

# WATER QUALITY AND NUTRIENT SOURCES IN THE OWASCO LAKE WATERSHED: A 2010 UPDATE.

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## INTRODUCTION

A 2005 water quality survey, under the direction of Dr. John Halfman, Finger Lakes Institute, Hobart and William Smith Colleges, ranked water quality parameters from seven eastern Finger Lakes and determined that Owasco, Honeoye and Seneca Lakes had the worst water quality, whereas Skaneateles, Canandaigua and Keuka Lakes had the best water quality and Cayuga fell in between these end-members (Fig. 1., Halfman and Bush, 2006). The preliminary report noted a correlation between the ranking and a first-order, qualitative assessment of water quality protection legislation. Subsequent analysis determined that this ranking more likely reflects other factors, for example, the degree of water quality enforcement, land use activities and/or the impact of recent exotics like zebra and quagga mussels or the carnivorous zooplankton the spiny water flea.

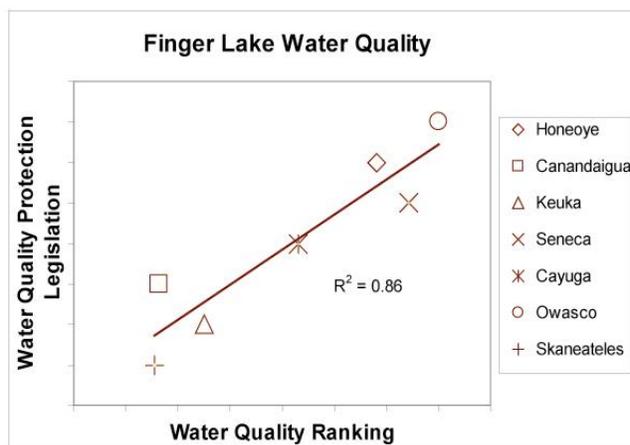


Fig. 1. The 2005 water ranking of seven Finger Lakes (Halfman and Bush, 2006).

Owasco Lake is one of the smaller Finger Lakes but it is still critical to the local health, well-being and economy of the surrounding region. It provides drinking water to 44,000 people in Cayuga County supplying Class AA water to City of Auburn, Towns of Owasco, Sennett, Fleming, Aurelius, Springport, Brutus, Throop, Montezuma, Mentz, Port Byron, and other lakeshore residents with total permitted withdrawals of 16 million gallons of water per day. The lake is also essential for the economic and social structure of the region supporting an agricultural and tourism based economy. Finally, Owasco has the largest watershed surface area to lake volume ratio (17:1) of the Finger Lakes. The large ratio plays a critical role in the lake's short water residence time of 1 to 3 years (Callinan, 2001). It also suggests that the lake is quickly influenced by runoff and associated pollutant threats from the watershed, but also will more quickly respond to remediation efforts to improve water quality in the lake.

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Funding from the Fred L. Emerson Foundation, Auburn, NY, and New York State secured by New York Senator Michael Nozzolio enabled an expansion of the Finger Lakes water quality survey to include a detailed investigation of Owasco Lake and its watershed in the summers of 2006 and 2007. It enabled an expansion of the sampling scheme to include 11 lake and 7 stream sites within the Owasco Watershed during these two field seasons. The objectives were to:

- (1) establish consistent and comprehensive monitoring to document spatial and temporal trends in nutrient concentrations and other water quality parameters in the lake;
- (2) bring particular focus to the extent and sources of nutrients from the watershed to the lake and associated watershed-lake interactions; and,
- (3) promote the development of effective and comprehensive watershed management policies to initiate the remediation of Owasco Lake.

The conclusions of the 2006 and 2007 research are outlined below (Halfman et al., 2007):

- (1) Owasco Lake is a borderline oligotrophic – mesotrophic ecosystem. None of the water quality parameters are life threatening at the present time.
- (2) Water quality of the lake is impaired at the southern end of the lake, especially during and just after precipitation events and during years with more precipitation. The degraded water quality is interpreted to reflect, and is consistent with, the delivery of point and non-point sources of nutrients and suspended sediments from the Owasco Inlet.
- (3) The nutrients and suspended sediments originated from a wastewater treatment facility point source, and non-point sources like onsite wastewater systems, agricultural activities, soil erosion, fertilized lawns, roadside ditches and construction activities.
- (4) The lake, and especially the southern end of the lake, was less impaired in 2007. The improvement was due to a combination of: a DEC mandated reduction in phosphorus loading by the Groton Wastewater Treatment facility, adoption of additional best management practices in the watershed, establishment and follow through on recommendations by the Watershed Inspector, and most importantly, significantly lower rainfall in 2007 and thus lower associated runoff of nutrients to the lake.
- (5) The study revealed that Owasco Lake became less impaired when nutrient loading from the watershed to the lake was significantly reduced.

This report discusses Owasco Lake water quality data from 2008 and 2009, and stream data from the fall of 2009 through the spring of 2010. The acquisition of the 2008 and 2009 lake data was supported by the Finger Lakes Institute at Hobart and William Smith Colleges. The purpose was to continue the ongoing monitoring campaign of the western Finger Lakes to investigate any changes in water quality in the surveyed lakes. The complete list now includes the eight easternmost Finger Lakes: Honeoye, Canandaigua, Keuka, Seneca, Cayuga, Owasco, Skaneateles, and Otisco. Otisco Lake was added to the survey in 2008.

The 2009 and 2010 stream monitoring program was supported by the Owasco Watershed Lake Association (OWLA) and the Town of Fleming. Dr. Joe Wasileski, President, OWLA, made this opportunity possible. The purpose was to investigate the seasonal variability of nutrient loading to the lake from the watershed, identify nutrient sources in the Dutch Hollow Creek Watershed, and compare and contrast nutrient loading from Dutch Hollow Creek, Veness Creek, Fay's Creek and Owasco Inlet.

## METHODS

**Lake Research:** The 2008 and 2009 lake survey sampled Sites 1 and 2, on a monthly basis, during the summer field season, and used identical methods as the earlier investigations (Table 1, Fig. 2). A CTD water quality profile, secchi disk depth, and surface and bottom water samples were collected at each site. The CTD electronically gathers water column profiles of temperature ( $^{\circ}\text{C}$ ), conductivity (as specific conductance,  $\mu\text{S}/\text{cm}$ ), dissolved oxygen ( $\text{mg}/\text{L}$ ), pH, turbidity (NTUs), photosynthetically active radiation, (PAR,  $\mu\text{E}/\text{cm}^3\text{-s}$ ), and fluorescence (chlorophyll-a,  $\mu\text{g}/\text{L}$ ) using a SeaBird SBE-25 CTD. The CTD was lowered from the surface to  $\sim 1\text{m}$  above the lake floor, collecting data every 0.5 seconds along the downcast. Water samples were analyzed onsite for temperature ( $^{\circ}\text{C}$ ), conductivity (specific conductance,  $\mu\text{S}/\text{cm}$ ) and pH using hand-held probes, and analyzed back in the laboratory for total phosphate, dissolved phosphate, nitrate, chlorophyll-a, and total suspended solid concentrations.

Table 1. Lake site locations and maximum water depths.

Site Name	Latitude	Longitude	Water Depth
Site 1	42° 52.40' N	76° 31.35' W	34 m
Site 2	42° 49.15' N	76° 30.45' W	52 m

**Stream Research:** Stream sites in the 2009 and 2010 survey emphasized streams identified by Owasco Watershed Lake Association and the Town of Fleming (Fig. 2). Five sites were located

along Dutch Hollow Creek, an agriculturally rich watershed (Fig. 3), where the creek crosses Rt. 38A near its terminus, North Road, Benson Road, one of its tributaries that crosses Benson Road and labeled Young's Creek (the tributary drains Young's Farm), and farther upstream along 38A just upstream of Old State Road. In addition, Veness Creek was sampled at Silver Street Road, Fay's Creek at Route 38, and Owasco Inlet at Rt. 38 just downstream from Moravia. These eight sites were sampled on 9/15/09 (fall), 12/17/09 (winter), 4/16/10 (just after the spring thaw), 5/25/10 (late spring), and 6/8/10 (after a rain storm).

Water samples were measured onsite for temperature ( $^{\circ}\text{C}$ ), conductivity (specific conductance,  $\mu\text{S}/\text{cm}$ ), and pH using hand-held probes. Water samples were also transported to the laboratory and analyzed for nutrients (total phosphate, dissolved phosphate, and nitrate), and total suspended solids concentrations. Most importantly, stream discharge (the volume of water per unit time) was calculated from stream width, depth and velocity (using a Marsh-McBirney flow meter) measurements at five equally distributed locations aligned perpendicular to the flow across the stream's width. Ten equally distributed locations were utilized at Moravia because the stream was much wider at this site. Both stream discharge (water volume per unit time, e.g.,  $\text{m}^3/\text{s}$ ) and concentrations (mass per unit volume, e.g.,  $\mu\text{g}/\text{L}$ ) are critical to calculate the flux (mass per unit time, e.g.,  $\text{kg}/\text{day}$ ) of nutrients, suspended sediments, and any other parameter discharged by a stream.

**Laboratory Analyses:** Laboratory procedures for nutrient, chlorophyll-a, and total suspended solid concentrations followed standard limnological techniques (Wetzel and Likens, 2000). Once back in the lab, all water samples were filtered through pre-weighed,  $0.45\ \mu\text{m}$  glass-fiber filters. The filter and residue were dried at  $80^{\circ}\text{C}$  overnight and the weight gain and filtered volume used to determine the total suspended sediment concentration ( $\text{mg}/\text{L}$ ). Lake water was also filtered through a Gelman HA  $0.45\ \mu\text{m}$  membrane filter. The filtered residue was kept frozen until chlorophyll analysis, and the filtrate stored at  $4^{\circ}\text{C}$  for soluble reactive (dissolved) phosphate ( $\mu\text{g}/\text{L}$ ) and nitrate ( $\text{mg}/\text{L}$ ) colorimetric analyses by spectrophotometer. A third water sample was analyzed for total phosphates ( $\mu\text{g}/\text{L}$ ) colorimetrically by spectrophotometer after the

