Analysis of the Existing Water Quality Database for the Sandy Creek and South Sandy Creek Watersheds – 1997 to 2005

Joseph C. Makarewicz and Theodore W. Lewis
Department of Environmental Science and Biology
State University of New York at Brockport

Technical Report to the Jefferson County Soil and Water Conservation District

Project Funded by
The Finger Lakes – Lake Ontario Watershed Protection Alliance
through the
Jefferson County Soil and Water Conservation District

October 2006

Table of Contents

Analysis of the Existing Water Quality Database for the Sandy Creek and South Sandy Creek Watersheds – 1997 to 2005

Summary

In general, the overall water quality of South Sandy Creek and Sandy Creek is quite good with relatively low levels of nutrients and high dissolved oxygen concentrations. Evaluation of the available parameters demonstrated that the existing water quality is consistent with the ability to support a desirable and healthy aquatic food web. Analysis and interpretation of the data available was limited by chemical methodology, especially in regards to phosphorus. Although we can not demonstrate an improvement in water quality, we can conclude that the there has not been any major degradation in the water quality of Sandy Creek and South Sandy Creek.

Recommendations

1. The officials and citizens of Jefferson County should continue to be proactive in protecting and maintaining the water quality of the County's surface water and the Lake Ontario watershed. Their work is a wonderful success story.
2. Critically review the laboratory capabilities including their detection limits, especially as it pertains to phosphorus. State and National Laboratory Certification does ensure that a rigorous quality control / quality assurance program will be in place. However, lab certification does not necessarily ensure data in the range to evaluate ambient water quality levels. Many certified labs focus on sewage and industrial effluent which may have concentrations of nutrients orders of magnitude higher than surface runoff. There are also many non-certified labs that specialize in lake and stream monitoring. There is a need to consider detection limits of analytical methodology. If it is not low, as it was here for phosphorus, improvements can not be demonstrated as high percentages of analyses are below the detection limit of the method employed.
3. Other water quality parameters, such as total Kjeldahl nitrogen (organic nitrogen) and total suspended solids could be added to the analytical regime to detect possible improvements in the watersheds. Suspended solids would have been a useful parameter as turbidity was not measured until 1999, after BMP implementation had occurred. Total Kjeldahl nitrogen could have been used to detect improvements due to management practices that involved manure handling, storage and spreading.
4. The study was also limited by inconsistent sampling sites in the watersheds. There were numerous geographical changes of sites over time which made a full historical trend analysis and BMP induced changes in water quality impossible.
5. To prove scientifically, at the watershed scale, that water quality improvements are due to implemented Best Management Practices is difficult. To accomplish this goal, the study should be proposed **prior** to the implementation of the practices with sampling design and methodology developed and maintained that will allow the question asked to be answered. Even with this approach, satisfactory results are tenuous.

Introduction

Runoff from agricultural lands containing soil and nutrients poses a known threat to the water quality of embayments and coastal regions of Lake Ontario (Makarewicz 2000). The Lakeview Marsh State Wildlife Management Area in Jefferson County, NY is a prime example of these types of ecologically valuable coastal wetland and embayment habitats. This embayment / wetland complex is fed by the watersheds of Sandy Creek and South Sandy Creek. The mouths of these creeks contain globally rare freshwater dunes, diverse wetlands and several types of globally rare vegetation. Sandy Creek also provides an emergency unfiltered drinking water supply for the Village of Adams and the Hamlet of Adams Center. In general, the environmental effects of agricultural runoff, including eutrophication and sedimentation, on surface water bodies are serious local, regional and national issues. These issues create a dilemma for governmental leaders in agricultural areas; their most important economic industry, agriculture, may also be the cause of environmental degradation. For farmers, this is further exacerbated by the high profile increase of governmental regulation on agricultural operations. The agricultural industry needs scientific evidence that they are capable of being part of the solution not just part of the problem.

Current theory states that nutrient reduction from impacted watersheds will improve lake water quality by reducing limiting nutrients thus decreasing phytoplankton, metaphyton and macrophyte populations (Osgood 1999). Clearly BMPs, if properly initiated, will lead to a reduction of nutrient and soil loss from the watershed and to nutrient declines in the water body that receives its discharge. In Lake Erie, for example, massive reductions in point and non-point loads of phosphorus has led to significant improvements in water quality, reductions in phytoplankton populations and reductions in nuisance algal species (Makarewicz and Bertram 1991).

In reference to watersheds and lakes, the "Phosphorus Paradigm" is that phosphorus reduction will reduce algae and macrophyte populations and improve water clarity and quality. However, the evidence for a connection between nutrient reductions by BMPs and reductions of nuisance plant growth is not as strong as it is generally believed (Osgood 1999). Most examples of successful restoration of lakes suffering from over loads of phosphorus represent "point" source reduction or control: sewage effluent that has been treated or diverted (Moss *et al*. 1997). Dealing with non-point sources has proven to be more difficult. Phosphorus in runoff usually comes from multiple sources, such as storm sewers, fertilized lawns or agricultural fields. In addition, the treatment or management practice is normally a low-tech approach resulting only in a partial reduction in phosphorus compared to much higher rates of removal for point source loading. As a result, it is not possible to totally eliminate the limiting nutrient phosphorus. Unlike point sources, which can be turned off, non-point sources can only be turned down.

The assumption of the "Phosphorus Paradigm" that we can obtain the same results from reduction of non-point loading as point source loading has to be critically tested (Osgood 1999). Several studies have shown the "local" effectiveness of BMP implementation in reducing nutrient loss, soil loss and bacteria counts (Cook *et al*. 1996, Meals 1996, Meals

2001, Gilliam 1995). For example, with livestock operations a >90% reduction in phosphorus loss to immediate downstream locations was achieved by trapping manure in a lagoon (Gilliam 1995). Phosphorus export from cornfields was 1500% higher where manure was spread in the winter rather than in the spring (Meals 1996). It follows that timing of manure spreading is critical to reducing phosphorus losses and other nutrients, such as nitrate, from a watershed to downstream systems.

However, from a watershed perspective, local effects do not always translate to ecosystem or watershed-wide reductions in nutrients and soil loss (Meals 1996). In fact, BMPs introduced in small portions of watersheds in the Finger Lakes/Lake Ontario region have not effectively demonstrated a connection between nutrient and erosion reduction and visual or measurable lake-wide reductions of nutrients, metaphyton, or aquatic plant populations (Bosch *et al*. 2001). This inability to demonstrate mitigation of stresses caused by nutrient enhancement in downstream systems is the result of confounding factors inherent in non-experimental evaluations and/or the use of very large watersheds where a single manipulation (i.e., a BMP) of a small area will not provide a large enough reduction in nutrients to affect change in downstream nutrient concentration, nutrient loading, and metaphyton and macrophyte population size.

The Site:
The headwaters of Sandy Creek are in Lewis County. The 95,600-acre watershed extends across Jefferson County, through the Tug Hill Plateau (Figure 1). The watershed of South Sandy Creek is almost entirely in Jefferson County and consists of 68,600 acres (Figure 1). There are approximately 110 farms (85% dairy operations) in the two watersheds resulting in 53% of the land use in the Sandy Creek watershed and 29% of the land use in the South Sandy Creek watershed to be in agriculture (JCWQCC 2002).

Jefferson County's Sandy and South Sandy Creeks watershed and associated embayments (Lakeview Pond, Floodwood Pond, and Colwell Ponds, all within the Lakeview Marsh State Wildlife Management Area) have been the site of a regional watershed approach. Over $1 million has been spent on 25 farms implementing Best Management Plans (BMPs) to mitigate the impacts of dairy farming on down stream systems (Table 1 and Figure 1). The Jefferson County Water Quality Coordinating Committee (WQCC) has been collecting stream monitoring data and water quality information for Lake Ontario tributaries in Jefferson County since October 1997. This information is used to support funding for water quality implementation projects on a watershed approach annually and has been used to update the New York State Department of Environmental Conservation Priority Waterbodies List (PWL) for the water bodies in Jefferson County. The goal of the proposed project is to evaluate the existing database of water quality data and to determine the effect of the implemented BMPs on water quality of Sandy and South Sandy Creeks, which drain into Lakeview Marsh, an embayment of Lake Ontario. By evaluating the effectiveness of the current water quality program in Jefferson County to control pollution from agricultural stormwater runoff, the agricultural community (both government and private) can evaluate the effects of their actions and make informed decisions for future management. This final report, documenting the findings and the methods, will enhance the capacity of

the Jefferson County Water Quality Coordinating Committee (JCWQCC) and its member agencies to make management decisions for the specific watersheds and allow the Committee to use the methodology to perform its own analysis of additional water quality information collected in other areas of the county.

Methods

The Jefferson County Soil and Water Conservation District founded the Jefferson County Water Quality Coordinating Committee (JCWQCC) in 1990. The JCWQCC is responsible for water quality problems in Jefferson County and has collected water samples at both the Sandy Creek and South Sandy Creek on a regular basis since the program's inception in 1997 (JCWQCC 2002). All samples were collected and analyzed by the JCWQCC or their consultants. Data was provided to SUNY Brockport for analysis and interpretation.

Water quality sampling locations and duration have been variable since 1997 due to staffing problems and changes in the County's sampling priorities. Two main sites, one in each watershed near the mouth of the streams, have been consistently sampled throughout the study period. The main site on South Sandy Creek is Site 2 on NYS Route 3 while the main site on Sandy Creek is Site 6 also on NYS Route 3 (Figure 1). Additional sites have been sampled during the study period and a detailed listing of the sampling sites, duration of samples taken, and their location is presented in Table 2.

A total of six sites were monitored and 477 samples were collected on the two streams over a nine year period. Detailed field and laboratory methods were presented in the 2002 Annual Water Quality Report by the Jefferson County Water Quality Coordinating Committee (JCWQCC 2002). In general, sampling was conducted on a bi-weekly basis when possible. Field measurements of dissolved oxygen, conductivity, pH, and temperature were done with a Hydrolab H20 which was calibrated weekly. Stream water samples were collected for laboratory analysis and transported on ice. Samples were either analyzed within 24 hours or preserved with acid prior to analysis. Water samples were analyzed by JCWQCC at their offices for nitrate, nitrite, ammonia and total phosphorus using a Hach DR/2010 and EPA approved procedures (Table 3). **Additional forms of phosphorus were analyzed and reported in the original data set but were not used in this report.** Operationally total phosphorus has four components: (soluble reactive phosphorus, organic soluble phosphorus, organic suspended phosphorus and acid hydrolyzable suspended phosphorus). In many instances, a chemical fraction of phosphorus was reported at a higher concentration than that of total phosphorus. For example, soluble or dissolved phosphorus was reported as higher than total phosphorus. This is impossible. This could be due to improper cleaning of sampling bottles and glassware used in analysis, improper lab technique and/or that many of the measurements were below or near the detection limit of the equipment employed. As a result only total phosphorus is reported on here.

A quality control program was proposed in the 2002 report (JCWQCC 2002) which included replicate samples and a quarterly inter-laboratory comparison with a State

Certified Laboratory. But unfortunately, the quality control program was not implemented.

Results

The water quality data that is available for the six sites monitored on Sandy Creek and South Sandy Creek is summarized in the database rubric presented in Table 2. A statistical summary of the data (average, standard error and range) is presented in Table 4 while all data available for dissolved oxygen, conductivity, pH, water temperature, nitrate, nitrite, ammonia, total phosphorus and turbidity for Sites 1-6 are presented in Tables 5-10. A detailed summary by parameter of the data follows.

Dissolved Oxygen

There is ample oxygen in both Sandy Creek and South Sandy Creek to support desirable aquatic life. Mean oxygen concentrations ranged from 10.2 mg/L to 11.6 mg/L for the entire sampling period. The lowest DO concentration observed was 4.6 mg/L at Site 4 on Sandy Creek in August of 1998. That level of oxygen is still able to support fish such as trout and salmon.

Conductivity

Conductivity, which is a measure of dissolved solids, was higher near the base of the Sandy Creek watershed than at the base of the South Sandy Creek watershed. The base site on Sandy Creek (Site 6) had a mean conductivity of 0.346 mS/cm while the mean conductivity was 0.205 mS/cm at base site on South Sandy Creek (Site 2) for the sampling period from 1997 through 2005. This result suggests that less material is being lost from the South Sandy Creek watershed than the Sandy Creek watershed. As might be expected, conductivity decreased higher up in the watershed (e.g., Site 4 and Site 1).

pH

The pH of both Sandy Creek and South Sandy Creek were very near a neutral level of 7.00. The mean pH of Sandy Creek (Site 6) was 8.09 and the mean pH of South Sandy Creek (Site 2) was 7.74 for the study period from October of 1997 to September of 2005. Acidic pH levels were routinely observed during the deep winter months most likely due to contributions of concentrated acidic precipitation that had been stored in the snow pack. The minimum pH level observed in South Sandy Creek was 5.51 at Site 1 on 10 December 1997 while a minimum pH reading of 5.17 was measured at Site 6 on Sandy Creek on 3 January 2000. The minimum pH readings observed are not a threat to most desirable aquatic life.

Water Temperature

The mean temperature over the entire study period of October 1997 to September 2005 was nearly identical for the base sites on both Sandy Creek (13.6 °C) and South Sandy Creek (13.5 °C). The maximum temperature observed in South Sandy Creek was 27.3 °C) on 22 June 1998 at Site 1. The highest temperature recorded during the study period on Sandy Creek was a reading of 30.5 °C on 21 July 2005 at Site 6.

Nitrate

The concentrations of nitrate were higher in Sandy Creek (mean = 0.9 mg N/L at Site 6) versus South Sandy Creek (mean = 0.5 mg N/L at Site 2). Nitrate levels ranged from non-detectable to a maximum of 4.5 mg N/L on 27 May 2003 (Site 6) in Sandy Creek for the entire sampling period. The maximum nitrate level found in South Sandy Creek during the study period was substantially lower than Sandy Creek (1.6 mg N/L on 8 July 1999 at Site 2). At both creeks, a seasonal cycle in nitrate levels was observed with nitrate reaching a peak in the winter and a minimum during the summer.

