THE 2017 WATER QUALITY MONITORING REPORT FOR OWASCO LAKE, NY.

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INTRODUCTION

Since the initial Finger Lake Institute (FLI) water quality survey of the eastern Finger Lakes in 2005, Owasco Lake and its watershed has been the focus of additional research due to the lake's poor water quality in comparison to neighboring Finger Lakes. This focus established a monitoring program of Owasco Lake and its watershed to: (1) document spatial and temporal trends in pertinent water quality / water clarity / limnological parameters; (2) investigate the source and magnitude of nutrients in the watershed, as their inputs promote algal growth and thus degrade water quality; (3) investigate associations between the water quality data and the recent rise in blue-green algae and their associated toxins; and, (4) promote the development of comprehensive and effective watershed management policies to improve water quality in Owasco Lake. This multi-year effort was supported, in part, by the Fred L. Emerson Foundation, Auburn, NY, New York State funds secured by New York State Senator Michael Nozzolio, the Owasco Lake Watershed Association (OWLA), the Town of Fleming, Cayuga County Soil and Water Conservation District, Finger Lakes – Lake Ontario Watershed Protection Alliance and most notably the Cayuga County Legislature. Thank you all for your support.

The ongoing monitoring effort has identified the following results to date:

- The trophic status (productivity level) of Owasco Lake fluctuates above and below the oligotrophic (good water quality) – mesotrophic (intermediate water quality) boundary.
- Phosphorus is the limiting nutrient in Owasco Lake. Inputs of phosphorus would stimulate additional algal growth and degrade water quality.
- The lake has experienced late-summer blooms of blue-green algae. Blue-green algae are a concern due to their affiliation with impaired / eutrophic (poor water quality) water bodies, their ability to form unsightly, surface water, algal scums. More importantly, some species of blue-greens may produce toxins that have health implications for humans and other warm blooded organisms.
- Nutrient and sediment sources include point sources like wastewater treatment facilities and onsite wastewater (septic) systems, and nonpoint sources like animal and crop farms, lawn fertilizers, soil erosion, stream bank erosion, roadside ditches, and construction activities.
- A DEC mandated reduction of effluent phosphorus starting in 2007 by the Groton Wastewater Treatment Facility has reduced nutrient loading to the Owasco Inlet and thus Owasco Lake. The adoption of some agricultural best management practices in the watershed and follow through on recommendations made by the Watershed Inspector's

Office and the Owasco Lake Watershed Management Council should also reduce nutrient loads to the lake as well.

- Streams and tributaries are the primary source of nutrients and sediments to the lake, especially during "wet" years but also in "dry" years.
- Event *vs.* base flow analysis of daily nutrient and sediment loads from Dutch Hollow Brook indicated that over 90% of the loads are delivered during precipitation/runoff events, especially in the spring season.
- Annual nutrient load estimates positively correlated to precipitation totals, especially precipitation in the spring season.
- Since 2011, annual phosphorus budgets for Owasco Lake typically resulted in larger inputs than outputs. The continued net addition of phosphorus to the lake continues to degrade water clarity and water quality.
- Phosphorus loading must be curtailed to improve water quality in Owasco Lake. This must be accomplished sooner rather than later because if the loads were curtailed today, it would still take a minimum of five water retention times, i.e., approximately a decade, for the lake to naturally cleanse itself of excess phosphorus and improve water quality.

The water quality research is also passing into an exciting phase. NY State funds to Cayuga County Soil and Water Conservation District and Owasco Lake Watershed Association should establish preliminary BMPs in the Owasco Lake watershed. Support has been secured by Cayuga County Planning to expand the recent Owasco Lake Watershed Management & Waterfront Revitalization Plan to develop an EPA Nine Key Elements Plan. DEC has established a Finger Lakes HUB, group to oversee efforts to improve water quality in the 11 Finger Lakes. Finally, Governor Cuomo just announced a $65 million investment to combat the blue-green algae problems in the twelve most deserving lakes in the state. Owasco Lake and its immediate neighbors were selected. Let's keep this momentum going.

Numerous economic reasons mandate remediation efforts in the watershed. First and foremost, the lake is a public drinking water source for Auburn, Owasco and neighboring communities, and supplies numerous private systems for lakeshore residents. Second, the lake is the focus for recreational, sports fisheries, and other tourism industries in the region. In both cases, poor water quality yields economic challenges. Declining water quality will also negatively impact local property values and tax revenues. Recent[1] property assessments in the watershed, like other Finger Lake watersheds, reveal significantly larger property assessments per acre for parcels adjacent to the lakeshore than parcels away from the lake (Fig. 1). Municipal budgets are therefore

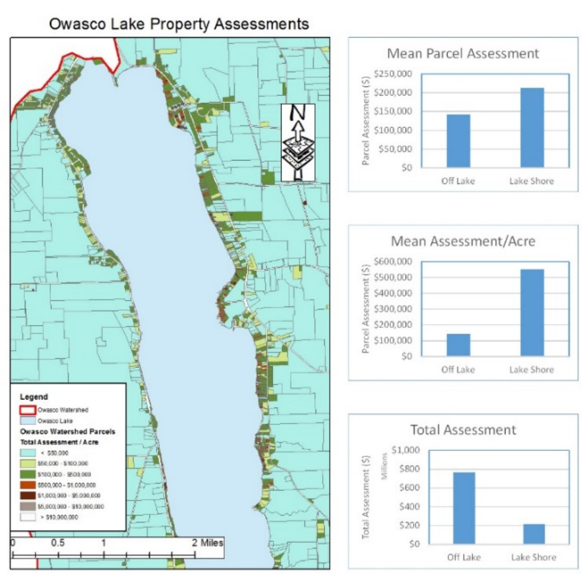


Fig. 1. Owasco Lake property assessments per acre of land. Lakeshore property assessments are significantly larger than properties away from the lake.

[1] Assessment data and parcel's map acquired from Cayuga County in the summer 2016.

reliant on the revenue from the lakeshore acreage. This revenue will decline as property values decline in the wake of deteriorating water quality. A 2016 survey of selected real estate venues indicated that lakeshore properties have recently declined in value, and have taken longer to sell once put on the market in the watershed. Therefore, municipal officials should do everything in their power to maintain water quality in the lake. More importantly, we owe it to future generations to leave this lake in better shape than when we got it. Finally, Owasco Lake has been severely impacted by blue-green algae blooms over the past six years, five of those years some blooms also had very high toxin concentrations.

METHODS

The offshore lake and stream sample sites and field/laboratory methods used in 2017 were similar to the 2005 – 2016 programs.

Owasco Lake: The 2017 lake survey sampled Sites 1 and 2 on a monthly basis from late May through late September (Table 1, Fig. 2). These two sites have been sampled since the 2005 survey, and have been deemed representative of the open water limnology in Owasco Lake. The specific 2017 monthly survey dates were: 5/23, 6/21, 7/15, 8/15 & 9/27. Additional funding in 2017 from the Emerson Foundation supported the deployment of the water quality monitoring buoy, increased the number of sample dates to weekly surveys in July, August and September, and added six nearshore sites to the lake monitoring effort. In consort with previous Owasco Lake WQ reports, this report will focus on the offshore results. The results of the nearshore effort will be discussed in a separate report[2].

The lake-monitoring field methods were identical to the earlier research. A CTD profile, fluoroprobe profile, Secchi disk depth, vertical plankton tow (80-μm mesh), and surface and bottom water samples were collected at each site. The CTD electronically measures water column profiles of temperature (°C), conductivity (reported as specific conductance, μS/cm, a measurement proportional to salinity), dissolved oxygen (mg/L), pH, turbidity (NTUs), photosynthetic active radiation intensities (PAR, $\mu E/cm^2$-s), and fluorescence (a measure of chlorophyll-a, μg/L) using a SeaBird SBE-25 CTD. The CTD was lowered from the surface to ~1m above the lake floor, collecting data every 0.5 seconds (~0.2 meters) along the downcast. The protective caps covering the PAR, fluorescence and turbidity sensors were mistakenly not removed from the sensor on 9/20 preventing collection of data on that cruise. The bbe fluoroprobe electronically measures water column profiles of four different algal groups and yellow substances based on their accessory pigments. It distinguishes among: 'green' algae (Chlorophyta and Euglenophyta), 'brown' algae (diatoms: Baccillariophyta, Chyrsophyta, and Dinophyta), 'blue-green' algae (Cyanophyta), and 'red' algae (Cryptophyta). It was attached to the CTD, and deployed with the CTD. The plankton collected by each tow were preserved in an alcohol-formalin solution and enumerated to species level back in the laboratory under a microscope. Water samples were analyzed onsite for temperature (°C), conductivity (specific conductance, μS/cm), pH, dissolved oxygen (mg/L), and alkalinity (mg/L, $CaCO_3$) using hand-held probes and field titration kits, and analyzed back in the laboratory for total phosphate (μg/L, P), dissolved phosphate (SRP, μg/L, P), nitrate (mg/L, N), chlorophyll-a (μg/L), dissolved silica (μg/L, Si), and total suspended solid (mg/L) concentrations. Lab samples were stored at 4°C until analysis.

[2] Halfman, et al., 2018. Blue-green algae in Owasco Lake, the 2017 Update. The 2017 annual report to the Fred L. Emerson Foundation.

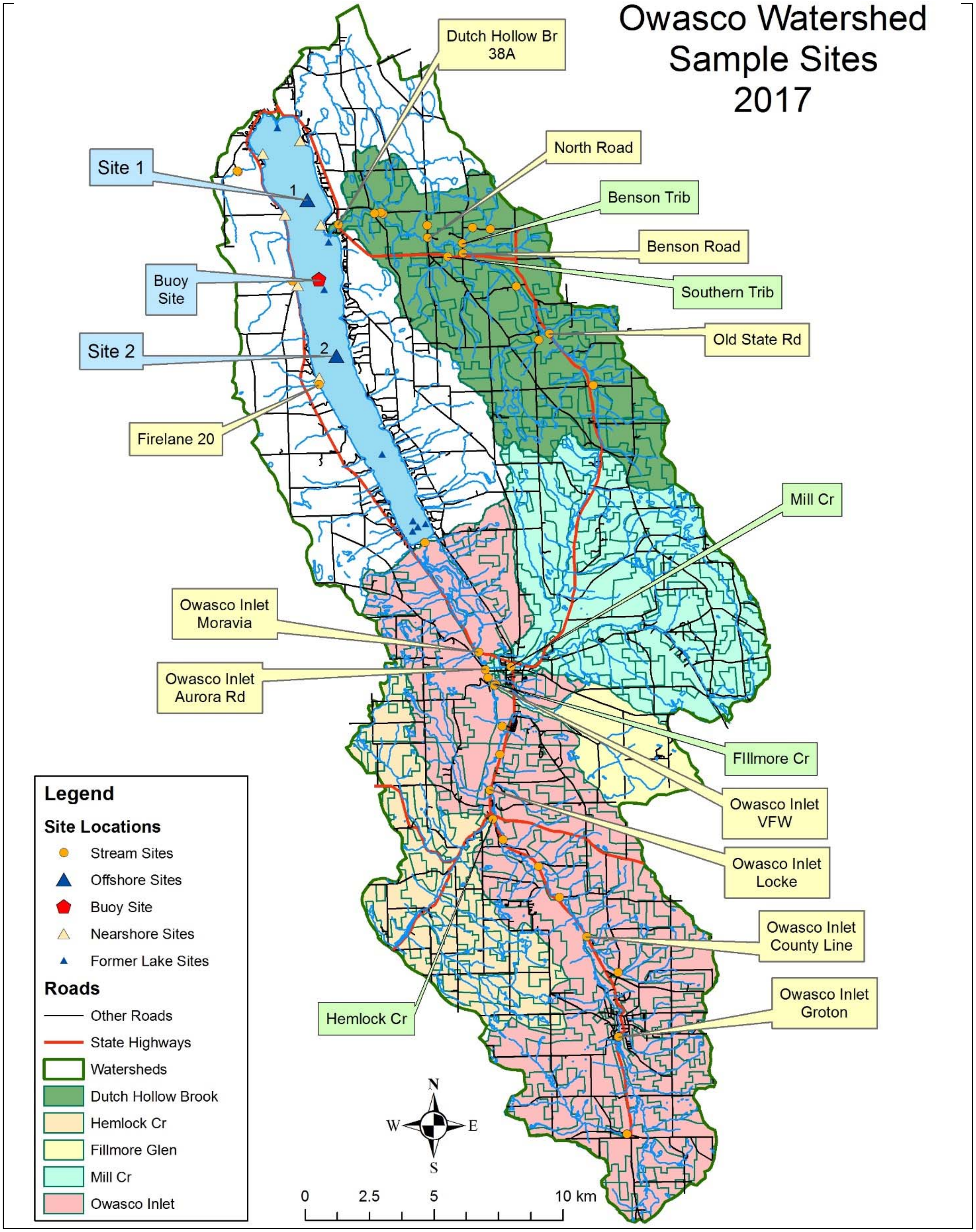


Fig. 2. The 2017 lake and stream sites. The 2017 stream sites focused on previously sampled sites within Dutch Hollow Brook and the Owasco Inlet. The small tributary near the terminus of Fire Lane 20 was also sampled.

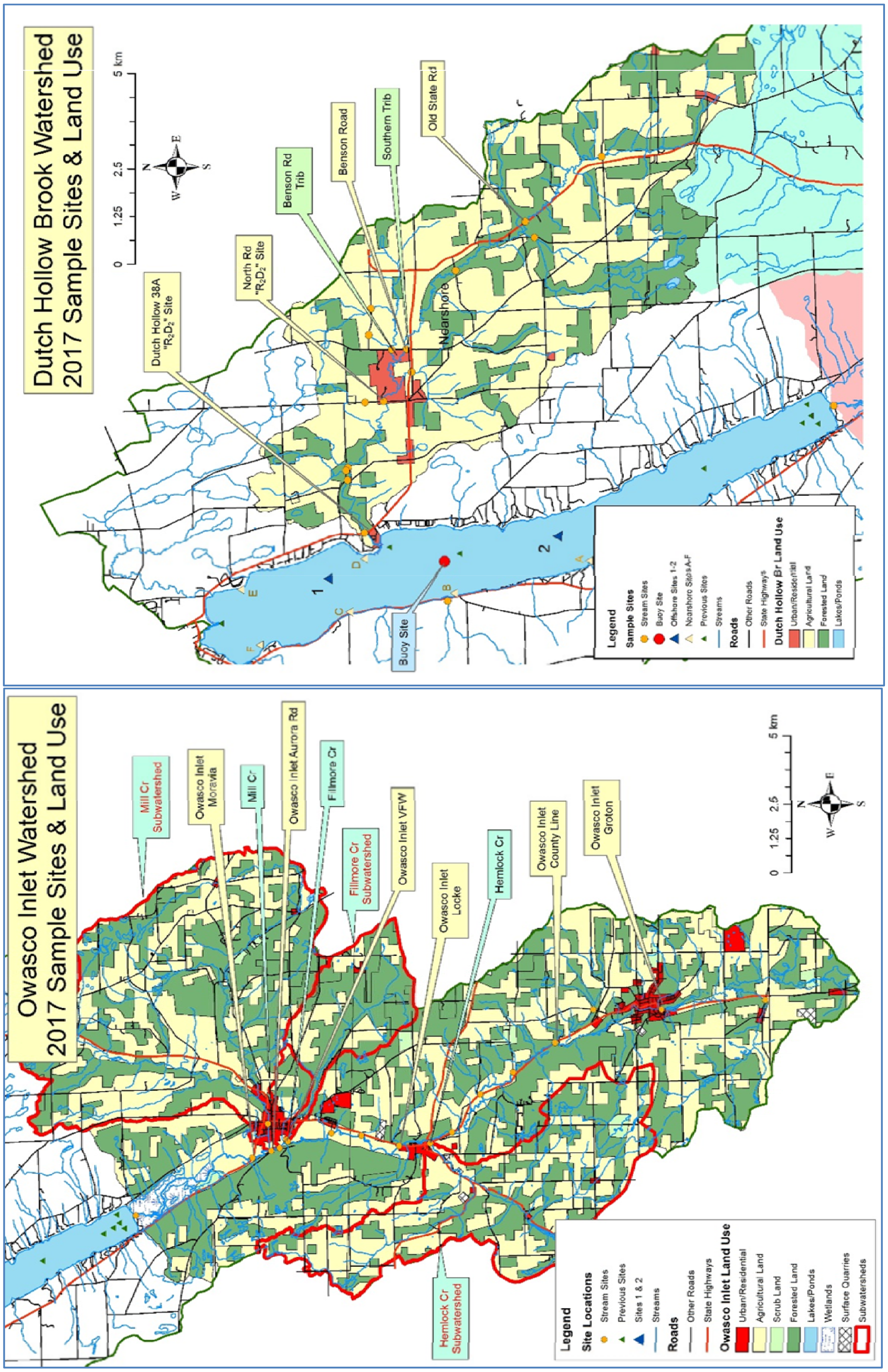


Fig. 2 continued. 2017 site locations and land use within Dutch Hollow Brook and Owasco Inlet watersheds.

Table 1. Owasco Lake Site Locations and Water Depths.

Site Name	Latitude	Longitude	Water Depth
Offshore Sites:			
Site 1	42° 52.40' N	76° 31.35' W	34 m
Site 2	42° 49.15' N	76° 30.45' W	52 m
Buoy Site	42° 50.35' N	76° 30.85' W	49 m
Nearshore Sites:			
A – Fire Lane 20	42° 48.69' N	76° 30.92' W	2 - 3 m
B – Wyckoff Rd	42° 50.61' N	76° 31.58' W	2 - 3 m
C – Stone School Rd	42° 52.01' N	76° 31.98' W	2 - 3 m
D – Burtis Pt	42° 51.89' N	76° 30.96' W	2 - 3 m
E – Martin Pt	42° 53.64' N	76° 31.59' W	4 - 5 m
F – Buck Pt	42° 53.35' N	76° 32.65' W	2 - 3 m

Drone Flights: A drone was flown at 100 m along six nearshore locations to investigate its suitability to measure water clarity and other parameters (Fig. 3). DJI's Phantom 3 Advanced with a Sony EXMOR gimbaled camera was used. It captured 12 megapixel digital images. Each image spanned an area of ~200 by 300 meters at a flight altitude of 100 m. Multiple, overlapping images were collected at Sites A - F to investigate nearshore attached algae and macrophyte distributions, the distribution of blue-green algae blooms and open water algal concentrations (Table 1, Fig. 2). The overlapping images were spatially aligned in Adobe Photoshop. The composite image was then georeferenced in ArcGIS to 2015 satellite digital orthoimagery (NYS Clearinghouse data). Flights dates were: 7/11, 7/18, 8/1, 8/8, and 8/15, plus a few additional partial flights.

Fig. 3. The drone used in this study, a Phantom 3 Advanced by DJI.

Owasco Buoy: The FLI meteorological and water quality monitoring buoy manufactured by YSI/Xylem was redeployed at its mid-lake site from 4/13 through 11/3 (Table 1, Fig. 2). As in previous deployments, the buoy was programmed to collect water column profiles using a YSI/Xylem EXO2 water quality sonde every 12 hours (noon and midnight). The sonde measured temperature (°C), conductivity (μS/cm, reported as specific conductance), dissolved oxygen (mg/L & % saturation, by optical sensor), turbidity (NTUs by backscattering), and fluorescence, the fluorescence sensor measured both total chlorophyll and blue-green algae phycocyanin concentrations (μg/L, after specific pigment excitation by different wavelengths of light). Data was collected every 1.5 meters down the water column starting at 1 m. The buoy also contained a standard suite of meteorological sensors that, as in previous years, recorded five-minute, mean air temperature, barometric pressure, relative humidity, light intensity and wind speed and direction data every 30 minutes. All of the data were periodically transferred to HWS by cellular phone ~1 hour after collection. Buoy hardware and software issues prevented collection of water quality data from 5/11 to 5/14, 5/22 to 5/26, 6/7 to 6/8, 8/6 to 8/9, 9/12 to 9/13, 10/3 to 10/5 and 10/7 to 10/9, and an occasional 30 minute reading of meteorological data.

Owasco Streams: The 2017 stream monitoring focused on Dutch Hollow Brook, Owasco Inlet, and a small tributary at the end of Fire Lane 20 (west). The stream sites were visited four times, specifically 6/7, 6/9, 6/28, and 7/7, for onsite analyses and collection of water samples for nutrient and sediment analyses back in the laboratory.

Dutch Hollow Brook was sampled at six sites in 2017 (Fig. 2). Progressing upstream, four sites were sequentially located along 38A, including the terminus at Rt 38A, and sequentially upstream at North Rd, Benson Rd, and near Old State Rd. Two unnamed tributaries in the watershed were also sampled. The South tributary was sampled at Rt 38A just east of the Owasco town center. The Benson tributary was sampled along Benson Rd just north of the Benson Rd site. These sites duplicated those used in the past.

Owasco Inlet was sampled at nine sites in 2017 (Fig. 2). Proceeding upstream, five sites were sequentially located along the main stream starting at Moravia on Rt 38, Aurora St in Moravia, VFW just upstream of Fillmore Cr, immediately downstream of Locke, at the County Line, and just upstream of Groton (near Spring St). Three tributaries, Mill, Fillmore, and Hemlock Creeks, were also sampled just upstream from where they join the Inlet. These sites duplicated those used in the past.

The small tributary at the end of Fire Lane 20 (west) was also sampled.

Stream discharge, water temperature, conductivity, dissolved oxygen, pH and alkalinity were measured onsite using hand-held probes or field titration kits. Water samples were also collected and analyzed in the laboratory for total phosphate (TP), dissolved phosphate (SRP), nitrate and total suspended sediment (TSS) concentrations. Laboratory samples were stored at 4°C until analysis. Stream discharge (the volume of water per unit time flowing past a site) was calculated from measured stream width, depth and velocity data (using a 30 m tape, wading rod and HACH FH950 portable velocity flow meter with electromagnetic sensor). The discharge at Rt 38 near Moravia was not measured by hand during the flood on 6/7. The USGS gauge at Moravia (4235299) flow was used instead. Both velocity and stream depth were measured at ten (or five) equally distributed segments aligned perpendicular to stream flow. The velocity was measured at ~60% of the stream depth and assumed the average velocity for each segment. Ten segments were utilized when the stream was wide (>10 m) or more accuracy was necessary, e.g., some of the Inlet sites and the Dutch Hollow Brook at 38A and North Rd. Stream discharge (water volume per unit time, e.g., m^3/s) is necessary to calculate the flux (loading) of nutrients and suspended sediments, because flux of a substance (its mass/time, e.g., kg/day) equals stream discharge (volume water/time, e.g., m^3/s) times its concentration (mass/volume water, e.g., mg/L).