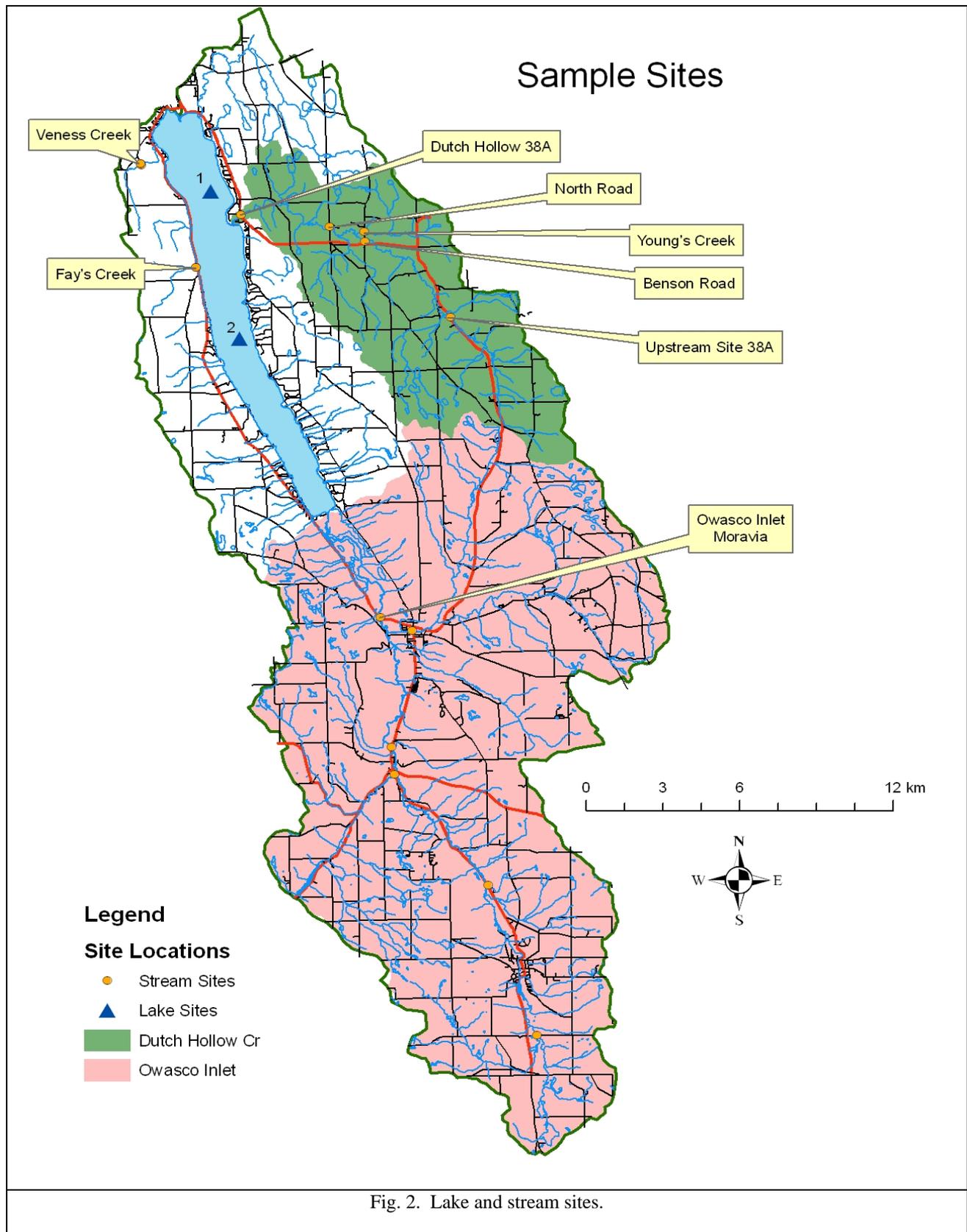


Fig. 2. Lake and stream sites.

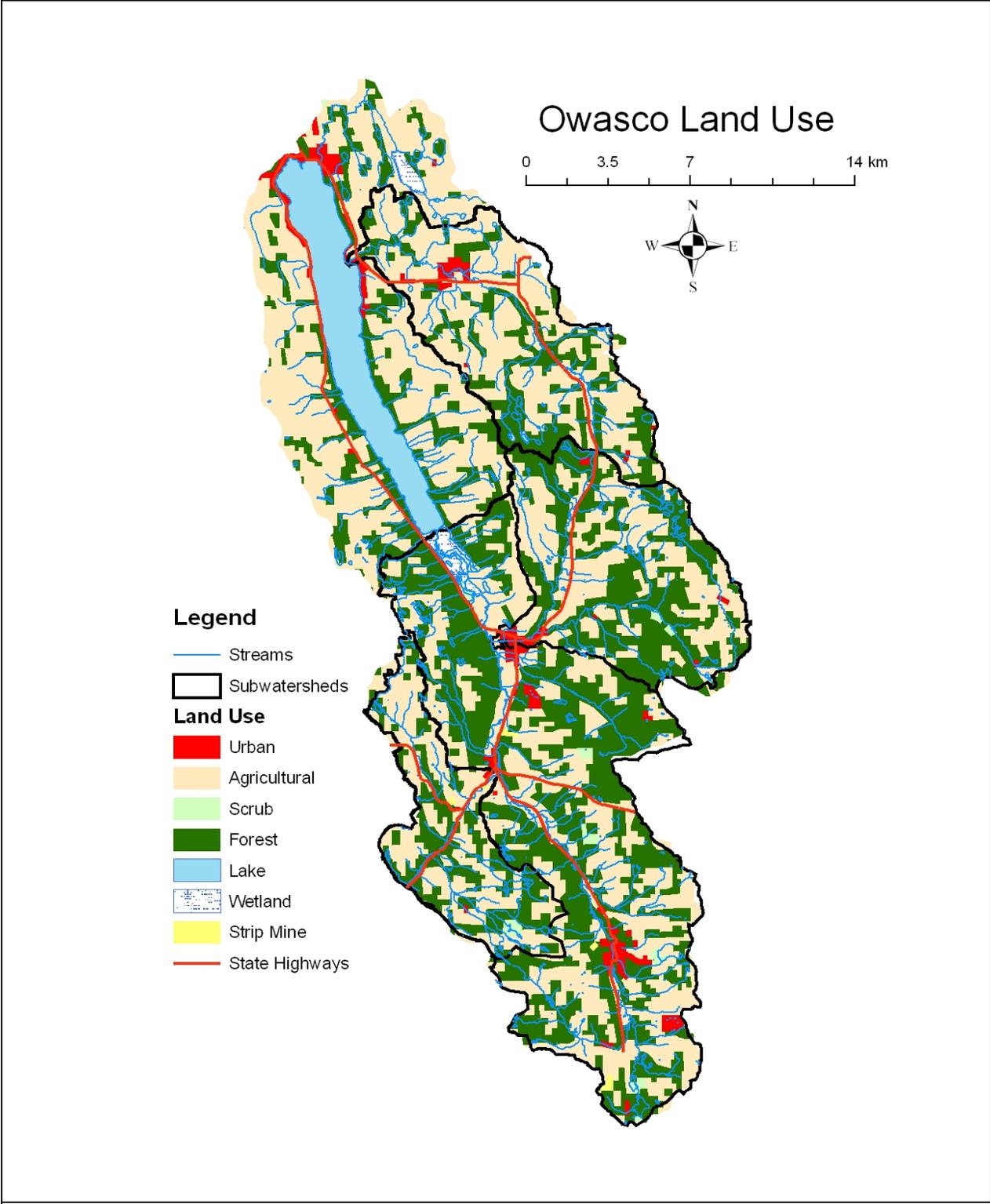


Fig. 3. Land use in the Owasco Watershed.

phosphate-rich particulates were digested in hot (100°C) persulfate. Laboratory precision was determined by analyzing replicate tests on the same water sample on a number of occasions: total suspended solids 0.2 mg/L, phosphate 0.1 µg/L, and nitrate 0.1 mg/L. All water samples were kept at 4°C until analysis and typically analyzed within a week of collection.

## **LAKE RESULTS & DISCUSSION**

**Lake CTD Profiles:** The water temperature profiles were typical for any summer season and similar to previous years (Fig. 4). A thermocline, the depth in the water column that separates the warmer, surface-water, epilimnion from the colder, bottom-water, hypolimnion, was typically observed at 10 to 13 meters at both sites on every survey date. The thermocline was deeper in the late September or early October profile due to the seasonal decay of the epilimnion. Surface water temperature ranged from just over 10°C to 23°C.

Conductivity (specific conductance, proportional to water salinity) data from the epilimnion of the open lake ranged from 300 to 325 µS/cm in both years, and decreased through the summer season. Bottom water conductivities were ~330 µS/cm, and were more uniform than the surface water in both years. These data are slightly lower (~10 µS/cm) than those detected in 2006 but similar to other previous years.

Fluorescence profiles revealed the largest concentrations of algae within the epilimnion. Algal peaks typically extended downward into the metalimnion of the lake. Subsurface peak chlorophyll-a concentrations were up to 5 µg/L, and more typically were between 1 and 4 µg/L, with slight smaller algal concentrations in 2008 than 2009. Hypolimnetic concentrations were near 0.3 µg/L. These data are consistent to the 2007 data, the first year this parameter was measured.

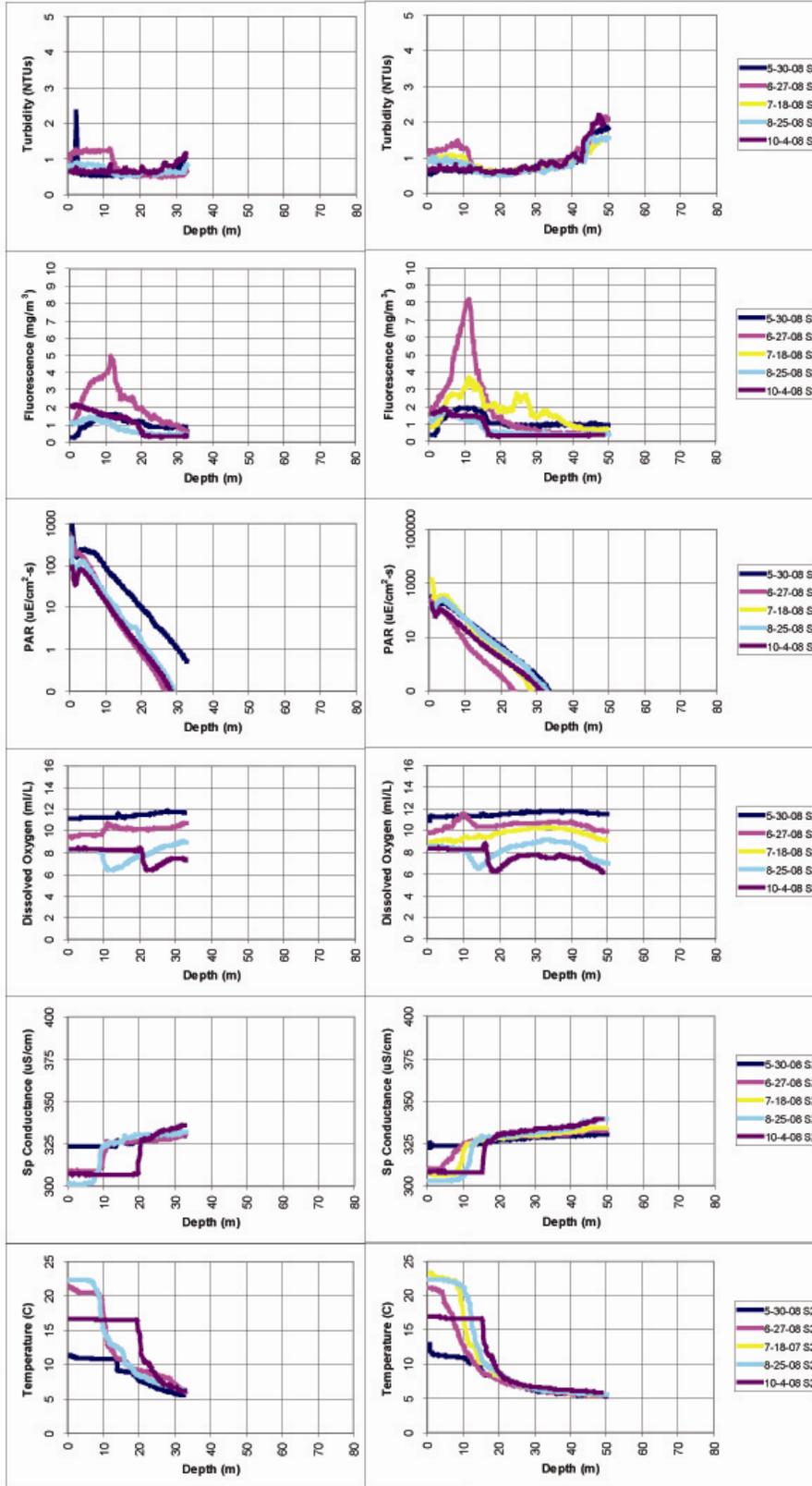
Turbidity profiles revealed near surface (epilimnetic) and, at Site 2, lake-floor intervals of increased turbidity (decreased water clarity). The near surface turbidity occupied most of the epilimnion, occasionally extended down into the metalimnion, and revealed turbidities up to 2 NTUs. The origin of the epilimnetic turbidity is probably autochthonous (formed within the lake), and proportional to plankton biomass, as similar peaks in fluorescence are also observed at this depth. The epilimnetic turbidity data are consistent with previous years.

