A Non-Point Source Study of Skaneateles Lake Tributaries

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by

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Abstract

Skaneateles Lake and its watershed are valuable natural resources to local communities, and the lake is the source of drinking water for the nearby city of Syracuse. In recent years, foam has been seen forming on the surface of Skaneateles Lake, and during late summer of this year was an outbreak of blue-green algae. Previous studies suggest that runoff from agricultural land in particular may be contributing nutrients to the lake that could influence the water quality. This study took surface water samples from four tributaries of Skaneateles Lake and analyzed them for orthophosphates, nitrate nitrogen, ammonia nitrogen, and total suspended solids. To compare the nutrient contributions of agricultural land with those of other land use types, two tributaries were chosen with mostly agricultural sub-watersheds and two were chosen with primarily forested sub-watersheds. The nutrient analyses on water samples did not show a clear distinction between agricultural and forested watersheds. However, secondary analyses on phosphorous in sediments derived from agricultural activity and sediment loading rates during wet weather events suggest significant impacts from agriculture.
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Project Objective

The objective of this project was to gather preliminary data on the effects of land use on the water quality of Skaneateles Lake. Water samples taken from the tributaries were tested for total suspended solids (TSS) to measure the effects on turbidity, and tested for nitrate and ammonia nitrogen (NO$_3$/NH$_3$) and orthophosphate (OPO$_4$) for their effects on algal blooms. Samples were taken from tributaries in sub-watersheds with primarily agricultural and forested land to compare the relative contribution of selected pollutants by land use type. Samples were also taken during dry and wet weather to understand how runoff influences loading concentrations.

To capture the effects of nutrient application in the forms of inorganic fertilizers or applied animal waste to agricultural land, samples were collected during the summer months of 2016 and 2017. It was hoped this timing would include most annual pollutants from tributaries to the lake, due to increased nutrient levels in runoff and disturbed soils from agricultural practices.

Results from this project will be used to help determine where land management improvements could be made to improve the water quality of the lake. A brief review of agricultural best management practices (BMPs) is included in this report, along with recommendations for improved practices that might be practical for the Skaneateles Lake watershed going forward. These suggested practices are not site specific and should be applied on a case by case basis.
Executive Summary

Skaneateles Lake is a vital economic and recreational resource in Central New York. Since the Lake is an attractive location for summer cottages and lake houses, as well as the drinking water source for the City of Syracuse, the water quality of the lake is a great concern. With almost half of the Skaneateles Lake watershed are being agriculture, pollution from non-point source runoff is a great concern (OCSWCD, n.d). This study attempted to characterize the influences of runoff to the lake by analyzing water samples from select tributaries for nutrient and sediment concentrations and determining their loading rates during wet and dry weather conditions. Sampling locations were selected based upon the land use compositions of their sub-watersheds in an attempt characterize influences from agricultural land and forested land. The study also included a literature review of best management practices and potential funding sources and an analysis of good and poor practices identified in the watershed.

The nutrient analyses resulted in non-detectable levels for orthophosphates and inconclusive results for ammonia nitrogen and nitrites. However, sediment samples collected from sediment traps downslope of agricultural fields contained higher concentrations of phosphorous than the water. Nitrate concentrations in the water samples varied with little correlation between wet weather and dry weather conditions as well as between primarily agricultural watersheds and primarily forested watersheds. Sediment and nitrate loading increased greatly within their respective watersheds during wet weather events. Sediment loading had increased several orders of magnitude between dry and wet weather conditions. The extreme increase in sediment loading combined with high phosphorous concentrations in agricultural sediments indicates that sediment
loading to the lake creates a risk of turbidity increases and provide a long-term source of phosphorous to the lake. The additional phosphorous could act as a nutrient source for blue-green algae and increase the risk for harmful algal blooms, which can put the City of Syracuse at risk of losing the Filtration Avoidance Waiver on Skaneateles Lake.

Many farmers around Skaneateles Lake are already using BMPs on their properties. The Skaneateles Lake Watershed Agricultural Program (SLWAP) works closely with farmers on a voluntary basis to create whole farm plans incorporating BMPs into their farms. This program had completed 44 whole farm plans by 2004 with another 10 farms enrolled. Good practices observed around the lake include cover crops, strip cropping, and installment of vegetated buffers along streams and ditches. Poor practices included the lack of cover crops, tilling and planting up to ditches and roadways, and the lack of erosion prevention measures on steep slopes. It is recommended that further studies be completed on nutrient sources in the watershed to develop a nutrient budget. It is also recommended that the SLWAP further promote best management practices to farmers and develop an education plan for farmers to better understand the practices.

**Introduction**

Skaneateles Lake has been the primary water supply for the Village of Skaneateles and the City of Syracuse since 1894. In 2004 the lake acquired a filtration avoidance waiver from the New York State Department of Health. The filtration avoidance waiver makes water treatment very inexpensive and will remain in effect so long as the water quality remains high (Harty, 2015). Apart from being a source of
drinking water, the lake and its watershed are a valued recreational resource in Central New York.

The water quality of Skaneateles Lake is uniquely high among the Finger Lakes. Being oligotrophic, Skaneateles Lake has very low nutrient concentrations and hence very little algal or macrophyte growth. A 2001 study of the Finger Lakes determined the mean nitrogen to phosphorus (N:P) ratio in Skaneateles lake to be 241:1 (Callinan, 2001). This ratio is the highest of the Finger Lakes and indicates that the rate limiting nutrient in plant growth is phosphorus (Guildford & Hecky, 2000). This same study determined that Skaneateles Lake had the lowest total phosphorous concentrations of all the Finger Lakes and one of the lowest chlorophyll a concentration (Callinan, 2001). All these factors together contribute to the unusually high-water quality and clarity of the lake.

Since the Clean Water Act of 1972, found in the Code of Federal Regulations Title 40, regulated waste discharge from point sources, the most prevalent source of pollution in most watersheds is nonpoint source in the form of runoff. As runoff flows over land it picks up sediment and nutrients that will eventually end up in a tributary to the lake. However, the effects of water from tributaries on water quality can vary depending on the land type it comes from and amount of precipitation. Understanding how land use type and rainfall influence the quality of runoff entering Skaneateles Lake can provide information to improve water quality management.

The City of Syracuse began the SLWAP in 1994 as a means of controlling agricultural nutrient contributions to the lake (NYSSWCC, n.d.). It is a fully voluntary program in which local farmers work with the Onondaga County Soil and Water
Conservation District (OCSWCD) to implement practices intended to reduce erosion on the farms and nutrient loading to nearby streams. These practices are collectively called Best Management Practices (BMPs), and the individualized plans created are called Whole Farm Plans (OCSWCD, n.d.).

**Previous Work**

Previous ESF student research of Skaneateles Lake and its watershed has been motivated by the ideas mentioned above: the lake is a critical water resource to the City of Syracuse; agricultural activity contributes significantly to the nonpoint source pollution of the lake and its tributaries; and large-scale implementation of BMPs should be used to prevent farm sources of nitrogen (N) and phosphorous (P) from entering the surface waters.