Runoff/Event Flow versus Base Flow Variability: A Teledyne ISCO automated water sampler, and two pairs of *ONSET* HOBO U290L-04 loggers were deployed at the Rt 38A site in Dutch Hollow Brook from 4/25 to 11/2 to investigate the impact of event *versus* base flow variability on the delivery of nutrients and sediments to the lake (Figs. 4a & 4b). One logger in each pair was deployed in air and the other deployed underwater at a fixed elevation to account for changes in atmospheric pressure and isolate pressure changes due to changes in water level detected by these unvented pressure transducers. The configuration also provided air and water temperature measurements at the site. Deploying two pairs of loggers hedged against losing a logger.

The autosampler was programmed to collect 1-L of water every day (4 am). This frequency collected both event and base flow samples in 2016. At each site, stream discharge was measured and autosamplers were serviced every one to two weeks. Each sample was analyzed for suspended sediment and nutrients. Over the 191 day deployment at 38A, some water samples were not collected at 38A due to a pinched water hose (7/3 to 7/8 and 8/8 to 8/26), and nine TP samples were prematurely discarded before analysis.

The data loggers were programmed to record hourly pressure and temperature data. The stage data and weekly to bi-monthly site visit stream discharge measurements established a rating curve, a relationship between stream height and stream discharge to estimate a stream discharge for every ISCO water sample. A significant flood near the end of the deployment uprooted the logger's stakes from the stream bed on 10/30 a few days before the equipment was removed for the season (11/3).

Fig. 4a. Servicing "R_2D_2" the Teledyne ISCO automated water sampler located at the Rt 38A site. It collected 1-liter of water daily (4 am) and was serviced every one to two weeks.

Fig. 4b. An ONSET HOBO U20L-04 data logger. Each pair of data loggers measured hourly water and air pressure to calculate hourly stream stage (height), and air and water temperatures.

Laboratory Analyses: Laboratory analyses for nutrient, chlorophyll-a (only lake samples), and total suspended sediment concentrations used standard limnological techniques[3]. Briefly, an aliquot of each sample was processed for total phosphate colorimetric analysis by spectrophotometer after digestion of any organic-rich particles in hot (100ºC) persulfate for 1 hour. Additional sample water was filtered through pre-weighed, 0.45 μm glass-fiber filters. The filter and residue were dried at 80°C for at least 24 hours. The weight gain and filtered volume determined the total suspended sediment concentration. A known volume of lake water was also filtered through a Gelman HA 0.45 μm membrane filter, and the filtered residue was kept frozen until chlorophyll-a analysis by spectrophotometer after pigment extraction in 90% acetone. The filtrate was saved and stored at 4°C until dissolved phosphate (SRP), nitrate and dissolved silica colorimetric analyses by spectrophotometer. Laboratory precision was determined by periodic replicate analyses resulting in the following mean standard deviations: total suspended sediments ±0.2 mg/L, phosphate ±0.1 μg/L (both TP and SRP), silica ±5 μg/L, and nitrate ±0.1 mg/L. For the plankton enumerations, over 100 individuals were identified to genus (and typically species) level and reported as date averaged relative percentages. Multiple reagent blanks and standards were run for each analysis for a continual check on data quality. The nitrate triplicate blanks and standards occasionally yielded concerns.

[3] Wetzel and Likens, 2000. Limnological Analyses, 3rd Edition. Springer-Verlag, New York.

LAKE MONITORING RESULTS & DISCUSSION

Lake CTD & Fluoroprobe Profiles: The 2017 water temperature profiles revealed near typical late spring through early fall transition (Fig. 5). The 5/23 cast revealed the initial establishment of seasonal stratification, the initiation of less dense and warmer epilimnion (surface water) overlying the denser and uniformly cold hypolimnion (bottom water). Epilimnetic temperatures ranged from 11ºC (~50ºF) in late May to 23ºC (~74ºF) in July, and atypically cooled to 19ºC (66ºF) for a few weeks in early September only to warm again to 22ºC (~70ºF) through the last cruise of the survey (9/27). Hypolimnetic temperatures remained cold, warming from 5º to 6ºC (~39ºF) through the survey.

Epilimnetic salinity (specific conductance) ranged from 294 to 320 μS/cm in 2017 (~150 ppm TDS). Like previous years, epilimnetic salinity in 2017 decreased by ~25 μS/cm (~10 ppm TDS, a small amount) from the largest values detected in the late spring to the late summer as the epilimnion was progressively diluted by less saline precipitation and stream runoff. The 2017 early spring specific conductance was similar to those detected in 2016 and 2015, and all three years were slightly larger than previous years. The annual change in salinity is interpreted to reflect the extent of road salt application during the preceding winter, e.g., the larger salinity in 2015 was due to more snowfall and road salt the previous winter, concentrations which carried over into the spring of 2017.

The 2017 hypolimnetic specific conductance data were just above 329 μS/cm and remained relatively uniform over time and depth (Fig. 5). These values were slightly smaller than those in 2015 and 2016, and all three years were 10 to 20 μS/cm larger than previous years. Again, the use of an estimated 10,000 tons of additional road de-icing salt from the larger and more frequent snowfall in 2014 & 2015 probably maintained the slightly larger hypolimnetic salinity in 2014 and 2015 than earlier years, and the larger concentrations carried over into 2016 until the dilution by spring rains in 2017.

The dissolved oxygen sensor malfunctioned in 2017, and resources were not available to fix it.

Profiles of photosynthetic available radiation (PAR), i.e., light intensity, in 2017 were similar to earlier results (Fig. 5). Light decreased exponentially with water depth from a maximum intensity of a few 100 to a few 1,000 $\mu E/cm^2$-s at the surface to 1% of surface light intensities within the epilimnion at water depths of 10 to 15 m. The observed decrease in light reflects the normal exponential absorption and conversion of longer wavelengths of light (infrared, red, orange, yellow) to heat, and scattering of shorter wavelengths of light (ultraviolet, violet, blue) back to the atmosphere. The range in surface intensities reflected the season, the extent of cloud cover, and the turbidity of the water (suspended sediment and/or algal density) on the survey date. The 1% of surface light threshold represents the minimum amount of light required for algae to photosynthesize enough biomass to survive. Thus, algal photosynthesis and growth was restricted by light to the epilimnion in Owasco Lake. Many of the profiles revealed a marked decrease in light at 2 or 3 meters. It corresponded to the sensor passing through the shadow of the boat.

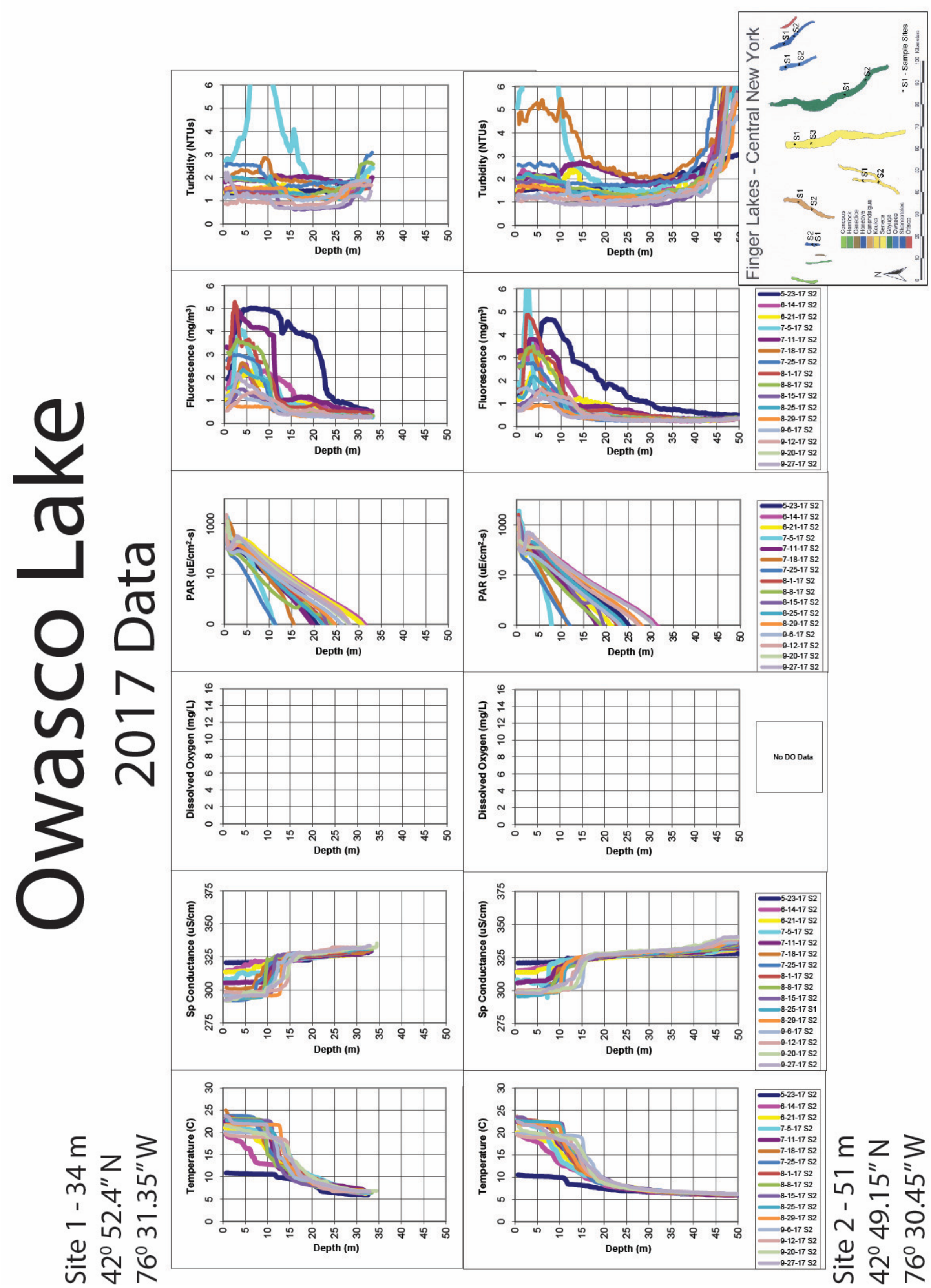


Fig. 5. CTD profiles from Sites 1 & 2 from every survey in 2017. The PAR (light) data are plotted on an exponential scale, so that the expected exponential change in light intensity with water depth appears as straight lines. The dissolved oxygen sensor malfunctioned this year.

Fluorescence, a measure of algal concentrations, revealed peaks in algal abundance within the epilimnion at approximately 5 to 15 m below the lake's surface (Fig. 5). Peak concentrations exceeded 4 μg/L (mg/m^3) on 5/23 and again on 7/5, 7/11 and 8/1, and above 3 μg/L (mg/m^3) on 6/14 and 8/8 but were lower, between 1 and 2 μg/L on the other survey dates. The 2017 epilimnetic data were slightly larger than previous years. Hypolimnetic concentrations were consistently below 1 μg/L, i.e., algae are typically absent in the dark bottom waters.

The turbidity profiles revealed uniform or nearly uniform turbidities from 1 to 3 NTUs down to the lake floor at Site 1 and down to just above (5 to 10 m) the lake floor at Site 2 (Fig. 5). At Site 2, turbidity then increased from the uniform turbidities up to 7 NTUs on multiple occasions, just above the lake floor. Occasionally a spike in turbidity to 10 NTUs was detected on 5/23 and 7/5 just above the thermocline, each spike was detected just after an intense precipitation event. The water column background concentrations, occasional epilimnetic spikes in turbidity, and the lake floor increase in turbidity at Site 2 was much more pronounced in 2017 than those detected since 2014. The change from year to year typically parallels the change in rainfall and wind velocities, as the primary source of suspended sediments (turbidity) is runoff events from precipitation and snowmelt and resuspension events by waves. Algae and algal blooms provide another source of turbidity. 2017 experienced near normal rainfall but more intense event, especially within the Owasco Inlet subwatershed (see below). Intense events during an "in-between" rainfall year can contribute as much sediments as a "wet" year with less intense events.

The fluoroprobe data revealed the dominance of green algae, diatoms and cryptophytes. Mean epilimnetic fluorescence concentrations exceeding 10 μm/L (mesotrophic/eutrophic threshold) at one or more sites on six of the fifteen surveys of the lake (Fig. 6). Site 1 and 2 also revealed small concentrations of blue-green algae (up to 4 μg/L) in the epilimnion after late August.

Limnology & Trophic Status: Date averaged mean chlorophyll concentrations in the epilimnion ranged from 1.4 to 7 μg/L in 2017 (Table 2 in appendix, Fig. 7). On 9/20, one site sampled a BGA bloom and the chlorophyll concentration spiked to 18.8 μg/L. The annual mean of 5.2 μg/L was within the 4 to 6 μg/L not to exceed DEC threshold for potable water bodies[4]. Nitrate concentrations ranged from 0.1 to 1.0 mg/L and an order of magnitude (10 times) below the 10 mg/L maximum contaminant level (MCL) established by the EPA. The lake was not impaired due to phosphorus, as the annual mean total phosphate concentration was 14.4 μg/L, below the 20 μg/L total phosphate (TP) threshold established for impaired (eutrophic) water bodies by the DEC. Two dates, 5/23 and 9/12 were an exception, with a date-averaged TP concentrations of 21 and 25 μg/L. The May date was just after a rainfall event. The September date was during a blue-green algae bloom that impacted Site 1 and other nearshore sites. Secchi disk depths ranged from 1.2 to 4.9 meters, and averaged 3.1 meters in 2017 (Fig. 7). This was the shallowest annual average detected by the FLI monitoring effort. Total suspended sediments date-averaged concentrations ranged from 1.3 to 7.8 mg/L and averaged 2.8 mg/L. The 2017 data were larger than previous years in the survey, except for 2014 and 2015. The largest TSS concentration in 2017 coincided with the 9/20 bloom.

[4]Callinan, C.W., J.P Hassett, J.B. Hyde, R.A. Entringer & R.K. Klake. 2013. Proposed nutrient criteria for water supply lakes and reservoirs. American Water Works Association Journal, E157-E172.

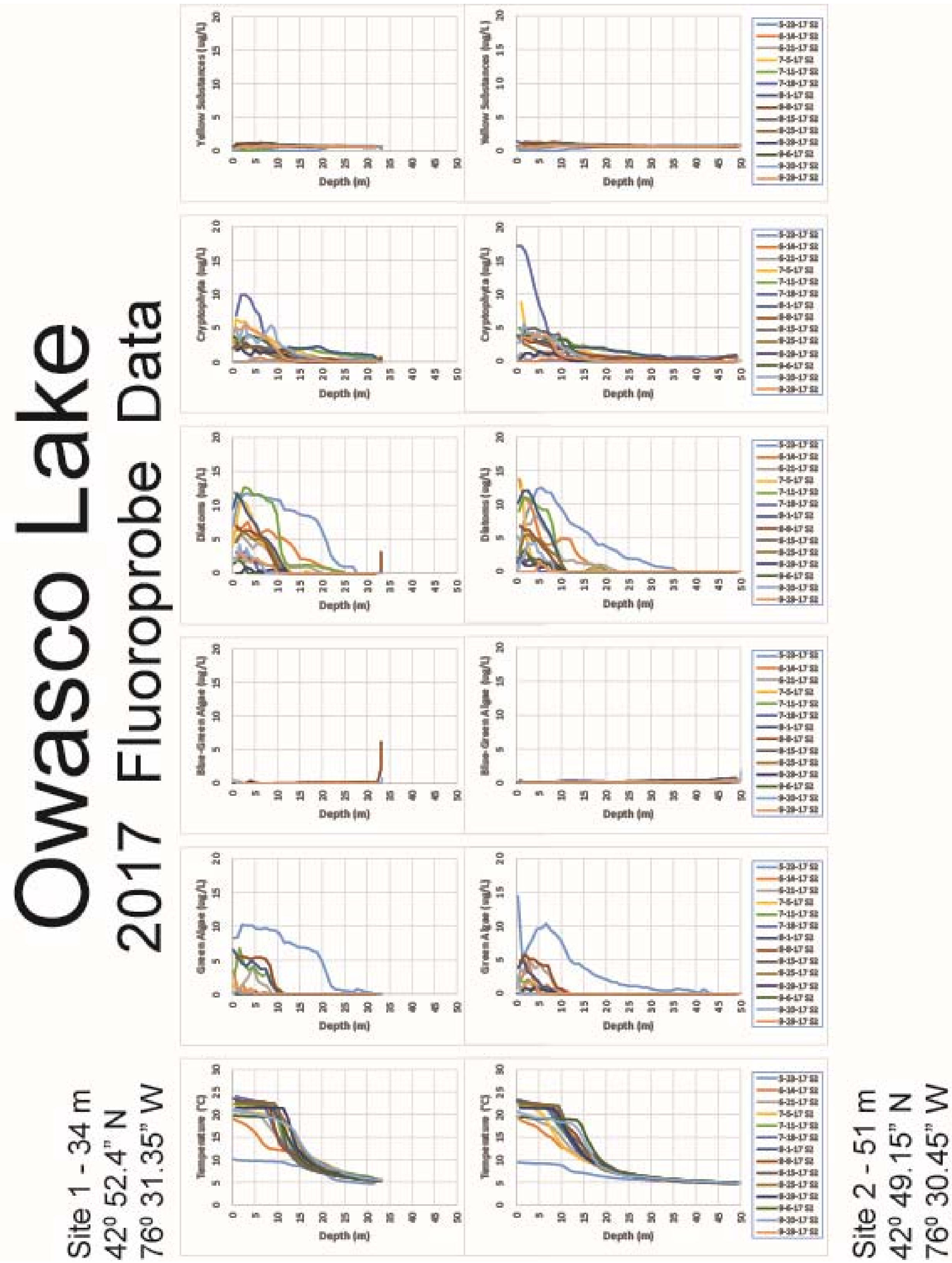


Fig. 6. Fluoroprobe profiles from Sites 1 & 2 of the four algal groups.

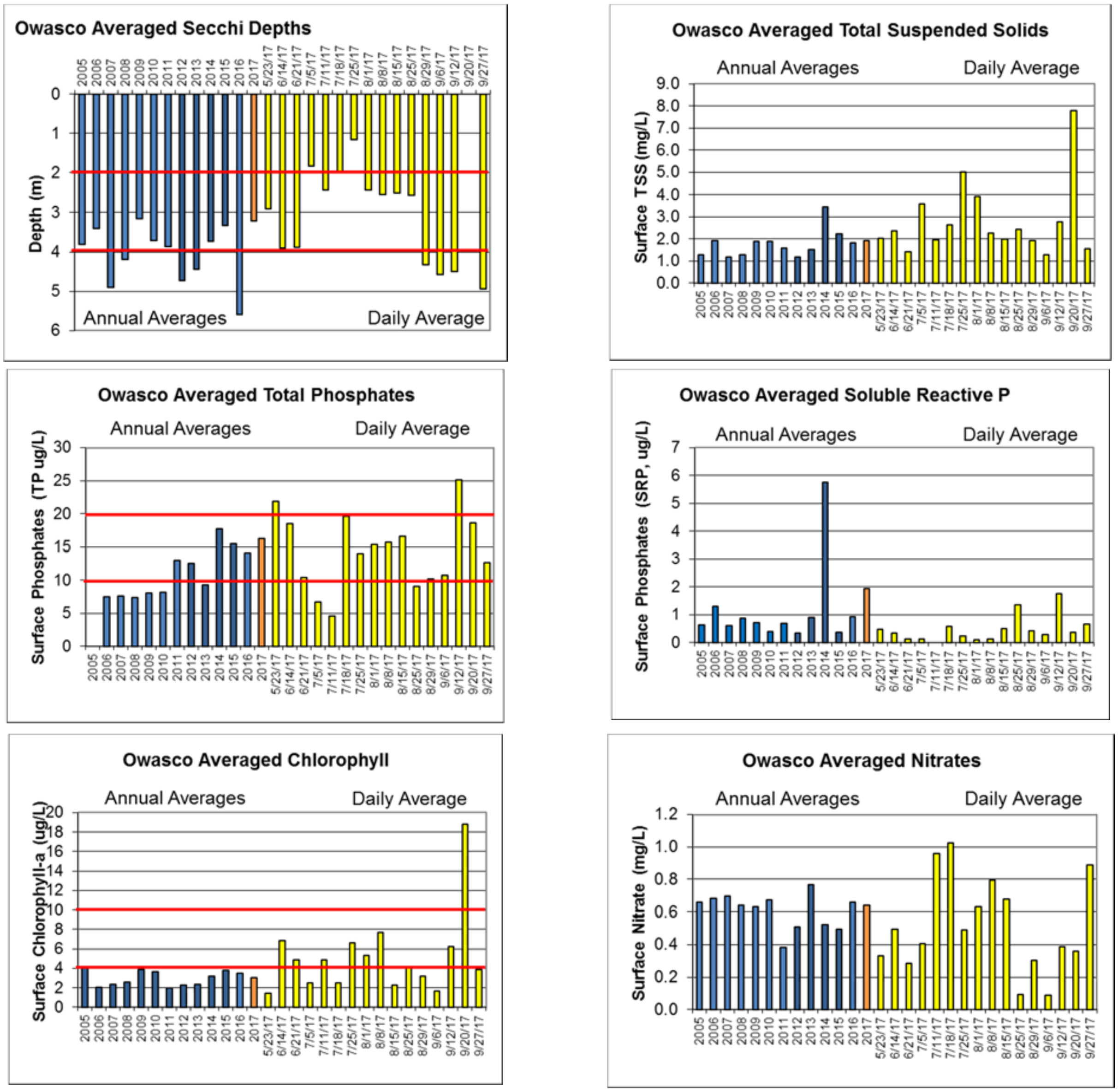


Fig. 7. Annual average surface water concentrations from 2005 (blue) to 2017 (orange), and date averaged offshore surface water data from 2017 (yellow). When appropriate, boundaries for oligotrophic, mesotrophic and eutrophic concentrations are marked.

From one year to the next, annual average Secchi disk data deepened, suggesting improved water clarity from 2009 through 2012 but water quality declined since, except for a reversal in 2016. It suggests that the major trigger for the decline in water quality during 2014 and 2015 and again in 2017 was the larger rainfalls and/or more intense rainfall events in those years. It was very dry in 2016, allowing the lake to temporarily recover. The influence of precipitation totals, precipitation intensity, stream runoff and water quality in the lake will be discussed again in a later section of this report.

Since 2005, annual mean total phosphate concentrations have increased from ~8 to over 17 µg/L by 2015 with a slight dip in 2013 (Fig. 7). After another dip in 2016, TP increased to 16.2 µm/L in 2017. Annual mean dissolved phosphate concentrations were larger in 2006 and 2017 (1.9 µm/L) than other years, but no annual mean was close to 5.8 µm/L detected in 2014 (Fig. 7).