Nitrite

There was very little nitrite found in either Sandy Creek (mean = 0.007 mg N/L) or South Sandy Creek (mean = 0.004 mg N/L) during the sampling period. This is not surprising as nitrite is not common in surface water that does not receive industrial discharges. The maximum concentration of nitrite was 0.086 mg N/L found at Site 6 in Sandy Creek on 21 June 2000.

Ammonia

Ammonia concentrations were nearly identical (both with a mean of 0.13 mg N/L) in runoff from both the South Sandy Creek and Sandy Creek watersheds. Elevated concentrations of ammonia in both streams coincided with the spring planting season and may be a result of agricultural activities (Figure 2).

Turbidity

The mean turbidity for both South Sandy Creek (6.04 NTU) and Sandy Creek (5.00 NTU) was relatively high. Maximum turbidity levels for both streams were about 57 NTU and occurred during the winter / spring runoff period before vegetation curtailed erosion of the soil from the surface runoff.

Total Phosphorus

The mean total phosphorus concentration for South Sandy Creek (Site 2) was 0.02 mg P/L for the period October 1997 to September 2005. Phosphorus ranged from non-detectable to a maximum of 0.10 mg P/L on 16 July 2001. In Sandy Creek, the total phosphorus concentration had a mean of 0.02 mg P/L, ranging from non-detectable to a maximum of 0.14 mg P/L on 14 May 2002.

Discussion

When compared to other watersheds in New York State, the total phosphorus concentrations of both South Sandy Creek (17 µg P/L) and Sandy Creek (22 µg P/L) were relatively low (note the conversion of units to accommodate the comparison to other watersheds) (Table 11). The phosphorus concentrations are comparable to streams in watersheds with minimal impacts from agricultural applications. For example, in the Canandaigua Lake watershed, Fall Brook (19.4 µg P/L) and several other creeks are well below 20 µg P/L. By comparison, Sucker Brook in the Canandaigua watershed drains a watershed best characterized as urban. Sucker Brook's average concentration is 97.5 µg P/L. Similarly, the two Jefferson County watersheds are much lower in mean phosphorus concentrations than other watersheds that receive discharge from sewage treatment plants

(Lower Northrup Creek 263.6 µg P/L), contain intensive agricultural operations (Kendig Creek 143.0 µg P/L) or runoff from mucklands (Ley Creek 270.8 µg P/L) (Table 11).

The correlation between turbidity and total phosphorus in the two Jefferson County watersheds (r = 0.43 for Sandy Creek and r = 0.15 for South Sandy Creek) was weak. Often in New York State, there is a strong correlation between total phosphorus and turbidity in watersheds with significant agricultural operations as phosphorus is often lost from the watershed as soil particles are eroded from the agricultural fields. The lack of correlation between TP and turbidity suggests that the agricultural operations in the watersheds are doing a reasonable job at retaining soil and this phosphorus on farmland.

Numerous BMPs were implemented in the Sandy Creek and South Sandy Creek watersheds from 1998 through 2004 (Table 1 and Figure 1). These management practices were designed to reduce soil and nutrient loss from agricultural operations to the watershed and its downstream ecosystems. Management practices implemented include whole farm nutrient management plan, livestock exclusion from streams, construction of manure storage facilities to avoid the necessity of spreading during environmentally sensitive periods (i.e., over snow, during precipitation events), roof runoff management to keep precipitation water from picking up and carrying farm waste to the stream, etc.

Pre and post-BMP data existed. This allowed comparisons of the impact of management plans on both watersheds and the streams that drain these watersheds. Base sites (Site 2 on South Sandy Creek, Site 6 on Sandy Creek) near the mouth of each creek near Lake Ontario were chosen (Figure 1) for this analysis because these sites were the only sites sampled for the entire study period. Any management practices implemented should collectively be reflected as a decrease in nutrients in stream water draining the watershed. Referring to Table 12, there was a statistically significant "increase" ($p = 0.008$, ANOVA) in mean nitrate concentration after BMP implementation in the Sandy Creek watershed at Site 6. Increases in nitrate levels are generally related to increased use of fertilizer in a watershed – especially fertilization to improve yields of corn. A significant increase in pH was also observed in South Sandy Creek (7.50 to 7.81).

Interestingly, statistically there was no significant change between pre-BMP and post-BMP chemistry data for total phosphorus, nitrite, ammonia, and conductivity in both Sandy and South Sandy Creeks (Table 12). That is, there was no evidence of improved water quality after BMP implementation in both the Sandy Creek and South Sandy Creek watersheds. We can not conclude at this point in time that the BMPs had any effect on water quality. **This conclusion has to be viewed with caution.** The data set collected has a major limitation. Consider phosphorus, the key limiting factor to algal growth and an element likely to respond to nutrient management. The analytical method for total phosphorus (Hach Method 8190) in this study has a detection limit that is very high (0.009 mg/L) compared to many analytical labs (0.002 mg P/L). Ambient nutrient values, especially total phosphorus (0.02 mg P/L), in both Jefferson County creeks were at or near the lower detection limit of the laboratory's methodology. For example, fifty seven percent (267 of 465) of the Post-BMP total phosphorus measurements were at or below the detection limit of 0.009 mg P/L and sixty nine percent of the Pre-BMP total

phosphorus measurements were below the detection limit. From a statistical perspective, we can not demonstrate that a significant decrease in phosphorus occurred because the desired lower values could not be detected. The analysis is limited by the methodology employed. It is unfortunate that laboratory capabilities were not fully vetted before undertaking such a lengthy study. If the laboratory had a lower phosphorus detection limit, 0.002 mg P/L for example, there may have been sufficient analytical resolution to detect improvements in the water quality due to BMP implementation.

Acknowledgements

The members of the Jefferson County SWCD staff who were involved in sampling and the laboratory work were Brandon Cooney, Ryan Palmer, Brian Robbins, Jim Lavancha, Wayne Sech, Sharron Quinby, Chris Edgar, Chris Gerber, and Dustin Frost. Daniel White of SUNY Brockport computerized and analyzed the data base.

Literature Cited

Bosch, I.J., J.C. Makarewicz, J.P. Embridge, D.A. Johnson and M.D. Valentino. 2001. Population studies of Eurasian milfoil (*Myriophyllum spicatum*) and zebra mussels (*Dreissena polymorpha*) in Conesus Lake, NY (summer 2000). Livingston County Planning Department. Geneseo, N.Y.

Cook, M.G., P. G. Hunt, K. C. Stone and J. H. Canterberry. 1996. Reducing diffuse pollution through implementation of agricultural best management practices: a case study. Water Science and Technology. 33: 191-196.

Gilliam, J.M. 1995. Phosphorus control strategies. Ecological Engineering. 5(2-3): 405-414.

JCWQCC. 2002. 2002 Annual Water Quality Report. Produced by the Jefferson County Water Quality Coordinating Committee.

Makarewicz, J.C. 2000. North Coast: A Coastline in Trouble. Lake Ontario Embayment Initiative. Finger Lakes – Lake Ontario Protection Alliance. 38pp.

Makarewicz, J.C. 1988. Chemical analysis of water from Buttonwood, Larkin and Northrup Creeks, Lake Ontario basin west, May, 1987 - May, 1988. Report to the Monroe County, NY. Department of Health.

Makarewicz, J.C., T.W. Lewis and R.K. Williams. 1993. Nutrient Loading of Streams entering Sodus Bay and Port Bay, NY. Available from Drake Library, SUNY Brockport, Brockport, N.Y.

Makarewicz, J.C., T.W. Lewis and R.K. Williams. 1992. Nutrient Loading of Streams entering Sodus Bay and Port Bay, NY. Available from Drake Library, SUNY Brockport, Brockport, N.Y.

Makarewicz, J.C.,T.W. Lewis, R. Dilcher, M. Letson and N. Puckett. 1991. Chemical analysis and nutrient loading of streams entering Conesus Lake. Available from Drake Library, SUNY Brockport, Brockport, N.Y.

Makarewicz, J.C.,T.W. Lewis and R.K. Williams. 1991a. Nutrient Loading of Streams entering Sodus Bay and Port Bay, NY. Available from Drake Library, SUNY Brockport, Brockport, N.Y.

Makarewicz, J.C. and T.W. Lewis. 1999. Nutrient and Sediment Loss from Watersheds of Orleans County – Year 2. Available from Drake Library, SUNY Brockport, Brockport, N.Y.

Makarewicz, J.C. and T.W. Lewis. 1998. Nutrient and Sediment Loss from Watersheds of Orleans County. Available from Drake Library, SUNY Brockport, Brockport, N.Y.

Makarewicz, J.C. and T.W. Lewis. 1998a. Nutrient and sediment loss from watersheds of Canandaigua Lake. Available from Drake Library, SUNY Brockport, Brockport, N.Y.

Makarewicz, J.C. and T.W. Lewis. 1996. Spring nutrient and sediment loss from the Sucker Brook subwatershed of Canandaigua Lake. Available from Drake Library, SUNY Brockport, Brockport, N.Y.

Makarewicz, J.C., and T.W. Lewis 1999. Nutrient loading and segment analysis of stream entering Lake Neatahwanta with an evaluation of the muckland demonstration project. Technical report to the Oswego County Soil and Water Conservation District, Oswego, NY.

Makarewicz, J.C., and T.W. Lewis 2000. Nutrient and sediment loss from a Niagara County watershed, the East branch of Twelvemile Creek. Technical report to the Niagara County Soil and Water Conservation District, Lockport, NY.

Makarewicz, J.C., and T.W. Lewis. 2003. Nutrient and sediment loss from a Niagara County watershed: An update of Twelvemile Creek East and a report on Twelvemile Creek West. Technical Report to the Niagara County Soil and Water Conservation District. Lockport, NY.

Makarewicz, J.C., T.W. Lewis and D. White. 2006. Nutrient and soil losses from the Eighteenmile Creek watershed. Technical report to the Niagara County Soil and Water Conservation District, Lockport, NY.

Makarewicz, J.C. and P. Bertram. 1991. Restoration of the Lake Erie Ecosystem. Bioscience. 41:216-223.

Meals, D.W. 1996. Watershed-scale response to agricultural diffuse pollution control programs in Vermont, USA. Water Science and Technology. 33: 197-204.

Meals, D W. 2001. Water quality response to riparian restoration in an agricultural watershed in Vermont, USA. Water Sci. Technol. 43:175-182.

Moss, B., J. Madgwick, and G. Phillips. 1997. A Guide to the Restoration of Nutrient-enriched Shallow Lakes. Broads Authority, 18 Colegate, Norwich, Norfolk, Great Britain.

Osgood, D. 1999. Planning for Better Lakes: The Phosphorus Paradigm. LakeLine. 19:52-54.

Table 1. Best management practices that were implemented in the South Sandy Creek and Sandy Creek watersheds from 1998 to 2003. The map number refers to the location of the farm depicted on Figure 1 and Year refers to the year that the BMP was implemented.

Map Number / Farm	Best Management Practice	Year
1. Murcrest –	Manure storage structure	1999
	Silage leachate collection system and filter area	2000
	Roof runoff management system	1999
	Milking center waste transfer	1999
	Nutrient management plan	2003
	Riparian buffer	2003
2. Woodruff -	Manure storage structure	2002
	Silage leachate collection system and filter area	2003
	Milking center waste transfer	2002
	Nutrient management plan	2003
	Roof runoff management system	2000
	Heavy use area protection	2002
3. Gracey -	Manure storage structure	2000
	Milking center waste transfer	2000
	Nutrient management plan	2003
	Roof runoff management system	1998
	Heavy use area protection	1998
	Stream crossing	1998
4. Abbott-	Milking center waste treatment	1999
	Roof runoff management system	2001
	Manure piling area	2000
	Heavy use area protection	2001
	Nutrient management plan	2003
5. J. Eastman	Manure storage structure	1998
	Milking center waste transfer	2003
	Silage leachate collection system and filter area	1999
	Nutrient management plan	2003
	Roof runoff management system	1999
6. Allen -	Roof runoff management system	1998
	Milking center waste treatment	2000
	Riparian buffer	2002
	Heavy use area protection	1999
7. Baderman -	Manure storage structure	1998
	Roof runoff management system	1998
	Heavy use area protection	1998
	Nutrient management plan	2003
	Milking center waste transfer	1998
8. Cobb -	Roof runoff management system	2000
	Heavy use area protection	2001
	Nutrient management plan	2000
	Diversion – clean water exclusion	2000
9. Dodge -	Manure storage structure	1999
	Roof runoff management system	2000
	Nutrient management plan	2003
	Silage leachate collection system and filter area	2000
	Laneway improvement	2000
10. Goutrement -	Nutrient management plan	2003
	Roof runoff management system	1998
	Heavy use area protection	1999
	Milking center waste treatment	2000
	Manure piling area	2001
11. Henry -	Waterway	1998
	Heavy use area protection	1998

Table 1 (cont.). Best management practices that were implemented in the South Sandy Creek and Sandy Creek watersheds from 1998 to 2003. The map number refers to the location of the farm depicted on Figure 1 and Year refers to the year that the BMP was implemented.

