Eighteenmile Creek Watershed

The Location of Sources of Pollution

Part of the Lake Ontario Watershed
Located in Niagara County, New York

A Report to the Niagara County Soil and Water Conservation District

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Executive Summary

1. Previous monitoring had identified Eighteenmile Creek as having the highest load of phosphorus to Lake Ontario of the Niagara County streams. In comparison to other New York Lake Ontario tributaries, Eighteenmile Creek had relatively high phosphorus concentrations. For example, from 2003 to 2009, total phosphorus (TP) levels in creek water averaged 124.7±12.3 µg P/L and were significantly higher than the average for New York tributaries (83.8±7.0 µg P/L). Creek TP concentrations were significantly higher than in the open (9.5±0.7 µg P/L) offshore waters of Lake Ontario and exceeded the NYSDEC Ambient Guidelines for phosphorus of 20 µg P/L.
2. As a result of these data, Niagara County Soil and Water Conservation District (NCSWCD) contracted with The College at Brockport, State University of New York, to identify location/sources of pollution within the Eighteenmile Creek watershed.
3. Following the "segment analysis" approach, water samples were taken spatially over a one-year period on seven dates (9 March 2009, 6 April 2009, 8 April 2009, 29 May 2009, 30 June 2009, 26 August 2009, 3 December 2009) during or just after rainfall periods over the entire Eighteenmile Creek watershed. In total, 28 sites were sampled at least once, and over 540 water samples were analyzed for chemical analysis.
4. Five locations (Fig. 44) were identified as sources of nutrient and soil loss within the Eighteen mile Creek watershed.
    a. **The Lockport Water Treatment Plant (Sites 10, 11, and 13: Figs. 9, 32, 33, 34, 35, 44):** The City of Lockport's wastewater treatment plant (WWTP) is a major source of nutrients to the "West Branch" of Eighteenmile Creek and. Over the study period, TP concentrations at Site 13 just below the WWTP averaged 165.1 µg P/L, which is significantly above the 20 µg P/L NYS Guideline for Ambient Levels of Phosphorus in Surface Waters. The results from 26 August 2009, a nonevent period, provided clear evidence that the WWTP (West Jackson St.) was impacting downstream areas of Eighteenmile Creek. Compared to sites upstream of the WWTP, all nutrient concentrations increased downstream of the treatment plant. For example, from Sites 10 and 11 to the downstream Site 13, which is beyond the Lockport WWTP, increases of 153% for soluble reactive phosphorus (SRP)(62.0 to 156.9 µg P/L), 103% for nitrate (1.05 to 2.13 mg N/L), 35% for TP (136.1 to 183.2 µg P/L), and 16% for total Kjeldahl nitrogen (350 to 407 µg N/L) were observed (Figs. 32-35). Similarly on 6 April 2009, SRP increased >250% to 84.6 µg P/L at Site 13 (Fig. 9) downstream from the outfall of the wastewater plant, A similar pattern existed for TP where concentrations increased 65% as a result of the WWTP effluent.

    b. **Salt Barn (Site12A; Figs. 13, 19, 44):** The New York State DOT deicing salt storage barn (Lockport Junction Rd.) is a source of sodium to Eighteenmile Creek. On several occasions, sodium concentrations exceeding 100 mg/L were observed upstream of Site 12 (e.g., 9 March 2009: 131.20 mg/L; 6 April

2009:150.00 mg/L; 8 April 2009: 178.00 mg/L). Areas upstream of Site 12A were identified as the source of sodium. For example on 6 April 2009 sodium concentrations at Site 12A on a small feeder stream were almost 300% greater than Site 12B in the headwaters of Eighteenmile Creek. Within the watershed of Site 12A is a NYSDOT salt storage barn. This suggests that the origin of the salt is the de-icing salt barn. It is unlikely that the parking lot at Delphi plant would cause such a high increase. However, we were not able to sample on this property as it was fenced in when we were present. A similar result was observed on 8 April 2009 and 3 December 2009 (Fig. 43).

c. **Agricultural Land (Sites 3 and 4; Figs. 23, 44):** The fields west and northwest of Sites 3 and 4 (McKee Rd. and West Creek Rd., respectively) were the source of organic nitrogen observed. On 29 May 2009, high TKN concentrations were observed at Site 3 (894 µg N/L) and Site 4 (839 µg N/L). Elevated TP concentrations were also observed at these locations (>120 µg P/L) on this date. There was a strong smell in this area. Inspection of some of the adjacent fields revealed that had manure had been recently been applied to the fields.

d. **Agricultural Land (Site 12 Series; Figs. 8, 14, 38, 44**): Located in the general area of Campbell Boulevard and Old Saunders Settlement Road, this area drains agricultural land through a series of ditches. Elevated levels of TP were observed upstream of Site 12B on 6 April 2009 (198.9 µg P/L), 8 April 2009 (135.8 µg P/L), and 3 December 2009 (157.6 µg P/L). An extra site south of Site 12B at Site 12C revealed even higher TP levels (290.4 µg P/L) on 3 December 2009. The elevated TP concentrations were always associated with elevated levels of total suspended solids indicating that soil erosion, either stream bank or surface field erosion, was occurring in this headwater area. Similarly, high organic nitrogen levels (1909 µg N/L) were observed at Site 12C on 3 December. Site 12C is a small creek/ditch that drains a corn field at the very headwaters of Eighteenmile Creek on top of the Niagara escarpment.

e. **Agricultural** Land (Site 14 Series; Figs. 44): The Site 14 series of sites drains a series of agricultural operations with animals and corn silage stored on site. At least three, perhaps four CAFO operations exist in the watershed of this branch of the stream. Throughout the study period, the entire East Branch of Eighteenmile Creek had elevated levels of phosphorus, organic nitrogen, and nitrate. In fact, much of our effort went into locating sources within this branch of the creek. The source of much of the nutrient pollution of the East Branch was located above the Niagara Escarpment in the southwestern portion of the watershed. For example, on 3 December 2009 TP concentrations on Mackey Road (Site 14C2B1) reached 2,679.8 µg P/L in a small stream ditch that runs into the main branch. This represents a 100-fold increase over the NYS Guidelines for ambient levels of phosphorus (20 µg P/L). Site 14C2A had a nitrate concentration of 7.13 mg N/L, over five times that of the next highest station sampled on this date. Site 14C2B on Mountain Road and Site 14C2B1 on Mackey Road had concentrations of organic nitrogen (TKN) over 7,000 µg N/L, suggesting improperly stored manure or improper timing of manure application. Lastly, the loss of soil (TSS) from this agricultural area is significant at times (e.g., 3 December 2009).

Recommendations

- A key goal of good stewardship practices and management of the land and of wastewater should be to reduce nutrient losses and inputs into freshwater systems. Such a goal creates a situation whereby soil and nutrients are maintained on the land where needed, while soil and nutrient levels in downstream systems (rivers and lakes) are reduced where overfertilization causes overproduction of plants in streams and lakes or eutrophication.

- Likely locations of point and nonpoints sources of elevated levels of nutrients and soil loss within the Eighteenmile Creek watershed were identified. A visual inspection of these areas with landowners/agencies is suggested to pinpoint potential sources.

- A review of the City of Lockport's Wastewater Treatment Plant's New York State SPDES permit should be undertaken. Technology exists that would improve the ability of this treatment plant to remove phosphorus from its effluent.

- Discussions with NYS DOT should begin. Salt is clearly being lost from the storage facility on Lockport Junction Road, and this can probably be easily rectified.

- For agricultural sites, discussions with landowners and the implementation of Whole Farm Planning practices should begin or the plans in place should be critically reviewed. This is especially important for the CAFO's that hae been identified. Cornell Cooperative Extension could also be invited to participate.

- Many of the nonpoint pollution sites within the Eighteenmile Creek watershed are a function of runoff. In general, control of water movement can be a means of significantly reducing nonpoint source pollution, whether it be nutrients or soil. Since water must come in contact with the nutrient or soil source and then be transported to the surface (or subsurface) water body, the nutrients in our streams and lakes are functions of land use practices, soil fertility and quantities of transporting water. Management practices should target both field and barn runoff.

- Identified point and nonpoint sources of nutrients and solids can be remediated using Best Management Practices (BMPs). Management practices, which reduce the magnitude of surface runoff, are recommended to decrease the magnitude of soil and chemical losses from land areas. Studies in western New York have demonstrated (e.g., Makarewicz et al. 2009) that management practices such as buffer strips, sediment retention ponds, cover crops, zone tillage, contour plowing, timing of tillage practices and timing of manuring practices, where used, all can either reduce the erosive power of water running across the landscape or reduce the potential of nutrient and soil loss.

- Where agriculture was identified as a local cause of elevated nutrients or soil loss, a soil testing program, if not already in progress, should be instituted in row crop areas to determine the need for fertilization. Such a program should consider using the P and N-Index developed by Cornell University that considers credits from manure use. Fertilizer should not be used as an insurance program to maintain crop yields. At Conesus Lake, farmers were able to reduce fertilizer use and maintain corn yields, saving thousands of dollars (Jacobs 2006a and b). Also, articles titled “Nine Tips to Manage N Better” (Czymmek 2005) and “How Much P is Enough” (Ketterings and Czymmek 2005) provide a useful review of nutrient management issues that are applicable to the Eighteenmile Creek watershed. Farmers in western New York have reduced fertilizer usage and successfully maintained corn yields while saving money.