The large 2014 mean was biased by a sample collected immediately after intense May rains. Interestingly, mean annual SRPs in 2016, a “dry” year, and 2017 an “in-between” year were 2nd largest to 2014. Reduced external sources in 2016 suggests that decomposition of organics within the lake provides a critical SRP source. Chlorophyll-a concentrations were larger in 2009, 2010, and again in 2014 and 2015 (3.9, 3.7, 3.2 & 3.8 μg/L, respectively) than 2012, 2013 and 2013 (1.9 to 2.3 μg/L; Fig. 7). The 2016 annual mean concentration decreased from 3.8 in 2015 to 3.5 μg/L, and the concentration decreased again to 3.0 μm/L in 2017. The high total suspended sediment (TSS) annual mean concentrations continued their decline from a peak of 3.5 in 2014, down to 2.1 in 2015, 1.8 mg/L in 2016 and 1.9 in 2017 mg/L (Fig. 7). In summary, 2014 and 2015 revealed the worst water quality for the lake but 2017 was not too far behind. The largest spring rainfall totals dictated water quality deterioration in 2014 and 2015. The “in-between” rainfall of 2017 but not as straight-forward. This year experienced some very large events that probably delivered as much nutrients and sediments as numerous smaller events in the “wet” years. It indicates that both rainfall totals and intensities impact water quality. The 2016 “dry” year allowed the lake return to pre-2014 conditions, only to degrade in 2017. The nutrient loading information presented below support this conclusion.

The 2017 annual mean Secchi disk, total phosphate, chlorophyll-a and hypolimnetic dissolved oxygen saturation data (from the buoy) place Owasco Lake above the oligotrophic-mesotrophic trophic boundary (Table 3, Fig. 7). Only nitrogen, measured by nitrate concentrations, placed Owasco Lake below the boundary. Thus, the trophic status of Owasco Lake degraded from slightly below the boundaries in 2016 to slightly above the boundary in 2017, a return to the 2014 and 2015 mesotrophic trophic conditions. The fluctuations above and below the boundary however, indicates that the lake is in a delicate balance. Any increase or decrease in nutrient loads from one year to the next influence the lake’s water quality.

Table 3. Concentration ranges for Oligotrophic (low productivity), Mesotrophic (mid-range productivity), and Eutrophic (high productivity) lakes. The bold entries reflect Owasco’s 2017 annual mean values.

Trophic Status	Secchi Depth (m)	Total Nitrogen (N, mg/L, ppm)	Total Phosphate (P, μg/L, ppb)	Chlorophyll a (μg/L, ppb)	Oxygen (% saturation)
Oligotrophic	> 4	**< 2**	< 10	< 4	> 80
Mesotrophic	**2 to 4**	2 to 5	**10 to 20**	**4 to 10**	**10 to 80**
Eutrophic	< 2	> 5	> 20 (> 30)	> 10	< 10

A few additional observations about the limnological data are noteworthy. First, the mean, surface water, dissolved phosphate to nitrate ratio in the lake, the two nutrients that typically limit algal growth, averaged 1:1,900 in 2017. The P:N ratio required by algae is 1:7 (Redfield Ratio). The measured ratios indicate that phosphate has consistently been (since the start of the FLI monitoring effort) the limiting nutrient in Owasco Lake. The limiting nature of phosphorus is unlikely to change because fluvial sources yield 30 times more nitrogen than phosphorus, and fluvial sources of nitrates are augmented by additional sources of nitrogen to the lake (e.g., atmospheric acid rain nitrates) not available to phosphorus. Second, variability was observed in every parameter from one survey date to the next. The extent of the variability is best observed in the box and whiskers plots (Fig. 8). It reflects, for example, that algal blooms do not persist the entire summer but are instead episodic and bloom for a week or two at a time before nutrient limitations or grazing by zooplankton and mussels decrease the algal concentrations. Third, the dissolved nutrient concentrations revealed slightly larger concentrations in the hypolimnion than the epilimnion. The annual mean surface and bottom water concentrations were 0.5 and 1.2 μg/L for SRP, 0.5 to 0.8 mg/L for nitrate, and 1,100 to 1,700 μg/L for dissolved silica. Chlorophyll-a concentrations revealed the expected decrease from the epilimnion to the hypolimnion of 5.2 and 0.6 μg/L. The separation highlights the expected algal uptake of nutrients in the epilimnion and bacterial decomposition of organic materials and release of nutrients in the hypolimnion.

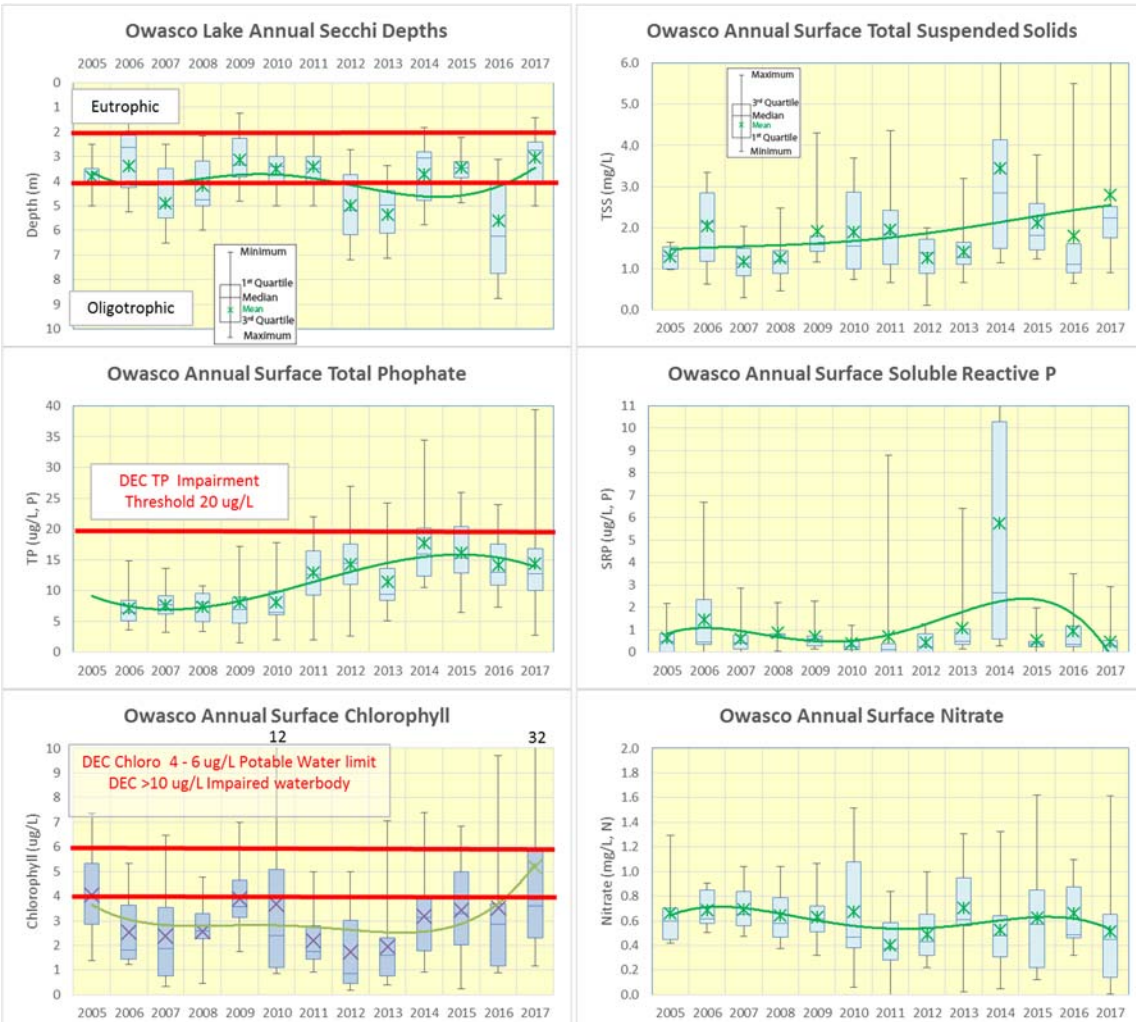


Fig. 8. Box and Whisker plots of the annual nutrient, chlorophyll and Secchi disk data.

Plankton Data: The phytoplankton (algal) species in Owasco Lake during 2017 were dominated by diatoms, primarily *Flagillaria* and *Asterionella*, with smaller numbers of *Diatoma*, *Melosira*, *Tabellaria*, and *Rhizoselenia*, (Table 4 in appendix, Fig. 9). Like previous years, *Asterionella* and *Fragillaria* dominated in the spring and early summer, *Rhizoselenia*, *Tabellaria*, and *Diatoma* replaced *Asterionelia*. *Dinobryon* (a dinoflagellate) dominated in the late summer. Two blue-greens, *Dolichospermum* (formerly called *Anabaena)* and *Microcystis* dominated in the fall. Interestingly, 2017 had the largest annual average of *Dolichosperma* (*Anabaena*) since the start of FLI's survey in 2005. The reason why is uncertain at this time but may reflect nitrogen limitations during the intense blooms because *Dolichosperma* can fix nitrogen dioxide (N_2) whereas *Microcystis* can not. In the past, *Tabellaria* instead of *Asterionella* occasionally dominated the algae population (e.g., 2011, 2012). Other phytoplankton species included a few *Ceratium* and *Coalcium*. Zooplankton species were dominated by rotifers, namely *Polyarthra* and *Vorticella* with some cladocerans, like *Copepods*, *Nauplius*, and *Cercopagis*, the fishhook water flea. Zebra and quagga mussel larvae were also detected in the plankton tows.

Two blue-green genera, *Microcystis* and *Dolichosperma* (*Anabaena),* were more prevalent in the late summer and early fall 2017 surveys (Fig. 9). Detection of BGA in the lake is not new. BGA were always detected in the open water of Owasco Lake since the initial FLI surveys in 2005. However, the annual means never exceeded 10% for any BGA species at these open water sites (Fig. 9). Typically the largest populations were restricted to the late summer and/or early fall, with *Microcystis* representing narly 40% of the plankton counts during a survey in 2007, 2010, 2014, 2015 and 2017, and *Anabaena* making up 30% of the late-summer counts in 2013. In fact, blue-green species were detected in a neighboring Finger Lake as long ago as 1914[5]. However, major blooms of BGA have been increasingly detected along the shoreline in Owasco Lake since 2012[6]. The companion report on the 2017 nearshore analyses has more details on the BGA issue.

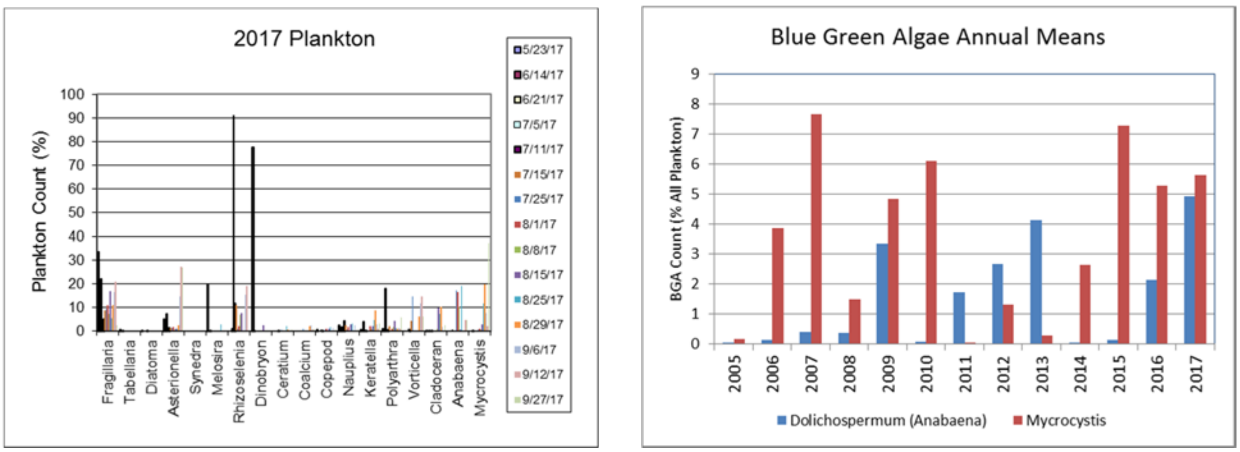


Fig. 9. Date averaged plankton data for 2017 (left) and the mean annual abundance of blue-green algae species since 2005 (right).

Finger Lake Water Quality Ranks: The 2017 Finger Lakes water quality ranks still place Owasco Lake as one of the worst lakes among the eight easternmost Finger Lakes (Table 5 in appendix, Figs. 10 & 11). The ranks were based on annual average Secchi disk depths, and surface water concentrations of chlorophyll-a, total and dissolved phosphate, nitrate and total suspended sediments collected by the May through October, monthly FLI survey. These ranks revealed similar trends as other comparative water quality / trophic state methods like the oligotrophic-eutrophic trophic states (discussed above), and Carlson's Trophic Indices[7] (combines chlorophyll-a, total phosphorus and Secchi depth data, Fig. 10). In 2017, water quality in Owasco ranked poorer than Canandaigua, Keuka, Seneca and Skaneateles Lakes, similar to Otisco Lake and better than Cayuga and Honeoye Lakes. Interestingly, all of the lakes except Honeoye revealed worse water quality in 2017 than 2016, and 2017 was typical of earlier, 2014 and 2015, poor water quality years. It indicates that the 2014, 2015 and 2017 rains and/or intense rain events induced sufficient nutrient and sediment loads to degrade water quality in all the Finger Lakes, and 2016, a dry year, was a year of recovery.

[5] Bloomfield, J.A. (ed.), 1978. Lakes of New York State. Vol.1: The Ecology of the Finger Lakes. Academic Press.
[6] http://www.dec.ny.gov/chemical/83332.html
[7] Carlson, R.E. 1977. A trophic state indicator for lakes. Limnology & Oceanography, 22:361-369.

The change in water quality among lakes is also influenced by a number of other sometimes competing and always intertwined factors. First and foremost, the degree of water quality protection legislation and its implementation. They are important to protect the lakes from nutrient and sediment loading issues. So does ecological, “top-down” pressures by zebra and quagga mussels, Asian clams and *Cercopagis*, the fishhook water flea.

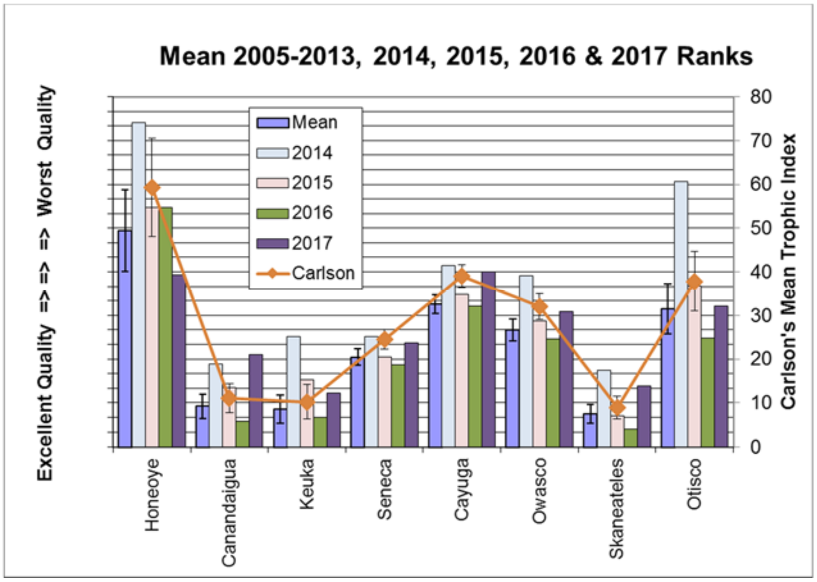
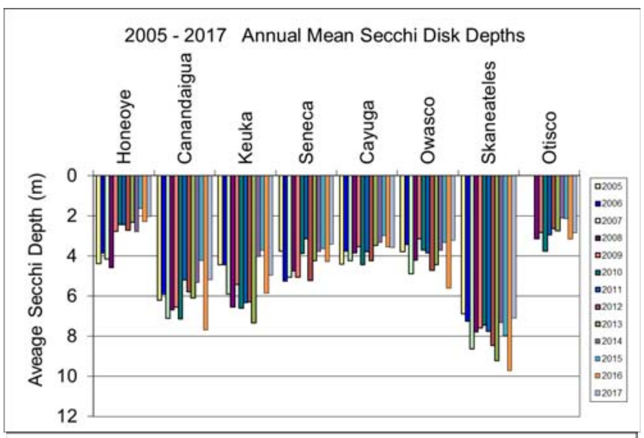
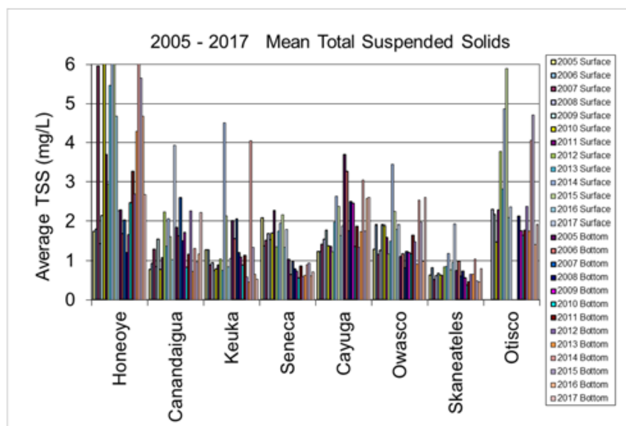
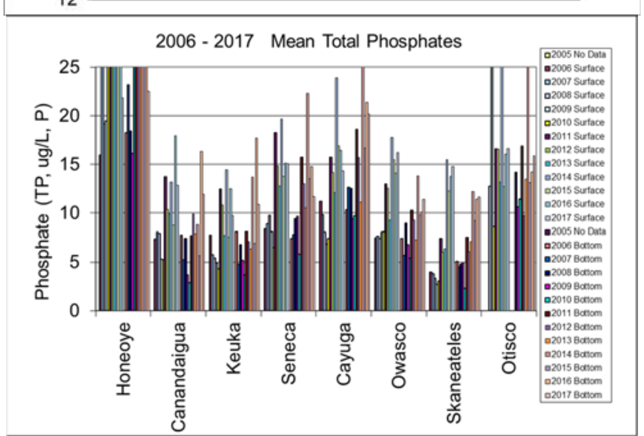
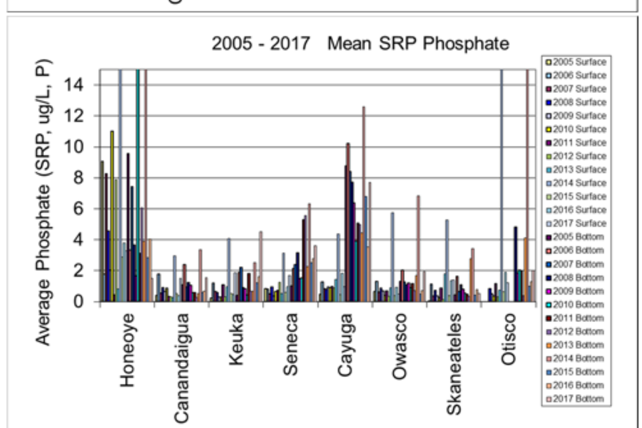


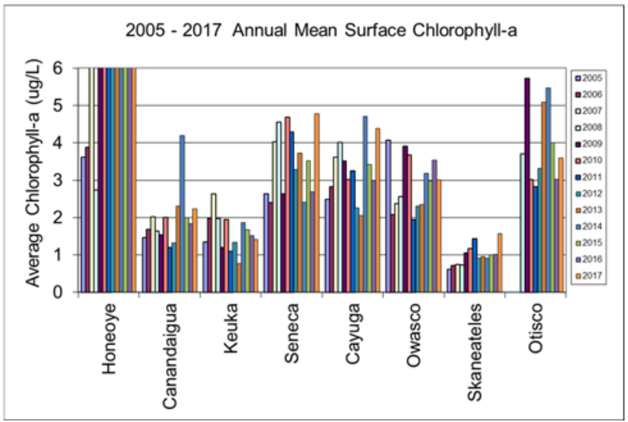
Fig. 10. Annual Water Quality Ranks from 2005 – 2017 for the eight easternmost Finger Lakes. The “mean” dark blue bar averaged the 2005 - 2013 ranks for each lake with a 1σ standard deviation error bar. Carlson’s mean trophic indices of the mean Secchi depths, total phosphate and chlorophyll concentrations are also shown.











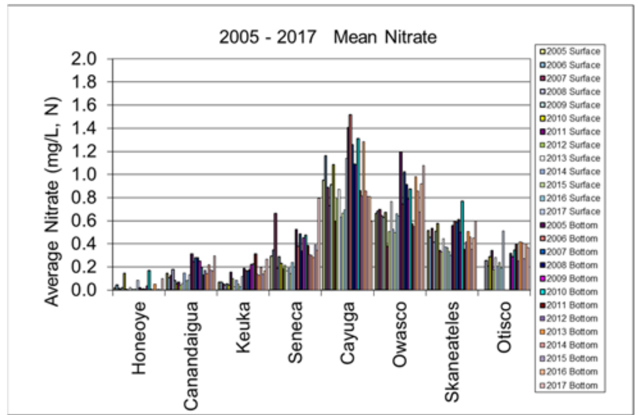


Fig. 11. Annual mean limnological data from the eight eastern Finger Lakes.

DRONE FLIGHTS

Drone images mapped the distribution and aerial extent of encrusting algae and macrophytes along the shoreline and continued an investigation of its use for algal, open-water concentrations (Fig. 12)[8]. The digital camera recorded the red, green and blue bands of the color spectrum that enabled further computer analysis back in the laboratory. Unfortunately, the combined 2016 and 2017 green to blue ratios only weakly correlated to total fluorescence measured by the buoys in Owasco and Seneca Lakes ($r^2 = 0.38$). Differences in water turbidity between years may have caused the challenges. The impact of other variables, e.g., glare from the sun, camera tilt angle, cloudiness, and extent and size of wind driven waves, also need further investigation.

Complete spectra (from 340 to 823 nm at ~0.5 nm intervals) of the upwelling and down-welling light were collected on a few occasions at a number of sites to find a better indicator of open-water algal concentrations (Fig. 13). The intent was to determine if the difference between upwelling and down-welling spectra could resolve algal concentrations as it should eliminate some of the variables mentioned above. The results revealed potential algal signatures in the near infrared portions of the light spectrum where plants emit the most light (wavelength of 750 nm). More work must be done next summer to improve these techniques, and we propose to continue our periodic drones flights and recovery of spectral signatures on more surveys to assess water quality in Owasco and neighboring lakes, and map the distribution and concentration of nearshore macrophytes, attached algae and blue-green algae blooms in the years ahead.

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[8]Swete, B., Bradt, S., Halfman, J.D., I. Dumitriu, 2016. Exploratory drone research on water quality of the Finger Lakes. Rochester Academy of Science 43rd Annual Fall Conference.

Dumitriu I., P. Spacher, J.D. Halfman. 2017. Drone quantification of algal distributions and concentrations in lakes. Intern. Assoc. Great Lakes Research, May Conference.

Fig. 12. Spliced drone images from Burtis Pt on 6/18 (left), Burtis Pt from 100m altitude on 9/23 (top right) and Burtis Pt from 25 m altitude (bottom right). Notice how BGA blooms are barely visible at 100 m but are visible from 25 m.