In 2008, Christian Schmidt submitted a master’s thesis evaluating the effectiveness of BMPs on farms in the Skaneateles watershed. Samples of soil solutions were taken from on-site lysimeters, tile drains, and streams, and analyzed for common N and P nutrient species. The study concluded there was a high risk of nitrate N leaching to groundwater under several cover types and management practices. It was noted BMP effectiveness could be impacted by factors such as seasonal climate, soil drainage and composition, and land cover.

In 2009, Soni Pradhanang, a SUNY ESF Ph.D. candidate, completed her thesis titled “Monitoring and Modeling of Water Quality in Streams of Skaneateles Lake Watershed, NY”. The major objective of the thesis was to develop and apply a numerical model for assessing the impact of land management practices on water quality. The
AnnAGNPS model was used to predict annual water yields and sediment loads for Skaneateles Lake sub-watersheds under different weather and land use scenarios. The model had mixed performance in forested (as opposed to agricultural) watersheds, but still effectively demonstrated negative impacts on surface water quality from agricultural land under wetter climate scenarios. Pradhanang also identified Skaneateles Lake as in need of constant monitoring to ensure that the water quality continues to meet the criteria required for continued operation under the New York State Department of Health filtration avoidance waiver.

Rhea Joseph, an undergraduate in the SUNY-ESF chemistry department, completed her senior research project with Dr. John Hassett in 2016. The report attempted to find the cause of the foam forming on the surface of Skaneateles and other Finger Lakes in recent years (Joseph, 2016). Incorrect methods were used in the analysis, which resulted in the data not being definitive. Dr. Hassett is continuing this project with another undergraduate student. In the future, SUNY-ESF chemistry may be able to narrow down the cause of the foam on the Finger Lakes. That information could make it possible to devise effective preventative methods.

**Methods**

**Tributary Selection**

Tributaries were selected based on their distribution of land use types with a goal of selecting tributaries with primarily agricultural and forested land uses. Selected tributaries also needed to meet criteria which ensured access was safe and favorable for testing. A tributary was considered safely accessible if samples could be easily obtained
in a wet weather event when the water levels were high. The most common safety problem involved steep banks which would make it difficult to escape quickly raising waters. To ensure that a tributary was favorable for testing, it needed to have flow under dry weather conditions, characterized by flow after 4 days without rain, and a defined bed. In addition to meeting these criteria, it was important that the tributaries selected be distributed around the lake to avoid statistical bias. A dozen tributaries were examined to identify the four final tributaries. Of the selected tributaries, three are on the east side of the lake and one is on the west. From north to south, the east side tributaries are the Skaneateles Sailing Club, High Vista Nature Preserve, and Randall Gulf. The final tributary is Bear Swamp Creek, in the southwestern corner of the watershed. A map showing an image and the location of each sampling site is shown in Figure 1.
Figure 1: Map of Skaneateles Lake delineated subwatersheds with sampling locations identified.
Skaneateles Sailing Club

This watershed is primarily agricultural. At the sampling location, the tributary has a defined channel that runs through a narrow concrete canal. During dry weather periods, the tributary dries up or becomes stagnant in the channel. Some of this water infiltrates into the soil and makes it into the lake which is only a few meters away. During both dry and wet weather events, water samples were taken from the center of the channel. Flow rate measurements for both events were also taken from this location.

Randall Gulf

Randall Gulf is a larger tributary that passes under Route 41 and Spafford Landing Road before entering the lake. Several smaller tributaries contribute to it, including one that runs through the Hinchcliff Family Preserve. This tributary has a similar distribution of forested land and agricultural land. The sampling location is upstream of the intersection between it and Spafford Landing Road. There is a section of the stream that naturally has a well-defined channel and consistent cross-sectional area.

High Vista Nature Preserve

This tributary passes through the High Vista Nature Preserve. The tributary runs through a culvert pipe beneath Vincent Hill Road. The sampling location is the area alongside Vincent Hill Road. Water samples for both wet weather and dry weather conditions can be collected before the culvert. Dry weather flow can also be assessed just upstream of the culvert. The land use types are approximately evenly split between forested and agricultural. The stream bed is rocky and these small rocks can be used to make a well-defined channel. In wet weather conditions, the water level is too high to use this method. Instead, the channel created by the culvert has been used.
Bear Swamp Creek

Bear Swamp Creek is one of the largest tributaries to Skaneateles Lake, and the largest tributary in this study. The sampling location is adjacent to fire lane 14c, which is based at the mouth of the tributary. Most of this watershed land use type is forested. This portion of the tributary has a flat bed and defined channel where flow rate measurements were taken. Water samples were taken from the same locations as the flow rate measurements for their respective events.

Table 1: Spatial and land use information for each of the sub-watersheds. Calculated via ArcMap, using Digital Elevation Model (DEM) data from the US Geological Survey National Map and land cover data from the Multi-Resolution Land Characteristics Consortium (MRLC).

<table>
<thead>
<tr>
<th>Tributary watershed</th>
<th>Total area (km²)</th>
<th>% Agricultural land cover</th>
<th>% Forested land cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sailing Club</td>
<td>1.42</td>
<td>77.7</td>
<td>12.1</td>
</tr>
<tr>
<td>Randall Gulf</td>
<td>2.48</td>
<td>40.4</td>
<td>44.7</td>
</tr>
<tr>
<td>High Vista</td>
<td>0.766</td>
<td>47.9</td>
<td>42.8</td>
</tr>
<tr>
<td>Bear Swamp Creek</td>
<td>23.4</td>
<td>22.1</td>
<td>61.4</td>
</tr>
</tbody>
</table>

Standard Sampling Procedures

Water samples were collected near the center of the tributaries by dipping sample bottles into the stream. Effort was taken to ensure no sediment was stirred up during sampling. The bottles were filled to about one inch from the cap. During wet weather
events caution was taken as to the velocity of the water and samples were taken as close to the center of the tributary as deemed safe.

Velocity measurements were taken by measuring out a set distance in the tributary and releasing a marshmallow at one end as a velocity probe. A stopwatch was used to record the time it took for the marshmallow to travel the distance. For some tributaries, the dry weather and wet weather velocity measurements were taken differently. This was either due to the course traveled by the tributary or to ensure safety. The tributaries for which this was done are indicated in the Tributary Selection section, below.

The method used for cross sectional area estimates was dependent on the geometry of the stream bed. If the bed was relatively flat and a defined channel existed, then the height of the water and width of the stream were measured. If no defined bed or channel existed, then multiple height measurements were taken across the channel and used with the channel width to calculate a cross sectional area.

**Laboratory Analysis**

Due to the absence of capabilities for conducting routine analytical procedures at SUNY ESF, chemical analyses were completed by a contract laboratory. TSS analyses were completed at SUNY ESF following the Standard Methods SM 2540 D. Wet weather samples collected in 2017 were tested for volatile solids following the protocol outlined in Standard Methods SM 2540 E. Volatile solids analyses were also completed for two soil samples following the same procedure.

Analyses for OPO$_4$, NO$_3$-N, and NH$_3$-N were conducted by Pace Analytical in Melville New York during the 2016 sampling period. The methods utilized were SM
4500-P-E, EPA 353.2, and EPA 350.1 for OPO$_4$,$_N$, NO$_3$-N, and NH$_3$-N analyses respectively. Samples collected in 2017 were tested for OPO$_4$, NO$_3$-N, and NO$_2$ by Pace Analytical using the same methods. Additionally, one sediment sample was analyzed for total phosphorous following method SM 22 4500-P E.

