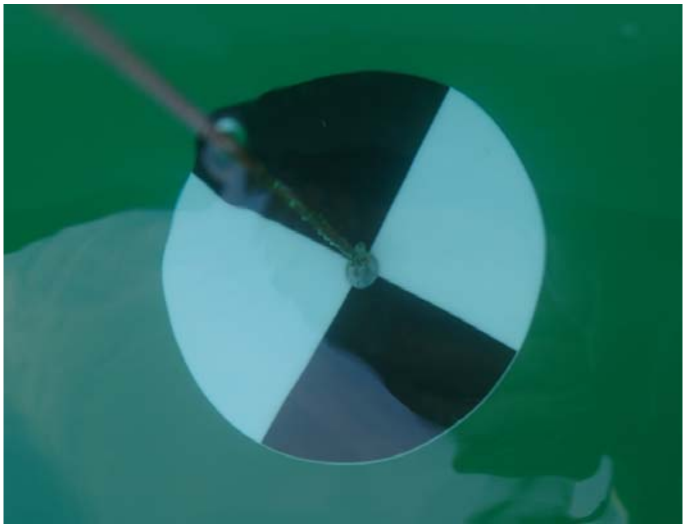
LONG TERM
WATER QUALITY REPORT

HEALTH OF CANANDAIGUA LAKE AND ITS TRIBUTARY STREAMS
2009



by

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Table of Contents:

Chapter I: Canandaigua Lake Research, 2006-2008

Executive Summary:

Lake Research:

1. Based on field research and laboratory analyses completed over the last three years, the health of Canandaigua Lake remained good to excellent.

2. Dissolved oxygen was available throughout the water column at all monitoring times and often was at or near 100% saturation, ideal conditions for the survival of aquatic life.

3. Seasonal temperature profiles characterized the development of thermal stratification that is typical of the deeper Finger Lakes.

4. The lake water pH was always above 7.00 (due to its high buffer capacity), helping to protect the lake from the potentially damaging effects of acidic precipitation storm events.

5. Conductivity, a measure of ions dissolved in the water, averaged between 350 and 400 µS/cm. Recent increases in conductivity may be related to increased runoff and suspended solids entering the lake.

6. Total phosphorus, the critical nutrient governing lake productivity and the element most responsible for lake eutrophication, was often below 10 µg/L during the monthly sample periods. However, there has been a long-term trend of increasing mean annual total phosphorus that may forewarn future degradation in water quality if the trend continues.

7. Excluding data from the mouth of the West River, monthly algal productivity estimated by the concentration of chlorophyll *a* ranged from 0.51 to 18.44 µg/L with a three year annual mean of 2.45 µg/L.

8. The average Carlson Trophic State Index of lake health continues to suggest that Canandaigua Lake remains an oligotrophic water body. Winter total phosphorus measurements should be conducted to better understand long term trends toward nutrient enrichment that are present in spring, summer and fall data.

Tributary Research:

9. Fifty storm/melt event and 48 baseline samples have been collected for 17 tributaries draining into Canandaigua Lake. The subwatersheds of these tributaries equal 79% of the total watershed area and represent the diverse array of land uses. Long term averages and rankings of the individual storm events were analyzed to determine the overall health of the tributaries that drain to the lake.

10. Vine Valley had the highest long term storm/melt event average concentration of total phosphorus over the last twelve years with 0.245 mg/L. Gage Gully was second with 0.229 mg/L and Sucker Brook was third with 0.221 mg/L. The long term average of ranking the individual storm event concentrations for each of the subwatersheds shows some change in the order of streams with Sucker Brook having the highest pollution rank, Vine Valley was second and Seneca Point Gully ranked third. Rankings provide a better understanding of which streams have consistently high concentrations.

11. The highest average baseline concentration of total phosphorus was at Seneca Point with 0.0833 mg/L. The second highest concentration was at Sucker Brook with 0.078mg/L. Third was the West River with 0.0700 mg/L. The lowest concentration of phosphorus was found in Grimes Creek (0.0078 mg/L). There was remarkable consistency between the 1997-1999 data and the 2007-2008 data.

12. Fisher Gully had the highest storm/melt event average total suspended solids (TSS) concentration over the last twelve years at 368.9 mg/L. Eelpot Creek was second with 335.5 mg/L. Naples Creek was third with 301.7 mg/L. All streams except Lower West River significantly exceed the TSS average levels reported in the National Urban Runoff Program (NURP) study of 54.5 mg/L. The long term average rank of individual storm events provides a different story on the consistency of high TSS levels in each of the subwatersheds. Fisher Gully drops from being the highest concentration to the middle of the pack when looking at the average ranking of the individual storm events. Eelpot, Naples and Cook's Point had the highest ranking demonstrating that these streams had concentrations that were consistently higher than the other streams in the watershed. The loading into Canandaigua Lake during an average event that was sampled totals over two million pounds of suspended solids from the seventeen streams sampled!

13. Gage Gully had the highest average storm/melt event concentration of nitrate/nitrite over the last twelve years with 3.92 mg/L. Deep Run was second with 2.62 mg/L. Fall Brook was third with 2.18 mg/L. The rankings (Figure 2-19) show the same order and also show consistency of results for this parameter. Agricultural land use and scattered rural septic systems are dominant in these subwatersheds, and likely contribute to these elevated levels. (Figures 2-20 and 2-21) provide the comparison between the 14 events sampled from 2001-June 2004 and the 14 events sampled from September 2004 to 2009 and demonstrate an overall reduction in nitrate/nitrite levels even with the much greater amounts of runoff occurring in the latter set of samples. This could be an indication of best management practices that have been put in place in the Gage, Deep Run, Fall Brook and Sucker Brook subwatersheds having a positive impact.

14. Baseline sampling shows a consistent pattern between the 1997-1999 dataset and the 2007-2008 dataset. There was a decrease in the baseline nitrate levels at Gage Gully of approximately 0.5 mg/L from the 1997-1999 to 2007/2008. This is consistent with the reduction in storm event nitrate concentrations. Overall averages still document that Fall

Brook, Deep Run, Gage Gully, Eelpot and Sucker Brook are all substantially over the 0.53 mg/L benchmark that is referenced in the NYS stormwater manual report.

15. Fecal coliform has been sampled since 1989 with a total of 95 samples collected. Sucker Brook had the highest long term average levels of recorded fecal coliform with 584 colonies per 100 ml. Vine Valley was second highest with 374 colonies per 100 ml**.** Cook's Point was third highest with 159 colonies per 100 ml.

16. The annual road salt monitoring revealed typical chloride concentrations (mg/L) in most tributary streams, with critical levels being exceeded only in Sucker Brook and the stream entering the lake at Cook's Point. Although sampling is a "once a year snapshot", these data reflect the severity of the winter seasons and the subsequent amounts of de-icing agents applied to highway surfaces.

17. A stream pollution index was calculated by combining the rankings for total phosphorus, nitrate/nitrite, TSS and fecal coliform. This stream pollution index equally weighs each of these parameters to form a more comprehensive understanding of the level of pollution in each subwatershed. Higher ranks represent greater levels of pollution as compared to the other streams in the watershed. The overall ranking documents that Sucker Brook has the highest overall pollution ranking with Deep Run, Vine Valley, Eelpot Creek, Fall Brook and Gage Gully grouped closely together.

18. As identified in the Canandaigua Lake Watershed Plan (Olvany, 2000), non-point sources of pollution are the major source of concern in the Canandaigua Lake watershed. Although there are two small wastewater treatment plants (Rushville, Bristol Harbour) discharging from point sources, the vast majority of pollution comes from non-point sources. No single non-point source is a substantial contributor to decreasing the water quality of the lake. However, it is the cumulative effect of all non-point sources that ultimately does impact the quality of Canandaigua Lake. Higher concentrations of a specific pollutant can reveal which streams have the greatest likelihood of being impacted by human activities that need to be mitigated. A management plan utilizes this information to devise a strategy to reduce the source of pollution.

Acknowledgments:

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Jonathon Pitchford, graduate intern with the Canandaigua Lake Watershed Council provided significant field research and initial results tabulation assistance. Valerie George, master's student with RIT, provided additional field assistance. Finger Lakes Community College provided administrative assistance from the Office of Resource Development and document reproduction through Central Office Services. The Science and Technology Department generously donated laboratory facilities. Rental of a college boat and sampling equipment were provided by the Department of Environmental Conservation and Horticulture. Conservation practicum students at the college helped collect scientific information, gained experience with equipment, and learned the value of lake research programs. College limnology students developed a heightened awareness of local lake processes and the significance of human impacts on those processes provided by the scientific information produced through the lake sampling and monitoring program, and the tributary chloride stream sampling program.

List of Figures:

List of Tables:

Introduction to Water Quality:

This report updates our knowledge on the health of Canandaigua Lake and the water quality of its tributary streams. The ecosystem-based approach utilized here draws on our research efforts as well as the historic work of others in order to better understand the consequences of human activities on water quality. Our primary goal is to inform and educate the Council and general public about significant issues that can adversely affect the lake. Our activities focus on extensive sampling and monitoring both in the lake and in the tributaries that enter the lake.

While certain aspects of lake ecology have been studied since the early 1900's, until recently the local scientific research efforts have been sporadic. For the last 16 years a regular sampling and monitoring program has reported on lake quality. This program provides an annual assessment of lake health and long-term analyses that, overall, suggest the lake remains clean and relatively pollution-free. However, concerns about the water quality impacts of changing watershed land uses (e.g., residential development, forestry, agriculture, storm-water management) have arisen. Therefore, monitoring of perennial tributary streams and direct drainage sub-basins became a focus of our research during the late 1990's. Watershed drainages have been sampled under baseflow conditions and during meteorological events (e.g., storm runoff and snow melt runoff). Streams contributing significant pollutants to the lake have been studied through segment analysis, helping to identify pollutant sources so remedial actions could be put in place.

Point and non-point sources of pollution are well known for most water bodies but the relative significance among sources is not as clearly understood. Consistent and comprehensive sampling and monitoring programs can help determine the importance of point and non-point sources of pollution. Lake research coupled with watershed-wide stream pollutant sampling and monitoring for indicators of environmental degradation are essential steps in determining water condition. Knowledge of water condition should assist local municipalities in policy decisions and in the selection of watershed best management practices designed to restore, enhance and protect water quality.

CHAPTER I – CANADAIGUA LAKE RESEARCH Canandaigua

Lake Sampling and Monitoring Parameters:

To assess the ecological health of Canandaigua Lake, the following water quality tests, sampling frequencies and synthetic indices were used. A brief explanation of each water quality parameter is provided below.

1. **temperature** – the heat content of a water body expressed in Centigrade degrees (ºC). It is important to water circulation patterns in the lake (e.g., seiches and fall turnover), stability of lake stratification, prediction of the extent of winter ice cover, metabolic rate of lake organisms, buoyancy afforded to the planktonic community, and overall habitat diversity within the lake basin. Patterns in lake temperature through the water column document the depth of the summer warm water zone at the surface (the epilimnion) and the remaining cold water zone near the bottom (the hypolimnion).

2. **dissolved oxygen** – the oxygen present as small gas bubbles (O_2) dissolved in the lake water. It is essential for the respiration of aquatic organisms, particularly desirable fish and invertebrates. Cold water has the potential to hold greater amounts of dissolved oxygen (DO). Relative content of DO, a function of water temperature, is measured as percent saturation. Values near 100% saturation are preferred for lake health. Absolute content of DO is measured as parts per million (ppm) or its equivalent, milligrams per liter (mg/L). DO has low solubility in water, with maximum amounts seldom exceeding 14.6 mg/L. Cold water fish species like trout require a minimum DO of 7 to 8 mg/L. Warm water fish species like bass are more tolerant but still require a minimum DO of 5 mg/L. DO is positively correlated with atmospheric pressure. DO levels are influenced by replenishment rates (contribution from aerated tributary streams, surface exchange with the atmosphere, production resulting from aquatic photosynthesis) and consumption factors (respiratory demands of lake organisms, amount of oxygen demanding wastes and decay rates). If DO levels drop to less than 1 mg/L, the lake water is anoxic, nutrients are released from bottom sediments and undesirable anaerobic biota will predominate. Such conditions have not been observed in Canandaigua Lake.

3. **conductivity** - the ability of water to support an electrical current. It is strongly influenced by ionic concentrations (Ca^{++}, Mg^{++}, Na^+ and K^+) and water temperature. Expressed as micromhos/cm or its equivalent, microsiemens (µS/cm). Addition of suspended soil particles from storm runoff and watershed erosion activities will temporarily increase conductivity. Lake seiches that re-suspend bottom sediments may locally increase conductivity readings.

4. **chlorophyll *a*** – a plant pigment that estimates algal abundance and, therefore, indicates plant growth conditions. Measured in micrograms per liter (µg/L) or its equivalent milligrams per cubic meter (mg/m^3). Primary production refers to organic molecules synthesized by phytoplankton according to this formula:

$$6CO_2 + 12H_2O + \text{energy} \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

Energy for this photosynthetic reaction is provided when sunlight penetrates water in the epilimnion. Plant pigments, especially chlorophyll *a*, are receptors for certain wavelengths of the incoming solar radiation.

5. **water clarity** - the depth of light penetration in the surface waters of a lake. It is determined with a secchi disk and expressed in meters (m). When compared with underwater photometer measurements, the secchi disk reading approximates the depth where five percent of the surface light remains. This is the compensation level for most aquatic plants. For the Finger Lakes, it is estimated that all surface light is gone at between two and three times the secchi disk reading. Lake clarity is influenced by suspended sediment and planktonic organisms.

6. **lake nutrients** – the compounds that promote biological growth in lake water. Several elements are considered essential, but the critical elements in lakes are phosphorus and nitrogen. Phosphorus is often considered the limiting factor for biological productivity in freshwater ecosystems. Phosphorus is needed for the production of cellular energy compounds (e.g., ATP). It is present as both inorganic and organic substances, including particulate and dissolved forms. Total phosphorus (TP) includes dissolved and particulate forms. It is expressed as parts per billion (ppb) or its equivalent, micrograms per liter (µg/L). The desirable threshold is less than 10 µg/L. TP concentrations that exceed 20 µg/L suggest nutrient enrichment. Up to ten percent of the TP is likely to be found in a dissolved form known as soluble reactive phosphorus (SRP). Most phosphorus is biologically absorbed or temporarily bound to bottom sediments from which it is released back to the water if benthic anoxia occurs. During rapid growth of aquatic plants,

all of the SRP can be absorbed. Then, lake processes would slow until phosphorus again became available through biological decay, bottom release and/or watershed runoff contributions. Recycling of phosphorus in small lakes has been estimated to be a matter of days or weeks while for larger lakes it can take months. Also a macronutrient, nitrogen contributes to protein synthesis in lake organisms. Nitrogen compounds commonly enter lakes through fertilizer runoff and biological decay. Decomposition processes release ammonia (NH_3), which may be harmful to aquatic life in high concentrations. In most lakes, ammonia is oxidized to inorganic nitrite (NO_2) and then nitrate (NO_3). Their combined measure is expressed as milligrams of nitrogen per liter (mg N/L) and levels exceeding 1 mg N/L suggest pollution from anthropogenic sources. Scientists suggest that winter data, when biological activity is low, may give the best estimate of a lake nutrients. Our sampling and monitoring program collects winter data about once every five years. Results from the month of April most closely resemble winter data.

7. **trophic status** – this is a synthetic index that describes the lake health by examining water clarity, winter TP levels and summer chlorophyll *a* according to modeling equations. The equations derived years ago need refinement to take into account the significant clearing of the water column resulting from the filter feeding of introduced zebra mussels. Trophic status is also related to lake morphometry, lake age and watershed activities. Large volume lakes dilute pollutants and tend to remain nutrient poor (oligotrophic). As lakes age, they usually gain sediment and nutrients from watershed activities. Then, lakes pass through the mesotrophic stage to the eutrophic condition (nutrient rich). When human activities in the watershed contribute sediment and nutrients, lakes are referred to as being culturally eutrophic.

8. **chloride** - a corrosive substance that may be found in water as a result of the application of de-icing agents to watershed highways, or from natural leaching of bedrock salts. Expressed in parts per million (ppm) or its equivalent, milligrams per liter (mg/L). Concentrations exceeding 250 mg/L are thought to be damaging to sensitive stream and lake organisms.

Methods:

In 2006, lake studies began on April 28 and concluded on November 29. In 2007, lake studies began on April 30 but were delayed by poor fall weather until December 7. In 2008, poor springtime weather slightly altered the schedule. Lake studies did not begin until May 9 but did finish on schedule on November 28. The same monthly methodology was used each year. Two mid-lake stations (Deep Run and Seneca Point) were visited monthly, April through November, by boat. At each mid-lake station, secchi disk depths were recorded, water samples were collected for chlorophyll *a* analyses and nutrient determinations, and a water quality profile was completed. Four additional stations were sampled in the lake: near-shore at Hope Point and Vine Valley, and at the mouths of Fallbrook Stream and the West River. Here samples were taken for chlorophyll *a* analyses and determination of surface nutrient levels. This monthly experimental design is consistent with previous lake monitoring conducted by Finger Lakes Community College. Our sampling protocols are described below:

Water clarity was measured through use of a secchi disk near noon (sun directly overhead), if possible, on a cloudless day. Readings were taken on the shady side of the boat to minimize glare from the water surface. Secchi disk depths were recorded as the average of when the disk disappeared from view while being lowered and when it reappeared while being retrieved. Readings were expressed to the nearest tenth of a meter.

For chlorophyll *a* analysis, integrated water column samples were collected with TYGON tubing extending through the epilimnion. Samples were stored on ice in 2 liter dark bottles to minimize changes in algal abundance. Samples were processed within 6 hours using the alkaline acetone procedure (Wetzel and Likens 1991).

A nonmetallic Van Dorn sampler was used to collect lake water at depths of 2, 25 and 50 meters. Each water sample was transferred to a bottle containing acid preservative, then stored on ice. All samples were tested for nutrient content following EPA analytical methods at the NYS certified (DOH ELAP # 10248) Life Science Laboratories, Inc.

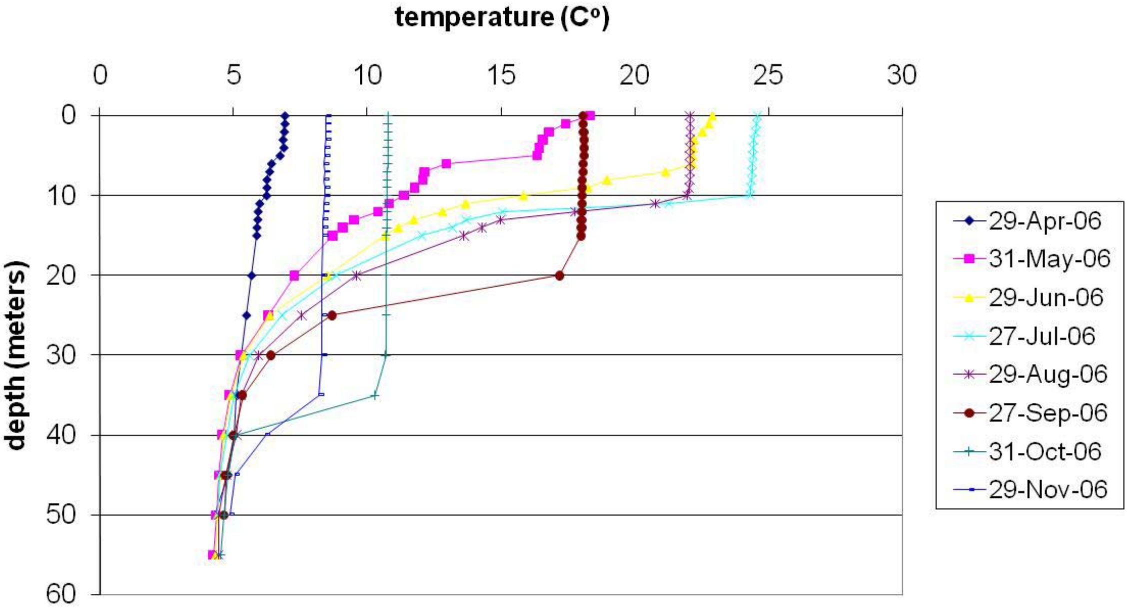
Profile analyses of the water column were taken with a Yellow Springs Instrument 6920 water quality sonde and 650 data logger. Instrument calibration was checked prior to each sampling. Mid-lake sites on Canandaigua Lake were sampled at one meter intervals from the surface to a depth of fifteen meters (approximate summer depth of the epilimnion), then at five meter intervals to a maximum depth of 60 meters. Boat drift on the surface often prevented reaching maximum depths.

Results and Discussion:

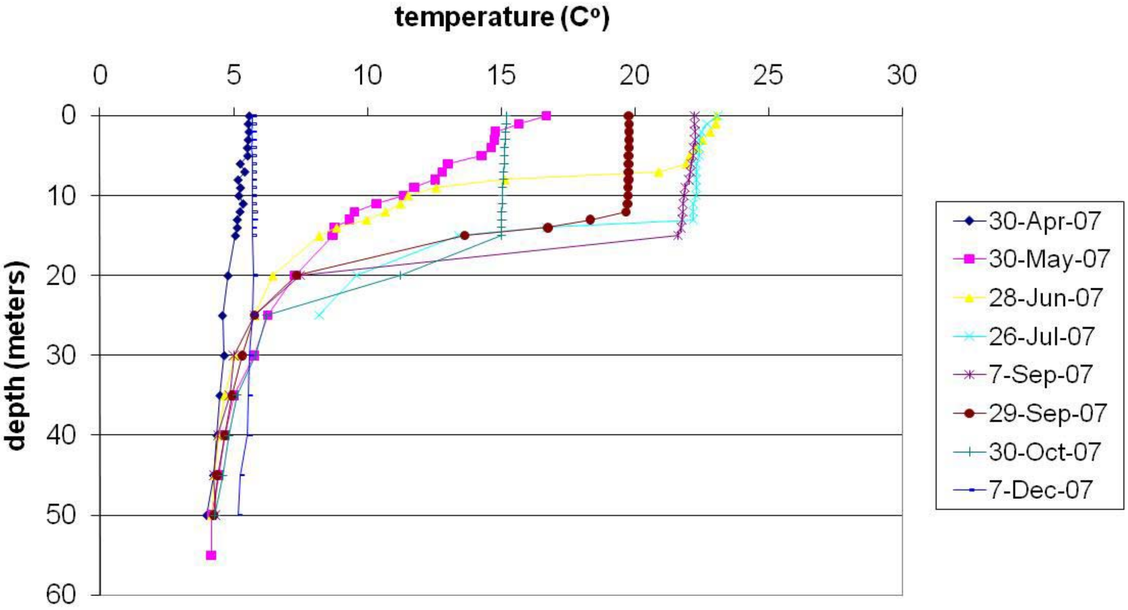
Background information on the limnology of Canandaigua Lake is found in Eaton and Kardos (1978), Sherwood (1993), Olvany (2000) and previous reports by the authors. It is a warm, monomictic lake that thermally stratifies during the summer and usually has large patches of open water during the winter. Ice-free areas allow winds to keep the lake well mixed during the winter months. The lake gradually gains heat at the surface during the spring and summer months. It is during this time period that wind works to displace some of the surface heat downward about 15 meters establishing a thermocline. As fall approaches, lake heat is slowly lost to a cooling atmosphere with lake turnover occuring in late November or early December. The development of thermal stratification at our two mid-lake stations is presented in the monthly temperature profile diagrams (Figures 1.1, 1.2). These profiles are typical of all earlier work conducted on Canandaigua Lake, and resemble profiles for other deep Finger Lakes.

Dissolved oxygen (DO) increases with depth at our two mid-lake stations in Canandaigua Lake (Figures 1.3, 1.4), creating an orthograde profile that is characteristic of deep, clean water lakes. DO in the epilimnion was always close to 100% saturation. In the hypolimnion, the summer DO was maintained between 9 and 13 mg/L, indicating excellent conditions for survival of important game fish like lake trout. Slight decreases in DO were detected at the end of summer near the bottom of the lake. Increased oxygen demand for benthic decomposition, perhaps related to zebra mussel populations that keep much of the food web interactions near the bottom, may be responsible. Fall turnover redistributes surface DO downward. High DO levels are presumed present throughout the water column during the winter. These seasonal DO patterns indicate that the lake remains a high quality habitat for many aquatic organisms.