Map Number / Farm	Best Management Practice	Year
12. Keeney -	Nutrient management plan	2001
	Riparian buffer	2003
	Livestock exclusion from stream	2000
	Roof runoff management system	2001
	Heavy use area protection	2001
	Manure piling area	2002
	Livestock laneway	2001
13. O'Dell -	Nutrient management plan	2003
14. Porterdale -	Roof runoff management system	2001
	Access road	2001
	Silage leachate collection system and filter area	2001
	Nutrient management plan	2003
15. Redway -	Nutrient management plan	2001
	Milking center waste treatment	1998
	Roof runoff management system	2001
	Heavy use area protection	2001
	Manure piling area	1999
16. Elmer -	Nutrient management plan	2003
	Roof runoff management system	2001
	Heavy use area protection	2001
	Milking center waste treatment	1999
	Silage leachate collection system and filter area	2000
17. Wall -	Roof runoff collection system	1999
	Heavy use area protection	2000
	Manure piling area	2000
18. Brown -	Silage leachate collection system and filter area	2000
	Roof runoff management system	2001
	Nutrient management plan	2003
19. Eisel -	Nutrient management plan	2004
	Manure storage structure	2005
	Milking center transfer system	2005
20. Gingerich -	Nutrient management plan	2003
21. Jenkins -	Nutrient management plan	2003
22. Lassen -	Nutrient management plan	2003
23. Hill -	Manure storage structure	2003
	Nutrient management plan	2003
	Silage leachate collection system and filter area	2002
	Roof runoff management system	2002
	Milking center waste transfer	2003
24. Shelmidine –	Manure storage structure	2004
	Nutrient management plan	2003
	Silage leachate collection system and filter area	2000
25. Gilligan -	Manure storage structure	2004
	Nutrient management plan	2003
	Roof runoff management system	2001
	Milking center waste transfer	2004

Table 2 . Summary of the water quality database for South Sandy Creek and Sandy Creek provided by the Jefferson County Soil and Water Conservation District. A "Yes" indicates there is data for that analysis from that station, a "No" indicates that there is no data available. DO = dissolved oxygen, Cond = conductivity, Temp. = water temperature, Amm = ammonia, AH P = acid hydrolyzable phosphorus, Total P = total phosphorus, Rct. P = reactive phosphorus and Turb = turbidity.

Site	**Station**	**Status**	**Sampling Period**		**Analyses**										
South Sandy Creek			Begin	End	DO	Cond	pH	Temp.	Nitrate	Nitrite	Amm	AH P	Total P	Rct P	Turb
1	South Sandy Rt. 189	Former	Sept. 1997[1]	2/3/1999	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes[1]	Yes[1]	Yes	No
2	South Sandy NYS Rt. 3	Current	10/27/1997	9/1/2005	Yes	Yes	Yes	Yes	Yes[2]	Yes[2]	Yes[2]	Yes[2]	Yes[2]	Yes[2]	Yes[3]
Sandy Creek															
3	Sandy Creek - North Branch (Rt. 155)	Former	10/10/1997	3/18/2002	Yes	Yes	Yes	Yes	Yes[4]	Yes[4]	Yes[4]	Yes[4]	Yes[4]	Yes[4]	Yes[5]
4	Sandy Creek - South Branch (Rt. 155)	Former	3/16/1998	3/18/2002	Yes	Yes	Yes	Yes	Yes[4]	Yes[4]	Yes[4]	Yes[4]	Yes[4]	Yes[4]	Yes[5]
5	Sandy Creek Co. Rt. 69	Current	6/6/2002	9/1/2005	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
6	Sandy Creek NYS Rt. 3	Current	10/27/1997	9/1/2005	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes[6]	Yes[6]	Yes	Yes[3]

[1] The first date given for this site is simply titled "Sept." The Sept. data does not include AH P or Total P for the first date.

[2] The first date (10/27/1997) lacks AH P and Total P data. The last date (9/1/2005) lacks data for Nitrate, Nitrite, Ammonia, AH P, Total P, Rct P, and Turbidity

[3] No turbidity data prior to 11/3/1999

[4] The first date (10/10/1997) lacks Nitrate, Nitrite, Ammonia, AH P and Total P data

[5] No turbidity data prior to 11/18/1999

[6] The first date (10/27/1997) lacks AH P and Total P data

Table 3. Methodology used for nutrient analysis using Hach Inc. procedures and the DR/2010 spectrophotometer. The estimated detection limits (EDL) are from Hach detailed methods which can be found at their web site (www.hach.com).

Compound	Hach Method	Method Name	EDL (mg/L)
Nitrate	8171	Cadmium Reduction	0.01
Nitrite	8507	Diazotization	0.001
Nitrogen, Ammonia	8038	Nessler	0.06
Phosphorus, Total	8190	Acid Persulfate Digestion, Ascorbic Acid	0.009

Table 4. Water quality data statistical summary for Sites 1 and 2 in the South Sandy Creek watershed and Sites 3 through 6 in the Sandy Creek watershed (Figure 1). Data are the mean ± the standard error of the mean with the range in parentheses. NA = not available, ND = non-detectable. Data for dissolved phosphorus and acid hydrolyzable phosphorus are not reported due to inconsistencies in the database (see Methods).

	Dissolved Oxygen (mg/L)	Conductivity (mS/cm)	pH	Temperature (°C)	Nitrate (mg N/L)	Nitrite (mg N/L)	Ammonia (mg N/L)	Total Phosphorus (mg P/L)	Turbidity (NTU)
Site 1	11.5 ± 0.4 (8.3 - 14.4)	0.127 ± 0.009 (0.032 - 0.202)	7.32 ± 0.16 (5.51 - 8.51)	10.9 ± 1.8 (-0.2 - 27.3)	0.2 ± 0.0 (0.1 - 0.6)	0.003 ± 0.000 (0.001 - 0.011)	0.09 ± 0.01 (0.03 - 0.23)	0.01 ± 0.00 (ND - 0.08)	NA
Site 2 (Main site on South Sandy Creek)	10.2 ± 0.3 (4.7 - 15.1)	0.205 ± 0.009 (0.052 - 0.833)	7.74 ± 0.05 (7.50 - 9.30)	13.5 ± 0.8 (-0.2 - 27.1)	0.5 ± 0.0 (0.04 - 1.6)	0.004 ± 0.000 (0.001 - 0.040)	0.13 ± 0.01 (0.03 - 0.67)	0.02 ± 0.00 (ND - 0.10)	6.04 ± 1.19 (1.04 - 57.40)
Site 3	11.6 ± 0.2 (6.6 - 14.8)	0.387 ± 0.008 (0.011 - 0.504)	7.80 ± 0.06 (6.03 - 9.04)	11.9 ± 0.9 (-0.4 - 27.9)	0.6 ± 0.1 (0.1 - 1.7)	0.004 ± 0.000 (0.001 - 0.023)	0.09 ± 0.01 (0.01 - 1.09)	0.02 ± 0.00 (ND - 0.13)	2.63 ± 0.20 (0.88 - 7.53)
Site 4	11.1 ± 0.3 (4.6 - 15.0)	0.231 ± 0.008 (0.009 - 0.464)	7.84 ± 0.07 (6.14 - 9.20)	11.6 ± 1.0 (-0.3 - 26.7)	0.5 ± 0.0 (ND - 1.9)	0.003 ± 0.000 (ND - 0.016)	0.13 ± 0.01 (0.01 - 0.88)	0.02 ± 0.01 (ND - 0.40)	4.77 ± 1.21 (0.52 - 37.70)
Site 5	10.2 ± 0.3 (5.8 - 14.5)	0.334 ± 0.010 (0.180 - 0.523)	8.48 ± 0.10 (7.28 - 10.57)	14.2 ± 1.2 (-0.4 - 26.4)	0.6 ± 0.1 (0.1 - 2.5)	0.005 ± 0.000 (0.002 - 0.014)	0.10 ± 0.01 (0.01 - 0.51)	0.01 ± 0.00 (ND - 0.05)	3.32 ± 0.67 (0.10 - 23.30)
Site 6 (Main site on Sandy Creek)	11.4 ± 0.2 (7.2 - 15.6)	0.346 ± 0.007 (0.138 – 0.523)	8.09 ± 0.07 (5.17 - 9.39)	13.6 ± 0.9 (-0.3 - 30.5)	0.9 ± 0.1 (0.1 - 4.5)	0.007 ± 0.001 (0.000 - 0.086)	0.13 ± 0.01 (ND - 0.84)	0.02 ± 0.00 (ND - 0.14)	5.00 ± 1.02 (0.76 - 56.30)

Table 5. Water quality data for Site 1 in the South Sandy Creek watershed located on Route 189 (Figure 1). DO = dissolved oxygen, Cond = conductivity, TP = total phosphorus, NA = not available, ND = non-detectable and S.E. = standard error of the mean.

Site 1 Date	DO (mg/L)	Cond (mS/cm)	pH	Temperature (°C)	Nitrate (mg N/L)	Nitrite (mg N/L)	Ammonia (mg N/L)	TP (mg P/L)	Turbidity (NTU)
9/15/1997	11.3	0.173	7.17	9.9	0.1	0.011	0.06	NA	NA
10/29/1997	12.1	0.182	7.60	6.2	0.1	0.001	0.05	0.01	NA
11/12/1997	12.4	0.191	7.40	4.4	0.1	0.003	0.04	0.01	NA
12/10/1997	13.5	0.032	5.51	0.3	0.2	0.005	0.09	0.08	NA
3/16/1998	14.4	0.082	6.26	0.0	0.3	0.005	0.08	0.02	NA
3/30/1998	11.5	0.046	7.08	8.8	0.3	0.002	0.05	0.06	NA
4/13/1998	11.6	0.090	7.59	10.4	0.1	0.002	0.04	ND	NA
4/27/1998	12.1	0.101	6.86	7.8	0.1	0.003	0.06	ND	NA
5/11/1998	10.1	0.101	7.70	15.5	0.1	0.002	0.14	ND	NA
5/26/1998	8.8	0.175	7.91	22.5	0.3	0.003	0.05	ND	NA
6/8/1998	10.9	0.175	7.84	14.0	0.2	0.005	0.03	ND	NA
6/22/1998	8.3	0.141	8.51	27.3	0.2	0.004	0.08	0.01	NA
7/6/1998	9.6	0.103	8.19	20.0	0.2	0.003	0.13	0.01	NA
7/21/1998	8.9	0.176	8.51	26.1	0.3	0.004	0.08	ND	NA
8/10/1998	8.4	0.202	8.27	24.1	0.2	0.004	0.05	0.01	NA
8/24/1998	8.9	0.113	7.42	19.5	0.6	0.001	0.23	0.04	NA
9/22/1998	10.2	0.162	8.19	17.1	ND	0.001	0.08	ND	NA
10/6/1998	11.2	0.152	7.74	10.4	0.1	0.003	0.08	ND	NA
10/21/1998	12.3	0.128	7.18	7.5	0.1	0.001	0.14	ND	NA
11/3/1998	13.6	0.129	7.18	3.9	0.1	0.001	0.07	ND	NA
11/17/1998	13.7	0.104	6.28	3.5	0.3	0.001	0.10	0.01	NA
12/8/1998	13.7	0.103	6.82	3.4	0.2	0.002	0.12	ND	NA
12/21/1998	14.0	0.104	6.20	-0.1	0.3	0.001	0.07	ND	NA
2/3/1999	14.4	0.077	6.29	-0.2	0.6	0.001	0.17	0.02	NA
Mean	11.5	0.127	7.32	10.9	0.2	0.003	0.09	0.01	NA
S.E.	0.4	0.009	0.16	1.8	0.03	0.0005	0.01	0.004	NA
Minimum	8.3	0.032	5.51	-0.2	0.1	0.001	0.03	ND	NA
Maximum	14.4	0.202	8.51	27.3	0.6	0.011	0.23	0.08	NA

Table 6. Water quality data for Site 2 in the South Sandy Creek watershed located on NY Route 3 (Figure 1). DO = dissolved oxygen, Cond = conductivity, TP = total phosphorus, NA = not available, ND = non-detectable and S.E. = standard error of the mean.

Site 2 Date	DO (mg/L)	Cond (mS/cm)	pH	Temperature (°C)	Nitrate (mg N/L)	Nitrite (mg N/L)	Ammonia (mg N/L)	TP (mg P/L)	Turbidity (NTU)
10/27/1997	11.3	0.184	6.78	6.0	0.5	0.003	0.21	NA	NA
11/1/1997	11.6	0.156	7.23	4.5	0.0	0.004	0.22	0.03	NA
11/23/1997	13.7	0.209	7.81	1.8	0.9	0.005	0.12	0.01	NA
12/8/1997	15.1	0.115	6.84	0.8	0.6	0.009	0.04	0.03	NA
3/18/1998	13.7	0.166	6.59	-0.2	0.8	0.005	0.10	0.02	NA
4/1/1998	11.3	0.079	7.32	10.1	0.5	0.003	0.16	0.01	NA
4/15/1998	11.0	0.192	7.61	11.2	0.6	0.004	0.05	0.03	NA
4/29/1998	12.8	0.203	7.80	10.8	0.5	0.004	0.07	ND	NA
5/13/1998	10.7	0.177	7.69	13.1	0.3	0.003	0.09	ND	NA
5/28/1998	8.5	0.302	8.04	20.0	0.7	0.010	0.08	0.01	NA
6/11/1998	6.7	0.291	7.82	21.0	0.5	0.010	0.10	0.01	NA
6/24/1998	8.2	0.239	7.94	22.2	0.2	0.005	0.07	0.01	NA
7/9/1998	9.1	0.180	7.86	19.6	0.3	0.004	0.10	0.02	NA
7/23/1998	7.9	0.233	7.86	23.8	0.5	0.006	0.09	ND	NA
8/12/1998	9.2	0.193	8.16	20.7	0.4	0.004	0.11	0.02	NA
8/26/1998	9.3	0.145	8.02	21.0	0.4	0.002	0.17	0.03	NA
9/24/1998	8.9	0.250	7.68	13.4	0.1	0.002	0.05	0.02	NA
10/8/1998	8.9	0.234	7.49	13.8	0.1	0.002	0.10	0.01	NA
10/22/1998	12.4	0.199	7.50	8.2	0.2	0.001	0.11	ND	NA
11/5/1998	13.1	0.208	7.26	4.5	0.2	0.002	0.06	0.01	NA
11/19/1998	14.7	0.162	7.06	2.1	0.3	0.003	0.06	0.01	NA
12/10/1998	14.4	0.159	7.13	2.9	0.3	0.031	0.07	ND	NA
12/22/1998	14.6	0.124	6.97	1.1	1.3	0.001	0.34	0.07	NA
1/27/1999	14.5	0.126	6.78	-0.1	1.1	0.003	0.22	0.01	NA
2/18/1999	14.0	0.169	6.80	-0.2	0.8	0.004	0.12	0.01	NA
3/5/1999	14.1	0.100	6.23	-0.2	1.1	0.003	0.16	0.03	NA
3/24/1999	13.5	0.230	7.08	3.2	0.9	0.004	0.12	ND	NA
4/15/1999	12.7	0.085	7.64	8.0	0.4	0.001	0.09	ND	NA
5/11/1999	9.8	0.202	7.95	13.7	0.3	0.006	0.10	0.01	NA
6/23/1999	7.0	0.311	7.78	24.4	0.3	0.006	0.14	0.01	NA
7/8/1999	8.6	0.221	7.79	20.9	1.6	0.002	0.18	0.03	NA
7/21/1999	7.8	0.238	7.93	24.0	0.3	0.004	0.11	0.01	NA
8/2/1999	9.1	0.268	8.20	24.6	0.3	0.003	0.10	0.01	NA
8/18/1999	10.2	0.283	8.41	22.5	0.3	0.004	0.09	0.01	NA
9/1/1999	9.0	0.325	8.07	19.8	0.4	0.002	0.09	0.01	NA
9/15/1999	9.7	0.292	8.18	20.0	0.2	0.004	0.06	0.03	NA
9/29/1999	7.9	0.227	8.07	20.1	0.1	0.002	0.09	0.02	NA
10/18/1999	11.2	0.163	7.67	9.9	0.4	0.003	0.16	0.06	NA
11/3/1999	11.5	0.158	7.72	9.0	0.2	0.003	0.06	0.03	2.24
11/15/1999	13.2	0.130	7.09	4.1	0.5	0.002	0.11	0.01	1.33
12/6/1999	11.8	0.132	7.54	8.0	0.6	0.002	0.07	0.02	3.64
3/2/2000	14.3	0.103	7.26	0.7	0.9	0.005	0.19	0.04	14.30
3/29/2000	14.0	0.108	7.27	2.0	0.7	0.003	0.29	0.05	38.70
4/12/2000	13.6	0.141	7.63	4.5	0.9	0.003	0.15	0.02	5.98
4/26/2000	13.2	0.142	8.05	6.5	0.7	0.003	0.08	0.01	2.22
5/10/2000	9.8	0.158	7.78	18.6	0.4	0.004	0.10	0.02	4.52
5/22/2000	11.2	0.146	8.07	12.4	0.6	0.003	0.12	0.01	NA
6/5/2000	10.7	0.193	8.12	14.9	0.6	0.004	0.10	ND	1.34
6/21/2000	8.9	0.177	7.96	19.4	0.6	0.006	0.25	NA	2.77

