the State has taken the initial steps towards remediation in preparing the Total Maximum Daily Load (TMDL), as published by the Cadmus Group in 2008. The reasoning behind these "4a" and "4c" classifications is that the NYS DEC needs a way to quantify the many impaired waterbodies that do not yet have a TMDL. Yet the DEC also recognizes that a published TMDL does not equate to improved water quality. Therefore, we have proposed to update the TMDL with new watershed data and observations. The goal is to create a watershed-based TMDL Implementation Plan update, which will include a list of actionable measures to reduce watershed nutrient loading to the lake. This implementation plan will be prepared and finalized in concert with the NY DEC as part of an overall lake management plan.

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.

https://www.dec.ny.gov/chemical/31290.html

One of the largest hurdles for updating watershed loading information is collecting stormwater samples. We examined the results of stormwater sampling conducted by the Town in 2010 in an effort to evaluate the catch basin filter inserts; yet there was no evidence that the filters were successfully removing phosphorus. The filters do, however, remove large quantities of sediment and particles, which should also remove phosphate adsorped to particle surfaces. However, purely sediment filter inserts will also perform well and may be supplemented for the purpose of cost savings in the uphill areas. Catch basins closest to lake level should still be fitted with the phosphorus specific filters.

We were also employed to study the stormwater biofilter, which was originally constructed with NY DEC grant funding, and was updated in 2017 by the Lake Oscawana Civic Association (LOCA), who generously donated funds for the remediation. Annual maintenance of the biofilter will be part of the District budget. Our sampling and investigation of the biofilter suggests that the groundwater levels are too high for the filter to adequately hold any stormwater in the settling basin. During April to July, the groundwater table is higher than the inflow pipe to the biofilter, meaning that there is no period of particle settling during the months with peak stormwater runoff. The biofilter pool is also definitively groundwater, as opposed to standing water, because it is frequently cooler than the stream 5 temperature. Samples collected at the inflow and outflow of the settling basin, shown in Photo 1, showed that the outflow had considerably higher total phosphorus than the inflow, meaning that at least the first part of the biofilter was not reducing phosphorus. Nitrogen, however, was either lessened or diluted by groundwater.

Biofilter Pool Outlet (Photo 1) - 4/11/18:

Total Phosphorus = 24 µg/L, Total Dissolved Phosphorus = 7 µg/L, Total Nitrogen = 247 µg/L

Biofilter Inlet (Photo 2) - 4/11/18:

Total Phosphorus = < 3 µg/L, Total Nitrogen = 327 µg/L

Photo 1

Photo 2

It's also important to note that ongoing research indicates that initial TP reduction of constructed wetlands, such as the lower section of the "biofilter" can be as high as 60%, but as nutrients saturate the system over 10-20 years, retention capacity declines[1]. 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. Continued watershed monitoring and stormwater sampling in 2018 will pinpoint specific locations for new stormwater management, and will also track the effectiveness of current highway stormwater control measures.

[1] WJ Mitsch, AJ Horne, RW Nairn (2000) Nitrogen and phosphorus retention in wetlands-ecological approaches to solving excess nutrient problems. Ecological Engineering, Vol. 14, pp1-7.