Deep Run Profile



Deep Run Profile



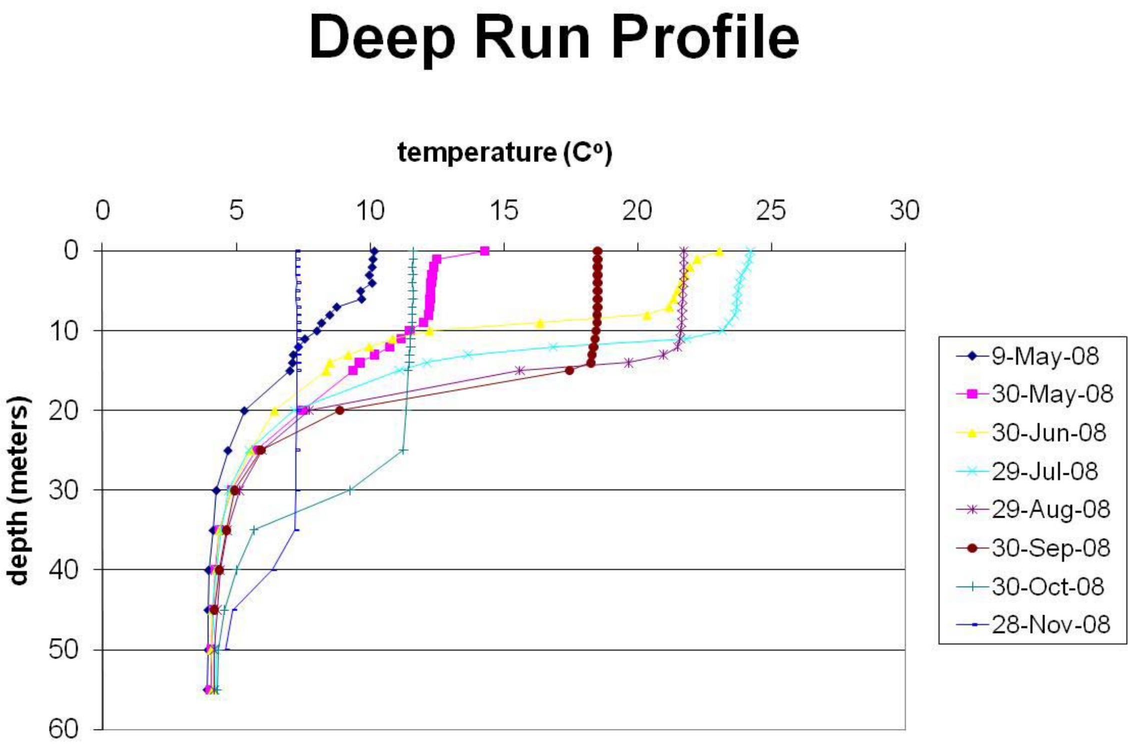
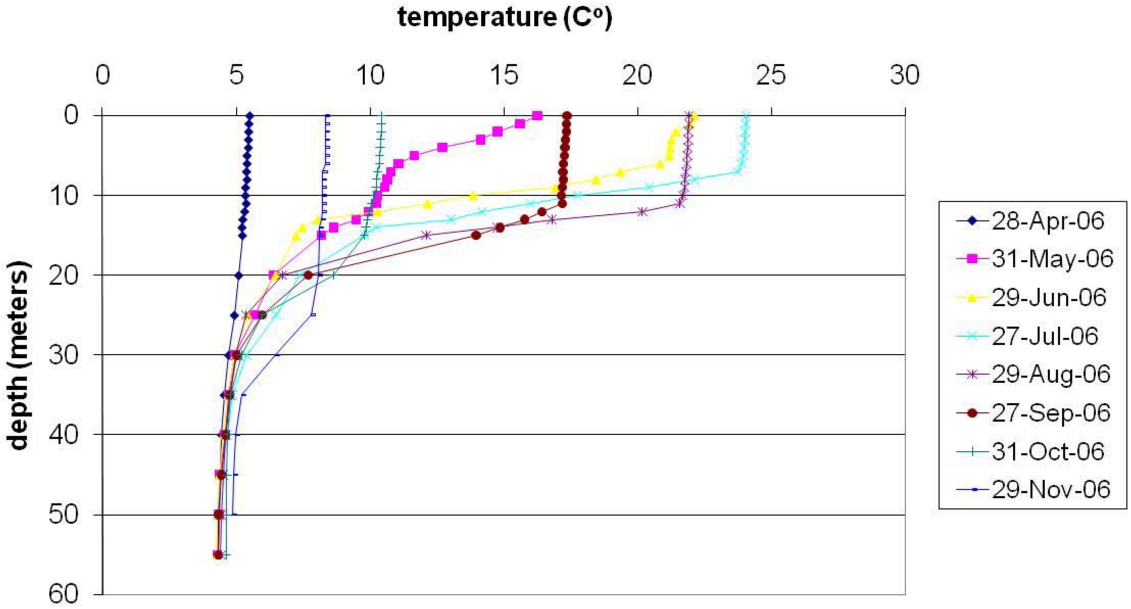
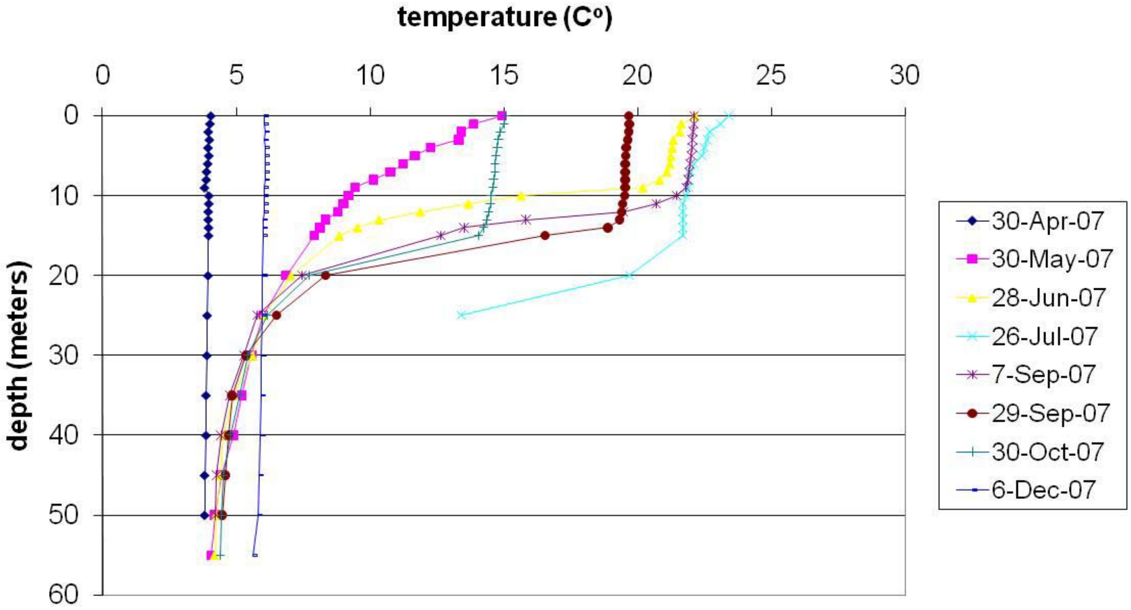


FIGURE 1.1: Development of thermal stratification in Canandaigua Lake, Deep Run Station.

Seneca Point Profile



Seneca Point Profile



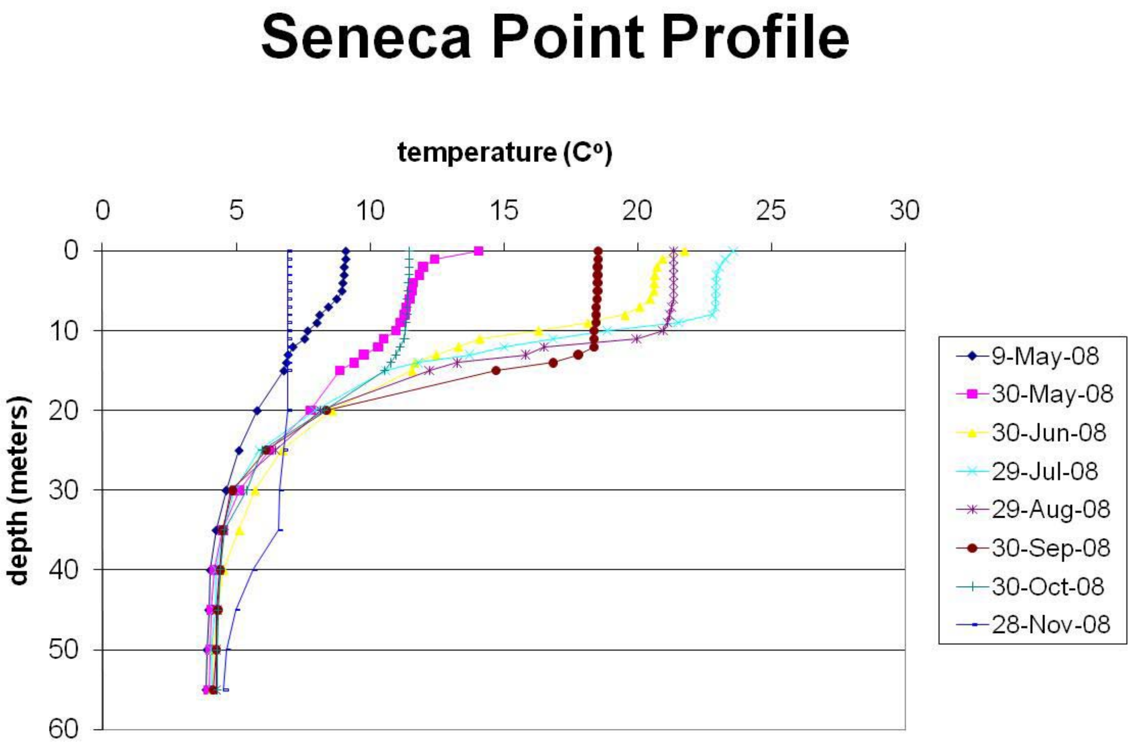
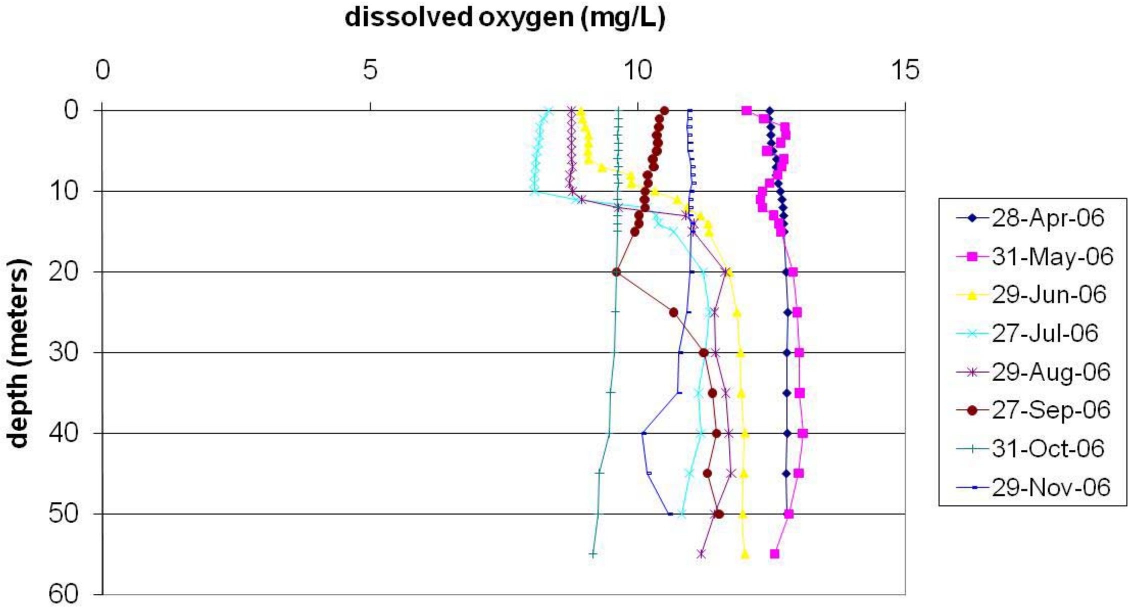
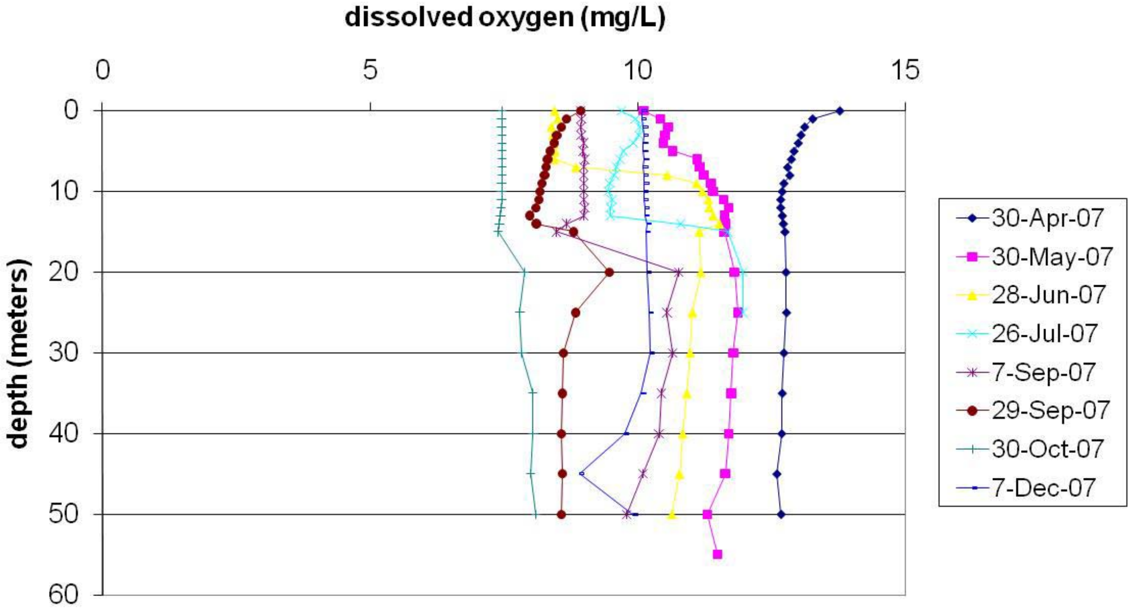


FIGURE 1.2: Development of thermal stratification in Canandaigua Lake, Seneca Point Station.

Deep Run Profile



Deep Run Profile



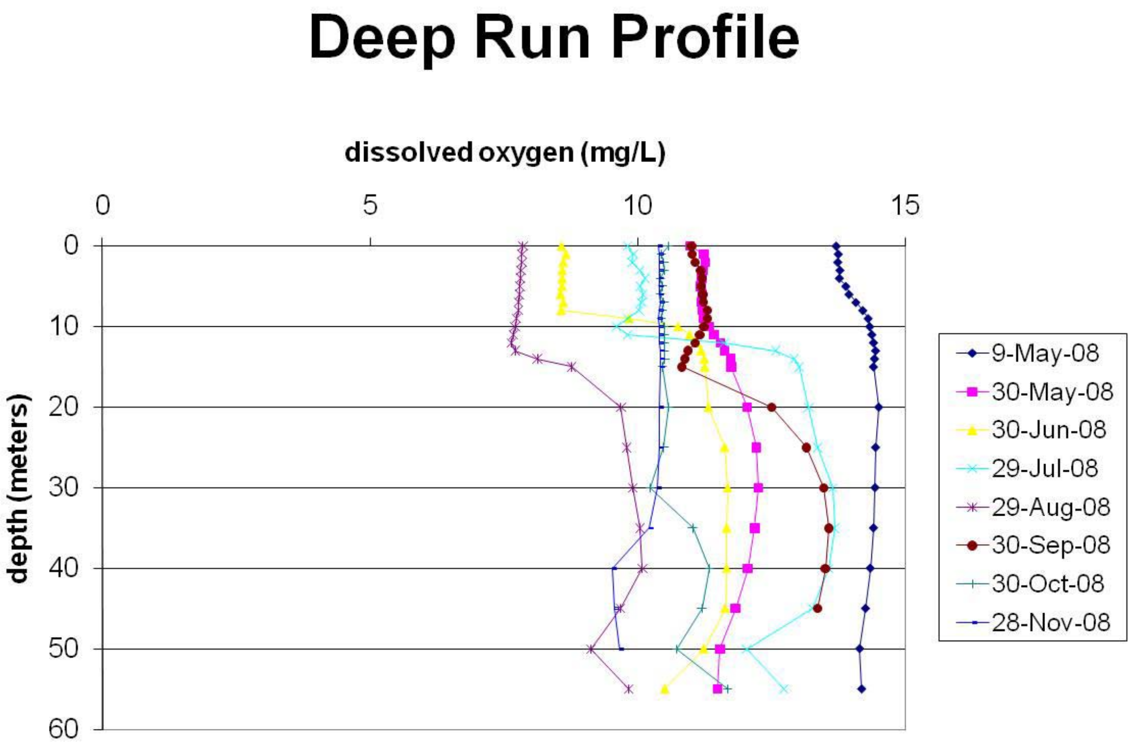
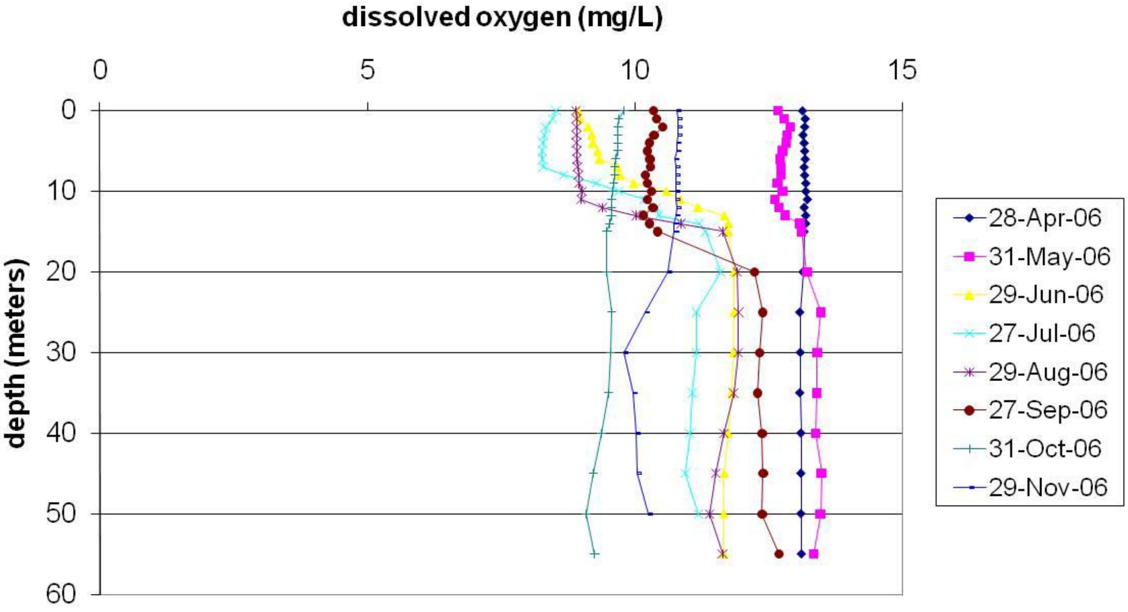
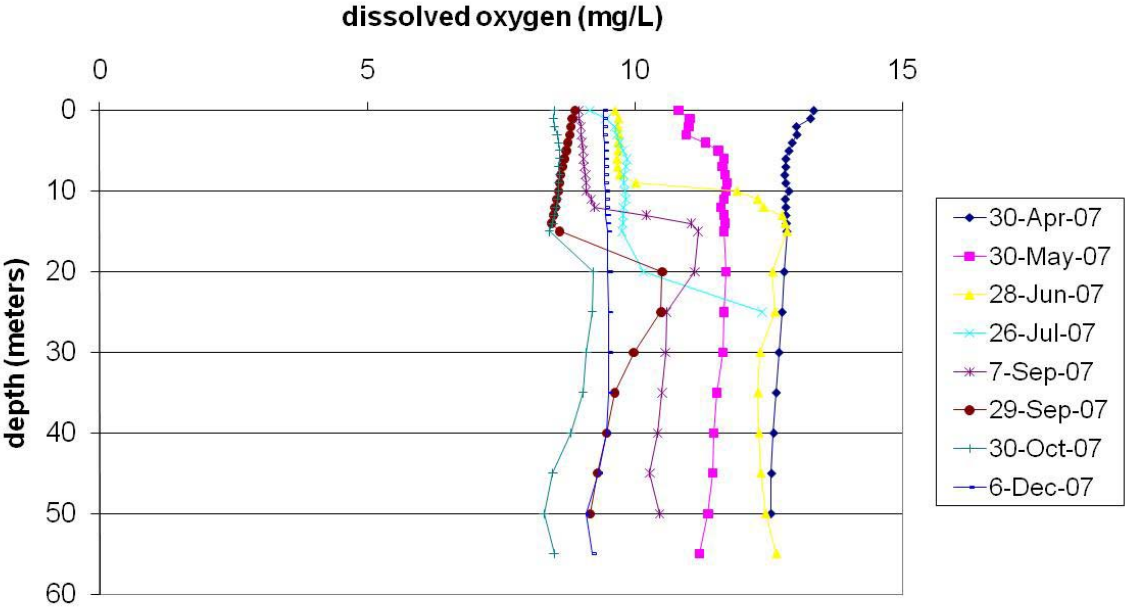


FIGURE 1.3: Dissolved oxygen profiles in Canandaigua Lake, Deep Run Station.

Seneca Point Profile



Seneca Point Profile



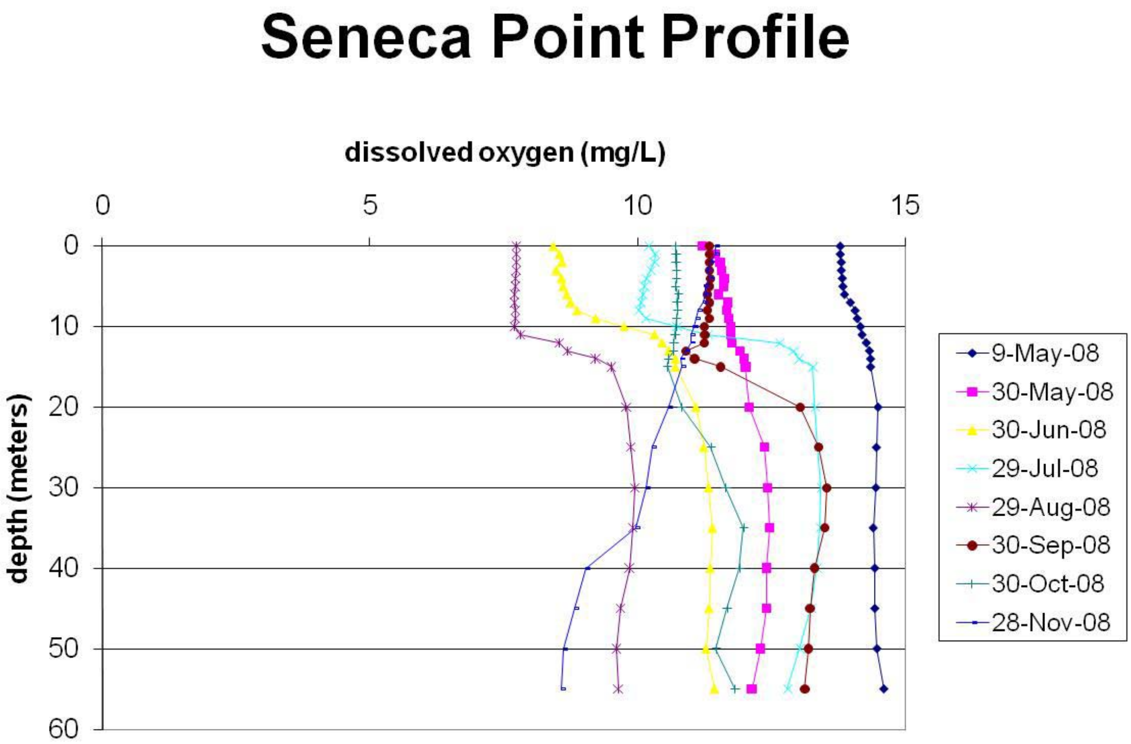


FIGURE 1.4: Dissolved oxygen profiles in Canandaigua Lake, Seneca Point Station.

Mean monthly specific conductance showed minor monthly fluctuation, and little change from top to bottom in the water column. Based on research beginning in 1996, conductivity has been in the approximate range of 350 – 400 μS/cm. This does represent an increase from 271 μS/cm in 1955 (Berg 1963), 285 μS/cm in 1973 (Oglesby in: Eaton and Kardos 1978), but is similar to the 350 μS/cm in 1993 (Gilman 1993). It is unclear whether the historic values were obtained from multiple sites sampled monthly April through November like the more recent monitoring. However, the recent data show only minor monthly variation, suggesting a comparison of potentially different monitoring intensities may still be valid. The data sets suggest a long-term trend of increasing conductivity in the lake, perhaps associated with sediment delivered to the lake as a consequence of erosion generated by watershed runoff. Changing watershed land use activities are thought to be a contributing factor.

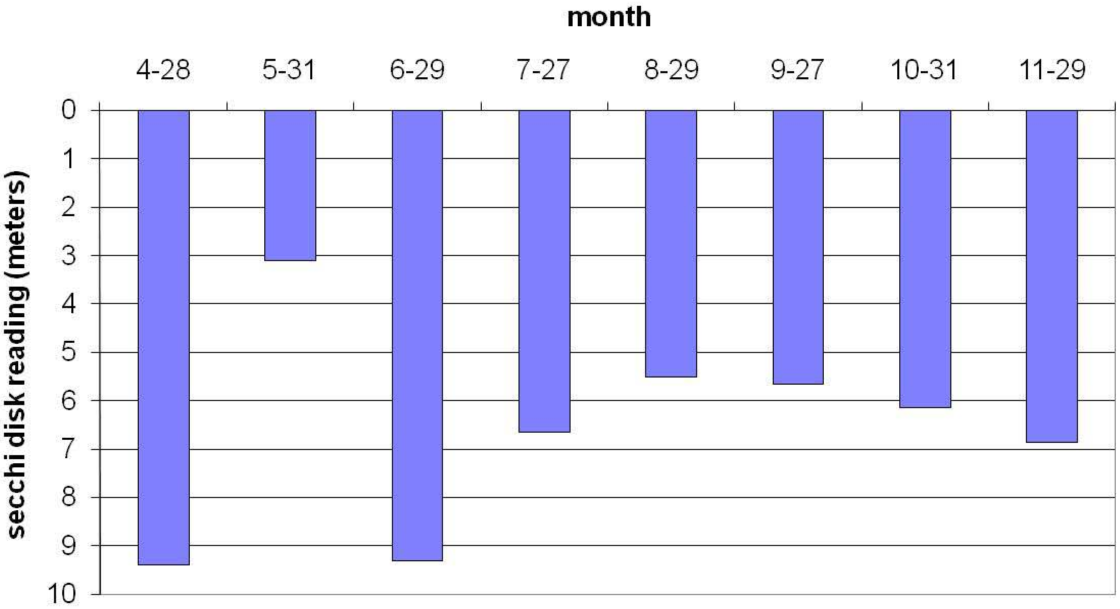
Secchi disk readings for oligotrophic lakes often average greater than 8 meters but exhibit seasonal variability. Readings are lower when light is blocked by substances in the water, including eroded soil particles, re-suspended bottom sediment and planktonic organisms. Readings can also be affected by cloud cover and wave action at the time of sampling. Typically, winter lake clarity will be high because only a few planktonic organisms are present. As winter ends, longer days facilitate the growth of phytoplankton (algae). Small-bodied zooplankton (e.g., rotifers) feed on the algae. During this time, nutrients are absorbed from the water by the plankton community. As large-bodied zooplankton (e.g., copepods and water fleas) proliferate, algal feeding is intensified resulting in a clearing of the water column by late spring. Then, fish reproduce and their young begin feeding on the larger zooplankton. With warm summer conditions, the phytoplankton recover because young fish have consumed zooplankton, thereby reducing the feeding pressure on the algae. Algal population densities can increase but are limited primarily by the low concentration of available phosphorus. Nutrient additions from watershed runoff can have significant impacts at any time but especially during the summer when many species of phytoplankton are present. When phosphorus and nitrogen are depleted, a shift to dominance by nitrogen-fixing cyanobacteria usually occurs. The cyanobacteria (formerly called blue-green algae) are known for the taste and odor problems they may cause in lake water. Eventually, cooler autumn water temperatures, less rainfall and subsequent runoff, and increased dormancy in the plankton community will initiate a clearing event and brings about improvements in the secchi disk readings. By winter, most planktonic organisms have entered a resting stage on the lake bottom, and watershed soils are frozen and covered by a protective layer of snow. Winter winds across the lake surface will mix nutrients throughout the water column.

From 2006 to 2008, clarity from April through November averaged 7.17 meters and reached a maximum of 10.1 meters. Lake clarity stabilized over the three year period, reversing a declining trend that began in 1999. Monthly data are presented in Table 1.1 and Figure 1.5. Additional historic data on lake clarity are discussed in previous reports by the authors.

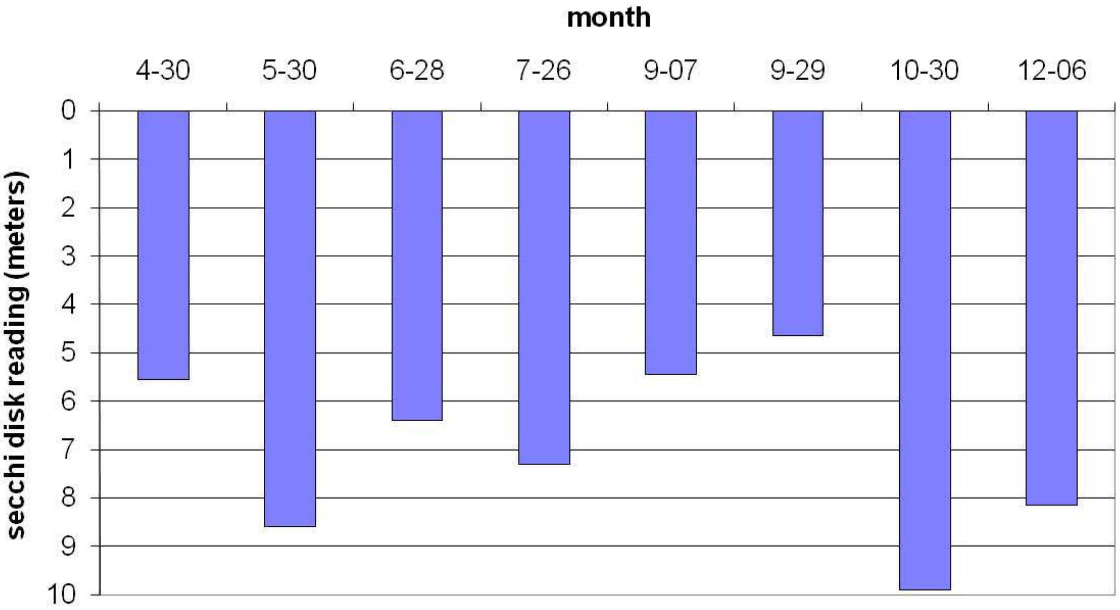
TABLE 1.1: Secchi disk readings (m) in Canandaigua Lake.

