

June 2002

Kevin Olvany, Watershed Program Manager
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Dear Kevin,

It is my pleasure to submit the 2001-2002 Canandaigua Lake Watershed Quality Report. This report includes scientific data regarding the condition of Canandaigua Lake and the water quality of major tributaries. The monthly lake sampling took place near the end of each month this year; there were no alterations due to inclement weather conditions. Students from the college participated in the lake sampling program, thereby maintaining the educational aspect of our important baseline monitoring. Tributaries were sampled during summer, fall and spring; the summer drought reduced the number of sampling opportunities. Stressed stream analysis was conducted along Fallbrook Stream and the Vine Valley Stream in order to identify sources of pollution within specific stream segments. The report includes a summary of lab analyses provided by Life Science Laboratories, Inc., as well as information generated at Finger Lakes Community College. The latter include *in situ* monitoring, and laboratory determinations of chlorophyll *a* concentrations and chloride levels. The report provides details on sampling frequency, field collection techniques, laboratory methods, water quality results and relevant discussions. Long-term trends in lake water quality are provided by including comparable data collected since 1996. The ongoing effects of zebra mussels on lake clarity and algal abundances are reviewed, and the unusual occurrence of foam on the lake surface is addressed.

My expanded role working with you and the Watershed Council has been enlightening. I am appreciative of the opportunity to attend, and participate in, a variety of committees, and to work with you in the streams where old issues need resolution and new concerns need careful attention.

Looking forward to continuing cooperative endeavors with the Watershed Council, especially the upgrading of the land cover classification for the watershed.

Sincerely,

Dr. Bruce Gilman

2001-2002

WATER QUALITY RESEARCH

FOR CANANDAIGUA LAKE

AND ITS WATERSHED

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SUMMARY

1. A comprehensive sampling and monitoring program is critical to expanding our knowledge about yearly changes in lake condition, to improve our understanding of the ecological impact of invasive organisms, to determine and quantify sources of pollution so that corrective actions can be taken, and to assure that recent, accurate data are available for environmental decision makers as they contemplate future land use policies and provide direction for future scientific research. Such a program should be ongoing, with its goals, sampling frequencies and test parameters subject to review, modification and updating. Local municipalities and interested lake organizations whose quality of life is intimately linked to the quality of the lake should provide funding. Finger Lakes Community College remains interested in providing expertise and support for future water quality research programs.
2. Based on year 2001 HYDROLAB monitoring, the physical limnology of Canandaigua Lake was normal. Monthly temperature profiles documented the typical progression towards summer stratification followed by an early winter turnover event. Dissolved oxygen values were near saturation throughout the water column for the months of April through November. A slight decline in dissolved oxygen was noted just above the thermocline during late summer. Lake conductivity averaged 406 $\mu\text{S}/\text{cm}$, a slight decrease from year 2000 values.
3. Lake water clarity, measured as secchi disk depth, averaged 6.7 m and reached a maximum of 8.9 m. Clarity continued a declining trend that began in 1999 (a 23% decrease from last year). Algal abundance, estimated by the concentration of chlorophyll *a*, averaged 2.39 $\mu\text{g}/\text{L}$ (a 38% increase from last year). Shoreline sampling stations had consistently less chlorophyll *a* when compared to mid-lake stations. Algal abundance has been increasing since 1999 and this year the phytoplankton community was often dominated by the cyanobacterium, *Microcystis aeruginosa*. Research in Lake Erie suggests that zebra mussels selectively filter against *Microcystis* (i.e., it is unpalatable to the mussels).
4. Nutrient levels in Canandaigua Lake water were low compared to an ecological standard range of virtually absent to 10.00 $\mu\text{g}/\text{L}$ for oligotrophic lakes. Total phosphorus (TP) averaged 9.07 $\mu\text{g}/\text{L}$ based on all stations over the eight months. This result was slightly higher when compared to last year (8.85 $\mu\text{g}/\text{L}$). However, there were only 13 instances when TP exceeded 10.00 $\mu\text{g}/\text{L}$, a 50% reduction from last year. TP profiles from mid-lake at Seneca Point had an overall mean of 2.90 $\mu\text{g}/\text{L}$ while results from mid-lake at Deep Run had an overall mean of 7.88 $\mu\text{g}/\text{L}$. The substantially higher mean at Deep Run results from extremely large TP values at the 50 meter depth during the summer months. Higher levels of TP are often related to increased loading from tributaries but in this case may be better explained by benthic processes like microbial decomposition of organic materials. Nitrogen supply, analyzed as the combination of nitrate (NO_3) and nitrite (NO_2), was approximately 0.26 mg N/L throughout the sampling period. The concentrations of nitrate and nitrite have been stable over the last three decades. Trophic State Index, a combined statistical measure of lake condition, remained in the oligotrophic category.

5. Near-shore lake water samples were collected for total coliform bacteria counts on May 30, June 26, July 24 and August 23. Results ranged from less than one colony to 60 colonies per 100 ml of water sample. These fall well below the standard of not to exceed 2400 colonies established for contact recreation in open waters. Tributary streams were examined for fecal coliform on April 25, May 24, June 7, July 23 and November 6. Results varied from less than one colony to 568 colonies per 100 ml of water sample. The fecal coliform standard for contact recreation is not to exceed 200 colonies per 100 ml of water sample.
6. Zebra mussel populations appear to have declined although no direct counts are available for comparison. The decrease in lake clarity and increase in chlorophyll *a*, combined with observations of fewer mussels attached to natural bottom substrates and an increased number of mussel shells at the shoreline, suggest that mussel populations may have exceeded the lake's carrying capacity and subsequently crashed. Reductions in palatable phytoplankton may limit mussel densities and trigger population collapses. To scientifically document future population shifts, sampling mussel density and completing an age analysis based on shell size classes should be regularly undertaken. Such a program would also increase the likelihood of detecting the invasion of quagga mussels, a taxonomic relative of zebra mussels and, perhaps, more damaging to the lake foodweb relationships. Quaggas first invaded the Finger Lakes at Seneca Lake in the year 2000 but have yet to be detected in Canandaigua Lake. Collected samples of mussels should also be considered for toxin analyses.
7. Beginning in early August, huge linear streaks of foam became a common sight on the lake surface. They are formed by Langmuir circulation, a process well known on large water bodies. What were peculiar about these streaks were their magnitude, persistence and composition. Some measured miles long, lasted for days and chemical analysis revealed a high fatty acid content. The source of these organic molecules (surfactants) is thought to be natural, possibly related in some way to the dieback in zebra mussels. Three hypotheses warrant further study: first, that the surfactant molecules are released from decaying zebra mussel flesh, second, that the surfactant molecules are from the decomposers that are breaking down zebra mussel flesh, and third, that the surfactant molecules are being released from the cyanobacterium, *Microcystis aeruginosa*. It is also possible that the surfactant molecules causing the foam are not the result of any of the three hypotheses and, instead, are produced from an unknown process. Research continues this summer.
8. Due to a prolonged summer drought, tributaries to Canandaigua Lake were sampled into spring 2002. Storm event sampling occurred on March 13, September 25, December 17, 2001 and February 1 and March 26, 2002. Mean total phosphorus concentration ranged from 43.0 Φ g/L (Lower West River) to 263.0 Φ g/L (Sucker Brook). Mean nitrate and nitrate levels ranged from 0.21 mg N/L (Lower West River) to 4.66 mg N/L (Gage Gully). Total suspended solids varied from 25.5 mg/L (Lower West River) to 712.5 mg/L (Fisher Gully). Large differences in these datasets result from complex interactions among storm intensities, nonsynchronous sampling and individually distinct subbasin characteristics. Improved flow measurements and updated land cover information would be helpful in evaluating tributary response to storm events.

9. Comparison of these storm-based stream concentrations to similar data collected over the time period 1997 to 2000 is complicated. It is difficult to generalize on long term changes in individual stream quality for several reasons. During one storm event, the stream may be sampled on the rising limb of the hydrograph (i.e., first flush of material off the subbasin drainage area) but for a subsequent event, the stream might be sampled on the falling limb of the hydrograph simply due to the time constraints of traveling around the lake. Comparative results could be misleading. In addition, stream cross-sectional area changes from erosional/depositional processes associated with each storm event. Subsurface flow through gravel beds at stream mouths has not been quantified. Discharge estimates, therefore, have a wide confidence interval. Earlier studies of nutrient loading are problematic when some estimated annual stream discharges exceeded 100% of the estimated precipitation delivered to that subbasin. Based on the scientific literature, stream discharges generally account for about a third of the annual precipitation.
10. February 2002 road salt contamination of tributary streams fit the long term pattern, with levels high enough for concern detected in Gage Gully (109 mg/L), the stream at Cook's Point (173 mg/L), and the Upper and Lower sampling sites in Sucker Brook (129 mg/L, 160 mg/L respectively). A segment analysis of the Cook's Point Stream revealed high chloride levels both above and below the Town of South Bristol Highway Garage.
11. Stressed stream analyses were conducted along Fallbrook Stream and the Vine Valley Stream. Fallbrook Stream was sampled at several locations during six storm events spanning August through March 2002. Along Fallbrook Stream, a mid-reach segment appears to be contributing the majority of the pollutants. Total phosphorus exceeded 500 $\mu\text{g/L}$, the combination of nitrate and nitrite surpassed 6 mg N/L, total kjeldahl nitrogen peaked at 5600 $\mu\text{g/L}$ and total suspended solids reached a maximum value of 1600 mg/L. A cooperative remediation program is underway which will assist the landowner as best management practices are implemented. The Vine Valley Stream was sampled at several locations during six storm events spanning March 2001 through May 2002. Along the Vine Valley Stream, an upstream segment appears to be contributing the majority of the pollutants. Total phosphorus exceeded 500 $\mu\text{g/L}$, the combination of nitrate and nitrite surpassed 6 mg N/L, total kjeldahl nitrogen peaked at 4200 $\mu\text{g/L}$ and total suspended solids reached a maximum value of 680 mg/L. Additional contacts with local owners are recommended so that best management practices can be implemented/enhanced in order to improve the condition of the Vine Valley Stream.
12. A survey of macro-invertebrate populations and a sampling of water quality in Naples Creek and the lake outlet at Chapin, New York, produced expected results for these lotic systems. Naples Creek was in excellent condition and dominated by Type I and II organisms. The lake outlet was in fair to good condition and supported Type I, II and III organisms.

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The Canandaigua Lake Watershed Council played a significant role this year through the participation of Kevin Olvany, Watershed Program Manager. Kevin's assistance with lake sampling and his tributary fieldwork was much appreciated. He provided timely transmission of samples to the Life Science Laboratory. His review of this report was valuable and our numerous discussions of lake foam, watershed land cover and stream loadings have been enlightening.

Fieldwork was completed with the assistance of conservation practicum students Daniella Barath, Pat McDonald and Seth Jensen.

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INTRODUCTION

The Canandaigua Lake sampling and monitoring program has been in place for several years and data collected have been the subject of numerous reports (Gilman 1993, Gilman 1994, Gilman 1995, Gilman 1996, Gilman 1997, Gilman 1998, Gilman 1999, Gilman 2001). The lake program has been designed to take a pro-active stance in regards to maintaining lake health. While the great majority of results over the years have indicated that the lake remains clean and relatively pollution-free, some findings have documented legitimate concerns about the impacts of watershed activities on the lake. For that reason, monitoring of tributary streams become a focus of recent research (Makarewicz and Lewis 1998, Makarewicz and Lewis 1999a, Makarewicz and Lewis 1999b, Makarewicz *et al.* 1999, Makarewicz and Lewis 2000, Makarewicz and Lewis 2001a, Makarewicz and Lewis 2001b, Makarewicz and Lewis 2001c). Preliminary work has also been conducted on direct drainage areas where intermittent rivulets periodically flow to the lake (Makarewicz and Lewis 2002). Results have shown that certain land use activities can increase loading of nutrients, sediments and pollutants from tributary streams to the lake. Segment analyses of tributaries contributing significant amounts of pollution to Canandaigua Lake have helped to pinpoint the upland sources of contamination and increase the success of remediation programs. Current work to better understand watershed land cover will help predict where additional problems may occur and where preventative actions would be desirable.

Other impairments of lake water quality may result from cultural activities associated with in-lake recreational pursuits. Concerns expressed by Canandaigua Lake Pure Waters, Inc., about petrochemical contaminants released by two stroke engines are valid and need to be addressed. Still other changes in water quality are the product of seasonal cycles, natural processes or foodweb disruption associated with the impacts of exotic species like the zebra mussel.

