

Sources for Bottom Water Phosphates and Suspended Sediments in Southern Cayuga Lake, New York

Abstract:

Water quality monitoring of the seven largest Finger Lakes in central and western New York State since 2005 identified elevated phosphates (greater than 8 ug/L) and suspended sediments (greater than 2 mg/L) in the hypolimnion of Cayuga Lake compared to the other large lakes in the survey (less than 2 ppb and 2 mg/L, respectively). Here, we report on the second year of a two year detailed study of Cayuga Lake that investigated the source of these elevated nutrient and sediment concentrations. Total suspended sediments (TSS) and total phosphates (TP) were detected at elevated concentrations a day or two after wind and/or rainfall events in Cayuga Lake than other sample dates in the survey. It strongly suggests that resuspension and runoff events are both important to the delivery of organically bound phosphates attached to suspended sediments to the hypolimnion of the lake.

Surface, mid-depth (40m above the lake floor), and bottom water (within 2 m of the lake floor) samples were taken at six different sites in the southern half of the lake every two to three weeks from May through October of 2007 and again in 2008. The samples were filtered and then analyzed in the lab for total phosphorus (TP), soluble reactive phosphate (SRP), dissolved silica, nitrates, chlorophyll-a, total suspended sediment (TSS), and major ion concentrations following standard limnological techniques. Secchi disk depths, plankton tows and CTD profiles were also collected at these six sites, and CTD casts were collected at two additional sites located just offshore of two major streams (Taughannock and Salmon Creeks). Our SBE-25 Sealogger CTD collects profiles of conductivity (SBE 4), temperature (SBE 3), depth (SBE 29), pH (SBE 18), dissolved oxygen (SBE 43), PAR (Biospherical QSP-2300), fluorescence, and turbidity (WETLabs ECO-FL-NTTU).

TSS concentrations in the hypolimnion were the highest at all the sites when there was both wind and rain a day or two before sampling, and lowest when rainfall and wind events were absent before sampling. TP also followed this trend probably due to organic matter absorbed onto particles that were delivered with the winnowed and fluvial sediments. SRP however was highest during the month of May and declined through the summer. We suggest that SRP entered the lake during spring runoff and more importantly, entered the hypolimnion from the bacterial decomposition of the winnowed and fluvial organic material. The conclusions are consistent with abundant macrophyte and terrestrial plant matter observed at the lake's surface, and occasionally sampled by the bottom niskun water sampler after wind and/or rain events. In summary, both internal (resuspension) and external (runoff) processes are critical for the elevated suspended sediments and phosphates in the hypolimnion of Cayuga Lake.

Analyses and Methods:

Sampling eight sites every two weeks during 2007 & 2008 May-October field seasons

Onsite Analyses

- CTD Profile - SealBird CTD SBE-25 Sealogger
- Profiles of Conductivity, Temperature, pH, Dissolved Oxygen, Turbidity, and Fluorescence
- Secchi Disk Depth
- Conductivity (Oakton Con 11 Series Conductivity Meter)
- Temperature (Oakton Con 11 Series Conductivity Meter) & pH (Oakton pH Testr 2)
- Dissolved Oxygen & Alkalinity Titrations (LaMotte Field Titration Kits)
- Vertical and Horizontal Plankton Tow

Water Samples

- Surface Water
- Mid Depth (40m above the lake floor)
- Bottom Water (within a few m of the lake floor)