Date	Deep Run Station	Seneca Point Station	Mid-Lake Average
28 April 2006	10.1	8.7	9.40
31 May 2006	3.1	3.1	3.10
29 June 2006	9.6	9.0	9.30
27 July 2006	6.9	6.4	6.65
29 August 2006	5.5	5.5	5.50
27 September 2006	5.5	5.8	5.65
31 October 2006	6.6	5.7	6.15
29 November 2006	7.1	6.6	6.85
30 April 2007	5.2	5.9	5.55
30 May 2007	9.3	7.9	8.60
28 June 2007	7.0	5.8	6.40
26 July 2007	7.2	7.4	7.30
7 September 2007	5.8	5.1	5.45
29 September 2007	4.4	4.9	4.65
30 October 2007	10.0	9.8	9.90
7 December 2007	7.7	8.6	8.15
9 May 2008	9.5	8.3	8.90
30 May 2008	8.0	8.4	8.20
30 June 2008	10.0	9.0	9.50
29 July 2008	4.8	5.3	5.05
29 August 2008	8.9	8.1	8.50
30 September 2008	4.5	5.5	5.00
31 October 2008	8.6	9.0	8.80
28 November 2008	9.1	9.8	9.45

Lake Clarity (2006)



Lake Clarity (2007)



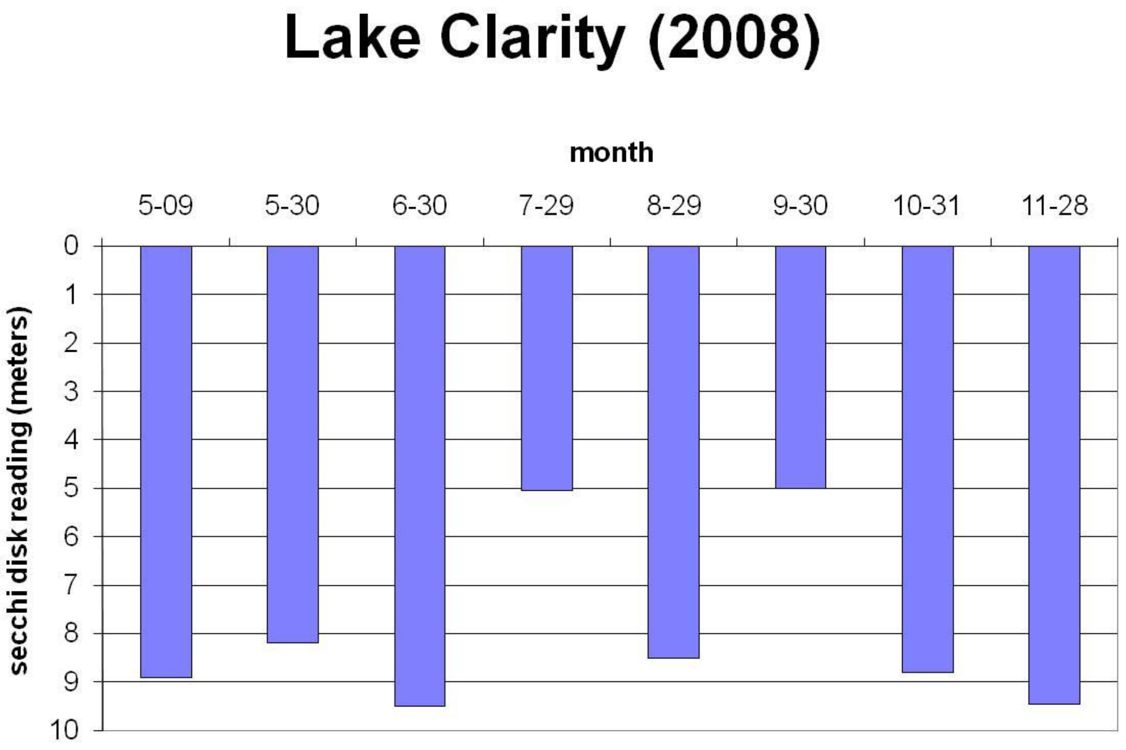


FIGURE 1.5: Monthly mean secchi disk readings from mid-lake stations in Canandaigua Lake.

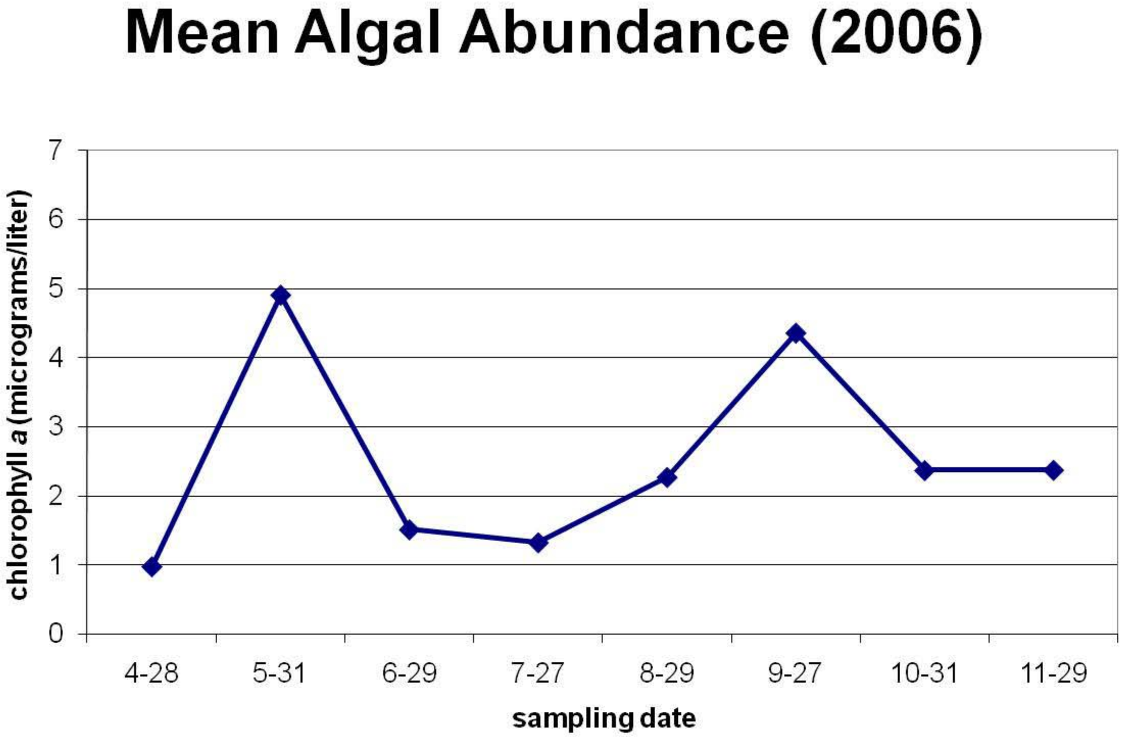
The levels of chlorophyll *a* during the monthly sampling season are presented in Table 1.2 and Figure 1.6. Chlorophyll *a* is the dominant pigment in phytoplankton and its concentration is used as an index of algal abundance. Algal populations develop quickly and species sequentially replace one another as lake conditions change during the growing season. During 2006, a peak in chlorophyll *a* occurred in late May followed by lower amounts during the summer. This initial peak may have been caused by more nutrient-rich runoff than typically occurs. The onset of zebra mussel filter feeding in the warming summer waters reduces algal populations. In all three years, a fall peak occurred in late September or late October. A bloom in nitrogen-fixing cyanobacteria populations appeared to be responsible. The dominant cyanobacteria species in the fall were *Microcystis*, *Aphanizomenon* and *Anabaena*. These organisms are known to be unpalatable to zebra mussels and may produce taste, odor and toxin problems in the water.

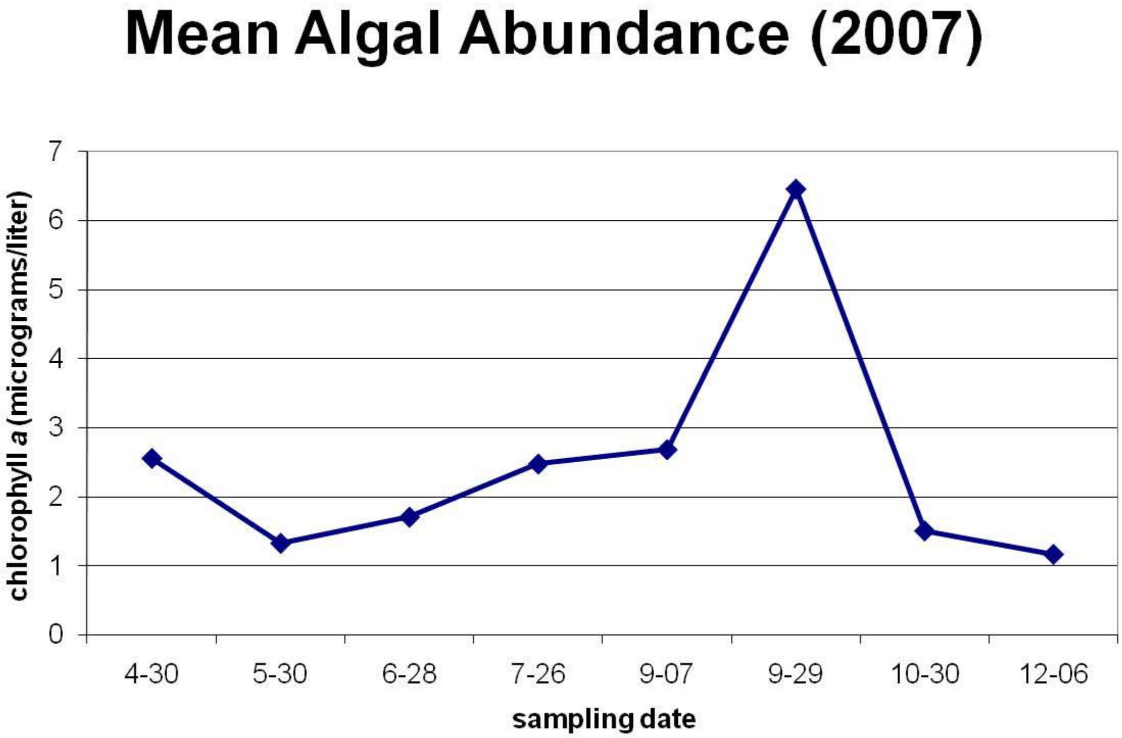
Algal abundance estimated by the concentration of chlorophyll *a* averaged 2.51 µg/L in 2006, 2.49 µg/L in 2007 and 2.36 µg/L in 2008. These data document a slightly decreasing trend in algal abundance and write the most recent chapter in food web interactions. Algal abundance had declined following zebra mussel invasion but then it began increasing in 1999. This indirect evidence suggested that zebra mussels had consumed most of the palatable algae leaving behind cyanobacteria to dominate the fall phytoplankton community. Competition for food resources among zebra mussels intensified in 1999, and by the summer of 2001 mussel populations crashed lake-wide. Increasing chlorophyll *a* levels from 2002 to 2004 pointed to a recovery in algal populations at the time when zebra mussel populations were low. Declines in chlorophyll *a* since 2005 suggest a resurgence in the numbers of zebra mussels. This may mark the beginning of another phase in the dynamic cycle among zebra mussels, algae and lake clarity.

TABLE 1.2: Chlorophyll *a* concentrations (µg/L) in Canandaigua Lake.

				2006				
Station	**4-28**	**5-31**	**6-29**	**7-27**	**8-29**	**9-27**	**10-31**	**11-29**
Fallbrook	0.51	1.55	0.68	1.13	1.76	3.00	6.16	1.64
Hope Point	0.62	7.20	0.96	1.07	3.83	2.21	1.30	1.17
Deep Run	0.96	7.01	1.80	1.75	2.26	4.32	1.81	2.33
Seneca Point	1.58	3.35	2.41	1.84	2.32	3.84	1.86	2.15
Vine Valley	1.24	5.42	1.73	0.85	1.19	8.42	0.73	4.59
West River	1.72	2.42	5.61	2.15	5.77	1.38	5.22	2.08
Mean	1.11	4.49	2.20	1.47	2.86	3.86	2.85	2.33
Adjusted Mean *	0.98	4.91	1.52	1.33	2.27	4.36	2.37	2.38
				2007				
	4-30	**5-30**	**6-28**	**7-26**	**9.07**	**9-29**	**10-30**	**12-06**
Fallbrook	1.53	0.57	1.47	1.49	4.22	18.44	2.04	1.08
Hope Point	2.04	1.15	1.70	1.64	2.01	3.33	1.21	1.12
Deep Run	2.60	1.50	1.95	3.39	2.77	4.33	1.42	1.19
Seneca Point	3.52	2.16	1.73	2.88	2.73	3.99	1.72	1.54
Vine Valley	3.11	1.28	1.70	2.99	1.70	2.18	1.17	0.93
West River	34.44	2.71	2.59	2.96	1.33	4.92	2.09	8.57
Mean	7.87	1.56	1.86	2.56	2.46	6.20	1.61	2.41
Adjusted Mean *	2.56	1.33	1.71	2.48	2.69	6.45	1.51	1.17
				2008				
	5-09	**5-31**	**6-30**	**7-29**	**8-29**	**9-30**	**10-31**	**11-28**
Fallbrook	0.88	1.02	1.74	2.20	2.94	3.13	1.75	1.41
Hope Point	1.20	1.94	1.66	2.04	1.76	1.74	9.38	1.34
Deep Run	1.47	1.68	2.11	2.52	2.02	3.54	1.51	1.58
Seneca Point	1.60	2.35	2.16	2.78	2.37	3.56	1.57	1.49
Vine Valley	1.04	2.43	1.72	1.61	1.92	1.64	12.66	1.08
West River	22.05	2.47	26.67	9.60	8.85	2.45	1.41	1.09
Mean	4.71	1.98	6.01	3.46	3.31	2.68	4.71	1.33
Adjusted Mean *	1.24	1.88	1.88	2.23	2.20	2.72	5.37	1.38

* adjusted mean = without West River values.


Mean Algal Abundance (2006)


Mean Algal Abundance (2007)

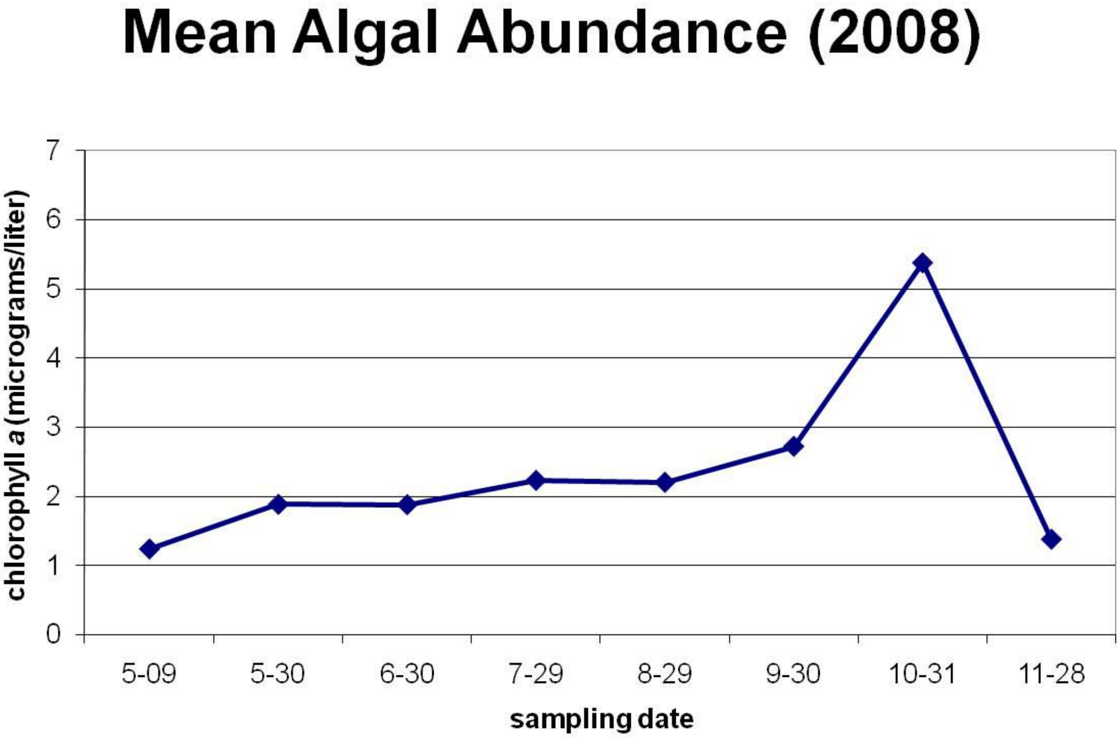


FIGURE 1.6: Mean chlorophyll *a* concentrations among sample stations in Canandaigua Lake.

There has also been a change in the seasonal pattern of chlorophyll *a* concentrations between shoreline and mid-lake stations (Table 1.3). Again, data from the West River station is excluded in the analyses. Ratios above 1.00 document more algal productivity along the shoreline. Conversely, when the ratio falls below 1.00, more algal productivity has been detected in the open water of the mid-lake stations. For a number of years, the ratio has favored less algal productivity along the shoreline and this effect had been attributed to efficient filter feeding by zebra mussels in the shallow near-shore environment (Gilman 2000). Now another change may be complicating this explanation. With improving water clarity along the shoreline, aquatic macrophyte communities have expanded into deeper waters. This has increased the number of macrophyte stems, which serve as a seasonal substrate where zebra mussels can attach and begin filter feeding. The mussels regurgitate "pseudo-fecal pellets", nutrient rich material that accumulates on the bottom, decays and eventually releases nitrogen and phosphorus to the near-shore waters. Benthic algal mats of *Spirogyra* have become increasingly common in the lake. Some mussels die during the growing season, presumably due to enhanced intraspecific competition (i.e., there are more mussels because the weeds offer more points for attachment). Dying mussels release more nutrients. When the macrophytes die at the end of their growing season, the attached zebra mussels collect along the bottom and a significant proportion of them die, decompose and release more nutrients back to the water. Planktonic algae can increase whenever more nutrients are available, and the ratio could return to or even exceed 1.00. The recent trends have begun to show increased algal productivity along the shoreline of the lake. Three complimentary mechanisms seem plausible. Some of the chlorophyll *a* in the water column could originate from the breakup of bottom dwelling algal mats by wave energy forces near the shoreline. It is also possible that selective filter feeding by zebra mussels has shifted the dominance of the algal community to unpalatable cyanobacteria species that now can proliferate. However, the increase in the standard deviation suggests that single events (months or sites with extremely high chlorophyll *a* levels) may also play an important role. These single events may be triggered by human activities in the watershed near the sampling sites. The lingering effects may upset lake ecology for many months.

TABLE 1.3: Ratio between shoreline (n = 3) and mid-lake (n = 2) chlorophyll *a* concentrations. 1996-2000 samples were collected at a depth of 2 meters, 2001-2008 samples collected by integrated column method.

Year	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Mean ± 1 standard deviation**
1996	1.05	1.13	0.84	0.75	0.87	0.79	0.77	0.94	0.89±0.14
1997	1.55	1.05	0.78	0.82	0.74	0.75	0.72	0.68	0.89±0.29
1998	0.90	0.54	0.57	0.50	0.86	0.77	0.83	0.77	0.72±0.16
1999	0.91	0.83	0.71	0.60	0.59	0.50	0.71	0.86	0.71±0.15
2000	0.94	0.66	0.80	0.59	0.72	0.57	0.47	0.67	0.68±0.15
2001	1.06	0.98	1.03	0.69	0.90	0.83	0.75	0.48	0.84±0.20
2002	1.06	0.46	1.05	0.84	1.11	1.63	0.56	0.69	0.93±0.37
2003	0.80	2.48	0.93	0.63	1.18	0.50	0.41	1.38	1.04±0.67
2004	0.41	1.03	1.30	0.61	0.81	0.47	0.42	0.79	0.73±0.32
2005	0.92	2.13	0.91	0.68	0.62	0.84	0.67	1.04	0.98±0.49
2006	0.62	0.91	0.53	0.57	0.99	1.11	1.49	1.10	0.92±0.33
2007	0.73	0.55	0.88	0.65	0.96	1.92	0.94	0.76	0.92±0.43
2008	0.68	0.89	0.80	0.74	1.01	0.61	5.15	0.83	1.34±1.55

An inverse relationship exists between chlorophyll *a* concentrations and secchi disk readings over the last 13 years (Figure 1.7). Algal abundance strongly influences lake clarity, moderated to some degree by feeding pressure from zebra mussel populations and human activities in the watershed that release nutrients to the lake. In 2005, however, lake clarity and chlorophyll *a* both declined, suggesting a growing role of importance for suspended sediment rather than algae in reducing the secchi disk reading. This provides support for the desirability to regulate human activities that can have negative consequences on water clarity and otherwise upset lake processes. Although clarity is now rebounding, one should not be complacent about pursuing proper management of watershed erosion through the use of best practices wherever possible.

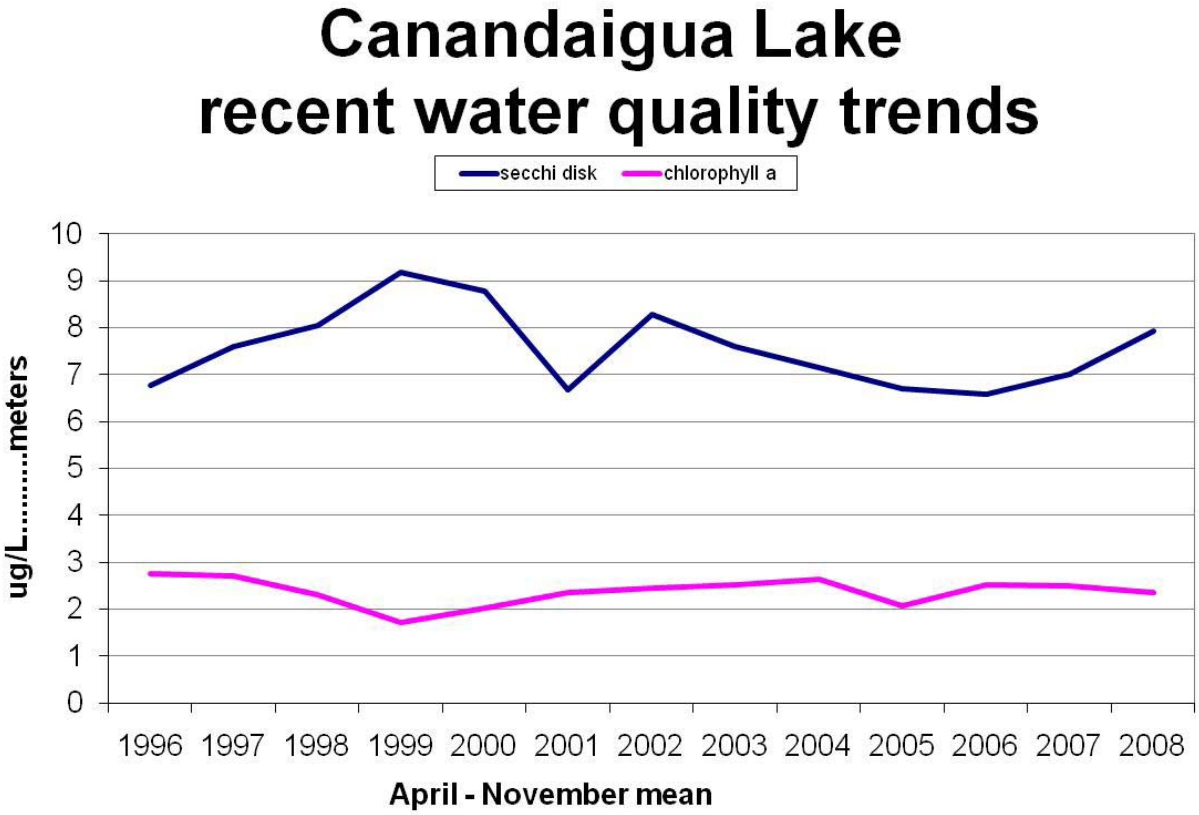
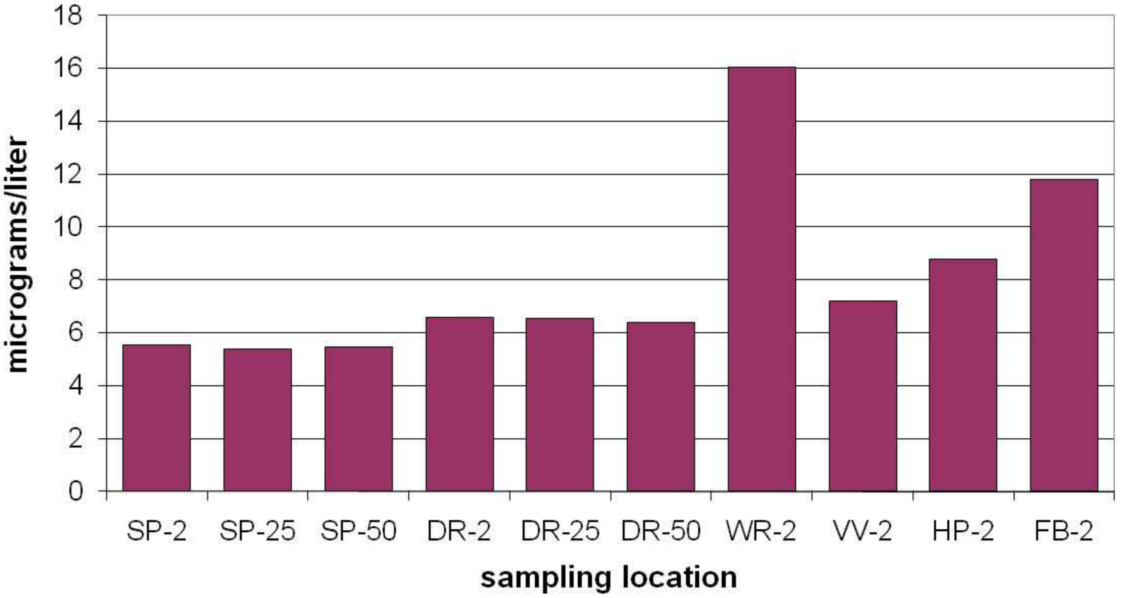


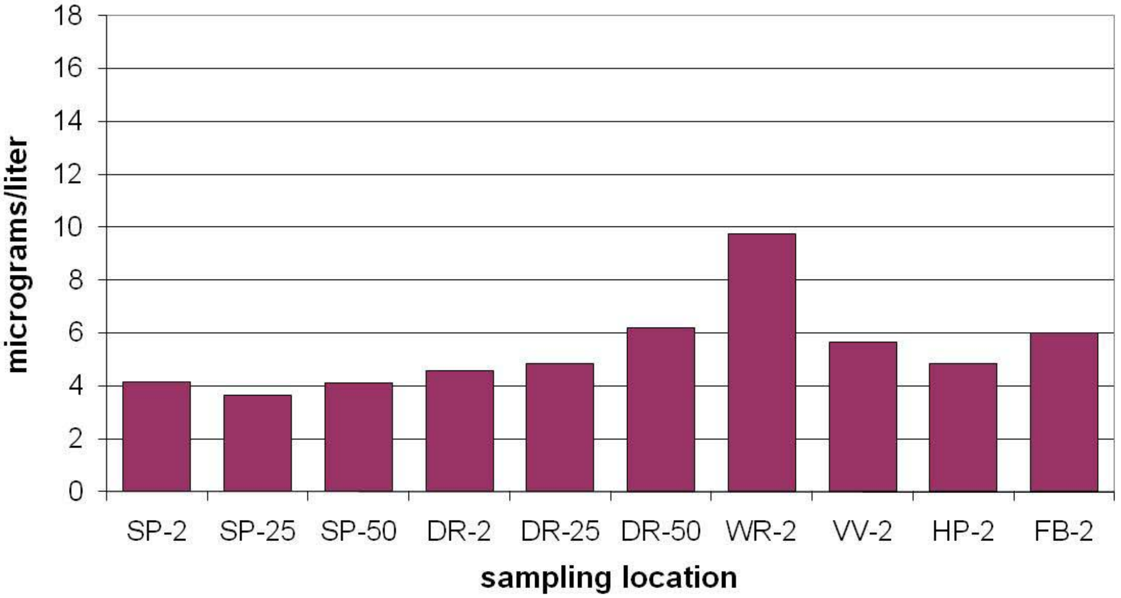
FIGURE 1.7: Recent water quality trends in lake clarity and algal abundance.