Introduction

Mitigation of soil and nutrient loss from the landscape continues to be a concern within watersheds of the United States and indeed worldwide. There are a number of reasons for this concern. Depletion of agricultural soil is counterproductive to good farming practices and crop productivity. Suburban, urban, and agricultural runoff and concomitant nutrient and soil loss to downstream aquatic ecosystems may produce undesirable effects including increased numbers of bacteria, algae, and macrophytes, increased siltation, and decreased aesthetics – in general, a deterioration in both surface (streams) and groundwater quality downstream resulting in cultural eutrophication of lakes and streams. In western New York, restoration and remediation of the Eighteenmile Creek watershed (Fig. 1) and the nearshore waters of Lake Ontario into which this creek empties has been a goal for over a decade.

Determination of sources and magnitude of soil and nutrient losses from a watershed is prerequisite to remedial action and essential to making cost-effective land management decisions as it reduces the likelihood of costly miscalculations based on the assumption of soil and nutrient sources and modeling rather than on their actual identification. This process enhances the ability of concerned groups to obtain external funding for demonstration and remedial projects. In July 2003, the Niagara County Soil & Water Conservation District (NCSWCD), in conjunction with the Department of Environmental Sciences and Biology at SUNY Brockport, began a monitoring program for Eighteenmile Creek, located in Niagara County, New York. The purpose of the monitoring program was to collect water quality data to quantify the concentration and loading of nutrients and suspended sediments transported from Eighteenmile Creek to Lake Ontario and to evaluate the health of the creek and its impact on Lake Ontario. In addition, the data serve as a database to make informed water quality management decisions including the development of a watershed management plan, and as a benchmark of discharge and nutrient data to measure the success of future remediation efforts Makarewicz *et al*. 2006). In a second report completed in 2008 (Makarewicz *et al.* 2008), Eighteenmile Creek was identified as having the greatest load of nutrients to downstream systems of 17 streams entering Lake Ontario from Niagara County.

This report, prepared by SUNY Brockport and the Niagara County Soil and Water Conservation District, identified sources of nutrients and soil loss in the Eighteenmile Creek watershed by a process titled “segment analysis.” This report served as a mechanism of transmittal of results and conclusions to all concerned parties and stakeholders of the Eighteenmile Creek watershed.

Background

Historically, Eighteenmile Creek is one of the six Areas of Concern (AOC) in New York State (Makarewicz and Lewis 2000). The Oswego River area AOC was recently delisted. The International Joint Commission (IJC) and the Great Lakes community are working on 42 Areas of Concern in the Great Lakes basin where beneficial uses of a waterbody have been identified as impaired. AOCs include harbors, river mouths, and river segments where Remedial Action Plans (RAPs) have been developed and are being implemented to restore and to protect beneficial uses. Fourteen use-impairment indicators have been applied to define water quality parameters.

Eighteenmile Creek has been polluted by past industrial and municipal discharges, by the disposal of waste, and by the use of pesticides. Fish consumption has been impaired by PCBs and dioxins found in the flesh of various game fish. The health of the benthos has also been impaired by PCBs and metals in creek sediments. At the mouth of Eighteenmile Creek on Lake Ontario, dredging restrictions have been placed on the disposal of dredged material from Olcott Harbor. Dredging is needed to maintain recreational boating and requires land-based confined disposal. Other use-impairment indicators in the Remedial Action Plan (RAP) that require further investigation to assess impairment are: the degradation of fish and wildlife populations, fish tumors, bird or animal deformities or reproductive problems, and the degradation of plankton populations (Makarewicz and Lewis 2000).

DEFINITIONS

mg/L and µg/L – units of concentration. Parts per million (ppm) equals mg/l. In 1 mg there is 1000 µg. For example, a concentration of 2 mg Na/L means there are two parts of sodium per I million mg of water.

Total Phosphorus (TP) - A measure of all forms of the element phosphorus. Phosphorus is an element required for plant growth on land or in water. In lakes, phosphorus is often the limiting factor of phytoplankton growth and is the cause of eutrophication, or overproduction, of lakes. Phosphorus may enter a watershed in soluble or organic form from several sources including sewage, heavy-duty detergents, fertilizer, and agricultural waste. Some forms of phosphorus are more available to, and cause more immediate activity in, plants.

Soluble Reactive Phosphorus (SRP) - A measure of the most available and active form of phosphorus.

Nitrate + Nitrite (NO_3+NO_2) - A measure of the soluble forms of nitrogen used readily by plants for growth. Sources of nitrates in the environment are many and include barnyard waste and fertilizer.

Total Kjeldahl Nitrogen (TKN) - The Kjeldahl method is a convenient method of analysis for nitrogen but cannot be used for all types of nitrogen compounds. It is, however, a good measure of organic nitrogen, including ammonia. Manure, for example, contains a large amount of organic nitrogen.

Sodium (Na) - A measure of the mineral, most commonly found as sodium chloride (NaCl), dissolved in water. NaCl naturally occurs in deep layers of local bedrock. Mined, it is stored and spread as a deicing agent on roads and other pavements.

Total Suspended Solids (TSS) - A measure of the loss of soil and other materials suspended in the water from a watershed. Water-borne sediments act as an indicator, facilitator and agent of pollution. As an indicator, they add color to the water. As a facilitator, sediments often carry other pollutants such as nutrients and toxic substances. As an agent, sediments smother organisms and clog pore spaces used by some species for spawning.

Methods

Segment Analysis: Point and nonpoint sources of nutrients, soils, and salts within a watershed may be identified through a process called "segment analysis" or in its fullest development "stressed stream analysis" (Makarewicz 1999). Stressed stream analysis is an integrative, comprehensive approach for determining the environmental health of a watershed and its constituent streams. Within a subwatershed, stressed stream analysis is an approach for determining how and where a stream and its ecological community are adversely affected by a pollution source or other disturbances. It is a technique that identifies the sources, extent, effects and severity of pollution in a watershed. In its fullest use, it combines elements of the sciences of hydrology, limnology, ecology, organismal biology, and genetics in an integrated approach to analyze cause-and-effect relationships in disturbed stream ecosystems.

Within a subwatershed, the stream is used to monitor the "health" of the watershed. Because nutrients are easily transported by water, they can be traced to their source by systematic geographic monitoring of the stream. Segment analysis is a technique that divides the impacted subwatershed into small distinct geographical units. Samples are taken at the beginning and end of each unit of the stream to determine if a nutrient source occurs within that reach. For example, high levels of a nutrient at the downstream portion of a segment indicate a source within that segment. By systematically narrowing the size of the segment, a source can be identified. At completion, the cause and extent of pollution have been identified. If needed, the severity of the pollution within the impacted subwatershed and/or the entire watershed can then be evaluated by spatial analysis of the quantity and quality of biological indicators, such as fish and invertebrates, and by biological examination of structural and functional changes in individual organisms and populations in affected communities. Once identified, sources of chemical pollutants may be corrected using "Best Management Practices" (BMPs). Examples of the successful application of the segment analysis process in identifying impacted subwatersheds and their associated streams may be found in Makarewicz and Lewis (1993, 2000, 2001, 2001a, 2002, 2002a) and Makarewicz *et al.* (1994). In this report, stressed stream analysis is limited to a segment analysis of chemical sources of Eighteenmile Creek.

Water Sampling and Chemistry: Following the “segment analysis” approach, water samples were taken spatially over a one-year period on seven dates (9 March 2009, 6 April 2009, 8 April 2009, 29 May 2009, 30 June 2009, 26 August 2009, 3 December 2009) during or just after rainfall periods (with the exception of 26 August 2009) over the entire Eighteenmile Creek watershed (Fig. 1). In total, 32 sites (Table 1) were sampled at least once and over 540 water samples were analyzed for chemical analysis. Initial site selection was accomplished by sampling at major bifurcations of streams. After the initial selection of sites, sites were picked based on previous results systemically attempting to locate a source as described above.

Water samples were analyzed for TP (APHA Method 4500-P-F, 1999), TKN (USEPA Method 351.2, 1979), NO_3+ NO_2 (APHA Method 4500-NO_3-F), and TSS (APHA Method 2540D). Except for TSS, all analyses were performed on a Technicon AutoAnalyser II. Method Detection limits were as follows: SRP (0.48 µg P/L), TP (0.38 µg P/L), NO_3+ NO_2 (0.005 mg N/L), TKN (0.15 µg N/L), and TSS (0.2 mg/L). Sample water for dissolved nutrient analysis (SRP, NO_3+ NO_2) was filtered immediately on site with 0.45-µm MCI Magna Nylon 66 membrane filters and held at <4°C until analysis.

Quality Control/Quality Assurance: Water samples were analyzed at the Water Chemistry Laboratory at The College at Brockport, State University of New York (NELAC – EPA Lab Code # NY01449). In general, the NELAC certification program includes biannual proficiency audits and annual inspections and documentation of all samples, reagents and equipment under good laboratory practices. All quality control (QC) measures are assessed and evaluated on an on-going basis. As required by NELAC and New York's ELAP certification process, method blanks, duplicate samples, laboratory control samples, and matrix spikes are performed at a frequency of one per batch of 20 or fewer samples. Field blanks (events and nonevents) are routinely collected and analyzed. Analytical data generated with QC samples that fall within prescribed acceptance limits indicate the test method was in control. For example, QC limits for laboratory control samples and matrix spikes are based on the historical mean recovery plus or minus three standard deviations. QC limits for duplicate samples are based on the historical mean relative percent difference plus or minus three standard deviations. Data generated with QC samples that fall outside QC limits indicate the test method was out of control. These data are considered suspect and the corresponding samples are either reanalyzed or the results flagged with an appropriate explanation. As part of the NELAC certification, the lab participates semi-annually in proficiency testing program (blind audits, Table 2) for each category of ELAP approval. If the lab fails the proficiency audit for an analyte, the lab director is required to identify the source and correct the problem to the satisfaction of the certification agency.