A comprehensive sampling and monitoring program can help clarify the relative importance of factors that contribute to, or damage, lake health. Selection of monitoring parameters should remain flexible because the influences of land use activities, introduced organisms and natural processes can change. Monthly lake monitoring coupled with year to year comparisons provides the benefit of detecting gradual deterioration in lake health that might otherwise go unnoticed. Similarly, baseline and storm sampling of tributary streams will reveal

the range of responses within a subbasin over time, and between subbasins experiencing the same meteorologic event. Segment analyses of suspect streams will detect locations of environmental concern. Public education efforts, especially at boat launching ramps, that recognize Canandaigua Lake as a valuable natural resource and suggest proper lake uses are important in protecting lake health.

The following water quality tests, sampling frequencies and synthetic indices were selected to assess the health of Canandaigua Lake and the water quality of tributary streams. A brief explanation for each parameter is provided.

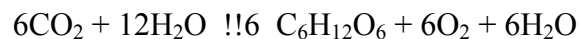
1. **lake temperature** - heat condition of a water body. Expressed in Centigrade degrees (EC). It is important to water circulation patterns in the lake (e.g., seiches and timing of fall turnover), stability of lake stratification, prediction of winter ice cover, metabolic rate of poikilothermic organisms, buoyancy afforded to the planktonic community and habitat diversity. Profile sampling for temperature should be conducted on a monthly schedule.

2. **lake dissolved oxygen** - oxygen present as a gas (O_2) dissolved in the lake water. Essential for the respiration of most desirable aquatic organisms, particularly fish and invertebrates. Cold water has the potential to hold greater amounts. Relative content of dissolved oxygen (DO) is measured as percent saturation. It is desirable to at or near 100 % saturation. Absolute content of DO is measured as parts per million (ppm) or its equivalent, milligrams per liter (mg/L). It has low solubility in water, with maximum amounts seldom exceeding 14.6 mg/L. DO is positively correlated with atmospheric pressure. DO concentration is influenced by replenishment rates (contribution from aerated tributary streams, surface exchange with the atmosphere, amount of aquatic photosynthesis) and consumption factors (respiratory demands of lake biota, amount of oxygen demanding wastes). If DO levels drop to zero, the lake water is anoxic, nutrients are released from bottom sediments and undesirable anaerobic biota will predominate.

3. **lake conductivity** - the ability of water to support an electrical current. Strongly influenced by ionic concentrations (Ca^{++} , Mg^{++} , Na^+ and K^+) and water temperature. Expressed as micromhos/cm or its equivalent, microsiemens ($\Phi S/cm$). Addition of suspended soil particles from storm runoff and watershed erosion activities will temporarily increase conductivity.

Seiches that resuspend bottom sediments may locally increase conductivity readings.

4. **lake chlorophyll *a*** - an estimate of algal abundance and, therefore, an indication of plant growth conditions in a lake. Primary production refers to organic matter synthesized by plants according to the general formula given below:



Energy for this photosynthetic reaction is provided when solar radiation penetrates water in the photic zone. Plant pigments, especially chlorophyll *a*, are receptors for this incoming light. Because of rapid seasonal changes in the phytoplankton community, algal abundance should be estimated monthly. Measured as $\Phi\text{g/L}$ or its equivalent mg/m^3 .

5. **lake clarity** - the depth of light penetration in the surface waters of a lake. Determined with a secchi disk and expressed in meters. When compared with underwater photometer measurements, the secchi disk reading approximates the depth where 95% of the surface light is gone. This is the compensation level for most aquatic vegetation. For the Finger Lakes, it is estimated that the entire surface light is gone at two to three times the secchi disk reading. Lake clarity is influenced by suspended sediment and planktonic organisms. Sampling should occur at least monthly, and at several stations on the lake, in order to document the full range of underwater light conditions that characterize the lake's photic zone.

6. **lake and stream nutrients** - measurements of substances that promote biological growth in water. While several elements are considered essential, the critical nutrients in freshwater lakes and streams are phosphorus and nitrogen compounds. Phosphorus is often considered the limiting factor for biological productivity in freshwater ecosystems. Phosphorus is a macronutrient needed for the production of energy compounds in all organisms. It is present as inorganic and organic compounds, including particulate and dissolved forms. Total phosphorus (TP) refers to both dissolved and particulate forms. Expressed as parts per billion (ppb) or its equivalent, micrograms per liter ($\Phi\text{g/L}$). In lakes, ten percent is the maximum likely to be found in the dissolved form (referred to as soluble reactive phosphorus [SRP]) at any time. 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 vegetation, all of the SRP is rapidly absorbed. Then the lake ecosystem slows down until

phosphorus again becomes available through biological decay, bottom release or watershed contributions. The turnover time for phosphorus in small lakes has been estimated to be a matter of days or weeks; for larger lakes a matter of months. Measurement of phosphorus should occur seasonally, with winter data, when biological activity is low, giving the best estimate of lake nutrient budget.

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. Total Kjeldahl Nitrogen (TKN) is a good measure of organic sources of nitrogen such as animal manures. It is expressed as micrograms of nitrogen per liter ($\mu\text{g N/L}$). It is convenient to measure stream nitrogen levels with a TKN test, especially those streams draining agricultural sub-basins. 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). Lake nitrogen, in its oxidized forms, should be sampled seasonally.

7. **lake trophic status** - a synthetic index that describes the overall lake condition by combining water clarity (secchi disk readings), winter total phosphorus levels and summer lake chlorophyll *a* according to modeling equations. Trophic status is related to lake morphometry, lake age and watershed activities. The modeling equations derived years ago need adjustment to take into account the significant impact of introduced organisms like the zebra mussel.

8. **lake and stream chloride** - measurement of 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). A critical threshold of 250 mg/L is thought to be damaging to sensitive stream and lake biota.

9. **coliform bacteria** – a group of bacteria that may be found in soils or animal wastes. Determined with a total coliform test. A fecal coliform test is conducted to verify that water has been recently contaminated with fecal materials that originated in warm-blooded intestines (e.g., animal or human wastes). Coliform bacteria in surface waters are used as an indicator that other disease-causing agents may also be present. Expressed as number of colonies that grew after

membrane filtration of 100 milliliters of sample water and 24 hours of incubation.

METHODS

Canandaigua Lake and Lake Shoreline

Lake studies began on April 25 and concluded on November 23, 2001. Two mid-lake stations (Deep Run and Seneca Point) were visited monthly by boat. At each station, secchi disk depths were recorded, a HYDROLAB water chemistry profile was taken, and water samples were collected for chlorophyll *a* analyses. A second set of mid-lake water samples was collected for determination of monthly nutrient profiles. 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. Samples were taken for chlorophyll *a* analyses and determination of nutrient levels. This experimental design was consistent with previous lake monitoring programs conducted by the Finger Lakes Community College and, in the case of chlorophyll *a* measurements, permitted correlation analysis between discrete and integrated water column samples.

Sampling water clarity occurred 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, mid-lake samples were collected at depths of 2 and 5 meters, and an integrated water column was collected with TYGON tubing that extended through the photic zone. At these stations, a single water column of about 15 meters was collected. This approximates the maximum depth of the epilimnion. At shoreline sites, samples were taken at a depth of 2 meters. Samples were stored in 2 liter dark bottles to discourage changes in algal abundance, and placed on ice in a cooler. 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. Sample water was transferred to bottles containing acid preservative, then stored on ice. Samples were tested for nutrient content following EPA analytical methods at the NYS certified (DOH ELAP # 10248) Life Science Laboratories, Inc., in Syracuse.

Profile analyses of the water column were taken with a HYDROLAB H-20 Surveyor (water quality sonde and data logger). Instrument calibration was checked prior to each sampling. Canandaigua Lake was sampled at one meter intervals from the surface to a depth of fifteen meters, then at five meter intervals to a maximum depth of 50 meters. Boat drift on the surface often prevented reaching maximum depths.

Periodic shoreline samples were gathered for total coliform determinations. Grab samples were collected for immediate coliform culturing at the NYS certified (DOH ELAP # 10910) City of Canandaigua Water Treatment Plant. Samples of 100 milliliters were passed through a membrane filter and results were expressed as the number of colonies on the incubation plate.

On two occasions, special trips on Canandaigua Lake were conducted. In early September, HYDROLAB profiles and nutrient samples were taken at the two mid-lake stations during a time period when the foam was first becoming a public concern. On February 22, 2002, in collaboration with the NYS DEC, similar mid-lake sampling took place off Black Point.

Canandaigua Tributaries and Lake Outlet

Tributary streams were visited on March 13, September 25 and December 17, 2001, and February 1 and March 26, 2002 (storm events within the watershed). Water was collected by grab samples in sections of typical flow. Sample water was then transferred to bottles containing acid preservative and stored on ice. Samples were tested for nutrient content and total suspended solids following EPA analytical methods at the NYS certified (DOH ELAP# 10248) Life Science Laboratories, Inc., in Syracuse. This portion of the tributary sampling program has been ongoing for five years and has gradually expanded to now include all major streams flowing to Canandaigua Lake. Established sampling locations are listed in the Appendix.

Tributary streams were also visited on February 27, 2002 and stream water samples were analyzed for road salt contamination (chloride [Cl⁻] concentration) at the Finger Lakes Community College environmental chemistry laboratory using the argentometric titration procedure (Standard Methods, 17th edition). This annual analysis has been conducted since 1990.

To better understand the sources of pollution within a subbasin, segment analysis of

individual streams is undertaken. A stream channel is broken into segments at road crossings or according to changes in land use. The main stem of the stream and its feeder branches are often tested following this methodology. Segments of Fallbrook Stream were sampled on August 19, September 25, November 25, November 29 and December 17, 2001. Samples were analyzed for sediment load and nutrient levels following the same procedures used for the major tributaries. Fecal coliform counts were determined for a mid-reach segment of Fallbrook Stream sampled on November 13, 2001. Segments of the Vine Valley Stream were sampled on March 13 and December 17, 2001, and February 1, March 26, April 3 and May 2, 2002. Samples were analyzed for sediment load and nutrient levels as described above.

The Canandaigua Outlet was visited for macroinvertebrates on October 29, 2001 by the Finger Lakes Community College Limnology class and a HYDROLAB stream water chemistry profile was taken upstream of the Route 488 highway bridge (Chapin, New York). A similar visit was made to Naples Creek on November 12, 2001 and a HYDROLAB stream water chemistry profile was taken upstream of the Route 245 highway bridge (near NYS Department of Environmental Conservation facility).

RESULTS AND DISCUSSION

Water quality of Canandaigua Lake

Canandaigua Lake is a warm monomictic lake that thermally stratifies during the summer and generally stays ice-free during the winter. The winter of 2001 was unusually warm and little ice formation occurred, even at the shallow ends of the lake basin! Background information on the limnology of the lake is found in Eaton and Kardos (1978), Sherwood (1993), Olvany *et al.* (1997) and previous reports by this author. The development of thermal stratification in the lake is presented in the temperature profiles (Figures 1, 2 and the Appendix). From near isothermal conditions during early spring, the lake gradually gains heat at the surface. The work of the wind displaces the surface heat downward 15 to 20 meters by the end of the summer. Strong winds will produce Langmuir circulation (wind streaking) and may blow off the top of waves (white cap effect). Turnover in the lake occurs in late November or early December, and normally lasts about one week. Winds keep the lake well mixed during the winter months.

Dissolved oxygen increases with depth in Canandaigua Lake (an orthograde profile). For 2001, epilimnetic oxygen was always close to or just exceeding 100% of saturation. Actual values ranged from low readings 8.2 mg/L during August to high readings of 12.7 mg/L in April. In the hypolimnion during the summer, the dissolved oxygen was maintained between 8.5 and 11 mg/L, a slight decrease from previous years. Fall turnover redistributed dissolved oxygen downward. High oxygen levels were present throughout the water column during the winter sampling. These seasonal dissolved oxygen patterns indicate that the lake is a high quality environment for aquatic organisms.

FIGURE 1 - Development of 2001 thermal stratification in Canandaigua Lake, Deep Run Station.

FIGURE 2 - Development of 2001 thermal stratification in Canandaigua Lake, Seneca Point Station.