Site 2 (cont) Date	DO (mg/L)	Cond (mS/cm)	pH	Temperature (°C)	Nitrate (mg N/L)	Nitrite (mg N/L)	Ammonia (mg N/L)	TP (mg P/L)	Turbidity (NTU)
7/12/2000	9.1	0.192	8.22	19.3	0.5	0.004	0.18	0.02	2.71
7/24/2000	9.8	0.202	8.33	19.5	0.3	0.003	0.03	0.02	1.69
8/7/2000	9.1	0.212	7.99	20.5	0.3	0.003	0.09	0.02	1.97
8/23/2000	8.6	0.206	8.20	18.8	0.4	0.003	0.06	0.04	4.75
4/11/2001	13.8	0.069	7.68	2.8	0.2	0.001	0.31	0.03	57.40
4/25/2001	12.0	0.070	8.02	9.5	0.5	0.005	0.14	0.01	10.80
5/21/2001	9.3	0.205	7.95	16.4	0.5	0.005	0.06	0.01	1.98
6/5/2001	10.9	0.144	7.86	11.8	0.3	0.002	0.09	0.03	3.18
6/20/2001	6.5	0.232	8.05	23.5	0.5	0.002	0.08	0.07	3.63
7/5/2001	5.9	0.171	7.13	20.0	0.2	0.003	0.17	0.03	3.88
7/16/2001	4.7	0.251	8.10	24.1	0.3	0.003	0.13	0.05	4.30
8/1/2001	5.9	0.312	7.74	24.1	0.1	0.001	0.11	0.10	5.13
8/13/2001	8.6	0.288	8.31	25.7	0.2	0.003	0.16	0.03	4.80
8/27/2001	7.3	0.214	7.38	21.6	0.4	0.003	0.26	0.01	9.20
9/10/2001	5.4	0.251	7.60	22.7	0.1	0.002	0.07	NA	NA
9/24/2001	7.4	0.278	8.05	19.0	0.2	0.007	0.27	0.01	6.07
10/11/2001	10.3	0.139	7.90	11.6	0.1	0.001	0.14	ND	1.79
11/13/2001	13.2	0.119	7.78	3.8	0.2	0.002	0.09	0.01	1.04
12/3/2001	12.2	0.129	7.81	5.2	0.6	0.003	0.13	0.01	1.80
12/20/2001	13.0	0.143	7.44	2.5	0.6	0.002	0.11	0.03	4.83
2/25/2002	13.9	0.152	6.91	2.7	1.2	0.002	0.12	0.01	3.59
3/11/2002	14.6	0.833	7.14	0.6	0.9	0.001	0.25	0.03	40.20
4/10/2002	13.5	0.052	7.66	3.0	0.8	0.003	0.67	0.10	1.60
5/14/2002	12.4	0.094	7.73	7.5	NA	NA	NA	NA	NA
6/20/2002	10.3	0.183	7.96	18.6	0.7	0.004	0.08	ND	2.83
7/3/2002	4.8	0.247	7.69	27.0	0.7	0.009	0.18	ND	3.31
7/18/2002	5.2	0.319	8.03	25.0	0.7	0.010	0.09	ND	2.90
8/1/2002	6.7	0.285	8.21	26.6	0.4	0.006	0.09	0.01	3.81
8/15/2002	5.7	0.352	7.97	27.1	0.4	0.005	0.12	0.01	5.13
9/24/2002	7.2	0.247	7.95	15.7	0.4	0.004	0.08	ND	2.38
10/8/2002	9.1	0.260	7.60	10.2	0.3	0.003	0.12	0.03	2.06
10/26/2002	12.8	0.176	6.73	2.9	0.4	0.003	0.10	0.02	1.84
11/5/2002	13.7	0.208	6.31	3.6	0.5	0.003	0.12	0.01	1.54
11/18/2002	12.6	0.144	7.11	2.2	0.6	0.002	0.10	ND	1.73
1/2/2003	13.0	NA	NA	0.0	1.5	0.002	0.11	ND	6.99
3/24/2003	13.4	0.127	6.83	4.5	1.4	0.004	0.20	ND	42.50
4/29/2003	11.5	0.107	8.00	11.6	0.4	0.003	0.07	ND	2.84
5/12/2003	10.7	0.121	7.55	11.7	0.6	0.002	0.23	0.03	23.80
5/27/2003	10.6	0.141	7.83	13.9	0.7	0.003	0.17	0.01	9.18
6/19/2003	9.0	0.250	8.34	17.6	0.9	0.006	0.09	ND	3.02
7/2/2003	8.2	0.325	8.70	21.8	0.1	0.011	0.08	ND	1.33
7/17/2003	8.6	0.318	8.64	22.6	0.5	0.005	0.12	ND	1.67
7/31/2003	7.7	0.334	8.51	24.5	0.3	0.003	0.03	ND	1.97
8/14/2003	8.8	0.193	8.69	23.9	0.4	0.003	0.17	0.01	3.49
9/3/2003	8.1	0.338	8.48	19.1	0.4	0.003	0.06	ND	4.22
10/8/2003	12.5	0.195	7.81	7.3	0.6	0.003	0.10	0.01	2.75
11/5/2003	11.1	0.167	7.70	11.0	0.6	0.003	0.11	0.01	3.48
12/2/2003	14.4	0.133	6.67	-0.1	0.8	0.003	0.09	ND	7.26
4/6/2004	14.0	0.136	7.08	2.4	0.6	0.003	0.05	ND	2.18
5/18/2004	10.0	0.200	8.38	17.8	0.6	0.005	0.03	0.04	1.50
6/1/2004	10.8	0.212	9.30	15.4	0.5	0.004	0.05	ND	1.66
6/15/2004	6.9	0.264	7.92	21.4	0.7	0.007	0.10	0.01	1.67
6/29/2004	8.2	0.276	8.06	17.4	0.6	0.005	0.07	0.01	1.97
7/13/2004	7.0	0.225	8.50	22.4	0.2	0.004	0.09	0.02	1.54
7/26/2004	7.0	0.230	8.06	20.4	0.2	0.003	0.07	0.01	1.50
8/9/2004	7.3	0.258	8.06	20.4	0.2	0.003	0.08	ND	1.62
10/13/2004	9.0	0.255	7.91	10.5	0.3	0.004	0.03	0.03	1.61

Site 2 (cont) Date	DO (mg/L)	Cond (mS/cm)	pH	Temperature (°C)	Nitrate (mg N/L)	Nitrite (mg N/L)	Ammonia (mg N/L)	TP (mg P/L)	Turbidity (NTU)
11/29/2004	10.0	0.126	7.52	3.6	0.5	0.001	0.18	0.04	9.87
5/5/2005	12.0	0.164	8.23	9.0	0.9	0.015	0.07	0.02	1.25
5/23/2005	9.8	0.218	7.85	11.3	0.5	0.040	0.08	0.01	1.74
6/6/2005	5.7	0.293	7.85	24.3	0.7	0.010	0.44	0.01	1.98
6/23/2005	7.1	0.219	8.19	18.8	0.5	0.004	0.11	ND	6.72
7/7/2005	7.3	0.332	7.79	24.8	0.4	0.003	0.13	0.07	4.57
7/21/2005	7.5	0.243	7.49	24.0	0.3	0.003	0.06	ND	1.36
8/15/2005	6.6	0.275	7.83	20.9	0.4	0.004	0.15	0.02	2.58
9/1/2005	8.3	0.121	8.90	18.9	NA	NA	NA	NA	NA
Mean	10.2	0.205	7.74	13.5	0.5	0.004	0.13	0.02	6.04
S.E.	0.3	0.009	0.05	0.8	0.03	0.000	0.01	0.002	1.19
Minimum	4.7	0.052	6.23	-0.2	0.0	0.001	0.03	ND	1.04
Maximum	15.1	0.833	9.30	27.1	1.6	0.040	0.67	0.10	57.40

Table 7. Water quality data for Site 3 in the Sandy Creek watershed located on Route 155 (Figure 1). DO = dissolved oxygen, Cond = conductivity, TP = total phosphorus, NA = not available, ND = non-detectable and S.E. = standard error of the mean.

Site 3 Date	DO (mg/L)	Cond (mS/cm)	pH	Temperature (°C)	Nitrate (mg N/L)	Nitrite (mg N/L)	Ammonia (mg N/L)	TP (mg P/L)	Turbidity (NTU)
10/10/1997	10.2	0.296	7.87	15.9	NA	NA	NA	NA	NA
10/29/1997	11.2	0.454	7.85	5.1	0.3	0.005	0.07	0.03	NA
11/12/1997	12.2	0.486	8.05	3.4	0.4	0.004	0.07	0.06	NA
12/10/1997	13.6	0.244	8.08	2.3	0.6	0.003	0.05	0.13	NA
3/16/1998	14.6	0.399	7.18	0.7	0.8	0.023	0.08	0.03	NA
3/30/1998	11.7	0.376	7.66	10.2	0.4	0.004	0.08	0.01	NA
4/13/1998	12.5	0.416	7.86	9.7	0.6	0.004	0.02	0.01	NA
4/27/1998	12.6	0.397	7.88	9.9	0.3	0.003	0.06	0.01	NA
5/11/1998	11.3	0.411	7.96	14.5	0.3	0.008	0.08	0.02	NA
5/26/1998	11.7	0.388	8.23	22.5	0.3	0.006	0.06	0.01	NA
6/8/1998	11.4	0.385	8.12	16.5	0.3	0.006	0.08	0.01	NA
6/22/1998	9.4	0.371	8.21	27.9	0.1	0.004	0.05	0.02	NA
7/6/1998	10.3	0.422	8.12	21.4	0.2	0.004	0.08	0.01	NA
7/21/1998	11.3	0.387	8.44	27.0	0.1	0.005	0.06	0.02	NA
8/10/1998	6.6	0.394	7.94	23.7	0.1	0.006	0.04	0.01	NA
8/24/1998	8.6	0.344	7.66	21.2	0.4	0.006	0.15	0.05	NA
9/22/1998	10.1	0.460	7.99	18.7	0.1	0.002	0.05	ND	NA
10/6/1998	12.0	0.465	7.92	13.3	0.2	0.002	0.07	0.01	NA
10/21/1998	11.1	0.504	7.57	9.7	0.2	0.002	0.10	0.01	NA
11/3/1998	12.3	0.498	7.44	6.5	0.2	0.002	0.03	0.02	NA
11/17/1998	12.8	0.490	7.36	5.0	0.4	0.002	0.05	0.01	NA
12/8/1998	12.0	0.498	7.44	6.5	0.5	0.003	0.04	0.01	NA
12/21/1998	14.1	0.489	7.25	2.4	0.6	0.002	0.03	ND	NA
2/3/1999	14.8	0.419	7.18	0.8	1.7	0.005	0.14	0.03	NA
2/22/1999	14.6	0.494	6.97	0.3	1.4	0.003	0.07	0.01	NA
3/15/1999	14.8	0.474	7.06	0.9	1.3	0.006	0.07	0.01	NA
4/5/1999	13.4	0.381	7.64	5.5	0.8	0.003	0.06	0.02	NA
4/19/1999	12.1	0.432	7.77	8.7	0.4	0.002	0.09	ND	NA
6/21/1999	10.0	0.389	8.11	24.4	0.1	0.003	1.09	0.03	NA
7/6/1999	7.9	0.440	7.94	26.2	0.1	0.003	0.13	0.01	NA
7/19/1999	11.0	0.342	8.40	26.0	0.3	0.002	0.09	0.01	NA
8/4/1999	8.1	0.361	9.04	20.3	0.2	0.002	0.15	0.04	NA
8/16/1999	9.4	0.315	8.10	20.9	0.1	0.002	0.10	0.02	NA
8/30/1999	9.7	0.317	7.97	16.6	0.1	0.002	0.10	0.02	NA
9/13/1999	9.7	0.328	7.97	18.2	0.1	0.002	0.13	0.02	NA
9/27/1999	10.7	0.342	8.47	16.2	0.1	0.002	0.09	0.03	NA
10/13/1999	12.7	0.374	8.26	16.1	0.1	0.002	0.08	0.03	NA
11/1/1999	12.8	0.463	7.99	11.0	0.4	0.003	0.02	0.02	NA
11/18/1999	14.7	0.441	7.62	3.5	0.8	0.003	0.06	0.02	0.90
12/9/1999	13.1	0.418	7.11	3.2	1.2	0.002	0.02	0.01	NA
12/22/1999	13.6	0.394	6.61	0.0	1.5	0.003	0.02	0.02	1.82
1/5/2000	13.7	0.011	6.03	0.3	1.1	0.005	0.04	0.03	3.67
2/29/2000	13.4	0.299	7.26	1.9	1.5	0.009	0.09	0.03	3.34
3/27/2000	13.1	0.380	7.71	6.2	1.1	0.004	0.06	0.01	1.36
4/10/2000	13.7	0.325	7.39	2.5	1.3	0.003	0.08	0.01	2.34
5/1/2000	12.2	0.349	8.02	11.1	0.8	0.004	0.08	0.02	1.56
5/10/2000	9.1	0.351	8.06	18.3	0.5	0.004	0.04	0.02	4.38
5/24/2000	10.8	0.369	8.19	15.4	0.6	0.003	0.11	0.02	2.30
6/13/2000	9.4	0.362	8.09	16.7	0.5	0.004	0.07	0.03	2.25
6/26/2000	10.6	0.362	8.33	24.1	0.4	0.004	0.14	NA	2.36