Phosphorus is the limiting nutrient for plant productivity and lake total phosphorus (TP) has been measured since 1996. Its concentration varies by site (Figure 1.8), by sampling month, and with depth below the lake surface. Based on 240 samples collected from multiple sites and depths over the last three years, the TP average was 6.84 µg/L with the range running from undetectable to 59.0 µg/L. For the 80 samples collected in 2006, total phosphorus averaged 7.92 µg/L. For the 80 samples collected in 2007, total phosphorus averaged 5.38 µg/L. The slight drop in TP was probably related to lower overall precipitation and reduced storm intensity. For the 80 samples collected in 2008, total phosphorus averaged 7.21 µg/L. In all three study years, the highest site average was for the station at the mouth of the West River. This drains the largest sub-basin within the watershed and contains many steep gullies that drain quickly to the valley floor even during low to moderate intensity storm events. While the High Tor wetlands retain some of the eroded sediment and nutrients in a region just upstream of the mouth of the West River, they can on occasion function as a nutrient source to Canandaigua Lake.

Mean Total Phosphorus (2006)



Mean Total Phosphorus (2007)



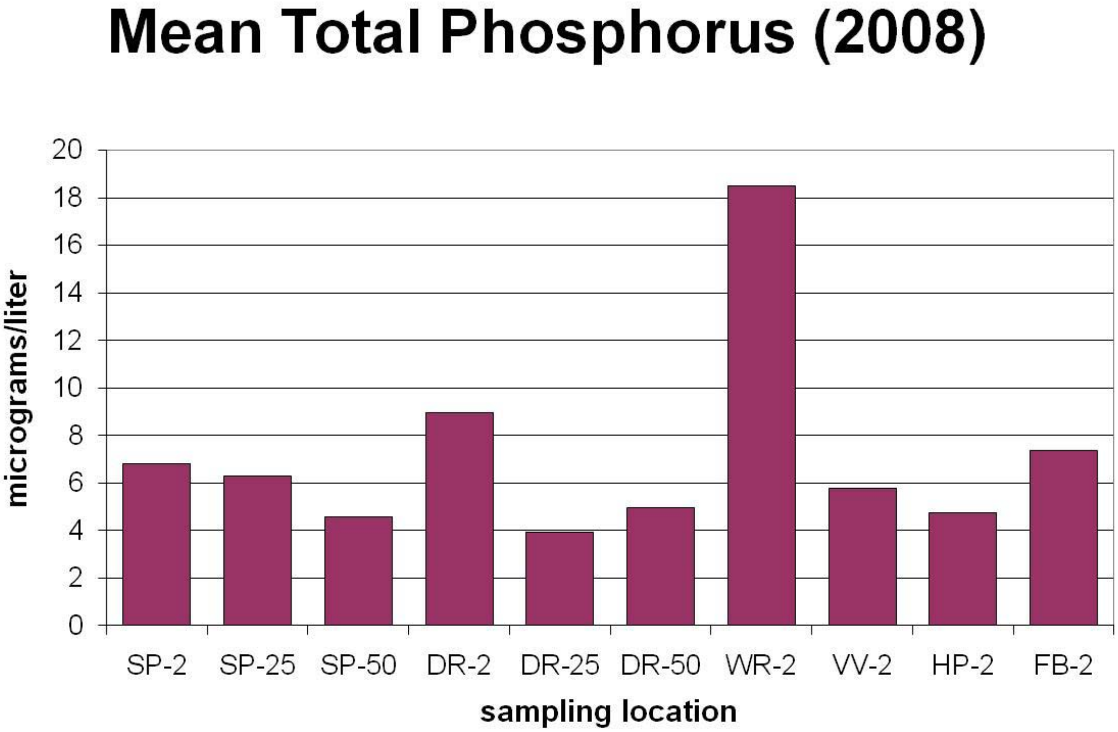


FIGURE 1.7: Mean total phosphorus in Canandaigua Lake by sampling station.

Between 2006 and 2008, there have been 38 instances (15.9%) when TP levels exceeded the desirable ecological threshold of 10 µg/L. This is a large increase over the previous three year period, 2003-2005, when 26 instances representing 10.7% were detected. Most of the high results were samples collected at the mouth of the West River during the early spring when wetland vegetation is dormant or during late fall when wetland vegetation is going senescent (Table 1.4), substantiating the changing role of the High Tor wetlands. During the growing season the wetlands usually act as a nutrient sink but in the dormant season they may act as a nutrient source to the lake. Since the beginning of the lake sampling program in 1996, the station at the mouth of the West River has had the highest total phosphorus concentrations in 65 of the 100 months (65.0 %).

TABLE 1.4: Total phosphorus data exceeding 10 µg/L, April 2006 through November 2008. Samples from the **West River** account for 14 (36.8%) of the instances.

Total Phosphorus (µg/L)	Sampling Site	Depth (m)	Date
59.0	**West River**	2	5-30-2008
41.0	Deep Run	2	5-30-2008
34.0	**West River**	2	7-29-2008
33.0	**West River**	2	10-31-2006
27.0	Seneca Point	2	5-30-2008
27.0	**West River**	2	6-30-2008
24.0	Fallbrook	2	9-27-2006
24.0	**West River**	2	6-30-2006
23.0	Seneca Point	25	5-30-2008
22.0	**West River**	2	9-29-2007
19.0	Vine Valley	2	5-30-2008
16.0	Fallbrook	2	4-28-2006
16.0	**West River**	2	9-27-2006
16.0	**West River**	2	10-30-2007
15.0	Deep Run	50	5-30-2008
14.0	**West River**	2	8-29-2006
13.0	Seneca Point	50	5-30-2008
13.0	Vine Valley	2	10-31-2006
13.0	**West River**	2	4-28-2006
13.0	**West River**	2	11-29-2006
12.0	Deep Run	50	10-31-2006
12.0	Deep Run	25	11-29-2006
12.0	Fallbrook	2	8-29-2006
12.0	Fallbrook	2	6-30-2008
12.0	Hope Point	2	11-29-2006
12.0	**West River**	2	6-28-2007
12.0	**West River**	2	7-26-2007
12.0	**West River**	2	9-30-2008
11.0	Fallbrook	2	10-31-2006
11.0	Fallbrook	2	11-29-2006
11.0	Fallbrook	2	8-29-2008
11.0	Vine Valley	2	6-28-2007
10.0	Deep Run	2	10-31-2006
10.0	Deep Run	50	5-30-2007
10.0	Deep Run	50	10-30-2007
10.0	Fallbrook	2	6-28-2007
10.0	Seneca Point	25	6-30-2008
10.0	Seneca Point	50	6-30-2008

During the summer of 1973, total phosphorus in the surface waters of Canandaigua (probably mid-lake at Black Point) ranged from 8 to 10 µg/L (Eaton and Kardos 1978). This was one year after Hurricane Agnes had brought tremendous rainfall that produced flooding throughout the watershed. Tributary streams contributed eroded sediment and nutrients to the lake, and the highest lake levels on record were noted. The mean annual lake TP results collected since 1996 are displayed in Figure 1.8. A trend line has been added to emphasize the subtle increases over this thirteen year period. The large increase beginning in 1999 corresponds with the decline and subsequent 2001 die-off of zebra mussels in the lake. While the mean annual TP levels have fluctuated between 5 and 10 µg/L, stream data suggests that more TP enters the lake then leaves through the Outlet. The absence of drastic increases in TP over time is the result of sound watershed practices (e.g., the restriction of phosphate builders in detergents, the vigilance of the watershed inspection program, the expansion of municipal sewer lines and the broader use of

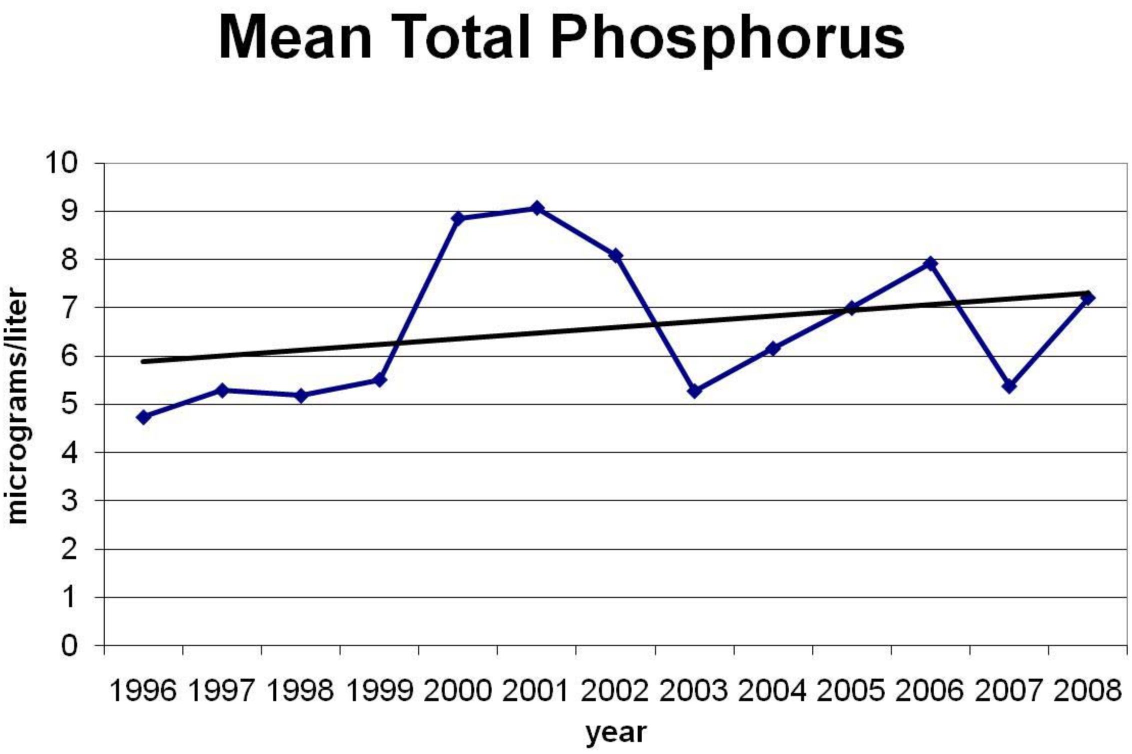


FIGURE 1.8: Long-term trends in mean annual total phosphorus in Canandaigua Lake.

best management practices in agriculture) and natural precipitation with iron in lake bottom sediments (also known as the "phosphate trap"). The increasing trend line over time suggests that a growing watershed population, coupled with an increase in impervious surfaces, represents a threat to lake health that could significantly increase phosphorus loading to the lake unless proper land use controls are in place regulating current and future development.

Mean monthly depth profiles of TP for the two mid-lake stations from 2006 to 2008 are presented in Table 1.5. Higher values are associated with the near surface depth of two meters. It is this upper region that receives sediment and nutrients from erosive watershed activities. Deep Run data are more variable but most often higher than Seneca Point data for the same reason. Most data are slightly higher when compared to 2003-2005 results.

TABLE 1.5: Three year seasonal profiles for total phosphorus (µg/L) at the two mid-lake sampling stations.

Deep Run Station

Depth (m)	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Apr-Nov mean**
2	3.93	17.77	7.17	4.37	3.87	6.60	5.17	4.77	6.70
25	4.67	4.47	5.03	5.17	4.50	5.37	5.20	6.50	5.11
50	3.90	9.80	4.80	6.73	4.47	3.43	7.83	5.83	5.85
Monthly mean	4.17	10.68	5.67	5.42	4.28	5.13	6.07	5.70	

overall mean = 5.89 µg/L

Seneca Point Station

Depth (m)	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Apr-Nov mean**
2	3.23	12.87	5.43	3.90	3.33	6.37	5.57	2.73	5.49
25	3.40	10.50	6.53	2.97	3.47	6.33	3.67	3.97	5.10
50	3.63	8.27	6.77	2.80	4.77	4.27	3.63	3.53	4.71
Monthly mean	3.42	10.54	6.41	3.22	3.86	5.66	4.29	3.41	

overall mean = 5.10 µg/L

Lake eutrophication is a natural process resulting from the gradual accumulation of sediments, organic matter and the nutrients they contain. As a lake basin slowly fills, nutrients accumulate and biological productivity is enhanced. The rate of natural eutrophication will depend on the morphometry of the basin, stability of watershed soils and meteorological conditions that transport sediment to the lake. Human activities (e.g., land development, agriculture, waste water discharges) accelerate the process bringing about cultural eutrophication. When this occurs, changes in trophic condition may happen so fast that aquatic organisms cannot adapt and so they are lost from the natural lake communities. Tolerant, invasive species often take their place, much to the detriment of watershed residents.

Typical lake eutrophication passes through this series of trophic states:

Oligotrophy: nutrient-poor, biologically unproductive
Mesotrophy: intermediate nutrient availability and biological productivity
Eutrophy: nutrient-rich, highly productive
Hypereutrophy: extremely productive, "pea soup" conditions

Oligotrophic lakes have low productivity causes by low nutrient supplies. Water can be exceptionally clear. These lakes are often deep and have steep basin walls. Water in mesotrophic lakes receive a moderate supply of nutrients from the watershed. Aquatic plant productivity is enhanced despite water clarity being somewhat reduced by suspended sediment and plankton. Eutrophic lakes have a high nutrient supply and experience pulses of extremely rapid plant growth. Water clarity can be greatly reduced at times. Dissolved oxygen along the lake bottom may be depleted by decomposers when they break down the organic remains of this high productivity.

Identification of a lake's trophic status is a useful way to determine overall “lake health". Comparisons can be made to other lakes, or from year to year in the same lake, to evaluate the effectiveness of lake restoration techniques and watershed BMPs. Early studies of Canandaigua Lake (Gilman and Rossi 1983, Gilman 1994) suggested that it was oligotrophic but nearing the mesotrophic state. To update the trophic status of Canandaigua Lake, the Carlson Trophic State Index (TSI) is used. This index is based on values for chlorophyll *a* concentration, winter total phosphorus and summer water clarity. The variables are interrelated in complex ways. Equations have been developed for each variable used to estimate trophic state (Table 1.6).

TABLE 1.6: Information pertaining to the Carlson Trophic State Index (TSI).

Variable	**Oligotrophic State**	**Mesotrophic State**	**Eutrophic State**
total phosphorus	< 10 µg/L	10 - 26 µg/L	> 26 µg/L
chlorophyll *a*	< 2 µg/L	2 - 8 µg/L	> 8 µg/L
secchi disk depth	> 4.6 m	1.9 - 4.6 m	< 1.9 m
Carlson TSI	< 37	37 - 51	> 51

The TSI formulas are:

$TSI_{SD} = 60 - 14.41(\ln \text{secchi disk reading})$

$TSI_{Chl} = 30.6 + 9.8(\ln \text{chlorophyll } a \text{ concentration})$

$TSI_{TP} = 4.15 + 14.42(\ln \text{total phosphorus level})$

where ln = natural logarithm = $\log_{10} \times 2.30$

The TSI can be useful in determining the extent of eutrophication in a lake but can be misleading if not interpreted correctly. Carlson's formulas were based on data from lakes throughout the United States, and may not necessarily apply to the Finger Lakes. In fact, since the formulas represent averages for many lakes, any one specific lake may not exactly follow the relationships described by the equations. In addition, each of these lake variables can be affected by other factors. For example, lake clarity can be influenced by highly colored water, suspended sediment and the presence of zebra mussels which filter feed on plankton community. Each and every trophic state can support a variety of human uses. Eutrophic lakes can have excellent warmwater fisheries while oligotrophic lakes can provide an excellent source of public drinking water. Mid-lake, summer (June, July, August) mean secchi disk readings and chlorophyll *a* concentrations, and winter TP when available, were used to calculate the TSI values in Table 1.7.

TABLE 1.7: Carlson TSI values for Canandaigua Lake.

Based on:	**Secchi disk**	**Chlorophyll *a***	**Total phosphorus**	**Average**
1995 data	36.9	46.3	36.0	39.7
1996 data	33.0	39.1	46.5	39.5
1997 data	30.2	40.6	27.4	32.7
1998 data	29.1	36.8	-	33.0
1999 data	28.6	35.6	-	32.1
2000 data	28.6	35.5	-	32.0
2001 data	33.3	37.9	22.7	31.3
2002 data	29.6	38.9	22.8	30.4
2003 data	31.1	37.4	-	34.3
2004 data	32.8	42.0	-	37.4
2005 data	30.7	37.7	-	34.2
2006 data	31.7	35.9	-	33.8
2007 data	33.3	38.7	-	36.0
2008 data	30.6	38.3	-	34.5

During the last three years, average TSI values for Canandaigua Lake fall within the oligotrophic condition. For the years of record, TSI based on secchi disk readings have always suggested an oligotrophic state for Canandaigua Lake (value <37). Although subject to daily conditions like cloud cover, surface water turbulence and precise time taken, secchi disk readings consistently indicate clean water conditions in Canandaigua Lake. TSI based on chlorophyll *a* concentrations had declined steadily from 1995 to 2001 probably as a result of filter feeding on phytoplankton by zebra mussels. Carlson's data collection took place before the zebra mussel invasion of North American lakes, so careful interpretation is essential. Since the 2001 zebra mussel die-off, the TSI based on chlorophyll *a* concentrations has fluctuated perhaps in response to changes in the total population of zebra mussels in the lake. The winter TP analysis produces a TSI that is relatively independent of zebra mussel effects and may provide a more realistic trophic status rating for Canandaigua Lake. It shows a downward TSI trend since 1996 suggesting that the watershed sources of phosphorus are being managed effectively. However, data points are few and winter TP has not been measured since 2002. As watershed development continues, it would be timely and appropriate to schedule a winter sampling run followed by calculation of a TSI estimate derived from the winter TP measurements.

CHAPTER 2 – TRIBUTARY RESEARCH

This chapter of the report summarizes twelve years (1997-2009) of monitoring the water quality of the seventeen major streams that drain to Canandaigua Lake. These seventeen streams represent 79% of the total drainage area of the watershed and also represent the diverse array of land uses within the watershed. The comprehensive monitoring program documented in this report draws on our research efforts to date and the historic work of others (Makarewicz et al.) in order to better understand the consequences of human activities on water quality. Long term averages and ranking for 50 storm events are analyzed along with estimating storm event loads comparing base flow water quality from 1997-1999 to 2007-2008.

Many potential sources of pollution contribute to the total burden of pollution entering Canandaigua Lake. On a national basis, the Environmental Protection Agency estimates that 80% of the remaining water pollution problems are from nonpoint sources. In the Canandaigua Lake watershed, that figure is closer to 100% because few waste water and industrial facilities are in the watershed (Canandaigua Lake Watershed Management Plan*,* Olvany 2000*)*. National, state and local monitoring programs have demonstrated that most non-point sources of pollution are carried into our waterways during precipitation events (e.g. rain or snow melt). Therefore the majority of our monitoring program resources have been allocated toward monitoring streams during storm events.

Phosphates and nitrates occur in small amounts in all aquatic environments and are required to maintain the growth and metabolism of plants and animals. However, in excess amounts, these nutrients can prove to be quite harmful. Through the process of cultural eutrophication, nutrients flow into streams, lakes, and other bodies of water. Over the last few years we are seeing an increased frequency of algae blooms (with a most recent filamentous algae bloom of *Spirogyra* in June 2009) and increased aquatic vegetation that is due, in part, to increased phosphorus levels coming from the tributary streams.

Methods:

Seventeen tributary streams were monitored during 50 storm/melt events between 1997 and 2009 (Figure 2.1). Baseline tributary sampling of these same 17 tributaries began on February 26, 2007 and continued monthly until January 28, 2008. The current baseline data set was compared to the monthly baseline data set developed by Markarewicz 1997-1999 which include 36 monthly baseline samples over three years. Makarewicz's reports from 1997-2000 documents the sampling methodologies used during those years. Gilman and Olvany's 2001-2002 and 2005 sampling reports along with this report document that we followed very similar sampling methodologies in order to maintain overall consistency. In total, approximately 850 storm event samples have been collected at the seventeen streams along with approximately 800 baseline samples. In addition to these samples, over 300 samples have been collected through stressed stream analysis in several different subwatersheds.

Grab samples were collected by the Watershed Manager and tested for phosphorus, nitrate/nitrite, and total suspended solids. Fecal coliform samples were collected once a month from May through October following the grab sampling approach. Sampling locations were chosen in seventeen subwatersheds in the locations shown in Table 2-1 and Figure 2-25 as close to the lake as possible without the influence of the lake. Sampling consisted of submerging an unpreserved pre-coded 500ml bottle into a typical flow pattern of the stream and moving it up and down within the water column in order to obtain a representative sample. The first bottle is then poured into a second pre-coded 500ml bottle with H_2SO_4 (sulfuric acid - preservative for the phosphorus and nitrate/nitrite analysis). The first bottle is then re-submerged into the water column following the same methodology and the resulting sample is analyzed for total suspended solids (TSS). Samples were stored in an ice chest until they were dropped off at Life Science Laboratories Canandaigua location in the old Wegman's Plaza. Life Science Laboratories, Inc is a certified (NELAP #10248) testing facility and follows the Environmental Protection Agency's analytical standard methods. Fecal Coliform analysis was completed at the City of Canandaigua's Water Treatment Plant (NELAP #10910).

The storm event sample dates corresponded to rain events and/or significant snow melt events. Precipitation readings are done on a daily basis at the Canandaigua Water Treatment Plant approximately 3 miles south on West Lake Rd. Readings are recorded at 8am each day and count for that day. Table 2-4 shows the precipitation levels the day after due to the fact that precipitation occurring after 8am will be counted in the next day's precipitation total. Precipitation occurring two days previous to the event is shown to better understand possible antecedent wetness conditions. The final two columns show the percentage of precipitation ending up as stream flow and total runoff in inches.

Results and Discussion:

The 50 storm/melt event samples and 48 baseline monthly samples that have been collected across seventeen tributaries to Canandaigua Lake from 1997 to 2009 provide a comprehensive data set to understand the long term sediment, nutrient and bacteriological (1989-2008) contributions from each of these streams. The specific parameters sampled include: total phosphorus, nitrate/nitrite, total suspended solids and fecal coliform.

Storm Event sampling results and discussion:

The 50 storm/melt events sampled span a broad cross section of precipitation/melt event variables. This comprehensive set of samples substantially reduces the major variability that can occur with the grab sampling method. Grab samples are one snapshot in time for that stream in that particular subwatershed. Every storm event and even every sampling year is different based on a multitude of factors. It is important to understand these variables when drawing conclusions because they can substantially affect sample results for an individual storm event or even an individual year.

Some of the major variables in storm event grab sampling include:

- **time of year**- similar sized storm events can yield very different results based on the time of year. Evapo-transpiration rates and ground conditions (frost) are just a couple factors that change throughout the year and impact results
- **time sampled within a storm event**- sampling during the "first flush" or early part of storm can yield very different results then sampling during the later stages of a storm event (Figure 2-1). Some storm events begin later in the evening and sampling crews are not able to sample until the early morning hours for safety reasons. It takes approximately 5-6 hours to get around the watershed and sample each of the streams and

possibly complete a segment analysis. This amount of time can significantly impact the validity of comparing results among streams.

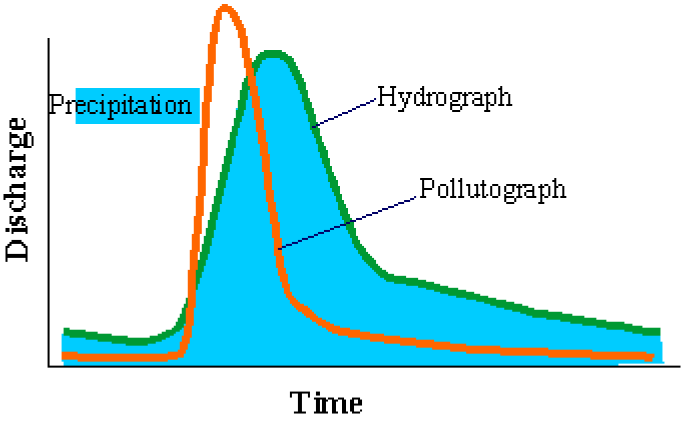
- **antecedent moisture conditions**- pre-existing soil moisture during a precipitation event can have a major influence on the amount of runoff. Questions that should be researched are when it rained previously, what are moisture conditions in the ground? An example of the lack or overabundance of soil moisture affecting stream flow is shown in Table 2-4. On August 31, 2005 the remnants of Hurricane Katrina came through our area and a total of 3 inches of rain fell over 24 hour period. Only 2% of that rain or 0.07 inches of runoff ended up as streamflow. On April 2-3, 2005 a rain event with no snow cover totaled 2.15 inches with 86% of that rain or 1.85 inches of runoff ending up as streamflow.

- **storm intensity, duration, and amount**- a one inch rain event over 12 hours vs. 2 hours not only impacts the amount of runoff but also the timing of pollutants in the stream and the timing of when the sample is taken. A three inch rain event can yield very different results than a 1 inch rain event. In addition, during melt events there is a tendency to have a substantially greater snow pack in the hills during the main spring melt which will increase runoff rates.

- **Time of Concentration (Tc) for each subwatershed**- the Tc is the time it takes for the whole subwatershed to be contributing to stream flow during a runoff event. The Tc is unique for each subwatershed and can impact the pollutant loading at the time of the grab sample.

- **different precipitation amounts/intensities throughout the watershed on a particular event (Figure 2-2)** There is one constant in a rain event…no two areas in the watershed receive the same amount of rain or the same intensity of rain. These differences make it difficult to interpret results among subwatersheds for the same event.

- **temporary land use change and timing of sample-** temporary land use changes such as fall plowing, or temporary winter wheat cover can have substantial impacts on the concentrations of pollutants.



Figures 2-1 and 2-2 showing a generalized pollutograph demonstrating the variability of concentrations throughout a storm event and the variability of precipitation amount and intensity during a storm event.

These are all important limitations of the grab sampling program that need to be understood when drawing conclusions. The monitoring program is not capable of detecting subtle changes or trends in streams. As described in Makarewicz's 1997-2000 report, the sampling design started twelve years ago does not allow us to scientifically document annual trends in the data. "Trend analyses would require sampling the discharge of streams continuously with appropriate nutrient sampling during events and baseline conditions." To document year to year trends on 17 streams would require automated sampling and flow equipment at each site and a much higher frequency of sample analysis. The costs to do this on a yearly basis would easily exceed $100,000. All variables would still not be accounted for, thus still requiring some estimation and assumptions in the interpretation of the data that is collected.