In 2001, mean monthly specific conductance, integrated across the water column for both deep water stations, peaked during April (. 440 Φ S/cm) and reached its lowest in September

(. 392 Φ S/cm). Conductivity generally declined from April to November 2001, in sharp contrast to the dramatic increase observed in September 2000 that was probably associated with storm runoff (Gilman 2000). Based on Canandaigua Lake Sampling and Monitoring Program research by the author, the year 2001 eight month average was 406 Φ S/cm compared to the 2000 average of 410 Φ S/cm, the 1999 average of 404 Φ S/cm, the 1998 average of 393 Φ S/cm, the 1997 average of 376 Φ S/cm, and the 1996 average of 362 Φ S/cm. These recent values represent an increase from 271 Φ S/cm in 1955 (Berg 1963), 285 Φ S/cm in 1973 (Oglesby in: Eaton and Kardos 1978), 350 Φ S/cm in 1993 (Gilman 1993) and approximate the level of 373 Φ S/cm noted in 1994 (Gilman 1994). The data reveals a long-term trend of increasing conductivity in the lake, most likely associated with soil particles derived from watershed erosion. It was speculated six years ago that zebra mussels might lower conductivity when they absorb calcium for shell formation. This year's slight increase in conductivity may be related to zebra mussel decline.

Secchi disk readings for oligotrophic lakes are often greater than 5 meters. Readings are lower when suspended particles (organic and inorganic) are high. Readings can also be affected by variability in cloud cover and surface wave action. Historic data on lake clarity are discussed in Gilman (2000). This year, clarity from April through November averaged 6.7 meters and reached a maximum of 8.9 meters. Lake clarity continued a declining trend that began in 1999. The 2001 lake clarity average dropped 24% when compared to year 2000 data. The lower readings in 2001 are directly related to increased algal abundance in the photic zone of the lake. Monthly data are presented in Table 1 and Figure 3. Canandaigua Lake was also visited during the winter on February 22, 2002 and had a secchi disk reading of 10.2 meters. Higher secchi disk readings are expected during the winter season because plankton populations (organic suspended solids) are naturally lower. Soil particles (inorganic suspended solids) are also less common because little erosion from the watershed occurs when most precipitation arrives as snowfall.

TABLE 1 - Secchi disk readings (m) in Canandaigua Lake.

Date	Deep Run	Seneca Point	Average
25 Apr 2001	8.3	5.5	6.90
30 May 2001	6.0	6.2	6.10
26 Jun 2001	8.2	6.9	7.55
24 Jul 2001	6.5	7.2	6.85
23 Aug 2001	5.2	5.8	5.50
30 Sept 2001	5.7	5.8	5.75
30 Oct 2001	6.8	6.0	6.40
23 Nov 2001	7.8	8.9	8.35

FIGURE 3 - 2001 average secchi disk readings in Canandaigua Lake. See data in Table 1.

The levels of chlorophyll *a* during the 2001 sampling season are presented in Table 2 and Figure 4. Algal populations develop quickly and species sequentially replace one another as the

lake conditions change and the growing season progresses. Limnologists refer to this as a rapid species turnover. During 2001, a peak in algal abundance occurred in late May followed by a significant drop. This may be caused by rapid species turnover but may also be related to the onset of zebra mussel filter feeding in the warming waters of June.

Mid-lake measurements based on an integrated column technique were highly correlated with the average of grab samples collected from the 2 and 5 meter depths (at Deep Run $r = 0.85$, at Seneca Point $r = 0.97$). It is recommended that the integrated column technique, also used by the NYS DEC, become the preferred method for all future studies on Canandaigua Lake.

Algal abundance estimated by the concentration of chlorophyll *a* based on all data except the West River station, averaged 2.39 $\Phi\text{g/L}$. This represents a 38% increase from last year's algal abundance and now approaches the historic levels reported in 1973 (Oglesby *in*: Eaton and Kardos 1978) and the pre-zebra mussel levels from the early 1990's. Algal abundance has been increasing since 1999 and this year the phytoplankton community was dominated by the cyanobacterium *Microcystis aeruginosa*. Research in Lake Erie suggests that zebra mussels selectively filter against *Microcystis* (i.e., it is unpalatable to the mussels). Reductions in palatable phytoplankton may limit zebra mussel densities and trigger population collapses. It appears probable that when chlorophyll *a* levels fall below about 2.00 $\Phi\text{g/L}$ and the remaining algal community is dominated by unpalatable species, zebra mussels simply run out of food. Indirect evidence suggests that a zebra mussel die-off is taking place in Canandaigua Lake. Fewer bottom substrates are colonized by mussels and more empty mussel shells are washing up along the shoreline. As zebra mussel populations decline, the dynamic equilibrium swings in favor of a recovery in the algal populations. The data from the summer of 2001 provides testimony to this process; chlorophyll *a* levels have risen and lake clarity has declined. More research on the relationship among zebra mussels, lake clarity and algal abundance will be conducted in 2002.

TABLE 2 - 2001 chlorophyll *a* concentrations (Φ g/L) in Canandaigua Lake. Adjusted mean graphically displayed in Figure 4.

Station	4-25	5-30	6-26	7-24	8-23	9-30	10-30	11-23	
Fallbrook	1.02	1.05	1.70	0.96	2.90	1.24	0.90	0.91	
Hope Point	1.78	6.44	1.07	2.26	2.14	1.59	4.31	1.88	
Deep Run	1.10	2.29	1.53	2.15	2.88	1.80	2.85	2.98	
Deep Run (5 m)	1.44	2.37	2.88	2.20	2.80	2.05	2.83	2.97	
Deep Run (int)		1.16	2.91	1.95	2.23	2.88	1.45	3.25	3.05
Seneca Point	1.70	4.61	1.24	2.26	2.46	2.05	3.39	3.14	
Seneca Point (5 m)	1.70	8.73	1.72	2.23	2.71	2.26	3.58	3.16	
Seneca Point (int)	1.73	5.90	1.70	2.40	2.63	1.59	3.31	3.19	
Vine Valley	1.64	2.68	1.44	1.33	2.12	1.98	1.78	1.59	
West River	3.71	4.89	3.48	2.29	1.95	13.41	3.42	1.65	
									overall mean
mean	1.70	4.19	1.87	2.03	2.55	2.94	2.96	2.45	
adjusted mean *	1.47	4.11	1.69	2.00	2.61	1.78	2.91	2.54	2.39

* adjusted mean = without West River values, this station is excluded because it more often reflects river conditions rather than lake quality.

FIGURE 4 – 2001 chlorophyll *a* concentrations in Canandaigua Lake.

There has also been a change in the ratio of chlorophyll *a* concentrations between

shoreline and mid-lake stations (Table 3). The following comparisons are based on samples collected at a depth of two meters for two mid-lake stations and three shoreline stations. Data from the West River station is excluded because it often does not reflect lake quality. 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 has been directly related to the intensity of filter feeding by zebra mussels in the shallow near-shore environment (Gilman 2000). An indirect effect of the shoreline zebra mussel population may play a secondary role. With improving water clarity along the shoreline, aquatic macrophyte communities have expanded outward. As this occurs, nutrients are sequestered by aquatic weeds, reducing the amount available for the suspended algae. If the shoreline zebra mussel population declines, the reduction in their filter feeding should allow the quantity of suspended algae to increase and the ratio would return closer to 1.00. Algal ratios from 2001 support this possibility and suggest that a zebra mussel die-off has begun.

TABLE 3 - Ratio between shoreline (n = 3) and mid-lake (n = 2) chlorophyll *a* concentrations. All samples were collected at a depth of 2 meters.

Year	Month								mean $\forall$ 1 s.d.
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	
1996	1.05	1.13	0.84	0.75	0.87	0.79	0.77	0.94	0.89 $\forall$ 0.14
1997	1.55	1.05	0.78	0.82	0.74	0.75	0.72	0.68	0.89 $\forall$ 0.29
1998	0.90	0.54	0.57	0.50	0.86	0.77	0.83	0.77	0.72 $\forall$ 0.16
1999	0.91	0.83	0.71	0.60	0.59	0.50	0.71	0.86	0.71 $\forall$ 0.15
2000	0.94	0.66	0.80	0.59	0.72	0.57	0.47	0.67	0.68 $\forall$ 0.15
2001	1.06	0.98	1.03	0.69	0.90	0.83	0.75	0.48	0.84 $\forall$ 0.20

An inverse relationship exists between chlorophyll *a* concentrations and secchi disk readings over the last six years (Figure 5). The graph provides further circumstantial evidence that zebra mussel populations and their impact on lake processes are subject to continual change.

The density of zebra mussels in Canandaigua Lake is delicately and dynamically

balanced with the lake's algal abundance and that portion of the algal community that is palatable to the mussels. Declines in either will trigger a die-off, and lead to unforeseen consequences in ecological processes in the lake. Already the lake has experienced the growth of a benthic algal mat, fertilized by the pseudo-fecal pellets of a dense zebra mussel population. When zebra mussels decline, what will happen to bottom-dwelling algae? How quickly will the zebra mussels decay and how will their decomposition affect the quality of lake water? Research will begin this summer to help answer these questions.

FIGURE 5 - Recent water quality trends in lake clarity and algal abundance.

Nutrients in lake water fluctuate seasonally and vary with depth in the water column. Phosphorus is thought to be the limiting nutrient for lake productivity and total phosphorus has

been measured since 1996. Based on 455 samples collected from different sites and depths during the growing season (April through November), the long term total phosphorus average has been 6.59 $\Phi\text{g P/L}$ with the range running from undetectable to 200.0 $\Phi\text{g P/L}$. For the 84 samples collected in 2001, total phosphorus averaged 9.07 $\Phi\text{g P/L}$. Since 1996, there have been 55 instances (12.1%) when total phosphorus levels exceeded the desirable ecological threshold of 10 $\Phi\text{g P/L}$. This threshold is based on studies of hundreds of North American lakes; TP exceeding 10 $\Phi\text{g P/L}$ move the trophic condition of the lake from oligotrophic to mesotrophic (Wetzel and Likens 1999). Twenty of these instances occurred between 1996 and 1999. Twenty-two occurred during the year 2000! That number was reduced to only 13 instances in 2001. Surprisingly, Deep Run at a depth of 50 meters exceeded the desirable TP threshold three times, including a value of 95.0 $\Phi\text{g P/L}$ on July 24. These high phosphorus values at depth may in some way be related to organic decomposition along the lake bottom (note: samples from 50 meters at Deep Run are nearly at the bottom while samples from 50 meters at Seneca Point are still some distance off the bottom). Most of the other exceptionally high lake total phosphorus results over the past six years were from the mouth of the West River station either during the early spring when wetland vegetation is dormant or during late fall when wetland vegetation is senescent (Table 4), substantiating the seasonal role of the High Tor wetlands as a nutrient source to the lake.

During the summer of 1973, total phosphorus in the surface waters (mid-lake?) of Canandaigua ranged from 8 to 10 $\Phi\text{g P/L}$ (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. During the last six years, total phosphorus levels have averaged significantly less. In fact, total phosphorus data were at the laboratory detection limits (2.4 $\Phi\text{g P/L}$ for 1996-2000 [SUNY Brockport], 3.0 $\Phi\text{g P/L}$ for 2001 [Life Science Laboratory, Inc.]) nearly 25% of the time since 1996. The 1997 winter mean total phosphorus values of 5.00 $\Phi\text{g P/L}$ (range = 3.1 to 8.0 $\Phi\text{g P/L}$) for the two mid-lake stations fell below the historic 1973 data.

TABLE 4 - Total phosphorus data exceeding 10 $\Phi\text{g P/L}$, August 1996 through November 2001.

Samples from the **West River** account for 24 (43.6%) of the instances.