**Results**

The following tables contain results from the chemical analysis, solids analyses, and flow observations for samples taken in both 2016 and 2017. Due to the unusually dry weather in the Central New York region during the summer of 2016, only one complete set of wet weather data was collected. However, supplemental TSS data were collected and are shown in Appendix C. Results from total phosphorous and volatile solids analyses on sediment basin soil samples collected in 2017 are also presented.
Table 2: 2016 Dry weather sampling field data and laboratory test results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Primary Land Use Type</th>
<th>Cross sectional area (m²)</th>
<th>Velocity (m/s)</th>
<th>Flow rate (m³/s)</th>
<th>TSS (mg/L)</th>
<th>Orthophosphates (mg/L)</th>
<th>Nitrate Nitrogen (mg/L)</th>
<th>Ammonia Nitrogen (mg/L)</th>
<th>Mass loading Rate, sediments (kg/hr)</th>
<th>Mass loading Rate, Nitrates (kg/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skaneateles Sailing Club</td>
<td>Agricultural</td>
<td>0.074</td>
<td>N/A</td>
<td>N/A</td>
<td>8</td>
<td>ND</td>
<td>ND</td>
<td>0.19</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Randall Gulf</td>
<td>Agricultural</td>
<td>0.018</td>
<td>0.051</td>
<td>0.001</td>
<td>48.4</td>
<td>ND</td>
<td>1.47</td>
<td>ND</td>
<td>1.74</td>
<td>0.005</td>
</tr>
<tr>
<td>High Vista Nature Preserve</td>
<td>Forested</td>
<td>0.035</td>
<td>0.333</td>
<td>0.012</td>
<td>8.6</td>
<td>ND</td>
<td>2.37</td>
<td>ND</td>
<td>3.72</td>
<td>0.102</td>
</tr>
<tr>
<td>Bear Swamp Creek</td>
<td>Forested</td>
<td>0.310</td>
<td>0.203</td>
<td>0.063</td>
<td>1.2</td>
<td>ND</td>
<td>0.31</td>
<td>0.21</td>
<td>2.72</td>
<td>0.070</td>
</tr>
</tbody>
</table>

Samples collected: August 4, 2016
TSS analysis performed: August 10, 2016
Nutrient analysis performed: August 6 - August 19, 2016
<table>
<thead>
<tr>
<th>Sample</th>
<th>Primary Land Use Type</th>
<th>Cross sectional area (m²)</th>
<th>Velocity (m/s)</th>
<th>Flow rate (m³/s)</th>
<th>TSS (mg/L)</th>
<th>Orthophosphates (mg/L)</th>
<th>Nitrate Nitrogen (mg/L)</th>
<th>Ammonia Nitrogen (mg/L)</th>
<th>Mass Loading Rate, sediments (kg/hr)</th>
<th>Mass Loading Rate, Nitrates (kg/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skaneateles Sailing Club</td>
<td>Agricultural</td>
<td>0.071</td>
<td>0.077</td>
<td>0.005</td>
<td>8</td>
<td>ND</td>
<td>2.36</td>
<td>0.23</td>
<td>1.44</td>
<td>0.04</td>
</tr>
<tr>
<td>Randall Gulf</td>
<td>Agricultural</td>
<td>0.106</td>
<td>0.415</td>
<td>0.044</td>
<td>102.2</td>
<td>ND</td>
<td>1.37</td>
<td>0.19</td>
<td>161.89</td>
<td>0.22</td>
</tr>
<tr>
<td>High Vista Nature Preserve</td>
<td>Forested</td>
<td>0.075</td>
<td>0.396</td>
<td>0.030</td>
<td>94</td>
<td>ND</td>
<td>1.47</td>
<td>0.17</td>
<td>101.52</td>
<td>0.16</td>
</tr>
<tr>
<td>Bear Swamp Creek</td>
<td>Forested</td>
<td>0.537</td>
<td>0.668</td>
<td>0.359</td>
<td>39.6</td>
<td>ND</td>
<td>0.84</td>
<td>0.2</td>
<td>511.78</td>
<td>1.09</td>
</tr>
</tbody>
</table>

Samples collected: August 21, 2016

TSS analysis performed: August 22, 2016

Nutrient analysis performed: August 23 - September 6, 2016
<table>
<thead>
<tr>
<th>Sample</th>
<th>Primary Land Use Type</th>
<th>Cross sectional area (m²)</th>
<th>Velocity (m/s)</th>
<th>Flow rate (m³/s)</th>
<th>TSS (mg/L)</th>
<th>Volatile Solids (mg/L)</th>
<th>Orthophosphates (mg/L)</th>
<th>Nitrate Nitrogen (mg/L)</th>
<th>Nitrite (mg/L)</th>
<th>Mass Loading Rate, sediments (kg/hr)</th>
<th>Mass Loading Rate, Nitrates (kg/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skaneateles Sailing Club</td>
<td>Agricultural</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>98.8</td>
<td>N/A</td>
<td>ND</td>
<td>4.3</td>
<td>ND</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Randall Gulf</td>
<td>Agricultural</td>
<td>0.987</td>
<td>1.140</td>
<td>1.125</td>
<td>97.5</td>
<td>N/A</td>
<td>ND</td>
<td>0.24</td>
<td>ND</td>
<td>3960.0</td>
<td>0.972</td>
</tr>
<tr>
<td>High Vista Nature Preserve</td>
<td>Forested</td>
<td>0.979</td>
<td>0.449</td>
<td>0.439</td>
<td>97.8</td>
<td>N/A</td>
<td>ND</td>
<td>2.5</td>
<td>ND</td>
<td>1548.0</td>
<td>3.951</td>
</tr>
<tr>
<td>Bear Swamp Creek</td>
<td>Forested</td>
<td>1.001</td>
<td>0.510</td>
<td>0.511</td>
<td>98.9</td>
<td>N/A</td>
<td>ND</td>
<td>0.32</td>
<td>ND</td>
<td>1818.0</td>
<td>0.588672</td>
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</table>