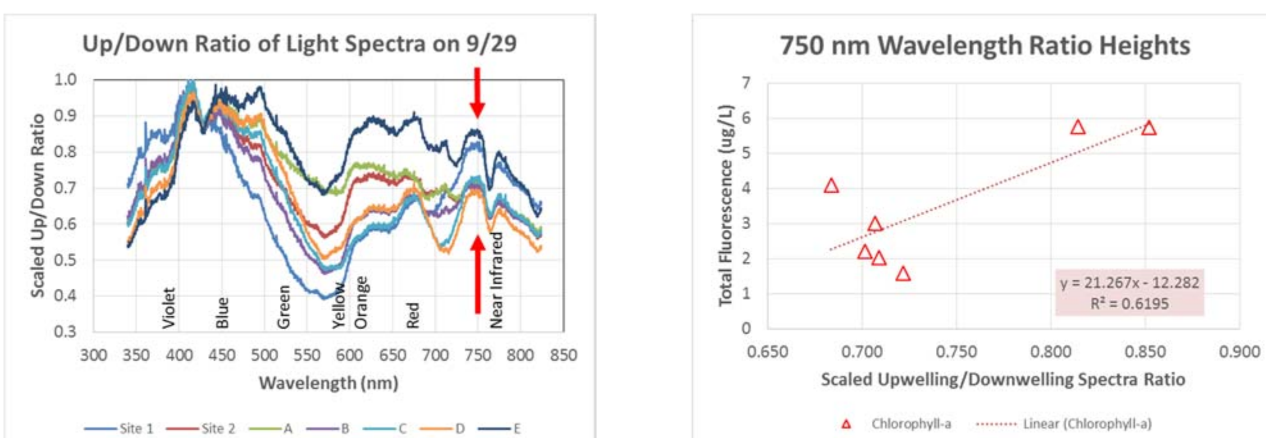


Fig. 13. Ratio of upwelling and down-welling spectra from Sites 1, 2 and A – E on 9/27 (left). Plant signatures are typically in the near infrared (~750 nm). Peak heights at 750 nm for each up/down spectral ratio vs. total fluorescence measured by bbe fluoroprobe (right).

Nearshore flights at 100 meters occasionally missed some nearshore BGA blooms (Fig. 12). Many of the blooms, when present, only extended a meter of two away from the shoreline, where they could be hidden from the drone flying at 100 meters by the shade from trees and other objects. Flights at lower altitudes however did resolve the presence of these nearshore blooms, typically concentrated in little indentations along the shoreline (Fig. 12). Interestingly, the locations with blooms in our extended nearshore survey also had the largest areas for macrophyte and attached algae colonization as determined by the relative areas of the shallow water, 2 - 4 m, shelf (Fig 14). Perhaps the macrophytes, attached algae and other nearshore organic matter was the source of the nutrients required to stimulate the BGA blooms. Bacterial decomposition and associated release of bioavailable nutrients in the nearshore sediments may be sufficient by late summer to stimulate these blooms. Wave action could then release the nutrients to the water column or the BGA could simply utilize the nutrients directly from the sediment. More details are presented in the companion BGA report. Next year's nearshore effort plans to collect data to confirm this hypothesis.

FOUR YEARS OF BUOY DATA

The FLI meteorological and water quality monitoring buoy was redeployed in Owasco Lake during the 2017 field season. It revealed higher resolution but otherwise consistent changes in the water column as described in the CTD section (Fig. 15). Epilimnetic (surface water) temperatures increased from 3.5ºC in April up to 25ºC in mid-July. Surface waters remained above 24ºC until mid-August then dipped temporarily to 19ºC by early September only to warm again to 22ºC (ºF) by the end of September. Eventually the surface water cooled down to 17ºC (ºF) by the end of the deployment. Hypolimnetic temperatures slowly increased from below 4 to 6.7ºC (40ºF) during the deployment.

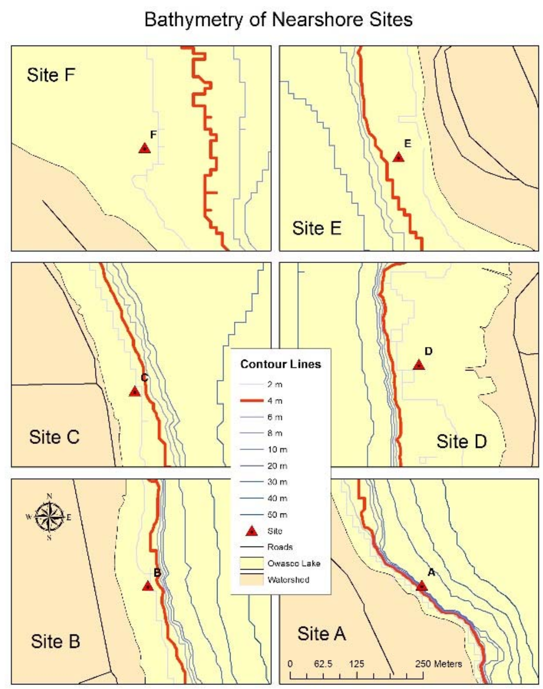


Fig. 14. Bathymetry of the six nearshore sites using a 2 m contour interval. The 4 m contour is highlighted in red as it probably represents the maximum depth for macrophyte growth.

In general, all four years revealed similar seasonal patterns explained by the typical daily, weekly and seasonal changes in climate. The epilimnion was slightly cooler in 2017 than 2014 and 2015 and the hypolimnion was slightly warmer in 2017 that the past three years. The 2017 timing of the epilimnetic peak temperature was similar to 2015, warming to 25ºC by late July whereas it warmed to 25ºC by early July in 2014. The seasonal cooling in the fall started earlier in 2014 as well, i.e., the surface waters cooled below 20ºC by mid-September in 2014 but was two weeks later in 2015, 2016 and 2017. The change probably reflected the earlier onset and longer duration of the very cold 2014/2015 winter season. Finally, the prolonged late-August dip in water temperatures in 2017 was observed but not to a similar magnitude in the earlier three years. It indicates that Owasco Lake responds to variability in rainfall and temperature.

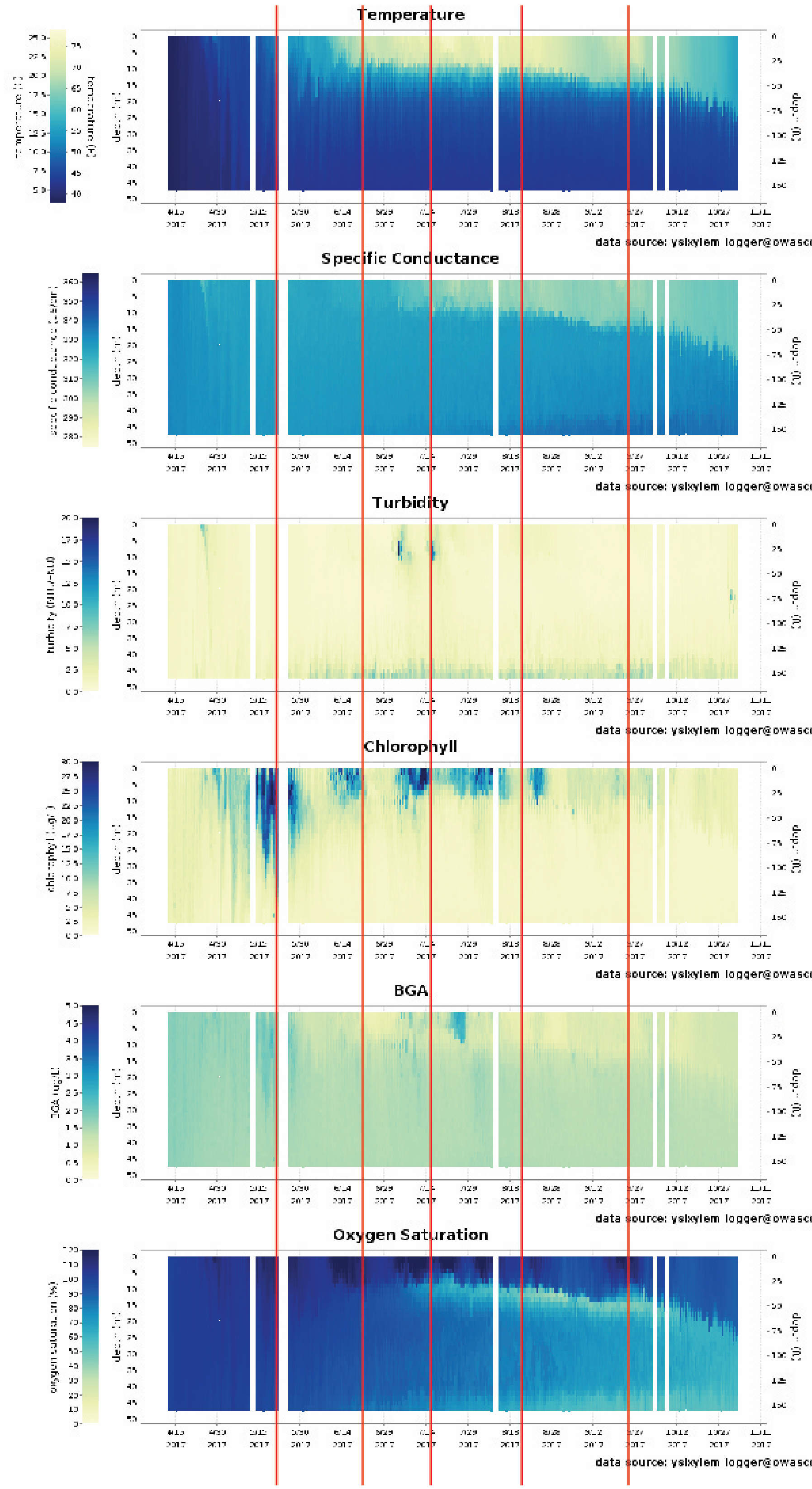


Fig. 15. Buoy water quality data in 2017. Note, algal concentrations shown above are over-estimates but these estimates provide accurate relative changes. Corrected values were used in this report and will be entered into the buoy website shortly. The red lines depict the monthly monitoring cruise dates.

The depth of the thermocline, the boundary between the epilimnion and hypolimnion, gradually increased through the field season from < 10 m to > 20 m in all four years. The thermocline depth deepened faster during September and October reflecting the vertical mixing of surface water to deeper depths as the epilimnion cooled into the fall, i.e., the gradual decay of summer stratification. It also revealed daily oscillations of 1 to 2 meters in response to internal seiche and/or wave activity. Similar oscillations were detected in previous years.

The epilimnetic specific conductance (proportional to salinity) decreased from 325 μS/cm in early July to 300 μS/cm by mid-July, and then increased by ~10 μS/cm by the end of October (Fig. 15). These changes are small (~10 ppm). The decrease probably reflects the dilution of the epilimnion by stream inputs and rainfall, but their impact is complicated by the relative salinities of the numerous subwatersheds flowing into the lake. A notable exception is in 2016, where the specific conductance decrease is abnormally large for a "dry" year. On closer inspection, it appears that the majority of the specific conductance drop was during 7/15/16 and 7/16/16. Perhaps zebra mussel larvae or encrusting algae fouled the sensor. The subsequent surface water increase in salinity reflects the mixing of slightly more saline hypolimnetic water into the epilimnion as the surface waters cool and vertically mixed with deeper water in the fall. The hypolimnetic salinity increased from just below 330 μS/cm to nearly 340 μS/cm from late April to late September, then decreased by a few μS/cm until recovery in late October. Similar hypolimnetic trends were observed in the earlier deployments, although hypolimnetic salinities were slightly larger in 2015 than both 2014 and 2016, whereas salinities were slightly smaller in 2015 than 2017.

The epilimnetic turbidity varied and was large in 2017 (Fig. 15). Large (5 to 8.5 NTUs) spikes in surface water turbidity were observed in April, two more in July, and smaller peaks in mid-August and September. Runoff associated turbidity spikes were also detected in previous years. The larger turbidities most likely reflected the runoff from spring rains and subsequent resuspension events by winds/waves, and late summer algal populations. Lake-floor turbidities were much larger in 2017 than previous years as well, and the 2015 and 2017 benthic turbidities were larger than those in 2014 and 2016. The change is interpreted to reflect the early spring rains and wind/wave resuspension events in 2015 and again in 2017, supplying suspended sediment to the nepheloid layer.

The chlorophyll-a concentrations measured by the buoy changed significantly from ~2 to over 20 μg/L on different temporal scales (Fig. 15). One to two week long blooms with concentrations exceeding 10 μg/L were detected in May, mid-June, early July through early August, late August and mid-September. The algae were typically concentrated within the upper epilimnion (shallower than 10 m), however the May bloom was unusual in that it extended down to 40 meters. More algae is expected in the surface water (epilimnion) because algae require light for photosynthesis. The early spring deeper depths are interpreted to reflect a weaker thermal stratification that allowed deeper mixing of the surface water. The September and October blooms probably responded to nutrient inputs from rain events and/or the decay of the seasonal thermal stratification and mixing of nutrient-rich hypolimnetic waters into the epilimnion. Algal concentrations have increased from 2014 through 2017, a disturbing water quality trend.

BGA concentrations never exceeded a few μg/L at the buoy, compared to the nearshore bloom concentrations of a few hundred to a maximum of 45,463 μg/L in 2017 (DEC and Watershed Inspector data, by permission, Fig. 15). The low open-water BGA concentrations were confirmed by the bbe fluoroprobe water column profiles (Fig. 6). The discrepancy therefore reflects the surface and shoreline hugging distribution of BGA blooms. It also confirms that minimal concentrations detected by the buoy in previous years was also due to the mid-lake, open-water, deployment of the buoy. It appears that shoreline annual mean BGA concentrations have increased over the past four years from ~ 10 to over 5,000 mg/L in 2017 (Fig. 16). Be careful over-interpreting these trends because they may be an artifact of sample bias, as the BGA concentrations typically change radically within a few meters of the shoreline.

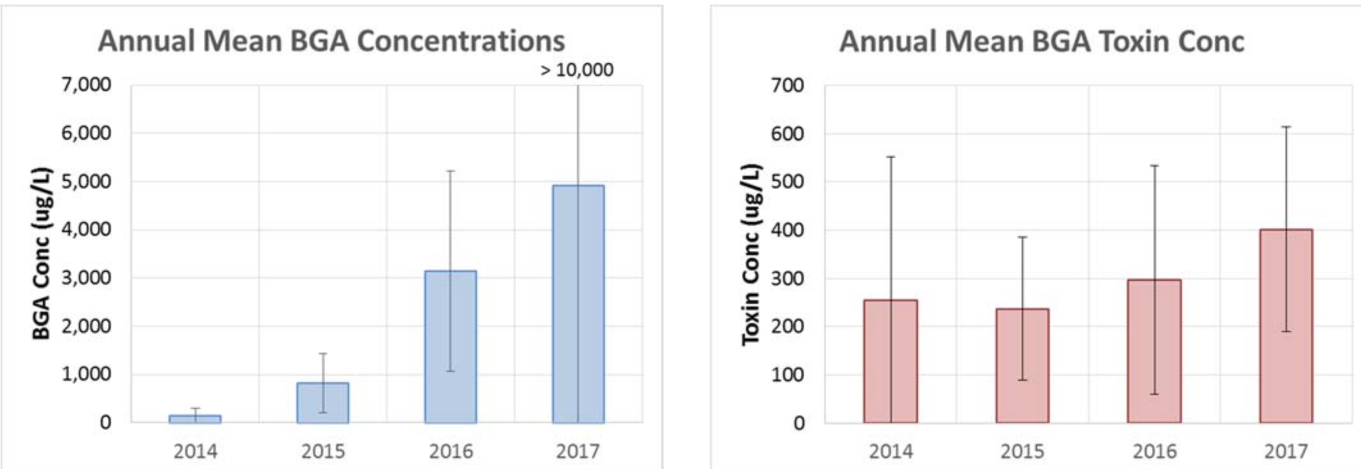


Fig. 16. Annual mean BGA and BGA toxin concentrations (with standard deviations) in Owasco shoreline areas.

Finally, epilimnetic dissolved oxygen (DO) concentrations in 2017 were at or just above saturation throughout the deployment (Fig. 15). Hypolimnetic DO concentrations decreased from nearly saturated concentrations in late May to below 40% saturation just below the thermocline by the end of August and down to 50% saturation along the lake floor by the end of September. The depletion reflects the respiration by bacteria, zooplankton and other animals at these depths. A similar pattern in DO was observed in previous years but the depletion was slightly more severe, i.e., to ~30% saturation in 2015, and extended later into the fall, i.e., into September during 2015 and 2017 than 2014 and 2016 although these differences are small.

STREAM MONITORING RESULTS & DISCUSSION

Stream Discharge: Stream discharge data from the four stream survey dates in 2017 ranged from nearly dry, 0.01 m^3/s (6/28) conditions at Fire Lane 20 to 9.65 m^3/s (6/7 flood) in Owasco Inlet at Moravia (Table 6 in appendix, Fig. 17). These flows revealed typical seasonal variability.

Spatial patterns in discharge were consistent over time. The 2017 mean and individual discharge measurements were larger at those sites with a larger drainage basin upstream from the site on any given sample day as in previous years (Fig. 18, $r^2 = 0.97$). The annual mean measured discharge of Owasco Inlet (299 km^2), Dutch Hollow Brook (77 km^2), Mill (78 km^2), Hemlock (47 km^2) and Fillmore Creek (16.5 km^2) were 6.19, 1.31, 2.43, 0.65 and 0.36 m^3/s, respectively, and proportional ($r^2 = 0.96$) to subwatershed area. Interestingly, Mill Creek has always yielded more water for its basin size every year of the FLI survey.

Within Dutch Hollow Brook, mean annual discharge at each site typically equaled or was slightly larger than the sum of the discharges at the next upstream site and any measured tributaries entering along the segment between sites (Fig. 17). For example, the sum of the mean annual discharge at North Rd was similar to the sum of the discharges at South, Benson tributary, and Benson Rd sites. Discharge increased downstream from North Rd to 38A on all sample dates unlike a few previous “dry” years. It suggests that surface runoff and shallow groundwater flow persistently contributed to and increased stream discharge from North Rd down to Rt 38A during “wet” years. In contrast, the stream probably lost water to evapotranspiration by plants, and/or into the permeable sand and gravel aquifer at the Dutch Hollow Brook delta, during extreme, i.e., nearly dry, base flows in “dry” years.

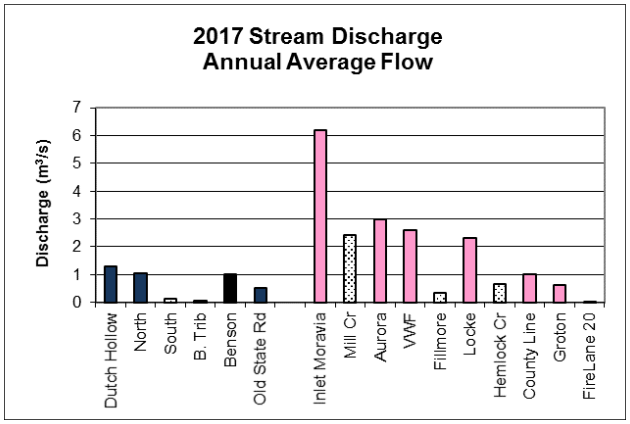


Fig. 17. Annual average stream discharge at each stream site in the Dutch Hollow Brook (purple), Owasco Inlet (pink) and Fire Lane 20 watersheds based on the 4 grab sample survey dates. Tributary sites are stippled. Sites are arranged, left to right, from downstream to upstream.

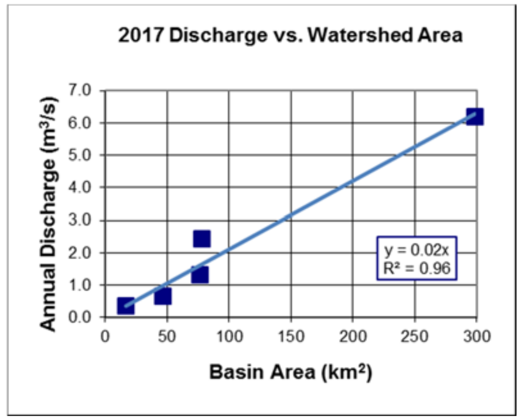


Fig. 18. Discharge vs. Basin Size.

Within Owasco Inlet, tributary inputs typically accounted for the majority of the observed downstream increases in discharge (Fig. 17). For example, the mean discharge at the Locke site was slightly smaller than the sum of the mean discharge upstream of Locke and Hemlock Creek. The discharge at Moravia (at Rt 38) was slightly smaller than the combined discharge at Mill Creek, a tributary to Owasco Inlet, and at Aurora St, the next upstream site. Groundwater inputs and/or other small tributaries probably provided the difference.

Seasonal Variability: Seasonally, the largest discharges of 2017 were detected in the spring and smallest in the fall based on the data logger estimated discharge data for Dutch Hollow at the Rt 38A site and the USGS gauge data for Owasco Inlet (Fig. 19). The spring dominance was also detected in previous years. The seasonal pattern between the summer and fall varies from year to year but always paralleled the seasonal change in precipitation and evapotranspiration (Fig. 20).

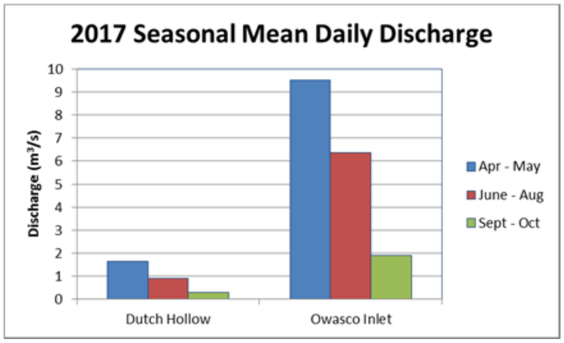


Fig. 19. Seasonal averaged stream discharge for the Rts. 38A and 38 sites, the terminal sites on Dutch Hollow Brook and Owasco Inlet, respectively.

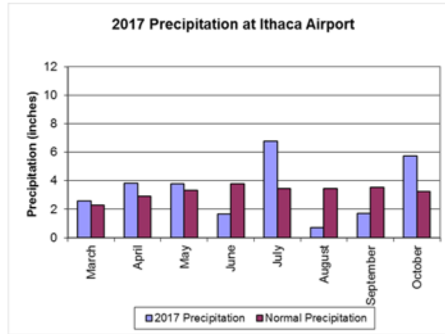


Fig 20. Monthly and "normal" precipitation totals for the Ithaca Airport.

Differences to Earlier Years: The 2017 annual mean discharge at the downstream sites was "in-between" those detected at Dutch Hollow Brook but the largest at Owasco Inlet over the past decade (Fig. 21). These differences are partially explained by parallel changes in precipitation. The 2017, May through June, and the 5-month field season precipitation totals were "in-between" the "dry" and "wet" years as measured at the Ithaca Airport (Fig. 22). It designates 2016 and 2012 as "dry" years, 2013, 2014 and 2017 as "in-between" years, and 2011 and 2015 as "wet" years. Perhaps localized events were more intense and/or more numerous in the Owasco Inlet subwatershed than Dutch Hollow.