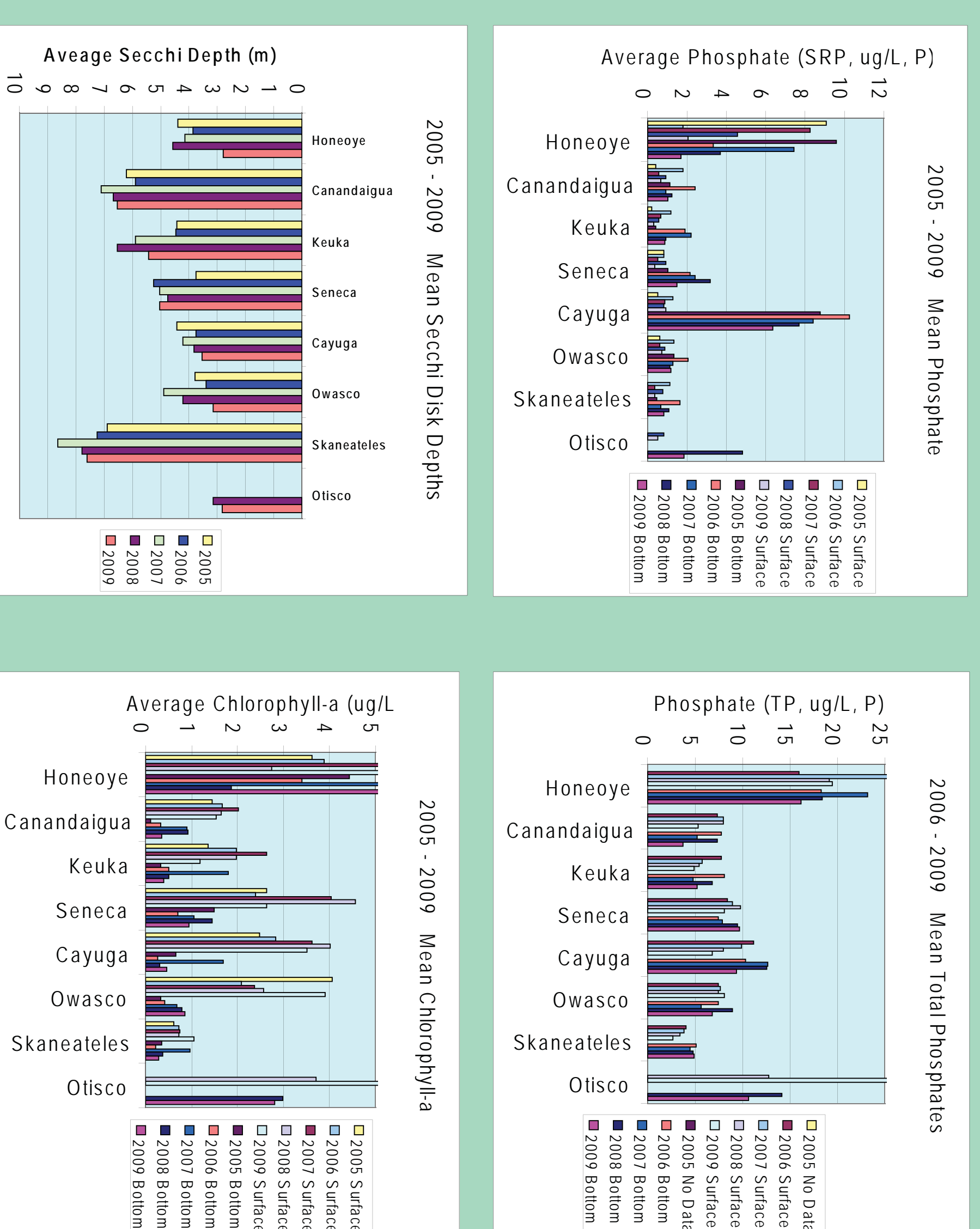
Laboratory Analyses:

- Water was analyzed in the laboratory and analyzed using standard limnological techniques (spectrophotometer and ion chromatograph):
- Total Phosphate (TP, as P), after digestion in warm (100°C) persulfate
- Water was filtered at 0.45 µm for dissolved nutrient and major ion analyses
- Soluble Reactive Phosphate (SRP, as P) of filtrate
- Nitrate (NO₃⁻, as N) and Silica (SRSI, as Si) of filtrate
- Chlorophyll-a, the filtered material was preserved in acetone for chlorophyll determination
- Total Suspended Sediments (TSS), using pre-weighed 0.45 µm glass fiber filters
- Major Ion (Na⁺, K⁺, Ca²⁺, Mg²⁺, Cl⁻, SO₄²⁻) Concentrations