Site 3 (cont.) Date	DO (mg/L)	Cond (mS/cm)	pH	Temperature (°C)	Nitrate (mg N/L)	Nitrite (mg N/L)	Ammonia (mg N/L)	TP (mg P/L)	Turbidity (NTU)
7/10/2000	9.7	0.346	8.12	20.2	0.3	0.005	0.12	0.03	4.40
7/26/2000	11.1	0.340	8.49	25.7	0.2	0.003	0.08	0.02	2.78
8/9/2000	10.4	0.395	8.21	23.5	0.2	0.004	0.07	0.01	2.34
8/21/2000	11.3	0.421	8.15	17.4	0.3	0.003	0.06	0.02	1.97
9/7/2000	11.8	0.410	8.25	19.7	0.3	0.004	0.08	0.01	2.47
9/22/2000	9.6	0.408	7.92	14.5	0.2	0.002	0.13	0.02	2.90
10/4/2000	9.7	0.454	8.00	13.8	0.3	0.004	0.06	0.01	1.75
10/19/2000	11.0	0.472	7.92	11.5	0.3	0.003	0.09	0.01	1.88
10/31/2000	13.7	0.445	7.48	6.0	0.4	0.003	0.02	ND	1.54
11/14/2000	12.3	0.458	7.47	6.4	0.4	0.004	0.10	ND	NA
12/6/2000	13.0	0.409	6.22	-0.3	1.6	0.008	0.12	0.01	2.35
12/18/2000	13.2	0.319	6.30	-0.2	1.3	0.005	0.13	0.03	3.82
1/2/2001	12.0	0.424	7.08	-0.3	1.4	0.004	0.03	0.02	1.61
2/22/2001	13.8	0.444	6.95	-0.3	1.5	0.005	0.06	ND	2.62
3/28/2001	14.8	0.411	6.61	1.0	1.2	0.005	0.06	0.03	1.74
4/9/2001	13.6	0.249	7.60	2.7	1.1	0.004	0.18	0.04	7.53
4/30/2001	12.3	0.340	8.29	11.2	0.6	0.005	0.06	0.01	2.44
5/15/2001	11.7	0.350	8.06	16.0	0.4	0.005	0.12	0.01	2.09
6/7/2001	11.0	0.357	8.29	21.2	0.2	0.003	0.08	0.03	3.17
6/18/2001	10.0	0.342	8.04	23.8	0.3	0.004	0.10	0.08	3.59
7/2/2001	9.8	0.337	7.97	20.6	0.3	0.002	0.09	0.03	4.87
7/17/2001	10.7	0.321	8.10	26.0	0.1	0.002	0.08	0.04	3.02
7/30/2001	7.8	0.368	8.08	19.1	0.20	0.001	0.08	0.08	4.92
8/15/2001	7.7	0.341	8.04	21.3	0.1	0.003	0.01	0.01	1.56
8/29/2001	8.7	0.354	8.12	20.2	0.3	0.004	0.11	0.06	2.55
9/12/2001	8.2	0.362	7.79	16.9	0.1	0.003	0.08	0.01	1.58
9/26/2001	9.9	0.344	7.84	14.4	0.9	0.005	0.19	0.03	5.95
10/18/2001	10.9	0.427	7.59	9.0	0.2	0.001	0.06	0.01	3.24
11/15/2001	11.9	0.436	8.05	7.5	0.6	0.002	0.03	ND	1.11
12/5/2001	11.8	0.420	8.52	7.6	0.9	0.005	0.05	0.03	1.91
12/18/2001	12.9	0.411	7.80	2.5	1.1	0.003	0.15	0.01	1.72
1/9/2002	12.8	0.409	8.17	-0.3	1.6	0.003	0.05	0.01	1.96
1/28/2002	14.1	0.388	7.82	2.0	1.4	0.002	0.02	0.01	2.18
2/14/2002	14.8	0.395	8.05	-0.4	1.6	0.003	0.05	0.02	0.88
3/18/2002	13.3	0.304	7.91	2.7	1.0	0.002	0.06	0.01	1.55
Mean	11.6	0.387	7.80	11.9	0.6	0.004	0.09	0.02	2.63
S.E.	0.2	0.008	0.06	0.9	0.1	0.0003	0.01	0.002	0.20
Minimum	6.6	0.011	6.03	-0.4	0.1	0.001	0.01	ND	0.88
Maximum	14.8	0.504	9.04	27.9	1.7	0.023	1.09	0.13	7.53

Table 8. Water quality data for Site 4 in the Sandy Creek watershed located on Route 155 (Figure 1). DO = dissolved oxygen, Cond = conductivity, TP = total phosphorus, NA = not available, ND = non-detectable and S.E. = standard error of the mean.

Site 4 Date	DO (mg/L)	Cond (mS/cm)	pH	Temperature (°C)	Nitrate (mg N/L)	Nitrite (mg N/L)	Ammonia (mg N/L)	TP (mg P/L)	Turbidity (NTU)
3/16/1998	14.9	0.208	7.14	0.8	1.90	0.002	0.04	0.02	NA
3/30/1998	11.1	0.115	7.57	11.2	0.50	0.003	0.15	0.03	NA
4/13/1998	12.1	0.235	8.01	10.6	0.70	0.005	0.05	0.02	NA
4/27/1998	12.4	0.239	7.93	8.5	0.50	0.004	0.07	ND	NA
5/11/1998	10.2	0.199	8.17	15.6	0.30	0.003	0.07	0.01	NA
5/26/1998	9.9	0.321	8.39	20.9	0.30	0.005	0.03	0.01	NA
6/8/1998	10.4	0.308	8.17	14.8	0.40	0.004	0.04	0.01	NA
6/22/1998	8.5	0.269	8.67	26.7	0.30	0.005	0.09	0.01	NA
7/6/1998	9.2	0.216	8.70	22.6	0.10	0.004	0.12	ND	NA
7/21/1998	9.8	0.316	8.55	25.2	0.10	0.004	0.07	ND	NA
8/10/1998	4.6	0.352	7.82	21.4	0.20	0.006	0.09	0.02	NA
8/24/1998	9.2	0.009	7.53	19.5	0.90	0.015	0.70	0.14	NA
9/22/1998	10.1	0.251	8.42	16.8	0.10	0.001	0.08	ND	NA
10/6/1998	10.9	0.263	8.21	13.6	0.10	0.002	0.08	ND	NA
10/10/1998	10.8	0.464	7.41	16.8	NA	NA	NA	NA	NA
10/21/1998	12.3	0.311	7.62	7.6	0.30	0.002	0.15	ND	NA
10/29/1998	12.2	0.202	7.77	3.8	0.30	0.007	0.27	0.02	NA
11/3/1998	13.6	0.256	7.47	4.0	0.20	0.002	0.06	0.01	NA
11/12/1998	13.4	0.228	7.80	0.5	0.40	0.004	0.08	0.01	NA
11/17/1998	13.8	0.203	7.29	3.3	0.40	0.001	0.09	0.01	NA
12/8/1998	13.8	0.235	7.46	3.3	0.50	0.003	0.08	ND	NA
12/10/1998	13.7	0.209	7.81	1.8	0.90	0.005	0.12	0.01	NA
12/21/1998	14.2	0.227	7.35	2.8	0.60	0.002	0.08	0.01	NA
2/3/1999	15.0	0.180	6.85	0.3	1.20	0.002	0.27	0.05	NA
3/15/1999	13.5	0.250	6.99	1.0	1.00	0.002	0.08	0.02	NA
4/5/1999	13.4	0.134	7.08	4.5	0.60	0.001	0.25	0.03	NA
4/19/1999	12.5	0.140	7.70	7.6	0.10	0.001	0.08	0.01	NA
6/21/1999	6.2	0.343	7.96	22.6	0.20	0.001	0.02	0.01	NA
7/6/1999	8.1	0.275	8.49	25.4	ND	0.002	0.11	0.03	NA
7/19/1999	8.7	0.301	8.32	24.4	0.20	0.002	0.04	0.02	NA
8/4/1999	7.5	0.284	9.20	19.9	0.30	0.001	0.36	0.07	NA
8/16/1999	6.7	0.309	7.89	19.3	0.20	0.003	0.07	0.01	NA
8/30/1999	6.5	0.329	7.72	18.1	0.10	0.004	0.01	0.01	NA
9/13/1999	7.3	0.346	7.85	20.6	0.20	0.003	0.03	0.01	NA
9/27/1999	10.0	0.291	8.59	17.8	0.10	0.001	0.06	0.01	NA
10/13/1999	10.5	0.253	8.27	14.4	0.10	0.002	0.10	0.01	NA
11/1/1999	11.9	0.241	8.22	10.5	0.20	0.002	0.10	0.01	0.52
11/18/1999	13.7	0.196	7.63	4.2	0.50	0.003	0.08	0.01	0.87
12/9/1999	14.0	0.183	7.12	1.6	0.80	0.003	0.07	0.02	NA
12/22/1999	13.7	0.155	6.88	-0.3	0.90	0.002	0.05	0.02	3.47
1/5/2000	13.8	0.118	6.69	-0.2	0.80	0.001	0.25	0.04	37.70
1/20/2000	13.8	0.272	6.60	-0.1	1.60	0.004	0.04	0.01	1.28
2/17/2000	14.1	0.224	6.14	-0.1	1.20	0.004	0.05	0.01	0.78
2/29/2000	13.7	0.132	7.15	2.4	1.30	0.006	0.34	0.04	3.09
3/27/2000	12.0	0.155	7.68	7.3	0.70	0.004	0.09	0.02	NA
4/10/2000	13.3	0.145	7.16	3.7	1.00	0.003	0.13	0.01	10.10
5/1/2000	11.9	0.212	8.14	10.5	1.00	0.004	0.04	0.01	1.09
5/10/2000	9.5	0.168	8.26	18.2	0.40	0.004	0.11	0.02	NA
5/24/2000	9.7	0.126	8.23	16.5	0.50	0.002	0.27	0.03	21.60
6/13/2000	9.5	0.227	8.19	16.2	0.70	0.005	0.17	0.02	1.43