Conclusions and Recommendations

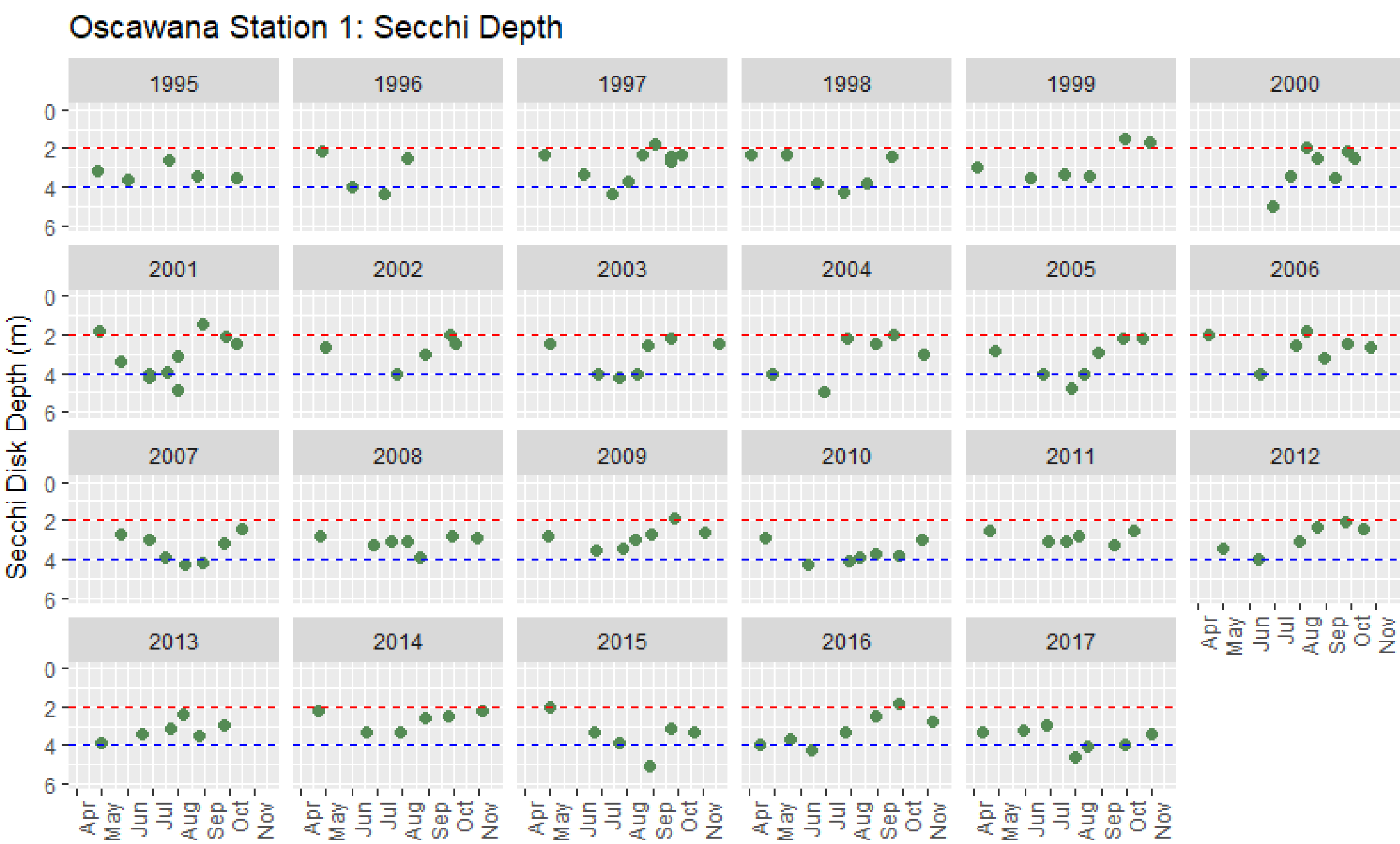
Overall Lake Oscawana had good water quality in 2017. The summer months had excellent water quality, as compared to historical values. In-lake nutrient sampling indicates that internal loading is somewhat controllable based on external loading. Worsened internal loading may be linked to weed harvesting and sediment disturbances, and improved internal nutrient loading may to be linked to septic system pumping and reduced weed harvesting. Unfortunately there is not a enough historical data about watershed management or in-lake weed harvesting to truly determine their impact on the lake, specifically in years with good water quality and low internal loading conditions. Yet there appears to be a relationship; the good summer water clarity and low bottom water phosphorus was observed in 2010 and again in 2017, indicating that continued watershed management will improve the internal loading situation.