Samples collected: July 7, 2017
TSS analysis performed: July 10, 2017
Nutrient analysis performed: July 8 - July 19, 2017
<table>
<thead>
<tr>
<th>Sample</th>
<th>Primary Land Use Type</th>
<th>Cross sectional area (m²)</th>
<th>Velocity (m/s)</th>
<th>Flow rate (m³/s)</th>
<th>TSS (mg/L)</th>
<th>Volatile Solids (mg/L)</th>
<th>Orthophosphates (mg/L)</th>
<th>Nitrate Nitrogen (mg/L)</th>
<th>Nitrite (mg/L)</th>
<th>Mass Loading Rate, sediments (kg/hr)</th>
<th>Mass Loading Rate, Nitrates (kg/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skaneateles Sailing Club</td>
<td>Agricultural</td>
<td>1.417</td>
<td>1.151</td>
<td>1.630</td>
<td>252.8</td>
<td>37.6</td>
<td>ND</td>
<td>3.3</td>
<td>0.096</td>
<td>14,839.2</td>
<td>19.3644</td>
</tr>
<tr>
<td>Randall Gulf</td>
<td>Agricultural</td>
<td>0.900</td>
<td>1.647</td>
<td>1.482</td>
<td>101.6</td>
<td>13.6</td>
<td>ND</td>
<td>0.18</td>
<td>ND</td>
<td>5,421.6</td>
<td>0.960336</td>
</tr>
<tr>
<td>High Vista Nature Preserve</td>
<td>Forested</td>
<td>0.883</td>
<td>1.221</td>
<td>1.078</td>
<td>77.6</td>
<td>12.8</td>
<td>ND</td>
<td>0.58</td>
<td>ND</td>
<td>3,013.2</td>
<td>2.250864</td>
</tr>
<tr>
<td>Bear Swamp Creek</td>
<td>Forested</td>
<td>2.218</td>
<td>1.565</td>
<td>3.471</td>
<td>132.8</td>
<td>18.4</td>
<td>ND</td>
<td>0.47</td>
<td>ND</td>
<td>16,596.0</td>
<td>5.872932</td>
</tr>
</tbody>
</table>

Samples collected: July 13, 2017  
TSS analysis performed: July 17, 2017  
Nutrient analysis performed: July 17 - August 1, 2017
Table 6: 2017 Wet weather sampling II field data and laboratory test results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Primary Land Use Type</th>
<th>Cross sectional area ((m^2))</th>
<th>Velocity ((m/s))</th>
<th>Flow rate (m^3/s)</th>
<th>TSS ((mg/L))</th>
<th>Volatile Solids ((mg/L))</th>
<th>Orthophosphates ((mg/L))</th>
<th>Nitrate Nitrogen ((mg/L))</th>
<th>Nitrite ((mg/L))</th>
<th>Mass Loading Rate, sediments ((kg/hr))</th>
<th>Mass Loading Rate, Nitrates ((kg/hr))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skaneateles Sailing Club</td>
<td>Agricultural</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>1</td>
<td>N/A</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>N/A</td>
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</tr>
<tr>
<td>Randall Gulf</td>
<td>Agricultural</td>
<td>1.452</td>
<td>0.562</td>
<td>0.816</td>
<td>36</td>
<td>8.3</td>
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<td>ND</td>
<td>ND</td>
<td>1,057.68</td>
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<td>High Vista Nature Preserve</td>
<td>Forested</td>
<td>0.544</td>
<td>0.367</td>
<td>0.200</td>
<td>29.5</td>
<td>5.8</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>211.97</td>
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<td>Bear Swamp Creek</td>
<td>Forested</td>
<td>0.318</td>
<td>0.326</td>
<td>0.104</td>
<td>12.8</td>
<td>2.6</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>47.77</td>
<td>N/A</td>
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Samples collected: August 22, 2017  
TSS analysis performed: August 25, 2017  
Nutrient analysis performed: August 24 - August 31, 2017

Table 7: Sedimentation basin soil samples test results

<table>
<thead>
<tr>
<th>Sedimentation Basin Soil Samples – 2017</th>
<th>Percent Organic by Weight (%)</th>
<th>Total Phosphorus ((mg/kg))</th>
</tr>
</thead>
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<td></td>
<td>4.66</td>
<td>843</td>
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Discussion

The summer of 2016 had a very low precipitation frequency, which made gathering wet weather samples very difficult. The optimal wet weather testing conditions would be at the end of or directly after a storm event that had lasted at least 2 hours with a half of an inch of rain per hour. The ideal storm would also have a defined front that would hit the entire lake. Finally, the ideal storm also needed to occur during the day as samples could not be collected at night for safety reasons. Due to the dry summer, this type of rain event did not occur. The storm that was sampled was the closest approximation to that ideal storm event that occurred this summer. Weather data collected from Syracuse Hancock International Airport indicates that there was 0.61 inches of precipitation on the day of sampling. Rain was first recorded at 9:54 am and last recorded at 2:54 pm. Medium to heavy rainfall was recorded between 1:06 pm and 1:54 pm. It is important to note that the Syracuse Hancock International Airport is about 30 miles from Skaneateles Lake so the weather conditions may not be consistent in the two areas. However, the weather station at the airport was the closest and most reliable system that could be accessed.

The summer of 2017 was equally unique in that it was an abnormally wet summer. The constant rainfall made collecting both dry and wet weather samples difficult. Dry weather samples were not collected until there was a significant period of no precipitation. A sample could be considered as dry weather if it was taken after four days of no rain. However, the constant heavy rain during the spring and early summer saturated the soil significantly so that rainfall from four days earlier was still influencing the streams. This can be seen in the 2017 dry weather sample as it exhibits TSS and chemical concentrations similar to wet weather events (Table 4). The first wet weather sampling event was closest to our ideal storm criteria with 0.59 in of precipitation between 1:54 am and 3:54 pm, with heavy precipitation recorded between 1:24 pm and 1:46 pm.
In the middle of July, a HOBO data logger was installed upstream of the sampling location on Bear Swamp Creek so the stream stage (through water pressure measurements) could be continually recorded. Even though it was installed roughly a week after a large, sustained rainfall event, the initial stage measurements were the highest recorded for the full period of measurement (see Appendix D). These data help illustrate the lasting effects of unusual rain events on stream conditions, and the difficulty of capturing a truly “dry” or “wet” stream sample.

Wet weather samples were also strongly influenced by the frequency of storm events, as samples needed to be collected during isolated events to characterize the influence of a single storm. If a wet weather sample was collected during an event the day after another large storm, the stream could exhibit impacts from both events. This limited sampling opportunities during the early summer. Late summer was much drier than early summer, so the streams were less influenced by the final wet weather event due to the unsaturated soils allowing infiltration. This caused the streams to exhibit characteristics more similar to a dry weather event (Table 6).

It was expected that the nutrient concentrations would increase during wet weather events. This was because runoff, particularly from agricultural properties, was thought to contribute to the tested nutrient levels. As such, it was also expected that primarily agricultural watersheds would exhibit higher nutrient concentrations than forested watersheds.

Overall the nutrient analysis results varied from our expectations. OPO$_4$ levels were too low to detect in both wet and dry weather conditions at all sampling locations. The lack of detection of OPO$_4$ could be influenced by the analytical method used. For instance, the method used for our samples only measured reactive phosphorous dissolved in the water. Any phosphorous adsorbed to inorganic sediments or contained in organic compounds would not have been detected. The sediment samples taken from a sedimentation basin downstream from agricultural land yielded total phosphorus concentrations of 843.
mg/kg. This indicates that the water may not have much dissolved phosphorous; however, the sediment being transported by it has significant adsorbed phosphorus. Once deposited, this sediment can become a long-term source of phosphorous to the water column in the lake (North, et al., 2015).

Meanwhile NO$_3$-N concentrations had little correlation with dry and wet weather events. In 2016 wet weather NO$_3$-N concentrations increased from dry weather in both the primarily agricultural and forested watershed while they remained constant or decreased in the evenly split watersheds. In 2017 there was no correlation for wet and dry weather events. These differences in results could be heavily influenced by the intense rainfall experienced during this summer. The variation in wet and dry weather NO$_3$-N concentrations over both years could be a result of the time of year the samples were collected and/or the amount of time between fertilizer application and sampling.