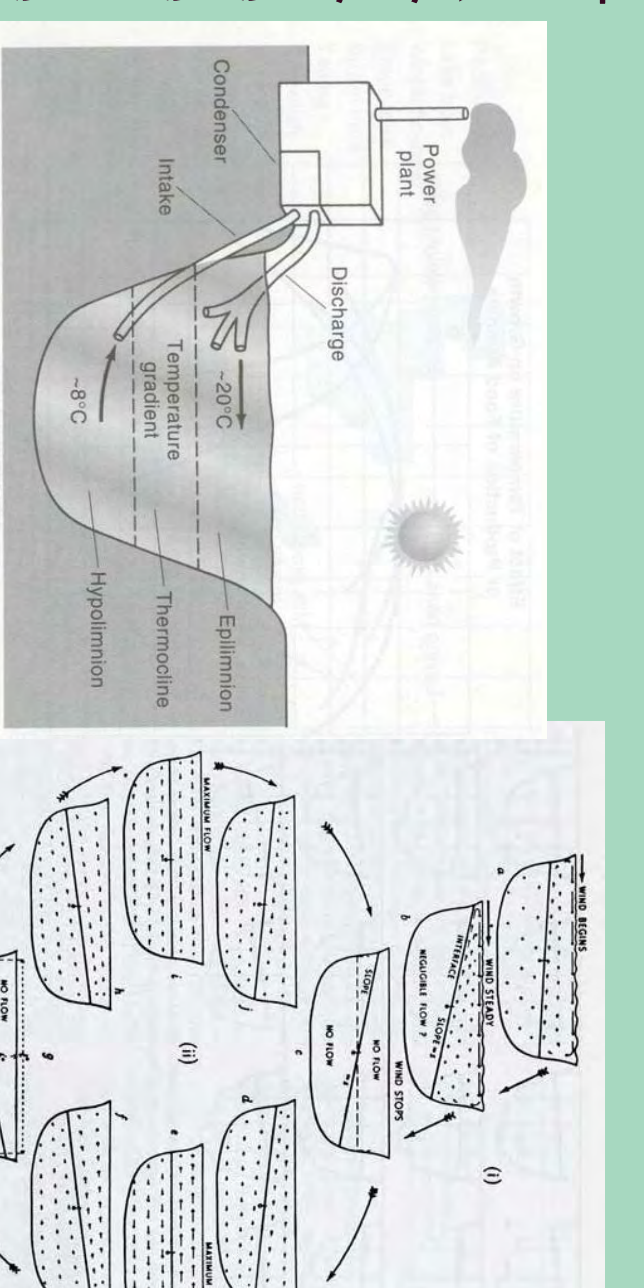
Background:

Cayuga Lake bottom waters have much more dissolved phosphates (SRP) and suspended sediments than any other major Finger Lakes (plots below). The bottom water phosphates could stimulate algal growth and degrade water quality if brought into the photic zone (surface water). Transport processes include: Cornell University's lake source cooling and/or Seiche activity. This study investigated their distribution and potential sources.



LAKE SOURCE COOLING

Cornell University uses cold (4°C) hypolimnion water from Cayuga Lake as coolant for summer air-conditioning needs at their campus. The warmer waste water is discharged into the epilimnion of the lake, along with any dissolved nutrients, like phosphates, taken from the hypolimnion.