Site 4 (cont.) Date	DO (mg/L)	Cond (mS/cm)	pH	Temperature (°C)	Nitrate (mg N/L)	Nitrite (mg N/L)	Ammonia (mg N/L)	TP (mg P/L)	Turbidity (NTU)
6/26/2000	7.8	0.242	8.50	25.9	0.60	0.005	0.07	NA	1.45
7/10/2000	8.9	0.201	8.38	21.3	0.70	0.004	0.18	0.03	4.42
7/26/2000	8.6	0.250	8.64	25.0	0.20	0.005	0.10	0.01	0.94
8/9/2000	9.1	0.231	8.63	23.8	0.20	0.003	0.12	0.02	1.32
8/21/2000	9.1	0.255	8.33	21.3	0.40	0.003	0.10	0.03	1.48
9/7/2000	9.9	0.322	8.34	19.9	0.50	0.004	0.04	0.03	1.45
9/22/2000	10.8	0.230	8.15	12.6	0.30	0.005	0.13	0.02	1.78
10/4/2000	10.3	0.295	8.19	12.0	0.40	0.005	0.08	ND	0.81
10/19/2000	11.1	0.211	8.17	12.1	0.30	0.003	0.14	0.02	1.61
10/31/2000	13.2	0.271	7.74	6.5	0.40	0.004	0.05	ND	0.67
11/14/2000	12.8	0.216	7.74	6.3	0.40	0.005	0.12	ND	NA
12/6/2000	13.5	0.239	6.56	-0.2	1.20	0.004	0.09	0.01	3.26
12/18/2000	13.1	0.146	6.74	-0.3	1.10	0.004	0.27	0.04	34.80
1/2/2001	12.6	0.228	7.10	-0.2	0.80	0.004	0.02	0.02	1.79
2/22/2001	14.2	0.231	6.92	-0.2	1.10	0.004	0.06	0.01	3.00
3/28/2001	14.8	0.232	7.12	0.9	1.00	0.003	0.07	0.01	1.98
4/9/2001	13.5	0.130	7.41	3.2	1.20	0.016	0.88	0.16	1.86
4/30/2001	10.8	0.171	8.15	12.9	0.60	0.005	0.12	0.01	2.11
5/15/2001	10.2	0.199	8.21	16.7	0.30	0.005	0.07	ND	1.66
6/7/2001	8.9	0.200	8.40	22.8	0.30	0.002	0.02	0.03	2.12
6/18/2001	8.3	0.283	8.12	20.3	0.40	0.003	0.01	0.06	1.14
7/2/2001	9.8	0.190	8.12	16.2	0.40	0.003	0.21	0.40	3.72
7/17/2001	7.8	0.338	8.40	23.0	0.10	0.004	0.11	0.04	0.65
7/20/2001	5.5	0.335	8.11	19.8	0.10	0.004	0.03	0.04	1.89
8/15/2001	7.0	0.339	8.04	24.0	0.10	0.003	0.10	ND	1.37
8/29/2001	8.7	0.255	8.58	22.3	0.20	0.002	0.14	0.01	2.48
9/12/2001	8.7	0.341	8.25	22.8	0.10	0.003	0.06	0.01	1.55
9/26/2001	10.0	0.176	7.86	13.5	0.50	0.002	0.33	0.03	14.70
10/18/2001	12.0	0.158	7.45	6.0	0.40	ND	0.25	0.02	16.60
11/15/2001	11.9	0.205	8.55	8.3	0.40	0.002	0.16	0.01	1.02
12/5/2001	11.8	0.180	8.81	9.2	0.40	0.003	0.10	0.01	1.58
12/18/2001	14.3	0.168	7.85	1.3	0.50	0.001	0.11	0.01	1.99
1/28/2002	14.3	0.195	7.50	2.5	0.70	0.003	0.23	0.01	6.94
2/14/2002	14.6	0.202	7.55	-0.3	1.10	0.002	0.08	0.01	1.68
3/18/2002	13.9	0.135	7.57	1.4	0.90	0.003	0.10	0.03	6.69
Mean	11.1	0.231	7.84	11.6	0.53	0.003	0.13	0.02	4.77
S.E.	0.3	0.008	0.07	1.0	0.04	0.0003	0.01	0.01	1.21
Minimum	4.6	0.009	6.14	-0.3	ND	ND	0.01	ND	0.52
Maximum	15.0	0.464	9.20	26.7	1.90	0.016	0.88	0.40	37.70

Table 9. Water quality data for Site 5 in the Sandy Creek watershed located on County Route 69 (Figure 1). DO = dissolved oxygen, Cond = conductivity, TP = total phosphorus, NA = not available, ND = non-detectable and S.E. = standard error of the mean.

Site 5 Date	DO (mg/L)	Cond (mS/cm)	pH	Temperature (°C)	Nitrate (mg N/L)	Nitrite (mg N/L)	Ammonia (mg N/L)	TP (mg P/L)	Turbidity (NTU)
6/6/2002	11.3	0.253	8.15	15.5	0.40	0.003	0.07	0.01	1.93
6/20/2002	8.7	0.290	8.31	23.4	0.50	0.003	0.02	0.01	3.35
7/3/2002	7.5	0.348	8.04	25.5	0.60	0.004	0.14	ND	2.03
7/18/2002	5.8	0.349	7.91	23.3	0.80	0.008	0.01	ND	2.21
8/1/2002	7.5	0.362	7.79	26.0	0.90	0.008	0.04	0.01	1.40
8/15/2002	5.8	0.358	7.76	26.4	1.10	0.014	0.07	0.02	1.43
9/25/2002	7.4	0.404	8.03	13.5	0.60	0.005	0.02	ND	1.23
10/8/2002	7.7	0.379	7.89	9.2	0.40	0.003	0.03	0.01	0.62
10/26/2002	12.3	0.297	7.28	2.2	0.50	0.003	0.11	0.02	2.12
11/5/2002	12.3	0.304	7.34	4.1	0.20	0.004	0.08	ND	0.96
11/18/2002	13.8	0.257	8.72	1.3	0.20	0.003	0.06	0.01	2.85
12/3/2002	13.8	0.337	8.70	-0.4	1.40	0.004	0.05	ND	NA
12/16/2002	13.9	0.310	7.50	-0.2	1.50	0.003	0.08	ND	1.99
1/2/2003	14.5	NA	NA	0.0	2.00	0.003	0.06	0.01	3.26
3/24/2003	13.5	0.256	9.55	3.7	2.50	0.005	0.17	0.01	23.30
4/7/2003	14.1	0.277	9.14	0.8	1.50	0.004	0.09	ND	3.83
4/29/2003	12.2	0.239	9.21	10.0	0.10	0.004	0.08	ND	1.76
5/12/2003	10.8	0.180	7.73	11.5	0.60	0.003	0.16	0.02	21.70
5/27/2003	10.5	0.245	8.33	13.2	0.60	0.003	0.21	0.02	9.68
6/16/2003	10.1	0.362	9.14	18.7	0.60	0.003	0.07	0.01	2.41
6/30/2003	9.9	0.433	8.70	21.6	0.70	0.009	0.06	ND	1.24
7/14/2003	10.3	0.432	8.29	21.9	0.60	0.006	0.03	0.01	1.02
7/30/2003	10.3	0.485	8.15	22.3	0.05	0.005	0.02	0.01	1.22
8/12/2003	8.3	0.403	8.32	20.8	0.40	0.006	0.15	0.02	5.41
8/25/2003	10.0	0.523	8.42	19.1	0.40	0.004	0.02	ND	0.10
9/23/2003	10.3	0.470	8.93	16.9	0.40	0.004	0.02	0.01	3.17
10/28/2003	11.4	0.337	9.86	7.5	0.50	0.003	0.08	0.01	9.65
11/25/2003	13.5	0.256	10.57	3.1	0.60	0.003	0.12	ND	5.00
3/31/2004	12.4	0.205	9.17	6.4	0.70	0.004	0.11	0.01	5.20
5/11/2004	11.1	0.292	8.96	19.3	0.30	0.005	0.03	0.01	3.67
5/28/2004	9.4	0.283	9.85	14.9	0.40	0.003	0.13	0.01	2.09
6/10/2004	8.4	0.353	10.14	18.1	0.60	0.006	0.09	0.01	1.10
6/28/2004	9.3	0.375	8.02	15.8	0.60	0.005	0.07	0.01	1.17
7/7/2004	9.8	0.361	8.28	21.2	0.40	0.004	0.08	0.01	0.98
7/21/2004	8.4	0.337	8.18	20.4	0.30	0.004	0.10	0.01	0.81
8/4/2004	9.8	0.383	8.52	21.3	0.20	0.003	0.04	0.01	0.95
10/19/2004	10.7	0.344	8.30	8.1	1.10	0.002	0.07	0.03	1.22
11/23/2004	10.6	0.317	8.44	5.7	0.30	0.003	0.01	0.05	0.89
12/9/2004	9.7	0.280	7.96	2.5	0.70	0.002	0.07	0.01	2.83
1/4/2005	7.6	0.266	8.03	2.2	1.00	0.003	0.04	0.01	3.50
5/16/2005	11.1	0.270	8.25	14.2	0.50	0.004	0.09	0.01	1.70
5/26/2005	10.6	0.314	8.14	14.4	0.05	0.005	0.05	0.01	1.04
6/10/2005	8.3	0.367	8.27	23.2	0.60	0.012	0.20	0.01	1.50
6/23/2005	9.5	0.357	8.66	23.1	0.70	0.006	0.16	ND	1.04
7/7/2005	7.7	0.432	7.73	20.4	0.80	0.012	0.51	ND	1.29
7/19/2005	8.2	0.339	9.13	24.5	0.30	0.005	0.18	ND	1.05
8/1/2005	11.1	0.363	8.19	21.9	0.30	0.004	0.09	ND	1.30
8/16/2005	8.6	0.397	8.11	20.6	0.50	0.009	0.09	ND	1.34
9/1/2005	8.0	0.239	8.98	18.0	0.70	0.004	0.36	0.05	9.99
Mean	10.2	0.334	8.48	14.2	0.65	0.005	0.10	0.01	3.32
S.E.	0.3	0.010	0.10	1.2	0.07	0.0004	0.01	0.002	0.67
Minimum	5.8	0.180	7.28	-0.4	0.05	0.002	0.01	ND	0.10
Maximum	14.5	0.523	10.57	26.4	2.50	0.014	0.51	0.05	23.30

Table 10. Water quality data for Site 6 in the Sandy Creek watershed located on NY Route 3 (Figure 1). DO = dissolved oxygen, Cond = conductivity, TP = total phosphorus, NA = not available, ND = non-detectable and S.E. = standard error of the mean.

Site 6 Date	DO (mg/L)	Cond (mS/cm)	pH	Temperature (°C)	Nitrate (mg N/L)	Nitrite (mg N/L)	Ammonia (mg N/L)	TP (mg P/L)	Turbidity (NTU)
10/27/1997	11.2	0.367	7.14	7.6	0.70	0.004	0.09	NA	NA
11/1/1997	13.5	0.361	7.50	5.3	0.60	0.003	0.10	0.10	NA
11/23/1997	14.0	0.354	8.48	2.5	0.50	0.005	0.09	ND	NA
12/8/1997	15.1	0.329	7.67	2.1	1.10	0.005	0.03	ND	NA
3/18/1998	14.9	0.344	7.66	3.3	1.80	0.005	0.07	0.01	NA
4/1/1998	11.3	0.232	7.95	11.0	0.60	0.005	0.13	0.02	NA
4/15/1998	12.0	0.361	8.46	12.5	1.20	0.007	0.09	0.01	NA
4/29/1998	10.2	0.359	8.48	19.6	0.60	0.009	0.07	0.01	NA
5/23/1998	10.3	0.319	8.81	19.8	0.10	0.004	0.11	0.01	NA
5/28/1998	11.0	0.356	8.68	24.0	0.20	0.007	0.08	0.01	NA
6/11/1998	10.8	0.345	8.65	19.3	0.10	0.003	0.09	0.01	NA
6/24/1998	9.9	0.376	8.51	25.2	0.10	0.003	0.09	0.01	NA
7/9/1998	9.5	0.333	8.65	25.6	0.20	0.006	0.10	0.01	NA
7/23/1998	9.8	0.375	8.49	27.2	0.30	0.011	0.12	0.02	NA
8/12/1998	8.9	0.280	8.71	25.0	0.50	0.007	0.30	0.06	NA
8/26/1998	9.0	0.192	8.21	22.5	0.60	0.001	0.36	0.05	NA
9/24/1998	11.3	0.380	7.93	11.6	0.30	0.003	0.05	0.01	NA
10/8/1998	10.4	0.375	8.03	13.9	NA	0.004	0.07	0.01	NA
10/22/1998	12.4	0.354	8.23	9.9	0.20	0.002	0.07	0.01	NA
11/5/1998	13.3	0.384	7.89	6.1	0.40	0.004	0.05	0.01	NA
11/19/1998	14.2	0.330	8.01	4.4	0.40	0.003	0.06	ND	NA
12/10/1998	14.4	0.323	8.25	5.5	0.50	0.004	0.06	0.01	NA
12/22/1998	14.9	0.223	7.13	1.6	0.90	0.000	0.31	0.08	NA
1/27/1999	15.6	0.317	7.24	0.8	1.80	0.005	0.16	0.04	NA
2/18/1999	14.7	0.331	7.37	1.6	1.30	0.003	0.09	0.02	NA
3/5/1999	15.0	0.322	7.06	-0.1	1.40	0.004	0.17	0.04	NA
3/24/1999	13.4	0.399	7.90	6.4	0.90	0.006	0.08	0.02	NA
4/15/1999	12.0	0.260	8.51	12.2	0.50	0.002	0.07	0.01	NA
5/11/1999	10.1	0.401	8.23	17.6	1.30	0.007	0.09	0.01	NA
6/23/1999	8.9	0.398	8.42	26.4	0.20	0.001	0.18	0.05	NA
7/8/1999	10.2	0.403	8.39	23.9	0.40	0.006	0.10	0.02	NA
7/21/1999	9.3	0.340	8.47	27.3	0.30	0.002	0.12	0.02	NA
8/2/1999	9.8	0.379	8.47	26.7	0.30	0.002	0.10	0.02	NA
8/18/1999	11.3	0.323	8.72	23.6	0.50	0.003	0.12	0.01	NA
9/1/1999	8.3	0.435	8.27	22.2	0.30	0.005	0.10	0.02	NA
9/15/1999	10.3	0.411	8.39	21.2	0.20	0.004	0.22	0.03	NA
9/29/1999	10.0	0.346	8.57	21.8	0.10	0.002	0.08	0.02	NA
10/18/1999	11.8	0.324	8.32	10.9	0.90	0.003	0.09	0.02	NA
11/3/1999	12.4	0.400	7.38	7.6	1.30	0.007	0.10	0.02	5.65
11/15/1999	13.5	0.304	8.02	5.1	1.10	0.004	0.10	0.01	1.42
12/6/1999	11.8	0.300	7.87	8.5	1.90	0.004	0.10	0.02	2.00
12/20/1999	14.4	0.325	6.06	-0.1	1.50	0.004	0.05	0.03	2.71
1/3/2000	13.7	0.236	5.17	-0.1	1.70	0.006	0.45	0.10	56.30
1/18/2000	13.3	0.462	5.85	-0.3	2.50	0.006	0.02	0.03	2.63
2/24/2000	13.4	0.352	6.87	-0.2	2.00	0.013	0.62	0.14	4.85
3/2/2000	14.2	0.243	7.05	2.0	1.50	0.005	0.31	0.12	11.90
3/29/2000	13.7	0.208	7.05	2.7	1.00	0.003	0.30	0.04	28.90
4/12/2000	13.4	0.280	7.89	6.4	1.60	0.003	0.07	0.02	6.80
4/26/2000	13.6	0.281	8.32	9.3	1.00	0.004	0.04	0.01	1.52
5/8/2000	10.0	0.271	8.65	22.6	0.60	0.008	0.06	0.02	1.87
5/22/2000	11.1	0.297	9.39	13.9	1.00	0.006	0.12	0.02	NA