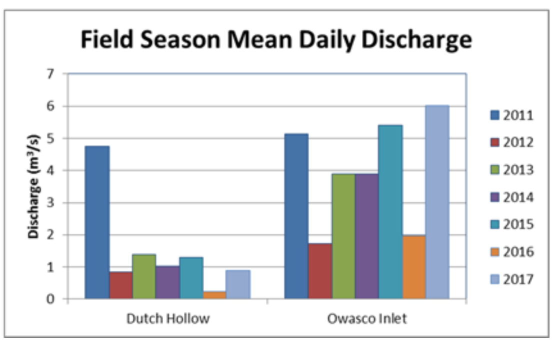


Fig. 21. Field season annual average stream discharge for the Rts. 38A and 38 sites. This plot used the estimated Dutch Hollow Brook data logger and USGS daily Owasco Inlet discharge data.

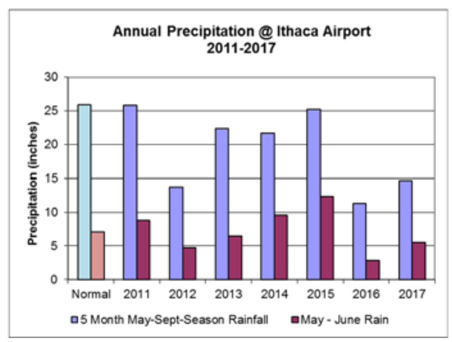


Fig. 22. Annual precipitation totals during the 8-month, March – October, field season, and during May & June at the Ithaca Airport.

The Owasco Inlet (USGS Gauge, 4235299) mean, field-season, daily discharge of 6.0 m^3/s indicates a "wet" year for 2017 compared to discharges of 5.1, 1.7, 3.9, 3.0, 5.4 and 2.0 m^3/s in 2011 through 2016, respectively (Fig. 23). Similar variability was observed for the Owasco Outlet (USGS Gauge, 4235440, Fig. 23). Annual mean daily outflows were 11.4, 5.9, 9.1, 8.6, 9.4, 7.3 and 12.8 m^3/s for 2011 through 2017, respectively. Clearly, 2013 and 2014 were "in-between" compared to the 2011, 2015 and 2017 "wet", and 2012 and 2016 "dry" years. Owasco Inlet discharge data designated 2017 as a "wet" year whereas the Dutch Hollow discharge implied an "in-between" year, and indicates that rainfall was NOT uniform across the entire Owasco Watershed. Since the Inlet is much larger than Dutch Hollow, the Inlet had a proportionally greater influence on water quality in the lake, perhaps designating 2017 as a "wet" year for water quality in the lake.

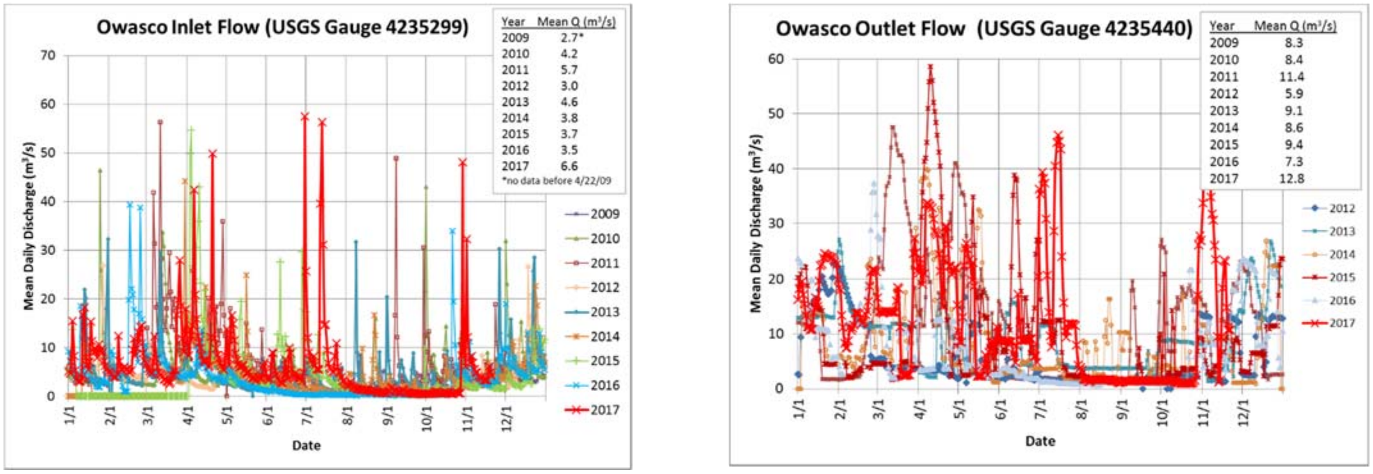


Fig. 23. Annual average stream discharge for the Owasco Inlet near Moravia (left) – USGS Stream Gauge 4235299 and the Owasco Outlet (right) – USGS Stream Gauge 4235440.

Extreme Events: Both the Owasco Inlet and Dutch Hollow revealed discharge events in their hydrology. Box and whisker plots of mean daily USGS discharge data for the May – June period at Owasco Inlet revealed larger mean flows in 2011, 2015 and 2017 (Fig. 24). The top whisker in the B&W plot also revealed larger events during 2011, 2014, 2015 and 2017 as well. The largest mean flows at Dutch Hollow Brook were in 2011 and 2015, not 2017. However, its largest events were in 2011, 2014, 2015 and 2017, and 2017 was more important if the event during early July is included (2017* in Fig. 24). This distinction is important because large events have an exponentially greater impact on nutrient and sediment loads to the lake. A few very large events can have the same impact on loads as much larger rainfall totals with more subdued events. It suggests that even though the mean discharge down Dutch Hollow was "in-between" in 2017, the large events could make up the difference and transform 2017 into a significant year for nutrient and sediment loads to the lake. Intense events will become increasingly more important was global warming intensifies, as one of the predictions for a greenhouse world is for more extremes in climate.

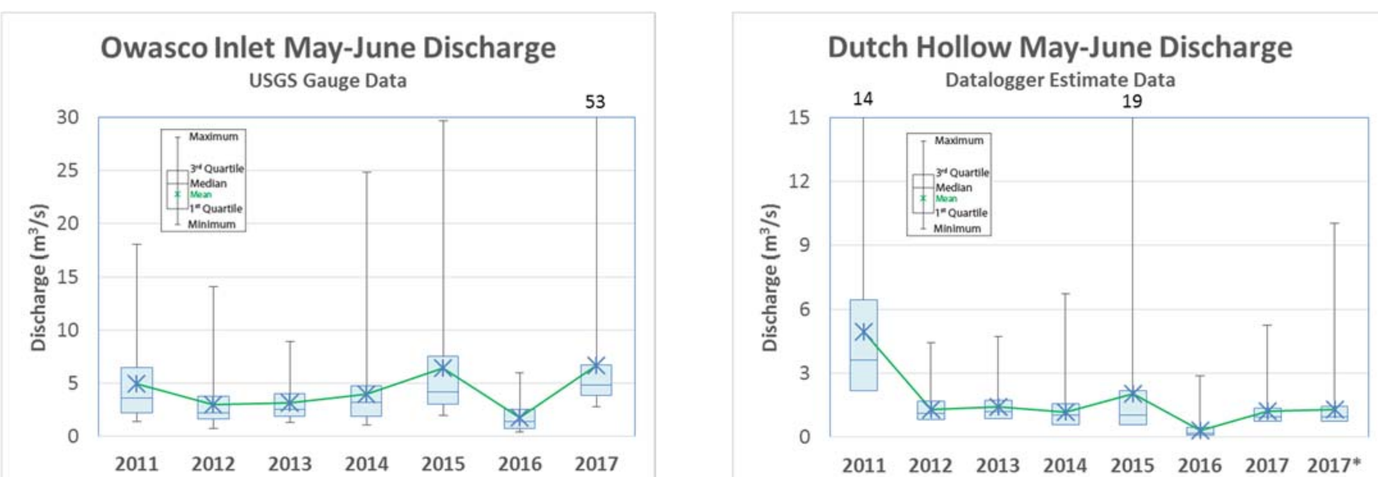
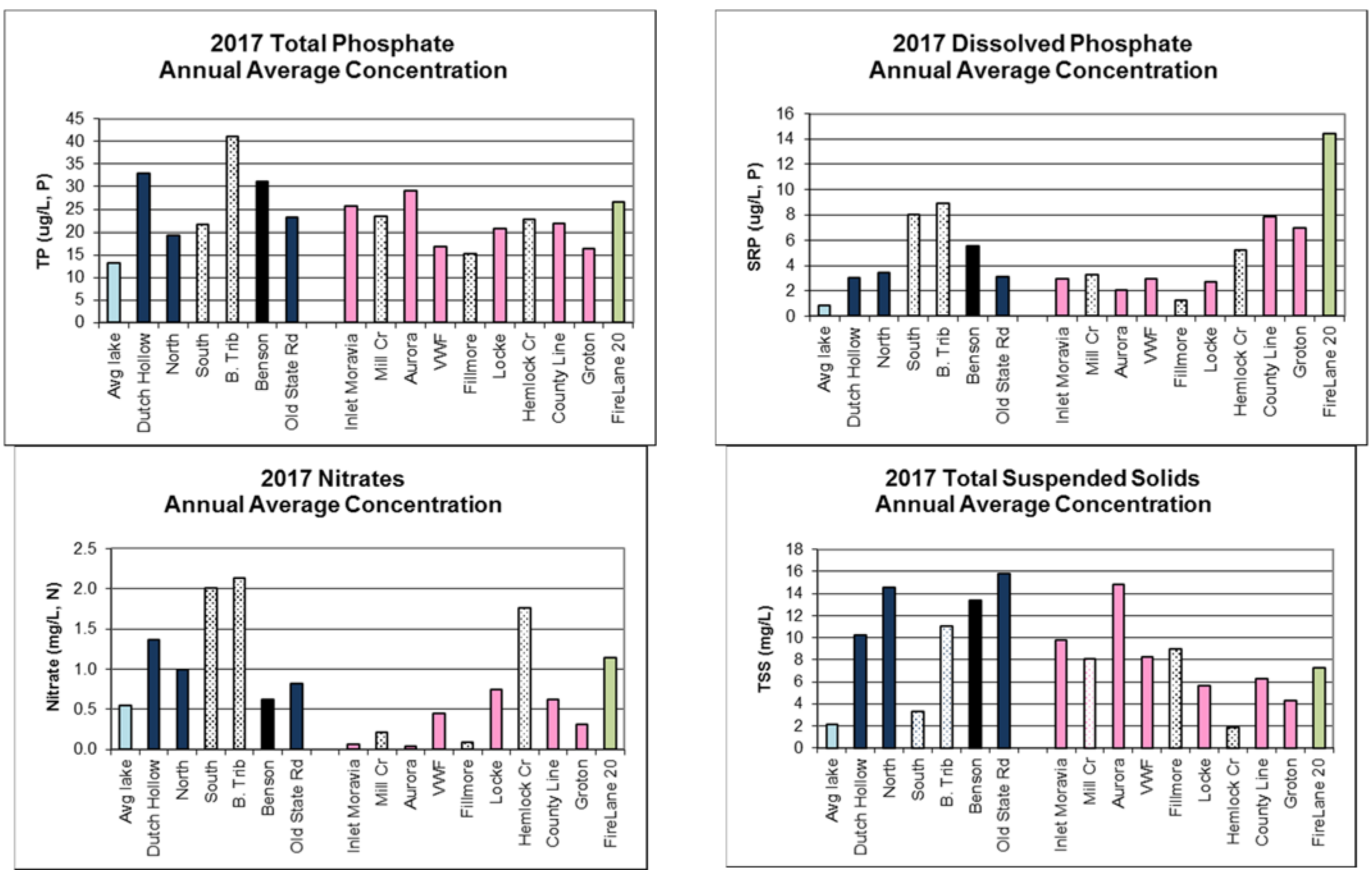


Fig. 24. Box and whisker plots of daily mean discharge during the May – June period over the past seven years for Owasco Inlet (left) near Moravia using the USGS Stream Gauge 4235299 data and Dutch Hollow Brook (right) using the Rt 38A data logger data. The 2017* included an event in early July.

Stream Concentration Data: Total phosphate (TP) concentrations in 2017 ranged from 4.0 to 80.2 μg/L, and averaged 28 μg/L in Dutch Hollow Brook, and ranged from 7.4 to 61 μg/L, and averaged 15.0 μg/L in Owasco Inlet (Table 6 in appendix, Fig. 25). Along Dutch Hollow Brook, the 38A, Benson Rd, and Benton Rd tributary sites revealed the slightly larger annual mean TP concentrations of 31 to 41 μg/L, whereas the North Rd, Benson Rd and Old State Rd sites revealed slightly smaller mean TP concentrations (at or under 23 μg/L). Of note, the Benson tributary had larger TP concentrations this year than the other sites whereas it was similar to the other sites in the past few years (Fig. 26). It suggests that recent remediation efforts within the Benson Tributary watershed could not decrease nutrient loading from the watershed in this event driven year.

Total suspended sediment (TSS) concentrations were largest at the North, Benson Rd, and Old State Rd sites (13 to 15.8 mg/L). The agriculturally-rich tributaries, South and Benson Rd tributaries, and the Rt 38A site were lowest (3.3 & 11 mg/L). A notable increase in TSS from North Rd to Rt 38A, was not observed in 2017 as in previous years. It suggests that recent agricultural BMPs decreased suspended sediment in the runoff. Alternatively, the very heavy spring rains and associated flooding washed the majority of the available soil away before these streams were sampled.



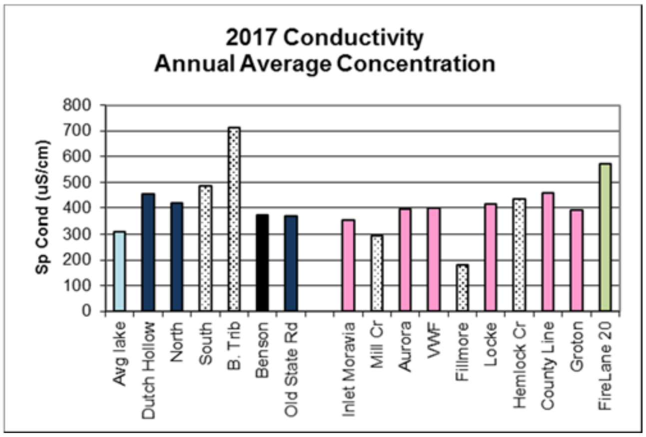
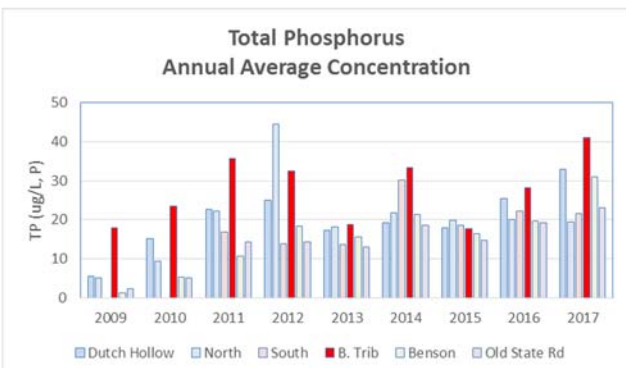
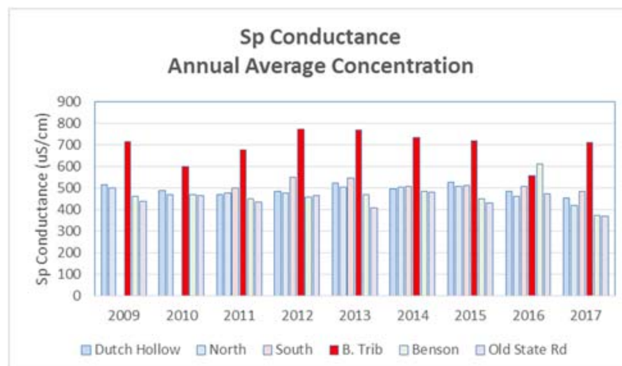


Fig. 25. Site averaged lake (light blue) and stream nutrient and suspended sediment concentrations for Dutch Hollow Brook (blue), Owasco Inlet (pink), and Fire Lane 20 (green). Tributary sites are stippled. Sites are arranged from downstream (left) to upstream (right).

Dissolved phosphate (SRP), nitrate and specific conductance (salinity) concentrations were slightly larger at the South and Benson tributary sites compared to the other sites in 2017. The concentrations were larger in 2017 at every site than 2016 but smaller in 2017 than earlier years.





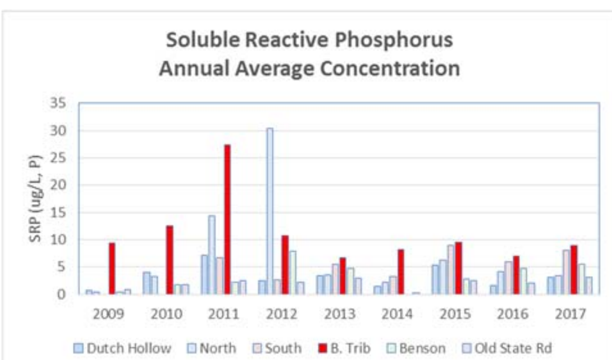


Fig. 26. Mean annual concentrations of total phosphorus, specific conductance and soluble reactive phosphorus at the Dutch Hollow Brook sites.

Along the Owasco Inlet, nutrient and sediment concentrations were similar to those at Dutch Hollow Brook. Mean annual TP and SRP concentrations increased slightly from Groton to County Line, and from Locke to Aurora, as in past years. The increase between these sites was not as dramatic as the pre-2007 notable increase in phosphorus between Groton and County Line attributed to the Groton WWTF effluent. The TP and SRP concentrations were typically smaller at Mill, Fillmore and Hemlock Creeks than the neighboring main stream sites but these differences were small. Mean annual total TSS concentrations did not reveal consistent patterns, except that Hemlock Creek had the smallest concentrations.

Fire Lane 20 data revealed the largest or near largest salinities and dissolved phosphate concentrations but similar TSS, TP and nitrate concentrations as the other sites. It appears that the agricultural and/or precipitation impact on this watershed increased in 2017 compared to 2016.

Stream Fluxes: Owasco Inlet revealed larger fluxes of nutrients and sediments than Dutch Hollow Brook, except for nitrates (TP 13.4 vs. 3.5 kg/day; SRP 1.4 vs. 0.3 kg/day; TSS 6,800 vs. 1,500 kg/day; N 40 vs. 199 kg/day, respectively, Fig. 27). Similar concentrations of nutrients and sediments between these two streams, but significantly larger discharges down the larger Owasco Inlet, resulted in its larger fluxes to the lake. As before, fluxes in the Owasco Lake watershed were sensitive to discharge and basin size. The fluxes measured in 2017 were larger than those in previous "dry" years but were less that the "wet" years (Fig. 28).

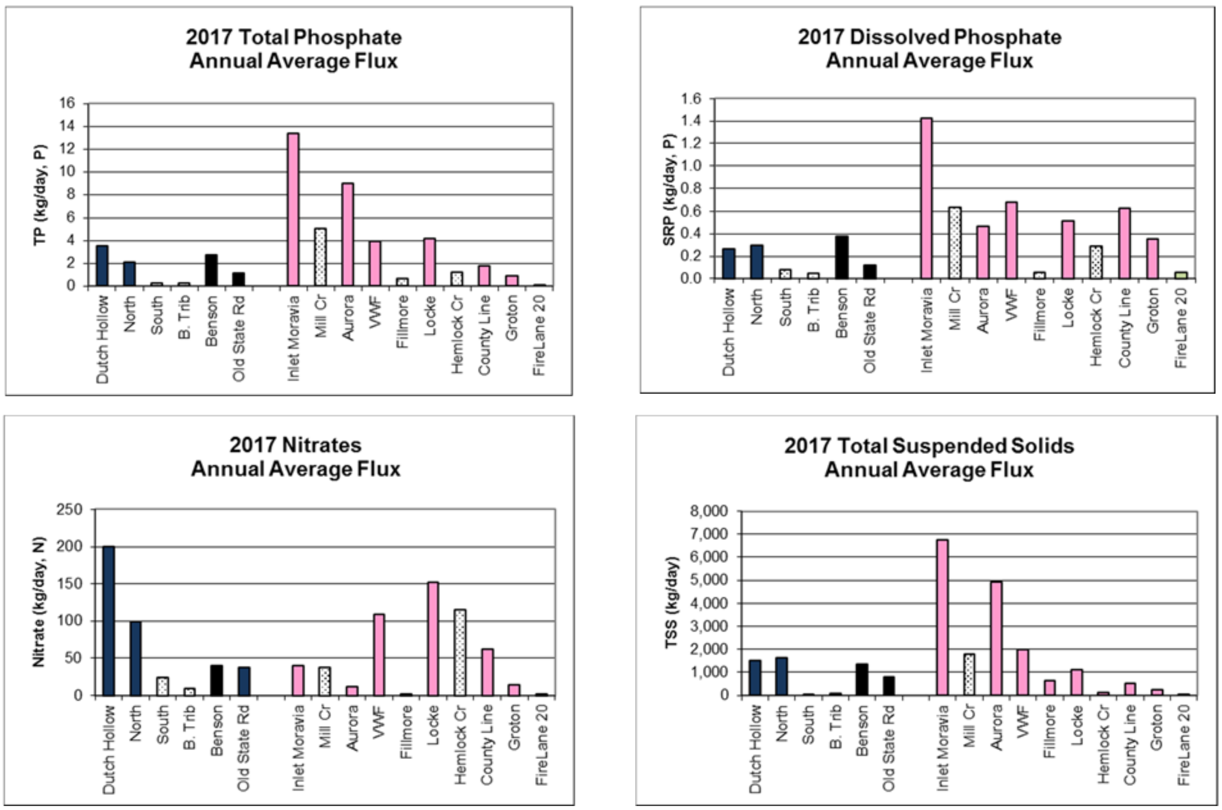


Fig. 27. Site averaged nutrient and sediment fluxes for Dutch Hollow (blue), Owasco Inlet (orange), and Fire Lane 20 (green). Tributary sites are stippled. Sites are arranged from downstream to upstream. Samples were not collected from the VFW site during the two largest "event" dates during 2016, which influenced the mean concentration and discharge and thus flux at this site

At the small end of the spectrum, fluxes at the Dutch Hollow Brook tributary sites (Benson and South sites) and Fire Lane 20 were smaller than the other sites in the survey. Small fluxes paralleled the smaller discharges at these sites. It follows that smaller watersheds with smaller discharges delivered the smallest fluxes, and larger watersheds with larger discharges delivered the largest fluxes. However, many small, 1st or 2nd order, tributaries (~40 in Fig. 2) like Fire Lane 20 drain into Owasco Lake. The combined TP load by all these small tributaries is estimated to be similar to the load from Dutch Hollow Brook (see phosphorus loading section below for tally of loads by source).