<u>Total phosphorus (Φg P/L)</u>	<u>Sampling site</u>	<u>Depth</u>	<u>Date</u>
200.0	West River	2 m	September 30, 2001
141.2	West River	2 m	October 29, 1998
95.0	Deep Run	50 m	July 24, 2001
88.2	Fallbrook	2 m	April 30, 1997
52.0	West River	2 m	April 26, 2000
51.4	Seneca Point	50 m	May 30, 2000
46.0	West River	2 m	October 30, 2001
39.0	Hope Point	2 m	October 30, 2001
36.2	Hope Point	2 m	July 31, 2000
33.0	West River	2 m	May 30, 2001
31.7	West River	2 m	August 31, 1998
30.8	West River	2 m	October 27, 1999
28.8	West River	2 m	July 31, 2000
22.7	West River	2 m	September 30, 2000
22.0	Deep Run	2 m	July 31, 2000
20.0	Deep Run	50 m	June 26, 2001
20.0	West River	2 m	August 31, 1999
19.6	Vine Valley	2 m	July 31, 2000
19.0	West River	2 m	October 30, 1996
17.8	West River	2 m	October 26, 2000
17.8	Vine Valley	2 m	May 30, 2000
17.2	West River	2 m	November 28, 2000
17.0	West River	2 m	June 26, 2001
15.8	West River	2 m	August 28, 1996
15.5	Seneca Point	25 m	May 30, 2000
15.0	Deep Run	50 m	April 26, 2000
15.0	West River	2 m	July 24, 2001
14.9	West River	2 m	April 17, 1999
14.7	West River	2 m	June 26, 1997
14.0	Seneca Point	2 m	July 31, 2000
13.3	Vine Valley	2 m	April 26, 2000
13.2	West River	2 m	July 27, 1998
13.0	West River	2 m	August 23, 2001
12.9	Seneca Point	2 m	August 31, 1999
12.8	Deep Run	50 m	July 31, 2000
12.8	Seneca Point	25 m	July 31, 2000
12.8	Fallbrook	2 m	April 26, 2000
12.6	Fallbrook	2 m	October 27, 1999
12.5	Hope Point	2 m	October 27, 1999

TABLE 4 (continued) - Total phosphorus data exceeding 10 Φ g P/L, August 1996 through November 2001. Samples from the **West River** account for 24 (43.6%) of the instances.

<u>Total phosphorus (Φg P/L)</u>	<u>Sampling site</u>	<u>Depth</u>	<u>Date</u>
12.1	Deep Run	50 m	May 30, 2000
12.0	West River	2 m	April 25, 2001
11.6	West River	2 m	June 28, 2000
11.1	Hope Point	2 m	December 3, 1996
11.0	Deep Run	2 m	May 30, 2001
11.0	Deep Run	50 m	November 23, 2001
11.0	Vine Valley	2 m	May 30, 2001
10.8	West River	2 m	May 20, 1998
10.5	Deep Run	2 m	April 26, 2000
10.5	Deep Run	25 m	April 26, 2000
10.3	Seneca Point	50 m	July 31, 2000
10.3	Deep Run	50 m	September 30, 1998
10.2	West River	2 m	June 29, 1999
10.2	Seneca Point	25 m	December 3, 1996

The West River site had the highest total phosphorus levels in 29 of the 44 months of sampling (65.9%) conducted since August 1996!

The 2001 winter mean total phosphorus value was 3.6 Φ g P/L (range = 3.1 to 4.3 Φ g P/L) for mid-lake at Black Point. From a long-term watershed perspective, total phosphorus levels have declined since the restriction of phosphate builders in detergents, the watershed inspection program and the expansion of sewer lines. Continuing growth trends in the watershed population and an increase in impervious surfaces, however, represent threats to lake health that could significantly increase nutrient budgets unless proper landuse strategies are in place.

Table 5 presents mean monthly profiles of total phosphorus for the two mid-lake stations for the years of record, 1997-2001. Surface waters average the lowest near the end of the growing season (August through November). This may be associated with thermal stratification of the lake, frequent summer droughts, high rates of biological absorption and slower species turnover within the plankton communities.

TABLE 5 - Seasonal profiles for total phosphorus (Φ g P/L) at the two mid-lake sampling stations. Data based on mean of monthly values, 1997 through 2001.

<u>Deep Run Site</u>									
<u>depth</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>	<u>Apr-Nov mean</u>
2	4.53	6.46	5.28	7.07	2.94	5.28	3.59	3.58	4.84
25	4.16	4.10	3.41	3.86	3.45	5.19	2.07	2.52	3.60
50	<u>5.16</u>	<u>5.93</u>	<u>7.54</u>	<u>23.24</u>	<u>4.36</u>	<u>5.59</u>	<u>2.07</u>	<u>5.69</u>	7.45
monthly mean	4.62	5.50	5.41	11.39	3.58	5.35	2.58	3.93	
overall mean = 5.30 Φ g P/L									
<u>Seneca Point Site</u>									
<u>depth</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>	<u>Apr-Nov mean</u>
2	3.57	5.08	4.92	5.46	5.56	4.51	2.68	3.57	4.42
25	5.21	5.82	4.64	4.10	2.15	4.54	2.70	2.52	3.96
50	<u>4.36</u>	<u>13.42</u>	<u>4.56</u>	<u>4.04</u>	<u>2.73</u>	<u>3.76</u>	<u>2.40</u>	<u>3.33</u>	4.83
monthly mean	4.38	8.11	4.71	4.53	3.48	4.27	2.59	3.14	
overall mean = 4.40 Φ g P/L									

Inorganic nitrogen (NO_3 and NO_2) had a mean of 0.29 mg N/L based on 498 samples collected from April 1996 through November 2001. Individual results ranged from 0.03 to 0.70 mg N/L. During the year 2001, inorganic nitrogen averaged 0.26 mg N/L. Eaton and Kardos (1978) report a mean of 0.31 mg/L $\text{NO}_3\text{-N}$ for July 1972 based on 52 samples, and a mean of 0.32 mg/L $\text{NO}_3\text{-N}$ for July 1973 based on 28 samples. Although not directly comparable, these findings suggest little change in the nitrogen compounds available for the support of biological activities during the last three decades. The ecological threshold for inorganic nitrogen is less than 1.00 mg N/L. Table 6 reveals a seasonal pattern of nitrogen depletion along the shoreline during the height of the growing season.

TABLE 6 - Monthly variation in mean inorganic nitrogen ($\text{NO}_3 + \text{NO}_2$ mg N/L) for mid-lake and shoreline sampling stations.

	<u>2001 average</u>							
	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>
shoreline	0.36	0.27	0.24	0.17	0.06	0.10	0.15	0.21
mid-lake	0.36	0.30	0.34	0.25	0.27	0.30	0.30	0.32
	<u>long-term average, 1996-2001</u>							
	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>
shoreline	0.38	0.29	0.24	0.17	0.12	0.16	0.21	0.29
mid-lake	0.38	0.33	0.33	0.30	0.29	0.32	0.31	0.31

Near-shore lake water samples were collected for total coliform bacteria counts on May 30, June 26, July 24 and August 23. Results ranged from less than one colony to 60 colonies per 100 ml of water sample. These fall well below the standard of “not to exceed 2400 colonies” established for contact recreation in open waters. Individual data are in the Appendix.

Trophic status of Canandaigua Lake

Lake eutrophication is a natural process resulting from the gradual accumulation of sediments and organic matter. As a basin slowly fills, nutrient concentrations and productivity are increased. The rate of the eutrophication process and, hence, the life span of the lake, will depend on the morphometry of the basin and the stability of watershed soils. Human activities (e.g., land use changes, agricultural fertilization practices, waste water discharges) accelerate this process bringing about cultural eutrophication. Often changes in lake condition occur too fast for the adaptive capabilities of natural communities and their respective organisms. Species are lost from the basin and premature aging of the lake begins.

Typical lake succession 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

Each trophic state is characterized by certain conditions. Oligotrophic lakes have low

productivity due to low nutrient supplies. Water is exceptionally clear. These lakes are often deep and have steep basin walls. Water in mesotrophic lakes receives a moderate supply of nutrients from the watershed, which may be recycled several times within the basin. Primary 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. Benthic depletion of dissolved oxygen is common.

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. In earlier weedbed studies of Canandaigua Lake (Gilman and Rossi 1983, Gilman 1994a), results suggested that Canandaigua Lake 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 8). The TSI can be useful in determining the extent of eutrophication in any given lake but other factors should also be considered. Carlson's equations were based on data from lakes throughout the United States, and may not necessarily apply to the Finger Lakes. In fact, since the equations 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, non-algal turbidity (the addition of sediment from localized watershed erosion), the presence of zebra mussels which can filter out much of the plankton community thereby improving clarity, and depth to, and nature of, bottom sediments. Acidification of Adirondack lakes has altered the perception of their trophic status.

TABLE 7 - Information pertaining to the Carlson Trophic State Index (TSI).

<u>Variable</u>	<u>Trophic State</u>		
	<u>Oligotrophic</u>	<u>Mesotrophic</u>	<u>Eutrophic</u>
total phosphorus	< 10 Φ g/L	10 - 26 Φ g/L	> 26 Φ g/L
chlorophyll <i>a</i>	< 2 Φ g/L	2 - 8 Φ g/L	> 8 Φ g/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 as follows:

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

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

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

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

Highly acidic lakes are biologically sterile leading to low chlorophyll *a* concentrations and good water clarity, mimicking the conditions of a naturally oligotrophic lake. It is also important to remember that changes in trophic status are not a condemnation of human impacts on lakes. Each trophic state can support different uses. Eutrophic lakes often support excellent warmwater fisheries while oligotrophic lakes can provide an excellent source of public drinking water.

Summer (June, July, August) monthly mean secchi disk readings and chlorophyll *a* concentrations were used to calculate the TSI values in Table 9. The TSI total phosphorus value for Canandaigua Lake was also determined this year based on the winter sampling.

TABLE 8 - Carlson TSI values for Canandaigua Lake.

Trophic State Index

based on:	secchi disk	Chl <i>a</i>	total phosphorus
1995 data	36.9	46.3	36.0
1996 data	33.0	39.1	46.5
1997 data	30.2	40.6	27.4
1998 data	29.1	36.8	-
1999 data	28.6	35.6	-
2000 data	28.6	35.5	-
2001 data	33.3	37.9	22.7

2001 TSI values for Canandaigua Lake fall closest to the oligotrophic (<37) condition. TSI based on secchi disk readings and chlorophyll *a* concentrations had declined steadily since 1995 as a result of filter feeding by zebra mussels, but increased slightly this year possibly due to a zebra mussel die-off. 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. While in general lake health has improved according to the Carlson TSI, there are localized nearshore instances that tell a different story. A significant dieback of Eurasian milfoil (*Myriophyllum spicatum*) was observed in August 2000 near the mouth of the West River. The macrophyte community collapse was remarkable and it was surmised that a biological control agent was at work. Spring 2002 monitoring at this site revealed an unusually heavy growth of curly-leaf pondweed (*Potamogeton crispus*) in the absence of Eurasian milfoil competition. This same effect was observed several years ago following an attempt to manage the aquatic plants through weedbed harvesting. Submerged aquatic plant communities are diverse and resilient!

Lake foam

Since early August 2001, Canandaigua Lake has experienced incredible amounts of

foam. The foam has been found lake-wide, and prevailing wind patterns create streaks of foam that in some cases have measured over 60 feet wide, 4 inches thick and up to 4 miles long! In past years, residents have seen foam on the lake surface and have reported some foam washing up on their beaches but never to this extent.

Foam is most commonly the result of natural properties of the water. Physical attraction among water molecules produces a strong bonding or cohesion. At the top of the lake this causes surface tension. Insects like water striders take advantage of surface tension to walk on the water in search of prey. Keen observers can actually see the depression made on the water's surface film by each of the insect's six feet. The entire community of organisms living on the surface film is called the neuston.

A reduction in surface tension is conducive to the formation of foam. Warmer water temperatures will slightly reduce surface tension; the addition of organic compounds will greatly reduce surface tension. These organic compounds are collectively called surfactants. For Canandaigua Lake, typical sources of organic compounds are the submerged aquatic plant communities at the south end and those along its shoreline, and the microscopic algae and animals (i.e., the phytoplankton and zooplankton). Submerged aquatic plants and algae secrete organic compounds during photosynthesis, as well as during senescence and decomposition. Decay of animal tissues can also add organic compounds to the water that may result in foaming. Organic compounds can also have cultural sources. Synthetic organic compounds, like detergents, contain surfactants mixed with water softening agents. For many years, detergent surfactants were resistant to bacterial attack and foaming was excessive and persistent. Recent advances in the manufacturing of detergents have resulted in new formulations of surfactants that degrade quickly by microbial action.

The foam on Canandaigua Lake first appeared during a prolonged period of summer drought. Most streams had little or no flow to the lake, and those streams with perennial flow did not have any surface foaming. The foam seemed to have originated from within the lake, not from the watershed. Initial sampling of the foam detected an oily touch but no odor. Samples stored in clear plastic bags and left in full sunlight over the weekend barely began to destabilize back into liquid. This foam was unusually persistent. Later observations revealed that rafts of foam were travelling down the lake outlet several miles to its junction with the NYS Barge Canal

in Lyons. Back on the lake surface, winds produced a series of parallel linear foam streaks and foam piled up along the shoreline, sometimes to a depth exceeding two foot. Shoreline residents and recreational lake users were clearly alarmed.