Similarly, the nitrogen regimes observed in 2017 suggest that the watershed has more of an effect on early season water clarity. The steady reduction in Total Nitrogen over the last decade also points towards update septic systems and regular pumping. Town records of septic system pumping should be maintained. A Town employee should also be responsible for keeping in touch with the Putnam Local Health Department as new septic systems are built and old systems replaced. These records are especially important to lake water quality.

The 2017 aquatic plant survey results indicate that there is a seasonal progression, as expected, in plant growth and density. During the monthly transect surveys, we did notice reduced Eurasian milfoil height in the water column, yet the plants were still present and growing densely beneath the surface. At this time, there is still no evidence that the grass carp are having measureable impact on aquatic plants. A full littoral zone aquatic plant survey will be conducted in 2018. The Town should acquire the GPS tracking device prior to the weed harvesting efforts in 2018. Harvester operators should continue to track their daily load numbers and LOMAC and NEAR can tabulate this data into weekly harvester load totals to be paired with GPS location data.

Initial watershed inspection mapped a large majority of the catch basins and inlets to the lake, but more stormwater monitoring is needed in order to update the TMDL and create an EPA and NY DEC compliant watershed-based implementation plan. Much of this watershed investigation and management planning work was completed in 2017 but will be finalized during the 2018 season. In the mean time, the Town needs to address Inlet 4. The local health sanitarian should be aware that very high levels of nitrogen in groundwater are present in this location.

Appendix



Minimum/poor threshold red dashed line,
Good/clear Water threshold blue dashed line.

Figure 22: Long Term Seasonal Water Clarity (separated by each year)