Results

Segment Analysis

9 March 2009 (Figs. 2-7)

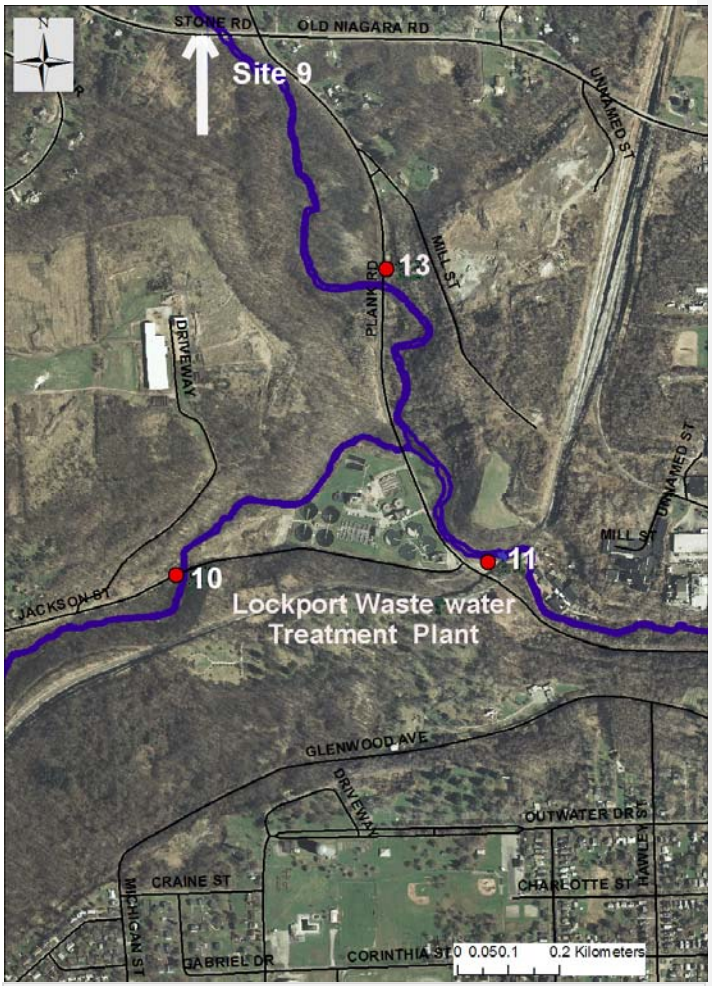
A rain (1.96 inches in three days) and flood event was sampled on 9 March 2009 on Eighteenmile Creek. Thirteen samples were taken along the entire length of the creek to initially segment the watershed and begin to isolate sources of soil and nutrients for further scrutiny (Fig. 1, Table 1). The main stem of Eighteenmile Creek was sampled at Sites 1 (near the mouth), 2 (Newfane), 9 (Ridge Road), 13 (below City of Lockport STP), 10 (above City of Lockport WWTP) and 12 Route 93 (upstream from the City of Lockport) (Fig. 1). The major East Branch of Eighteenmile Creek was sampled at Site 8 on Ridge Road and further upstream at Site 14 on Dale Road (Fig. 1). Other minor segments of Eighteenmile Creek that were sampled were represented by Sites 3 and 4 near Newfane, Site 11 that is below the Erie Canal in the City of Lockport and Sites 5 and 6 along Route 78 south of Newfane (Fig. 1).

Total Phosphorus (TP) and Soluble Reactive Phosphorus (SRP): (Figs. 2 & 3)

Site 8 at the base of the East Branch of Eighteenmile Creek had the highest SRP (128.1 µg P/L) and the second highest TP (360.3 µg P/L) concentrations observed on 9 March 2009. At Dale Road (Site 14) further upstream on the East Branch, phosphorus concentrations were still elevated (SRP = 103.1 µg P/L; TP = 293.6 µg P/L). Source(s) of P exist in the East Branch of Eighteenmile Creek, and more segments in this branch will be sampled during subsequent runoff events to identify them. The lower main stem of Eighteenmile Creek (Sites 1 and 2) also had elevated concentrations of phosphorus with the highest concentration of TP occurring near the mouth (Site 1 TP = 415.9 µg

P/L) due to contributions of P from second and third order branches and particulates (see TSS) being swept from the watershed during this runoff event.

The next echelon of phosphorus concentrations occurred at Sites 3, 9, 13, and 11 where TP ranged from 171 to 188 µg P/L. Site 3 is located on McKee Road and additional subsequent reconnaissance occurred in this reach that flows into the main stem of Eighteenmile Creek just south of Newfane. Sites 9 and 13 are on the main stem of Eighteenmile Creek just downstream from the City of Lockport's wastewater treatment plant, which is a possible source of P to the stream. There is also a second order branch that flows from the west and enters Eighteenmile Creek between Sites 9 and 13 that were sampled during later trips. Site 11 is in the City of Lockport and is in a reach that receives discharge from the Erie Canal.



Sites 10, 11, and 13

<u>Nitrate and Total Kjeldahl Nitrogen (TKN)</u>: (Figs. 4 & 5)

On this date, the East Branch of Eighteenmile Creek had elevated concentrations of both nitrate and TKN at both sites sampled in this branch. The East Branch of Eighteenmile Creek had the two highest nitrate (Site 8 = 1.33 mg N/L; Site 14 = 1.29 mg N/L) and the second and third highest TKN (Site 8 = 2,138 µg N/L; Site 14 = 2,186 µg N/L) concentrations observed during this runoff event. The other main stem sites (Sites 1, 2, 9, 13) on Eighteenmile Creek had elevated levels of nitrogen (nitrate range = 1.14 to 1.21 mg N/L; TKN range = 1,223 to 2196 µg N/L) on 9 March 2009. In addition, Site 11 had the fifth highest concentration of TKN (1,416 µg N/L) on this date.

<u>Total Suspended Solids (TSS) and Sodium</u>: (Figs. 6 & 7)

Total suspended solids concentrations increased from the East Branch (Sites 8 and 14) downstream through the main stem to Lake Ontario. Concentration of TSS was highest at or near the mouth of Eighteenmile Creek (Sites 1 and 2; 70.6 and 43.1 mg/L, respectively) on 9 March 2009, as erosion occurred throughout the watershed during this runoff event. Additionally, the East Branch of Eighteenmile Creek (Sites 8 and 14) had TSS concentrations greater than 30 mg/L. The West Branch (Site 9) was not a major contributor of soil during this storm.

There is a source of sodium upstream of Site 12 on Route 93 (131.2 mg Na/L) that impacts the entire West Branch. Additional sampling sites will be added upstream from Site 12 to further pinpoint this source of sodium. Sodium concentrations decreased to a level of 26.19 mg/L at Site 1 near the mouth of Eighteenmile Creek.

6 April 2009 (Figs. 8-13)

On the three days preceding this date and during sampling on this date1.05 inches of rain and snow was recorded and a runoff event was sampled on 6 April 2009. In response to the sampling effort and subsequent water chemistry analyses on 9 March 2009, ten additional sites were added to the sampling regime on 6 April. Twenty stream samples were collected with emphasis on the East Branch of Eighteenmile Creek (phosphorus, nitrogen and TSS), the area upstream of Site 12 (sodium) on Route 93, Site 11 (N) below the canal discharge, and an additional branch of the creek (Site 15 on Stone Road).

<u>Total Phosphorus (TP) and Soluble Reactive Phosphorus (SRP)</u>: (Figs. 8 & 9)

As water ran over the watershed, phosphorus concentrations increased in the creek from the headwaters to the mouth of the stream at Lake Ontario. The highest concentration of both TP (240.9 µg P/L) and SRP (88.2 µg P/L) occurred at the mouth of Eighteenmile Creek at Site 1. The progressive increase to a high P concentration at Site 1 at the entrance to Lake Ontario demonstrated that phosphorus from the watershed is not held back or contained by the dam on Eighteenmile Creek at Burt, NY. The East Branch of Eighteenmile Creek once again contributed large amounts of P to the creek. Five of the ten highest SRP concentrations (range = 50.4 – 68.6 µg P/L) and six of the ten highest TP concentrations (range = 140.2 –197.8 µg P/L) were found within the East Branch. The largest phosphorus increase in the East Branch occurred between the segment defined by Sites 14D (Kayner Road) downstream to Site 14C (Slayton Settlement Road). In this segment, SRP increased 69% (26.0 to 43.9 µg P/L) and TP increased by 138% (59.0 to 140.2 µg P/L) in this segment. Additional sites were added in this reach of the East Branch of Eighteenmile Creek during subsequent sampling efforts to further pinpoint the location of the source in this area.