In general, the primarily agricultural watersheds had higher NO$_3$-N concentrations than the forested watershed. The forested watershed had consistently lower concentrations for most sampling events as compared to the watersheds with more intense agriculture. This was to be expected since forested watersheds have significantly less land area where fertilizer is applied.

The influence of NO$_3$-N on the lake is better represented by the mass loading rate of kilograms of NO$_3$-N entering per hour than the concentration. A tributary may have high concentrations of nitrates but may contribute less to the Lake than a stream with a lower concentration and higher flow rate. There are many cases in this study where a stream had a greater NO$_3$-N concentration, but a lower mass loading rate than another tributary. There is no correlation in NO$_3$-N loading between agricultural and forested watersheds. There are several cases where a forested watershed with a lower NO$_3$-N concentration contributes more than an agricultural watershed with a higher NO$_3$-N concentration due to a higher flow rate. Since the
flow rate of water is the primary driver of NO$_3$-N loading, it is not surprising that wet weather events tend to have higher loading rates than dry weather events recorded in the same year.

NH$_3$-N concentrations were slightly higher in most watersheds during wet weather events than dry weather events. However, it decreased by 0.01 mg/L in Bear Swamp Creek. NO$_2$-N was only detected once at the Skaneateles Sailing club during a wet weather event.

![Suspended sediments in Randall Gulf during wet weather flow](image)

TSS concentrations were expected to increase during wet weather events and be higher in the agricultural watershed than the forested. In most watersheds, the TSS increased during wet weather events, sometimes more than doubling from the dry weather observations. During 2017 the wet weather samples were also tested for volatile solids to determine the percentage of organic matter present. These samples yielded 13% - 23% organic matter. This influx of organic matter could contribute to the oxygen demand of the lake and decrease the total dissolved oxygen.
Since the main concern when considering the turbidity of the lake is the quantity of sediment entering the lake, the mass loading rate of sediments is of greater concern than their concentration in the tributaries. The mass loading rates of sediments into the lake indicated that some watersheds with a lower TSS were contributing more sediment to the lake over time than those with higher TSS. Generally, across all tributaries the mass loading rates were higher for wet weather events than dry weather.

There was no correlation between sediment loading and land use type during either wet or dry weather events. During the first wet weather event of 2017 the two highest loading rates came from the Skaneateles Sailing club, an agricultural watershed and Bear Swamp Creek, a forested watershed. These loading rates were 14,839 kg/hr and 16,596 kg/hr respectively, which contrasts greatly from the lowest dry weather measurements in these streams of 0 kg/hr and 2.72 kg/hr.

These results indicate that most of the annual sediment load to Skaneateles Lake may occur in only a few large rainfall events, as is common in many watersheds. This rapid influx of sediments into the lake can greatly increase the turbidity in the short term and pose a risk to meeting the turbidity requirements for the filtration avoidance waiver. Since the majority of large rainfall events occur in the spring when agricultural fields are being tilled and fertilizers applied,
it is expected that the lake could experience large influxes of nutrients adsorbed to the sediments. These nutrients could then provide fuel for harmful algal blooms, which can further decrease water quality and pose a risk to the maintaining the filtration avoidance waiver.

**Agricultural Best Management Practices (BMPs)**

In this discussion of the maintenance and improvement of Skaneateles Lake water quality, it is crucial to look closely at the details of the Skaneateles Lake Watershed Agricultural Program (SLWAP), which currently works to reduce agricultural contributions of nutrients and sediment to lake tributaries (OCSWCD). Its promotion of agricultural Best Management Practices (BMPs) represents an excellent way to expand and improve an existing program that operates on a flexible, case-by-case (farm-by-farm) basis. Overviews of relevant BMPs, the SLWAP, and the current state of BMPs in the watershed are provided here to add context to our recommendations that follow.

The USDA Agricultural Research Service provides a useful distinction between BMPs that control nutrient loss at the “source”, meaning cropland where the nutrients are applied or produced, and BMPs that minimize nutrient transport from the source to surface water. Source BMPs focus on avoiding unnecessary buildup of nutrients on agricultural fields through efficient management, application, and storage of fertilizers and manure (Sharpley et al., 2006). Many of these practices require planning, but no additional equipment or infrastructure. For example, timing nutrient applications to fields to avoid major runoff events like spring snowmelt and major storms is a simple and cheap source BMP (NRCS, 2001). It is also easy enough to ensure that nutrients are applied with the appropriate method (broadcast application, plowing, or
subsurface placement) for a given field, so that nutrients are not at unnecessary risk of being eroded or leached from the field (Sharpley et al., 2006).

Some source BMPs may share a specific management goal for an agricultural process but use different approaches for different farm setups. The term “conservation tillage” encompasses a wide range of BMPs focused on minimizing soil surface disturbance. The exact methods vary with the field and crop(s) being grown, but it typically includes keeping the previous season’s crop residue (corn stalks, wheat stubble, etc.) on the fields during and after planting, and then tilling and planting without a full turnover of the soil (Sharpley et al., 2006). The USDA has pointed out that using extreme “no-till” methods can reduce total runoff and particulate nutrient loading but may exacerbate dissolved N and P concentrations in the remaining runoff (NRCS, 2001).

Other source BMPs require additional treatments or storage of nutrients but allow farms to further minimize the potential loss (and waste) of fertilizers and manure. Manure can be treated, physically as well as chemically, in ways that reduce the solubility of P and N compounds (Sharpley et al., 2006). In the proper buildings, fertilizers and manure can be stored securely between application periods to avoid loss and slow unwanted chemical transformations (NYSSWCC, 2014).

Transport BMPs generally involve more intensive approaches, since the objective involves intentional design or re-design of agricultural land for something separate from maximizing crop yields. Even so, most practices described here are still straightforward and inexpensive. Cover crops can be planted to, among other things, reduce rain impacts on soil and
improve infiltration rates (Sharpley et al., 2006). Strip cropping and contour farming involve planting alternating bands of two or more crops perpendicular to any major slopes, reducing runoff velocities and preventing erosion (Sharpley et al., 2006). Strips of buffer vegetation along the edges of planted fields, especially where the fields come close to streams, can reduce concentrations of nutrients and total suspended solids in runoff (NYSSWCC, 2014). Existing studies suggest the effectiveness of riparian buffer strips can vary widely; at least some of this variation seems to come from the width of the strip and the type(s) of vegetation planted (Sharpley et al., 2006).

![Figure 4: Buffer strip vegetation maintained at a field-stream boundary in the Skaneateles watershed.](image)

![Figure 5: Large-scale strip cropping along a hillslope in the Skaneateles watershed. The strips are planted perpendicular to the hill gradient.](image)
Sedimentation basins also deserve mention here as a crucial transport BMP but are likely to require the coordinated work of multiple landowners (possibly with local municipalities and conservation districts as well) to be enacted on an effective scale. Sedimentation basins are intentionally deepened, flattened “ponds” that can be built downhill from agricultural fields to collect sediment-heavy runoff (NRCS, 2001). Once the basins have filled, nutrient-rich sediment can be excavated and re-applied to fields. Some sediment might have limited capacity for sorption and biogeochemical transformation of the nutrients, however, and there is little evidence to suggest that poorly maintained basins (i.e., basins kept full for extended periods) are effective at controlling long-term losses of agricultural N and P (Sharpley et al., 2006).