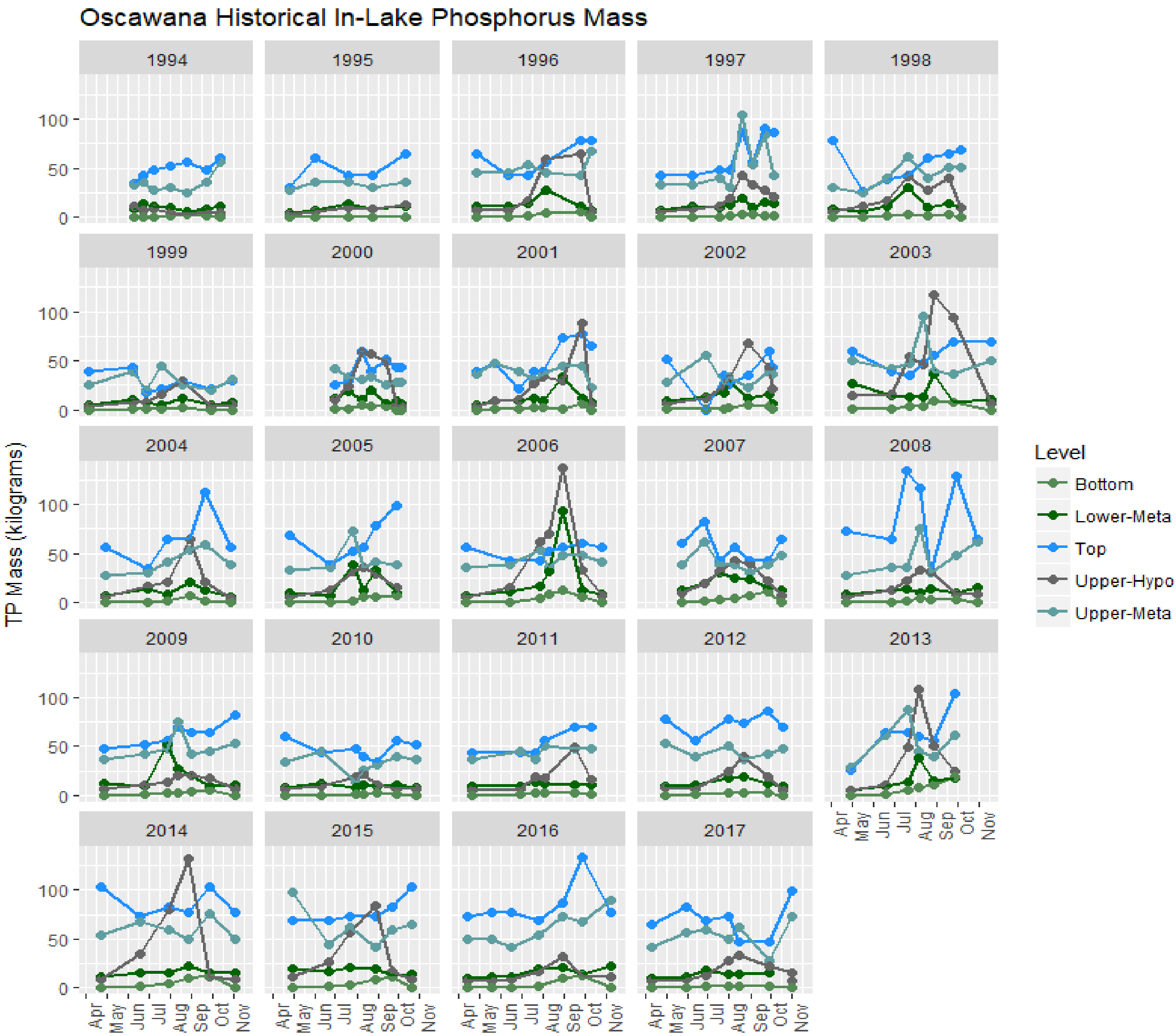


Figure 23: Historical In-Lake Phosphorus Mass by Depth Layer - Mass is calculated by multiplying the TP concentration by the total volume of the layer of water (see p18).