The impact of the City of Lockport's wastewater treatment facility (WTP) on Eighteenmile Creek was evident on 6 April 2009. The two branches of Eighteenmile Creek that drain the area upstream of the WTP (Sites 10 and 11) were relatively low in SRP (<23 µg P/L). Downstream from the outfall of the wastewater plant, SRP

Lockport Wastewater Treatment Plant

increased >250% to 84.6 µg P/L at Site 13 from Sites 10 and 11. A similar pattern existed for TP where concentrations increased 65% as a result of the WWTP effluent. Another notable result from 6 April is the high concentration of TP found at Site 12B on Campbell Boulevard in the headwaters of Eighteenmile Creek. Site 12B had the second highest TP concentration at 198.0 µg P/L which was attributed to particulate phosphorus (TSS was also high) as soluble phosphorus was low at 9.4 µg P/L.

Site 15, a branch of Eighteenmile Creek on Stone Road, was sampled for the first time on 6 April but was relatively low in phosphorus, ranking 13th of the 20 samples taken in both TP and SRP.

Nitrate and Total Kjeldahl Nitrogen (TKN): (Figs. 10 &11)

As with phosphorus, the highest levels of both nitrate and organic nitrogen (TKN) were found at Site 1 at the mouth of Eighteenmile Creek. A major portion of the nitrogen, especially TKN, lost from this watershed was from the East Branch of the creek. Site 1 had the highest nitrate concentration (1.32 mg N/L) as well as the highest TKN concentration (1,753 µg N/L), as nitrogen accumulated in the stream from surface runoff. The data suggest that the Burt Dam is not holding nor containing nutrients behind the dam before they reach Lake Ontario. Similar to phosphorus, the East Branch of Eighteenmile Creek had six of the ten highest concentrations of both nitrate and TKN found in the watershed on 6 April. The pattern of nitrate and TKN distribution in the East Branch was different for each parameter. Nitrate concentration increased downstream within the branch while TKN was high throughout the East Branch.

There were two reaches in the East Branch of Eighteenmile Creek where the nitrate increase was notable. Between Sites 14 and 8C and between Sites 14D and 14C, nitrate concentrations increased 40% and 80%, respectively, while TKN increased 12% and 8% between the same sites.

The City of Lockport's wastewater treatment plant was a source of nitrate to Eighteenmile Creek. Similar to SRP, nitrate increased 134% (0.53 mg N/L to 1.24 mg N/L) due to the effluent of the plant (Sites 10 and 11 to Site 13).

<u>Total Suspended Solids (TSS) and Sodium</u>: (Figs. 12 &13)

Soil loss from the watershed, as measured by TSS, followed the same pattern in many ways as the nutrients on 6 April 2009. The highest concentration of TSS (23.5 mg/L) was observed at Site 1 at the mouth of Eighteenmile Creek, and seven of the highest ten levels (range = 19.2 to 23.0 mg/L) were in the East Branch of Eighteenmile Creek. Site 12B in the headwaters of Eighteenmile Creek had the second highest TSS concentration (23.0 mg/L) which correlated with a similar pattern in TP, suggesting erosion as a pollution source in this reach of the creek.

A source of sodium exists in the area upstream of Site 12A on Old Saunders Settlement Road. At Site 12A the sodium concentration was 163.68 mg/L, 168% higher than at Site 12B. Further reconnaissance on this sodium source was done on subsequent sampling dates.

8 April 2009 (Figs. 14-19)

The prolonged runoff event of 6 April was sampled again on 8 April 2009. An additional 0.25 inches of precipitation fell on saturated soils in the watershed since the last sampling date on 6 April. The total precipitation for this runoff event was 1.30 inches over six days. A total of 15 sites were sampled on 8 April 2009 with three additional sites added between Sites 14D and 14C, and additional reconnaissance was done on the sodium source upstream of Site 12A.

<u>Total Phosphorus (TP) and Soluble Reactive Phosphorus (SRP)</u>: (Figs. 14 &15)

Site 13 below the City of Lockport's wastewater plant had the highest concentration of SRP on 8 April at 82.8 µg P/L, an increase of > 250% over the concentrations observed upstream (Sites 10 and 11) above the WTP influence. Site 1, at the mouth of Eighteenmile Creek, once again had the highest concentration of TP at 150.1 µg P/L followed by Site 12B on Campbell Boulevard which had a TP concentration of 135.8 µg P/L. Additional sites and reconnaissance will be completed above Site 12B to further characterize this source of TP.

The additional sampling and reconnaissance between Site 14D downstream to Site 14C yielded valuable information but did not definitively pinpoint a source. Between these two sites there is a wastewater treatment facility for the Village of Gasport and an effluent pipe from the Erie Canal which flows even when the canal is not full. Site 14C1 is upstream of the treatment plant; Site 14C2 is the effluent from the canal before it enters the creek; 14C3 is a small tributary into the creek on Mill Road. There was a small increase in SRP downstream of the Gasport wastewater treatment plant (28.0 µg P/L at Site 14C1 to Site 14C – 31.5 µg P/L) while the outfall of the canal was relatively low at 15.5 µg P/L. The highest TP concentration in the Site 14 series was at Site 14D, the site furthest upstream, at 121.5 µg P/L. This contradicts the results from the sampling two days previous which showed an increase of 138% from Site 14D downstream to Site 14C. Further sampling in this area and upstream of Site 14D is scheduled in order to better understand the sources in this reach of Eighteenmile Creek.

<u>Nitrate and Total Kjeldahl Nitrogen (TKN)</u>: (Figs. 16 &17)

The base of the East Branch of Eighteenmile Creek (Site 8) had the highest nitrate concentration at 1.57 mg N/L. Within the East Branch, nitrate increased 119% from Sites 14D and 14C3 (0.58 mg N/L) to 1.27 mg N/L at Site 14C1. Site 14C1 is upstream of the Gasport wastewater plant, so the WWTP appears not to be the source. Additional sampling is this reach is needed to pinpoint the source of nitrate.

The City of Lockport’s wastewater plant (upstream of Site 13) was identified as a source of nitrogen to Eighteenmile Creek. Nitrate (>180%) and TKN (93%, organic nitrogen) increased downstream of the plant’s effluent pipe. Nitrate was also elevated at Site 15 on Stone Road with a concentration of 1.33 mg N/L.

<u>Total Suspended Solids (TSS) and Sodium</u>: (Figs. 18 & 19)

The headwater site on Campbell Boulevard (Site 12B) had the highest TSS concentration (20.5 mg/L) on 8 April 2009. As observed on previous sampling days, erosion upstream from this site is causing elevated levels of TP (135.8 µg P/L) and will be investigated further. Another site where high TSS concentrations resulted in elevated TP concentrations (121.5 µg P/L) was Site 14D which has the second highest TSS level on 8 April at 18.3 mg/L.

Site 12A once again had high concentrations of sodium at 178.00 mg/L. Further reconnaissance of this reach resulted in the discovery of a NY State deicing salt storage barn. This storage facility is undoubtedly the source of sodium in this portion of Eighteenmile Creek.

Salt Barn near Site 12A on Lockport Junction Rd.

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29 May 2009 (Figs. 20-25)

A runoff event due to persistent rain was sampled in the Eighteenmile Creek watershed on 29 May 2009. Rainfall in the area was widely variable in the western New York region in late May of 2009. On May 29th and the three preceding days, 0.69 inches of rain was recorded at the National Weather Service office in Buffalo, NY, while 2.07 inches fell at the NWS office in Rochester, NY. Twelve samples concentrated near the main stem of Eighteenmile Creek were taken on 29 May 2009.

<u>Total Phosphorus (TP) and Soluble Reactive Phosphorus (SRP)</u>: (Figs. 20 & 21)

Site 13 below the City of Lockport's wastewater treatment plant had the highest concentration of SRP (141.6 µg P/L). The non-main stem branches in the Eighteenmile Creek watershed typified by Sites 15, 5, and 6 had relatively low concentrations of SRP (range: 6.0 – 18.7 µg P/L) during this runoff event.

Total phosphorus was highest in the main stem area of Sites 9, 11, and 13 (range: 98.4 to 205.3 µg P/L). At these same sites, TSS was also elevated, suggesting that some erosion of phosphorus laden-soil was being transported to the watershed during this rainy period in western New York.

Nitrate and Total Kjeldahl Nitrogen (TKN): (Figs. 22 & 23)

Nitrate was highest along the main stem of Eighteenmile Creek on 29 May 2009 with concentrations ranging from 0.73 mg N/L at Site 10 on West Jackson Street to 1.07 mg N/L at Site 9 on Ridge Road. Conversely in the minor branches (Sites 3, 4, 5, 6, and 15), nitrate concentrations ranged from 0.03 to 0.13 mg N/L.

The highest TKN concentration observed on 29 May 2009 occurred at Site 3 (894 µg N/L) where the sampling crew noted the smell of manure in the area. Manure had recently been spread on fields to the west and northwest of Sites 3 and 4. Site 4 had the second highest TKN concentration at 839 µg N/L, albeit flow was low in this portion of the watershed. Total Kjeldahl nitrogen at the other sites sampled on 29 May 2009 ranged from < 150 µg N/L at Site 15 to 730 µg N/L at both Sites 13 and 9.