INTERNAL SEICHE

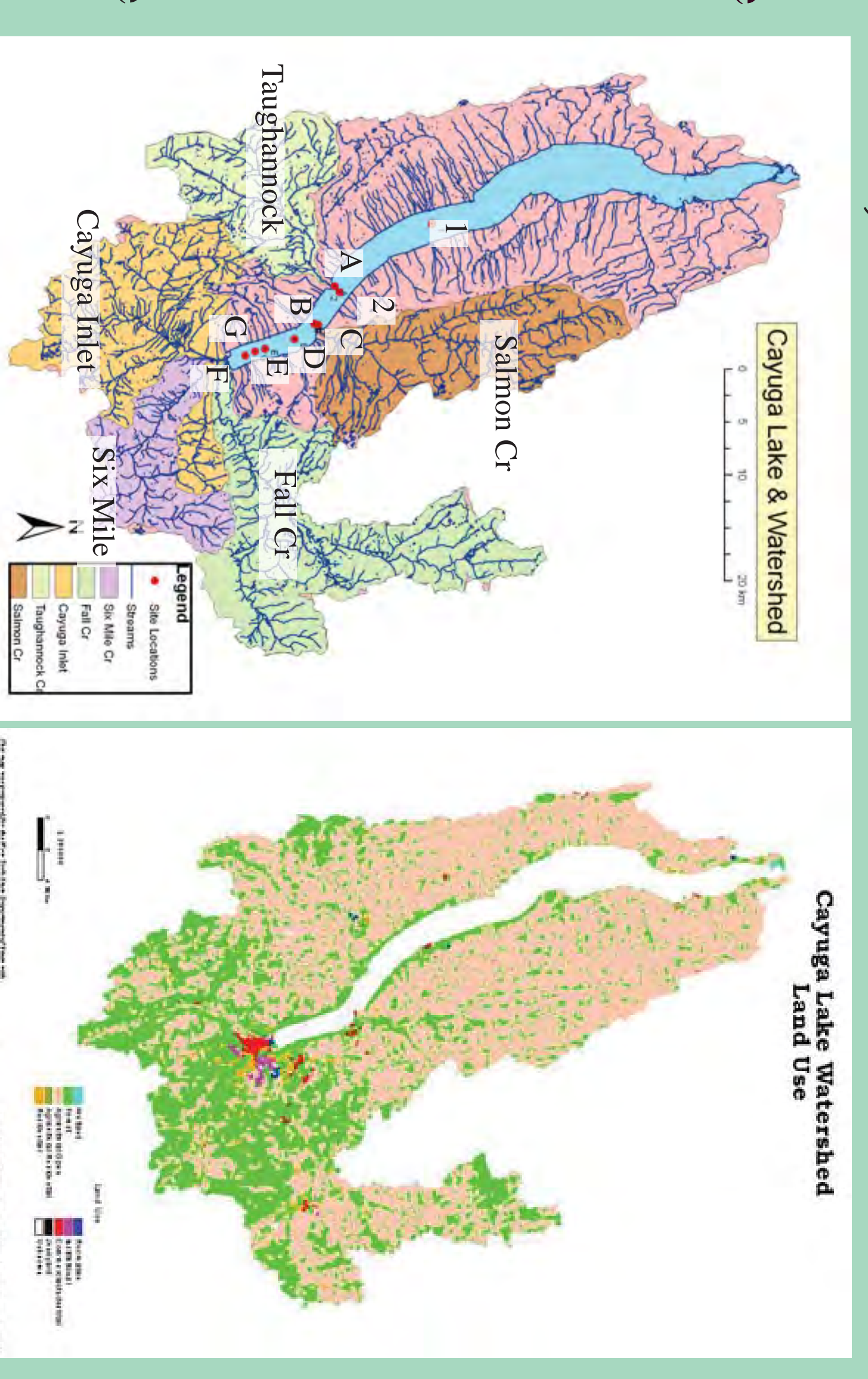
Strong winds blowing along the long axis of the lake set up internal seiche activity, the see-saw oscillation of the thermocline. This allows for the cold, phosphate rich, hypolimnion to be exposed at the surface at the southern and northern ends of the lake when the thermocline tilts towards the opposite shore.

Cayuga Watershed, Land Use & Site Locations:

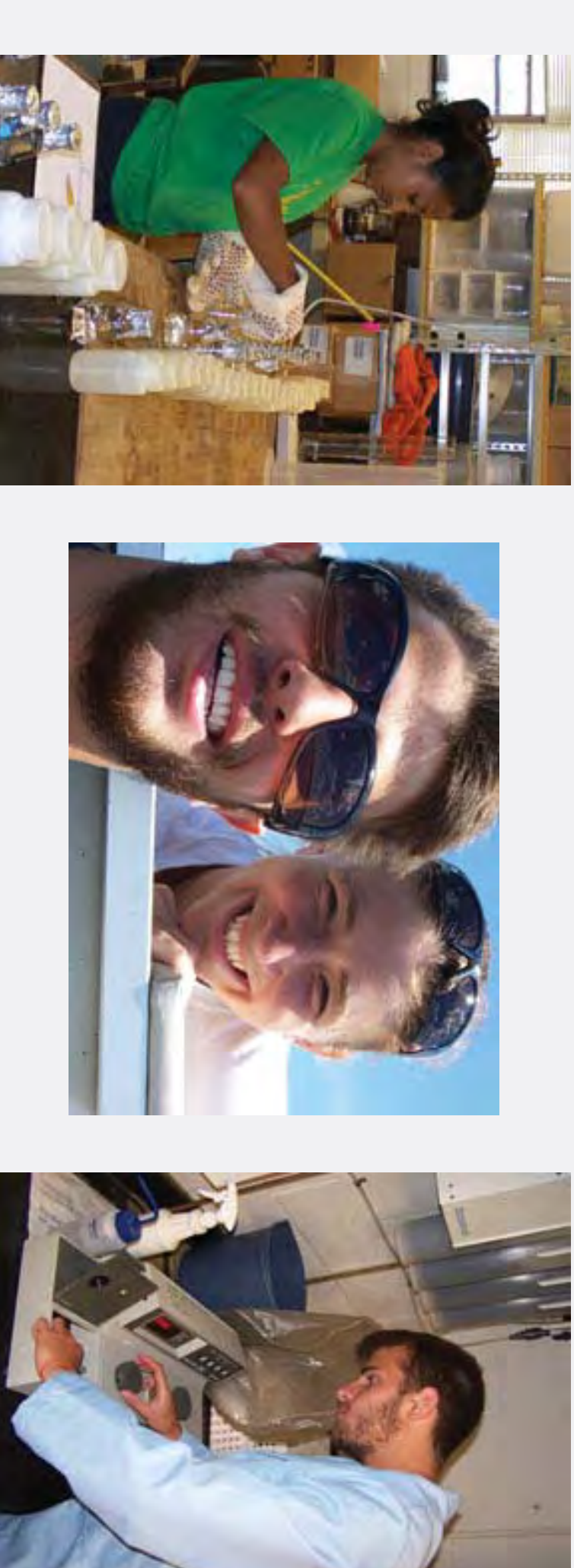
Site Locations:

- Two Sites, A & C, offshore of Taughannock and Salmon Creeks.
- Six Sites, 1, 2, B, D, E & G, along a southern mid-lake transect
- Land Use:

- Predominantly forested and agricultural land use, with some urban areas dominant, with more forested landscapes in the southern end of the watershed.



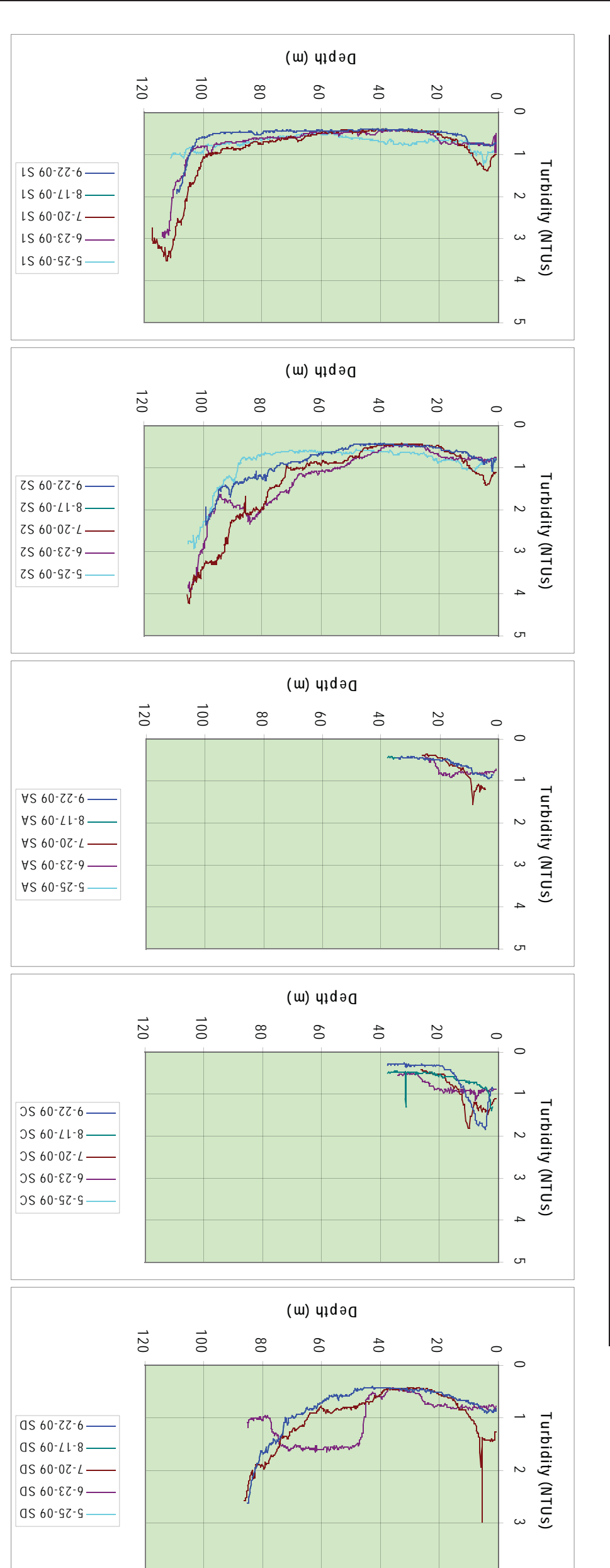
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2007 & 2008 Mean Water Analyses and CTD Profiles



2009 CTD Profiles



Spring Rains Plumes: Plumes offshore of Taughannock Creek and the southern end of the lake. Photos by Bill Hetch.