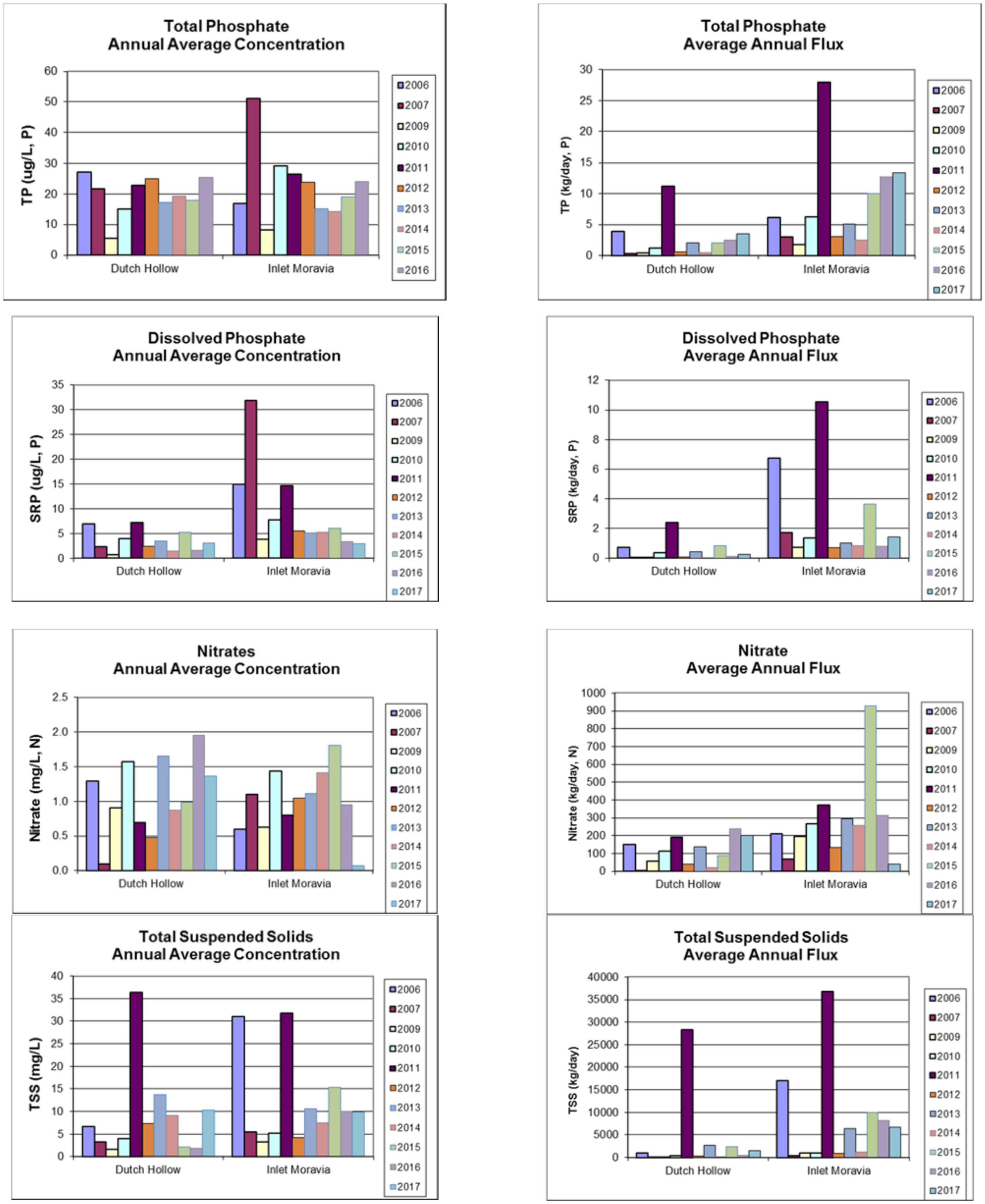


Fig. 28. Annual average stream grab sample concentrations (left) and fluxes (right).

As in previous years, no one tributary to Dutch Hollow Brook added significantly more nutrients. Thus, no one segment of this stream was the "primary" source of nutrients and sediments. Instead, Dutch Hollow Brook steadily gained nutrients along its entire course up to North Rd, a conclusion consistent with the pervasive nature of nonpoint sources throughout the watershed, and the drainage of agricultural land, animal feedlot operations, road-side ditches, golf courses, suburban homes and other nonpoint sources. The implications are critical. To remediate Dutch Hollow Brook's nonpoint source nutrient loading problem is more challenging than remediating a point source like Groton's wastewater treatment facility, because nonpoint source remediation efforts must be applied throughout the entire watershed, demanding cooperation by every land owner in the watershed.

The Owasco Inlet fluxes increased downstream in a similar manner as earlier years, except for nitrate (Fig. 27). Apparently a significant flux of nitrate entered Owasco Inlet at Hemlock Creek, and nitrogen was subsequently removed downstream, perhaps by algal and/or plant uptake. Hemlock has always revealed a high concentration of nitrate, but it was unusually high in 2017. The nitrate issues might also be related to poor quality (QA/QC) nitrate analyses in 2017. The input by adjacent tributaries typically account for the increases in downstream flux. Increases in phosphate from Groton to County Line were still apparent and reflected inputs from the Groton wastewater treatment facility (Fig. 29). However, the facility's contribution to the total load was significantly smaller than earlier years.

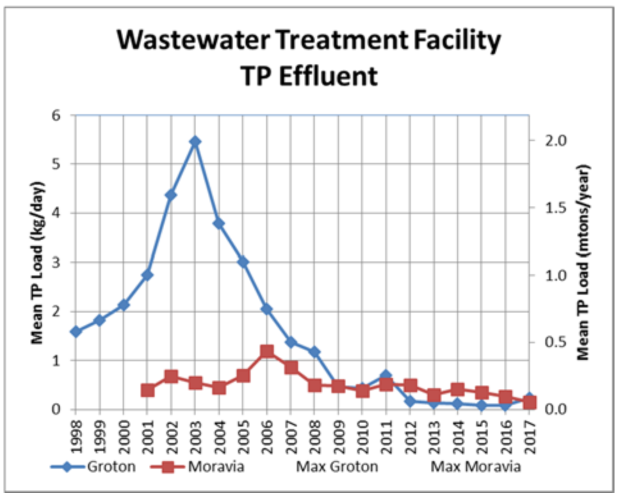


Fig. 29. Phosphorus loads from the Moravia and Groton wastewater treatment facilities.

EVENT SAMPLING ALONG DUTCH HOLLOW BROOK

Detailed Stage Data @ 38A along Dutch Hollow Brook: The 2017 mean stage data revealed textbook responses to precipitation events (Fig. 30). Each increase in stage corresponded to a precipitation event, with changes in stream height ranged from 5 to more than 100 cm above the adjacent base flow levels. Not all precipitation events induced a proportional stream response, especially during the spring when increases in stage were larger for similar sized precipitation events than the other seasons. The differences are interpreted to reflect seasonal changes in, for example, ground saturation, rainfall intensity, runoff/infiltration ratios and evapotranspiration. Similar seasonal and day to day, precipitation/event influenced changes in stage and temperature were detected during the past four years as well. Many more events were detected in 2017 than 2016, and similar to the earlier "wet" years (Figs. 30 & 31).

Detailed "Event vs Base Flow" Results @ 38A: Nutrients and sediments responded to the precipitation events throughout the 2017 deployment (Fig. 32). Total suspended sediments (TSS) increased dramatically from an average base flow concentration of ~7 mg/L to an average event flow concentration of 220 mg/L, and rose to a maximum of 734 mg/L on 10/30. These large TSS concentrations were restricted to the storm event, and declined quickly to base flow turbidities before the stream stage returned to base flow. It indicates that runoff events compared to base flow transported significantly more soil particles to and had a greater impact on water quality in the stream. It highlights the importance of large events.

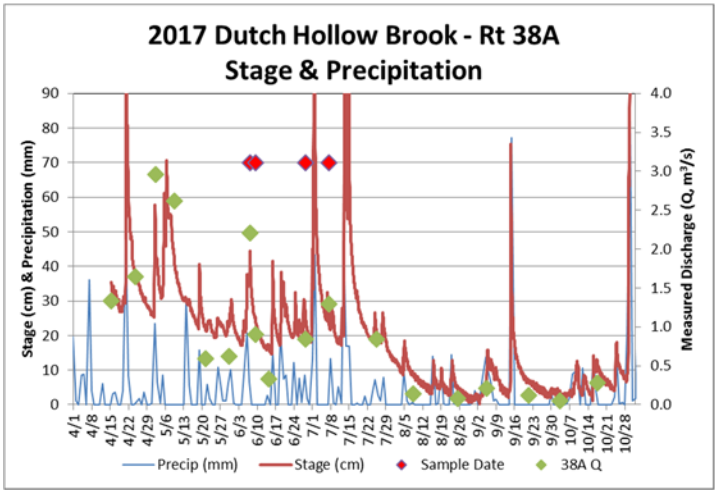


Fig. 30. Dutch Hollow Brook estimated discharge, precipitation, stream sample dates and measured discharge data for 2017 at Rt 38A. Precipitation data was from NY-CY-8, a CoCoRaHS station within the DH watershed.

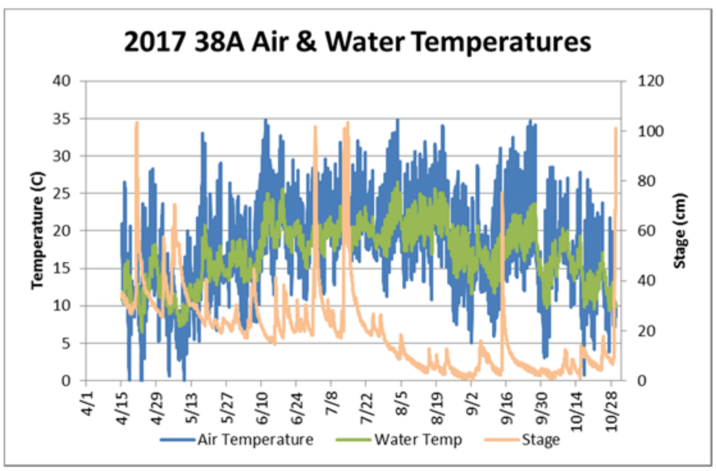


Fig. 31. Data logger stage, air and water temperature data at 38A.

Total (TP) and dissolved (SRP) phosphates revealed event responses as well. Mean TP and SRP event concentrations were significantly larger than base flow concentrations, increasing from base flow means of 13 and 3.2 μg/L to event means of 32 and 16 μg/L, respectively. Maximum event concentrations were 106 μg/L for TP and 67 μg/L for SRP. Again, 2017 event concentrations suggest a direct linkage to and the importance of precipitation induced runoff events for phosphorus loading to the lake. Thus, the remediation steps to reduce phosphate loading are similar to remediating suspended sediment, i.e., reduce the movement of soil particles from the watershed to the lake. The literature indicate that drain tile are an import source of SRP. It allows less phosphorus to be bound and retained in the soils. Although not specifically measured in this watershed, drain tiles and the ditches they empty into should be remediated as well.

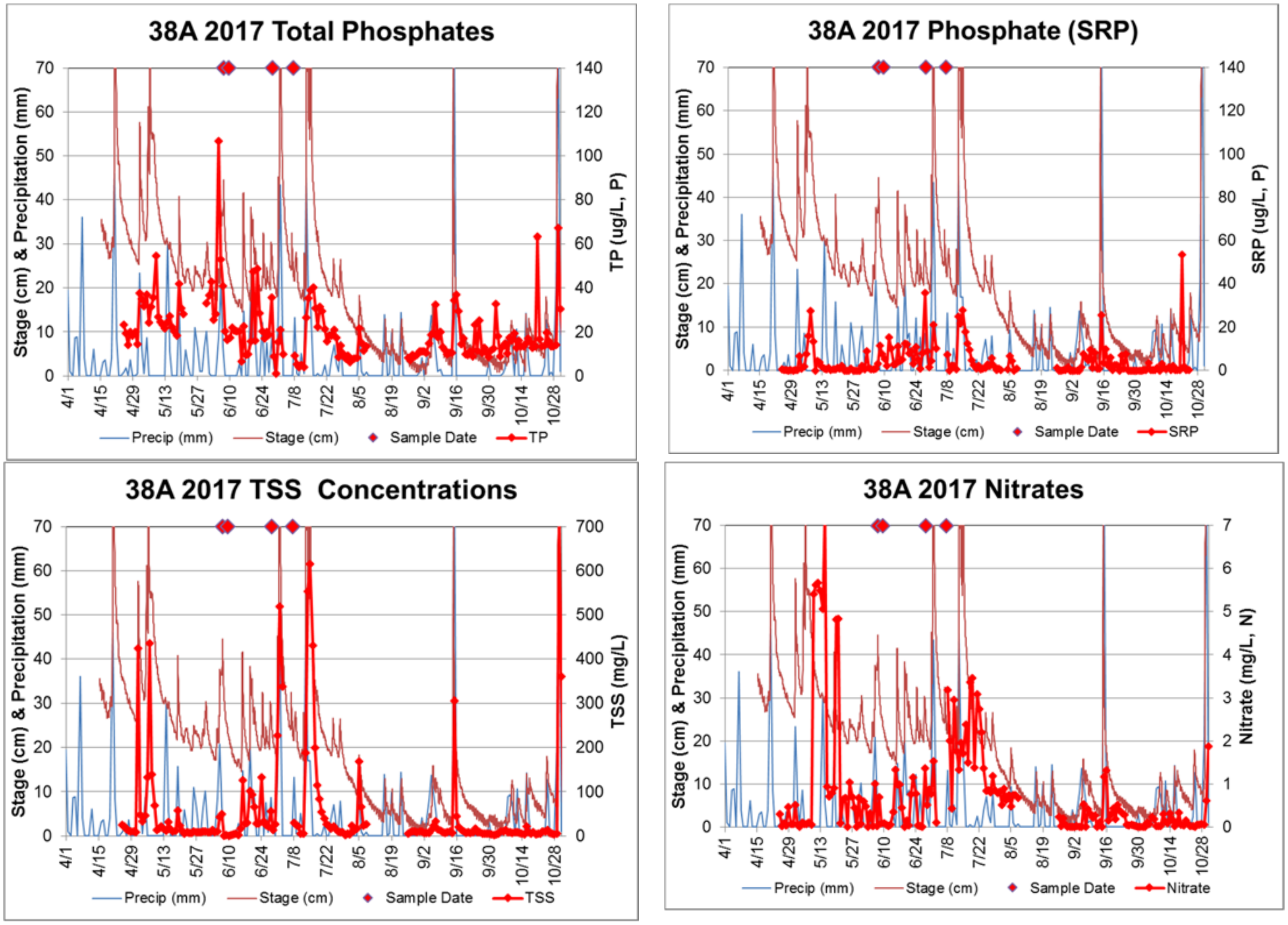


Fig. 32. Rt 38A daily nutrient and suspended sediment concentrations.

The event *versus* base flow results suggests a number of potential remediation practices to reduce TSS impairments as mentioned in previous reports. For example, roadside ditches should be hydro-seeded and/or utilize other flow reducing structures to decrease water velocities and the erosion potential of the draining water. Slower water speeds allows for greater deposition of the particles with the attached phosphorus before it enters the stream. This is more critical if drain tile effluent enters a roadside ditch as drain tiles efficiently transport phosphorus from the fields to the ditch. In agricultural areas, buffer strips of vegetation should be established and maintained alongside each stream course, because the vegetated strips reduces the runoff velocity and allows particles with attached phosphorus to settle out before entering the stream. Installation of gully plugs, vegetation strips and retention ponds in low lying areas provide another mechanism to retard the movement of suspended sediments before the runoff spills into the nearby stream. Farmers should also plant a winter crop cover, as it reduces topsoil erosion from their fields during the late fall, winter and early spring seasons. This is most critical in the early spring when the soils are thawed and still saturated, conditions ripe for the largest erosion rates. All of these practices worked in the Conesus Lake watershed. These practices however remove tillable acreage from the farmer and/or require additional time on the fields to, e.g., plant winter cover crops, and thus reduce her/his annual income.

Nitrates, once again, revealed a slightly different response to events than TSS, TP and SRP. The largest nitrate concentrations still correlated with events with mean event concentrations of 1.3 and base flow concentrations of 0.4 mg/L, however this difference was much smaller than those observed in the TSS, TP and SRP data. The increase to the peak concentration and subsequent decline to base flow conditions took slightly longer for nitrates as well. It indicates that runoff provided extra nitrates to the stream. However, precipitation events also rejuvenate near-surface groundwater flow, which contributed to the nitrate load as well, extending the nitrate response to the event as runoff flows faster than groundwater flow. Nitrates have a different event/base flow response than TSS, TP and SRP because nitrates are water soluble and not bound to particles, thus they can enter a stream by both runoff and groundwater routes. In contrast, phosphates are typically particle bound, thus groundwater does not transport TP, SRP and TSS.

Event vs. Base Flow Fluxes @ 38A: To calculate daily fluxes from Dutch Hollow Brook, a discharge was determined for each sample using a best-fit, 2nd order, polynomial relationship between the data logger stage data and weekly to bi-monthly discharge measurements at 38A (r^2 = 0.99). It established a stage/discharge rating curve for the site (Fig. 33). Even though years previous to 2016 employed a linear relationship, a 2nd-order, polynomial fit provided a better match to the 2016 and 2017 stage/discharge data.

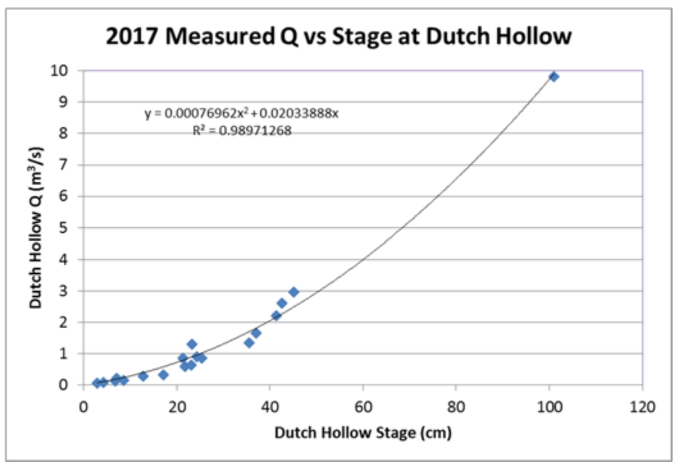


Fig. 33. Best fit correlations between weekly to bi-monthly measured discharge and data logger stage data at 38A site.

The TSS, TP, SRP and N fluxes were clearly event driven (Table 7, Fig. 34). In 2017, TSS, TP, SRP and N event *vs.* base flow fluxes at 38A averaged 29,200 *vs.* 175, 4.2 *vs.* 0.2, 2.1 *vs.* 0.1 kg/day and 14,400 *vs.* 900 kg/day N, respectively. During the 2017 April through October deployment, Dutch Hollow provided 2,510,000 kg of sediment to the lake during events, but only 15,000 kg during base flow conditions. In a similar light, the 2017 events delivered 365 kg of TP, 184 kg of SRP and 14,400 kg of N to the lake compared to base flow contributions of 30 kg of TP, 8 kg of SRP and 900 kg of N. In conclusion, each year revealed significantly larger event than base flow loads for TSS, TP, SRP and N along Dutch Hollow Brook (Table 7). Apparently, the importance of the largest events. It highlights that the flux from a few large events in an "in-between" year can equal the total flux of many smaller events in a wet year.

Annual changes were also observed. The 2017 mean annual fluxes for TSS were 2nd largest compared to previous years, reflecting the increase in large events during 2017 and/or the availability of loose sediments after the 2016 "dry" year (Fig. 35). The change was less striking for TP and SRP, where 2017 mean annual fluxes were closer to the 7 year average, and more consistent with the "in-between" rainfall in 2017. The high TSS in 2017 may reflect the transport of loose stream bed sediments in 2017 that were not moved in 2016, a "dry" year. The largest nitrogen fluxes were during 2016, a "dry" year, when nitrogen-rich groundwater inputs to the stream were more significant to the basin's hydrology.

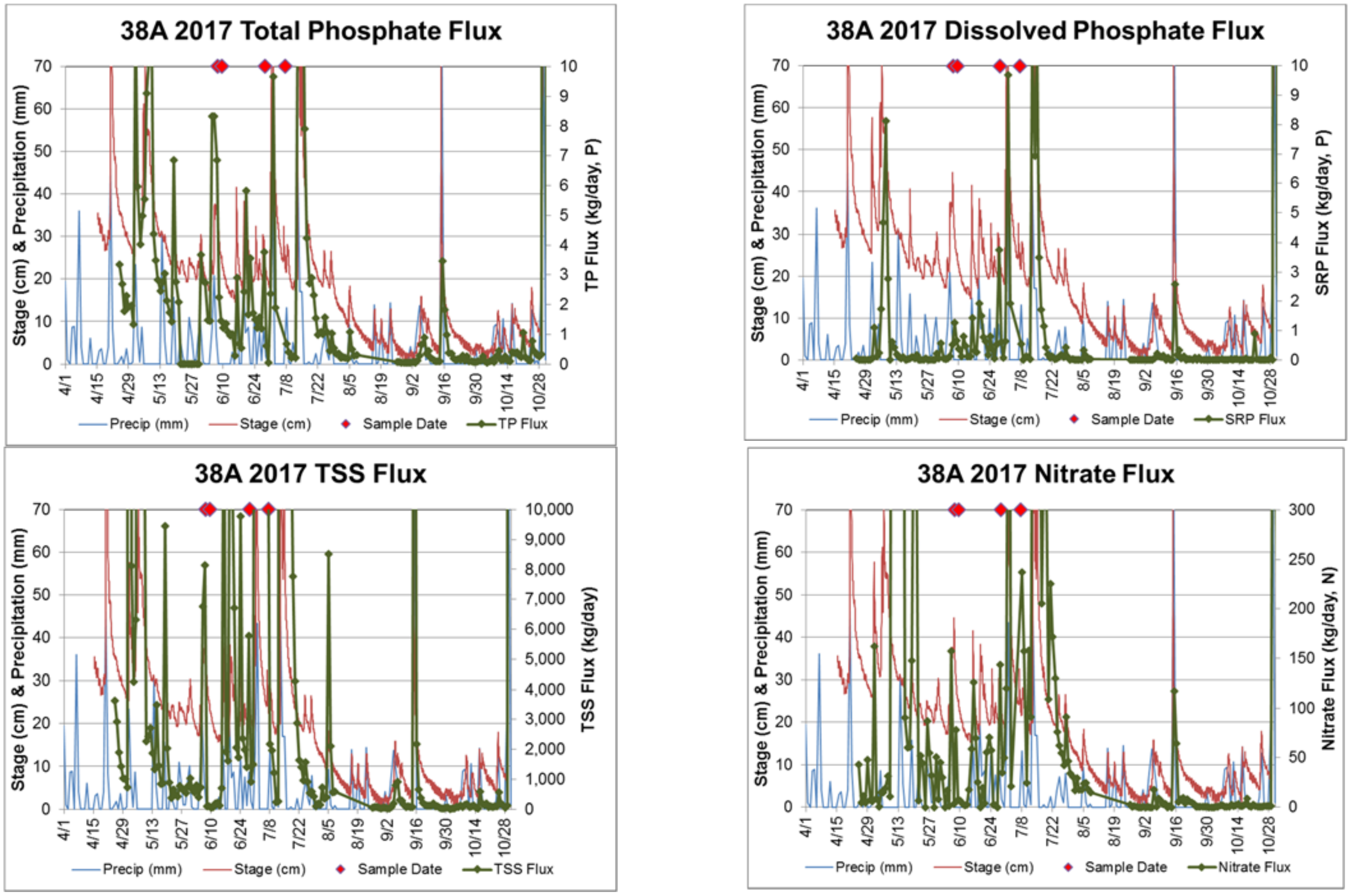


Fig. 34. Autosampler nutrient and suspended sediment fluxes.