Figure 6: Soil from a filled roadside sedimentation basin (left) was excavated and delivered to a field elsewhere in the watershed (right).

**Drainage Ditch Management**

Drainage ditches are ubiquitous in a landscape like the Skaneateles Lake watershed – nearly all farms use ditches for draining and irrigating their fields (Needelman et al., 2007). Despite their importance in carrying nutrients from farms to regional surface water, they are
mentioned infrequently in literature on BMPs. It is hoped the attention given to them here will highlight the possibilities for improved drainage ditch management, and improved water quality as a result.

Agricultural drainage ditches are an ancient engineering technique for rapidly removing runoff from fields after storm events, keeping water levels low enough to prevent crop damage (Needelman et al., 2007). The channels themselves can vary in size and features, depending on the goals of the drainage and the size of the area being drained. Ditches draining one or two smaller fields tend to be small, shallow, and straight; other ditches meant to drain entire hillsides are wider, fully channelized, and are sometimes designed with additional flow-control structures (NRCS, 2001; NYSSWCC, 2014).

Regardless of the size, drainage ditches often carry high concentrations of N and P coming from a variety of agricultural activity. Most of the N ending up in drainage ditches is traced directly from surface runoff, while most P tends to come from subsurface flows (Needelman et al., 2007). Surface P sources include point sources (e.g., poultry litter from a chicken farm) and erosion of previously deposited sediment with high P concentrations (Sharpley et al., 2006). Ditches are also a major conduit for sediment, carrying with it adsorbed nutrients and other contaminants. Ditch sediment can come from field runoff or even erosion of the ditch banks, if not properly maintained (Needelman et al., 2007). Sediments deposited in ditches have been observed to act as temporary storage for nutrients and sediment, but repeated erosion and re-suspension is common (Sharpley et al., 2006).
Many road drainage ditches are intentionally kept unvegetated, with the idea that it prevents suspended sediment from getting caught and accumulating (Needelman et al., 2007). Unfortunately, unvegetated drainage ditches have the tendency to channelize and erode more quickly than surrounding areas, providing particulate nutrients and sediment with a fast transport route from fields to streams even in low-relief landscapes (NRCS, 2001). Buffer strips along the banks of ditches can slow runoff and reduce lateral erosion. Flow-control structures are available for larger ditches; weirs and natural benches in a ditch can interrupt flow and promote pooling, which increases sedimentation (Needelman et al., 2007). When dredging a ditch is necessary to remove accumulated sediment, the USDA recommends attempting it when nutrient loads to the ditch are expected to be low (Sharpley et al., 2006).

**SLWAP and BMPs in Skaneateles**

The SLWAP was first established as the pilot project for the statewide Agricultural Environmental Management (AEM) program under the state Department of Agriculture and Markets, which has parallel goals to those mentioned in the introduction: to “[help]
farmers...meet business objectives while protecting and conserving the State’s natural resources” (NYSSWCC, n.d.). AEM provides non-competitive funding to all county soil and water conservation districts interested in setting up their own 5-year plans. (Funding opportunities are described in greater detail in this report’s conclusions.) Once implemented, these plans can be updated and renewed as necessary to maintain and expand funding for ongoing programs.

The SLWAP is centered on a process called a Whole Farm Plan, where farm owners and the Onondaga County Soil and Water Conservation District (OCSWCD, n.d) work together to install a series of BMPs on a farm (OCSWCD, n.d.). The BMPs chosen attempt to balance the needs of the farm with the potential environmental risks to the watershed. The guidelines for implementing specific BMPs are taken from the standards suggested by the USDA Natural Resources Conservation Service (NRCS).

Farm participation is completely voluntary and can stop at any desired level of the process. The specific steps of a Whole Farm Plan are outlined in their five-tier process:

- **Tier I – Questionnaire:** Determines what potential risks to water exist on the farm. Tier I serves as program enrollment.

- **Tier II – Worksheets:** Verifies that a water quality-related concern exists on the farm; SLWAP team and farmer work together to fill out worksheets – also, this step points out the good things that are already being done.

- **Tier III – Plan Development:** Farmer and SLWAP team develop a comprehensive plan.
- **Tier IV – Implement the Plan:** Install, operate and maintain Best Management Practices.

- **Tier V - Plan Revision:** Evaluate the Whole Farm Plan; revise and/or repair if necessary.

As of 2004, the SLWAP had 54 farms enrolled in the program, with 44 Whole Farm Plans already completed (OCSWCD, n.d.).

Many of the Skaneateles area farms currently using BMPs are easy enough to recognize from the road. These successful implementations do not necessarily mean the Whole Farm Plans have had their desired effects on every farm; but they do give hopeful looks at what more farms could be doing if the SLWAP was expanded. For the sake of privacy, we will not give the names and locations of farms that seem to be doing well or poorly -- except for Twin Birch Farms, which is an exceptional example of a variety of BMPs on a mixed dairy and vegetable crop farm. Many of the figures of BMPs included here came from Twin Birch.

Most of the good practices observed were simple transport BMPs: cover crops, strip cropping, and vegetated buffer strips for rivers and drainage ditches. These observations may be biased, since transport BMPs are easier to spot from a distance. Most cover crops were varieties of clover, although rye was observed as well. Strip cropping is almost always organized so the strips ran perpendicular to the overall slope of the field; in these cases, the strips were essentially examples of contour farming as well. Since the Skaneateles watershed is relatively small and narrow for the size of the lake, and many of the watershed’s farms sit on significant slopes, strip
cropping is especially effective in restricting soil losses from some of the larger and steeper fields.

Buffer vegetation was observed frequently too, although it varied much more in the forms it took. It was found in many locations along the path from farm to stream, from irrigation ditches between farm fields to sharp field-stream boundaries. Some riparian vegetation zones were as narrow as a few feet, and others may have been up to thirty or forty feet wide. There was a great variety of plant types represented in the buffers, woody as well as herbaceous vegetation, although buffers planted along smaller ditches were mostly grasses.

Much less common were BMPs that usually require significant investment to build and maintain. Twin Birch Farms has a large, concrete-bottom manure storage structure on their property. It has no permanent roof and could still be susceptible to precipitation and runoff, but the concrete lining removes the chance for direct groundwater infiltration. A series of roadside sedimentation basins were seen along a fire lane on the western side of the lake. They had been dug in a connected step-pool pattern on either side of a steep, forested part of the road to catch sediment from agricultural fields just uphill. When they have filled, the accumulated sediment is excavated and delivered to farms elsewhere in the watershed.

The poor management practices observed were simply the absence of the BMPs mentioned above. Many farm fields are placed on slopes but had no obvious methods in place for limiting downhill runoff or controlling erosion at the field edges. Some fields that bordered streams were tilled to the edge of the bank, with little or no riparian buffer. In some cases, the
stream-side edges of a field might be given buffer strips, but the drainage ditches that ran between the fields were channelized and unvegetated.