The wind-streaking phenomenon is a natural process that commonly occurs on large water bodies. It was first described in the oceans (Langmuir 1938) and later studies extended it to freshwater bodies (Harris and Lott 1973). As winds blow across the water surface, wind stresses the surface tension and produces surface waves that mix air in the water. Both processes are thought to be related to the formation of downwelling spirals diagrammed and photographed in Figure 6. Limnologists refer to the process as Langmuir circulation. At the end of the spiral roll, where water upwells and converges back on the surface, streaks are made visible by the accumulation of bubbles. If water has enhanced buoyancy due to the presence of organic films, the streaks will widen as they resist downwelling. The organic materials will be trapped on the bubble surfaces. Then, the foaming events seen since early August 2001 on windy days on the surface of Canandaigua Lake will be produced (Figure 7). Trapped with the foam are a variety of floating items, including fragments of submerged aquatic plants, terrestrial leaf litter, phytoplankton and zooplankton. The process is well understood. The puzzling question is: what is the source of the surfactant molecules? Through the Internet, contact was made with limnologists worldwide. The situation in Canandaigua Lake was described and photographs of the foam were attached to the e-mail. There was consensus that Langmuir spirals were at work, but a wide difference of opinion about the source of the surfactant molecules. One New Zealand researcher suggested polysaccharides derived from a microbe encouraged by run-off from dairy herds but most thought that the origin of the foam was a natural, in-lake process either due to proteins or fatty acids. Work in oceans and coastal environments has implicated the role of the algae *Phaeocystis* in foam formation. The nuisance algae, *Botryococcus* and *Nautococcus*, can also cause foaming on shorelines. In still other studies, diatoms have been shown to produce organic molecules that may result in foam.

FIGURE 6 – Langmuir circulation, diagrammatic formation and Canandaigua Lake images.

FIGURE 7 – Persistent, large foam streaks on the surface of Canandaigua Lake.

At the same time that foam appeared on the lake, other lake conditions had changed, suggesting a possible relationship. Lake clarity, measured as secchi disk depth, had been declining since 1999. In the summer of 2001, it averaged 6.7 meters. Algal abundance, estimated by the concentration of chlorophyll *a*, had increased over the last three years and this past year averaged 2.39 $\Phi\text{g/L}$. The algal community was dominated by the cyanobacterium,

Microcystis aeruginosa. Research in Lake Erie suggests that zebra mussels selectively filter against *Microcystis* (i.e., it is unpalatable to the mussels). So what had happened to the zebra mussel populations in the lake? The decrease in lake clarity and increase in chlorophyll *a*, combined with observations of fewer mussels attached to natural bottom substrates and an increased number of empty mussel shells at the shoreline, suggest that mussel populations may have exceeded the lake's carrying capacity and subsequently crashed. As mentioned earlier in this report, reductions in palatable algae may limit zebra mussel densities and trigger these population collapses.

Is there a connection between the die-off of zebra mussels, the dominance of *Microcystis* and the unusual foam on the surface of Canandaigua Lake? Three hypotheses are being considered. First, organic compounds are being released from the decaying flesh of the mussels. These decay products rise to the surface, act as surfactants, and are whipped by wind action into large, linear streaks of foam. A second possibility under consideration is that the microbial organisms decaying the zebra mussel flesh are actually the source of the surfactant molecules. Certainly their population numbers have dramatically increased during the zebra mussel die-off. The third hypothesis indirectly involves the zebra mussels. Because they selectively filter against *Microcystis*, leading to *Microcystis* dominance in the algal community, is it possible that the unexpectedly large population of this cyanobacterium is the source of the surfactant molecules? After an extensive literature search and personal communications with limnologists, evidence that links foam in other lakes to blooms of *Microcystis* was not uncovered. However, most research generally concludes that biota of lakes are known to produce a variety of fats and oils that will act as surfactants (Harris and Lott 1973).

Without laboratory analyses, it was impossible to determine whether the Canandaigua Lake foam was formed due to these hypotheses involving natural conditions or whether it was the result of some undetected human activity. Accordingly, foam samples were collected and sent to the SUNY College of Environmental Science and Forestry Chemistry Laboratory for analyses. Preliminary results detected high levels of fatty acids. More research centered on the foam problem will continue this year. Plans are underway to analyze more foam samples for the presence of organic substances as well looking for these same substances in zebra mussel flesh. Mussels will also be examined for toxic compounds through collaboration with SUNY

Plattsburgh and NYS DEC programs at no cost to the Canandaigua Lake Watershed Council. If the foam problem continues into 2003, it may be of value to analyze the toxic content of the foam because research with stream foams suggests that they can be greatly enriched with lipophilic pollutants such as petroleum hydrocarbons, chlorinated hydrocarbons and other contaminants (Napolitano and Richmond 1995).

Tributaries to Canandaigua Lake

For several years, a large number of perennial streams flowing to Canandaigua Lake have been sampled for their water quality at one or more locations. These historic data are described in reports by Makarewicz and Lewis (1998, 1999b, 2000). This stream monitoring program was continued in the year 2001 but, due to a prolonged summer drought, sampling the tributaries was extended into the spring of 2002. Storm event sampling occurred on March 13, September 25, December 17, 2001 and February 1 and March 26, 2002. Sampling sites are located in Figure 8. Event chemistry for individual tributaries is presented in the Appendix.

Tributary nutrient concentrations during storm events continues to be a problem in some streams, and on two occasions, total phosphorus exceeded the US EPA maximum permissible concentration of 500 $\Phi\text{g P/L}$ allowed for discharge of sewage effluent into the Great Lakes. The first time occurred on March 13, 2001 at Vine Valley with a concentration of 520 $\Phi\text{g P/L}$ and the second time occurred on February 1, 2002 at Fisher Gully with a concentration of 500 $\Phi\text{g P/L}$. Over the five storm events, mean total phosphorus concentration ranged from 43.0 $\Phi\text{g P/L}$ to 263.0 $\Phi\text{g P/L}$. The streams with the six highest average total phosphorus concentrations were Sucker Brook (263.0 $\Phi\text{g P/L}$), northern West River (198.3 $\Phi\text{g P/L}$), Vine Valley (196.0 $\Phi\text{g P/L}$), Naples Creek (182.8 $\Phi\text{g P/L}$), Eelpot Creek (169.4 $\Phi\text{g P/L}$) and Fisher Gully (151.2 $\Phi\text{g P/L}$). The order is slightly different from three year average reported in Makarewicz and Lewis (2000), with Eelpot Creek and Fisher Gully joining the list due to high TP single storm responses.

FIGURE 8 – Sampling sites, tributaries to Canandaigua Lake.

Mean nitrate and nitrite levels ranged from 0.21 mg N/L to 4.66 mg N/L. The streams with the nine highest mean nitrate and nitrite concentrations were Gage Gully (4.66 mg N/L), Deep Run (4.20 mg N/L), upper West River (2.17 mg N/L), northern West River (1.94 mg N/L), Fallbrook Stream (1.57 mg N/L), Sucker Brook (1.46 mg N/L), Tichenor Gully (1.45 mg N/L), Vine Valley (1.26 mg N/L) and middle West River (1.25 mg N/L). All other tributaries had less than 1.00 mg N/L. Makarewicz and Lewis (2000) reported similar findings in their event-based

sampling and in their base-line sampling, leading them to suggest that higher concentrations in groundwater (i.e., base-line samples) were associated with agricultural landuse. Failing septic systems may also play a role in elevated levels. Notable increases in combined nitrate and nitrite concentrations this year when compared to year 2000 data were detected in Tichenor Gully, Barnes Gully and Seneca Point Gully. No state guidelines exist for maximum possible levels in surface waters; NYS Department of Health has a standard of less than 10.00 mg N/L for drinking water.

The average concentration of total suspended solids loss from tributaries and delivered to the lake varied from 25.5 mg/L to 712.5 mg/L. This sediment may be washed off lands with little or no protective vegetative cover and/or may result from streambank erosion during storm events. Often nutrients like phosphorus are attached to the surfaces of soil particles, hence, total suspended solids and total phosphorus are highly correlated. The nine highest mean total suspended solids in streams were Fisher Gully (712.5 mg/L), Naples Creek (265.9 mg/L), Gage Gully (264.6 mg/L), Eelpot Creek (239.8 mg/L), Menteth Gully (213.6 mg/L), Vine Valley (211.0 mg/L), Seneca Point Gully (210.8 mg/L), Sucker Brook (196.2 mg/L) and Barnes Gully (185.8 mg/L). Notable increases when compared to year 2000 data were recorded in Fisher Gully, Vine Valley, Sucker Brook, Gage Gully and Tannery Creek. Concentrations in Deep Run were on the average lower than in previous years. Lowest levels of TSS were measured in the lower West River where slower flows allow settling out of most suspended particles.

Mean concentrations of nutrient and sediment for three time periods (1997-1999, 2000 and 2001) are presented in Figures 9, 10 and 11. Large differences in these data result from complex interactions among storm intensities, nonsynchronous sampling and individually distinct subbasin characteristics. It is difficult to generalize on long term changes in individual stream

FIGURE 9 – Comparison of tributary total phosphorus: 1997-1999, 2000, 2001.

FIGURE 10 – Comparison of tributary nitrate and nitrite: 1997-1999, 2000, 2001.

FIGURE 11 - Comparison of tributary total suspended solids: 1997-1999, 2000, 2001.

quality for several reasons. Although twenty-seven storm events have been studied since 1997, each event provides a different “picture” of a stream’s response. Seldom are the storms identical in intensity and duration. Also, soil moisture conditions prior to the storm will influence infiltration capacity during the event and, therefore, affect runoff to the tributary streams.

Another potential problem when comparing data involves timing. During one storm event, the stream may have been sampled on the rising limb of the hydrograph (i.e., first flush of material off the subbasin drainage area) but for a subsequent event, the stream might have been sampled on the falling limb of the hydrograph simply due to the time constraints of traveling around the lake. Conclusions about long term stream quality trends based on comparing stream

concentration results could be misleading. Long term monitoring does, however, provide an increasing set of data to build knowledge.

While stream loadings provide a better measure of a watershed's impact because they consider the discharge volume of water as well as the concentration of nutrient in the water, there are inherent assumptions in estimating loadings that should be remembered when that loading information is used to prioritize watersheds for remedial actions. Discharge is based on flow measurements, stream cross-sectional area and a bottom roughness coefficient. Use of road culverts as the site for these measurements helps to reduce the variability that is associated with otherwise natural segments of a stream. Discharge rating curves are developed from several storm events. Discharge is correlated to stream gage height through the rating curves so that in future storm events only gage height needs to be measured. There are some sources of error associated with this approach. Stream gage height measurements must follow a careful protocol to produce reliable discharge estimates. Even when stream gage heights are measured accurately, stream cross-sectional area can change from erosional/depositional processes associated with each storm event. Culvert boxes beneath roads contain sand bars and stream banks that are subject to movement during flood stage in the channel. Also, subsurface flow through gravel beds along the stream bottom is difficult to quantify. The stream may appear dry but it may actually be moving water to the lake.

Loading estimates extrapolate point data (i.e., the individual base-line and storm events) into annual volumes and amounts entering the lake based on modeling equations. A number of models are in common use, each based on assumptions that produce a confidence interval around the loading estimate. Earlier studies of nutrient loading in Canandaigua Lake tributaries are problematic because some estimated annual stream discharges exceeded 100% of the yearly estimated precipitation delivered to that subbasin (note: based on the scientific literature, stream discharges generally account for about a third of the annual precipitation, with the remainder moving through the water cycle via evapotranspiration and groundwater recharge). Despite this concern, consistency in annual ranking of priority subbasin watersheds since 1997 has been based on reliable concentration data and it has helped identify areas in need of remedial actions. Improved flow measurements and updated land cover information would be valuable in

enhancing the understanding of tributary response to storm events in the Canandaigua Lake watershed. The Watershed Council's recently received land cover grant will help in that regard.