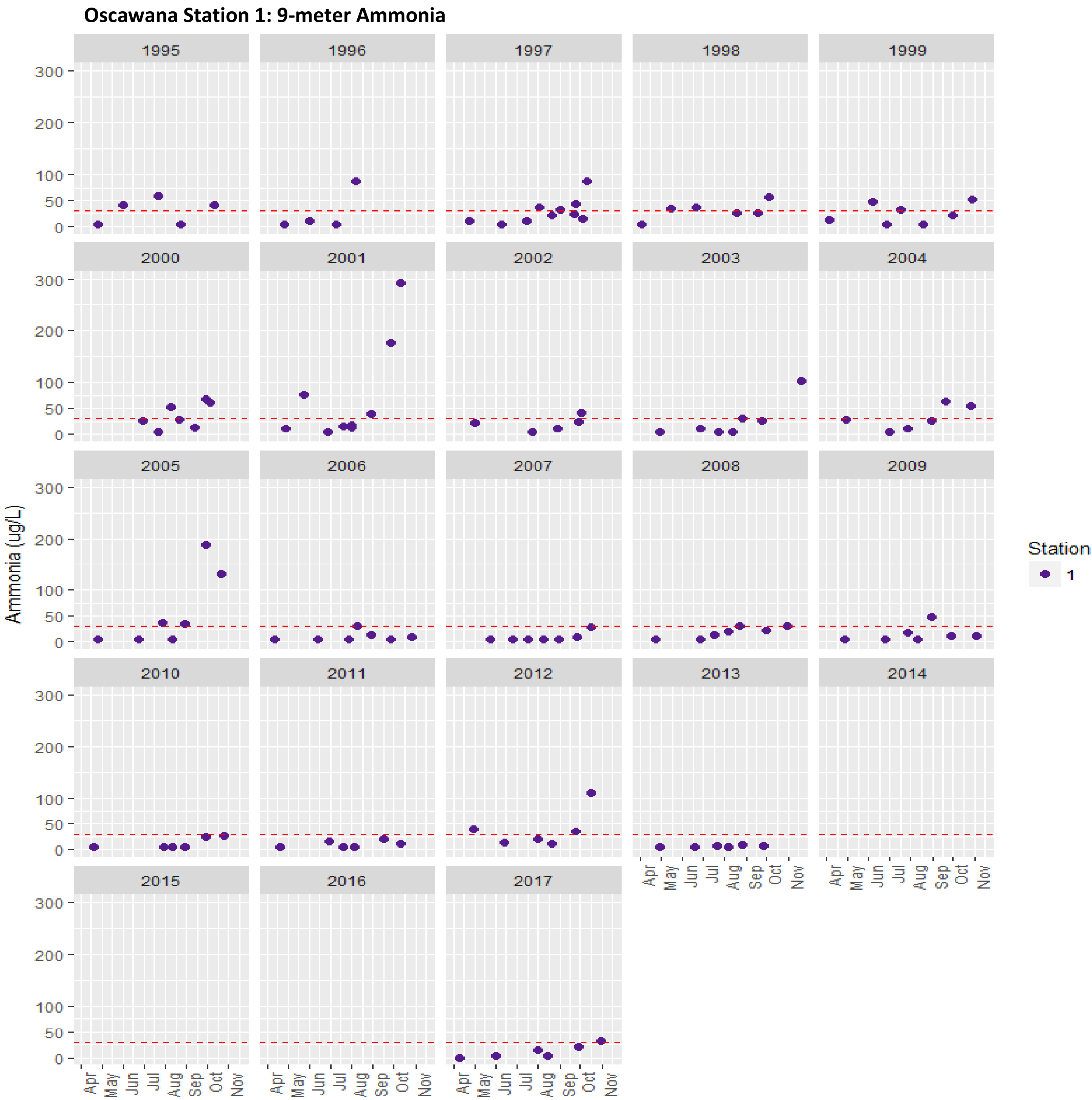


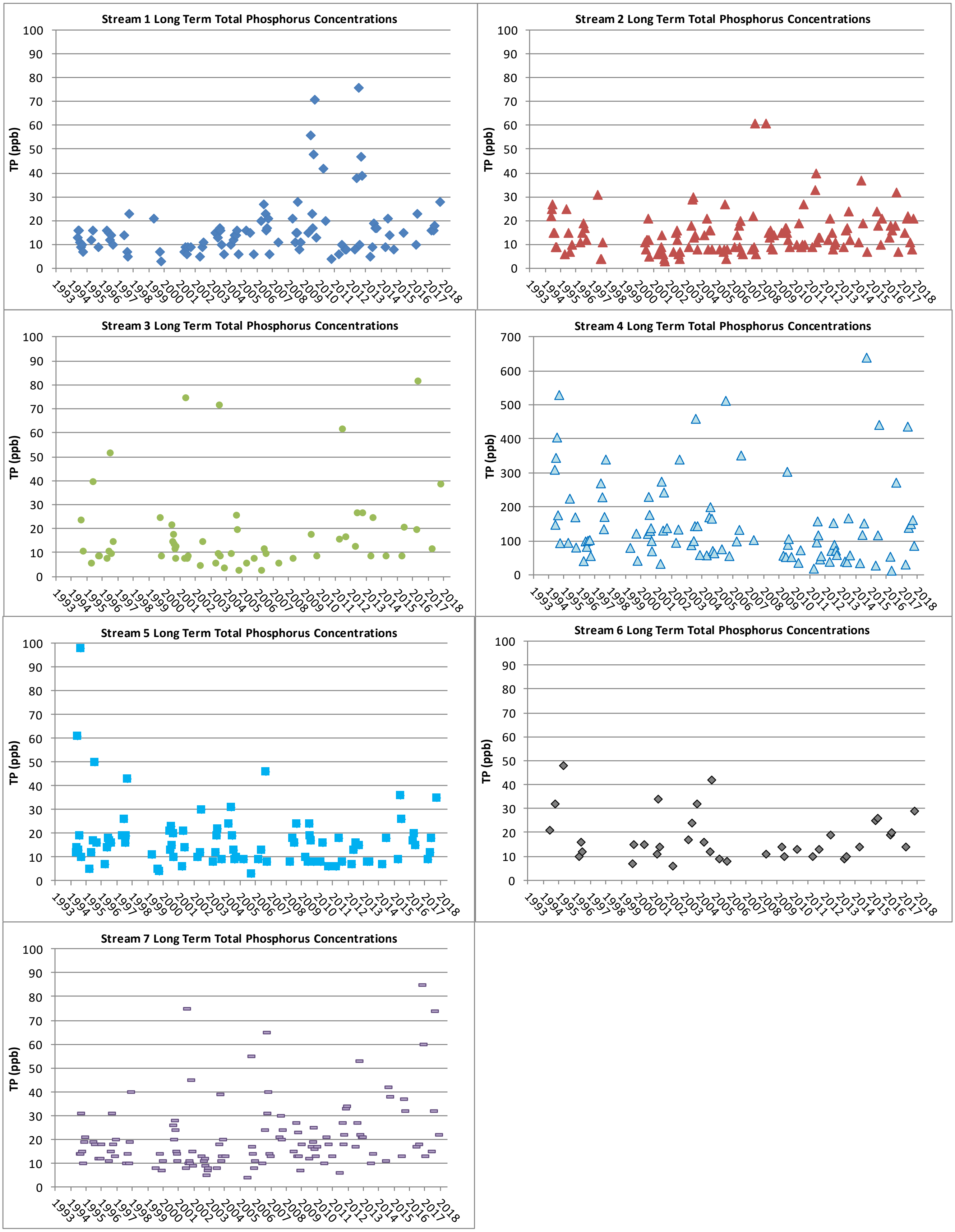
Figure 24: Long Term Bottom Water Ammonia Nitrogen Trends