The negative effects of this poor management could already be seen at many locations. After storm events, banks of unvegetated streams and drainage ditches appeared newly eroded. Occasionally the washed-out sediment from the fields visibly accumulated in lower-lying areas.

Figure 8: A corn field in the Skaneateles watershed, immediately after (left) and several weeks after (right) a major storm. The crops growing in the washed-out areas exhibited stunted growth, likely due to nutrient deficiencies.

Conclusion

This study is not nearly comprehensive enough to draw definitive conclusions on the relationships between water quality, land use type, and weather events. All nutrient levels either remained undetectable or varied with no pattern across different land use types and over wet and dry weather conditions. TSS measurements however increased during wet weather events in all tributaries except one with a majority agriculture land use. Loading rates of sediments and nitrates also saw significant increases during wet weather flow. These increases in loading along

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with the high phosphorous content of agriculturally derived sediments raises concerns for significant turbidity increases and algal blooms.

Due to funding constraints the number of samples collected was very small. Therefore, the conclusions of this report may not accurately represent the relationships being examined. The small difference in area between majority land use types in the sub watersheds may also reduce the reliability of conclusions. Although no explicit conclusions can be drawn about the relationships between weather, land use type, and water quality, our results suggest that wet weather events have a greater influence on the water quality of Skaneateles Lake than dry weather.

**Future Funding**

The SLWAP has quite a few options to pursue for funding the future implementation of BMPs. An exhaustive list or evaluation of these opportunities is outside the scope of this report, but it is recommended the program assesses these options to find some lines of funding that fall in line with the mission of SLWAP. Aside from organizing county-wide initiatives like SLWAP, the NYS Department of Agriculture and Markets organizes an “Agricultural Nonpoint Source Abatement & Control Grant Program” (NYSSWCC, n.d.). County soil and water conservation districts need to apply for competitive grants on behalf of their farmers, who then work together to coordinate a long-term conservation project. The project can encompass BMPs for flood protection, erosion control, reducing nutrient loss, or other similar problems. The grant program awarded a total of $15.3 million in 2016.

The New York DEC maintains its Environmental Protection Fund for a wide variety of capital projects, among which is farmland conservation and the Agricultural Non-Point Source
Pollution Abatement Program (DEC, 2013). This program operates in a similar way to the above grant from Agriculture and Markets: soil and water conservation districts apply for competitive grants, which can then be put towards a soil or nutrient conservation project. Both programs specifically mention BMPs, which is a good indication that they have in mind something similar to what the SLWAP currently does. The Environmental Protection Fund has given $120 million to 53 soil and water conservation districts since it began in 1993.

Naturally, the USDA has several programs in place to help farmers finance structural and environmental improvements to their land. The USDA Farm Service Agency offers a variety of grants and loans to farmers for improvements or repairs to infrastructure (US Farm Service Agency, 2012). None of the offers are designed to help specifically with implementing BMPs, but some of the more intensive BMPs described in the previous section could certainly be covered by a loan. The more promising USDA program is the Environmental Quality Incentives Program (EQIP), housed under the Natural Resources Conservation Service (NRCS, 2014). The EQIP targets farm owners looking to implement conservation practices on their land. The program requires that funded practices meet the standards of the NRCS, which is already the source of the SLWAP guidelines for BMPs. Payment rates can vary, depending on a payment rate set each year and the practices being implemented.

To more easily find and compare these available funding sources, it will likely be necessary to do more detailed research into the specific requirements, limitations, and application process of each program. A list with descriptions of each of the programs and their benefits could be compiled and presented to high priority farms as a means of educational outreach.
Current and Future Threats

Each year the NYS DOH evaluates the potential of source contamination for Skaneateles Lake under the Source Water Assessment Program (SWAP). In 2016 the lake was assessed as being moderately susceptible to contamination due to the amount of pastureland in the watershed (Dwyer, 2017). The pastureland makes the lake susceptible to contamination by protozoa, such as Cryptosporidium and Giardia. These protozoa are parasites that can cause intestinal illnesses with symptoms including nausea, diarrhea, cramps, and headaches (Dwyer, 2017). No reports of ill health effects caused by these protozoa have been filed, and the Village of Skaneateles installed a UV treatment system in 2012 to meet new EPA regulations regarding treatment for microorganisms (Dwyer, 2017).

Although these protozoa have not caused any illnesses yet, they do pose potential risks to people using the lake for recreation and those with lakeside homes or cottages who pump water directly from the lake. If their home water treatment systems do not include UV treatment, their water could be at risk of contamination. Pasture lands within the watershed that has insufficient stormwater management infrastructure or poor management practices could be a source of protozoa contamination as well as nutrients and fecal coliforms. Increasing quantities of these contaminants could cause Skaneateles Lake to fail to meet the criteria for the City of Syracuse to keep its Filtration Avoidance Waiver (NYSDOH, n.d.). This concern is especially prevalent, since a blue-green algae bloom exceeding high toxin levels outlined by the state occurred in Skaneateles Lake in mid-September 2017 as this report was being finalized.

One of most unique features of Skaneateles Lake, and one that makes it an important recreational resource, is the exceptional clarity of the water. During storm events eroded
sediments are carried into the lake and its tributaries by runoff, which increases the turbidity of the lake. Unstabilized slopes, exposed soils, and agricultural land increase the rate of erosion of sediments and the quantity of sediments transported to the lake. Thus, farms with poor management practices and construction sites not following stormwater management plans can significantly affect the turbidity of the lake.

Increased turbidity can have many negative effects on Skaneateles Lake. Sediments transported from agricultural land can have high concentrations of adsorbed phosphorous, which will become a large, continuous source of phosphorous to the lake. This phosphorous can become available to algae and other plants in the lake which could negatively affect dissolved oxygen levels and the spread of invasive species such as Eurasian watermilfoil. Other nutrients such as nitrates may also enter the lake with sediments and contribute to algal growth.

Small, colloidal sediments that enter the lake have such a small mass that they may never settle out of the water column. As more of these particles enter the lake, the water will become more turbid and lose its clarity. This increase in turbidity can also influence the maintenance of the Filtration Avoidance Waiver. Turbidity must not exceed 5 Nephelometric Turbidity Units to meet the waiver requirements during monthly tests (NYSDOH, n.d.). If these levels are exceeded the City of Syracuse must alert the Onondaga County Department of Health, which may result in the sending of notifications to residents of a turbidity event (NYSDOH, n.d.). Turbidity in the distribution system may influence disinfection, provide a medium for bacterial growth, and indicate additional contamination of the water (Dwyer, 2017) Continued failure of these criteria may result in the loss of the waiver and implementation of a more expensive water treatment system involving filtration.
In recent years a strange foam has been spotted within Skaneateles Lake and other Finger Lakes. In Skaneateles Lake this foam appears after large storm events where it accumulates in strips moving North to South along the lake. When there are high winds the foam is blown to the edges of the lake where it either accumulates along shore or gets blown into yards.

Not much is known about the origin of the foam. One thought is that it is a natural surfactant from the decomposition of biomass. This is supported by the sighting of foam in tributaries with significant forested land in the watershed. Another thought is that the foam could be a byproduct of herbicide applications. This is supported by the sighting of foam in swales alongside agricultural land. During sampling in 2017 foam was found in early August upstream in Bear Swamp Creek and entering the lake at its outlet.