Tributary streams were examined for fecal coliform on April 25, May 24, June 7, July 23 and November 6. Lack of stream flow in August, September and October prevented sampling. All sampled tributaries had fecal coliforms at some time during 2001. Results varied from less than one colony to 568 colonies per 100 ml of water sample. The fecal coliform standard for contact recreation is not to exceed 200 colonies per 100 ml of water sample. High fecal coliform levels suggest contamination with animal waste, including human sewage. On April 25, colonies were too numerous to count in the mouth of the Seneca Point Stream and in the discharge of the Bristol Harbor Sewage Treatment Plant (STP). Upstream of the Bristol Harbor STP, the fecal coliform count was only 2 colonies per 100 ml. This large difference was not detected on subsequent dates. There appear to be occasions when the STP is releasing fecal coliforms to the stream. Deep Run had a count of 312 colonies on that same day in April, most likely associated with animal manures. Fecal coliform counts exceeded 200 colonies per 100 ml on three of five sample dates for the Grimes Creek Raceway. An intermittent source of contamination exists in this watershed and it is recommended that more samples be collected to identify possible origins. All tributaries except the Grimes Creek Raceway were below the 200 colony standard during the May sample run. Menteth Gully, Hick's Gully, Fisher Gully, Deep Run and the Grimes Creek Raceway all slightly exceeded the 200 colony standard on July 23, 2001. All tributaries were below the standard on November 6, 2001 except for a sample collected at Hope Point.

Road salt contamination of tributaries varies with location and winter severity (Table 9 and Figure 12). February of 2002 demonstrated the effects of a mild winter with low snowfall. Chloride levels were highest in the Cook's Point Stream (173 mg/L), followed by Lower Sucker Brook (160 mg/L), Upper Sucker Brook (129 mg/L), and Gage Gully (109 mg/L). Only four streams had chloride concentrations exceeding 100 mg/L. The situation at Cook's Point remains a problem despite the new building covering the Town of South Bristol Highway Department's salt pile since 1995. A segment analysis of the Cook's Point stream on February 27, 2002 revealed high levels just below the historically contaminated soil (152 mg/L) but also high

chloride levels upstream of the Highway Department Barns (114 mg/L) as well as in the small tributary flowing under the bridge in the driveway to the South Bristol Town Hall (122 mg/L). These data suggest that the high concentration of chloride in the Cook's Point Stream may be related to the quantity of de-icing salt applied in the rugged terrain of this subwatershed.

Apparently, most of the salt in the historically contaminated soil has leached away. Low results at Clark's Gully and Conklin Gully document background levels typical of forested watersheds lacking major highway corridors.

Thirteen years of chloride record now exist for these tributary streams to Canandaigua Lake. Figure 13 presents a graphical summary where each year is represented by the mean chloride concentration in tributary streams. The year 2000 stands out as a harsh winter where more road salt was being applied during the month of February. While the winter cumulative road salt application totals may vary only slightly from year to year, the event-based application rates produce the significant differences captured in these data.

TABLE 9 - Road salt contamination in Canandaigua Lake tributaries, 2001 and 2002.

Sample location	Chloride concentrations (mg/L)				
	2-18-2001	2-27-2002	1990 - 2002		
			mean	range	
T21 Fallbrook		63	80	53	24 - 167
T20 Deep Run	88	86	56		19 - 179
T19 Gage Gully	142	109	87		17 - 343
T18 Fisher Gully	29	11	11		0 - 29
T17 Upper Vine Valley	35	86	30		14 - 49
T17 Lower Vine Valley	29	53	23		11 - 40
T14 Upper West River	62	70	48		17 - 106
T13 Lower West River	38	44	31		17 - 40
T16 Clark's Gully	1	2	1		0 - 5

T11 Conklin Gully	4	6	3	1 - 10
T12 Upper Naples Creek	25	25	20	10 - 50
T12 Lower Naples Creek	26	32	20	10 - 34
T27 Cook's Point	124	173	134	48 - 244
T10 Tannery Creek *		27		
T09 Reservoir Creek *		37		
T08 Eelpot Creek *		21		
T06 Hick's Point	47	60	47	15 - 116
T05 Seneca Point Gully	49	42	39	14 - 94
T04 Barnes Gully	98	65	67	28 - 203
T03 Menteth Gully	77	76	53	16 - 109
T02 Tichenor Gully	79	74	51	27 - 103
T01 Upper Sucker Brook	168	129	132	43 - 489
T01 Lower Sucker Brook	254	160	160	34 - 607
Outlet	30	39	29	19 - 58

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

FIGURE 12 - Road salt contamination in Canandaigua Lake tributaries.

FIGURE 13 - Long-term watershed chloride trends based on February sampling, 1990-2002.

Stressed stream analyses

Sample Site Descriptions in the Appendix

Fallbrook Stream – Chronological Account of Stressed Stream Analyses

Figures 14-18, Table 10

August 19, 2001

The initial sampling occurred during event conditions caused by 1.4 inches of rainfall during the preceding 24 hours. The goal was to expand the sampling from the crossing of the stream at the Rt. 364 bridge (site FB-1) to upstream segments, and then document the variability of nutrient concentrations and suspended solids. Because of impending nightfall following this Sunday thunderstorm, only one additional location was sampled, site FB-6A, an outflow draining from the west into the main stem of Fallbrook Stream. Results are presented in Table 10 and Figures 14-18. Site FB-6A had considerably higher levels of total phosphorus (500 Φ g P/L

compared to 140 Φ g P/L at site FB-1), combined nitrate and nitrite (2.4 mg N/L compared to 0.4 mg N/L at site FB-1), total kjeldahl nitrogen (180 Φ g N/L compared to 34 Φ g N/L at site FB-1) and total suspended solids (2200 mg/L compared to 320 mg/L at site FB-1). This mid-reach section of Fallbrook Stream was identified as an area of concern. For the next storm event, four additional sites between these two locations were selected for sampling (sites FB-2, FB-3, FB-4 and FB-5).

September 25, 2001

Between 2.5 and 2.7 inches rain fell during this storm. Streams throughout the greater Canandaigua Lake watershed were turbid. Due to increased storm intensity, all segments of Fallbrook Stream had generally worse results. As observed in August, the highest values were detected in the mid-reach segment at site FB-6A. Total phosphorus was 510 Φ g P/L, combined nitrate and nitrite was 3.1 mg N/L, total kjeldahl nitrogen was 3400 Φ g N/L but total suspended solids dropped to 61 mg/L. The flow of water in the main stem of Fallbrook Stream was not as great as expected for the intensity of the storm. In fact, at site FB-6, the stream was dry. Inspection farther upstream revealed an active beaver dam along Mumby Road that was acting as a retention basin.

November 25, 2001

The general location of site FB-6A was investigated in greater detail on this date. In addition to the outflow draining from the west, the main channel of Fallbrook Stream (site FB-6), a culvert pipe draining from the south (site FB-6B) and the roadside ditch (site FB-6C) were added to the previously sampled locations. The day was overcast, with seasonal temperatures and a storm intensity of 0.6 inches. Elevated levels of nutrients and sediment were detected at site FB-3, site FB-6A and site FB-6B. At sites FB-6A and FB-6B, total kjeldahl nitrogen had extremely high levels of 3800 and 4200 Φ g N/L, respectively, suggesting contamination with animal wastes. The main channel (site FB-6) was dry due to the upstream beaver impoundment.

November 29, 2001

Only four days later, another storm dropped 0.8 inches of rainfall on the region. The ground was previously saturated, so much of this precipitation ended up as surface runoff and

contributed to streamflow. One new site was sampled, site FB-4A, a roadside drainage ditch from the east that joined the branch at site FB-4. Except for a lowering of contaminant levels at site FB-3, results were quite similar to November 25 data. Highest levels of total phosphorus, combined nitrate and nitrite, total kjeldahl nitrogen and total suspended solids were again detected at sites FB-6A and FB-6B. A consistent pattern was being repeatedly confirmed.

December 17, 2001

An improvement in roadside property drainage along Rt. 247 south of sites FB-6A and FB-6B was examined by adding site FB-6D to the sampling regime. Three additional sites upstream of the mid-reach segment of concern were also added. These were site FB-7 along Mumby Road (location of the beaver activity), site FB-8 along Depew Road and site FB-9 along County Road 18. Storm totals were 1.1 inches of rainfall just three days after a 1.0 inch storm event. But the storm duration was over 18 hours, thus reducing the overall storm intensity. The greatest concentration of total phosphorus was at site FB-6B (500 Φ g P/L), closely followed by site FB-6A (450 Φ g P/L), then sites FB-6C (270 Φ g P/L) and FB-4A (180 Φ g P/L). Combined nitrate and nitrite were highest at sites FB-6B, FB-6A and FB-8 but did not exceed the U.S. EPA maximum contaminant level of 10 mg N/L designated for safe drinking water. Total kjeldahl nitrogen and total suspended solids were highest at sites FB-6A and FB-6B.

March 26, 2002

Several new sampling locations upslope of site FB-6B were added on this date. These new sites were selected with the participation of the landowner to help determine their potential relative contribution to the contamination that was occurring in the mid-reach segment of Fallbrook Stream. Over 0.8 inches of rainfall fell during an early morning event. High total phosphorus concentrations were detected at site LE-LD (1600 Φ g P/L), site LE-1 (1300 Φ g P/L), site LE-1M (960 Φ g P/L), site LE-2 (800 Φ g P/L) and site LE-HW (430 Φ g P/L). Combined nitrate and nitrite exceeded the EPA standard at site LE-3 where a concentration of 11.0 mg N/L was measured. High values were also noted for sites FE-6**, LE-HW and LE-2. The highest total kjeldahl nitrogen concentration of the six sample dates was measured at site LE-LD (11000

Φg N/L). High levels also occurred at sites LE-2 and LE-1. Total suspended solids were high at site LE-LD (3600 mg/L), site LE-1 (720 mg/L) and site LE-HW (620 mg/L).

Each of these series of stressed stream segments confirmed with increasing accuracy that a mid-reach segment of Fallbrook Stream was being impacted. A cooperative program is underway which will assist with the implementation of best management practices. The Watershed Program Manager and Ontario County Soil and Water Conservation District (SWCD) personnel are working with the pro-active landowner on such projects as relocating a manure storage area in order to minimize contamination of Fallbrook Stream.

TABLE 10 – Results of stressed stream analyses for Fallbrook Stream. TP = total phosphorus, NO₃ + NO₂ = combined nitrate and nitrite, TKN = total kjeldahl nitrogen, TSS = total suspended solids.

	site	TP Φg P/L	NO ₃ + NO ₂ mg N/L	TKN Φg N/L	TSS mg/L
08/19/01	FB-1	140	0.40	320	34
	FB-6A	500	2.40	2200	180
09/25/01	FB-1	130	0.83	560	20
	FB-2	140	0.87	560	14
	FB-3	120	1.10	680	5
	FB-4	62	0.60	490	<4
	FB-5	200	1.90	890	8
	FB-6	dry			
	FB-6A	510	3.10	3400	61
11/25/01	FB-1	160	0.20	270	45
	FB-2	220	0.07	300	56

	FB-3	510	1.80	3000	1600
	FB-5	80	0.23	170	4
	FB-6	dry			
	FB-6A	510	0.92	3800	200
	FB-6B	510	1.10	4200	1500
	FB-6C	390	0.35	410	160
11/29/01	FB-1	70	0.09	270	18
	FB-2	60	0.12	450	17
	FB-3	80	0.31	240	26
	FB-4	70	0.41	210	11
	FB-4A	120	0.58	280	11
	FB-5	150	1.20	410	11
	FB-6	dry			
	FB-6A	510	1.70	4700	1400
	FB-6B	510	1.80	5400	270
	FB-6C	260	1.20	420	16

TABLE 10 (continued) – Results of stressed stream analyses for Fallbrook Stream.

TP = total phosphorus, $\text{NO}_3 + \text{NO}_2$ = combined nitrate and nitrite, TKN = total kjeldahl nitrogen, TSS = total suspended solids.

	site	TP <u>µg P/L</u>	$\text{NO}_3 + \text{NO}_2$ <u>mg N/L</u>	TKN <u>µg N/L</u>	TSS <u>mg/L</u>
12/17/01	FB-1	6	1.70	220	<4
	FB-2	5	2.70	150	<4
	FB-3	7	2.10	270	<4
	FB-4	26	1.20	160	10
	FB-4A	180	0.89	490	78
	FB-5	14	3.20	270	<4
	FB-6	13	0.62	200	<4
	FB-6A	450	6.50	1600	200
	FB-6B	500	7.20	1800	190
	FB-6C	270	0.90	600	95
	FB-6D	80	1.30	650	14
	FB-7	82	0.08	860	7
	FB-8	24	6.80	740	<4
	FB-9	36	0.17	560	5

03/26/02	LE-1	1300	0.78	2800	720
	LE-2	800	2.00	7600	61
	LE-3	21	11.00	680	<4
	FB-6C	100	1.00	880	96
	FB-6**	50	3.90	1300	71
	FB-6D	86	0.83	910	65
	LE-1M	960	1.20	1400	190
	LE-HW	430	2.40	1500	620
	LE-LD	1600	0.82	11000	3600

FIGURE 14 – Sampling sites, stressed stream analyses of Fallbrook Stream.