Even with these limitations there is great value in the grab sampling program. The large data set sampled over the last 12 years capture this variability, reveal the more frequent event intensities and consequently provide us a high level of confidence that the long term averages and rankings reflect an accurate estimate of the nutrient, sediment and bacteria levels in these subwatersheds. It also allows us to document long term changes in trends and to identify areas where we need to work in subwatersheds to identify potential sources of the higher concentrations.
Although the current sampling program does not provide reliable year to year trends, it does allow us to observe trends that are maintained over multiple years. The sampling program also allows us to prioritize streams based on multiple events and years of sampling. Finally, it allows us to make rough comparisons between the results from our streams to national research.

Benchmarks:

Table 2.1 in the NYS Stormwater Manual (2001) lists the National Median Concentrations for Chemical Constituents in Stormwater. This data came from the comprehensive National Urban Runoff Program (NURP) that sampled urban type streams across the United States during storm events during the late 1970s. The results from the NURP study document that the median concentration of total phosphorus (TP) was 0.26 mg/L, total suspended solids (TSS) was 54.5

mg/L, and nitrate/nitrite concentrations was 0.53 mg/L. Although there are multiple variables involved with comparing these concentrations to our sampling effort, the NURP study provides a decent benchmark to use as a guide when comparing our streams to national level research. National research has documented that urban type streams usually have elevated levels of phosphorus, sediment, nitrates, and bacteria when compared to streams with rural land cover, so if we come close to these levels there is cause for concern. Also, the NURP study was completed back in the 1970s and early 1980s when many of the treatment technologies for point sources of pollution were being upgraded and most of the non-point source pollution control techniques were not in place. Therefore, the levels reported in the NURP study should be higher than the sample data collected within the Canandaigua Lake Watershed during the 1997-2009 timeframe.

The U.S. Environmental Protection Agency (EPA) and additional research generally conclude that background natural levels for total phosphorus is 0.1 mg/L and 0.6 mg/L for Nitrate/nitrite. Concentrations exceeding these thresholds indicate human influence.

Rankings:

Grab samples are snapshots in time and a few samples that are either substantially higher or lower can skew averages (even with many samples). Therefore, the long term average data is supplemented by providing a long term average ranking of each of the individual storm events. Each of the fifty storm events are ranked from 1 (lowest concentration) to 17 (highest concentration) and then averaged. This ranking approach was used in order to try to reduce the impact of extremely high or low individual storm event results that are outliers and may be skewing the raw average data. Additionally, the ranking approach documents which streams are consistently high or low regardless of the event intensity and grab sample timing.

The ranking approach is used for each of the parameters. Finally, a cumulative ranking is also provided for the long term average ranking for phosphorus, TSS, nitrate/nitrite and fecal coliform. This cumulative ranking provides an overall stream pollution index for the subwatershed.

Loading estimates:

Loading of a specific pollutant is calculated by multiplying the concentration within the stream by the stream discharge to determine the amount of a specific pollutant that is entering the lake. Discharge was calculated by determining the net inflow (which is based on lake level change, outflows, evapotranspiration, precipitation on the lake, and withdrawals) into the lake and dividing it by the amount of precipitation landing on the entire watershed. The last column in Tables 2-3 and 2-4 documents the percentage of precipitation ending up as runoff to the lake and the estimated loading occurring for each of the storm events sampled. A comprehensive mass balance model following this approach was developed for another project, but has been extremely useful in estimating loading. The percentage ending up as streamflow is based on four days of net inflows and precipitation in order to capture the entire hydrograph or runoff event. Some sampling events show greater than 100% of the precipitation that landed during those four days ending up as streamflow due to spring snowmelt events where the existing snow pack melts and adds to the runoff estimate.

There are limitations to using this approach to determining individual stream discharge. The first limitation is assuming that the percentage of precipitation ending up as streamflow is uniform throughout the subwatersheds sampled. Differences in landcover, impervious cover, slope, soils, precipitation, and other variables bring some inaccuracy into this uniform approach. It is estimated that the percentage of precipitation ending up as streamflow fluctuates by about 20% among the different subwatersheds based on the various factors. However, previous attempts at estimating discharge and pollutant loading based on periodic flow measurements were significantly inaccurate and interpreting the data was problematic. In some cases, total annual discharge in many of the streams was estimated to be over 150% of the total precipitation in the drainage area. Thus, the current monitoring program authors believe the approach used in this report to estimate discharge to be a substantially improvement over periodic stream flow measurements of storm event streamflow. It also gives us a method for comparing runoff amounts between storms where higher percentages indicate more overland flow to the streams.

We are only able to look at the runoff values for storm events starting in 2001 because we were unable to obtain individual storm event dates and concentrations numbers from the previous researchers in order to develop runoff values for those specific storm events. Therefore, we have 28 storm events in which runoff values have been determined. Based on 28 storm events, the average precipitation event sampled was 1.47 inches with 59% or 0.651 inches ending up as runoff. It is important to remember that some individual spring sampling events were greater than 100% of precipitation because of snowmelt adding to the overall runoff equation on that particular event.

Although pollutant loading is an important part of the scientific equation, large streams such as the West River may give a false conclusion that they are a major source of pollution. The shear amount of discharge from the surrounding drainage area is substantially greater than all of the other subwatersheds. From a watershed management perspective, concentrations and rankings provide a vital piece of data that can indicate the level of human disturbance in the subwatershed that is increasing total phosphorus above the 0.1mg/L guidance value for streams.

Multi-year comparisons: One potential method to determine if we are seeing improving or decreasing water quality in the streams is to compare an equal amount of storm/melt events. Each of the three storm event parameters sampled analyze 14 events from 2001-July 2004 to 14 events from September 2004-2009. Although the number of storm events is the same, the runoff volume was almost double for the storms from September 2004-2009 (11.50 inches of runoff) to the 2001-July 2004 (6.72 inches of runoff). This substantially influences the concentrations because greater runoff increases erosion levels, thus increasing the overall concentration of all the parameters especially TSS and total phosphorus which attaches to soil particles. Therefore, drawing conclusions from the multi-year comparison approach is problematic, but the authors felt it was worthy of still displaying the results in the report.

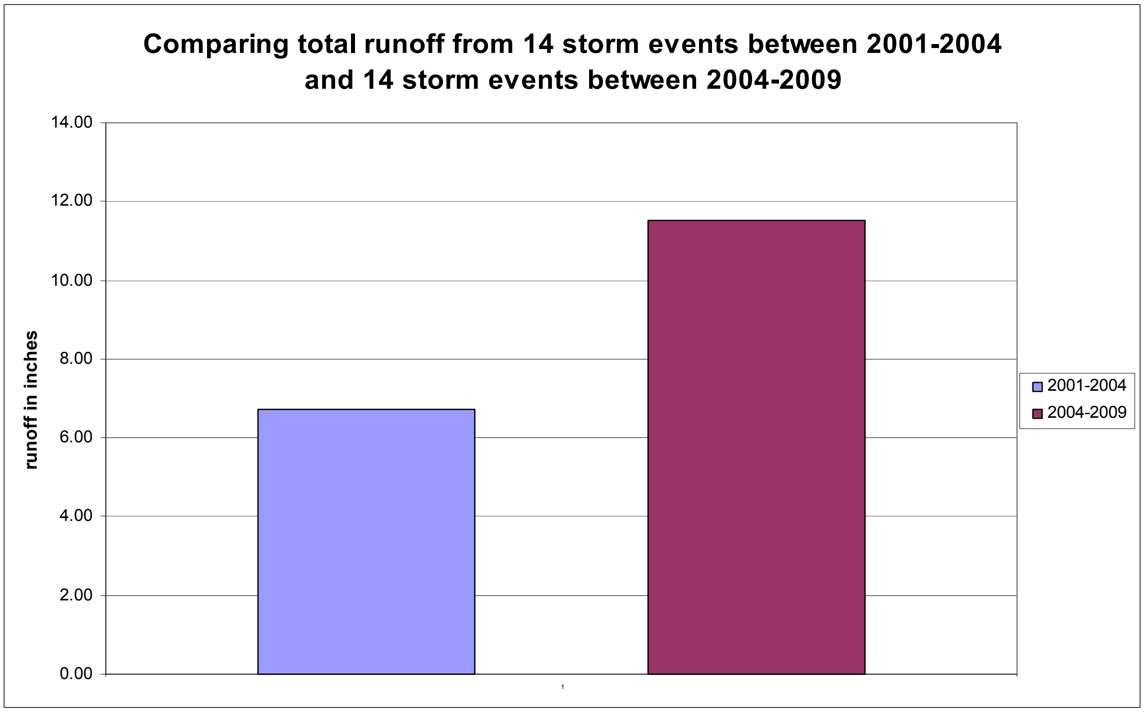


Figure 2-3 Comparing runoff totals between 14 events in 2001-2004 to 14 events in 2004-2009.

Total Phosphorus:

Phosphorus is considered the limiting nutrient that determines the level of algae and macrophyte growth in the lake; therefore it is a primary pollutant of concern. Chapter One of this report identified the upward trend in total phosphorus in the lake over the last 13 years indicating the importance of monitoring and developing best management practices to reduce the human sources of phosphorus entering the lake.

Average storm/melt concentration: Based on 50 storm events Vine Valley had the highest long term average concentration of phosphorus over the last twelve years with 0.245 mg/L (see Figure 2-4). Gage Gully was second with 0.229 mg/L and Sucker Brook was third with 0.221 mg/L. Table 2.1 and Figure 2.1 display the long term storm event phosphorus levels for each of the seventeen subwatersheds sampled. Individual storm event concentrations show remarkable numbers on two specific storm events October 20, 2006 and March 14, 2007 with several streams substantially exceeding 0.5 mg/L, which is a limit imposed on sewage treatment plants. The overall average for the seventeen streams on October 20, 2006 storm event was 0.773mg/L and March 14, 2007 event it was 0.663 mg/L. The highest individual storm event concentration was 2.4 mg/L at Gage Gully on the October 20, 2006 storm event.

Although no stream's long term average exceeded the NURP study "benchmark" of 0.26 mg/L of total phosphorus, several streams came in close. It is important to remember the timing of the NURP study in that many of the improvements to wastewater treatment plants and urban runoff controls had not been made yet, thus increasing the overall concentrations in streams. In addition to the NURP study several reports and environmental indices have identified a guidance value of 0.1mg/L of total phosphorus in determining if a stream is polluted.

Ranking: The average ranking of the individual storm events shows some change in stream order with Sucker Brook (12.4) having the highest rank, Vine Valley (10.6) coming in second and Seneca Point Gully (10.3) ranked third. Figure 2-5 displays the long term average ranking of the individual storm events for each of the seventeen subwatersheds sampled. These long term average rankings of individual storm events document that Sucker Brook has a higher concentration on a more consistent basis than any other subwatershed.

Loading: Figure 2-6 details estimated loading during the average storm event. Although the West River at the Sunnyside Road sampling station has the lowest concentration of phosphorus, it has the highest loading. This is due to the shear size of the subwatershed (24,743 acres) or 22.7% of the whole lake watershed! Table 2-3 documents the acreage for each of the subwatersheds. What is less obvious from Figure 2-6 is the cumulative loading that comes through Naples Creek and into Canandaigua Lake. The monitoring program samples the four major tributaries that form Naples Creek (Grimes, Eelpot, Reservoir and Tannery) and separates out their individual loads. The combined drainage area of these tributaries that form the Naples Creek Complex equals 29,029 acres or 26.6% of the total watershed area. The total load from the Naples Creek Complex during a typical storm event is 518 pounds of phosphorus where as the load from the West River is 299 pounds.

Although loading is an important part of the scientific equation, large streams such as the West River may give the false conclusion that there are major sources of pollution in its subwatershed because of the shear amount of discharge influencing the total load when the concentration part of the equation is at or below generally recognized background levels. From a watershed management perspective, concentrations and rankings provide a vital piece of data that can indicate the level of human disturbance in the subwatershed that is increasing pollution above the 0.1mg/L guidance value for streams.

Multi-year comparisons: Figure 2-7 displays a comparison of average total phosphorus levels for 14 events from 2001-July 2004 and 14 events from September 2004-2009. There are substantial increases in average total phosphorus concentrations in the 2004-2009 time frame for most of the subwatersheds. These increases can be partially explained by Figure 2-3 that documents almost a doubling in runoff between the first 14 events to the second 14 events. Other variables that could explain these differences include timing of samples during the peak of an event could skew the overall average. However, the dramatic increase in some streams is cause for concern and additional research is recommended.

The data set was also compared through the ranking approach in Figure 2-8. Generally the rankings appear similar with Sucker Brook decreasing slightly, potentially indicating some success in the restoration work that has occurred to date.

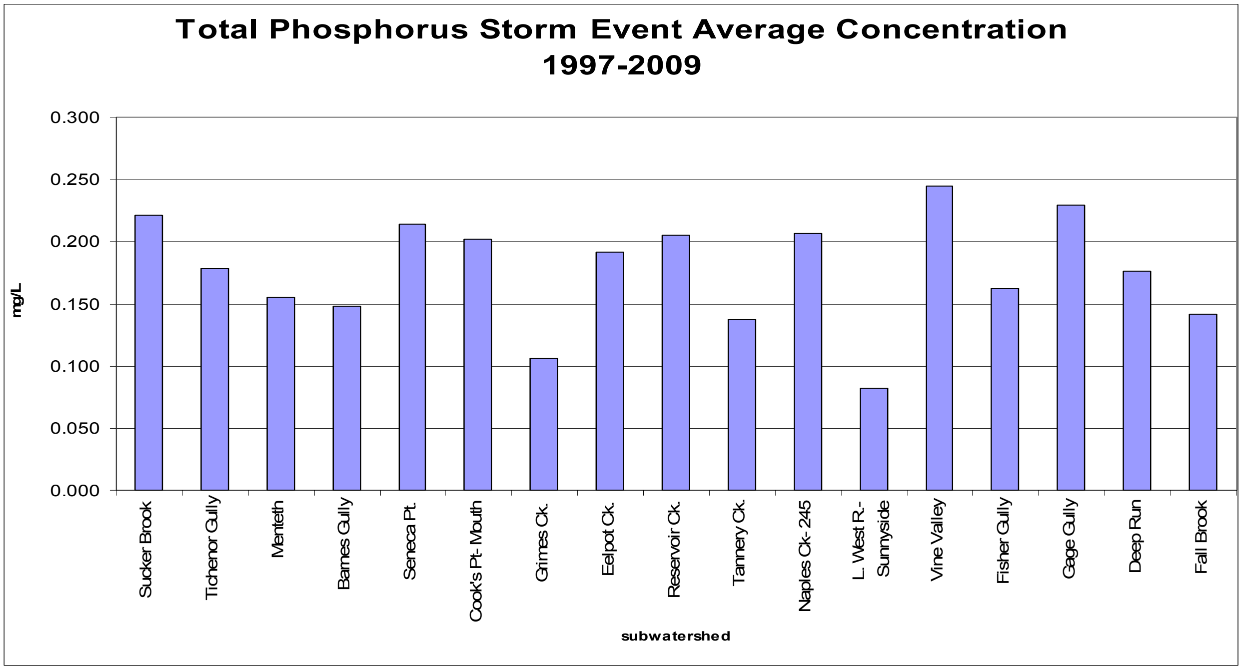


Figure 2-4 Total Phosphorus Storm Event Concentration 1997-2009.

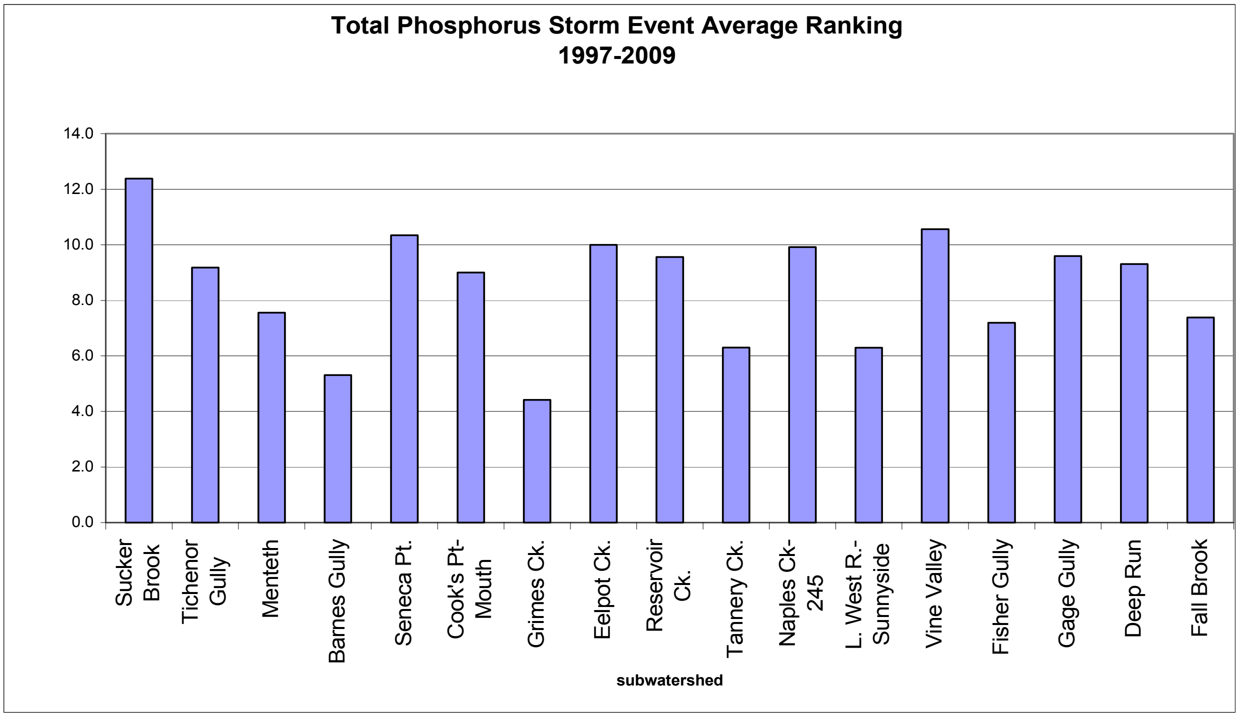


Figure 2-5 Total Phosphorus Storm Event Average Ranking 1997-2009.

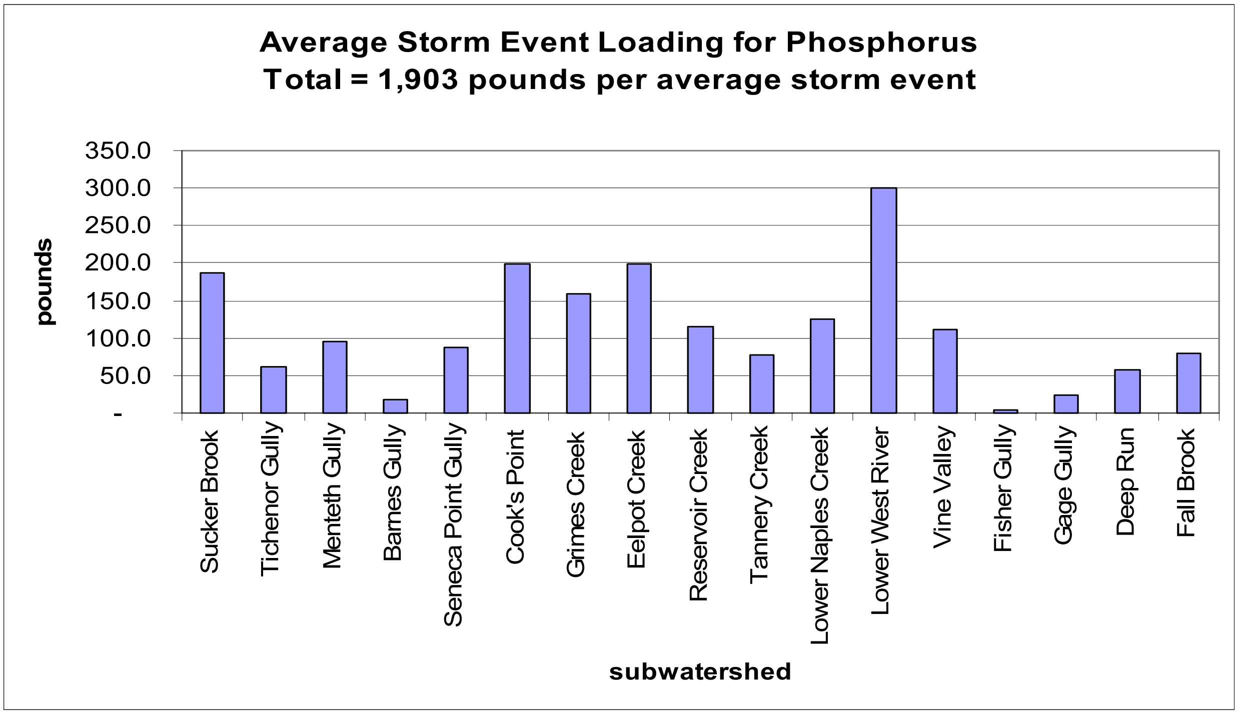


Figure 2-6 Total Phosphorus Storm Event Average Loading.

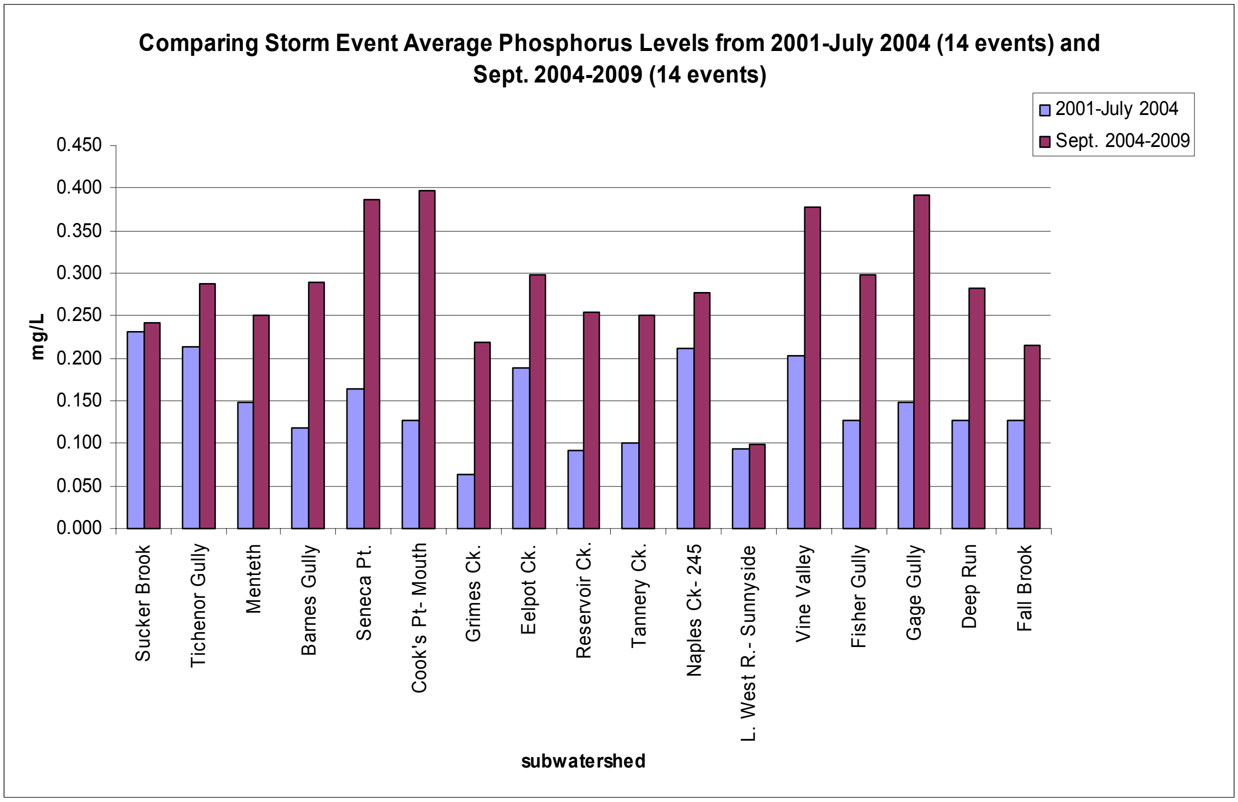


Figure 2-7 Comparing Storm Event Average Total Phosphorus Levels from 2001-July 2004 and Sept. 2004-2009

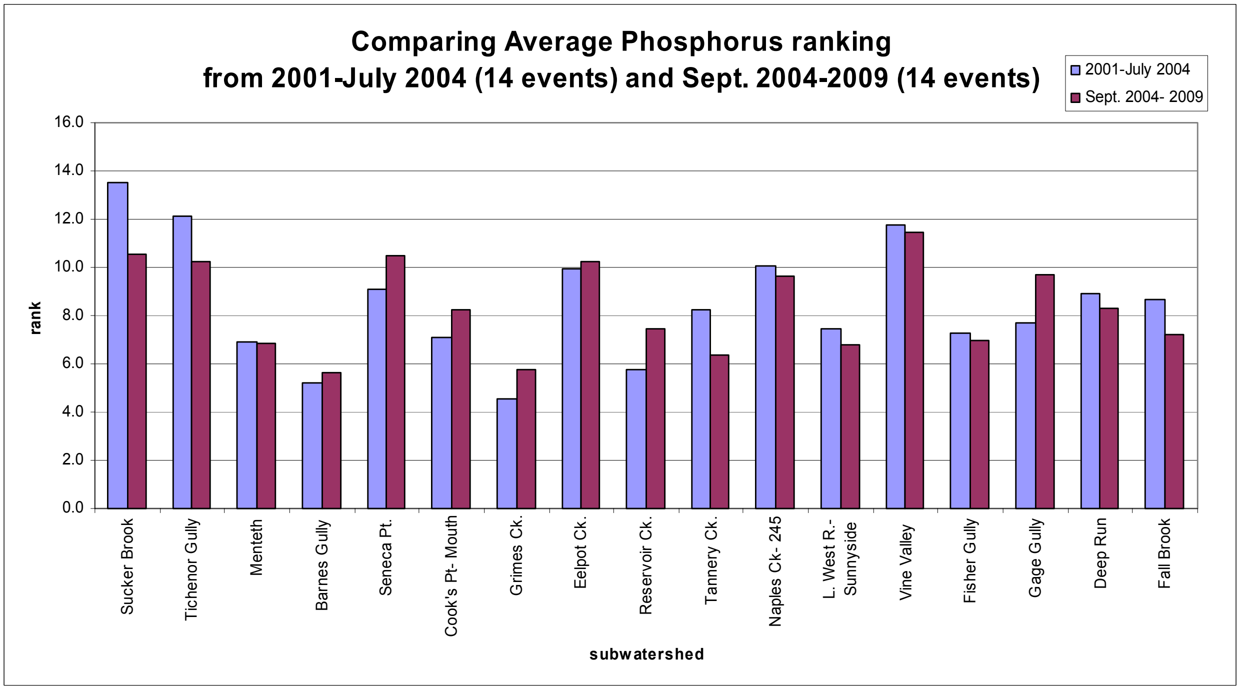


Figure 2-8 Comparing Storm Event Average Total Phosphorus ranking from 2001-July 2004 and Sept. 2004-2009

Baseline Total Phosphorus:

Based on 12 baseline samples during 2007 and 2008, average concentrations of total phosphorus are listed in Table 2-5. The highest baseline average concentration of total phosphorus was at Seneca Point with 0.0833 mg/L. This stream receives a regular wastewater discharge from Bristol Harbour Resort Complex. The second highest concentration was at Sucker Brook with 0.078 mg/L. Third was the West River with 0.0700 mg/L which receives wastewater discharges from the Village of Rushville and a poultry business, and fourth was Gage Gully with 0.0249 mg/L. The lowest concentration of phosphorus was found in Grimes Creek (0.0078 mg/L).