Site 6 (cont.) Date	DO (mg/L)	Cond (mS/cm)	pH	Temperature (°C)	Nitrate (mg N/L)	Nitrite (mg N/L)	Ammonia (mg N/L)	TP (mg P/L)	Turbidity (NTU)
6/5/2000	9.4	0.324	8.58	20.9	1.20	0.018	0.08	0.02	2.11
6/21/2000	9.6	0.283	8.74	22.7	1.30	0.086	0.66	NA	2.33
7/12/2000	9.4	0.294	8.61	26.0	0.70	0.011	0.14	0.02	1.97
7/24/2000	9.7	0.312	8.57	26.4	0.60	0.007	0.11	0.02	2.23
8/7/2000	9.6	0.328	8.40	26.1	0.70	0.011	0.15	0.02	2.60
8/23/2000	10.0	0.332	8.36	19.7	0.50	0.007	0.08	0.02	2.01
9/5/2000	11.3	0.395	8.38	18.6	0.80	0.007	0.07	0.02	1.08
9/18/2000	10.4	0.322	8.54	20.0	0.30	0.004	0.07	0.02	NA
10/2/2000	10.6	0.362	8.54	18.3	0.40	0.005	0.11	0.01	1.13
10/16/2000	12.1	0.368	8.20	10.7	0.40	0.006	0.07	ND	1.72
10/30/2000	13.7	0.376	7.90	7.9	0.70	0.004	0.05	ND	1.04
11/16/2000	13.5	0.289	7.79	5.8	0.50	0.007	0.08	0.05	2.01
12/4/2000	14.4	0.367	7.36	1.1	1.80	0.006	0.06	0.02	3.29
12/21/2000	13.8	0.312	6.82	-0.2	1.70	0.005	0.10	0.02	6.60
3/26/2001	15.0	0.366	5.80	2.5	1.70	0.007	0.03	0.02	2.45
11/13/2001	13.2	0.297	8.55	7.5	0.40	0.005	0.10	0.01	1.22
12/3/2001	12.7	0.299	8.46	6.3	1.00	0.003	0.09	0.01	1.41
12/20/2001	13.8	0.311	7.78	2.8	1.20	0.003	0.09	0.01	2.18
1/28/2002	14.2	0.312	6.87	3.8	1.80	0.003	0.06	0.02	3.83
2/25/2002	13.6	0.292	7.47	4.2	1.90	0.003	0.05	0.01	3.94
3/11/2002	14.2	0.204	7.29	1.2	1.30	0.001	0.40	0.04	39.50
4/10/2002	12.6	0.138	8.23	5.1	1.10	0.006	0.84	0.10	1.45
5/14/2002	12.1	0.176	7.94	7.8	1.40	0.001	0.71	0.14	NA
6/20/2002	9.7	0.290	8.40	26.3	0.70	0.007	0.08	0.01	1.69
7/3/2002	8.6	0.391	7.16	25.3	0.80	0.018	0.11	0.02	3.31
7/18/2002	7.9	0.368	8.39	25.3	0.70	0.023	0.15	0.02	3.35
8/1/2002	7.2	0.374	8.65	28.1	0.40	0.006	0.07	0.02	4.38
8/15/2002	7.5	0.399	8.52	26.8	0.40	0.009	0.22	ND	3.83
9/24/2002	9.8	0.485	8.40	15.0	1.40	0.018	0.08	ND	2.27
10/8/2002	9.5	0.427	7.87	8.7	0.50	0.005	0.07	0.01	0.84
10/26/2002	13.4	0.380	7.42	2.6	1.00	0.005	0.07	0.01	1.15
11/5/2002	11.5	0.400	7.55	5.9	1.50	0.005	0.02	ND	0.76
11/18/2002	13.7	0.316	8.14	3.0	0.80	0.004	0.05	ND	1.30
1/2/2003	14.4	NA	NA	0.0	2.50	0.002	0.06	0.01	6.13
3/24/2003	13.3	0.288	7.20	4.9	2.20	0.003	0.17	0.02	32.60
4/7/2003	13.8	0.349	7.19	2.4	1.80	0.003	0.09	ND	4.77
4/29/2003	11.9	0.284	8.70	14.7	0.80	0.003	0.04	ND	2.15
5/12/2003	10.9	0.206	7.91	11.7	0.70	0.003	0.22	0.03	22.80
5/27/2003	10.5	0.288	8.22	14.8	4.50	0.004	0.18	0.02	9.96
6/19/2003	9.6	0.437	8.75	18.8	0.90	0.006	0.10	0.01	1.46
7/2/2003	10.1	0.447	8.65	27.0	0.80	0.016	0.01	0.01	1.18
7/17/2003	10.4	0.451	8.46	26.5	0.60	0.010	0.00	0.01	1.59
7/31/2003	9.9	0.472	8.48	26.4	0.30	0.005	0.13	ND	0.87
8/14/2003	9.3	0.412	8.95	25.3	0.40	0.005	0.06	0.01	4.84
9/3/2003	10.0	0.523	8.88	19.2	0.60	0.007	0.07	ND	1.88
9/17/2003	10.5	0.520	8.56	24.5	0.70	0.007	0.02	0.01	1.91
10/8/2003	12.8	0.504	7.82	9.3	0.90	0.002	0.09	0.01	2.24
11/5/2003	11.5	0.355	8.54	11.3	0.80	0.006	0.12	0.01	2.63
12/2/2003	14.9	0.308	7.49	0.5	1.20	0.004	0.02	0.01	5.26
4/6/2004	12.9	0.317	8.13	6.1	0.80	0.005	0.06	0.01	2.07
5/17/2004	10.9	0.353	8.64	16.3	0.70	0.005	0.05	ND	1.58
6/1/2004	9.8	0.385	9.03	20.4	0.70	0.007	0.11	0.01	1.37
6/15/2004	9.9	0.392	8.50	20.6	0.70	0.018	0.09	0.02	2.06
6/29/2004	10.5	0.419	8.41	17.9	0.50	0.005	0.09	0.02	1.67
7/13/2004	9.7	0.340	8.86	26.8	0.10	0.003	0.09	0.02	1.45
7/26/2004	9.7	0.416	8.43	20.4	0.30	0.004	0.14	0.02	1.68
8/9/2004	9.5	0.419	8.44	19.0	0.20	0.004	0.06	0.01	1.05

Site 6 (cont.) Date	DO (mg/L)	Cond (mS/cm)	pH	Temperature (°C)	Nitrate (mg N/L)	Nitrite (mg N/L)	Ammonia (mg N/L)	TP (mg P/L)	Turbidity (NTU)
10/13/2004	9.8	0.459	8.55	14.6	0.30	0.005	0.05	0.02	1.35
11/29/2004	10.2	0.257	7.94	4.1	0.90	0.002	0.20	0.05	9.99
5/5/2005	12.2	0.312	9.23	13.6	0.40	0.016	0.05	0.01	1.08
5/23/2005	10.8	0.392	8.31	11.4	0.80	0.006	0.10	0.01	2.12
6/6/2005	8.8	0.394	8.37	22.0	0.30	0.025	0.34	0.03	5.17
6/23/2005	8.5	0.357	8.83	24.4	0.30	0.010	0.09	ND	1.92
7/7/2005	9.2	0.462	7.91	20.6	0.30	0.008	0.25	0.02	2.38
7/21/2005	7.4	0.362	8.54	30.5	0.20	0.005	0.44	ND	1.46
8/15/2005	9.1	0.460	8.51	21.2	0.50	0.010	0.07	0.01	1.18
9/1/2005	8.4	0.254	9.16	19.7	0.80	0.004	0.29	0.04	9.99
12/15/2005	10.8	0.387	8.03	0.0	1.50	0.006	ND	0.02	2.41
Mean	11.4	0.346	8.09	13.6	0.87	0.007	0.13	0.02	5.00
S.E.	0.2	0.007	0.07	0.9	0.06	0.001	0.01	0.002	1.02
Minimum	7.2	0.138	5.17	-0.3	0.10	0.000	ND	ND	0.76
Maximum	15.6	0.523	9.39	30.5	4.50	0.086	0.84	0.14	56.30

Table 11. Nonevent (baseline) total phosphorus concentrations and watershed areas from creeks in central and western New York. Data is from Makarewicz 1988, Makarewicz and Lewis 1996, 1998, 1998a, 1999, 2000, 2003 Makarewicz *et al*.1991a, 1992, 2006.

Creek	Total phosphorus (µg P/L)	Watershed Area (ha)	**Land Use**
Canandaigua Lake Watershed 1997			
Fall Brook	19.4	1343	Agriculture /suburban
Deep Run Gully	7.4	525	Agriculture
Vine Valley	28.4	1115	Agriculture
Clark Gully	9.1	325	Forested
Naples Creek	5.5	8143	Agriculture / Suburban
Sucker Brook	97.5	1759	Urban / Agriculture
Seneca Point	94.8	1048	
Oswego County 1997			
Sheldon	92.0	1357	Muckland
Summerville	108.1	409	Suburban
Ley	270.8	632	Muckland / Agriculture
Wayne County 1991-92			
Sodus	46.3	3065	Agriculture
Wolcott	115.6	4416	Agriculture
Second	31.3	2610	
Orleans County 1997-98			
Oak Orchard	126.4	36989	Agriculture
Johnson	88.3	25530	Agriculture
Sandy	96.9	23056	Agriculture / Suburban
Orleans County 1998-99			
Oak Orchard	103.5	36989	Agriculture
Johnson	95.8	25530	Agriculture
Sandy	123.7	23056	Agriculture / Suburban
Seneca County 1990-94			
Kendig Creek	143.0	5149	Agriculture
Livingston County 1990-91			
Hanna's	74.6	718	Agriculture / Suburban
Conesus Inlet	28.2	4475	Wetlands / Agriculture
South McMillan	30.6	2687	Agriculture
Monroe County 1987-88			
Upper Northrup	68.60	1049	Suburban
Lower Northrup	263.60	1862	Suburban / Sewage Plant
Niagara County 1998 - 2002			
Twelvemile Creek East	46.0	16372	Agriculture / Suburban
Twelvemile Creek West	68.1	9321	Agriculture / Suburban
Niagara County 2003 – 2005			
Eighteen Mile Creek - Ide Road	171.9	23494	Urban / Agriculture
Jefferson County 1997-2005			
Sandy Creek	**22**	**38690**	**Agriculture**
South Sandy Creek	**17**	**27760**	**Agriculture**

Table 12. Mean values for nutrient and physical parameters for Sandy Creek and South Sandy Creek before and after implementation of best management practices (BMP's) in the watersheds. Site 1 is located on South Sandy Creek at Rt. 189; Site 2 is located on South Sandy Creek at NYS Rt. 3; Site 3 is located on the north branch of Sandy Creek at Rt. 155; Site 4 is located on the south branch of Sandy Creek at Rt. 155; Site 5 is located on Sandy Creek at Rt. 69; Site 6 is located on Sandy Creek at NYS Rt. 3. Pre-BMP = 1997 and 1998, Post-BMP = 1999 to 2005, NA = data not available. ** indicates significant difference (ANOOVA).

Site	Total phosphorus (mg P/L)		Nitrate (mg N/L)		Nitrite (mg N/L)		Ammonia (mg N/L)		Conductivity (mS/cm)		pH	
	Pre-BMP	Post-BMP	Pre-BMP	Post-BMP	Pre-BMP	Post-BMP	Pre-BMP	Post-BMP	Pre-BMP	Post-BMP	Pre-BMP	Post-BMP
1	0.01	NA	0.21	NA	0.003	NA	0.09	NA	0.127	NA	7.32	NA
2 (Main site on South Sandy Creek)	0.02	0.02	0.45	0.52	0.005	0.004	0.11	0.13	0.191	0.209	7.50	**7.81
3	0.02	0.02	0.34	0.67	0.005	0.003	0.06	0.10	0.416	0.377	7.83	7.78
4	0.02	0.03	0.45	0.55	0.004	0.003	0.12	0.13	0.245	0.226	7.88	7.83
5	NA	0.01	NA	0.65	NA	0.005	NA	0.10	NA	0.334	NA	8.48
6 (Main site on Sandy Creek)	0.02	0.02	0.54	**0.94	0.005	0.007	0.11	0.14	0.333	0.350	8.15	8.08