Bottom water turbid layers (nepheloid layers) were prevalent at Site 2, the southernmost site. A fluorescence peak was not observed in this layer, indicating that the source of the benthic turbidity was allochthonous (brought to the lake from the watershed), probably the Owasco Inlet, other tributaries and sediments eroded by waves and currents. Once suspended, the sediments were probably brought to the deepest basin of the lake by density flows. Nepheloid layers were less prevalent in 2008 than 2009, and not well developed in earlier years, especially 2007.

Dissolved oxygen concentrations from both 2008 and 2009 decreased from 100% saturation at the surface down to as low as 4 mg/L in late July and August at the base of the epilimnion, only to increase to but remain slightly below saturation in the upper hypolimnion and finally decrease down to 6 mg/L or at or below 60% saturation in the hypolimnion of the lake by the end of the survey. These low concentrations were near the threshold that initiates respiratory stress in sensitive aquatic organisms, and result from the oxygen-consuming respiration of animals and

# Owasco Lake 2008

Site 1



Site 2

Fig. 4a. 2008 CTD Profiles.

# Owasco Lake 2009

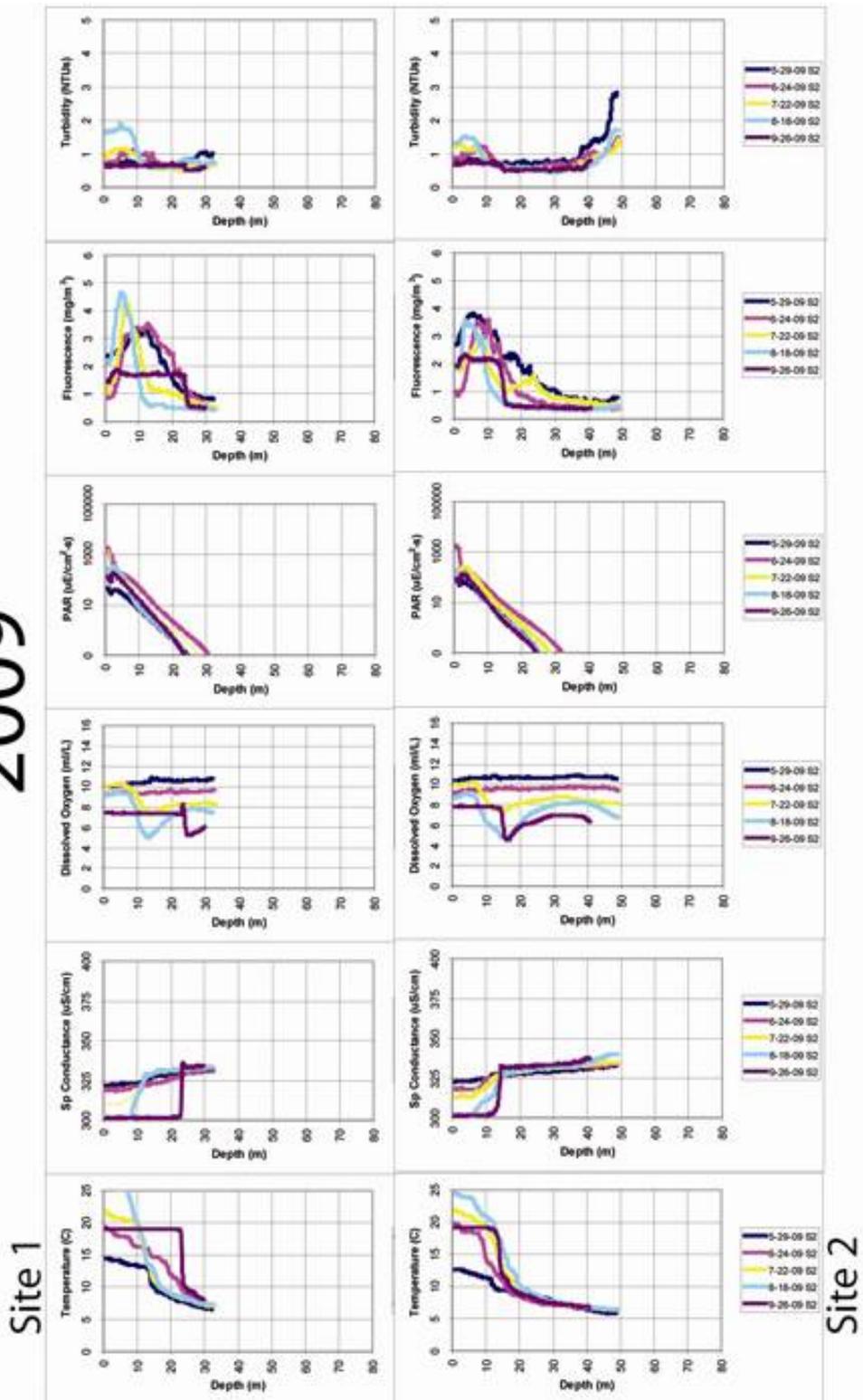


Fig. 4b. 2009 CTD Profiles.

bacteria at the base of the epilimnion, and at the lake floor. Similar trends were observed in previous years.

Photosynthetically active radiation (PAR) profiles revealed exponentially decreasing light intensities from highs of over 200 to 2000  $\mu\text{E}/\text{cm}^2\text{-s}$  at 1 meter depth, the range reflects the extent of cloud cover during the sample date, to 1% of surface light intensities at approximately 15 to 25 meters. The general shape and depth of available light is typical of a northern temperature oligotrophic-mesotrophic lake. Most of the profiles reveal a sharp decrease in light at 2 or 3 meters. It corresponds to the sensor passing through the boat's shadow. These data are consistent to the 2007 data, the first year this parameter was measured.

**Lake Nutrient Data:** Mean annual nutrient data indicate that the surface water, open-lake concentrations were typically uniform across the lake on any survey date, and reflected the well mixed nature of the epilimnion by wind, waves, and surface currents (Table 2 and Fig. 5). As before, the annual mean surface-water nutrient concentrations suggest that the lake is borderline oligotrophic – mesotrophic. None of these open-lake concentrations are a health threat nor do they suggest highly productive, eutrophic systems, as the nitrate concentrations are always below the EPA's MCL of 10 mg/L and total phosphate concentrations are always below DEC's 20  $\mu\text{g}/\text{L}$  standard for impaired water bodies. Dissolved nutrient concentrations reveal a small increase from the epilimnion (surface) to the hypolimnion (bottom), e.g., annual mean SRP 0.6 to 1.3  $\mu\text{g}/\text{L}$ , nitrate 0.6 to 0.9 mg/L in 2008; and SRP 0.7 to 1.2  $\mu\text{g}/\text{L}$ , nitrate 0.6 to 0.8 mg/L in 2009, and is interpreted to reflect the normal seasonal progression resulting from algal uptake of nutrients and their growth in the epilimnion, and algal decomposition and nutrient release by bacteria in the hypolimnion.

Surface water, annual mean, nutrient concentrations revealed small changes from 2008 to 2009. Total phosphate concentrations increased slightly from 2008 to 2009 (7.4 to 8.1  $\mu\text{g}/\text{L}$ ) and dissolved phosphate concentrations decreased slightly from 2008 to 2009 (0.9 to 0.7  $\mu\text{g}/\text{L}$ ). In contrast, nitrate concentrations remained the same. The small changes in phosphate concentrations suggest that algal productivity increased slightly from 2008 to 2009. Uniform nitrate concentrations are expected, because nitrates are not the limiting nutrient in Owasco Lake.

These observations indicate that phosphate concentrations change from year to year, and phosphates are the limiting nutrient in Owasco Lake. Thus, control measures to improve water quality should focus on phosphate because less phosphates result in less algae and improved water quality, whereas more phosphates fertilize more algae, which impairs water quality.

**Lake Chlorophyll-a, Secchi Disk, & Total Suspended Solids (TSS) Data:** Like the nutrient data, chlorophyll-a, secchi disk depths and TSS data are uniform across the open lake on any given day (Table 2 and Fig. 4). An increase in surface water mean annual chlorophyll-a and TSS concentrations, and shallower secchi disk depth data from 2008 to 2009 are consistent with increased algal productivity from 2008 to in 2009 (2.6 to 3.9  $\mu\text{g}/\text{L}$ , 1.3 to 1.9 mg/L, 4.2 to 3.2 m). These interpretations and the changes in the secchi disk, TSS and chlorophyll-a data from 2008 to 2009 are consistent with the CTD data.

**Table 2: Annual Mean Lake Data.**

	Honeoye	Canandaigua	Keuka	Seneca	Cayuga	Owasco	Skaneateles	Otisco
<b>2008 Average Values (<math>\pm 1\sigma</math>)</b>								
Secchi Depth (m)	4.6 $\pm$ 0.9	6.7 $\pm$ 1.6	6.5 $\pm$ 0.7	4.7 $\pm$ 2.8	3.8 $\pm$ 1.0	4.2 $\pm$ 1.2	7.8 $\pm$ 1.2	3.1 $\pm$ 0.9
Total Suspended Solids (mg/L), Surface	1.4 $\pm$ 0.8	0.9 $\pm$ 0.5	1.0 $\pm$ 0.2	1.7 $\pm$ 0.8	1.5 $\pm$ 0.5	1.3 $\pm$ 0.7	0.6 $\pm$ 0.2	2.3 $\pm$ 1.9
Total Suspended Solids (mg/L), Bottom	1.2 $\pm$ 0.2	1.5 $\pm$ 1.0	1.2 $\pm$ 0.5	0.8 $\pm$ 0.4	2.5 $\pm$ 1.5	1.2 $\pm$ 0.6	0.7 $\pm$ 0.4	2.1 $\pm$ 0.7
Dissolved Phosphate ( $\mu$ g/L, SRP), Surface	4.6 $\pm$ 6.1	0.9 $\pm$ 0.6	0.6 $\pm$ 0.5	0.9 $\pm$ 1.3	0.8 $\pm$ 0.8	0.9 $\pm$ 0.7	0.7 $\pm$ 0.5	0.8 $\pm$ 1.2
Dissolved Phosphate ( $\mu$ g/L, SRP), Bottom	3.7 $\pm$ 5.2	1.3 $\pm$ 0.9	0.9 $\pm$ 0.6	3.2 $\pm$ 3.1	7.7 $\pm$ 4.2	1.1 $\pm$ 1.1	1.1 $\pm$ 1.1	4.8 $\pm$ 9.7
Total Phosphate ( $\mu$ g/L, TP), Surface	19.2 $\pm$ 5.6	7.9 $\pm$ 3.3	5.4 $\pm$ 2.7	9.8 $\pm$ 2.9	8.0 $\pm$ 1.4	7.4 $\pm$ 2.7	3.4 $\pm$ 1.7	12.8 $\pm$ 3.1
Total Phosphate ( $\mu$ g/L, TP), Bottom	18.4 $\pm$ 3.8	7.4 $\pm$ 4.5	6.8 $\pm$ 4.3	9.4 $\pm$ 3.0	12.5 $\pm$ 3.7	8.9 $\pm$ 2.0	4.8 $\pm$ 2.1	14.2 $\pm$ 9.6
Nitrate as N (mg/L), Surface	0.0 $\pm$ 0.0	0.2 $\pm$ 0.2	0.0 $\pm$ 0.0	0.2 $\pm$ 0.1	0.7 $\pm$ 0.4	0.6 $\pm$ 0.2	0.4 $\pm$ 0.2	0.3 $\pm$ 0.1
Nitrate as N (mg/L), Bottom	0.0 $\pm$ 0.0	0.3 $\pm$ 0.2	0.2 $\pm$ 0.1	0.3 $\pm$ 0.1	1.1 $\pm$ 0.5	0.9 $\pm$ 0.4	0.6 $\pm$ 0.2	0.3 $\pm$ 0.2
Silica (SR $\mu$ g/L), Surface	823 $\pm$ 266	994 $\pm$ 163	462 $\pm$ 148	309 $\pm$ 291	358 $\pm$ 188	751 $\pm$ 514	290 $\pm$ 89	334 $\pm$ 413
Silica (SR $\mu$ g/L), Bottom	865 $\pm$ 252	1589 $\pm$ 513	1157 $\pm$ 419	470 $\pm$ 117	1033 $\pm$ 225	1474 $\pm$ 531	825 $\pm$ 231	1298 $\pm$ 890
Chlorophyll a ( $\mu$ g/L), Surface	2.7 $\pm$ 1.9	1.6 $\pm$ 1.0	2.0 $\pm$ 1.1	4.6 $\pm$ 2.7	4.0 $\pm$ 1.4	2.6 $\pm$ 1.3	0.7 $\pm$ 0.3	3.7 $\pm$ 0.6
Chlorophyll a ( $\mu$ g/L), Bottom	1.9 $\pm$ 0.9	0.9 $\pm$ 1.1	0.5 $\pm$ 0.2	1.5 $\pm$ 1.4	0.3 $\pm$ 0.2	0.8 $\pm$ 0.6	0.4 $\pm$ 0.2	3.0 $\pm$ 1.7