This data set was compared to the historic set of 36 samples collected from 1997-1999 and documented in Makarewicz's reports. Figure 2-9 displays this comparison showing remarkable consistency between the two datasets. It is important to note that no average baseline concentration exceeded the 0.1mg/L threshold generally considered to be indicating pollution arising from human activites. This also reinforces the research that most of the pollution entering the lake occurs during storm events.

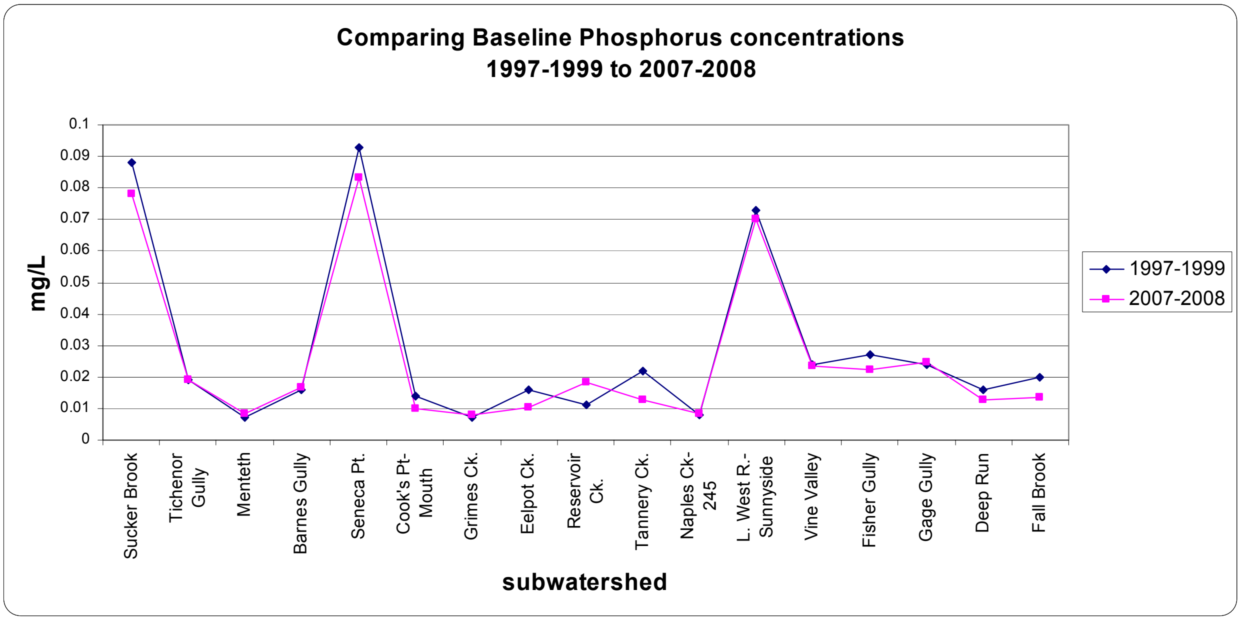


Figure 2-9 Comparing Baseline Average Total Phosphorus concentration from 2007-2008 and 1997-1999

Storm/melt event Total Suspended Solids (TSS): Fisher Gully had the highest average TSS concentration over the last twelve years at 368.9 mg/L (Figure 2-12). Eelpot Creek was second with 335.5 mg/L. Naples Creek was third with 301.7 mg/L. All streams except Lower West River significantly exceed the TSS levels reported in the NURP study of 54.5 mg/L.

The picture provided is of Fisher Gully and documents one of the high TSS concentration events back in February 2002 with a recorded concentration of 3,400mg/L. The April 2, 2005 storm/melt event that generated 1.85 inches of runoff yielded the highest recorded TSS result in the watershed at Fisher Gully (7,400 mg/L).

Fisher Gully is a high gradient (steep) gully, located along the southern portion of the Town of Gorham and at northern edge of the Appalachian Plateau. Fisher Gully is an important tributary because it outlets approximately 100 feet from the Village of Rushville's intake pipe. In the past few years a logging operation occurred in the lower reaches of the drainage area and a golf course was built in the upper reaches of the drainage area. Both of these activities are potential sources of sediment loading to the gully, coupled with stream bank erosion. Both sites were monitored and the owner/operators made any necessary erosion control changes that were requested. Protecting Fisher Gully is a high priority for the Town of Gorham (Richard Calabrese pers. comm.). They partnered with several entities including New York State DEC and the Finger Lakes Land Trust to permanently protect approximately 95 acres of the gully's drainage area.

Ranking: The long term average rank of individual storm events provides a different story on the consistency of high TSS levels in each of the subwatersheds (Figure 2-13). Fisher Gully drops from being the highest concentration to mid-range when looking at the average ranking of the individual storm events. Eelpot (13), Naples (12.2) and Cook's Point (10.7) had the highest ranking demonstrating that these streams had concentrations that were consistently higher than the other streams. We are completing a stressed stream analysis of Eelpot Creek while Valerie George of RIT is completing her master's thesis comparing Grimes Creek and Eelpot Creek.

Major sources of sediment within the watershed include any land disturbing activity such as development, agriculture, impervious surfaces, road bank erosion, mined lands, and timber harvesting. Stream bank erosion is another major source of sediment. Stream erosion does occur naturally, but is exacerbated when upland activities disturb the riparian buffer or increase the volume and velocity of water entering the stream system as overland flow.

Sediment accumulation in trout spawning areas of the southern watershed streams is a major concern. As sediment accumulates, it fills the void spaces in the gravelly streambed and suffocates fish eggs. Sediment is also a major concern along the lakeshore. Sediment with attached phosphorus will provide the appropriate bottom substrate for increased growth of aquatic vegetation. There is some anecdotal evidence of increased macrophyte growth along the littoral zone. Exotic, invasive species such as Eurasian milfoil and Curly Leaf Pondweed can dominate areas with recent sediment deposition.

Loading: Based on only the 17 streams sampled, the loading into Canandaigua Lake during an average event totals over two million pounds of suspended solids! It is impossible to discern what exact percentage of that is derived from natural erosion or human influenced activities. However, as documented in the graphics, human induced erosion is an important part of the equation and is what we attempt to manage.

Eelpot had the highest average loading of 347,949 pounds of suspended solids per storm event sampled. We are currently working with a master's student to document the potential sources of TSS in the subwatershed. Natural features such as slope and a large percentage of highly erodible soils as well as evidence of substantial stream bank erosion are contributing factors. There is some agricultural land use and a network of roads and private driveways that may also contribute.

Multi-year comparisons: Figures 2-15 and 2-16 document a similar trend as phosphorus did between the two sets of 14 events, with substantial increases in concentrations during the most recent events. However, runoff amounts play an important role in TSS concentrations. Figure 2-17 documents the relationship between TSS concentrations and the amount of runoff with a correlation coefficient (r-squared) value of 0.552. Tannery Creek showed the greatest increase in rank and Reservoir Creek showed the most substantial decrease.

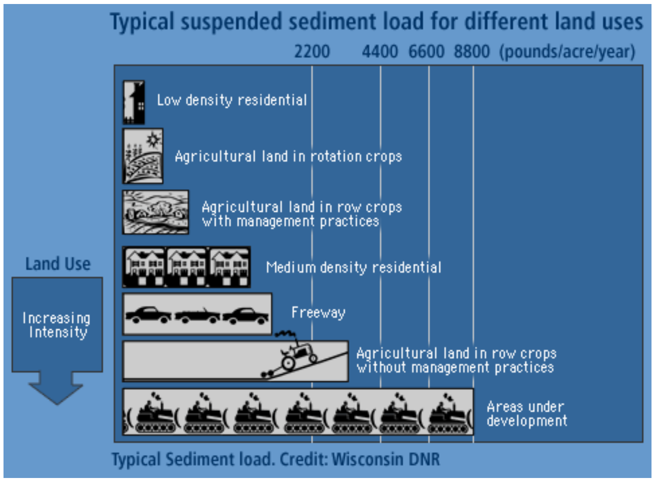


Figure 2-10 Graphic from Wisconsin DNR documenting the impact of TSS and its sources.

Figure 2-11 Photos documenting examples of local sources of TSS in our watershed.

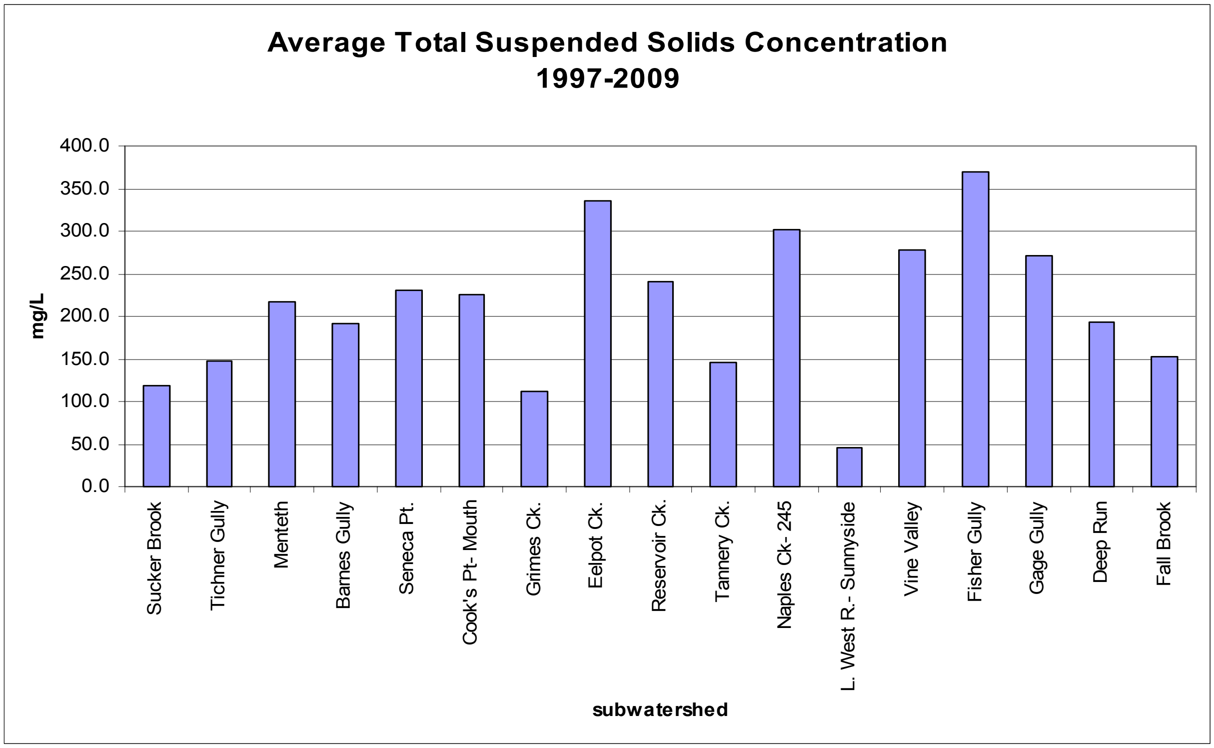


Figure 2-12 Average TSS Concentration 1997-1999.

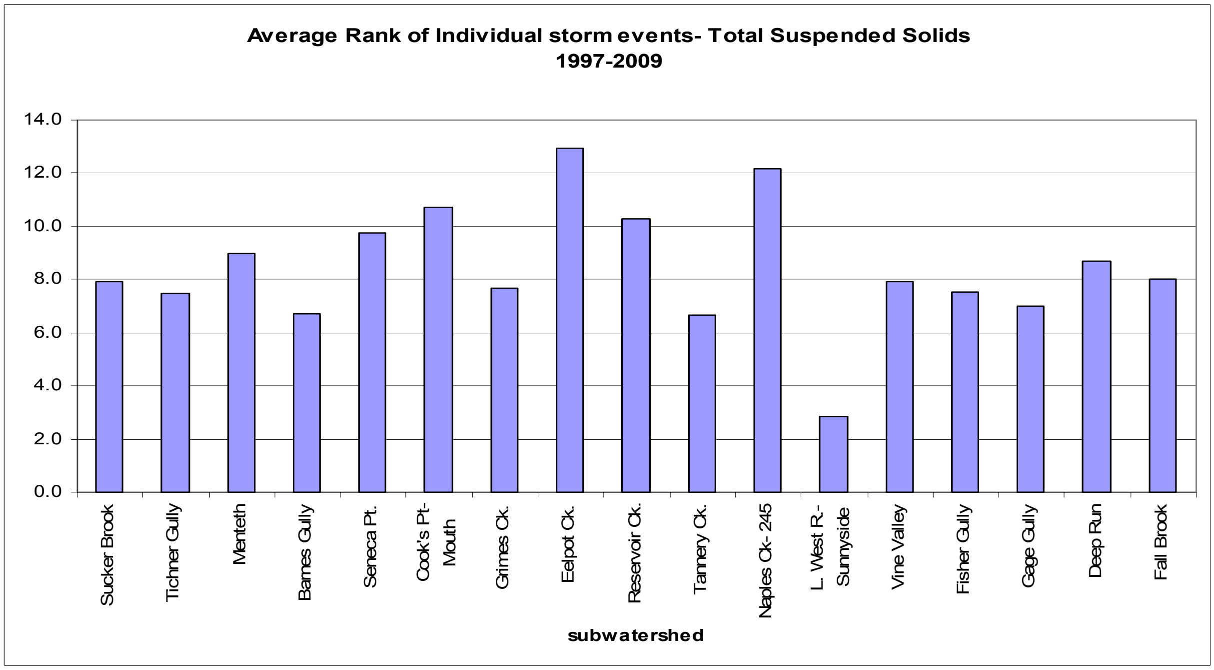


Figure 2-13 Average TSS rank 1997-1999.

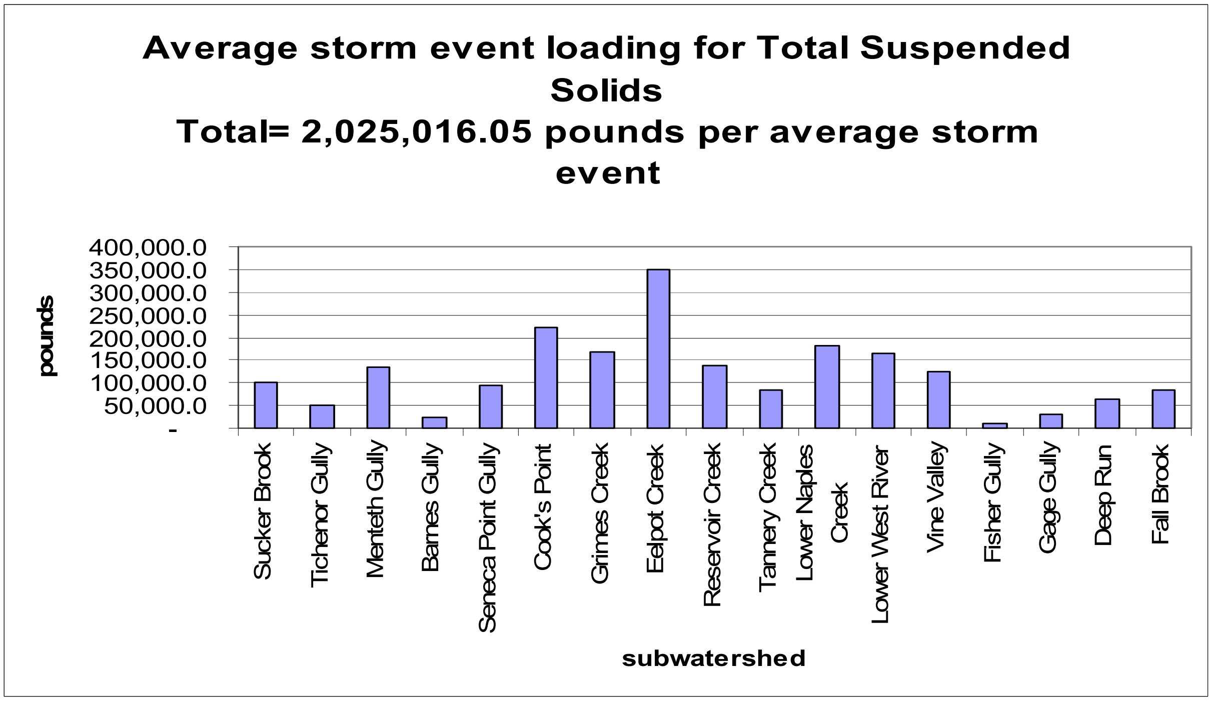
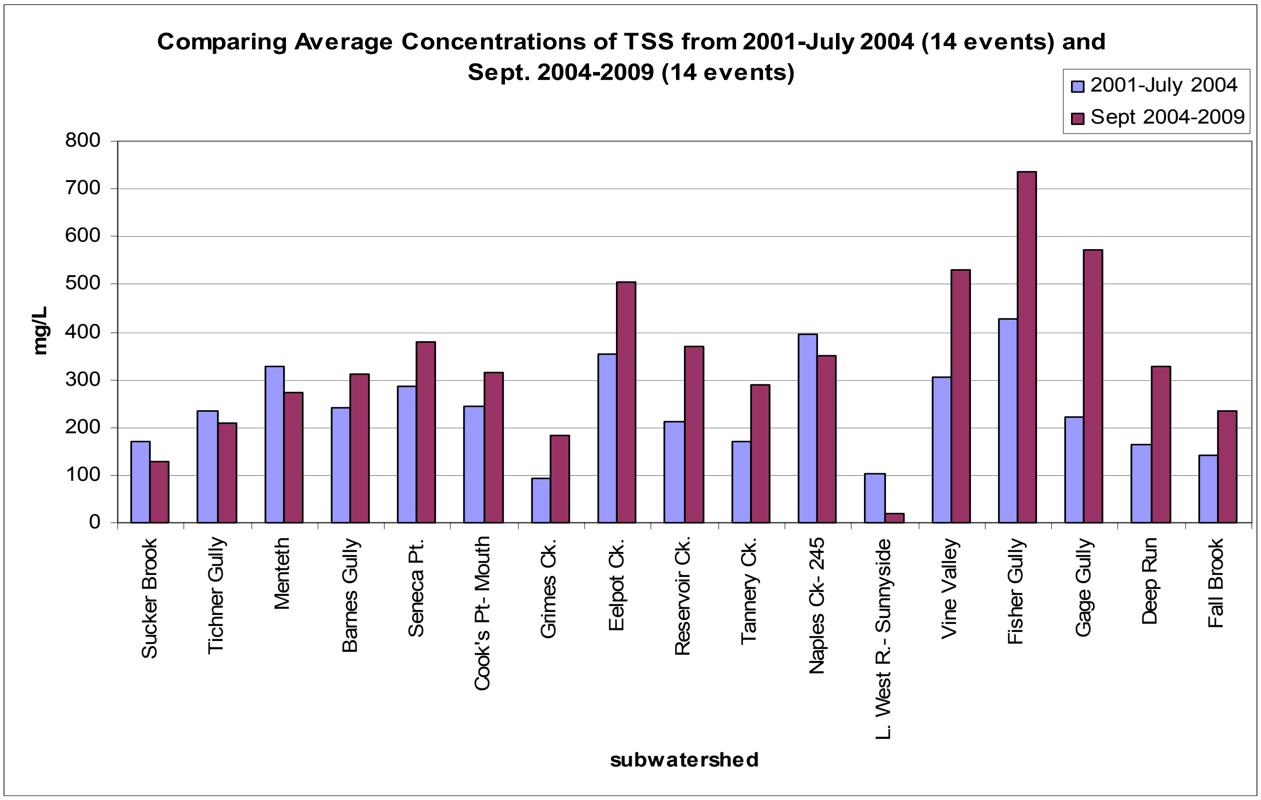


Figure 2-14 Average TSS Loading.



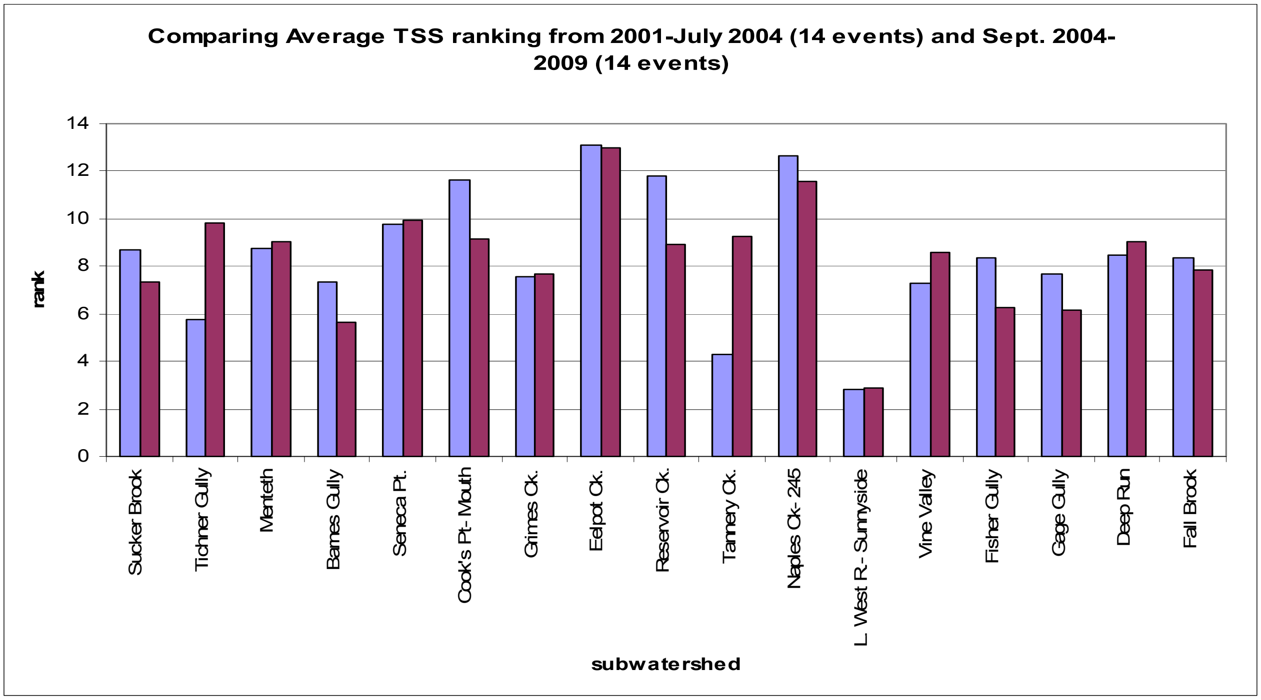


Figure 2-15 Comparing Average TSS Concentration from 2001-July 2004 (14 events) and Sept. 2004-2009 (14 events).

Figure 2-16 Comparing Average TSS ranking from 2001-July 2004 (14 events) and Sept. 2004-2009 (14 events).

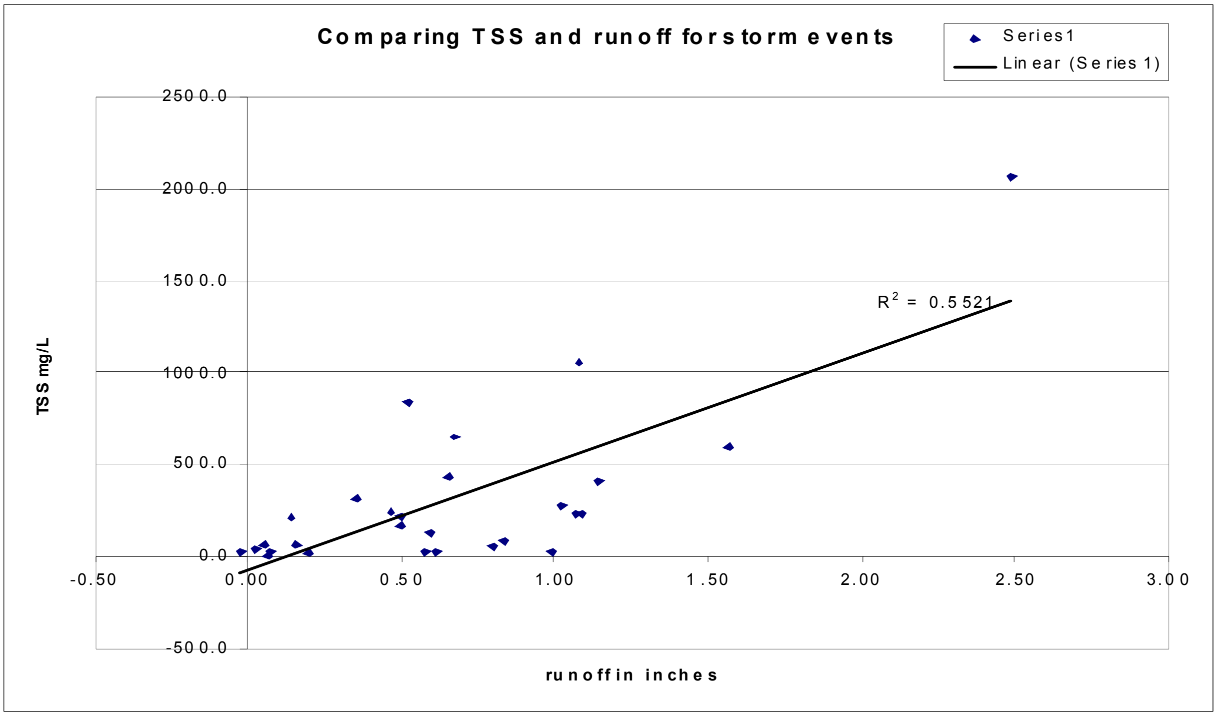


Figure 2-17 Comparing Average TSS Concentration and runoff in inches.

Nitrate/Nitrite:

Nitrate/Nitrite is a measure of the dissolved forms of inorganic nitrogen in the environment. Although Nitrate/Nitrite is not the limiting nutrient to the lake, it is an indicator of pollution and can impact the levels of some algae in the lake. Sources of nitrates are many and include septic systems, barnyard waste, manure, fertilizers (agricultural and residential) and atmospheric deposition. Continued monitoring of nitrate/nitrite levels is warranted to determine if any long term trends occur in nitrate/nitrite concentrations.

Gage Gully had the highest average concentration over the last twelve years with 3.92 mg/L (Figure 2-18). Deep Run was second with 2.62 mg/L. Fall Brook was third with 2.18 mg/L. Sucker Brook was fourth with 1.54 mg/L. Vine Valley was fifth with 1.21 mg/L. The rankings (Figure 2-19) show the same order and also show consistency of results for this parameter. Agriculture dominates each of these subwatersheds along with scattered septic systems as the two likely sources of these elevated levels. The NURP studies provided a median concentration of 0.53 mg/L, thus these five streams are substantially higher than the NURP threshold.

Multi-year comparisons: Figures 2-20 and 2-21 provide the comparison between the 14 events sampled from 2001-June 2004 and the 14 events sampled from September 2004 to 2009 and demonstrate an overall reduction in nitrate/nitrite levels even with the much greater amounts of runoff occurring in the latter set of samples. This could be an indication of best management practices that have been put in place in the Gage, Deep Run, Fall Brook and Sucker Brook subwatersheds having a positive impact. The rankings remain consistent.

Baseline sampling: Figure 2-22 shows a consistent pattern between the 1997-1999 and the 2007-2008 data sets. There was a decrease in the baseline nitrate levels at Gage Gully of approximately 0.5 mg/L from the 1997-1999 to 2007-2008 data sets. This is consistent with the reduction in storm event nitrate concentrations. Overall averages still document that Fall Brook, Deep Run, Gage Gully, Eelpot and Sucker Brook are all substantially over the 0.53mg/L benchmark.