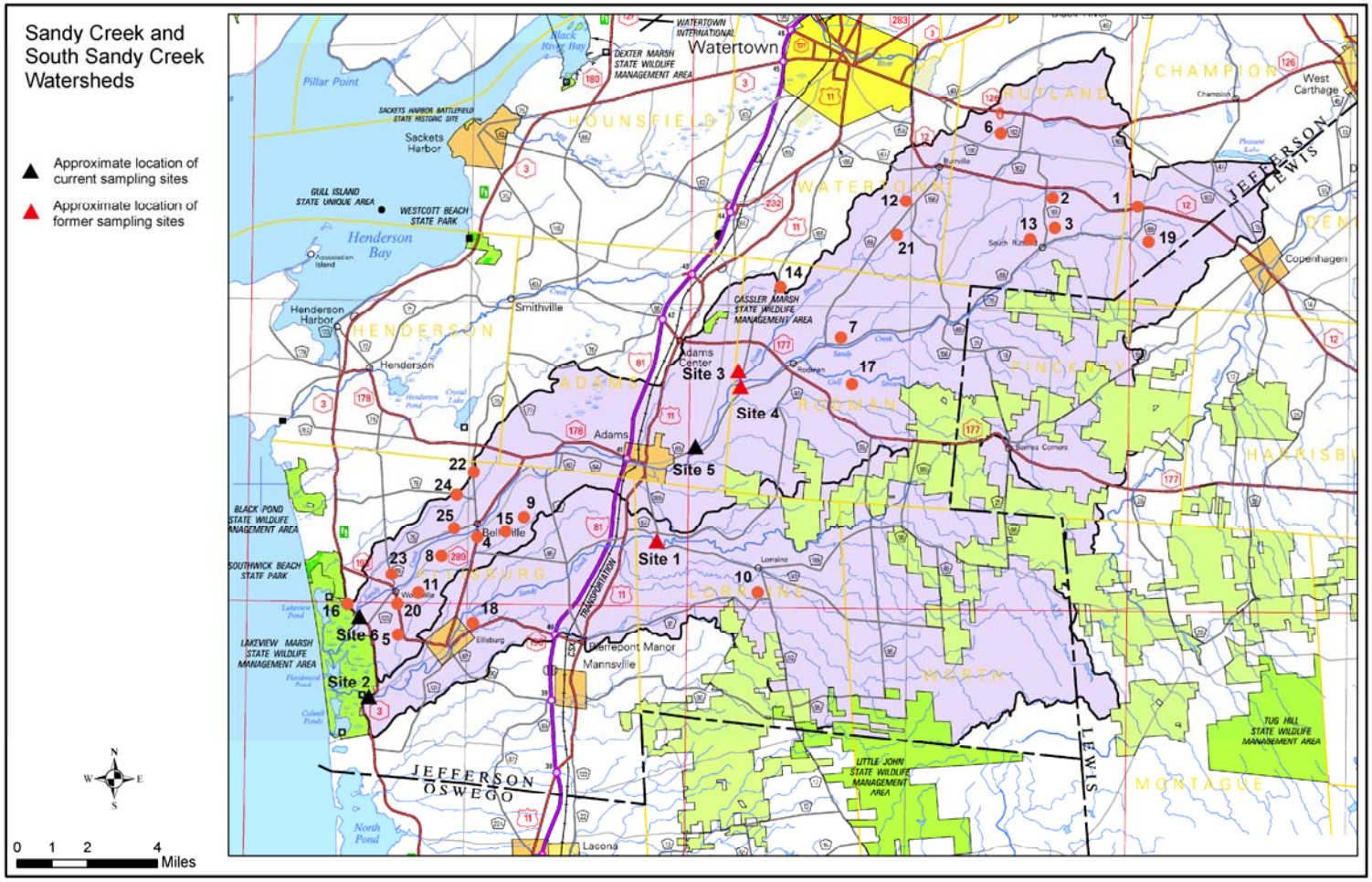

Figure 1. Map of the Sandy Creek and South Sandy Creek watersheds showing the locations of the six water monitoring sites. The numbered red circles are approximate locations of farms where Best Management Practices were implemented and the numbers refer to the farms on Table 1.

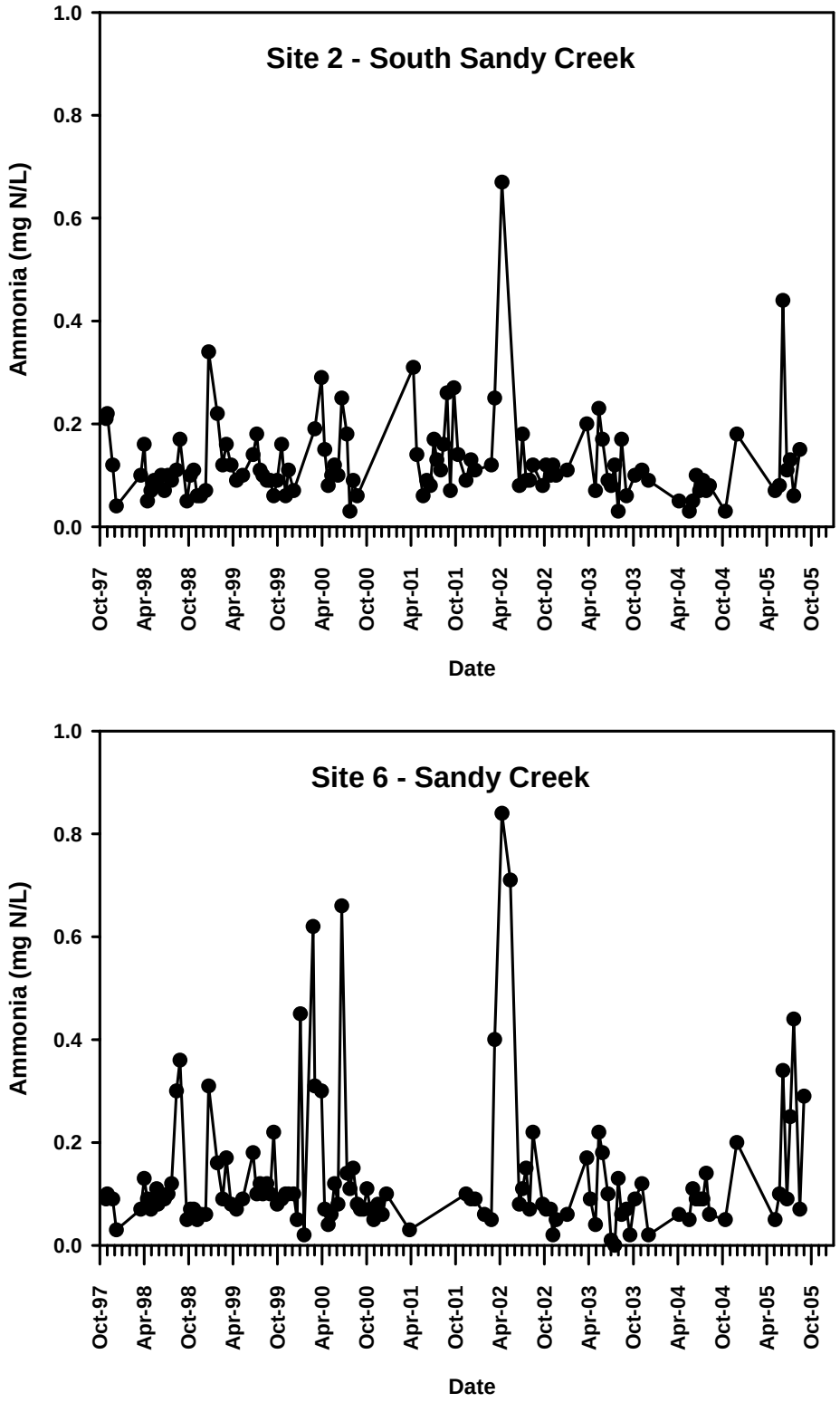

Figure 2. Ammonia concentrations for Site 2 on South Sandy Creek and for Site 6 on Sandy Creek for the period October 1997 to December 2005.

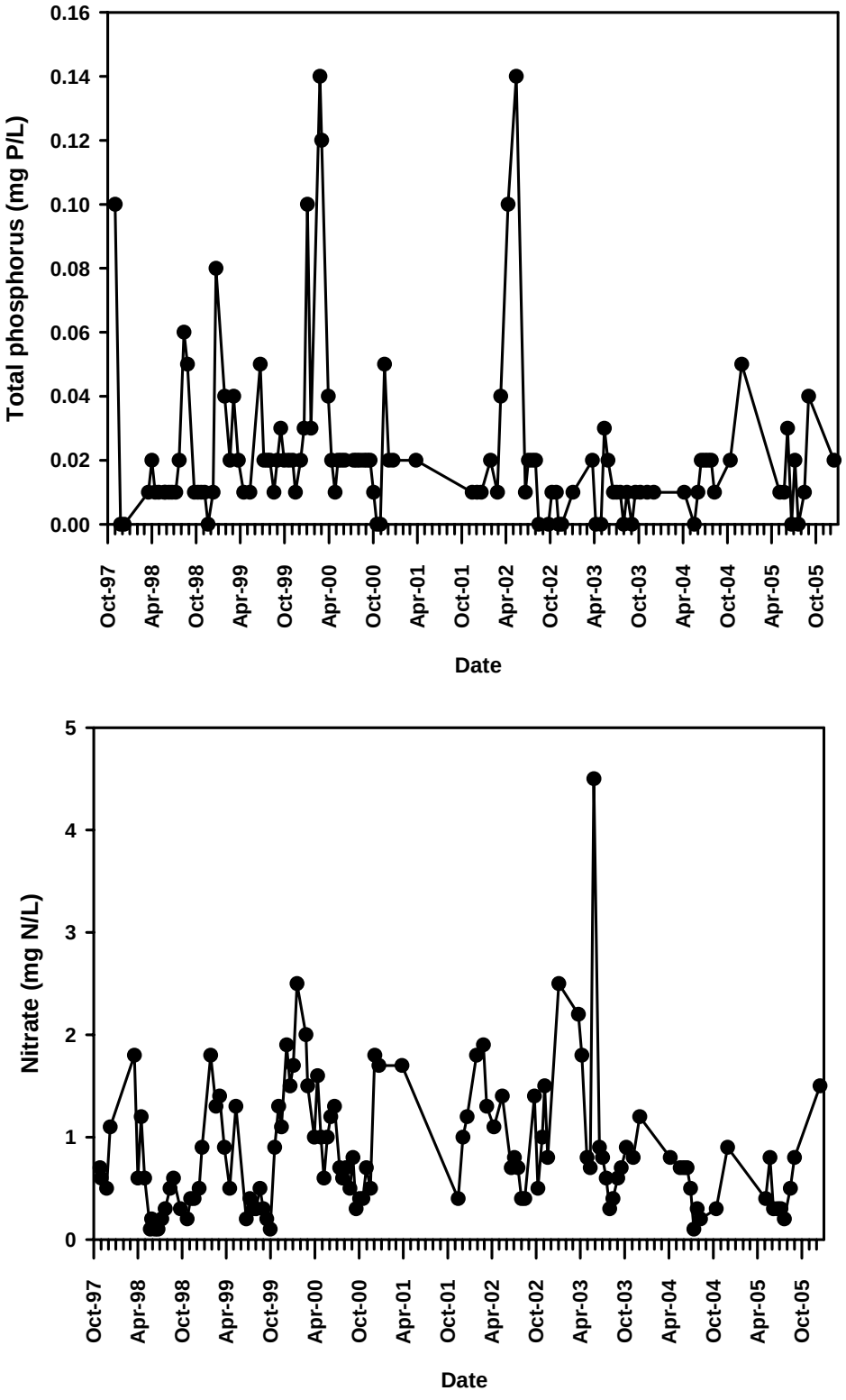

Figure 3. Total phosphorus and nitrate concentrations for Site 6 on Sandy Creek for the period October 1997 to December 2005.

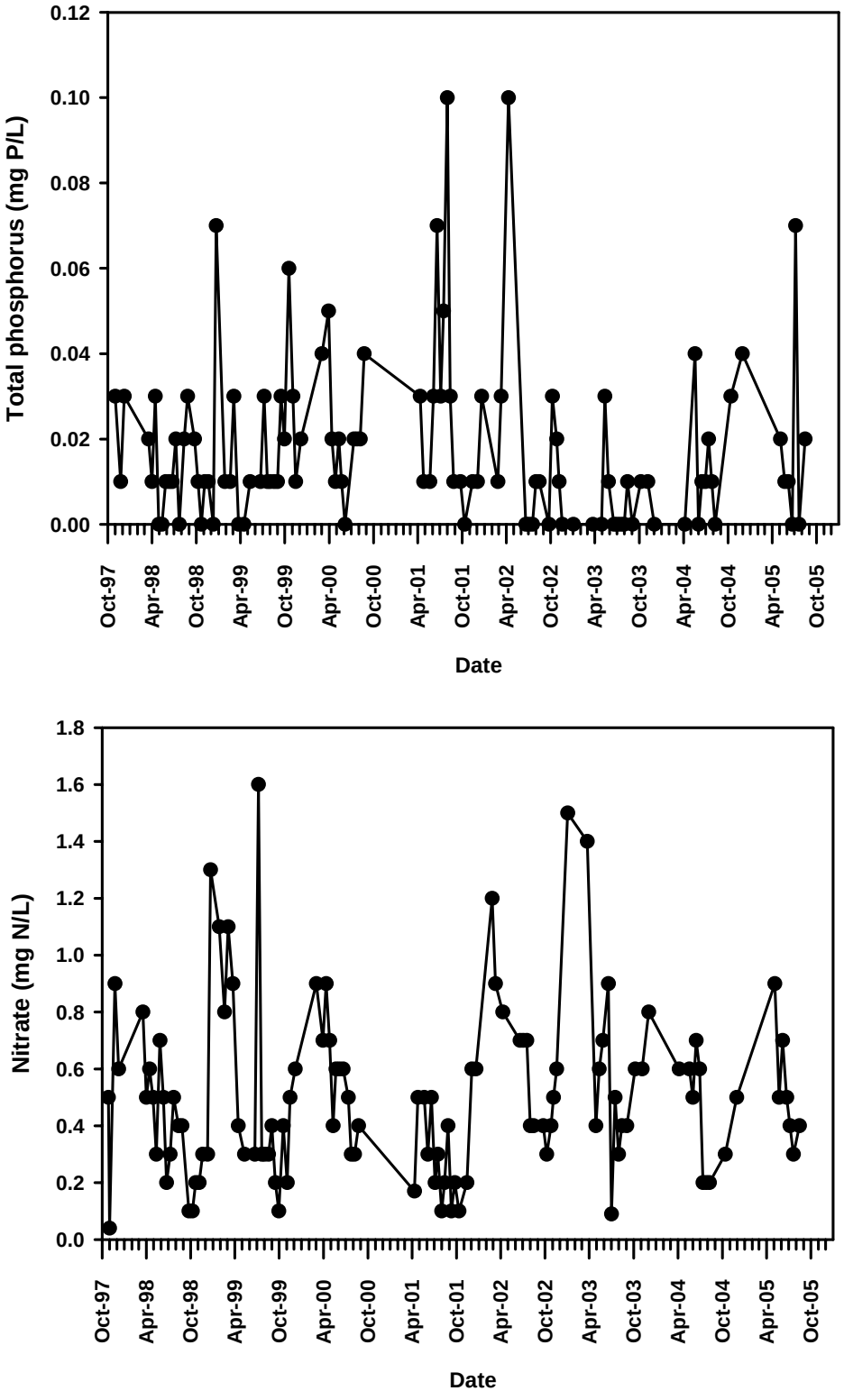

Figure 4. Total phosphorus and nitrate concentrations for Site 2 on South Sandy Creek for the period October 1997 to December 2005.