These relationships were even more apparent when rainfall totals focused on May through June; a time frame when soils are saturated and thus more rain is directed to runoff than infiltration, but the soils are thawed enough to enable soil erosion. Plant life is also absent or just rebounding from winter dormancy at this time, and thus not available to retard runoff velocities and reduce water volumes by evapotranspiration. Farm fields are also typically tilled bare of vegetation in preparation for spring planting of crops at this time, increasing their potential for erosion as well (Fig. 36).

The event *versus* base flow data also indicate that grab samples underestimated annual fluxes down a stream. For example, the 2017 autosampler estimated a mean sediment flux of 14,800 kg/day, total phosphates 2.2 kg/day, dissolved phosphates 1.1 kg/day, and nitrates 84 kg/day; whereas the grab sampling estimated an annual mean flux of 1,590 kg/day for sediments, 3.5 kg/day for total phosphates, 0.3 kg/day for dissolved phosphates, and 200 kg/day for nitrates. The grab samples typically estimated smaller fluxes because these samples were usually biased to base flows. Grab samples are therefore less accurate for detailed flux estimates compared to the daily data collected by the autosampler and data loggers. However, grab samples are essential for stream segment analysis and the investigation of nutrient and sediment sources from within a watershed.

Table 7: 2011 – 2015 Autosampler Fluxes at Dutch Hollow Brook.

2011 (6/9-11/4)	TSS	Nitrate	TP	SRP
Mean (kg/day)	8,700	75	2.7	1.7
Event (kg/day)	24,500	180	6.9	4.5
Base Flow (kg/day)	115	19	0.4	0.1
% by events	99%	84%	90%	96%
2012 (3/20-11/2)	**TSS**	**Nitrate**	**TP**	**SRP**
Mean (kg/day)	2,400	69	1.9	0.4
Event (kg/day)	6,850	150	4.0	0.6
Base Flow (kg/day)	190	28	0.9	0.2
% by events	95%	73%	70%	60%
2013 (4/10-10/29)	**TSS**	**Nitrate**	**TP**	**SRP**
Mean (kg/day)	7,550	270	4.4	1.3
Event (kg/day)	12,000	370	6.4	1.8
Base Flow (kg/day)	290	100	1.3	0.3
% by events	99%	85%	89%	91%
2014 (4/19-10/28)	**TSS**	**Nitrate**	**TP**	**SRP**
Mean (kg/day)	14,600	115	3.5	1.6
Event (kg/day)	36,000	185	6.5	3.2
Base Flow (kg/day)	300	67	1.5	0.5
% by events	99%	65%	74%	81%
2015 (4/19-10/28)	**TSS**	**Nitrate**	**TP**	**SRP**
Mean (kg/day)	35,600	180	3.7	2.3
Event (kg/day)	81,500	370	7.7	5.2
Base Flow (kg/day)	185	27	0.5	0.0
% by events	99%	93%	94%	99%
2016 (4/13-10/25)	**TSS**	**Nitrate**	**TP**	**SRP**
Mean (kg/day)	7,482	1,323	1.4	0.7
Event (kg/day)	25,844	4,602	4.7	2.3
Base Flow (kg/day)	137	11	0.1	0.0
% by events	99.5	99.8	97.1	99.2
2017 (4/25-11/25)	**TSS**	**Nitrate**	**TP**	**SRP**
Mean (kg/day)	14,770	84	2.2	1.1
Event (kg/day)	29,195	167	4.2	2.1
Base Flow (kg/day)	176	9	0.3	0.1
% by events	99.4	94.1	92.3	96.0

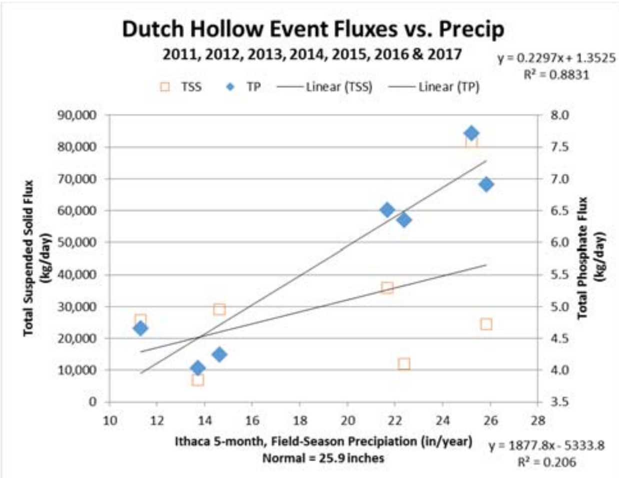


Fig. 35. Estimated annual total phosphorus loads vs field season (5-month) rainfall at the Ithaca Airport.

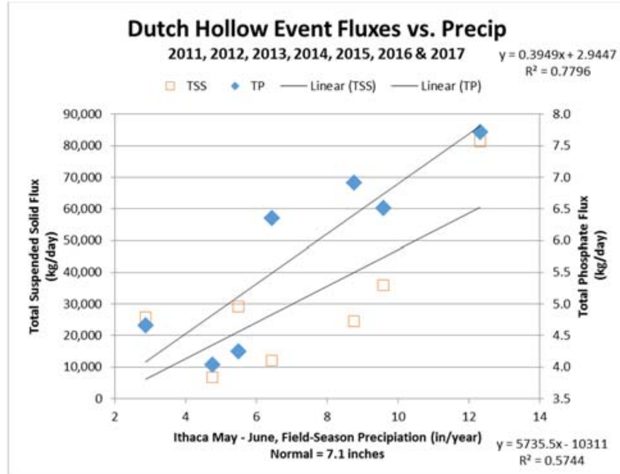


Fig. 36. Estimated annual total phosphorus loads vs May-June spring rainfall at the Ithaca Airport.

PHOSPHORUS BUDGET:

Phosphorus loads are critical to the health and water quality of Owasco Lake because phosphorus limits algal growth and thus impairs water quality and clarity. The development of blue-green algae blooms, some with life threatening concentrations of toxins, also highlight its importance. Clearly, stream loads dominate the inputs, even in “dry” years. However, the stream inputs are only one part of the equation. A complete budget must also include other inputs like atmospheric loading, onsite septic systems and lakeshore lawns. Outputs must also be calculated to estimate the net change in phosphorus for the lake (Fig. 37). The net change is critical because the amount of phosphorus will increase in the lake, if inputs exceed outputs. Phosphorus will decrease in the lake, if inputs are less than outputs. Finally, phosphorus remains the same, i.e., at equilibrium, when inputs equal outputs. To improve water quality, the inputs of phosphorus must be smaller than outputs for a number of years (multiple water retention times). A sustained reduction allows phosphorus in the lake to leave by the outlet or be buried in the sediments, and increasingly limit algal growth and improve water quality and clarity. The required “cleansing” time frame in the Owasco watershed is a decade or more.

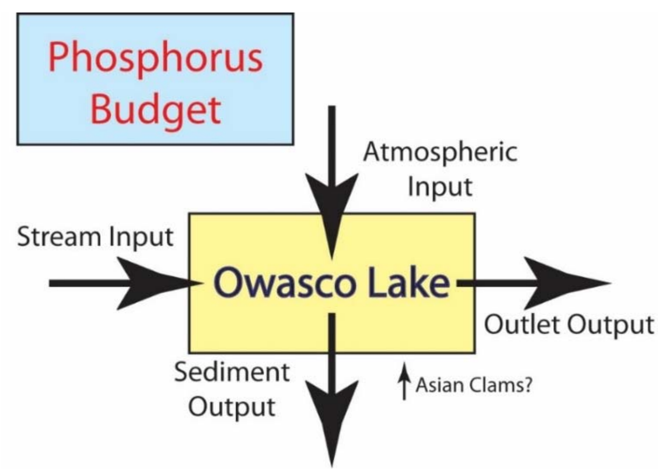


Fig. 37. The Owasco Lake phosphorus budget: Sources and sinks for phosphorus in Owasco Lake. Water quality improves if **inputs are less than outputs**, for a number of years.

The Inputs: The Moravia and Groton WWTF added 0.1 metric tons P to the Owasco Inlet in 2017[9]. The detailed 38A autosampler data calculated a mean total phosphate flux of 2.2 kg/day from Dutch Hollow Brook in 2017. Owasco Inlet delivered 13.4 kg/day based on the available 2017 stream grab data. The 2017 load from Owasco Inlet was then estimated at 8.2 kg/day assuming a proportional change between the mean grab sample total phosphorus loads to the detailed autosampler loads from Dutch Hollow Brook. An extrapolation of fluxes and surface areas from Dutch Hollow Brook, Mill Creek, Hemlock Creek and Owasco Inlet to the entire Owasco watershed, estimated an input of 5.0 metric tons of phosphorus from every stream to the lake in 2017. The stream extrapolation incorporates all the 1st and 2nd order (small) tributaries like Fire Lane 20. The 2011 report estimated atmospheric and septic system inputs at 0.1 metric tons/year and ~1 metric ton/year, respectively. Loads from water fowl were estimated. The 0.1 mton/year contribution from 1,000 geese that poop on average 3 times/day, yielding 1.5 g dry poop/dropping at 1% phosphorus content[10], living on Owasco Lake for the entire year was deemed insignificant and ignored. The estimated exaggerated geese numbers and length of stay. The contribution from clams/mussels (Asian clams and zebra/quagga mussels) is unclear at this time as clam and mussel lake-floor densities are unknown.

The total 2017 influx of phosphorus is estimated at 6.2 metric tons/year.

The Outputs: Phosphorus is lost from the lake through the Outlet in the form of algae, dissolved organic-rich compounds, organic-rich particulates, and the occasional larger organism (e.g., fish). Approximately 3.7 metric tons of phosphorus escaped out the Outlet in 2017 assuming a 2017 annual mean total phosphate concentration in the lake of 9.2 μg/L, and a 2017 mean daily discharge of 12.8 m^3/s through the Owasco Outlet (USGS Owasco Outlet Gauge #04235440). The 2011 report estimated the flux of phosphorus to the sediments of a few metric tons per year and this estimate is again used here. The earlier report cautioned that more work was required to firm up this sediment burial estimate, because the flux was based on only a few sediment cores.

The total 2016 efflux of phosphorus is estimated at 6.5 metric tons/year.

The Net Flux: Owasco Lake thus lost approximately 0.3 metric tons of phosphorus in 2017. Since 2011, the lake gained phosphorus during five years and almost gained as much as it lost in the past two years (Fig. 38). Since 2011, the mean annual input was 9.7 mtons/year, 3.0 metric tons/year more than the mean output of 6.6 mtons/year. Earlier estimates of annual nutrient fluxes were based on limited summer grab samples thus not included in this report. The pervasive positive balance indicates that significant remediation efforts must take place to move Owasco Lake to a negative balance and eventually improve water quality. The decrease to near equilibrium conditions in 2016 and 2017 is encouraging and perhaps Owasco Lake is responding to the performed remediation efforts, but inputs must be much less than outputs to improve water quality.

The contribution from stream sources changed from year to year, whereas the inputs from other sources were relatively constant over the past seven years (Fig. 39). For example the annual contribution from the Owasco Inlet, excluding the wastewater treatment facilities (WWTFs),

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[9] http://cfpub.epa.gov/dmr/facility_search.cfm Groton: NY0025585, Moravia: NY0022756.
[10] Fleming and Fraser, 2001. The impact of water fowl on water quality – a literature review. Ridgetown College, U of Guelph, Ontario, Canada.

ranged from 7.2 to 30.0 metric tons since 2011. The variability reflects changes in precipitation intensity and totals. In contrast, the WWTFs contributed from 0.1 to 0.4 metric tons/year over the same time interval. Despite the variability in stream inputs, they are always the largest contributors of phosphorus to the lake, ranging from 78 to 91% of the total load, and averaged 85% of the load. The stream dominance clearly pinpoints where remediation efforts should be focused to reduce phosphorus loads to the lake. Remediation therefore should include reduction in inputs from non-point sources like agricultural areas, both animal farms (manure spreading and barnyard runoff) and crop farms (drain tile effluent), road-side ditches and construction sites. Finally, the large nutrient and sediment inputs in 2011, 2014, 2015 and 2017 were coincident with and probably "triggered" the recent BGA blooms[11]. Even though coincidence does not prove causation, these four years of excessive loads were unique within this time frame. Assuming these large loads were the trigger, the time is paramount to start large-sale nutrient loading reduction programs in the watershed. Otherwise the lake will continue to degrade and experience more BGA blooms into the future.

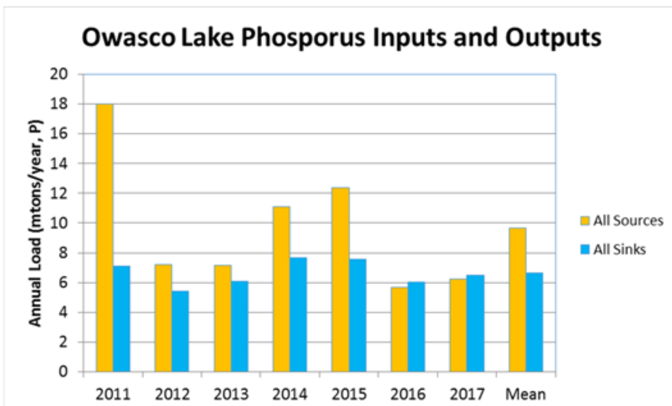

Fig. 38. Estimated annual total phosphorus inputs and outputs for Owasco Lake.

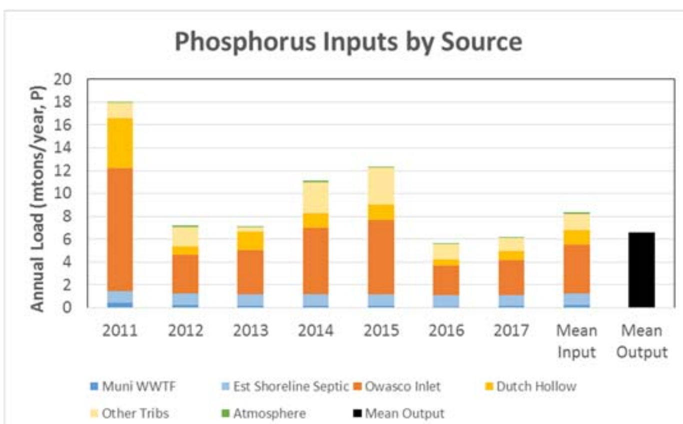

Fig. 39. Estimated annual inputs of phosphorus by source for Owasco Lake.

[11]Halfman, J.D., 2017. Water quality of the eight eastern Finger Lakes, New York: 2005 – 2016. Finger Lakes Institute, Hobart and William Smith Colleges. 51 pg.
Halfman, J.D., 2017. Decade-scale water quality variability in the eastern Finger Lakes, New York. Clear Waters. Fall 2017, v. 47, No. 3, pg. 20-32. http://nywea.org/clearwaters/uploads/Decade-ScaleWater7.pdf

CONCLUSIONS & RECOMMENDATIONS:

This report confirms and expands on earlier findings.

Owasco Lake Water Quality:

- Owasco Lake is a borderline oligotrophic – mesotrophic lake. The improvements in water quality from 2011 through 2013 were lost in 2014 and 2015, regained in 2016, but lost again in 2017.
- Phosphorus is the limiting nutrient for algae growth in Owasco Lake.
- The water quality degradation in 2014, 2015 and 2017 is attributed to the heavy rains and/or intense precipitation events in those years, especially in the spring.
- The 2017 spring rainfall was not one of the largest on record but it experienced large events. In contrast, the 2017 algal blooms and suspended sediment concentrations were some of the worst on record. The dichotomy highlights the importance of rainfall totals AND event intensities.
- The water quality buoy provided a more robust view of water quality in the lake by detecting algal blooms and other events missed by the monthly lake surveys over the past four years.

Blue-Green Algae Blooms:

- Blue-green algae (BGA) concentrations were small at the open-water sites, typically much smaller (up to 10,000 x's smaller) than the shoreline blooms.
- The annual mean BGA concentrations in the shoreline blooms steadily rose from 2014 through 2017. Many of the blooms contained threatening and increasing concentrations of toxins, both microcystins and anatoxins over the past four years.
- Bubblers, ultrasonic vibrators, benthic mats and other in-lake strategies might provide stop-gap measures to reduce the extent of the BGA blooms until the nutrient loading issue is resolved. NEVER use herbicides because Owasco Lake is a drinking water source for over 44,000 people, and herbicides are toxic to humans.
- Lakeshore owners that draw water from the lake need affordable mechanisms (or financial support) to reduce their risks from the BGA toxins.
- More details on BGA blooms and the associated HABs are contained in a companion report that focuses on the water quality analysis of a number of nearshore sites.

Stream Loads & Watershed Phosphorus Budget:

- Daily discharge data for Owasco Inlet and Dutch Hollow Brook revealed the worst events in 2011, 2014, 2015 and 2017. The 2017 events were probably more localized, as they impacted Owasco Inlet more than Dutch Hollow Brook. Event localization will be increasing more prevalent as global warming increases its impact in the future.
- The excessive nutrient loads during 2014 and 2015, and again in 2017, were coincident with and perhaps triggered the onset of the blue-green algae in Owasco and many other Finger Lakes. Once these loads triggered the initial blooms, BGA have typically returned in larger numbers to the same nearshore locations.
- Segment analysis lacked significant point source signatures along Dutch Hollow Brook and Owasco Inlet.
- Both the Moravia and Groton municipal wastewater treatment facilities have done an amazing job keeping their phosphorus loads to a minimum.
- The event *versus* base flow analysis at Dutch Hollow Brook highlights the dominance of events and associated runoff of nonpoint sources to the delivery of phosphates and sediments

to the lake. It also provided more accurate load estimates than grab samples, especially in those years when surveys were limited to base-flow conditions during the summer months. Event and base-flow loads in 2017 were “in-between” those determined for earlier years and correlated very well to field-season and May-June rainfall. It pinpoints potential remediation strategies to decrease the erosive powers of runoff.

- The estimated phosphate budget for Owasco Lake indicated that the lake lost some phosphorus in 2017. The loss reflects larger algal concentrations in the lake and larger flows out the outlet.
- Partitioning the total loads by major sources, i.e., Owasco Inlet, Dutch Hollow Brook and other streams, lakeshore onsite septic systems, municipal wastewater treatment facilities, and the atmosphere, confirms that streams are the primary source of nutrients and sediments to the lake over the decade long monitoring effort. Owasco Inlet was always the largest fluvial contributor and Dutch Hollow Brook was not too far behind. The stream inputs however vary from year to year, dependent on the amount and intensity of the spring rains. Contributions from geese and other large water fowl are insignificant.

Remediation Strategies:

The ongoing nutrient loading and its negative impact on the lake’s water quality commands the immediate use of numerous remediation strategies. The sooner they are installed the sooner the lake might return to its original oligotrophic state.

- More BMPs should be installed, where necessary, to reduce nutrient and sediment loading from agriculturally-rich watersheds. The critical areas for BMPs are along stream banks and in the low lying and other water saturated areas in each field. The BMPs include buffer strips, gully plugs, vegetation strips, barnyard cleanup, and other means to slow down and stop the runoff of nutrients and sediments.
- Roadside ditches, especially those that accept tile drain effluents, should be hydro-seeded, have catch basins installed and employ other strategies to retain the nutrient and sediment load on land before the runoff enters the lake. The ditches and catch basins will require periodic cleaning to be effective.
- The time is also ripe to strengthen existing regulations and uniformly adapt these new/strengthened regulations across the entire watershed. The areas of focus include: onsite septic systems, disposal of animal wastes and deer (and other) carcasses, drain tiles, phosphorus-free fertilizers, grass-clipping and leaf litter disposal, and other areas of concern to reduce the nutrient and sediment loading to the lake. Even though many of these issues are already regulated, clearly the current regulations are **NOT** stringent enough because Owasco Lake currently has a nutrient loading problem.
- Perhaps all human and animal wastes in the watershed should be treated at a municipal wastewater treatment facility instead of the current practices. This option would be expensive though.
- Additional flood basins should be built near the terminus of Owasco Inlet and initiate another project at Dutch Hollow Brook. Floating wetlands should be anchored just offshore of tributary mouths, as the vegetation would utilize some nutrients and thus reduce nutrient loads to the lake. Do not let the vegetation die and decompose in the water and thus release these sequestered nutrients back into the lake.
- Nutrients should also be removed from the lake, when feasible. For example, macrophytes should be harvested from the nearshore areas in the late summer. Those macrophytes and attached algae that wash up on the shoreline should be removed before

they decompose along the lakeshore. The BGA blooms themselves should be vacuumed before they disappear.

- Owasco Lake is probably too large and the existing phosphorus concentration too small for phosphorus sequestration techniques like using binders like Alum and Phoslock (bentonite clay) that remove available phosphorus from the water column and bury it into the sediments. However phosphorus binding materials should be used in road-side ditches and at the opening of drain tiles to remove phosphorus from this effluent stream.
- The sports fisheries is probably too vital for the local economy to use bio-manipulation strategies.
- Finally, the financial burden to install the remediation efforts cannot be placed solely on farmers, lakeshore landowners or other individual groups. Water quality is a watershed-wide issue. Everyone benefits from a cleaner lake. Thus, everyone must support the remediation efforts. Yeah for Governor Cuomo!

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Table 2. 2017 Lake Data.