	Honeoye	Canandaigua	Keuka	Seneca	Cayuga	Owasco	Skaneateles	Otisco
<b>2009 Average Values (<math>\pm 1\sigma</math>)</b>								
Secchi Depth (m)	2.8 $\pm$ 1.0	6.5 $\pm$ 1.0	5.4 $\pm$ 0.9	5.1 $\pm$ 2.1	3.5 $\pm$ 1.0	3.2 $\pm$ 1.1	7.6 $\pm$ 1.1	2.8 $\pm$ 0.8
Total Suspended Solids (mg/L), Surface	2.1 $\pm$ 1.7	1.6 $\pm$ 1.5	0.7 $\pm$ 0.2	1.5 $\pm$ 0.7	1.8 $\pm$ 0.8	1.9 $\pm$ 1.0	0.7 $\pm$ 0.2	2.2 $\pm$ 0.7
Total Suspended Solids (mg/L), Bottom	1.7 $\pm$ 0.7	1.7 $\pm$ 0.6	1.1 $\pm$ 0.3	0.7 $\pm$ 0.4	2.5 $\pm$ 1.1	1.2 $\pm$ 0.6	0.6 $\pm$ 0.3	1.8 $\pm$ 0.6
Dissolved Phosphate ( $\mu$ g/L, SRP), Surface	2.0 $\pm$ 1.6	0.7 $\pm$ 0.4	0.3 $\pm$ 0.2	0.4 $\pm$ 0.4	0.9 $\pm$ 1.2	0.7 $\pm$ 0.6	0.4 $\pm$ 0.3	0.5 $\pm$ 0.4
Dissolved Phosphate ( $\mu$ g/L, SRP), Bottom	1.7 $\pm$ 2.1	1.0 $\pm$ 0.9	0.8 $\pm$ 0.5	1.5 $\pm$ 2.0	6.4 $\pm$ 3.1	1.2 $\pm$ 0.9	0.8 $\pm$ 0.6	1.9 $\pm$ 2.1
Total Phosphate ( $\mu$ g/L, TP), Surface	19.5 $\pm$ 8.9	5.3 $\pm$ 1.9	4.9 $\pm$ 1.1	8.1 $\pm$ 1.9	6.8 $\pm$ 1.9	8.1 $\pm$ 5.2	2.7 $\pm$ 1.8	36.1 $\pm$ 60.3
Total Phosphate ( $\mu$ g/L, TP), Bottom	16.1 $\pm$ 5.2	3.7 $\pm$ 1.9	5.2 $\pm$ 2.1	9.7 $\pm$ 5.0	9.4 $\pm$ 3.0	6.8 $\pm$ 5.1	4.9 $\pm$ 2.5	10.6 $\pm$ 11.1
Nitrate as N (mg/L), Surface	0.0 $\pm$ 0.0	0.1 $\pm$ 0.0	0.1 $\pm$ 0.1	0.3 $\pm$ 0.2	0.9 $\pm$ 0.5	0.6 $\pm$ 0.2	0.5 $\pm$ 0.2	0.2 $\pm$ 0.1
Nitrate as N (mg/L), Bottom	0.0 $\pm$ 0.1	0.3 $\pm$ 0.1	0.2 $\pm$ 0.2	0.5 $\pm$ 0.2	1.1 $\pm$ 0.6	0.8 $\pm$ 0.3	0.5 $\pm$ 0.2	0.3 $\pm$ 0.1
Silica (SR $\mu$ g/L), Surface	801 $\pm$ 93	939 $\pm$ 239	444 $\pm$ 184	279 $\pm$ 266	403 $\pm$ 205	737 $\pm$ 232	384 $\pm$ 210	321 $\pm$ 297
Silica (SR $\mu$ g/L), Bottom	821 $\pm$ 131	1243 $\pm$ 253	1052 $\pm$ 265	400 $\pm$ 179	976 $\pm$ 240	1189 $\pm$ 323	661 $\pm$ 255	854 $\pm$ 444
Chlorophyll a ( $\mu$ g/L), Surface	14.1 $\pm$ 14.6	1.5 $\pm$ 0.9	1.2 $\pm$ 0.7	2.6 $\pm$ 2.1	3.5 $\pm$ 2.3	3.9 $\pm$ 1.7	1.1 $\pm$ 0.9	5.7 $\pm$ 4.1
Chlorophyll a ( $\mu$ g/L), Bottom	7.9 $\pm$ 7.7	0.4 $\pm$ 0.1	0.4 $\pm$ 0.1	0.9 $\pm$ 1.2	0.5 $\pm$ 0.2	0.9 $\pm$ 0.6	0.3 $\pm$ 0.2	2.8 $\pm$ 1.1

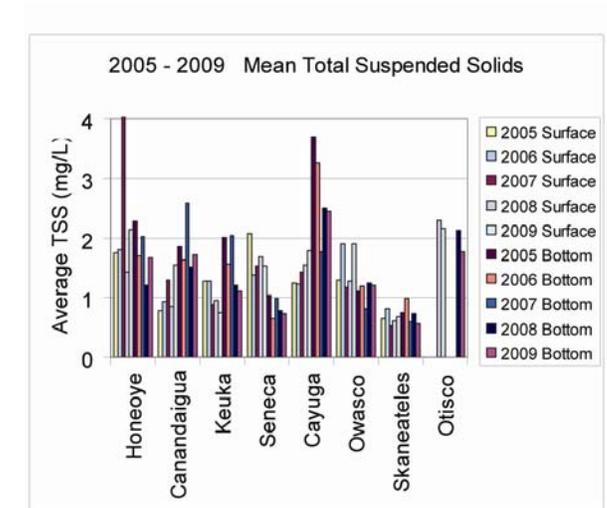
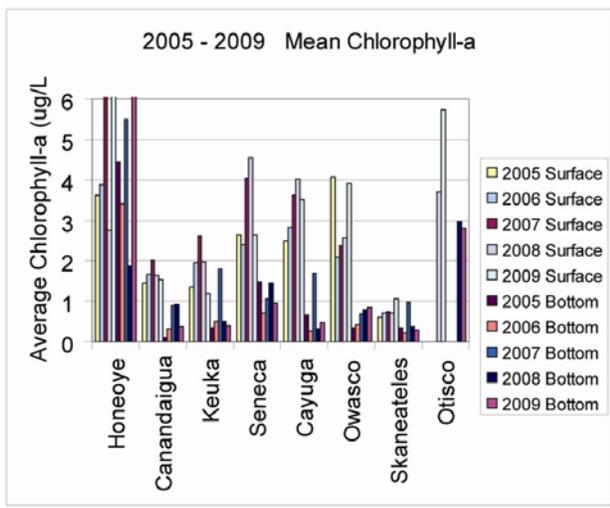
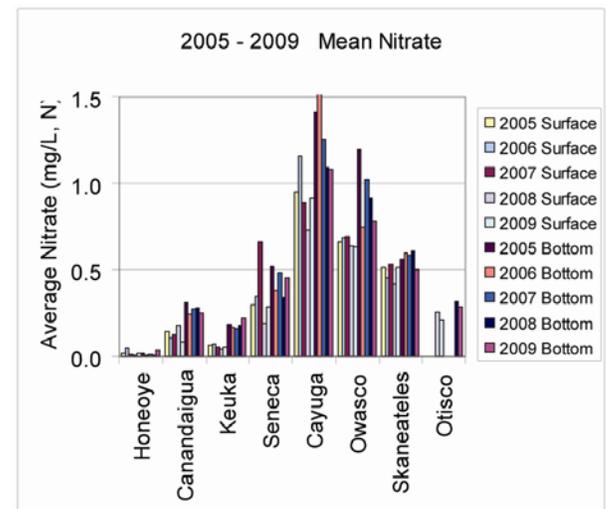
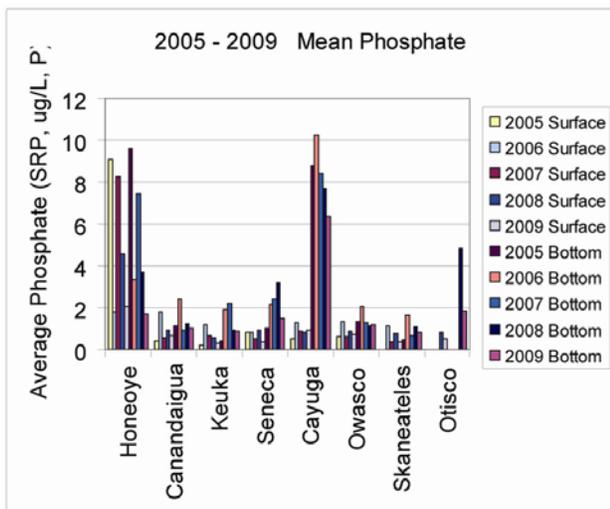
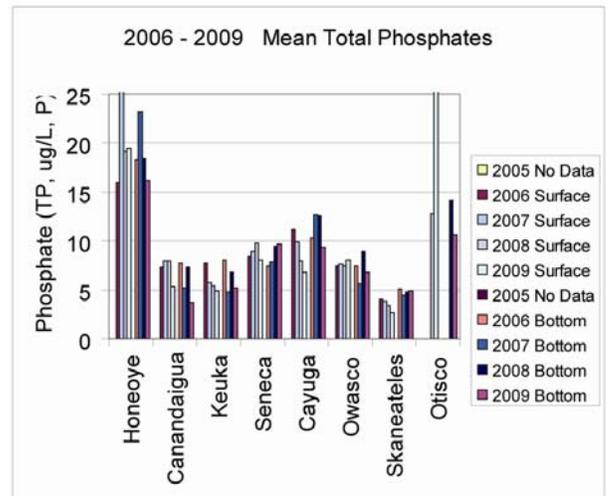
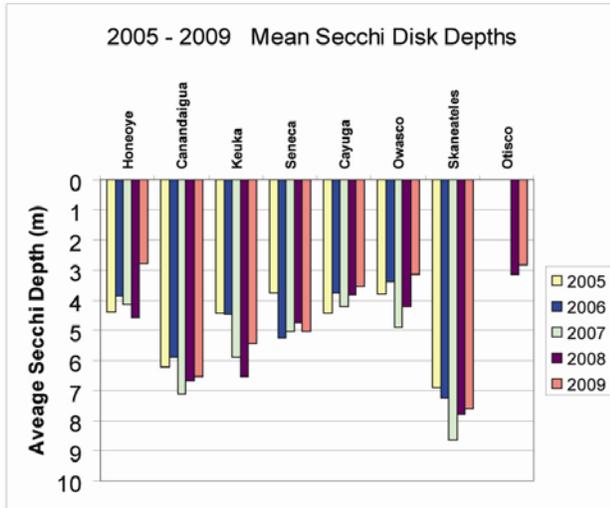