FIGURE 15 – Total phosphorus, stressed stream analysis of Fallbrook Stream.

FIGURE 16 – Combined nitrate and nitrite, stressed stream analysis of Fallbrook Stream.

FIGURE 17 – Total kjeldahl nitrogen, stressed stream analysis of Fallbrook Stream.

FIGURE 18 – Total suspended solids, stressed stream analysis of Fallbrook Stream.

Vine Valley Stream – Chronological Account of Stressed Stream Analyses

Figures 19-23, Table 11

March 13, 2001

The day was cold, overcast and windy. About 0.5 inches of rainfall had recently fallen following some melt of snowfall from the first days of the month. This was the initial sampling of segments in the Vine Valley Stream subbasin. The stream headwaters are largely agricultural while the lower reaches flow through a high density seasonal trailer park. Site VV-1 is located about 100 meters upstream from Canandaigua Lake. Site T-17 is located where the stream crosses beneath the South Lake Road bridge. Sites VV-2, VV-3 and VV-4 represent seasonal branches that drain northward off South Hill, cross South Vine Valley Road and then join the main stem of the Vine Valley Stream. Site VV-5 is located where the main stem flows beneath the bridge on Dinehart Cross Road. On this day, high concentrations of total phosphorus were detected at site VV-1 (510 Φ g P/L), site T-17 (520 Φ g P/L) and site VV-5 (470 Φ g P/L). Combined nitrate and nitrite levels were low at all sites. Total kjeldahl nitrogen peaked at site VV-5 (2600 Φ g N/L), suggesting contamination from animal manures associated with upstream agricultural activity. Total suspended solids were moderately elevated at the two downstream segments (site T-17 and site VV-1).

December 17, 2001

Weather had been unusually warm for mid-December. One inch of rainfall occurred on December 14 and another 1.1 inches on December 17 when the sampling took place. Site VV-6, farther upstream where the main channel crosses North Vine Valley Road, was added to the sampling sites. It had the highest level of total phosphorus (180 Φ g P/L), exceeding all other sites by nearly tenfold. Combined nitrate and nitrite, and total kjeldahl nitrogen were also highest at this upstream site. Permission should be sought to sample on private property above and below the concentrated animal feeding operation to confirm its role in impacting the Vine Valley Stream. Total suspended solids were below detection throughout the stream and its associated dendritic branches.

February 1, 2002

The two days prior to this sampling included nearly every meteorological condition: ice, rain, snow and strong winds! In total, over 1.8 inches of precipitation was recorded. The seasonal drainages off South Hill (sites VV-2, VV-3, VV-4) had low results. Total phosphorus concentration was greatest at site VV-6 (480 Φ g P/L), closely followed by site VV-5 (440 Φ g P/L). Levels of combined nitrate and nitrite were highest at sites VV-5 and VV-6 (6.3 and 5.6 mg N/L, respectively). The two upstream sites once again had the greatest concentration of total kjeldahl nitrogen (4200 Φ g N/L), further supporting agricultural impacts. Curiously, site VV-1, near Canandaigua Lake, also had high total kjeldahl nitrogen (3900 Φ g N/L) perhaps suggesting septic system problems nearby. All segments except site VV-4 had total suspended solids exceeding 350 mg/L.

March 26, 2002

Rain fell slowly throughout the evening of March 25, totaling 0.8 inches. Nutrient and sediment concentrations in the stream were only slightly elevated due to the low intensity nature of the storm. The highest concentration of total phosphorus was detected at site VV-6 (220 Φ g P/L). This site also had the highest combined nitrate and nitrite (3.7 mg N/L), total kjeldahl nitrogen (1600 Φ g N/L) and total suspended solids (90 mg/L). The two downstream stations had slightly elevated levels of total kjeldahl nitrogen (460 and 650 Φ g N/L, respectively). Although concentrations were lower on this sampling date, results fit the pattern of earlier dates.

April 3, 2002

Overcast with 0.9 inches of rain falling on this day. A new site, VV-4B, was established to examine another seasonal drainage off South Hill that passes beneath Dinehart Cross Road just north of its intersection with South Vine Valley Road. Elevated levels of total phosphorus, combined nitrate and nitrite, and total kjeldahl nitrogen were measured in samples from sites VV-5 and VV-6. All other results were low.

May 2, 2002

Only 0.4 inches of rain fell immediately prior to this sampling date, but it was an intense morning storm. With the growing season actively underway, it was anticipated that nutrients levels might be lower due to biological absorption. In fact, total phosphorus was still high at site VV-6 (240 Φ g P/L) as well as total kjeldahl nitrogen (1300 Φ g N/L). Total suspended solids were moderately low to very low at all sites. Combined nitrate and nitrite peaked at site VV-6 (3.2 mg N/L).

Each of these series of stressed stream segments confirmed with increasing accuracy that an upstream segment of the Vine Valley Stream was being impacted. Ongoing work including riparian area management and nutrient management will hopefully alleviate existing problems. One landowner is voluntarily cost sharing to pay for improvements on his property that are sponsored through a NYS grant. Additional contacts with local owners are recommended so that best management practices can be implemented/enhanced to improve the quality of the stream.

TABLE 11 – Results of stressed stream analyses for the Vine Valley Stream.

TP = total phosphorus, $\text{NO}_3 + \text{NO}_2$ = combined nitrate and nitrite, TKN = total kjeldahl nitrogen,

TSS = total suspended solids.

	site	TP <u>µg P/L</u>	$\text{NO}_3 + \text{NO}_2$ <u>mg N/L</u>	TKN <u>µg N/L</u>	TSS <u>mg/L</u>
03/13/01	VV-1	510	1.20	1900	350
	T-17	520	1.30	1800	420
	VV-2	120	0.67	250	41
	VV-3	230	0.47	430	100
	VV-4	64	0.29	220	12
	VV-5	470	2.30	2600	120
12/17/01	VV-1	15	0.33	150	<4
	T-17	12	0.29	160	<4
	VV-2	23	0.21	76	<4
	VV-3	6	0.48	110	<4
	VV-4	dry			
	VV-5	6	1.00	140	<4
	VV-6	180	3.30	600	<4
02/01/02	VV-1	360	1.90	3900	680
	T-17	310	1.90	2200	560
	VV-2	140	0.25	800	350
	VV-3	190	0.33	1200	360
	VV-4	30	0.07	120	6

	VV-5	440	6.30	4200	410
	VV-6	480	5.70	4200	470
03/26/02	VV-1	53	1.30	460	70
	T-17	55	1.40	650	67
	VV-2	14	0.12	170	12
	VV-3	37	0.17	180	30
	VV-4	9	0.07	130	4
	VV-5	36	0.26	260	14
	VV-6	220	3.70	1600	90

TABLE 11(continued) – Results of stressed stream analyses for the Vine Valley Stream.
 TP = total phosphorus, $\text{NO}_3 + \text{NO}_2$ = combined nitrate and nitrite, TKN = total kjeldahl
 nitrogen, TSS = total suspended solids.

	site	TP <u>Φg P/L</u>	$\text{NO}_3 + \text{NO}_2$ <u>mg N/L</u>	TKN <u>Φg N/L</u>	TSS <u>mg/L</u>
04/03/02	VV-1	50	1.40	430	29
	T-17	52	1.50	450	25
	VV-2	13	0.09	240	4
	VV-3	14	0.16	160	5
	VV-4	6	0.04	130	4
	VV-4B	16	0.22	180	4
	VV-5	150	3.50	770	30
	VV-6	150	2.30	570	21
05/02/02	VV-1	78	0.44	710	110
	VV-2	65	0.49	700	97
	VV-3	43	0.08	290	35
	VV-4	10	0.02	170	4
	VV-4B	30	0.11	95	12
	VV-5	110	1.54	840	130
	VV-6	240	3.20	1300	110

FIGURE 19 – Sampling sites, stressed stream analyses of the Vine Valley Stream.

FIGURE 20 – Total phosphorus, stressed stream analysis of the Vine Valley Stream.

FIGURE 21 – Combined nitrate and nitrite, stressed stream analysis of the Vine Valley Stream.

FIGURE 22 – Total kjeldahl nitrogen, stressed stream analysis of the Vine Valley Stream.

FIGURE 23 – Total suspended solids, stressed stream analysis of the Vine Valley Stream.

Special Studies

On September 6, 2001, shortly after the foam first appeared on the lake, a nutrient profile was completed at the two mid-lake sampling stations to determine if nutrient levels had suddenly increased and, if they had, could this account for the foam. Total phosphorus concentrations at both stations, and at all three depths in the water column (2 m, 25 m, 50 m) were below the detection limit of 3.0 Φ g P/L. The depth profile for nitrate and nitrite at Deep Run was 0.05 mg N/L, 0.37 mg N/L and 0.38 mg N/L, and at Seneca Point was 0.04 mg N/L, 0.35 mg N/L and 0.36 mg N/L. Chlorophyll *a* concentrations at the mid-lake stations averaged 3.34 Φ g /L and secchi disk depth averaged 4.8 meters. These results seemed typical and, therefore, provided no insight on the cause of the large foam streaks.

The Canandaigua Lake Outlet was surveyed on the afternoon of October 29. It was an overcast day with an air temperature about 10EC. Water temperature was 8.88EC and the dissolved oxygen level was 12.15 mg/L representing 105% of saturation. This relative measure often exceeds 100% in fast flowing, well aerated streams. The conductivity was 445 Φ S/cm. The Outlet contained a variety of Type I, II and III macro-invertebrates including dobson fly larvae, crane fly larvae, damsel fly nymph, stonefly nymph, mayfly nymph, riffle beetle larvae, water penny, scud, water boatman, leatherback water bug, water strider, leech, zebra mussel, annelid worm, crayfish, and net-spinning and case-building caddis fly larva. Fish observed included smallmouth bass, fall fish, long-nosed dace and blunt-nosed minnow.

Conditions in Naples Creek on a cool, overcast afternoon (November 12) were excellent. Water temperature was 8.63EC and dissolved oxygen stood at 11.87 mg/L representing 102% of saturation. The conductivity averaged 473 Φ S/cm. The stream macro-invertebrates observed by students included crane fly larvae, 3 species of stonefly nymph, damselfly nymph, dragonfly nymph, mayfly nymph, caddis fly larvae, fish fly larvae, leatherback water bug, water boatman

and 2 species of crayfish. These are Type I and II organisms typical of cold, clean waters. Fish present included plentiful rainbow trout parr, creek chub and black-nosed dace .