Additional research has been ongoing on a small drainageway the flows through the eastern part of the Village of Naples that is called the Grimes Creek Raceway. Average nitrate/nitrite concentrations at Ontario Street were 5.22 mg/L during baseline conditions and are much higher than any of the 17 streams sampled. The Watershed Council is working with the Village of Naples in continuing the research to document the need for a centralized sewer system.

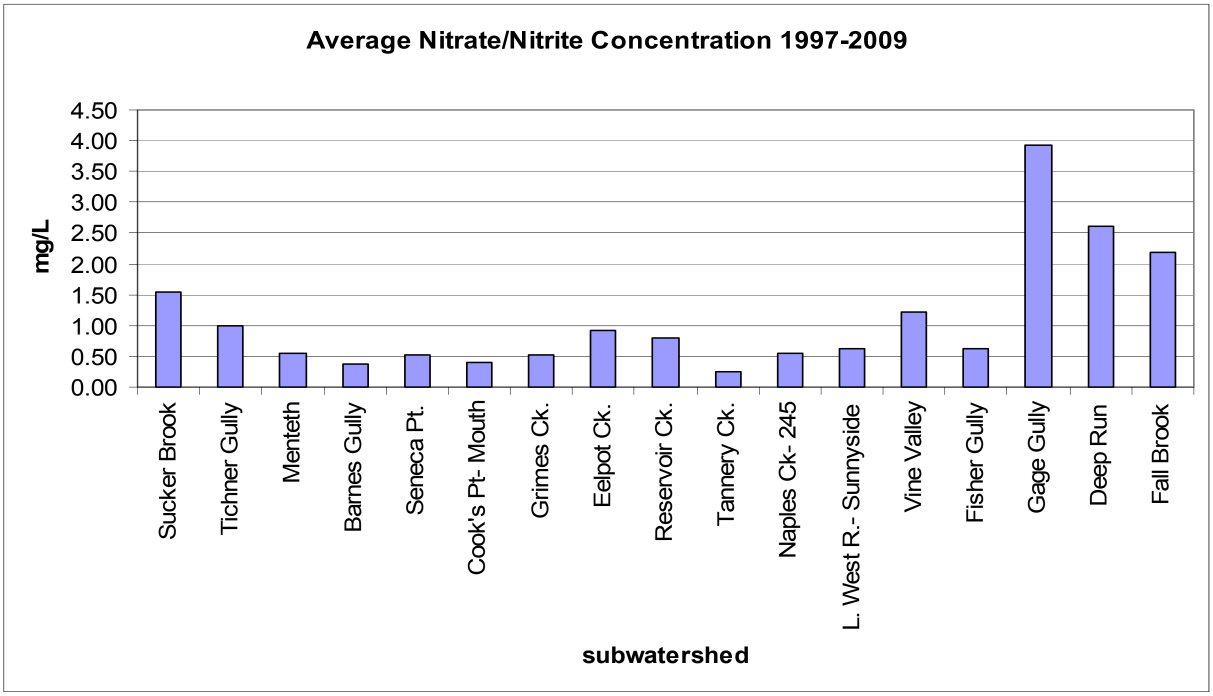


Figure 2-18 Average Nitrate/Nitrite Concentrations 1997-2009.

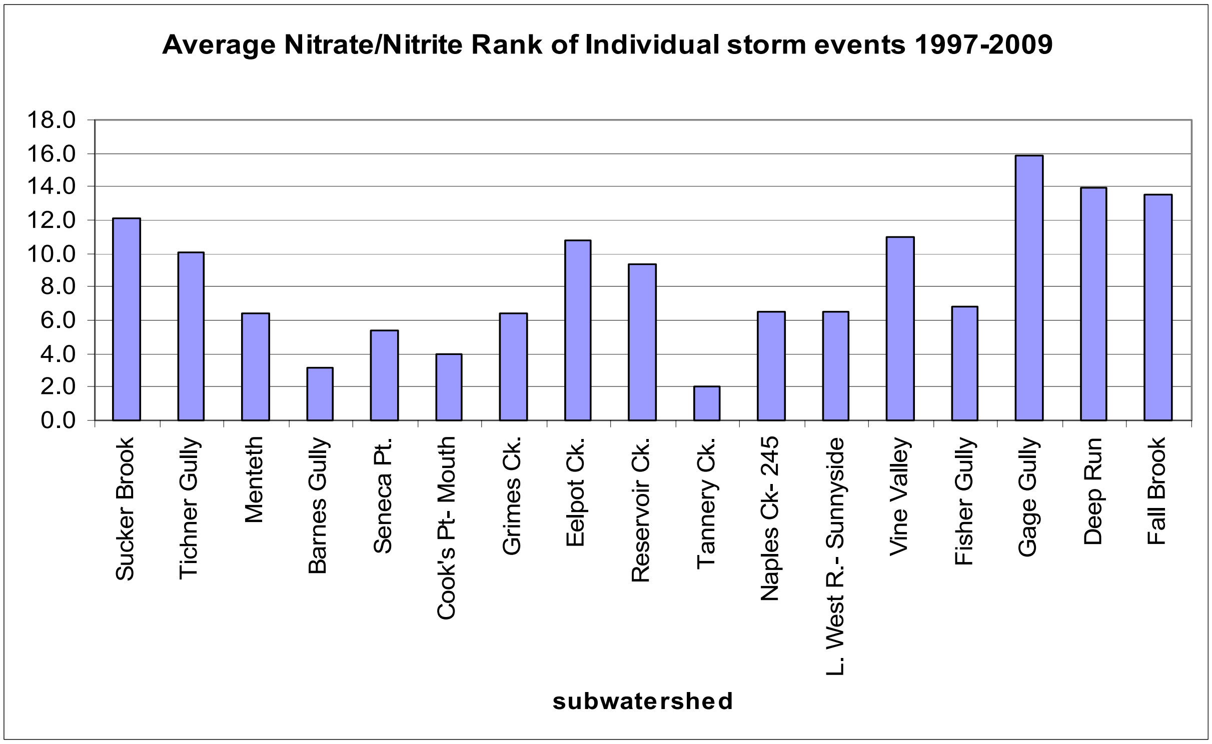


Figure 2-19 Average Nitrate/Nitrite Rank 1997-2009.

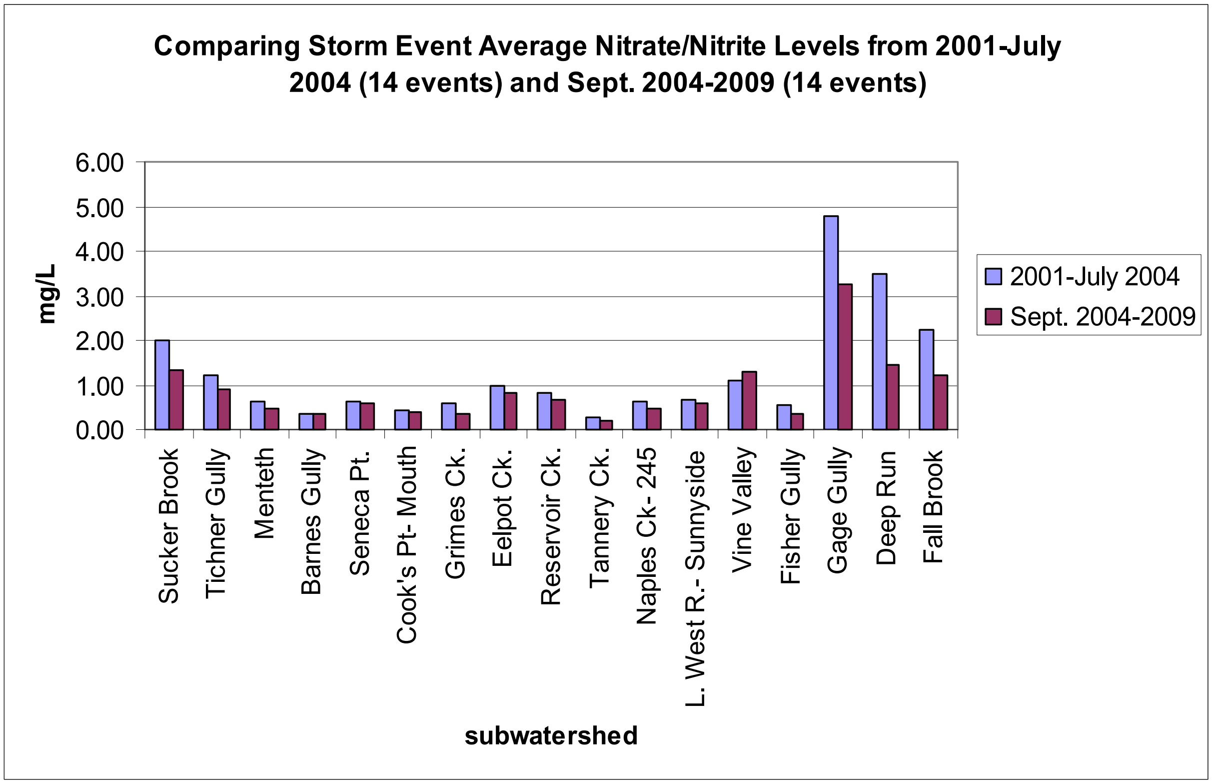


Figure 2-20 Comparing Average Nitrate/Nitrite concentration from 2001-July 2004 (14 events) and Sept. 2004-2009 (14 events).

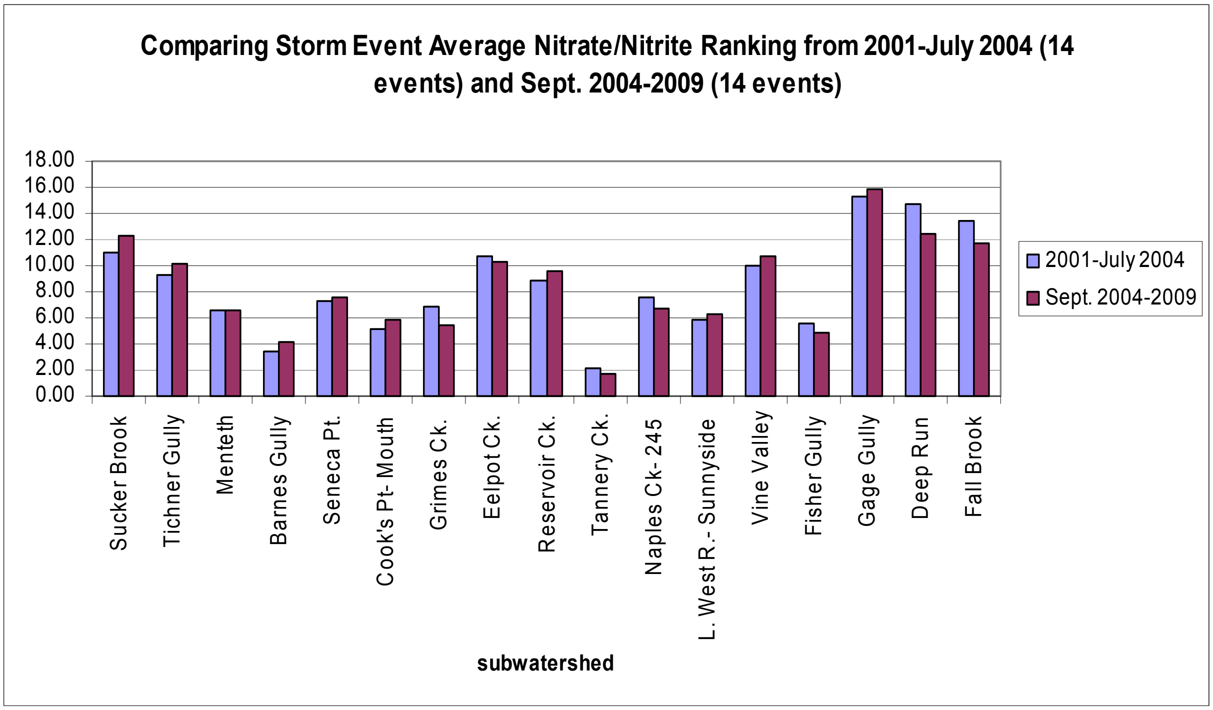


Figure 2-21 Comparing Average Nitrate/Nitrite ranking from 2001-July 2004 (14 events) and Sept. 2004-2009 (14 events).

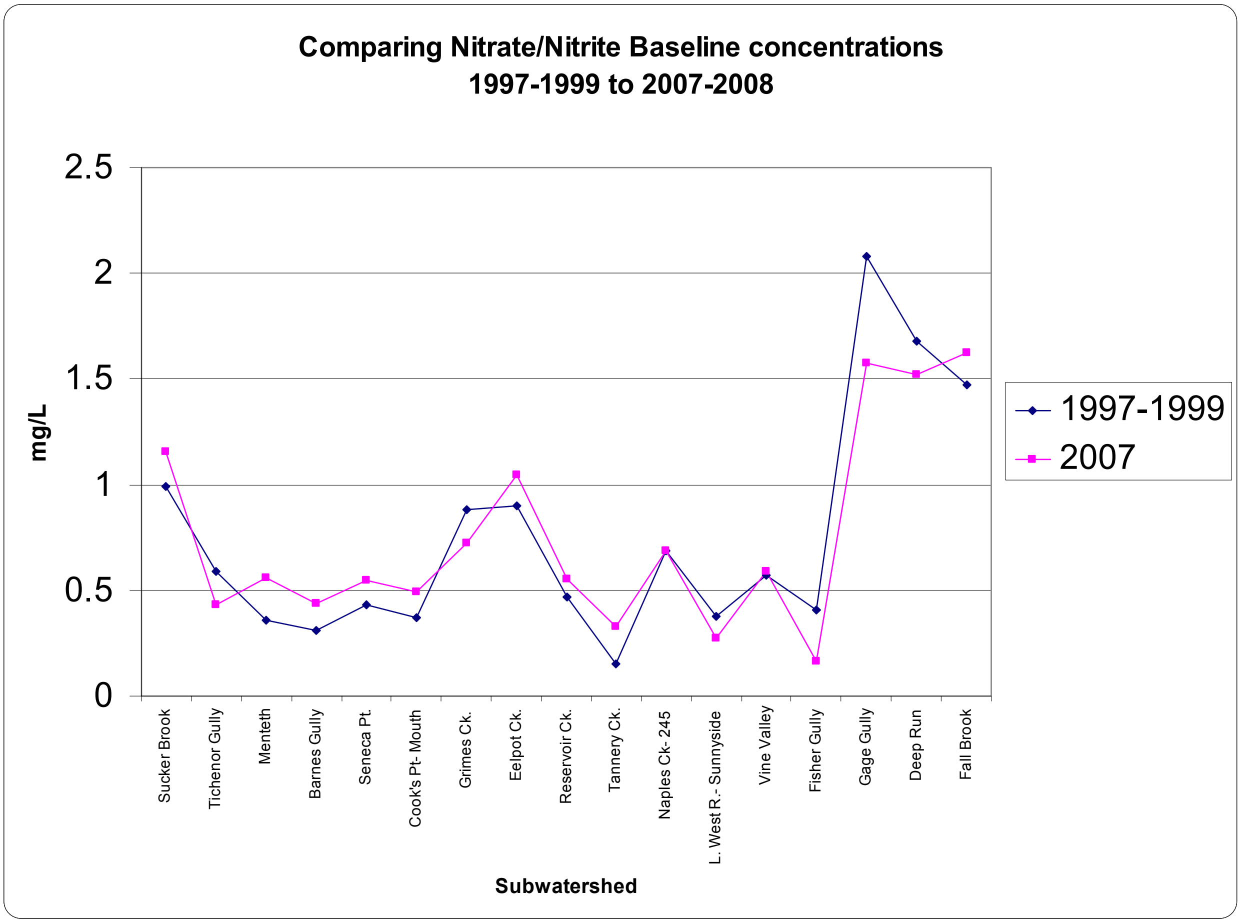


Figure 2-22 Comparing Average Baseline Nitrate/Nitrite from 1997-1999 and 2007/2008.

Fecal Coliform:

Fecal coliform is an indicator bacteria found in the feces of warm blooded animals and is used to determine the presence of harmful bacteria and other potential pathogens in water. Approximately 95 samples have been collected during baseline conditions on a fairly regular basis between the months of April through November since 1989.

Figure 2-23 demonstrates that during this 16 year span Sucker Brook had the highest long term average levels of recorded fecal coliform with 584 colonies per 100 ml. Vine Valley was second highest with 374 colonies per 100 ml**.** Cook's Point was third highest with 159 colonies per 100 ml. There are several instances within the top three streams where the bacteria colonies were "too numerous to count" (TNTC) on the petri dish and were assigned a value of 2,000 colonies in order to have that individual sample count toward the overall average. This number is somewhat arbitrary, but it is a reasonable estimate of the actual total had they been countable.

For finished treated drinking water, current Department of Health regulations prohibit fecal coliform bacteria in numbers exceeding one colony per 100 ml. The threshold for swimming is 200 colonies per 100 ml. Using these thresholds, the data suggests that some of the streams are being impacted by warm blooded animals, to some extent human waste. The main sources of fecal coliform include: failed septic systems, sanitary sewer cross connection with storm sewer, warm blooded animal waste (e.g., livestock, waterfowl, pets and deer).

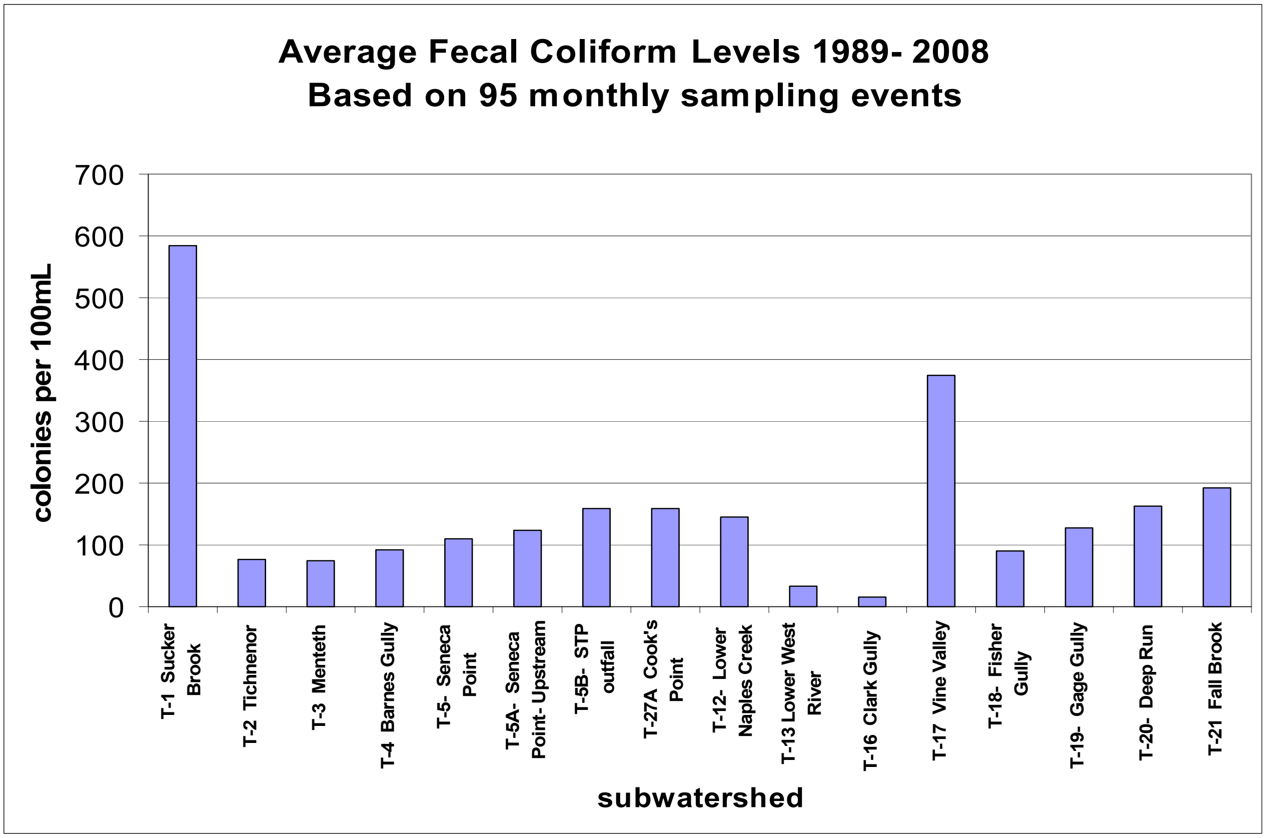


Figure 2-23 Average Fecal Coliform Levels 1989-2008.

Overall ranking of streams and conclusions:

Figure 2-24 and Table 2-1 average the rankings for total phosphorus, nitrate/nitrite, TSS and fecal coliform into one overall stream pollution ranking of the subwatersheds. This stream pollution index equally weighs each of these parameters to form a comprehensive understanding of the level of pollution in each subwatershed. The ranking is counterintuitive in that highest numbers represent the greatest levels of pollution. The overall ranking documents that Sucker Brook (12.4) has the highest pollution index with Deep Run (11.5), Vine Valley (11.4), Eelpot Creek (11.3), Fall Brook (11.0) and Gage Gully (10.9) grouped closely together.

As identified in the Canandaigua Lake Watershed Plan (Olvany, 2000), non-point sources of pollution are the major source of concern in the Canandaigua Lake watershed. Although there are two small wastewater treatment plants (Rushville, Bristol Harbour) discharging from point sources, the vast majority of pollution comes from non-point sources. No single non-point source is a substantial contributor to decreasing the water quality of the lake. However, it is the cumulative effect of all non-point sources that ultimately does impact the quality of Canandaigua Lake. Higher concentrations of a specific pollutant can reveal which streams have the greatest likelihood of being impacted by human activities that need to be mitigated. A management plan utilizes this information to devise a strategy to reduce the source of pollution.

Due to all the variables inherent in grab sampling, sampling at the mouth of the stream does not allow us to determine the sources of upstream pollution and is not equipped to detect reductions resulting from individual best management practices that have been implemented unless the pre-existing source was the main source of elevated levels. However, this sampling design identifies which streams require additional sampling throughout its subwatershed.

Current research is being completed on the Sucker Brook and Eelpot subwatersheds to attempt to identify which stream segments are contributing to the high concentrations of pollutants that are sampled. After identifying the segment, the possible source will be identified and work with the appropriate agencies to develop a plan for implementing best management practices. Results are being tabulated and additional reports will be coming out this fall on these two streams. In addition, the Canandaigua Lake Watershed Council is in the beginning stages of updating the existing Watershed Management Plan and will be utilizing this report as an integral information piece to determine where to focus management efforts.

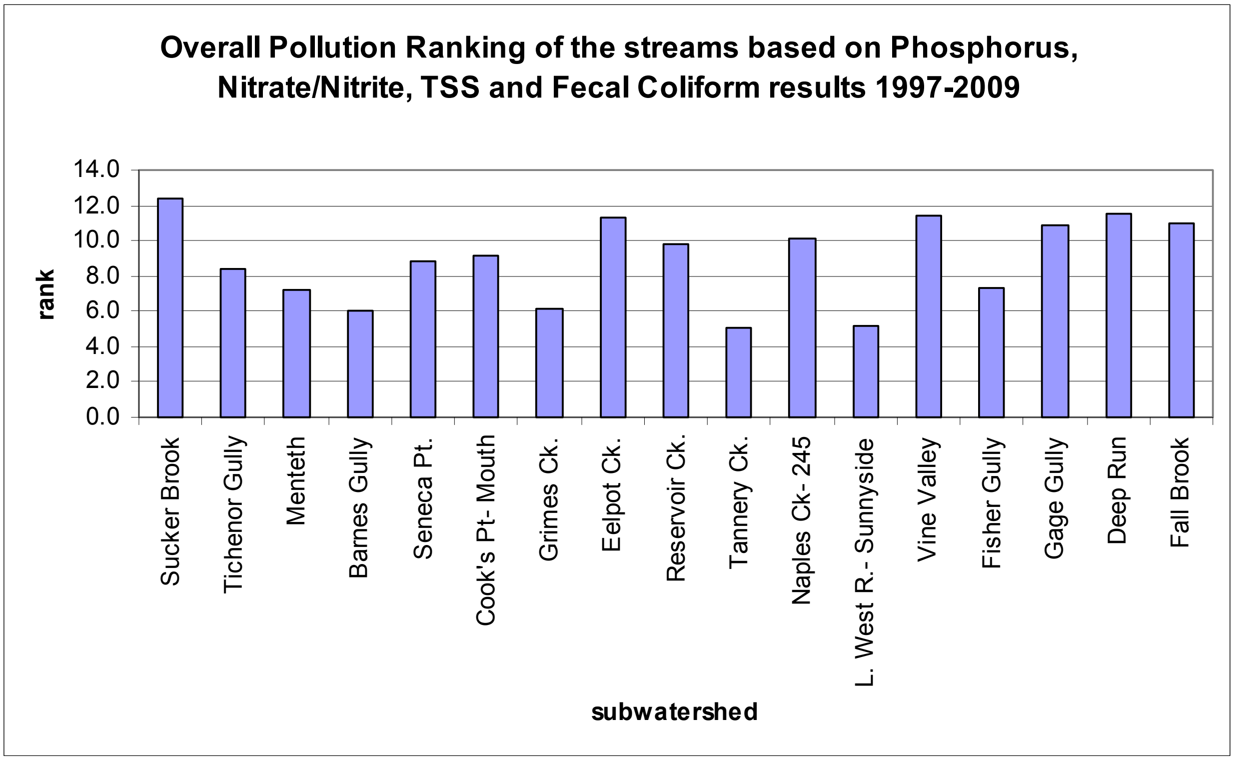


Figure 2-24 Overall Ranking of the streams based on phosphorus, nitriate/nitrite, TSS and Fecal Coliform results.

Table 2-1 Average event ranking for Tot. Phos., Nitrate/Nitrite, TSS along with baseline fecal coliform.

Stream	**Total Phosphorus**	**Nitrate/ Nitrite**	**Total Suspended Solids**	**Fecal Coliform**	**Overall Ranking**
T-1 Sucker Brook	12.4	12.1	7.9	13	**12.4**
T-2 Tichenor Gully	9.2	10.1	7.5	3	**8.5**
T-3 Menteth Gully	7.6	6.4	9.0	2	**7.3**
T-4 Barnes Gully	5.3	3.1	6.7	5	**6.0**
T-5 Seneca Pt. Gully	10.3	5.4	9.7	6	**8.9**
T-27A Cook's Pt	9.0	4.0	10.7	9	**9.2**
T-7 Grimes Creek	4.4	6.4	7.7		**6.2**
T-8 Eelpot Creek	10.0	10.8	13.0		**11.3**
T-9 Reservoir Creek	9.6	9.4	10.3		**9.8**
T-10 Tannery Creek	6.3	2.1	6.7		**5.0**
T-12 Naples Creek	9.9	6.5	12.2	8	**10.2**
T-13 L. West River	6.3	6.5	2.8	1	**5.2**
T-17 Vine Valley	10.6	11.0	7.9	12	**11.4**
T-18 Fisher Gully	7.2	6.8	7.5	4	**7.4**
T-19 Gage Gully	9.6	15.8	7.0	7	**10.9**
T-20 Deep Run	9.3	14.0	8.7	10	**11.5**
T-21 Fall Brook	7.4	13.5	8.0	11	**11.0**

Table 2-2 Average event concentration for Tot. Phos., Nitrate/Nitrite, TSS along with baseline fecal coliform.