Fig. 5. Mean Annual Lake Data

**Owasco Water Quality Rank:** Is Owasco Lake water quality getting progressively better or worse? Annual water quality ranks for the eight easternmost Finger Lakes from 2005 to 2009 are shown in Figure 6. These ranks were based on annual average secchi disk depths, and annual average surface water concentrations of chlorophyll-a, total and dissolved phosphate, nitrate and total suspended sediment. Bacteria counts were included in the initial 2005 ranking but excluded since, and excluded from this tabulation. Canandaigua, Keuka and Skaneateles Lakes stand out as the lakes with the best water quality (ranks below 7). Honeoye and Otisco are the worst lakes in the survey (ranks above 12). For example, annual average secchi disk depths are over 7 meters and chlorophyll-a concentrations are 1 to 2  $\mu\text{g/L}$  in the best lakes, but are near or shallower than 3 meters and above 3  $\mu\text{g/L}$  in the worst. Owasco Lake is still near the worst end of the spectrum (ranks between 11 and 16).

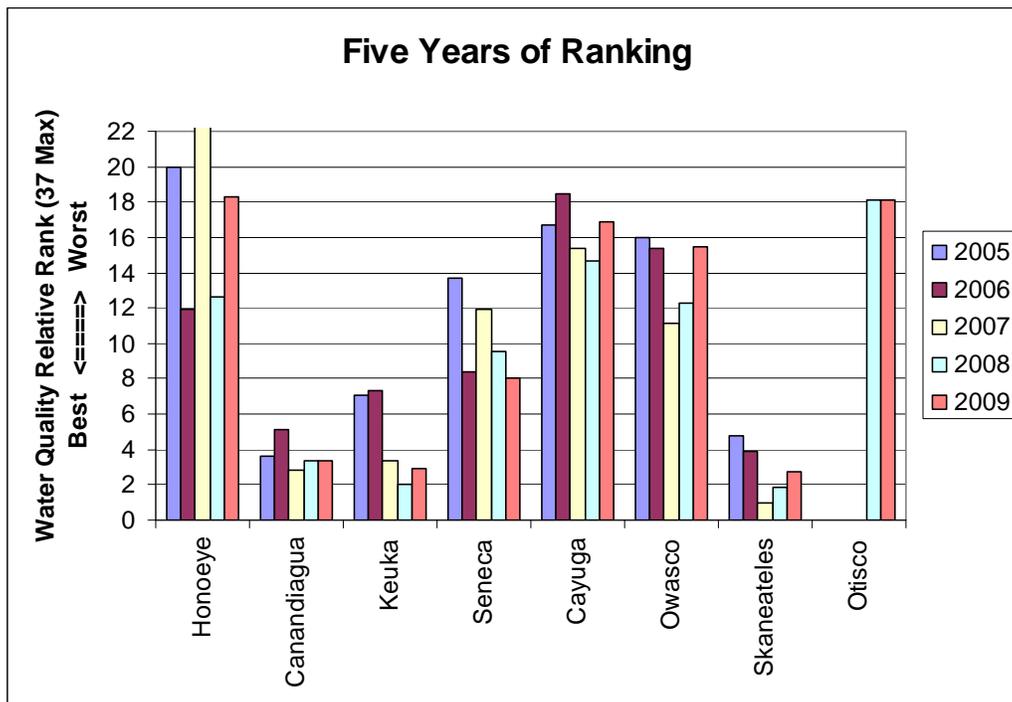


Fig. 6. Annual Water Quality Ranks for the eight easternmost Finger Lakes.

The change in water quality between lakes is due to a number of factors. As determined earlier, the degree of water quality protection legislation and its implementation are important. For example, the Skaneateles, Canandaigua and Keuka watersheds are excellent examples that have adopted a number of stringent regulations that protect and maintain the pristine nature of their lakes. Various BMPs were recently implemented and their effectiveness tested to improve water quality at Conesus Lake. In an effort to determine some of the other critical variables influencing water quality, the mean water quality rank for each watershed was compared to water residence time, watershed population, watershed size, lake volume and percentage of agricultural land in each watershed. The only significant result was that the annual rank correlates to the percentage of agricultural land in the watershed ( $r^2 = 0.81$ , Fig. 7). Other correlations were weak or very weak with correlations ( $r^2$ ) of 0.4 and typically much lower. The land use correlation indicates that runoff of non point sources is another critical factor that influences water quality in the surveyed Finger Lakes.

Honeoye was excluded from this land use to water quality rank correlation due to its shallow nature (maximum depth < 10 meters) and legacy phosphate that provides significant internal phosphate loading from the lake floor. The internal phosphate loading is sufficiently intense to enable nitrates to be the limiting nutrient in this watershed.

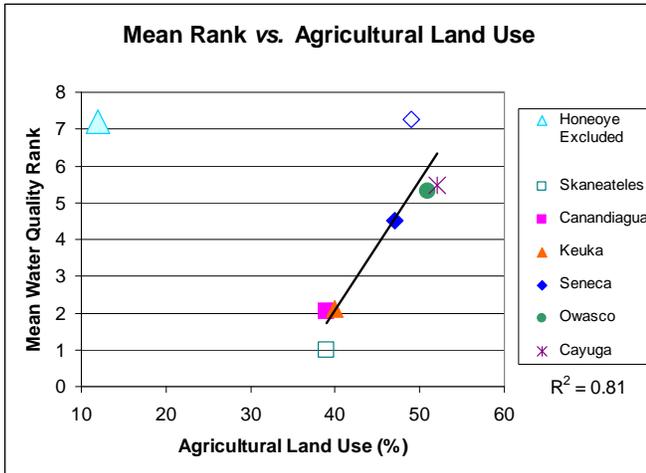


Fig. 7. Correlation of mean water quality ranks to percentage of agricultural land in each watershed. Honeoye was excluded from the analysis.

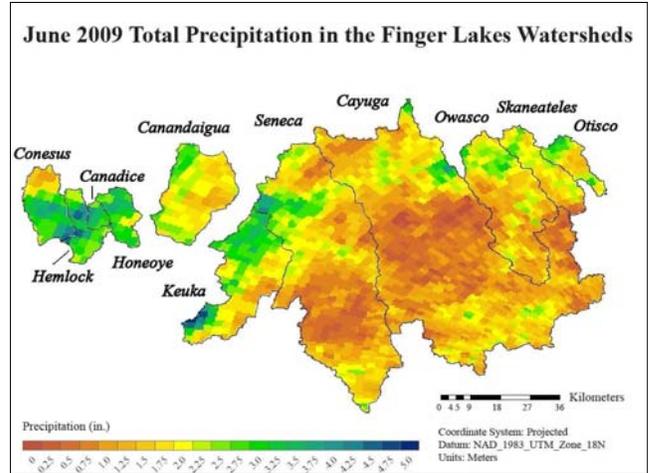


Fig. 8. Rainfall totals for June, 2009, from GIS raster-based 420x420m weather radar data. Notice the huge variability from watershed to watershed.

**Year-to-Year Changes in Rank:** Water quality in Owasco Lake also changes from one year to the next (Fig. 6). Water quality was worst in 2005 and 2006, improved during 2007 and 2008 but declined back to 2006 levels in 2009. Because some of the other lakes revealed similar trends, it suggests a regional explanation like precipitation patterns. The annual variability at Owasco is consistent with precipitation totals ( $r^2 = 0.74$ ) and the implied delivery of non point source nutrients. Two years, 2007 and 2008, experienced less precipitation in the Owasco Watershed (2008 < 800 mm/yr, 2007 < 400 mm/yr) than the other years, 2005, 2006 and 2009 (> 950 mm/yr) as determined by GIS analysis of NASA’s Tropical Rainfall Measuring Mission data, a 27 x 27 km raster dataset of global, monthly precipitation totals. Interestingly, the change in annual precipitation from one year to the next was not consistent between watersheds, but the annual precipitation was proportional to water quality ranking in many of the other watersheds. Most likely the impact of water residence time and exotic species play a part as well. Clearly, more work must be done using more detailed rainfall summaries to substantiate this claim. The work is tedious as it involves conversion of hourly, vector-based, weather radar data available at the National Climatic Data Center into 420 x 420 m raster-based annual summaries (Fig. 8).

The relationship indicates that the year to year variability may, in part, be dictated by variations in precipitation, and more specifically, the delivery of non point source nutrients from the watershed to the lake, e.g., runoff of nutrients from agricultural land. This analysis identified an important silver lining. If nutrient loading decreases in any year, then water quality improves! Thus, hope exists to improve water quality in the Finger Lakes and achieve the ultimate goal to preserve, protect and promote these lakes for future generations. However the opposite is also true. If nutrient loading continues then water quality in the lake will continue to degrade.

Exotic species like the zebra and quagga mussels, and/or the exotic carnivorous zooplankton, the spiny water flea may play a role as well. Zebra and quagga mussels filter feed plankton. Thus, they effectively remove algae and other plankton from the lake, and thus “improve” water quality. In contrast, the spiny water flea eats other herbaceous (plant eating) zooplankton. Once eaten, the herbaceous zooplankton are no longer available to eat algae (plants). The typical result is a mid-summer bloom of algae due to decreased predation, and thus impaired water quality. Dr. Brown’s (HWS) preliminary data from the 2007 survey indicated that this carnivore has already influenced water quality in Owasco Lake. She and co-workers from SUNY-ESF and Cornell U. are currently following up on this research.

### **STREAM RESULTS & DISCUSSION**

**Stream Discharge:** Stream discharge in this survey ranged from 0.0 to 4.6 m<sup>3</sup>/s (Table 3, Fig. 9). Spatially (between sites), the mean discharge was larger at sites with larger drainage basins upstream on any given sample day. For example, the discharge at Owasco Inlet was consistently larger than any other stream on any given day. Temporally (over time), the largest discharge at any one stream was on 12/17/09, and smallest on 9/25/09 and 5/25/10. Veness Creek was dry on 9/15/09 and 5/25/10. The variability in discharge at each site reflects the weather conditions, with larger discharges during or just after precipitation events and/or spring thaw. Frozen conditions on 12/17/09 increased the runoff to infiltration ratio as well to provide proportionally even more water to the streams.