As the world is confronted with the challenges of a changing climate agricultural and water management policies will need to adapt to address these changes. One of the greatest impacts of climate change is the increasing frequency of intense storms. With more intense
storms occurring more frequently, farms will be subject to increases in runoff and erosion that will contribute to sediment and nutrient loading.

In July of 2017 a study was published which analyzed changes in nitrogen loading across the continental United States purely because of predicted increases in precipitation. The study used 21 climate models across 2105 different sub-basins and predicted changes in both the near future and far future for three different scenarios. These scenarios were mitigation, stabilization, and business as usual (Sinha, 2017).
Figure 11: Percent Changes in mean total nitrogen load within large regions within the continental United States

To understand changes due specifically to increases in precipitation, the only variables manipulated in each model were annual precipitation and extreme springtime precipitation.
According to these models there will be robust increases in nitrogen loading in the Great Lakes region before the end of the century (Sinha, 2017). According to Figure 12, the Great Lakes region is the only region where more than half the models tested for the business as usual scenario indicate a significant increase in nitrogen loading in both the near and far future. Although this study only analyzes nitrogen loading, an increase in nitrogen loading would correlate with an increase in phosphorous and sediment loading from sheet runoff. All loading increases would increase the frequency and severity of harmful algal blooms and turbidity events in the watershed’s lakes and rivers.

**Recommendations**

This study should be followed by more investigations into the surface water quality of the watershed – hopefully studies that have the resources to deepen their analyses and broaden their scope. An expanded program for monitoring nonpoint source nutrient loading could help better define the estimates of that loading. In the same vein, a watershed-wide nutrient source assessment should be conducted to determine the relative contributions of different sub-watersheds. For specific chemicals, it could be instructive to start with an assessment on the contributions of glyphosate (also known as Roundup, the herbicide applied to GMO corn) to local P levels.

In 2016 the New York Department of Environmental Conservation (DEC) announced the creation of the “Finger Lakes Water Hub”, a team tasked with addressing water quality issues in the Finger Lakes (DEC, 2016). The DEC also put forward a $600,000 initiative to study the occurrences of harmful algal blooms (HABs) in Owasco Lake, just west of Skaneateles Lake. It
is hoped the Skaneateles watershed will receive the attention it needs from this interest and investment in the water quality problems of the area.

Given that agricultural runoff contributes significantly to nonpoint source pollution, an investigation into BMPs on farms surrounding the lake should be completed. Examples of farms implementing good and poor management practices could be identified, and then farm-specific recommendations for improvements could be made. This study was not designed to provide a detailed list of the BMPs that will be most or least effective in the Skaneateles watershed. Based on what has been presented here, however, we suggest that non-point source BMPs be developed and implemented for agriculture, drainage ditch maintenance, lawn maintenance, and septic system operations.

The SLWAP should be expanded and promoted as the best way for watershed management that aligns the needs of agriculture with lake and tributary water quality problems. To that end, it should be a top priority to reach out to farmers and farm owners, whether or not they are currently involved in SLWAP, to keep them informed and aware of the bigger picture behind the program. A formal education plan could be developed, with a goal of balancing the needs of residents, farmers, and state and local governments. However this expanded outreach and education is delivered, it should stay focused on the more relevant and motivating points: poor Skaneateles water quality would affect everyone negatively; BMPs can be installed in a way that is minimally inconvenient and eventually a net benefit; and the program can keep local farmers connected to many potential sources of funding for these projects.
Some farmers are concerned with using BMPs since some would reduce the amount of arable land, and potentially profits. To make BMPs more attractive work could be done to develop methods of BMP implementation that provide added benefits to the farmer. For example, planting riparian buffers with alternative food crops, such as hazelnuts or berries, would not need fertilizer and could offset the costs of planting.

**List of Recommendations**

- The NPS monitoring program should be expanded to better define the nutrient loading
- A comprehensive nutrient source assessment should be conducted
- A nutrient management plan should be developed
- Non-Point Source Best Management Practices should be developed for:
  - Agriculture
  - Road drainage ditch maintenance
  - Lawn maintenance
  - Septic system operation and maintenance
- An assessment should be conducted on the potential role of Glyphosate (Roundup) used on GHO corn within the Skaneateles watershed and the onset of HAB’s
- An education plan should be developed to meet the need of all residents and government entities within the watershed. Everyone needs to be engaged
- Funding sources including the following should be assessed and pursued
  - NYS Agriculture and Markets
  - NYS Department of State
  - NYS Department of Environmental Conservation
Appendices

Appendix A – Skaneateles Lake Watershed Land Use map
Appendix B – Sub-watershed Boundaries map
### Appendix C – Supplemental TSS Data

#### Table 8: Dry weather sampling supplemental data July 12, 2016

<table>
<thead>
<tr>
<th>Dry Weather</th>
<th>Sample</th>
<th>Primary Land Use Type</th>
<th>Collection time</th>
<th>TSS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Skaneateles Sailing Club</td>
<td>Agricultural</td>
<td>11:20 AM</td>
<td>11.2</td>
</tr>
<tr>
<td></td>
<td>Randall Gulf</td>
<td>Agricultural</td>
<td>12:15 PM</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>High Vista Nature Preserve</td>
<td>Forested</td>
<td>11:48 AM</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Bear Swamp Creek</td>
<td>Forested</td>
<td>12:53 PM</td>
<td>2.6</td>
</tr>
</tbody>
</table>

Samples collected: July 12, 2016

TSS analysis performed: July 26, 2016

#### Table 9: Dry weather sampling supplemental data July 28, 2016

<table>
<thead>
<tr>
<th>Dry Weather</th>
<th>Sample</th>
<th>Primary Land Use Type</th>
<th>Collection time</th>
<th>Cross sectional area (m²)</th>
<th>Velocity (m/s)</th>
<th>Flow rate (m³/s)</th>
<th>TSS (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Skaneateles Sailing Club</td>
<td>Agricultural</td>
<td>4:40 PM</td>
<td>0.074</td>
<td>0.000</td>
<td>0.000</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>Randall Gulf</td>
<td>Agricultural</td>
<td>5:53 PM</td>
<td>0.024</td>
<td>0.102</td>
<td>0.002</td>
<td>9.8</td>
</tr>
<tr>
<td></td>
<td>High Vista Nature Preserve</td>
<td>Forested</td>
<td>5:22 PM</td>
<td>0.025</td>
<td>0.378</td>
<td>0.009</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>Bear Swamp Creek</td>
<td>Forested</td>
<td>6:34 AM</td>
<td>0.098</td>
<td>0.446</td>
<td>0.044</td>
<td>0</td>
</tr>
</tbody>
</table>

Samples collected: July 28, 2016

TSS analysis performed: July 29, 2016
Appendix D – In-stream pressure data from Bear Swamp Creek

Figure 12: Continuous water pressure measurements from the sampling site at Bear Swamp Creek, collected with a HOBO data logger. The pressure values can be used as an analogue to stream stage. The data logger was installed in the week following a massive storm in