2017 Owasco Lake Site Averaged and Date Averaged Data

Site Averaged Surface Water Data

Site	Secchi Depth (m)	Suspended Solids (TSS, mg/L)	Total Phosphate (TP, ug/L)	Dissolved Phosphate (SRP, ug/L)	Nitrate (N, mg/L)	Silica (Si, ug/L)	Chlorophyll (a, ug/L)
1	3.0	3.5	15.5	0.6	0.5	1062	6.7
Buoy	3.1	—	—	—	—	—	—
2	3.1	2.1	13.3	0.3	0.5	1152	3.7
A	3.8	1.9	14.3	1.2	0.7	1088	3.3
B	1.8	1.7	12.4	0.6	0.6	1039	3.2
C	2.0	2.0	12.1	1.1	0.5	1030	4.2
D	1.7	1.8	12.6	0.3	0.6	1032	2.7
E	2.4	2.3	13.2	1.1	0.6	1025	4.2
F	1.8	1.9	12.5	1.8	0.5	937	4.0
Average	**2.5**	**2.1**	**13.2**	**0.9**	**0.5**	**1046**	**4.0**

Site Averaged Bottom Water Data

Site	Secchi Depth (m)	Suspended Solids (TSS, mg/L)	Total Phosphate (TP, ug/L)	Dissolved Phosphate (SRP, ug/L)	Nitrate (N, mg/L)	Silica (Si, ug/L)	Chlorophyll (a, ug/L)
1	—	1.5	8.5	0.7	0.7	1601.9	0.6
Buoy	—	—	—	—	—	—	—
2	—	3.6	9.9	1.6	0.9	1791.2	0.5
Average	—	**2.5**	**9.2**	**1.2**	**0.8**	**1696.6**	**0.6**

Date Averaged Surface Water Data

Date	Secchi Depth (m)	Suspended Solids (TSS, mg/L)	Total Phosphate (TP, ug/L)	Dissolved Phosphate (SRP, ug/L)	Nitrate (N, mg/L)	Silica (Si, ug/L)	Chlorophyll (a, ug/L)
5/23/17	2.9	2.0	21.9	0.5	0.3	1459.0	1.4
6/14/17	3.9	2.4	18.5	0.3	0.5	1074.9	6.8
6/21/17	3.9	1.4	10.4	0.1	0.3	1144.1	4.9
7/5/17	1.8	3.6	6.7	0.1	0.4	1008.4	2.5
7/11/17	2.4	2.0	4.6	0.0	1.0	1065.8	4.8
7/18/17	2.0	2.6	19.6	0.6	1.0	1116.4	2.5
7/25/17	1.2	5.0	14.0	0.2	0.5	1195.1	6.6
8/1/17	2.4	3.9	15.4	0.1	0.6	1266.7	5.4
8/8/17	2.5	2.3	15.6	0.1	0.8	1122.1	7.7
8/15/17	2.5	2.0	16.6	0.5	0.7	1040.2	2.3
8/25/17	2.6	2.4	9.1	1.4	0.1	981.5	4.0
8/29/17	4.3	1.9	10.2	0.4	0.3	1045.6	3.2
9/6/17	4.6	1.3	10.7	0.3	0.1	1012.1	1.7
9/12/17	4.5	2.8	25.1	1.8	0.4	1132.8	6.3
9/20/17	—	7.8	18.6	0.4	0.4	1017.8	18.8
9/27/17	4.9	1.6	12.7	0.7	0.9	1034.1	3.9
Average	**3.1**	**2.8**	**14.4**	**0.5**	**0.5**	**1107.3**	**5.2**

Date Averaged Bottom Water Data

Date	Secchi Depth (m)	Suspended Solids (TSS, mg/L)	Total Phosphate (TP, ug/L)	Dissolved Phosphate (SRP, ug/L)	Nitrate (N, mg/L)	Silica (Si, ug/L)	Chlorophyll (a, ug/L)
5/23/17	—	2.0	15.1	2.8	0.7	1539	1.0
6/14/17	—	1.6	11.2	0.1	0.2	1587	0.0
6/21/17	—	2.5	7.3	1.2	0.5	1552	0.3
7/5/17	—	1.9	8.4	0.3	0.9	1542	0.6
7/11/17	—	2.0	1.7	0.0	0.4	1546	0.3
7/18/17	—	2.7	9.2	3.1	0.8	1748	0.5
7/25/17	—	3.4	5.9	2.9	1.3	1877	0.8
8/1/17	—	2.5	10.7	0.6	1.1	1767	1.2
8/8/17	—	2.5	10.4	0.0	1.5	1827	0.4
8/15/17	—	2.4	11.3	0.7	1.6	1700	0.5
8/25/17	—	2.9	5.0	3.0	0.1	1648	0.5
8/29/17	—	2.7	5.4	0.0	0.8	1677	0.9
9/6/17	—	2.8	6.9	0.4	0.0	1701	0.2
9/12/17	—	2.4	14.8	0.4	0.4	1842	0.4
9/20/17	—	—	—	—	—	—	—
9/27/17	—	3.4	14.2	1.9	1.7	1895	0.6
Average	—	**2.5**	**9.2**	**1.2**	**0.8**	**1696.6**	**0.6**

Table 4. Annual Average Plankton Data from 2005 through 2016, and Daily Average Data for 2017.

Plankton Group			Diatoms					Dinoflagellates			Rotifers & Zooplankton						Blue Greens	
Plankton Species	Fragillaria %	Tabellaria %	Diatoma %	Asterionella %	Melosira %	Synedra %	Rhizoselenia %	Dinobryon %	Ceratium %	Coalcium %	Copepod %	Nauplius %	Keratella %	Polyarthra %	Vorticella %	Cladoceran %	Dolichospermum (Anabaena) %	Mycrocystis %
2005 Average	34.9	1.4	0.0	9.9	0.2	5.6		14.6	4.5		0.9	1.1	2.5	3.2	10.3	2.8		0.3
2006 Average	24.3	1.7	0.0	7.1	1.4	0.7	2.6	41.5	0.7		0.2	0.1	2.4	0.8	0.3	0.6	0.1	3.8
2007 Average	30.0	0.5	0.0	23.3	0.2	2.1	3.8	12.9	0.7		0.4	0.4	0.6	0.4	3.8	2.8	0.4	7.7
2008 Average	52.3	0.1	0.0	14.6	0.2	0.1	1.2	18.7	0.6	0.2	0.4	0.5	0.3	0.9	4.3	0.6	0.4	1.5
2009 Average	9.7	7.1	0.0	12.3	0.2	1.0	7.8	26.6	0.7	2.0	0.7	0.6	3.6	0.7	4.3	2.1	3.4	4.8
2010 Average	36.8	0.5	0.0	19.1	0.2	1.4	0.7	4.6	0.0	2.6	0.6	0.8	3.3	0.7	3.2	5.6	0.1	6.1
2011 Average	26.0	14.1	0.0	15.0	0.4	1.4	15.0	5.3	0.5	1.8	0.9	0.7	2.8	1.0	3.9	2.0	0.2	2.6
2012 Average	27.0	25.5	0.0	10.9	13.0	2.2	1.1	8.1	0.3	0.2	0.5	0.5	0.3	1.5	0.9	0.6	0.3	0.8
2013 Average	27.6	0.3	26.9	3.9	3.8	0.0	5.9	0.0	0.1	2.1	0.5	0.9	1.3	2.4	1.2	4.1	0.3	0.6
2014 Average	21.8	0.3	5.8	15.2	0.2	1.5	2.5	20.2	0.1	0.0	2.7	2.7	1.1	6.4	1.8	1.1	0.1	2.6
2015 Average	28.6	7.5	1.0	20.2	0.3	0.8	3.9	3.7	0.1	0.1	0.7	0.9	1.8	3.5	0.8	3.1	0.1	7.3
2016 Average	11.5	2.8	6.7	13.7	1.2	0.3	0.2	11.7	0.0	0.1	0.7	1.0	4.0	5.0	1.7	1.5	2.1	5.3
5/23/17	33.5	0.6	0.4	5.0	19.7	0.0	0.0	0.0	0.0	0.0	0.4	2.3	0.6	1.1	0.0	0.1	0.0	0.0
6/14/17	3.5	0.0	0.0	2.9	0.0	0.0	0.0	77.6	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0
6/21/17	22.2	0.4	0.0	7.3	0.2	0.0	1.0	0.3	0.0	0.0	0.0	1.7	3.7	17.8	0.0	0.1	0.0	0.3
7/5/17	2.5	0.0	0.0	1.4	0.0	0.0	90.9	0.0	0.0	0.0	0.2	0.3	0.5	0.2	0.8	0.0	0.2	0.0
7/11/17	4.9	0.0	0.3	1.3	0.0	0.0	11.8	0.0	0.1	0.0	0.1	4.3	0.4	0.5	0.6	0.1	0.0	0.0
7/15/17	8.7	0.0	0.0	1.5	0.0	0.0	10.8	0.0	0.0	0.0	0.4	2.5	0.0	2.2	4.1	0.2	0.4	0.4
7/25/17	9.6	0.0	0.0	1.3	0.0	0.0	1.0	0.0	0.4	0.9	0.5	0.7	0.2	0.3	14.6	0.3	17.1	0.6
8/1/17	11.1	0.0	0.1	1.5	0.0	0.0	2.0	0.1	0.0	0.3	1.1	1.7	2.2	1.1	0.0	0.3	16.4	1.1
8/8/17	7.3	0.1	0.0	0.4	0.0	0.0	6.8	0.0	0.0	0.0	0.1	0.0	0.9	1.9	0.0	0.9	10.4	0.6
8/15/17	17.0	0.2	0.0	1.0	0.0	0.0	7.7	2.3	0.2	0.2	1.0	2.9	2.0	4.2	0.0	9.8	0.6	2.8
8/25/17	5.5	0.0	0.0	1.1	2.8	0.0	0.0	0.0	2.2	0.4	1.8	3.1	4.7	1.5	0.4	7.4	19.1	11.8
8/29/17	10.8	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.5	2.0	0.2	0.1	8.6	1.0	6.3	10.3	0.0	19.9
9/6/17	16.7	0.0	0.3	14.7	0.2	0.0	15.4	0.0	0.0	2.4	1.4	2.5	2.9	1.3	11.7	1.7	0.0	7.6
9/12/17	21.0	0.0	0.2	27.4	0.0	0.0	19.3	0.0	0.0	0.6	0.4	0.1	0.9	0.8	14.8	0.1	4.8	2.0
9/27/17	2.3	0.0	0.0	27.0	0.0	0.0	0.0	0.0	0.6	0.9	0.6	0.6	3.2	5.7	6.3	2.4	4.7	37.4
2017 Average	11.8	0.1	0.1	6.4	1.5	0.0	11.1	5.4	0.3	0.5	0.6	1.5	2.0	2.7	4.0	2.3	4.9	5.6

Note: Only included plankton from Offshore Sites with at least 2% of the total counts on any survey day, in any year.

Table 5: Annual Average 2017 Lake Data from the Finger Lake Survey.

2017 Average Values (± 1s)	Honeoye	Canandaigua	Keuka	Seneca	Cayuga	Owasco	Skaneateles	Otisco
Secchi Depth (m)	2.0 ± 0.7	5.2 ± 0.7	5.0 ± 1.0	3.4 ± 1.1	3.6 ± 1.3	3.2 ± 1.2	7.1 ± 2.7	2.8 ± 0.8
Total Suspended Solids (mg/L), Surface	2.3 ± 1.1	3.9 ± 5.5	1.1 ± 0.4	1.8 ± 0.5	1.9 ± 0.7	1.9 ± 0.6	1.9 ± 0.9	2.4 ± 1.0
Total Suspended Solids (mg/L), Bottom	2.7 ± 1.6	2.2 ± 1.4	0.5 ± 0.2	0.7 ± 0.3	2.6 ± 0.6	2.6 ± 1.7	0.8 ± 0.5	1.9 ± 0.9
Total Phosphate (µg/L, TP), Surface	21.9 ± 7.3	12.8 ± 5.6	9.7 ± 6.1	15.1 ± 4.1	14.4 ± 4.1	16.2 ± 5.6	14.8 ± 10.4	16.6 ± 4.2
Total Phosphate (µg/L, TP), Bottom	22.5 ± 5.6	11.9 ± 7.2	10.9 ± 7.1	11.7 ± 4.9	20.2 ± 5.1	11.4 ± 4.0	11.6 ± 7.1	15.9 ± 7.2
Dissolved Phosphate (µg/L, SRP), Surface	3.3 ± 4.5	1.5 ± 2.2	1.9 ± 3.4	1.7 ± 3.1	0.9 ± 1.1	0.5 ± 0.3	1.4 ± 2.2	1.2 ± 2.4
Dissolved Phosphate (µg/L, SRP), Bottom	1.5 ± 1.1	1.6 ± 2.7	4.5 ± 9.5	3.6 ± 4.9	7.7 ± 3.7	1.9 ± 1.8	0.5 ± 1.0	2.0 ± 4.6
Nitrate as N (mg/L), Surface	0.1 ± 0.1	0.1 ± 0.2	0.1 ± 0.2	0.2 ± 0.2	1.1 ± 0.9	0.6 ± 0.5	0.3 ± 0.3	0.5 ± 0.4
Nitrate as N (mg/L), Bottom	0.1 ± 0.1	0.3 ± 0.3	0.3 ± 0.3	0.8 ± 1.2	0.6 ± 0.9	1.1 ± 1.0	0.6 ± 0.5	0.4 ± 0.3
Silica (SR µg/L), Surface	917 ± 472	836 ± 265	961 ± 162	152 ± 72	339 ± 262	1159 ± 176	493 ± 94	533 ± 206
Silica (SR µg/L), Bottom	1063 ± 557	1343 ± 125	1370 ± 66	399 ± 198	1019 ± 138	1687 ± 199	735 ± 69	1467 ± 483
Chlorphyll a (µg/L), Surface	18.5 ± 14.4	2.2 ± 1.2	1.4 ± 1.0	4.8 ± 4.8	4.4 ± 3.8	3.0 ± 1.8	1.6 ± 1.1	3.6 ± 1.5
Chlorphyll a (µg/L), Bottom	9.2 ± 5.8	0.8 ± 0.9	0.2 ± 0.2	0.4 ± 0.3	0.2 ± 0.3	0.6 ± 0.3	0.2 ± 0.2	1.9 ± 1.2

Table 6. 2017 Stream Data.

2017 Stream Segment Analysis Data

Date & Location	Discharge (m^3/s)	Specific Conductance (µS/cm)	Water Temp (°C)	Nitrate (mg/L, N)	Suspended Solids (mg/L)	Total Phosphate (µg/L, TP as P)	Phosphate SRP (µg/L, SRP as P)
6/7/2017							
Dutch Hollow 38A	2.21	397	14.3	2.9	22.8	32.7	0.2
Dutch Hollow North Rd	1.86	357	14.0	1.3	27.9	33.3	2.3
Dutch Hollow South Trib	0.11	441	13.6	4.4	5.9	33.9	11.7
Dutch Hollow Benson Trib	0.10	668	15.5	1.5	29.7	32.9	6.6
Dutch Hollow Benson Rd	1.86	303	13.7	0.1	22.4	32.9	1.2
Dutch Hollow Old State Rd	0.85	295	13.4	0.8	23.2	30.4	1.0
Owasco Inlet Rt 38 Moravia	9.65	289	14.4	0.1	22.6	26.1	0.7
Mill Creek	3.72	247	14.1	0.0	9.6	27.4	1.5
Owasco Inlet Aurora St	4.58	318	15.3	0.1	38.6	61.5	0.9
Fillmore Cr	0.93	137	15.4	0.0	29.6	24.5	2.3
Owasco Inlet VFW	3.62	355	15.7	0.7	11.1	22.8	3.4
Owasco Inlet Locke, downstream	3.08	375	15.6	0.8	4.6	22.6	1.2
Hemlock Cr	0.72	388	15.2	2.1	2.1	44.0	0.0
Owasco Inlet County Line	1.43	420	16.2	0.6	8.7	17.9	4.6
Owasco Inlet Groton	0.80	369	17.0	0.1	3.2	19.6	6.1
Fire Lane 20	0.05	618	15.0	0.2	2.0	44.2	50.0
discharge for Rt 38 on 6/7/2017 from USGS gauge due to high flow.							
6/9/2017							
Dutch Hollow 38A	0.90	469	17.0	0.8	2.5	77.0	0.9
Dutch Hollow North Rd	0.74	435	15.8	1.1	2.7	19.0	0.4
Dutch Hollow South Trib	0.16	482	15.0	1.4	2.3	22.8	3.8
Dutch Hollow Benson Trib	0.11	691	17.9	0.1	7.4	35.6	4.3
Dutch Hollow Benson Rd	0.73	409	16.0	0.9	2.3	34.6	16.5
Dutch Hollow Old State Rd	0.38	402	16.3	1.0	5.7	20.5	5.7
Owasco Inlet Rt 38 Moravia	4.77	353	17.0	0.1	3.8	46.1	2.2
Mill Creek	1.96	287	16.5	0.7	3.4	32.5	1.3
Owasco Inlet Aurora St	2.58	384	17.9	0.1	5.1	25.5	1.2
Fillmore Cr	0.27	174	19.0	0.1	2.9	13.9	0.7
Owasco Inlet VFW	2.02	395	18.4	0.0	3.4	19.4	2.6
Owasco Inlet Locke, downstream	1.93	407	18.2	0.1	3.3	30.4	3.7
Hemlock Cr	0.37	426	17.6	0.0	1.3	23.8	0.6
Owasco Inlet County Line	1.13	448	18.8	0.8	3.9	21.7	6.2
Owasco Inlet Groton	0.52	389	19.7	0.6	2.1	8.5	8.0
Fire Lane 20	0.06	555	16.6	0.5	1.2	23.0	0.9
6/28/2017							
Dutch Hollow 38A	0.84	489	16.9	0.4	4.9	18.4	7.2
Dutch Hollow North St	0.70	439	16.1	0.2	14.3	11.8	5.4
Dutch Hollow South Trib	0.08	504	15.2	0.2	1.8	15.3	10.6
Dutch Hollow Benson Trib	0.03	731	17.8	4.6	3.6	80.2	20.7
Dutch Hollow Benson Rd	0.76	375	15.7	0.5	10.4	37.0	1.9
Dutch Hollow Old State Rd	0.43	372	15.6	0.7	16.9	24.8	3.9
Owasco Inlet Rt 38 Moravia	3.87	390	16.1	0.0	2.5	19.0	3.6
Mill Creek	1.69	326	15.6	0.0	7.6	17.5	3.7
Owasco Inlet Aurora St	2.12	434	16.4	0.0	7.0	22.1	4.0
Fillmore Cr	0.05	209	19.1	0.1	1.9	12.5	1.2
Owasco Inlet VFW	2.28	421	16.9	1.0	10.0	18.0	3.6
Owasco Inlet Locke, downstream	2.21	438	17.0	0.9	7.4	15.8	3.5
Hemlock Cr	0.53	437	16.9	2.3	0.6	15.6	15.0
Owasco Inlet County Line	1.20	468	17.3	0.9	4.6	20.7	10.9
Owasco Inlet Groton	0.49	398	17.6	0.6	5.9	9.0	8.2
Fire Lane 20	0.01	554	16.5	0.1	3.5	9.8	5.1

Table 6. 2017 Stream Data (continued)

2017 Stream Data Continued							
7/7/2017							
Dutch Hollow 38A	1.29	455	20.0	1.4	10.9	4.0	3.9
Dutch Hollow North Rd	0.92	444	20.3	1.4	13.3	13.4	5.8
Dutch Hollow South Trib	0.18	514	20.1	2.0	3.3	14.2	5.9
Dutch Hollow Benson Trib	0.05	758	21.1	2.3	3.4	15.3	4.0
Dutch Hollow Benson Rd	0.63	400	19.8	1.0	18.3	19.7	2.6
Dutch Hollow Old State Rd	0.46	403	19.4	0.8	17.5	16.7	2.0
Owasco Inlet Rt 38 Moravia	6.46	380	19.6	0.0	10.4	11.7	5.3
Mill Creek	2.35	319	19.3	0.1	11.7	16.1	6.5
Owasco Inlet Aurora St	2.63	449	20.0	0.0	8.6	7.4	2.3
Fillmore Cr	0.17	205	22.7	0.1	1.6	10.1	0.6
Owasco Inlet VFW	2.50	434	20.2	0.0	8.6	7.4	2.2
Owasco Inlet Locke, downstream	2.00	447	20.6	1.2	7.2	14.2	2.6
Hemlock Cr	0.99	481	19.1	2.6	3.6	7.6	5.5
Owasco Inlet County Line	0.24	493	21.4	0.2	8.0	26.7	9.6
Owasco Inlet Groton	0.61	409	21.5	0.0	6.1	28.6	5.5
Fire Lane 20	0.02	556	19.4	3.7	22.4	29.4	1.8
2017 Average Values							
Dutch Hollow 38A	1.31	452.50	17.05	1.37	10.28	33.02	3.05
Dutch Hollow North Rd	1.06	418.75	16.55	0.99	14.55	19.38	3.46
Dutch Hollow South Trib	0.13	485.25	15.98	2.01	3.33	21.55	8.01
Dutch Hollow Benson Trib	0.07	712.00	18.08	2.14	11.03	41.00	8.91
Dutch Hollow Benson Rd	1.00	371.75	16.30	0.62	13.34	31.07	5.56
Dutch Hollow Old State Rd	0.53	368.00	16.18	0.82	15.83	23.12	3.16
Owasco Inlet Rt 38 Moravia	6.19	353.00	16.78	0.07	9.83	25.70	2.96
Mill Creek	2.43	294.75	16.38	0.21	8.07	23.39	3.25
Owasco Inlet Aurora St	2.98	396.25	17.40	0.04	14.83	29.12	2.10
Fillmore Cr	0.36	181.25	19.05	0.09	9.00	15.26	1.23
Owasco Inlet VFW	2.61	401.25	17.80	0.44	8.28	16.90	2.94
Owasco Inlet Locke, downstream	2.31	416.75	17.85	0.75	5.63	20.75	2.74
Hemlock Cr	0.65	433.00	17.20	1.76	1.90	22.75	5.27
Owasco Inlet County Line	1.00	457.25	18.43	0.62	6.30	21.74	7.85
Owasco Inlet Groton	0.61	391.25	18.95	0.31	4.33	16.43	6.93
Fire Lane 20	0.03	570.75	16.88	1.14	7.28	26.58	14.44
2017 Average Fluxes				N kg/day	TSS kg/day	TP kg/day	SRP kg/day
Dutch Hollow 38A				154.8	1164.0	3.7	0.3
Dutch Hollow North Rd				90.3	1326.7	1.8	0.3
Dutch Hollow South Trib				23.0	38.1	0.2	0.1
Dutch Hollow Benson Trib				13.5	69.9	0.3	0.1
Dutch Hollow Benson Rd				53.6	1149.8	2.7	0.5
Dutch Hollow Old State Rd				37.5	727.3	1.1	0.1
Owasco Inlet Rt 38 Moravia				35.7	5253.3	13.7	1.6
Mill Creek				44.4	1694.7	4.9	0.7
Owasco Inlet Aurora St				10.7	3813.6	7.5	0.5
Fillmore Cr				2.6	277.6	0.5	0.0
Owasco Inlet VFW				100.0	1863.0	3804.4	661.9
Owasco Inlet Locke, downstream				148.6	1121.3	4136.1	545.8
Hemlock Cr				98.9	106.7	1277.2	295.9
Owasco Inlet County Line				53.3	543.6	1875.3	677.0
Owasco Inlet Groton				16.1	226.6	860.9	363.2
Fire Lane 20				3.3	21.4	0.1	0.0