**Stream Concentration Data:** Total phosphate (TP) concentrations ranged from 0.7 to over 50 µg/L, and averaged 12 µg/L (Table 3 and Fig. 9). Variability was observed between sample dates at each site and between sites. Temporally, TP concentrations were largest at each site during the 6/8/10 discharge event. At this time, TP concentrations exceeded 20 µg/L, the limit for impaired surface water, at all sites, except at the most upstream site on Dutch Hollow Creek. Presumably, runoff of soils and other phosphate-rich particles from non point sources impact water quality in these streams. In contrast, phosphate concentrations were not significantly larger during the 12/17/09 event (0.0 to 4.6 µg/L) than other sample dates. Perhaps the frozen conditions prevented the movement and runoff of soils. The largest TP concentration of ~50 µg/L was detected at Owasco Inlet on 4/16/10 just after the spring thaw. It is consistent with sampling the tail end of the spring flush of phosphate-rich particulates. The spring thaw was presumably just missed at the other, smaller streams.

Spatially, the tributary to Dutch Hollow Creek (labeled Young’s Creek) and Owasco Inlet revealed the largest mean TP concentrations (just above 20 µg/L) over the course of the study, whereas the Benson Road site and the most upstream site on Dutch Hollow Creek revealed the smallest mean TP concentrations (below 4 µg/L). The difference can be explained by land use activities upstream from the sample site. For example, the presence (or absence) of agricultural land, exposed stream banks, and other various point and non point sources (waste water treatment facilities and other on-site treatment systems) can account for the differences.

Similar trends were also revealed by the dissolved phosphate (SRP), total suspended solids (TSS), and to a lesser degree nitrate concentrations. Temporally, SRP, TSS and nitrate

**Table 3: Stream Data.**

**2009 - 2010 Owasco Watershed Stream Project Data**

Date	Site Location	Discharge (m <sup>3</sup> /s)	pH	Conductivity (µS/cm)	Water Temp (°C)	Nitrate (mg/L, N)	TSS (mg/L)	Total Phosphate (µg/L, TP as P)	Dissolved Phosphate (µg/L, SRP as P)
9/15/09	Dutch Hollow Rt 38A	0.13	8.4	501	16.5	0.8	1.1	5.2	0.7
9/15/09	Dutch Hollow North Rd	0.07	8.4	506	16.9	1.5	1.2	5.7	0.0
9/15/09	Dutch Hollow Benson Rd	0.07	8.3	501	16.8	0.7	9.4	0.7	0.8
9/15/09	Young's Creek	0.00	7.9	667	16.4	1.1	1.5	13.6	5.5
9/15/09	Dutch Hollow 38A Upstream	0.05	8.2	472	16	0.2	1.5	2.3	1.3
9/15/09	Owasco Inlet Moravia	1.07	8.2	455	16.8	0.4	1.8	10.0	5.5
9/15/09	Fay's Creek	0.00	7.7	559	17.5	0.0	41.4	2.7	6.0
9/15/09	Veness Creek	no flow	--	--	--	--	--	--	--
12/17/09	Dutch Hollow Rt 38A	1.24	8.2	526	0.5	1.0	2.2	5.8	0.7
12/17/09	Dutch Hollow North Rd	1.06	8.1	493	0.1	1.9	3.1	4.3	0.8
12/17/09	Dutch Hollow Benson Rd	0.82	8.1	422	-0.2	1.7	5.8	1.7	0.0
12/17/09	Young's Creek	0.10	8	761	-0.2	3.0	2.0	22.2	13.2
12/17/09	Dutch Hollow 38A Upstream	0.57	8.1	401	-0.2	2.0	5.6	2.2	0.5
12/17/09	Owasco Inlet Moravia	4.64	8.1	365	-0.1	0.9	4.8	6.4	2.3
12/17/09	Fay's Creek	0.05	8.1	533	0	0.8	1.5	11.3	0.3
12/17/09	Veness Creek	0.01	7.9	695	0	1.4	2.5	11.2	3.4
4/16/10	Dutch Hollow Rt 38A	0.73	8.5	430	12.4	0.8	0.9	9.0	0.2
4/16/10	Dutch Hollow North Rd	0.60	8.5	388	12.7	1.5	0.9	4.4	0.4
4/16/10	Dutch Hollow Benson Rd	0.40	8.5	468	14.1	0.7	1.3	6.9	0.3
4/16/10	Young's Creek	0.05	8.3	326	14.2	1.7	0.5	9.4	1.6
4/16/10	Dutch Hollow 38A Upstream	0.28	8.7	485	13.6	1.0	1.6	2.0	0.5
4/16/10	Owasco Inlet Moravia	2.83	8.6	470	12.9	1.2	6.3	51.5	3.0
4/16/10	Fay's Creek	0.02	8.5	438	12.6	0.2	1.0	5.9	0.3
4/16/10	Veness Creek	0.01	8.4	658	14.2	0.5	1.0	10.1	0.9
5/25/10	Dutch Hollow Rt 38A	0.26	8.6	493	18.1	1.4	1.8	9.1	1.9
5/25/10	Dutch Hollow North Rd	0.28	8.7	484	18.8	1.6	3.4	7.7	1.6
5/25/10	Dutch Hollow Benson Rd	0.28	8.5	459	18	1.0	1.8	1.3	0.7
5/25/10	Young's Creek	0.02	8.3	725	19.7	3.5	1.5	29.5	13.2
5/25/10	Dutch Hollow 38A Upstream	0.19	8.7	448	18	1.0	2.7	4.1	0.7
5/25/10	Owasco Inlet Moravia	1.86	8.5	407	18.1	1.7	4.9	12.5	5.2
5/25/10	Fay's Creek	0.00	8.5	453	22	0.1	4.6	8.8	0.9
5/25/10	Veness Creek	no flow	--	--	--	--	--	--	--
6/8/10	Dutch Hollow Rt 38A	1.17	8.8	539	15.4	2.6	9.2	27.1	9.7
6/8/10	Dutch Hollow North Rd	0.78	8.7	529	15.1	2.0	5.7	15.9	7.7
6/8/10	Dutch Hollow Benson Rd	0.54	8.7	480	14.6	3.9	5.6	7.7	4.4
6/8/10	Young's Creek	0.11	8.4	748	16.7	10.7	3.2	31.8	22.8
6/8/10	Dutch Hollow 38A Upstream	0.28	8.8	459	15.1	1.2	7.1	8.8	4.2
6/8/10	Owasco Inlet Moravia	1.93	8.8	403	16.6	1.4	4.5	23.8	15.0
6/8/10	Fay's Creek	0.02	8.6	380	17.6	1.5	5.5	22.9	4.9
6/8/10	Veness Creek	0.02	8.5	710	17.3	3.9	3.0	26.7	16.6

concentrations were larger after the 6/8/10 discharge event than the other sample dates. Spatially, SRP, TSS and nitrate concentrations were larger at Young's Creek and Owasco Inlet than other sites. Nitrate revealed one notable exception. Nitrate concentrations were smaller and less variable at the Owasco Inlet than Dutch Hollow Creek suggesting an agriculturally-influenced groundwater source for the nitrates to Dutch Hollow Creek. The largest nitrate concentration was detected at Young's creek during the high discharge event (6/8/10). It suggests that surface runoff of nitrates from non point sources added to the groundwater sources of nitrates at this site. Phosphates lack a similar ground water source because phosphates bind to soil particles and are not very water soluble, whereas nitrates are water soluble.

These interpretations are consistent with 2010 stream data from the Seneca Lake watershed. Phosphate concentrations were relatively larger in the early spring samples and smaller after the spring thaw (Fig. 10). The Owasco streams were sampled just after the initial decline of phosphate concentrations in the smaller tributaries in the Seneca Lake watersheds. Total

phosphates and total suspended sediments were much larger in samples collected during or just after a heavy rain in the Seneca Lake watershed as well.