Total Suspended Solids (TSS) and Sodium: (Figs. 24 & 25)

Similar to TKN, suspended solids were highest at Site 4 (27.4 mg/L) where the stream ran very turbid but with minimal flow. The main stem of Eighteenmile Creek in and just downstream from the City of Lockport also had elevated levels of TSS as demonstrated by Site 11 at 16.9 mg/L, Site 13 at 18.9 mg/L, and Site 9 at 14.6 mg/L. With the exception of Site 4 (described above), the northern downstream section of the watershed (Sites 1 through 6) had relatively low concentrations of TSS (range = 2.4 to 5.5 mg/L). The sampling crew noted that much less rain had fallen on the northern section of the watershed during this event.

Sodium was exceedingly high at Site 6 at over 200 mg/L; the source is unknown at this time. Elevated levels of sodium were not observed at this site during March. As previously identified, sodium was elevated in the branch containing Site 10 at 157.68 mg/L.

30 June 2009 (Figs. 26-31)

Eleven sites including a new site (14C1A) on Rochester Road in Gasport were sampled in the Eighteenmile Creek watershed on 30 June 2009 following three days of rain (0.47 inches total). Sampling during this event concentrated on the Site 14 series in and around Gasport, NY and the area near the City of Lockport's wastewater treatment plant (Sites 10, 11, and 13).

Total Phosphorus (TP) and Soluble Reactive Phosphorus (SRP): (Figs. 26 & 27)

As on previous sampling dates, phosphorus was highest at the mouth of Eighteenmile Creek at Site 1 (TP = 158.4 µg P/L; SRP = 149.6 µg P/L). In the Site 14 series, Site 14D had elevated levels of both SRP and TP (SRP = 85.1 µg P/L, TP = 116.7 µg P/L). This area is in agricultural land use and additional upstream samples need to be taken to further confirm the sources in this area. There is some evidence that the wastewater treatment plant in Gasport is contributing SRP to Eighteenmile Creek as the SRP concentration increased 74% (34.4 to 59.8 µg P/L) between Sites 14C1 downstream to 14C. Conversely, there is no evidence on this date that the City of Lockport's wastewater treatment plant was contributing significant phosphorus to Eighteenmile Creek as the phosphorus concentrations from Site 11 (upstream of the plant, TP = 83.6 µg P/L; SRP = 41.3 µg P/L) were virtually identical to those of Site 13 (downstream of the plant, TP = 85.6 µg P/L, SRP = 39.0 µg P/L).

Farm near Site 14

Nitrate and Total Kjeldahl Nitrogen (TKN): (Figs. 28 & 29)

The City of Lockport's wastewater treatment plant was contributing significant amounts of nitrogen, unlike with phosphorus, to Eighteenmile Creek on 30 June 2009. Site 13, directly downstream of the plant, had the highest concentration of both nitrate and TKN on this sample date. Compared to the sampling sites immediately upstream of Site 13 (Sites 10 and 11), TKN increased 137% (486 to 1,153 µg N/L) and nitrate increased 97% (1.06 to 2.09 mg N/L).

There was also a source of nitrogen (especially nitrate) detected in the area between Sites 14D downstream to Site 14C1A. Total Kjeldahl Nitrogen increased a modest 27% between these sites but nitrate increased 1108% from 0.12 mg N/L to 1.45 mg N/L. There is an area in this reach of the creek where ponding occurs, but there is also an area south of Mountain Road that is heavy in agriculture. The smell of fermenting crop silage, a potential source, was located in this area. There are also several small rivulets from Mountain Road flowing down toward Eighteenmile Creek that drain upland areas.

Total Suspended Solids (TSS) and Sodium: (Figs. 30 & 31)

Soil loss as measured by TSS was relatively low (range = 3.2 mg/L at Site1 to maximum of 36.4 mg/L at Site 14C,) during this sampling event due to vegetative cover that is present during this time of the growing season and to the moderate rainfall (0.47 inches over three days).

Sodium concentrations were highest in the Eighteenmile Creek reach represented by Site 10 on West Jackson Street. The sodium source in this reach was identified previously in this study (Salt storage barn on Lockport Junction Road).

26 August 2009 (Figs. 32-37)

The impact of two wastewater treatment plants on water quality in Eighteenmile Creek was investigated under nonevent stream conditions on 26 August 2009. Six sites were sampled around the municipal treatment plants in Gasport (upstream of Site 14C) and Lockport, NY (upstream of Site 13).

Three sites were sampled in Gasport, NY. Two sites were sampled upstream of the wastewater facility, located north of the Erie Canal on Bolton Road, the main branch of Eighteenmile Creek (Site 14C1) and the outflow of the Erie Canal (Site 14C2). A site downstream of the treatment plant (Site 14C on Slayton Settlement Road) was also sampled on 26 August 2009. Results showed an overall minimum impact of this treatment plant on Eighteenmile Creek. The only parameter measured that was significantly higher as a result of the plant effluent was nitrate which increased 81% from 0.43 mg N/L at Site 14C1 to 0.78 mg N/L at Site 14C, downstream of the treatment plant. The other parameters measured either were nearly the same (TSS and sodium) or decreased (TP, TKN, and SRP) downstream from the plant. The decrease observed in TP, TKN, and SRP was probably due to the input of Erie Canal water, which had substantially lower concentrations of these constituents, to Eighteenmile Creek. The net result is that the major source of nutrients in the Gasport area is upstream of the wastewater treatment plant and will be investigated further in subsequent sampling efforts.

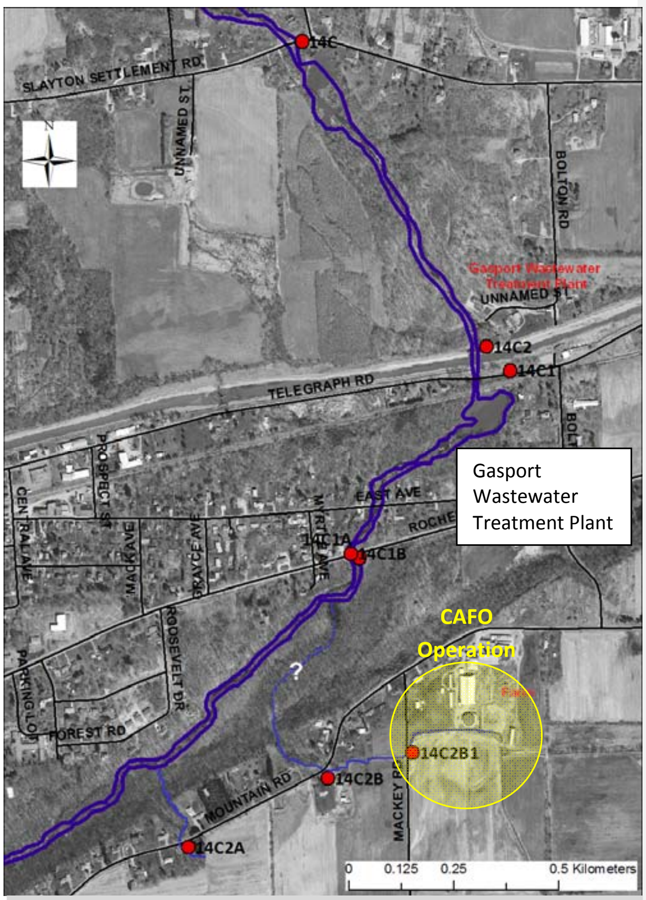
The other three sites sampled on 26 August 2009 centered around the City of Lockport's wastewater treatment plant. Site 13 encompasses the effluent from the plant and two major branches of Eighteenmile Creek sampled at Sites 10 and 11. All nutrient parameters increased in concentration downstream of the treatment plant over those concentrations found in the upstream branches. The branch sampled at Site 10 always had the lowest nutrient concentration followed by the branch sampled at Site 11. Compared to Site 11, Site 13 below the treatment plant had increases of 153% for SRP (62.0 to 156.9 µg P/L), 103% for nitrate (1.05 to 2.13 mg N/L), 35% for TP (136.1 to 183.2 µg P/L), and 16% for TKN (350 to 407 µg N/L). The City of Lockport's wastewater treatment plant is a major source of nutrients to Eighteenmile Creek.

3 December 2009 (Figs. 38-43)

Twenty eight sites including four new sites were sampled throughout the Eighteenmile Creek watershed on 3 December 2009 following five days of rain and snow (2.22 inches of water total). This event encompassed a runoff during the fall season after the summer agricultural crops had been harvested. Four new sites (14C1B, 14C2A, 14C2B, 14C2B1) were added in the Site 14 portion of Eighteenmile Creek upstream of Gasport, New York to further pinpoint the sources of nutrients and soil loss previously found in this portion of the stream. The sites represent agricultural runoff from the area around the Niagara escarpment which runs along Mountain Road.

<u>Total Phosphorus (TP) and Soluble Reactive Phosphorus (SRP):</u> (Figs. 38-39)

The highest concentration of phosphorus was found within the new sites in and around the Niagara escarpment. The new sites in the 14C2 series, 14C2B on Mountain Road and further upstream at the rivulet (Site 14C2B1) on Mackey Road, had the highest concentrations of both TP and SRP on 3 December 2009 with the Mackey Road site reaching a TP concentration of 2,679.8 µg P/L. This area drains an agricultural operation with animals and silage stored on site. Another rivulet draining agricultural land and running over the escarpment further west on Mountain Road (Site 14C2A) also had elevated concentrations of phosphorus (SRP = 287.4 µg P/L, TP = 497.0 µg P/L). Phosphorus concentrations in other areas of the Eighteenmile Creek watershed ranged in TP from 46.3 µg P/L at Site 12A on Old



The Site 14 Series of Sampling Sites

Saunders Settlement Road to 379.5 µg P/L at Site 2 on Ewings Road, but these concentrations pale in comparison to the levels found in the Site 14 area south of Gasport, NY.