Red dashed line indicates target bottom water maximum levels.

Table 5: All 2017 Station 1 In-Lake Nitrogen Data

Station and Depth (m)	Date	Ammonia	Nitrate	Total Nitrogen	% TN that is Ammonia
Oscawana St1 1m	4/10/2017	ND	ND	235	0%
Oscawana St1 4m	4/10/2017	ND	ND	283	0%
Oscawana St1 6m	4/10/2017	ND	ND	271	0%
Oscawana St1 9m	4/10/2017	ND	ND	275	0%
Oscawana St1 1m	5/31/2017	3	ND	284	1.1%
Oscawana St1 4m	5/31/2017	5	ND	259	1.9%
Oscawana St1 6m	5/31/2017	6	ND	242	2.5%
Oscawana St1 9m	5/31/2017	79	ND	315	25.1%
Oscawana St1 1m	6/28/2017	NSS	NSS	305	NA
Oscawana St1 4m	6/28/2017	NSS	NSS	258	NA
Oscawana St1 6m	6/28/2017	NSS	NSS	330	NA
Oscawana St1 9m	6/28/2017	199	NSS	473	42.1%
Oscawana St1 1m	7/31/2017	14	ND	282	5.0%
Oscawana St1 4m	7/31/2017	19	ND	293	6.5%
Oscawana St1 6m	7/31/2017	17	ND	279	6.1%
Oscawana St1 9m	7/31/2017	255	ND	624	40.9%
Oscawana st1 1m	8/15/2017	3	ND	282	1.1%
Oscawana st1 4m	8/15/2017	13	ND	285	4.6%
Oscawana st1 6m	8/15/2017	3	ND	298	1.0%
Oscawana st1 9m	8/15/2017	524	ND	800	65.5%
Oscawana St1 1m	9/29/2017	21	ND	244	8.6%
Oscawana St1 4m	9/29/2017	22	ND	241	9.1%
Oscawana St1 6m	9/29/2017	25	ND	262	9.5%
Oscawana St1 7m	9/29/2017	46	ND	363	12.7%
Oscawana St1 10m	9/29/2017	2009	ND	2424	82.9%
Oscawana St1 1m	10/31/2017	32	21	326	9.8%
Oscawana St1 4m	10/31/2017	29	21	327	8.9%
Oscawana St1 6m	10/31/2017	27	22	328	8.2%
Oscawana St1 9m	10/31/2017	27	21	342	7.9%