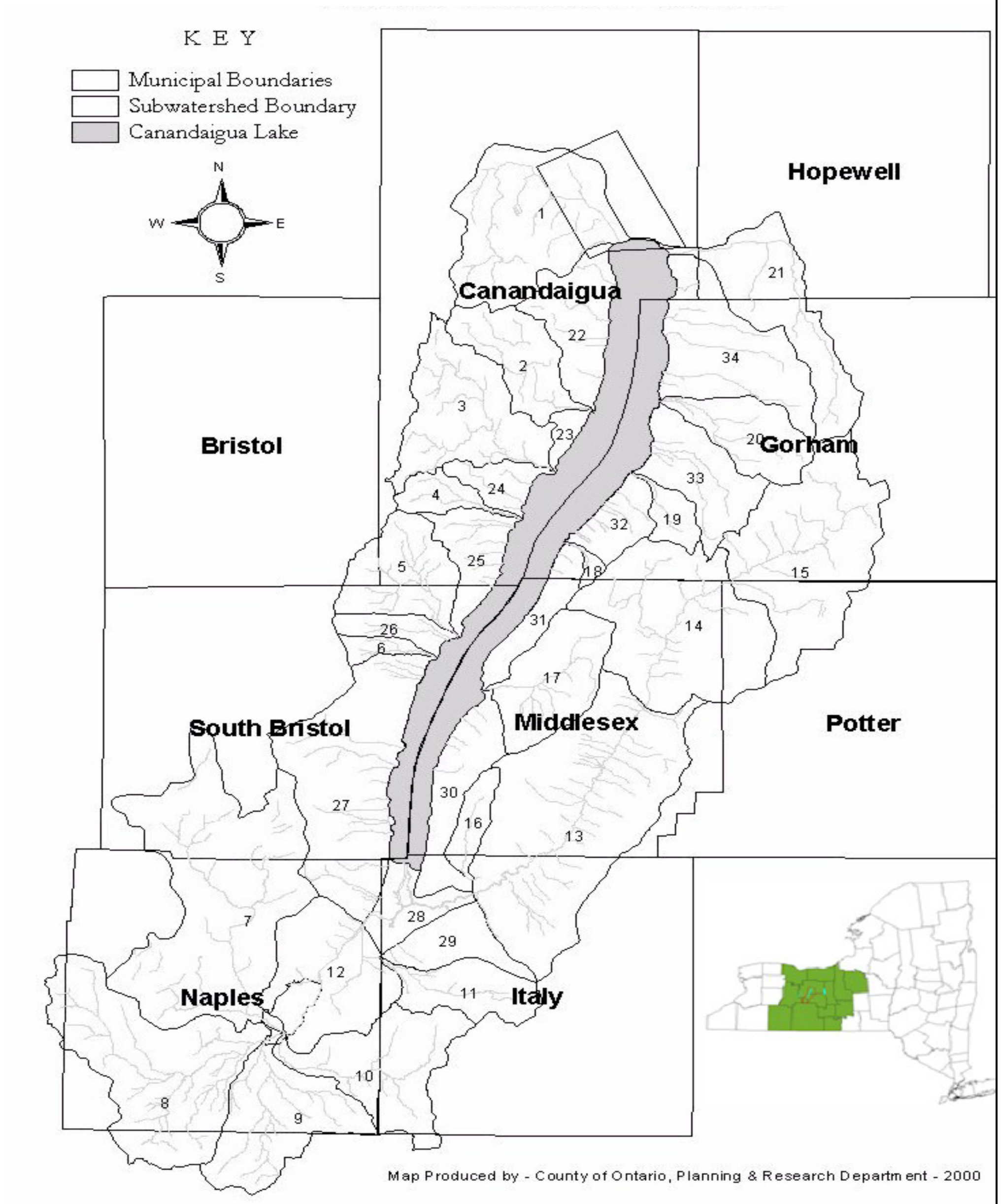
Stream	TP (mg/L)	Nitrate/nitrite (mg/L)	TSS (mg/L)	Fecal coliform (colonies per 100ml)
T-1 Sucker Brook	0.221	1.54	118.3	584
T-2 Tichenor Gully	0.178	0.99	148.2	76
T-3 Menteth Gully	0.155	0.55	217.6	75
T-4 Barnes Gully	0.148	0.36	191.6	92
T-5 Seneca Pt. Gully	0.214	0.53	229.7	110
T-27A Cook’s Pt	0.202	0.41	225.2	159
T-7 Grimes Creek	0.106	0.52	112.4	-
T-8 Eelpot Creek	0.192	0.93	335.5	-
T-9 Reservoir Creek	0.205	0.79	241.5	-
T-10 Tannery Creek	0.137	0.25	145.7	-
T-12 Naples Creek	0.206	0.54	301.7	145
T-13 L. West River	0.082	0.62	45.5	32
T-17 Vine Valley	0.245	1.21	277.8	374
T-18 Fisher Gully	0.163	0.62	368.9	91
T-19 Gage Gully	0.229	3.92	270.8	128
T-20 Deep Run	0.176	2.62	193.8	164
T-21 Fall Brook	0.141	2.18	152.5	191

Table 2-3 Average event loading for Total Phosphorus and TSS.

Sub-watershed #	NAME	ACRES	Total Phosphorus (mg/L)	Total load of Phosphorus during an average sampled storm event	TSS (mg/L)	Total load of TSS during an average sampled storm event
1	Sucker Brook	5,751.60	0.221	187.5	118.3	100,378.8
2	Tichenor Gully	2,375.10	0.178	62.4	148.2	51,927.6
3	Menteth Gully	4,173.10	0.155	95.4	217.6	133,963.4
4	Barnes Gully	849.20	0.148	18.5	191.6	24,003.5
5	Seneca Point Gully	2,772.90	0.214	87.5	229.7	93,964.5
27	Cook's Point	6,665.00	0.202	198.6	225.2	221,430.3
7	Grimes Creek	10,192.60	0.106	159.4	112.4	169,012.9
8	Eelpot Creek	7,029.60	0.192	199.1	335.5	347,929.9
9	Reservoir Creek	3,840.50	0.205	116.1	241.5	136,827.5
10	Tannery Creek	3,864.20	0.137	78.1	145.7	83,059.2
12	Lower Naples Creek	4,102.30	0.206	124.7	301.7	182,587.6
13	Lower West River	24,743.40	0.082	299.3	45.5	166,088.4
17	Vine Valley	3,074.30	0.245	111.1	277.8	125,993.2
18	Fisher Gully	188.10	0.163	4.5	368.9	10,236.8
19	Gage Gully	734.50	0.229	24.8	270.8	29,343.3
20	Deep Run	2,199.60	0.176	57.1	193.8	62,887.7
21	Fall Brook	3,804.00	0.141	79.1	152.5	85,581.3
		86,360.0 Acres		1,903.5 pounds		2,025,216.05 pounds
		79.2% of watershed area				1012.6 Tons

Table 2-4 Precipitation amounts for each storm event along with estimated % ending up as stream flow and runoff in inches.

Date	Precip. (inches) 2 Days Before	Precip. (in) 1 Day Before	Precip. (in) Day Of	Precip. (in) Day After (after 8am on sampling date)	Estimated % of Rain ending up as streamflow	Runoff Inches
3/13/2001	0.00	0.00	0.44	0.07	134%	0.59
9/25/2001	0.00	0.00	2.52	0.21	1%	0.027
12/17/2001	1.04	0.00	0.04	1.11	6%	0.07
2/1/2002	0.37	0.40	1.15	0.01	58%	0.67
3/26/2002	0.01	0.05	0.03	0.82	59%	.50
3/26/2003	trace	0.00	0.50	trace	123%	0.62
6/1/2003	0.00	0.00	1.63	0.00	49%	0.80
7/23/2003	0.02	0.95	0.98	0.45	11%	0.16
10/27/2003	0.00	0.00	0.66	0.22	6%	0.05
11/19/2003	0.19	0.01	0.03	1.09	47% (sampled early in event)	0.53
3/27/2004	0.04	0.00	0.42	0.03	220%	0.99
4/1/2004	0.00	0.11	0.03	0.87	35%	0.5
4/13/2004	0.00	0.00	0.33	1.10	87%	1.08
7/14/2004	0.52	0.45	0.66	0.21	10%	0.14
9/9/2004	0.00	0.22	2.31	0.58	33%	1.07
4/2/2005	0.00	0.00	0.42	1.73	86% - no snow- 2 foot rise in lake	1.85
8/31/2005	0.00	0.23	2.44	0.51	2%-Katrina-dry low antecedent	0.07
10/25/2005	0.93	0.07	0.50	1.26	29%	0.46
9/3/2006	0	trace	1.99	0.02	19%	0.35
10/20/2006	0.44	trace	0.99	0.90	34%	0.66
12/1/2006	0	0	1.32	0.65	45%	0.83
3/14/2007	0	0	0	0.57	165%	1.57
4/18/2007	0.85	0.94	0.11	trace	78%	1.14
10/23/2007	0.03	0	0.20	0.94	0.1%	0.01
12/12/2007	0.11	0	0.73	0	18%	0.20
2/5/2008	trace	0	0.59	0.72	57%	1.02
2/12/2009	0	0	0.58	0.44	107%	1.09
3/11/2009					125%	0.58



Map Produced by - County of Ontario, Planning & Research Department - 2000

Figure 2-25 Map of watershed and subwatersheds.

Subwatersheds

1 Sucker Brook
2 Tichenor Gully
3 Menteth Gully
4 Barnes Gully
5 Seneca Pt. Gully
6 Hicks Pt.
7 Grimes Creek
8 Eelpot Creek
9 Reservoir Creek
10 Tannery Creek
11 Parrish Gully
12 North Naples
13 Lower W. Rr
14 Middle W. Rr
15 Upper W. Rr
16 Clark Gully
17 Vine Valley
18 Fisher Gully
19 Gage Gully
20 Deep Run
21 Fall Brook

Direct Drainage

22 Butler Road
23 Foster Road
24 Deuel Road
25 Coy Road
26 Stid Hill
27 South Bristol
28 W Rr Naples Cr Jc
29 Hi-Tor
30 South Hill
31 Bare Hill
32 Jones Road
33 Cottage City
34 Lincoln Hill

TABLE 2-5. Average baseline concentrations of phosphorus, total nitrate/nitrite, and TSS in 2007.

Subwatershed	**Location**	**Average Phosphorus (mg/L)**	**Average Total Nitrate/Nitrite (mg/L)**	**Average TSS (mg/L)**
T-1	Sucker Brook	0.1156	1.1548	3.4580
T-2	Tichenor Gully	0.0193	0.4695	3.9167
T-3	Menteth	0.0082	0.5572	2.1667
T-4	Barnes Gully	0.0169	0.4756	7.8818
T-5	Seneca Point	0.0833	0.5479	3.2083
T-27A	Cooks Point	0.0101	0.4933	2.0000
T-7	Grimes Creek	0.0078	0.7225	2.0000
T-8	Eelpot Creek	0.0105	1.0475	2.2083
T-9	Reservoir Creek	0.0183	0.5542	3.5000
T-10	Tannery Creek	0.0128	0.3299	2.4167
T-12	Naples Creek	0.0085	0.6900	2.0000
T-13	West River	0.0700	0.2720	8.1364
T-17	Vine Valley	0.0236	0.5888	2.0000
T-18	Fisher Gully	0.0222	0.1616	4.8333
T-19	Gage Gully	0.0249	1.5783	2.0000
T-20	Deep Run	0.0126	1.5213	2.0000
T-21	Fall Brook	0.0136	1.6243	2.0000

Additional research by FLCC

Annual Road Salt monitoring program:
Mid-winter visits were made to tributary streams and mid-stream grab samples were analyzed for road salt contamination (chloride [Cl^-] concentration) at the Finger Lakes Community College chemistry lab using the argentometric titration procedure (Standard Methods, 17th edition). This monitoring has been conducted since 1990.

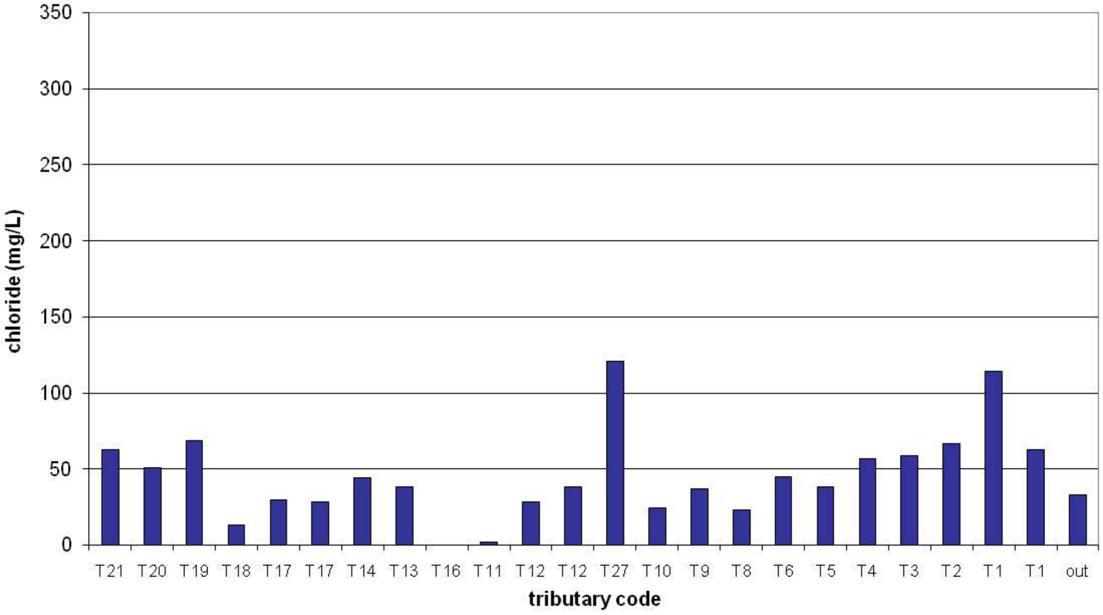
Road salt contamination of tributary streams varies with location and winter severity (Table 2.6 and Figure 2.6). Chloride levels remain high in Lower Sucker Brook, Upper Sucker Brook, Gage Gully and the Cook's Point Stream. Low results at Clark's Gully and Conklin Gully document background levels typical of forested watersheds lacking major highway corridors.

TABLE 2.6: Chloride concentration (mg/L) in Canandaigua Lake tributaries, 2006 - 2009.

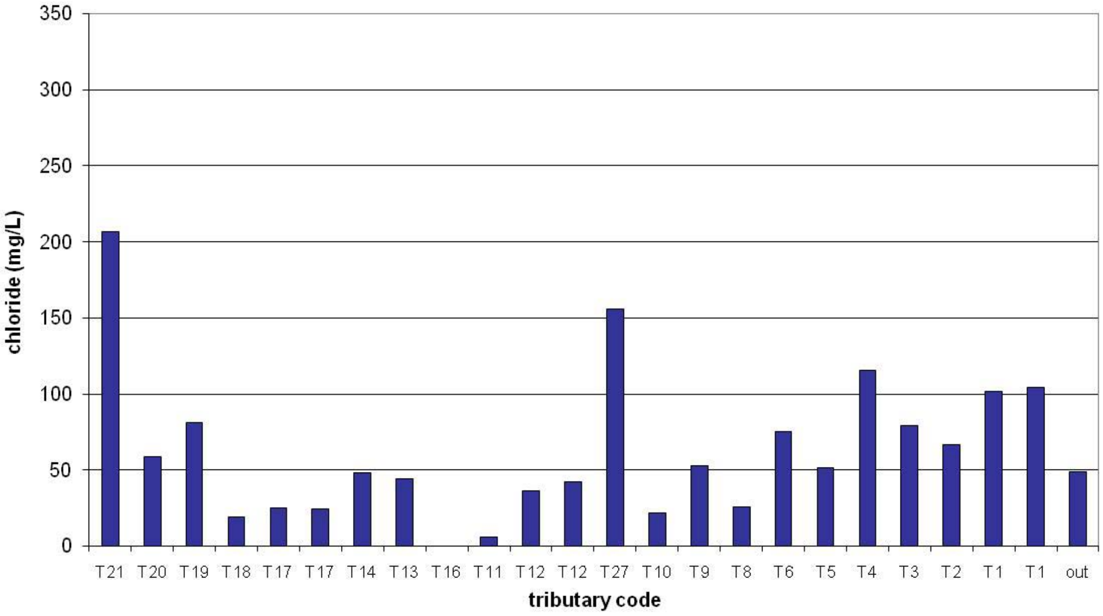
Tributary	**Code**	**2-23 2006**	**2- 2007**	**2-28 2008**	**2-27 2009**	**long-term average**	**long-term minimum**	**long-term maximum**
Fallbrook	T21	63.0	207.0	108.5	69.0	72.4	24.0	207.0
Deep Run	T20	51.0	58.5	96.5	67.5	67.6	22.2	178.5
Gage Gully	T19	68.5	81.5	169.0	97.5	98.7	17.2	342.5
Fisher Gully	T18	13.0	19.0	32.5	17.0	18.3	0.0	102.5
Upper Vine Valley	T17	29.5	25.0	50.5	54.0	33.4	14.3	86.0
Lower Vine Valley	T17	28.5	24.5	54.0	63.5	29.3	12.0	63.5
Upper West River	T14	44.5	48.0	82.0	72.5	53.7	26.0	105.5
Lower West River	T13	38.5	44.0	55.0	59.5	38.5	17.0	77.5
Clark's Gully	T16	0.0	0.0	0.5	2.5	0.9	0.0	4.1
Conklin Gully	T11	2.0	6.0	6.0	7.0	3.8	1.0	7.5
Upper Naples Creek	T12	28.5	36.5	43.0	37.0	26.2	11.0	49.5
Lower Naples Creek	T12	38.5	42.0	48.5	35.0	27.2	12.0	51.5
Cook's Point Stream	T27	121.0	156.0	184.5	188.4	154.4	75.0	322.0
Tannery Creek *	T10	24.5	21.5	38.5	30.0	31.1	14.0	49.0
Reservoir Creek *	T9	37.0	53.0	56.0	40.5	50.1	29.0	82.0
Eelpot Creek *	T8	23.0	26.0	29.0	27.5	25.8	21.0	30.5
Hick's Gully	T6	45.0	75.0	105.0	52.5	58.4	15.0	148.0
Seneca Point Stream	T5	38.5	51.5	87.5	45.0	47.2	20.9	93.5
Barnes Gully	T4	57.0	115.5	176.5	119.5	85.4	29.0	202.5
Menteth Gully	T3	58.5	79.0	115.5	86.5	64.8	27.0	115.5
Tichenor Gully	T2	67.0	67.0	134.5	88.0	62.4	27.0	134.5
Upper Sucker Brook	T1	114.0	102.0	252.5	140.5	146.1	54.4	489.0
Lower Sucker Brook	T1	63.0	104.5	183.0	211.9	174.9	34.5	607.0
Outlet	out	33.0	49.0	36.0	35.5	36.9	18.5	110.5

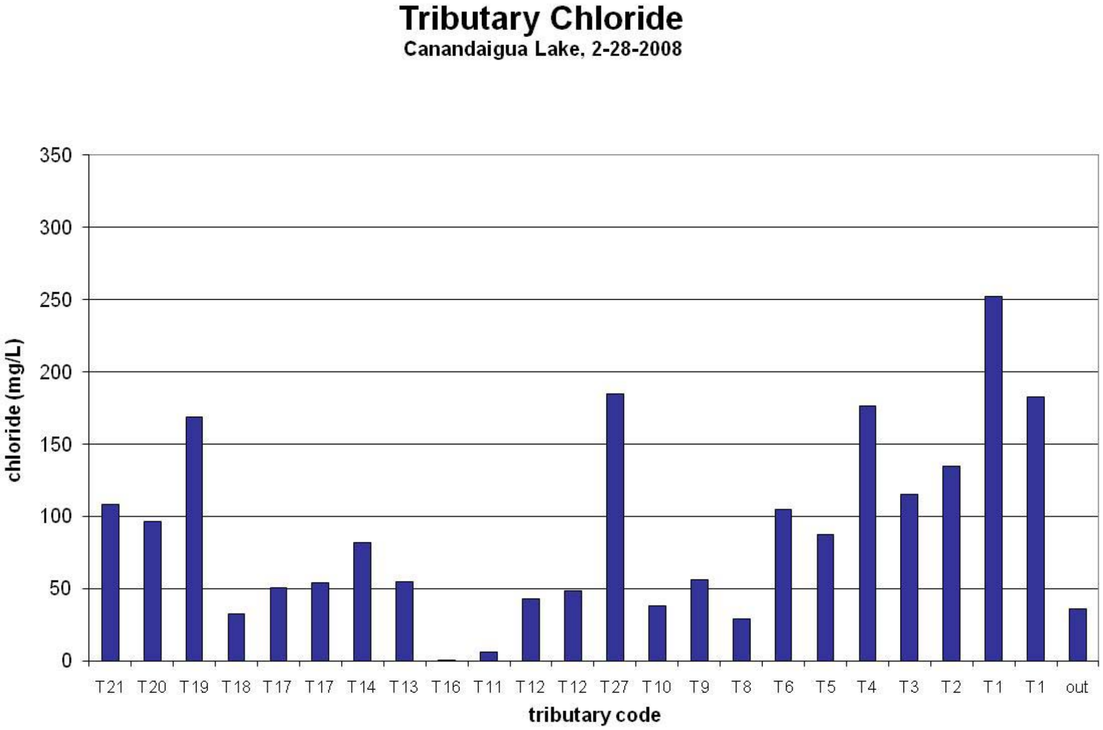
* new sites added to the road salt sampling program in February 2002

Tributary Chloride
Canandaigua Lake, 2-23-2006



Tributary Chloride
Canandaigua Lake, 2-2007





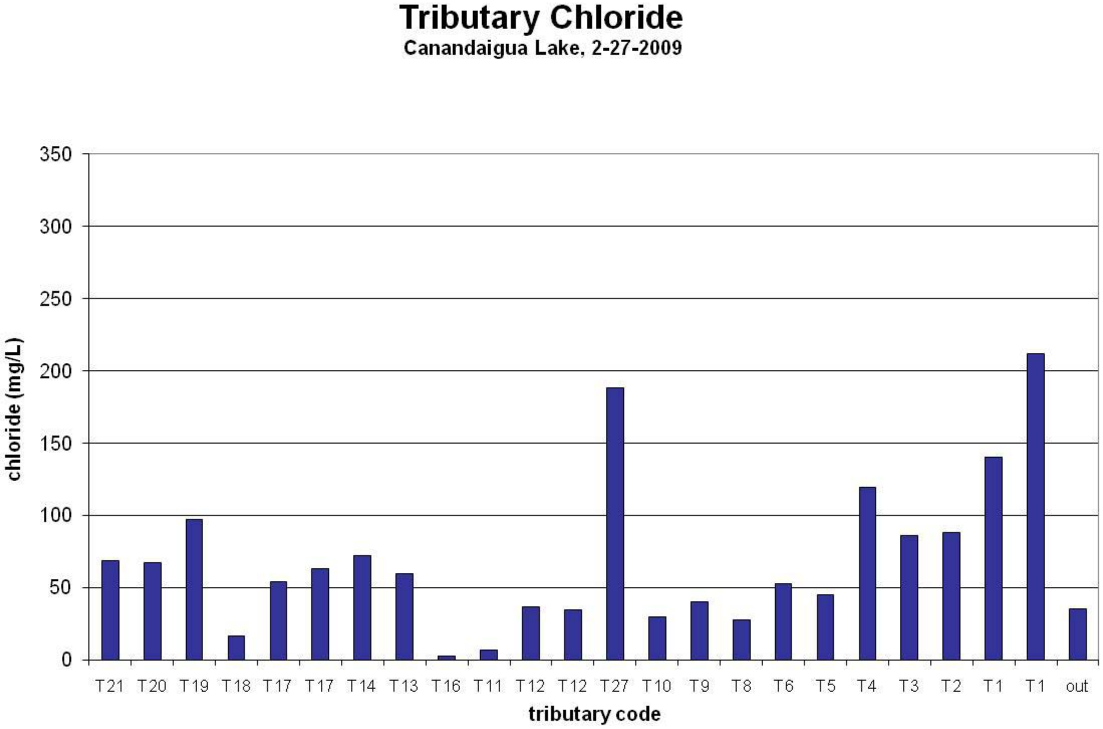


FIGURE 2-26: Road salt contamination in Canandaigua Lake tributaries.

Twenty years of chloride record now exist for these tributary streams to Canandaigua Lake.

Figure 2.7 presents a graphical summary where each year is represented by the mean chloride concentration in tributary streams. The years 2000, 2003, 2005 and 2008 stand out as harsh seasons where more road salt was being applied during mid-winter months. The annual pattern is similar although of a slightly higher magnitude when compared to the years of record for Honeoye Lake tributary streams (Gilman, personal communication). While the cumulative road salt application amounts used by local highway departments may vary little from year to year, the event-based application rates produce the significant differences captured in these data.

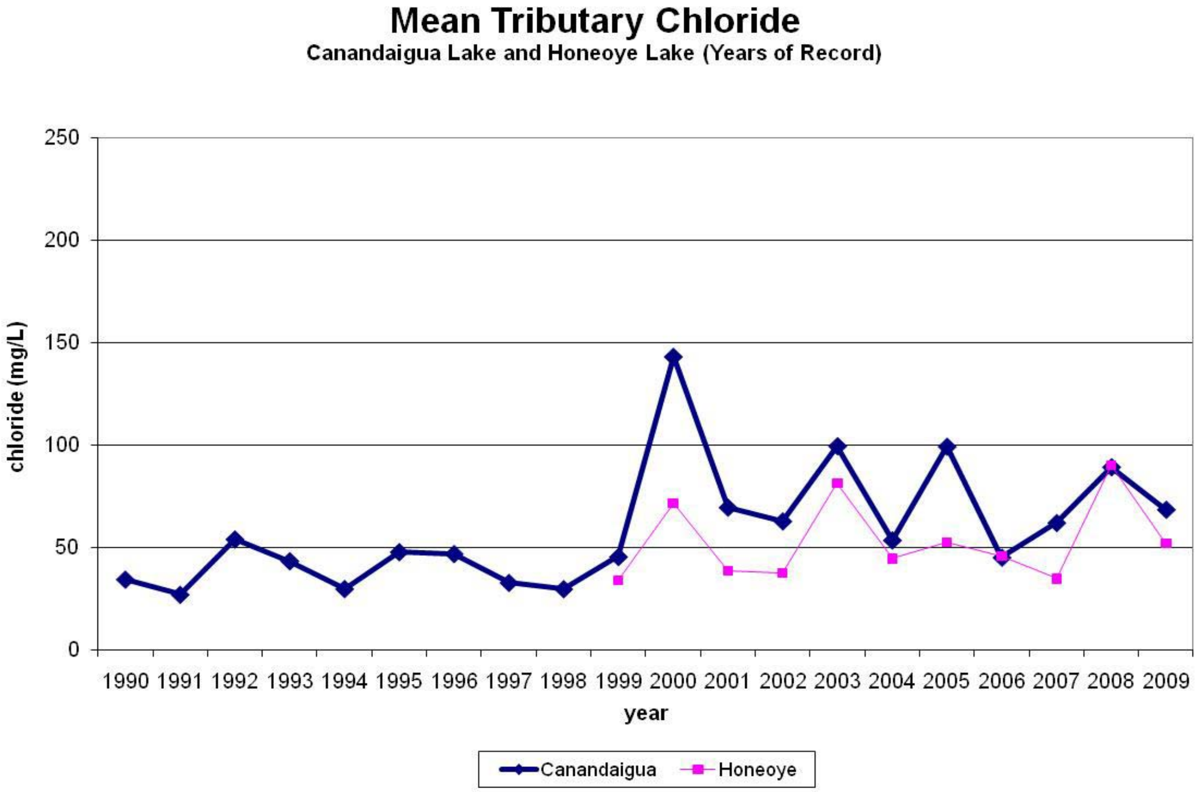


FIGURE 2.27: Long-term watershed chloride trends based on mid-winter sampling, 1990-2006.

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