<u>Nitrate and Total Kjeldahl Nitrogen (TKN):</u> (Figs. 40 & 41)

With the exception of Site 14C2A on Mountain Road, nitrate concentrations were relatively unremarkable on 3 December 2009 (range = 0.12 mg N/L to 1.40 mg N/L). Site 14C2A had a

nitrate concentration of 7.13 mg N/L, over five times that of the next highest station sampled. This rivulet draining an agricultural area was also very high in phosphorus and is a major source to Eighteenmile Creek.

Total Kjeldahl nitrogen concentration followed high phosphorus concentrations in the Mountain Road area south of Gasport, NY. Both Sites 14C2B (Mountain Road) and 14C2B1 (Mackey Road) had concentrations of TKN over 7,000 µg N/L. Like phosphorus, these concentrations of TKN dwarfed the other values found on this date (range = 991 µg N/L at Site 15 to 2,088 µg N/L at Site 8). One other TKN concentration of note is 1,909 µg N/L found at Site 12C draining a corn field at the very headwaters of Eighteenmile Creek.

<u>Total Suspended Solids (TSS) and Sodium</u>: (Figs. 42 and 43)

Total suspended solids ranged from 6.0 mg/L at Site 12A to 73.0 mg/L at Sites 14C and Site 2. The agricultural area in the Site 14 series near Gasport, NY dominated the soil loss to Eighteenmile Creek on 3 December 2009 with eight of the ten highest concentrations of TSS found there. Clearly soil loss occurred from this agricultural area. Sodium was once again very high in stream water above Site 10.

DISCUSSION
Sources of Nutrients in Eighteenmile Creek

Five areas in the Eighteenmile Creek watershed were identified as sources of nutrients (phosphorus and nitrogen) or soils. Maps, including a summary map (Fig. 44) are included in the text to locate these areas.

- **<u>The Lockport Water Treatment Plant</u> (Sites 10, 11, and 13; Figs. 9, 32, 33, 34, 35, 44):** The City of Lockport's wastewater treatment plant (WWTP)is a major source of nutrients to Eighteenmile Creek. Over the study period, TP concentrations averaged 165.1 µg P/L at Site 13 just below the WTP, well above the NYS Ambient Guideline of 20 µg P/L. The results from 26 August 2009, a nonevent period, provided clear evidence that the Lockport WTP (West Jackson St.) was impacting downstream areas of Eighteenmile Creek. On this day, all nutrient parameters increased. For example, from Sites 10 and 11 to Site 13, which is downstream from the Lockport WWTP, increases of 153% for SRP (62.0 to 156.9 µg P/L), 103% for nitrate (1.05 to 2.13 mg N/L), 35% for TP (136.1 to 183.2 µg P/L) and 16% for TKN (350 to 407 µg N/L) were observed (Figs. 32-35). Similarly on 6 April 2009, SRP increased >250% to 84.6 µg P/L at Site 13 (Fig. 9) downstream from the outfall of the wastewater plant. A similar pattern existed for TP. Total phosphorus concentrations increased 65% below the WWTP.

- **Salt Barn (Site12A; Figs. 13, 19, 44):** The New York State DOTdeicing salt storage barn (Lockport Junction Road) is a source of sodium to Eighteenmile Creek. On several occasions, sodium concentrations exceeding 100 mg/L were observed upstream of Site 12 (e.g., 9 March 2009: 131.20 mg/L; 6 April 2009:150.00 mg/L; 8 April 2009: 178.00 mg/L). Areas upstream of Site 12A generally had lower sodium concentrations. For example, on 6 April 2009 (Fig. 13) sodium concentrations increased from Site 12B to Site 12A by almost 300%. Between Sites 12A and 12B is the NYSDOT salt storage barn. A similar result was observed on 8 April 2009 (Fig. 19) and on 3 December 2009 (Fig. 43).

- **Agricultural Land (Sites 3 and 4; Figs. 23, 44):** The fields west and north of Sites 3 and 4 (McKee Rd. and West Creek Rd., respectively) were the source of organic nitrogen observed on 29 May 2009. High TKN concentrations were observed at Sites 3 (894 µg N/L) and Site 4 (839 µg N/L). Elevated total phosphorus (>120 µg P/L) and TSS (27.4 mg/L) concentrations were also observed at these locations on this date. There was a strong smell in this area. Inspection of some of the adjacent fields revealed manure had been recently applied to the fields.

- **Agricultural Land (Site 12 Series; Figs. 8, 14, 38, 44**): Located in the general area of Campbell Boulevard and Old Saunders Settlement Road, this area drains agricultural land through a series of ditches. Elevated levels of TP were observed upstream of Site 12B on 6 April 2009 (198.9 µg P/L), 8 April 2009 (135.8 µg P/L), and 3 December 2009 (157.6 µg P/L). An extra site south of Site 12B at Site 12C revealed even higher TP levels (290.4 µg P/L) on 3 December 2009. The elevated TP concentrations were always associated with elevated levels of TSS indicating that soil erosion, either stream bank or surface field erosion, was occurring in this headwater area. However, high organic nitrogen levels (1909 µg N/L) were observed at Site 12C on 3

December suggesting a manure application to fields. Site 12C is a small agricultural drainage ditch that drains a corn field at the very headwaters of Eighteenmile Creek.

- **Agricultural Land (Site 14 Series; Figs. 44):** The Site 14 series of sites drain an area of agricultural operations with animals and corn silage stored on site. At least three, perhaps four CAFO operations exist in the East Branch of the creek. Throughout the study period, the entire East Branch of Eighteenmile Creek had elevated levels of phosphorus, organic nitrogen, and nitrate. In fact, much of our effort went into locating sources within this branch of the creek. The source of much of the nutrient pollution of the East Branch was above the Niagara Escarpment in the southwestern portion of the watershed adjacent to a CAFO operation. For example on 3 December 2009, TP concentrations on Mackey Road (Site 14C2B1) reached 2,679.8 µg P/L, 100 times higher than the NYS Guidelines for ambient levels of phosphorus in surafce waters (20 µg P/L). Site 14C2A had a nitrate concentration of 7.13 mg N/L, over five times that of the next highest station sampled on this date. Site 14C2B on Mountain Road and Site 14C2B1 on Mackey Road had concentrations of organic nitrogen (TKN) over 7,000 µg N/L, suggesting the possibility of improperly stored manure or silage. Lastly, soil loss from this area can be high at times.

Nonpoint Sources: How Do Nutrients and Soils Move from the Land to Streams?

The quality and quantity of runoff from a watershed into a stream are ultimately influenced by the land use and interactions with inhabitants of the watershed. The amount of runoff is determined by the amount of excess precipitation, that which neither sinks into the ground nor is stored at the surface. Precipitation excess is determined primarily by climate, vegetation, infiltration capacity, surface storage, and land use by people. Impervious landscapes (e.g., parking lots), removal of wetlands and vegetation in general, storm sewers, blockage of streams by debris, etc., all contribute to rapid rises in stream level and potential flooding. Surface runoff dissolves constituents, such as the soluble forms of nutrients (phosphate and nitrate) and salts (sodium) from the soil and other surfaces it contacts, carrying them to the stream. Runoff also scours and erodes the surfaces it flows over, sweeping soil particles containing phosphorus and nitrogen from the watershed into the stream. Land use and surface conditions determine, to a large degree, the magnitude of the loss of these constituents from the watershed to the stream via these processes. For example, a tilled agricultural field that is subjected to surface runoff from precipitation or snowmelt will lose a large amount of soil and nutrients to the stream as that water flows over the exposed surfaces. Land use and agricultural practices initiated by people can and do affect stream water quality and stream discharge. If we can identify the sources of pollution, remedial action plans and best management plans can be initiated that mitigate downstream and lake effects.

Best Management Practices (BMPs)

BMPs are actions, behaviors, or techniques that reduce pollution and the amount of runoff flowing into waterways and that cover a wide range of practices on the land. Non-structural BMPs include such practices that minimize site disturbance through sound planning and design and include cropping sequence, soil testing, fertilization rates, tillage practices, etc. For example, on dairy or livestock farms, soil testing is combined with manure analysis to develop manure application plans to make the best use of recyclable manure nutrients. Structural BMPs include construction of manure lagoons, terraces, buffer strips, sediment control basins, etc. Contour strip cropping, where alternate strips of land are planted to row crops or sod crops perpendicular to the predominant slope, is an example of another structural BMP. By shortening the lengths of slope where water can flow freely (tilled strips), runoff and kinetic energy of water are reduced, and soil erosion is minimized.

Identified point and nonpoint sources of nutrients and solids can be remediated using BMPs. BMPs selected address the specific needs of each farm. Whether or not management practices include a reduction of cropland or fertilization, control of water movement can be a means of significantly reducing nonpoint source pollution. Since water must come in contact with the nutrient source and then be transported to the surface (or subsurface) water body, the nutrients in water bodies are functions of soil fertility and quantities of transporting water.