Results:

- Turbidity:**
 - The largest benthic nepheloid layers were detected at Sites 2, B and D, through out the 2007 and 2008 field seasons. These three sites are the deepest sites in the southern basin.
 - Near surface turbid intervals are consistent with algal fluorescence and chlorophyll-a data.
- On a few occasions, turbid plumes were detected offshore of Taughannock and Salmon Creeks, Sites A & C. When they were detected, a substantial precipitation event had occurred within the previous two days.
- Total suspended solid (TSS) concentrations were larger in the bottom waters of Sites 2, B and D than the other bottom water and surface water locations. These three sites are the deepest sites in the southern basin. Occasionally, the bottom water sampler recovered terrestrial plant matter, e.g., leaves, and nearshore aquatic vegetation.
- Both CTD Turbidity and TSS bottom water concentrations were larger in 2008 than 2007.
- Phosphate:**
 - Soluble reactive phosphate (SRP) concentrations increased with water depth.
 - Total phosphate (TP) concentrations increased with water depth although increase is not as pronounced as the SRP data. Site G is an exception being the shallowest where the same concentration was observed at all depths.
 - Total phosphate and total suspended solids, and soluble reactive phosphate and total suspended solids do not correlate, as the R² values are very close to 0.
- Other Data:**
 - Chlorophyll-a concentrations were 5 times larger in the surface waters than the bottom waters and slightly larger in 2008 than 2007. Site G, the shallowest site, had larger concentration in surface and mid-depth samples, both sample depths within the epilimnion at this site, than the hypolimnetic, bottom water sample.
 - Secchi disk depths decreased from north to south, a trend consistent with increasing surface water chlorophyll concentrations, and water quality degradation at the southern end of the lake.

Discussion:

- Suspended Sediments at lake floor are probably related to resuspension events by wind, runoff events, and less importantly, settling algae.
- Fluvial Source:**
 - The major sources of phosphates to the southern end of the lake were previously estimated to include:
 - Spring runoff from the tributaries, especially Fall Creek and Cayuga Inlet (~50%)
 - Hatch's Wastewater Treatment Facilities (~45%)
 - Cornell's Lake Source Cooling Project (3%)
- Taughannock and Salmon Creeks are probably important contributors as well. Our data occasionally detected turbid plumes interpreted as runoff events but did not record the spring snow melt as we started too late in the spring. Aerial photographs however depict significant turbid plumes in May (see below). Rainfall was minimal in 2007 and 2008.
- When it rained, larger nepheloid turbidities in 2007 and 2008 were detected during or just after major precipitation events than the other survey dates.
- Recycling of phosphate by the bacteria is also a major source, which suggests that high phosphorus loading in the lake is an ongoing problem.
- Wind Resuspension Source:**
 - Large nepheloid layer turbidities in 2007 and 2008 were detected during or after the windiest days of the collection of the sample, either in consort or isolated from large turbidities after major precipitation events. This suggests that northerly wind and the associated resuspension of shallow water sediments are major contributors to the suspended sediments in the nepheloid layer.
- Algal Source:**
 - The nepheloid layer was largest in the deeper southern part of the lake, little or no nepheloid layers were detected at the northern site (Site 1), nor at the shallower sites in the south (Site A, C, E & G). This distribution pattern suggests that algae is a less vital source for the material in the nepheloid layer.
- Other Observations and Future:**
 - Most importantly, there is no correlation between the amount of phosphate and suspended sediments showing that all the other factors discussed above are major contributors of the nepheloid layer.
 - The inconsistency of the data at Site G in relation to other sites is probably due to its shallow depth compared to other sites.
 - Phosphates are currently not found within the suspended sediments, and suggests that bacterial recycling is critical to release the phosphates delivered to the deep water sites.

Acknowledgements:

This research was supported by external grants and Hobart & William Smith Colleges, New York. Tara Ware, Casey Franklin, Rachel Dye, Evan Brown assisted in the 2007 fieldwork and laboratory analyses. Kerry O'Neill, Katherine Hoering, and Samuel Georgian assisted with the 2008 fieldwork and laboratory analyses. This project builds on research by numerous undergraduates over the past decade. This poster updated a poster previously presented at the 2008 Annual Meeting of the American Geophysical Union with 2009 data.