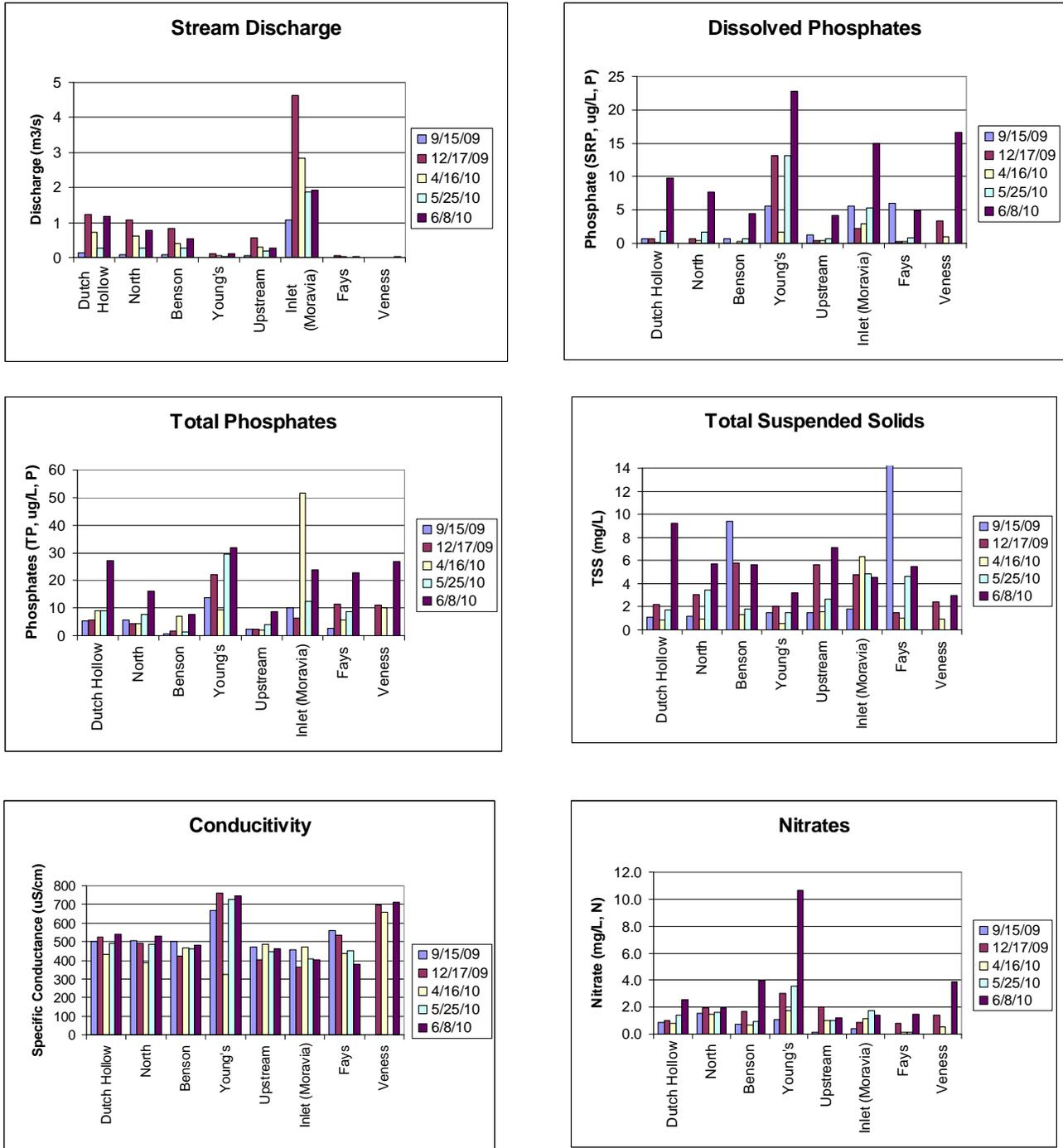


Fig. 9. 2009-2010 Stream Concentration Data

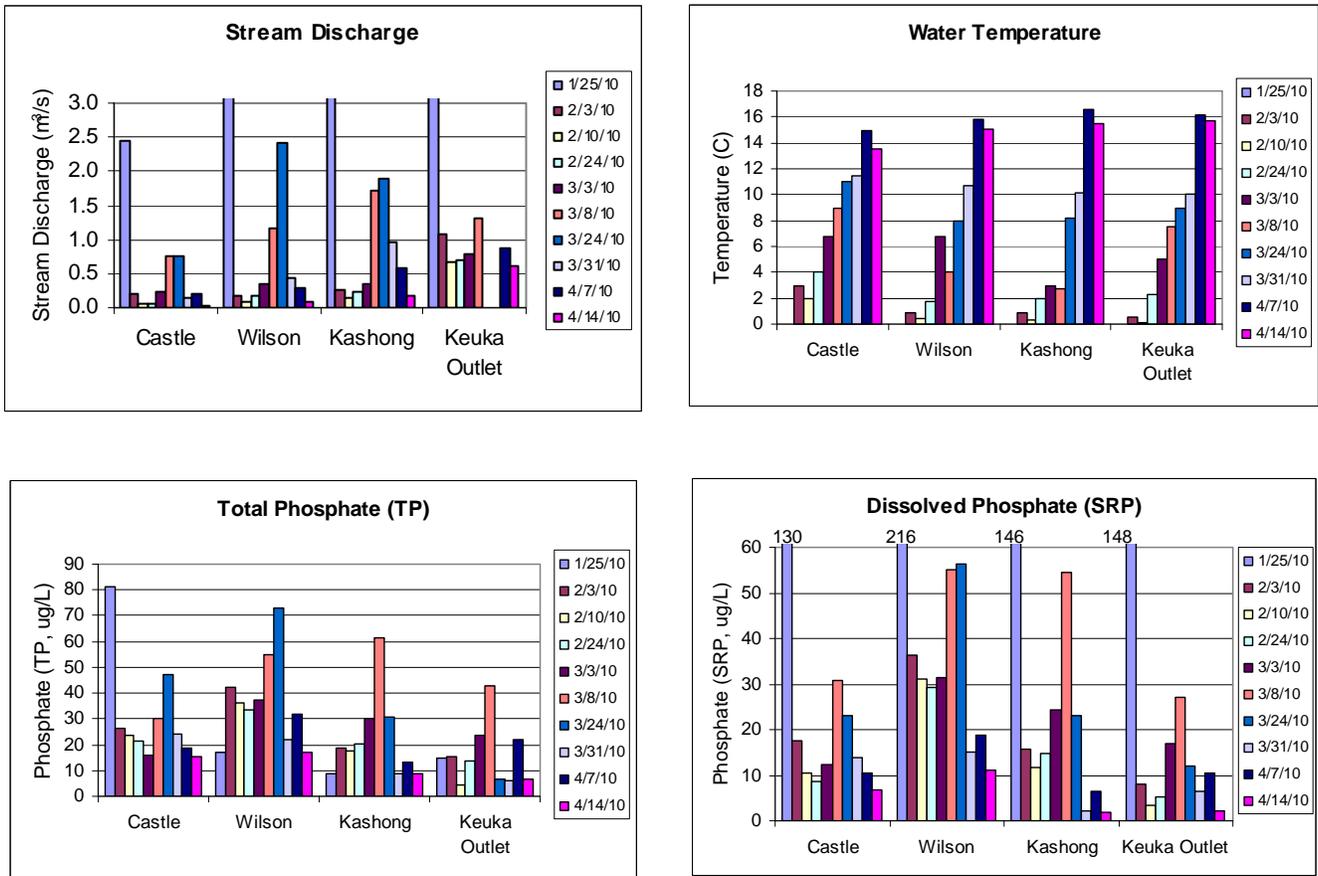


Fig. 10. Seneca Lake Stream Data.

**Stream Fluxes:** Temporally, the largest fluxes of materials at any site occurred during the largest discharge event on 6/8/10 (Fig. 11). Thus, stream discharge is a critical parameter when evaluating nutrient loading to the lake. Spatially, the Owasco Inlet revealed a significantly larger flux of material to the lake than any other stream (TP 6.2 kg/day vs. 1.2 or lower; SRP 1.4 kg/day vs. 0.3 or lower; TSS 1,023 kg/day vs. 340 or lower; 266 kg/day vs. 112 or lower). Owasco Inlet is the largest watershed that empties into Owasco Lake, approximately four times larger than Dutch Hollow Creek, and spans 57% of the Owasco watershed. Thus, the relatively large (but not the largest) concentrations of nutrients and suspended sediments and the largest discharge of water to the lake by the Owasco Inlet means that it has the largest flux of materials to the lake.

These 2009 and 2010 results are consistent with the earlier hydrogeochemical findings in the Owasco and neighboring watersheds. For example, a large flood event on 6/27/06 provided the largest discharge (~ 11 m<sup>3</sup>/s) and nutrient concentrations (~35 µg/L) along the Owasco Inlet, resulting in a phosphate flux of over 34 kg/day, much larger (10 to 1,000 times) than the other sites and other samples dates in the earlier surveys.

Veness Creek and Fay's Creek, in comparison to Dutch Hollow Creek and Owasco Inlet, are very small watersheds with smaller stream flows. Even though the concentrations may be large at these sites, their loadings are at least 100 times smaller than the Owasco Inlet on any sample date due to their very small discharge. It suggests that nutrient loading to the lake is most critical at the two largest streams, Dutch Hollow Creek and Owasco Inlet.

Annual mean stream concentrations and fluxes support this claim (Fig. 12a & 12b). Both Dutch Hollow Creek and Owasco Inlet revealed the largest fluxes of materials to the lake. Thus, these two streams are very significant sources of phosphate to the lake compared to the other tributaries in the watershed. Phosphate concentrations are also greater in these two streams than the mean surface-water lake concentration. As a result, these streams add phosphate to the lakes in significant quantities. Consequently, the extra phosphate fertilizes the algae, increases algal productivity, and impairs water quality.

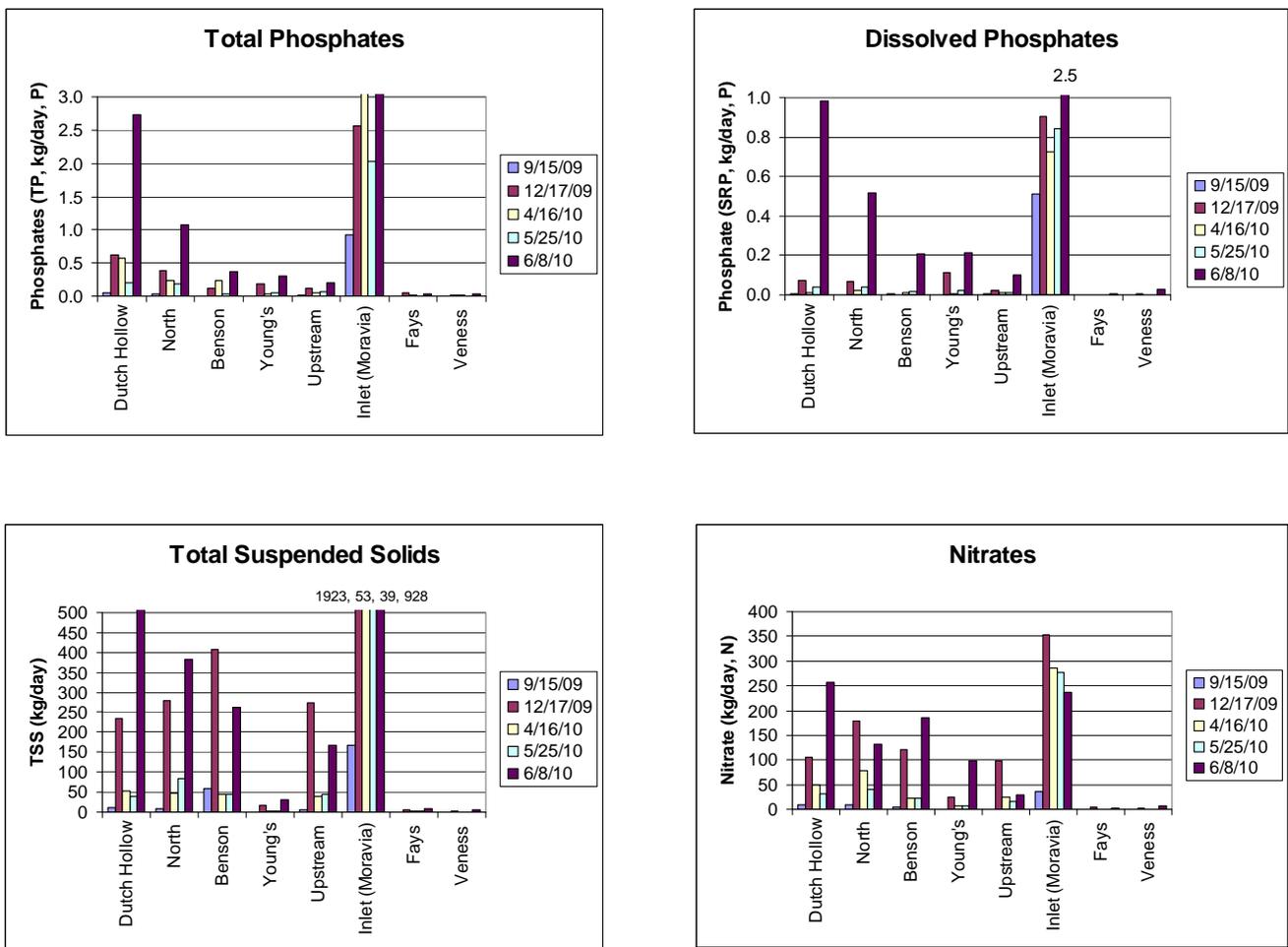


Fig. 11. 2009-2010 Stream Flux Data.