Water Management: Management practices, which reduce surface runoff, have been shown to dramatically decrease the magnitudes of sediment and chemical losses from land areas (Haith 1975). At Conesus Lake, construction of retention ponds/gully plugs successfully reduced the loss of soil by a factor greater than 70% in the first year (Makarewicz *et al*. 2009). Curtailment of winter manuring practices, or limiting of winter manuring practices to non-hydrologically sensitive, steep-sloped watersheds also reduced losses of nutrients from a watershed (Lewis and Makarewicz 2009). Construction of buffer strips, contour planting, timing of tilling practices, and sediment retention ponds are methods successively shown to reduce overland flow of water from affected watersheds.

Agriculture: Haith (1975) and the NYSDEC (Morton 1985, 1992) recommend use of buffer strips of forest or grass between the pollutant source and a stream to intercept the runoff, resulting in removal by deposition or filtering by the vegetative cover. Other cropland management practices include diversions, terraces contour cropping, strip cropping, waterways, minimum and no tillage. Livestock operation controls include barnyard runoff management, manure storage facilities, and livestock exclusion from woodlands. They may also include structural devices such as grassed waterways, sediment retention basins, erosion control weirs, and animal waste holding tanks. BMPs are designed to reduce sediment and nutrient transport to streams and lakes. They may benefit the farmer in the long term by decreasing fuel and fertilizer costs and by improving soil productivity. Furthermore, with the advent of Concentrated Animal Feed Operations (CAFO) permits, regulatory control of farms with large numbers of animals may be inevitable. A bibliography containing references for nutrient management may be found after the reference section.

Introduction of whole farm planning practices may serve the farming community well. Besides soil loss, much of the loss of nutrients in the Eighteenmile Creek watershed was in the dissolved form as nitrate and phosphorus. Information on nutrient management in agriculture settings in New York State is reviewed in a recent issue of Northeast Dairy Business and is applicable to other crops. For example, articles titled “Nine Tips to Manage N Better” (Cyzmmek 2006) and “How Much P is Enough” (Ketterings and Cyzmmek 2005) provide a useful review of nutrient management issues that are applicable to the Eighteenmile Creek watershed. Farmers in western New York have reduced fertilizer usage and successfully maintained corn yields while saving money.

Also, adoption of whole farm planning practices has proven to be very successful and serves several purposes on farms in the Conesus Lake area. These include:

1. Maintaining soil fertility by leaving more nutrients and soil on agricultural land;

2. Reducing the amount of soil and nutrients washed into Eighteenmile Creek and eventually into Lake Ontario. This reduces the overproduction (eutrophication) of downstream systems and the aesthetically unappealing blooms of algae and weeds (Makarewicz 2009, Bosch 2009a and b); and

3. Potentially increasing an economic return to the farmer. Recent work on dairy farms in Conesus Lake has demonstrated that a reduction in nitrate fertilization rates actually maintained corn yields and reduced nitrate lost to downstream systems while allowing a savings in money to the farmer. Soil testing documented that levels of soil phosphorus were more than adequate for maintaining yields (Jacobs 2006a).

Comparison To Other Lake Ontario Rivers and Lakeside Locations

This study of sources of pollution in Eighteenmile Creek identified several point and nonpoint sources of nutrients and salts within the watershed. The question does arise as how Eigtheenmile Creek compares with other Lake Ontario creeks and other locations along the shoreline of Lake Ontario. In a recently completed study (Makarewicz and Nowak 2009), 19 locations along the New York side of Lake Ontario were sampled for up to six years. The waters were analyzed for total phosphorus, soluble reactive phosphorus, total Kjeldahl nitrogen, nitrate, total suspended solids, and sodium. We focus on phosphorus as it stimulates the growth of plants, causing blooms of algae such as *Cladophora*. At Eighteenmile Creek, water samples were taken on Lake Ontario at swimmable depth near the mouth of the creek and in the creek from 2003 to 2009. Total phosphorus levels in the lakeside waters (average=41.8$\pm$9.8 µg P/L, Fig. 1a) were lower than in Eighteenmile creek water (average=124.7$\pm$12.3 µg P/L). However, both lakeside and creek phosphorus levels exceeded the NYSDEC ambient guideline of 20 µg P/L for phosphorus concentrations. Compared to TP concentrations in other Lake Ontario streams (83.8$\pm$7.0 µg P/L), average TP concentrations in Eighteenmile Creek (124.7$\pm$12.3 µg P/L) were higher, while the nearby lakeside waters (41.8±9.8 µg P/L) had lower concentrations than the average for lakeside Lake Ontario (62.0±7.4 µg P/L) (Table 1). Both creek and lakeside TP concentrations were higher than in open (9.5±0.7 µg P/L) offshore waters of Lake Ontario (Table 3). Clearly, the levels of phosphorus in the nearshore waters of Lake Ontario exceed the NYSDEC Ambient Guidelines for phosphorus. Also, creek waters are significantly higher than the average for streams and creeks reported on by Makarewicz and Nowak (2009). Water quality of Eighteenmile Creek and the nearby waters of Lake Ontario will be improved with management of the sources identified in this report.

Literature Cited

Bosch, I., Makarewicz ,J., Bonk, E., Ruiz, C., Valentino, M. 2009a. Responses of lake macrophyte beds dominated by Eurasian watermilfoil (*Myriophyllum spicatum*) to best management practices in agricultural sub-watersheds: Declines in biomass but not species dominance. J. Great Lakes Res. *35:99-108.*

Bosch, I., Makarewicz, J., Lewis, T.W., Bonk, E., Finiguerra, M., Grovemen, B. 2009b. Management of agricultural practices results in declines of filamentous algae in the lake littoral*. J. Great Lakes Res. 35:90-98.*

Czymmek, K. 2006. Nine tips to manage N better. Northeast Dairy Business. April:34-35.

Jacobs, E. 2006a. Dairy changes manure application. *Northeast Dairy Business* 7: 41-42.

Jacobs, E. 2006b. Started P projects provides a win-win. *Northeast Dairy Business* 7:1-2.

Haith, D.A. 1975. *In:* Influence of land development and land use patterns on water quality. G.D. Gates and D.A. Haith eds. PB 248071. NTIS.

Ketterings, Q, and Czymmek, K. 2005. How much phosphate is enough? *Northeast Dairy Business.* April: 37-39.

Lewis, T. W. and Makarewicz, J.C. 2009. Winter application of manure on an agricultural watershed and its' impact on downstream nutrient fluxes. *J Great Lakes Res.* 35:43-49.

Makarewicz, J.C. 1999. Stressed Stream Analysis. *Waterworks*. 7:1-4.

Makarewicz, J.C., and Lewis, T.W. 1993. *Stress stream analysis of two sub-watersheds of Conesus Lake.* Available from Drake Memorial Library, SUNY Brockport, Brockport, NY.

Makarewicz, J.C. and Lewis, T.W. 2000. Eighteenmile Creek Remedial Action Plan. Area of Concern Planktonic Community Study. Olcott Harbor at Eighteenmile Creek. New York State Department of Environmental Conservation. 625 Broadway, Albany , NY.

Makarewicz, J.C., and Lewis,T.W. 2001. *Stressed stream analysis of Deep Run and Gage Gully in the Canandaigua Lake watershed*. Technical report to the

Canandaigua Lake Watershed Task Force, Canandaigua, NY. Available from Drake Memorial Library, SUNY Brockport, Brockport, NY.

Makarewicz, J.C., and Lewis,T.W. 2001a. *Segment analysis of Marsh Creek, the location of sources of pollution. Part of the Lake Ontario watershed located in Orleans County, NY*. Technical report to the Orleans County Soil and Water Conservation District, Albion, NY. Available from Drake Memorial Library, SUNY Brockport, Brockport, NY.

Makarewicz, J.C., and Lewis, T.W. 2002. *Segment analysis of Sheldon Creek, the location of pollution sources, part of the Lake Neatahwanta watershed.* Technical Report to the Oswego County Soil and Water Conservation District. Fulton, NY. Available from Drake Memorial Library, SUNY Brockport, Brockport, NY.

Makarewicz, J.C., and Lewis,T.W. 2002a. *Stressed stream analysis of North Gully and Southwest Creeks in the Conesus Lake watershed*. Technical Report to the Livingston County Planning Department, Geneseo, NY. Available from Drake Memorial Library, SUNY Brockport, Brockport, NY.

Makarewicz, J.C., Lewis, T.W., and Williams, R.K. 1994. *Nutrient Loading of Streams entering Sodus Bay and Port Bay, NY. A summary of Port Bay and Sodus Bay tributary monitoring and stressed stream analysis of Glenmark and Wolcott Creeks.* Available from Drake Library, SUNY Brockport, Brockport, N.Y.

Makarewicz, J.C., Lewis, T.W., White, D., Seider, M., and Digiacoma, V. 2006. Nutrient and soil losses from the Eighteenmile Creek watershed. Report to the Niagara County Soil and Water Conservation District. Available From Drake Library, SUNY Brockport., NY.

Makarewicz, J.C., Lewis, T.W., White, D. Seider, M. and Digiacoma, V. 2008. Characterization and prioritization of the watersheds of Niagara County, New York. Report to the Niagara County Soil and Water Conservation District. Available From Drake Library, SUNY Brockport., NY.