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APPENDIX

1. Stream sampling descriptions in the Canandaigua Lake watershed.

Station	Description		
T21 Fallbrook	midchannel and downstream from Rt 364		
T20 Deep Run	midchannel and downstream from Rt 364		
T19 Gage Gully	midchannel and just upstream from East Lake Road		
T18 Fisher Gully	midchannel and downstream, under large willow near Water Plant		
T17 Upper Vine Valley	midchannel and downstream from Dinehart Cross Road		
T17 Lower Vine Valley	midchannel, end of northern entrance (lakeside) to trailer park		
T14 Upper West River	midchannel from Rt 364 bridge		
T13 Lower West River	midchannel from Sunnyside Road bridge		
T16 Clark's Gully	midchannel and just upstream from West Avenue		
T11 Conklin Gully	midchannel and downstream at underground cable crossing sign		
T12 Upper Naples Creek	midchannel at Rt 245 bridge		
T12 Lower Naples Creek	midchannel at Parrish Flats bridge		
T27 Cook's Point	midchannel and downstream from Cook's Point Road		
T10 Tannery Creek	midchannel at East Hill Road		
T09 Reservoir Creek	midchannel at Rt 21 bridge		
T08 Eelpot Creek	midchannel from lower fishing access parking lot		
T06 Hick's Point	midchannel at Seneca Point Road bridge		
T05 Seneca Point Gully	midchannel and downstream from Seneca Point Road		
T04 Barnes Gully	midchannel and downstream, at base of old stairs along north bank		
T03 Menteth Gully	midchannel and downstream from West Lake Road		
T02 Tichenor Gully	midchannel and upstream, at old bridge foundation		
T01 Upper Sucker Brook	midchannel at upper bridge in Woodlawn Cemetery		
T01 Lower Sucker Brook	midchannel upstream of NYS boat launch		
Lake Outlet	midchannel and downstream from old Lakeshore Drive bridge		
FB-1	Rt. 364 bridge	VV-1	stream mouth
FB-2	5 & 20 west	VV-2	S. Vine Valley Road (west)
FB-3	Smith Road culvert	VV-3	S. Vine Valley Road (middle)
FB-4	5 & 20 middle	VV-4	S. Vine Valley Road (east)
FB-4A	road drainage from east	VV-4B	Dinehart Cross Road (south)
FB-5	Freshour Road culvert	VV-5	Dinehart Cross Road culvert

FB-6	main channel	VV-6	N. Vine Valley Road culvert
FB-6A	outflow coming from west		
FB-6B	culvert from south		
FB-6C	road drainage from west		
FB-6D	new drainage from Rt. 247		
FB-7	Mumby Road culvert		
FB-8	Depew Road culvert		
FB-9	County Road 18 culvert		

2. Monthly Canandaigua Lake *in situ* field data: mid-lake at Deep Run

Monthly Canandaigua Lake *in situ* field data: mid-lake at Seneca Point

Winter Canandaigua Lake *in situ* field data: mid-lake at Black Point

3. Tributary total phosphorus concentration (Φ g P/L) during storm events.

		3/13/01	9/25/01	12/17/01	2/01/02	3/26/02	mean ►	s.e.
T-1	Sucker Brook	430	210	95	250	330	263 ►	56
T-2	Tichenor Gully	190	64	11	220	160	129 ►	39
T-3	Menteth Gully	270	32	4	66	270	128 ►	59
T-4	Barnes Gully	23	23	5	110	200	72 ►	37
T-5	Seneca Point Gully	140	140	59	170	240	150 ►	29
T-6	Hick's Point Gully	35		6	120	68	57 ►	25
T-27A	Cook's Point	160		4	200	86	113 ►	43
T-7	Grimes Creek	33	29	6	180	23	54 ►	32
T-8	Eelpot Creek	410	31	7	360	39	169 ►	89
T-9	Reservoir Creek	370	54	11	120	72	125 ►	64
T-10	Tannery Creek	200	54	18	190	60	104 ►	38
T-12	Naples Creek	180	340	9	360	25	183 ►	75
T-13	Lower West River	25	54	46	47		43 ►	6
T-13A	Middle West River	160		36	120	22	85 ►	33
T-13B	Upper West River	180		29	180		130 ►	50
T-14	Northern West River	240	290	23	240		198 ►	60
T-17	Vine Valley	520	83	12	310	55	196 ►	96
T-18	Fisher Gully	110	38	21	500	87	151 ►	89
T-19	Gage Gully	130	47	8	440	50	135 ►	79
T-20	Deep Run	130	38	5	220	42	87 ►	39
T-21	Fallbrook Stream	200	130	120	160	40	130 ►	27

3 (continued). Tributary total phosphorus concentration (Φ g P/L) during storm events, years of record.

		<u>1997-1999</u>	<u>2000</u>	<u>2001-2002</u>
		(15 events)	(7 events)	(5 events)
T-1	Sucker Brook	227	146	263
T-2	Tichenor Gully	85	95	129
T-3	Menteth Gully	51	185	128
T-4	Barnes Gully	35	162	72
T-5	Seneca Point Gully	106	176	150
T-6	Hick's Point Gully	38	124	57
T-27A	Cook's Point	93	218	113
T-7	Grimes Creek	44	52	54
T-8	Eelpot Creek	93	136	169
T-9	Reservoir Creek	223	274	125
T-10	Tannery Creek	34	123	104
T-12	Naples Creek	182	83	183
T-13	Lower West River	74	51	43
T-13A	Middle West River			85
T-13B	Upper West River	202	78	130
T-14	Northern West River			198
T-17	Vine Valley	233	62	196
T-18	Fisher Gully	70	142	151
T-19	Gage Gully	171	170	135
T-20	Deep Run	150	96	87
T-21	Fallbrook Stream	130	51	130

4. Tributary combined nitrate and nitrite concentration (mg/L) during storm events.

		3/13/01	9/25/01	12/17/01	2/01/02	3/26/02	mean ►	s.e.
T-1	Sucker Brook	1.40	0.44	3.10	1.60	0.80	1.46 ►	0.46
T-2	Tichenor Gully	0.83	1.00	3.10	1.40	0.92	1.45 ►	0.42
T-3	Menteth Gully	0.83	0.84	0.51	0.35	0.47	0.60 ►	0.10
T-4	Barnes Gully	0.56	1.50	0.25	0.51	0.28	0.62 ►	0.23
T-5	Seneca Point Gully	0.71	1.30	0.43	0.87	0.58	0.78 ►	0.15
T-6	Hick's Point Gully	0.70		0.15	0.51	0.41	0.44 ►	0.11
T-27A	Cook's Point	0.69		0.75	0.43	0.34	0.55 ►	0.10
T-7	Grimes Creek	0.81	0.89	0.68	0.52	0.62	0.70 ►	0.07
T-8	Eelpot Creek	0.98	0.59	0.68	1.50	1.10	0.97 ►	0.16
T-9	Reservoir Creek	0.81	0.34	0.35	1.60	0.90	0.80 ►	0.23
T-10	Tannery Creek	0.66	0.28	0.16	0.40	0.26	0.35 ►	0.09
T-12	Naples Creek	0.85	0.60	0.56	0.82	0.71	0.71 ►	0.06
T-13	Lower West River	0.36	0.03	0.34	0.11		0.21 ►	0.08
T-13A	Middle West River	1.10		1.20	1.40	1.30	1.25 ►	0.06
T-13B	Upper West River	1.50		1.60	3.40		2.17 ►	0.62
T-14	Northern West River	1.80	0.34	1.40	4.20		1.94 ►	0.82
T-17	Vine Valley	1.30	1.10	0.29	2.20	1.40	1.26 ►	0.31
T-18	Fisher Gully	0.78	1.50	0.99	1.20	0.24	0.94 ►	0.21
T-19	Gage Gully	4.00	2.70	3.90	8.80	3.90	4.66 ►	1.06
T-20	Deep Run	1.60	0.92	5.60	8.90	4.00	4.20 ►	1.44
T-21	Fallbrook Stream	1.40	0.83	1.20	2.70	1.70	1.57 ►	0.32

4 (continued). Tributary combined nitrate and nitrite concentration (mg N/L) during storm events, years of record.

		<u>1997-1999</u> (15 events)	<u>2000</u> (7 events)	<u>2001-2002</u> (5 events)
T-1	Sucker Brook	1.23	1.69	1.46
T-2	Tichenor Gully	0.89	0.88	1.45
T-3	Menteth Gully	0.62	0.47	0.60
T-4	Barnes Gully	0.46	0.22	0.62
T-5	Seneca Point Gully	0.43	0.42	0.78
T-6	Hick's Point Gully	0.44	0.50	0.35
T-27A	Cook's Point	0.45	0.31	0.44
T-7	Grimes Creek	0.56	0.63	0.70
T-8	Eelpot Creek	0.88	1.03	0.97
T-9	Reservoir Creek	0.88	0.78	0.80
T-10	Tannery Creek	0.32	0.23	0.35
T-12	Naples Creek	0.55	0.55	0.71
T-13	Lower West River	0.57	0.71	0.17
T-13A	Middle West River			1.00
T-13B	Upper West River	1.35	2.44	1.30
T-14	Northern West River			1.55
T-17	Vine Valley	0.98	1.75	1.26
T-18	Fisher Gully	0.90	0.62	0.94
T-19	Gage Gully	3.24	4.88	4.66
T-20	Deep Run	2.22	4.00	4.20
T-21	Fallbrook Stream	2.36	3.35	1.57

5. Tributary total suspended solids (mg/L) during storm events.

		3/13/01	9/25/01	12/17/01	2/01/02	3/26/02	mean ►	s.e.
T-1	Sucker Brook	270	280	31	110	290	196 ►	53
T-2	Tichenor Gully	110	6	4	200	270	118 ►	53
T-3	Menteth Gully	160	4	4	470	430	214 ►	101
T-4	Barnes Gully	11	4	4	390	520	186 ►	112
T-5	Seneca Point Gully	52	8	4	630	360	211 ►	124
T-6	Hick's Point Gully	14		4	350	130	125 ►	80
T-27A	Cook's Point	39		4	340	150	133 ►	76
T-7	Grimes Creek	23	4	4	270	32	67 ►	51
T-8	Eelpot Creek	320	4	4	820	51	240 ►	157
T-9	Reservoir Creek	260	14	4	410	130	164 ►	77
T-10	Tannery Creek	140	12	9	440	71	134 ►	80
T-12	Naples Creek	120	230	6	940	34	266 ►	173
T-13	Lower West River	5	4	7	87		26 ►	21
T-13A	Middle West River	79		4	160	24	69 ►	35
T-13B	Upper West River	82		4	270		119 ►	79
T-14	Northern West River	110	30	4	200		86 ►	44
T-17	Vine Valley	420	4	4	560	67	211 ►	117
T-18	Fisher Gully	44	4	5	3400	110	713 ►	672
T-19	Gage Gully	36	4	4	1200	79	265 ►	234
T-20	Deep Run	42	4	4	460	68	116 ►	87
T-21	Fallbrook Stream	91	20	16	310	44	96 ►	55

5 (continued). Tributary total suspended solids (mg/L) during storm events, years of record.

		<u>1997-1999</u> (15 events)	<u>2000</u> (7 events)	<u>2001-2002</u> (5 events)
T-1	Sucker Brook	85	68	196
T-2	Tichenor Gully	52	68	118
T-3	Menteth Gully	52	242	214
T-4	Barnes Gully	43	192	186
T-5	Seneca Point Gully	74	147	211
T-6	Hick's Point Gully	49	130	100
T-27A	Cook's Point	120	272	107
T-7	Grimes Creek	81	77	67
T-8	Eelpot Creek	157	227	240
T-9	Reservoir Creek	123	248	164
T-10	Tannery Creek	19	16	134
T-12	Naples Creek	253	135	266
T-13	Lower West River	28	11	20
T-13A	Middle West River			53
T-13B	Upper West River	164	45	71
T-14	Northern West River			69
T-17	Vine Valley	128	32	211
T-18	Fisher Gully	62	179	713
T-19	Gage Gully	104	125	265
T-20	Deep Run	150	75	116
T-21	Fallbrook Stream	146	38	96

6. Coliform bacteria results. TNTC = too numerous to count, ns = not sampled

Lake shoreline – total coliform colonies per 100 ml.

Site	5/30/01	6/26/01	7/24/01	8/23/01
L-1	26	30	5	7
L-2	<1	1	3	18
L-3	8	41	6	2
L-4	1	1	3	4
L-5	16	1	19	4
L-6	<1	<1	20	11
L-7	45	1	5	7
L-8	20	4	14	19
L-9	<1	3	11	7
L-10	<1	20	2	60

Tributaries – fecal coliform colonies per 100 ml.

Site	4/25/01	5/24/01	6/07/01	7/23/01	11/06/01
T-1	33	70	ns	ns	ns
T-2	<1	61	ns	ns	ns
T-3	5	122	ns	292	ns
T-4	1	17	16	ns	ns
T-6	12	108	ns	380	ns
T-8	29	32	ns	ns	18
T-12	11	19	ns	122	56
T-13	16	14	ns	59	2
T-14	1	55	ns	ns	ns
T-15	TNTC	8	136	8	36
T-15A	2	15	ns	21	44
T-15B	TNTC	28	ns	20	<1
T-16	2	5	ns	ns	ns
T-17	3	13	ns	22	17
T-18	2	47	ns	256	2
T-20	312	168	ns	568	156
T-A	8	ns	ns	ns	ns

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T-B	62	52	ns	208	<1
T-C	TNTC	1504	ns	20	<1
T-D	176	188	ns	ns	318

7. 2000-2001 daily precipitation records (City of Canandaigua Water Treatment Facility)