ND = None Detected; NSS = No Sample Sent to Lab



Figures 25 (1-7): Long Term Stream Total Phosphorus Results

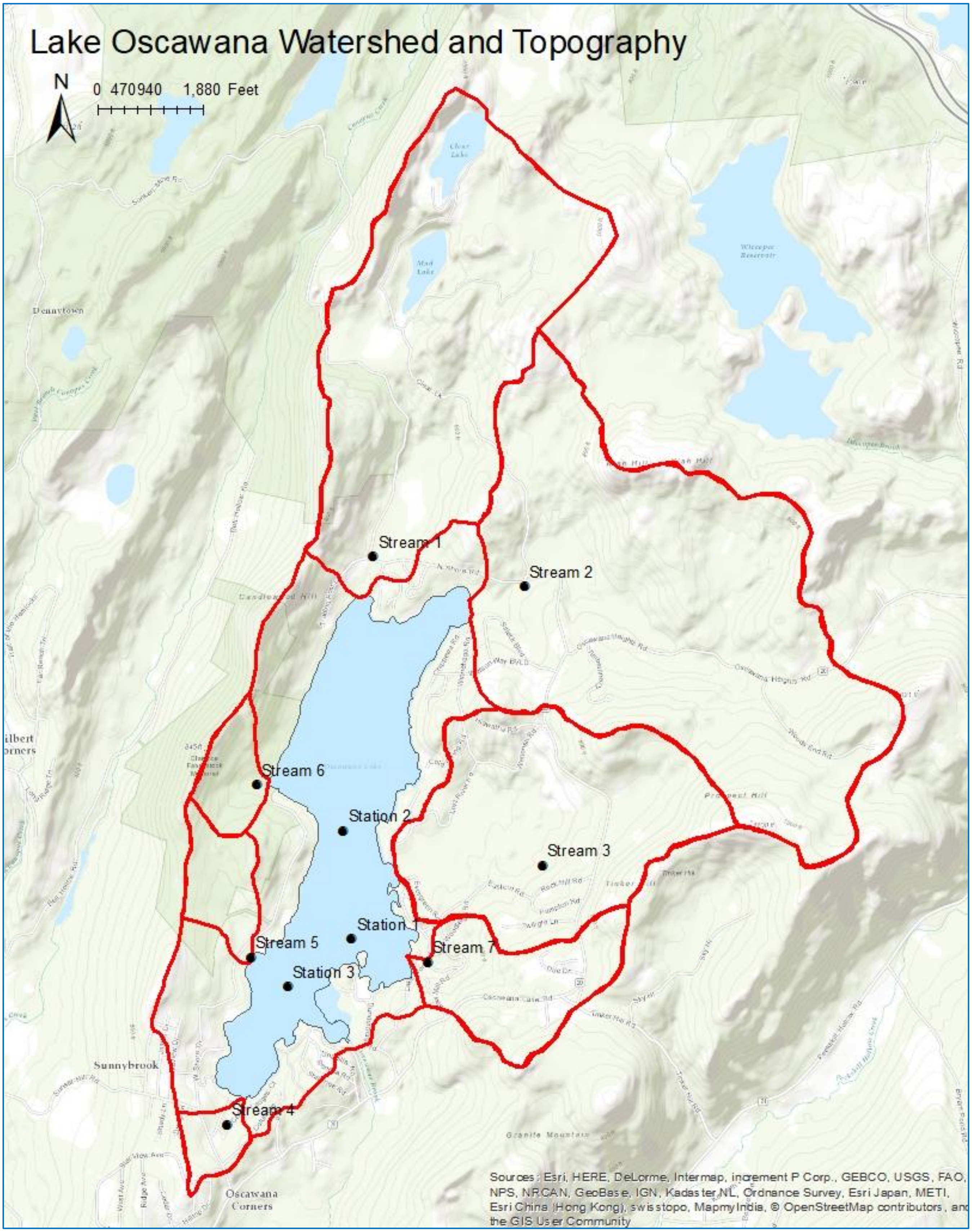


Figure 26: Oscawana Watershed Boundary and Sampling Locations