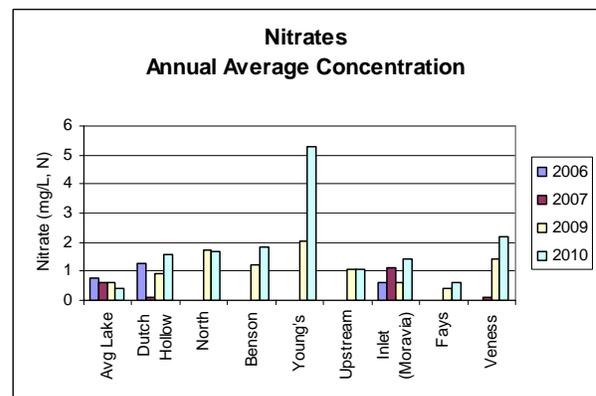
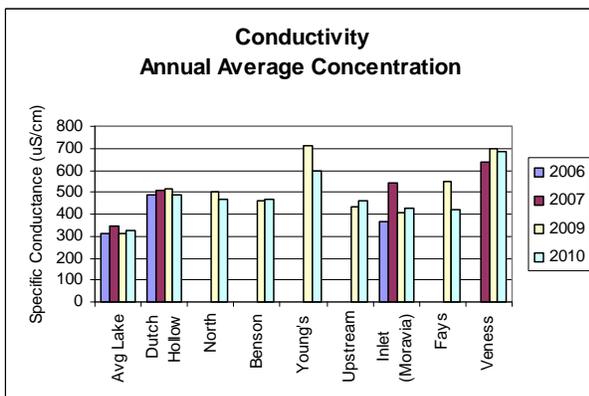
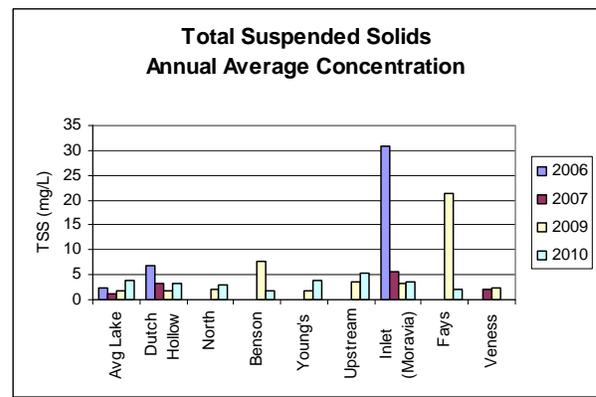
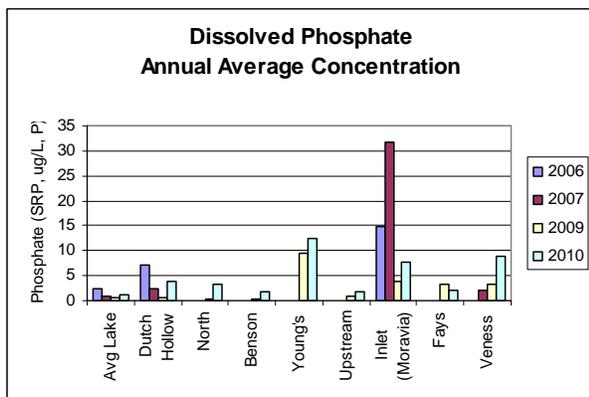
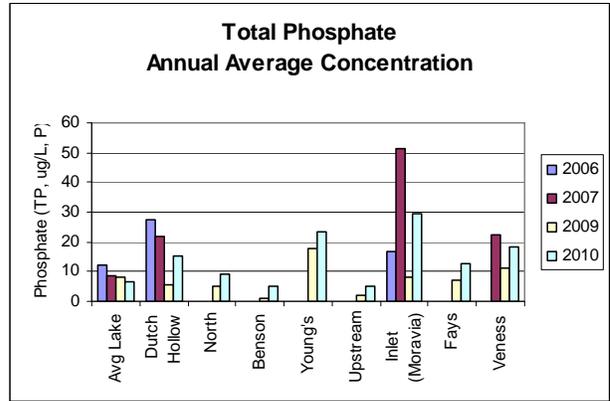
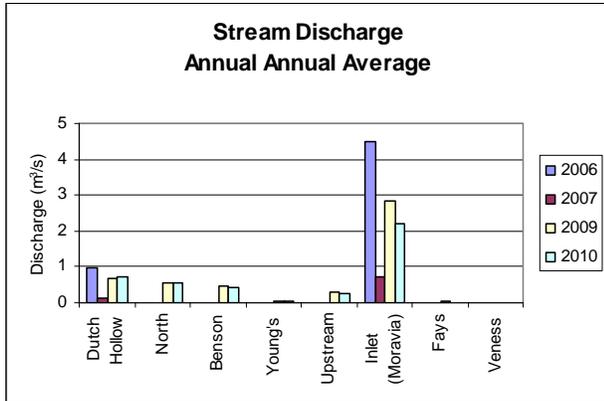


Fig. 12a. Annual Stream Concentration Data

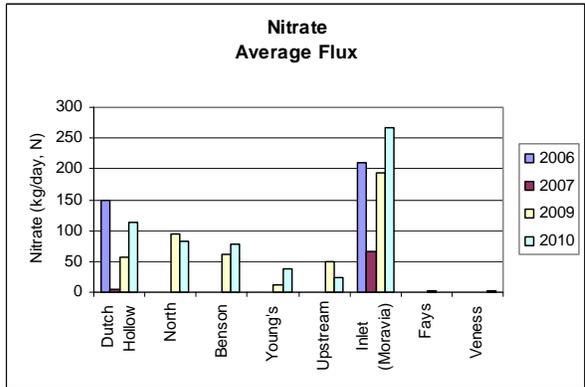
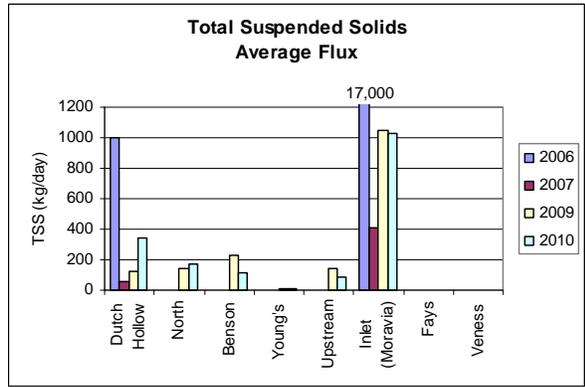
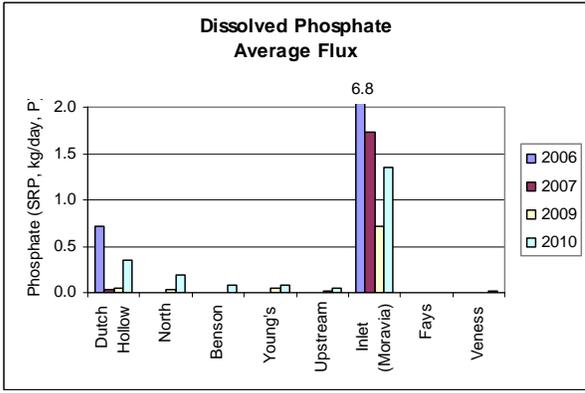
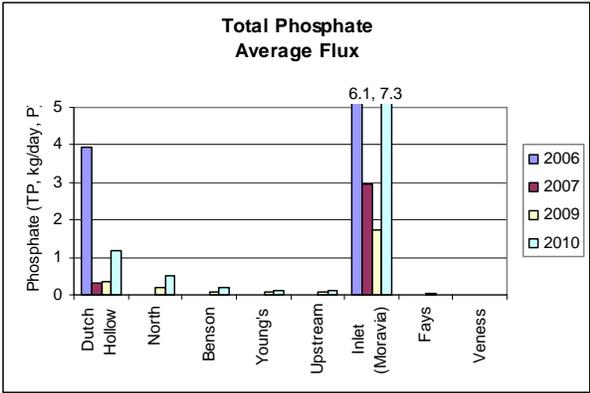


Fig. 12b. Annual Average Flux Data.

## **CONCLUSIONS & RECOMMENDATIONS:**

This report confirms and expands on the 2007 and earlier findings. As previously observed, Owasco Lake is a borderline oligotrophic – mesotrophic ecosystem. None of the water quality parameters are life threatening at the present time. The sources of nutrients and suspended sediments include point sources from a wastewater treatment facility, and non-point sources from onsite wastewater systems, agricultural activities, soil erosion, fertilized lawns, roadside ditches and construction activities. The data in this report highlight the importance of runoff of non point sources in association with major precipitation events and probable nutrient loading during the spring thaw although more data are required to confirm this.

Due to the variety of the pollutant sources, remediation efforts should be multifaceted to improve water quality in Owasco Lake. A number of remediation efforts outlined below were recently initiated and/or already proposed for the watershed. This is good, and this important work should be continued into the future. All of them should help improve water quality in the lake. Without it, water quality would decline over time.

***Watershed Inspector:*** Maintain the services of the county-based watershed inspector. Education, inspection, and other nutrient reduction measures spearheaded by the watershed inspector will reduce nutrient and suspended sediment loadings to the lake. It also generates a domino effect that triggers improved water quality in the lake and eventually saves money for those using Owasco Lake as a source of drinking water. This is due to a reduction in the cost of filtering algae and suspended sediments from the lake water before it is delivered to the consumer. The hire of additional inspectors would increase these benefits at minimal cost to the public (pennies/year/user).

***Agricultural BMPs:*** It is satisfying to notice that progress has been made on the adoption and implementation of various “best management practices” (BMPs) in the watershed. BMPs reduce the non point source nutrient contribution from the agricultural sector, both crop farming and animal husbandry. Steps should continue to identify the best BMPs for this watershed and identify pathways so that the entire economic burden is not placed solely on the farmer but perhaps instead on state and federal funds, and/or the users of the lake’s water. Excellent examples exist in the region. Skaneateles, Canandaigua and Conesus watersheds are important examples.

***Owasco Inlet Floodplain:*** The floodplain/wetland geomorphology of the Inlet from Moravia to the lake suggests that it could remediate the impact of floods on the lake. Floodplains and wetlands provide excellent natural systems to reduce the peak discharge of flood events and reduce the associated nutrient and suspended sediment loads from the floodwaters. However, this occurs only if the floodwaters are allowed spill over the stream banks and flood the floodplain. Spreading the flood waters over the entire Owasco Flats area, decreases the peak and total discharge of storm events by decreasing the volume of water and increasing the lag time to deliver this water to Owasco Lake. The Owasco Flats would also remove nutrients and suspended sediments from the flood waters by allowing the assimilation of nutrients by plant life in the floodplain and time for the sediments to settle on the floodplain. At the present time, however, man-made levees along the Inlet prevent the natural flooding of the floodplain. These levees enabled homeowners and farmers to utilize the fertile floodplains with a lower risk of loss. Remediation of the floodplain is probably the most ambitious effort outlined here, because the

land within the floodplain must be bought, artificial levees removed, and distribution channels built for this plan to work without undue hardships to the local residents. Both tasks are costly, and this plan only addresses the excess nutrients and suspended sediments provided by the flood events and not base flow.

**Education:** Education is critical so that local residents understand the need for properly functioning onsite wastewater treatment systems and environmentally friendly (less fertilized) lawns in order to reduce the seepage and runoff of nutrients to the lake. The education starts at primary and secondary school but should also include the average homeowner, government officials, and environmental protection associations.

**Marcellus Shale Drilling for Natural Gas:** A new water quality threat to the Finger Lakes Region is the potential for accidents while drilling and “hydrofracking” the Marcellus Shale for its natural gas. The threat is more pronounced for the Southern Tier than the Finger Lakes region, because the bulk of the drilling is proposed to occur in the Southern Tier. However, problems in Pennsylvania and elsewhere have resulted in contaminated surface waters with saline and turbid fluids that also have proprietary toxic chemicals. Clearly, a similar spill would be “problematic” for the Finger Lakes region as the region relies on the Finger Lakes for drinking water. Thus, a near-real time monitoring stations for salinity and turbidity should be established at the southernmost streams in the Finger Lakes watersheds. This array would provide an early warning system that would help protect our lakes from future threats from the south.

**Stream and Lake Monitoring:** Finally, water quality monitoring of selected streams and lake sites should continue into the future. At a minimum, both event and base flow samples, measured for phosphates and perhaps total suspended solids over the four seasons, should be taken from both Dutch Hollow Creek and Owasco Inlet, the largest contributors to the lake. The skeleton plan enables a cost-effective evaluation of the implemented pollutant reduction strategies. However, FLI lacks funds to do this extensive, watershed specific project, without external support. Lake sites should also be monitored to assess the change in water quality over time. The Finger Lakes Institute anticipates a continuation of its monitoring of the lake at Sites 1 and 2 as part of the Finger Lakes survey in the years to come but only if funding permits. The data are critical to further investigate the land use and precipitation associations to water quality.

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