Makarewicz, J.C., Lewis, TW., Bosch, I., Noll, M.R., Herendeen, N., Simon, R., Zollweg, J. , and Vodacek, A. 2009. The impact of best management practices on downstream systems: Soil loss and nutrient chemistry and flux to Conesus Lake. 35 (supplement 1): 23-36.

Makarewicz, J.C., and Nowak, M. 2009. Eighteenmile Creek: Niagara County, New York. Available from the Center for Environmental Information. Rochester, NY.

Morton, W. B. 1985. *Stream Corridor Management: A Basic Reference Manual*, Albany, NY: NYS DEC.

Morton, W. B. 1992. Reducing the Impacts of Stormwater Runoff from New Development, Albany, NY: NYS DEC.

NUTRIENT MANAGEMENT BIBLIOGRAPHY

Stuart Klausner. Nutrient Management: Crop Production and Water Quality, Cornell University: NYS Water Resources Institute, 1995. Also available as software from the NYS Soil and Water Conservation Committee, 1997.

D.R. Bouldin, W.S.Reid and D. J. Lathwell. Fertilizer Practices Which Minimize Nutrient Loss, Ithaca, NY: Cornell University, 1971.

Makarewicz, J.C., Lewis, TW., Bosch, I., Noll, M.R., Herendeen, N., Simon, R., Zolweg, J. , and Vodacek, A. 2009. The impact of best management practices on downstream systems: Soil loss and nutrient chemistry and flux to Conesus Lake. J. Great Lakes Res. 35 (supplement 1): 23-36.

Making Nutrient Management Work for You- Getting More from Animal Manure and Fertilizer. Harrisburg, PA: Pennsylvania Association of Conservation Districts, n.d.

The Nutrient Management Yardstick, Minneapolis, MN: Institute for Ag. and Trade Policy, n.d.

Patricia Longabucco. Controlling Agricultural Nonpoint Source Water Pollution in New York State: A Guide to the Selection of Best Management Practices to Improve and Protect Water Quality. Albany, NY: NYSW DEC, 1991.

Klausner, Leonard, Telega, Lanyon, Hadcock, Pell, and Tillapaugh, Pro-Dairy Nutrient Management on Dairy Farms. Ithaca, NY: Cornell Cooperative Extension, 1993

Johnston, Loux, Ropp, and Adams. Best Management Practices: A Manure Nutrient Management Program. Columbus, OH: Ohio State University Extension, 1998

Hilborn, D. and Brown, C. 10 Steps to Complete a Nutrient Management Plan for Livestock & Poultry Manure. Ontario (Canada) Ministry for Agriculture, Food and Rural Affairs, 1997.

Website: for Agricultural Environmental Management in New York State: www.agmkt.state.ny.us/soilwater/AEM/index/html

Table 1. Locations of sampling sites in the Eighteenmile Creek watershed.

Site	Road / Location	Latitude	Longitude
Site 1	MAIN STEM:Mouth of Creek at Lake Ontario	43.33907	-78.71710
Site 2	MAIN STEM: Ewings Rd – Upstream of Burt Dam	43.27795	-78.7112
Site 3	McKee Road	43.27584	-78.7153
Site 4	West Creek Road	43.28184	-78.7174
Site 5	Route 78	43.25456	-78.6948
Site 6	Route 78	43.24655	-78.6901
Site 8	EAST BRANCH: Ridge Road	43.21917	-78.6954
Site 8C	Day Road	43.21957	-78.6513
Site 9	MAIN STEM, WEST BRANCH: Ridge Road	43.21936	-78.7158
Site 10	MAIN STEM, WEST BRANCH: West Jackson St. – Upstream of Lockport WTP	43.18439	-78.7107
Site 11	Plank Road. – Upstream of Lockport WTP and below spillway of Erie Canal	43.18447	-78.7032
Site 11C	Upson Park	43.17497	-78.6894
Site 12	Upper Mountain Road	43.16817	-78.7283
Site 12A	Old Saunders Settlement Road	43.16138	-78.7355
Site 12B	Campbell Blvd	43.15390	-78.7546
Site 12C	Saunders Settlement Road	43.14952	-78.7578
Site 13	Plank Road – Downstream Lockport WWTP	43.18971	-78.7055
Site 14	EAST BRANCH: Dale Road	43.22723	-78.6261
Site 14A	Orangeport Road	43.23587	-78.5961
Site 14B	Quaker Road	43.23716	-78.5494
Site 14C	Slayton Settlement Rd – Downstream Gasport WTP and Mill dam	43.20834	-78.5654
Site 14C1	Telegraph Road –Above Mill Dam	43.20115	-78.5596
Site 14C1A	Rochester Road	43.19722	-78.5642
Site 14C1B	Rochester Road	43.19731	-78.5644
Site 14C2	Canal Outfall - Gasport	43.20168	-78.5603
Site 14C2A	Mountain Road	43.19111	-78.5694
Site 14C2B	Mountain Road	43.19250	-78.5653
Site 14C2B1	Mackey Road	43.19300	-78.5653
Site 14C3	Mill Road	43.18191	-78.5820
Site 14D	Kayner Road	43.18056	-78.5892
Site 14E	Gasport Road	43.15456	-78.57388
Site 15	Stone Road	43.20489	-78.72833
	NYSDOT Salt Barn – Lockport Junction Road	43.16606	-78.75449

Table 2. Proficiency audit of the Water Quality Laboratory at The College at Brockport.

NEW YORK STATE DEPARTMENT OF HEALTH

ENVIRONMENTAL LABORATORY APPROVAL PROGRAM

Lab 11439 SUNY BROCKPORT EPA Lab ID NY01449 Page 1 of 1
WATER LAB LENNON HALL

BROCKPORT, NY 14420, USA Shipment: 315 Non Potable Water Chemistry Shipment Date: 14-Jul-2008

Analyte	Sample ID	Result	Mean/Target	Acceptance Limits	Method	Score
Approval Category : **Non Potable Water**						
Sample: **Residue**						
Solids, Total Suspended	1502	58.8	59.9	47.5 – 67.8	SM18-20 2540D	Satisfactory
Sample: **Organic Nutrients**						
Kjeldahl Nitrogen, Total	1504	18.5	16.8	11.1 – 21.7	EPA 351.2	Satisfactory
Phosphorus, Total	1504	4.06	3.99	3.26 – 4.78	SM18-20 4500-PF	Satisfactory
Sample: **Inorganic Nutrients**						
Nitrate (as N)	1507	2.32	2.37	1.87 – 2.88	SM18-20 4500-NO3 F	Satisfactory
Orthophosphate (as P)	1507	3.78	3.95	3.25 – 4.68	SM18-20 4500-PF	Satisfactory
Sample: **Minerals II**						
Sodium, Total	1537	48.77	47.6	40.4 – 54.7	SM 18-20 3111B	Satisfactory
Sample: **Nitrite**						
Nitrite as N	1541	0.95	0.926	0.742 – 1.11	SM 18-20 4500-NO2 B	Satisfactory

Figure 1. Map showing the Eighteenmile Creek watershed. The white numbered circles are the sampling sites for segment analysis. Sampling sites on the main stem of Eighteenmile Creek are Sites 1, 2, 9, and 10. Site 14 is at the base of the East Branch, while Site 8 is at the base of the West Branch.

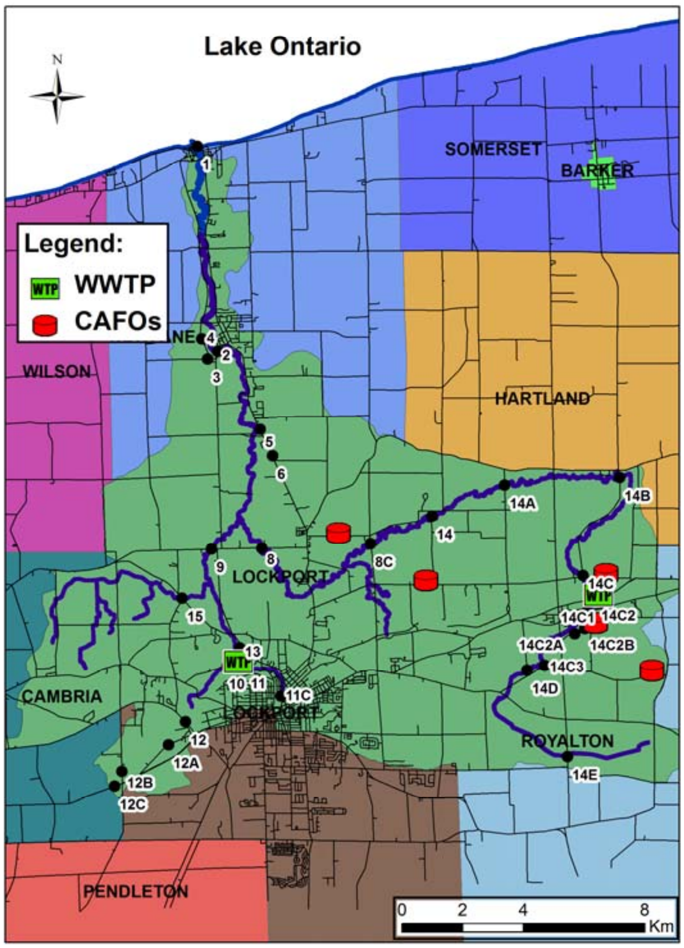


Figure 2. Total phosphorus (TP) concentrations at various sites (red circles) along Eighteenmile Creek on 9 March 2009.

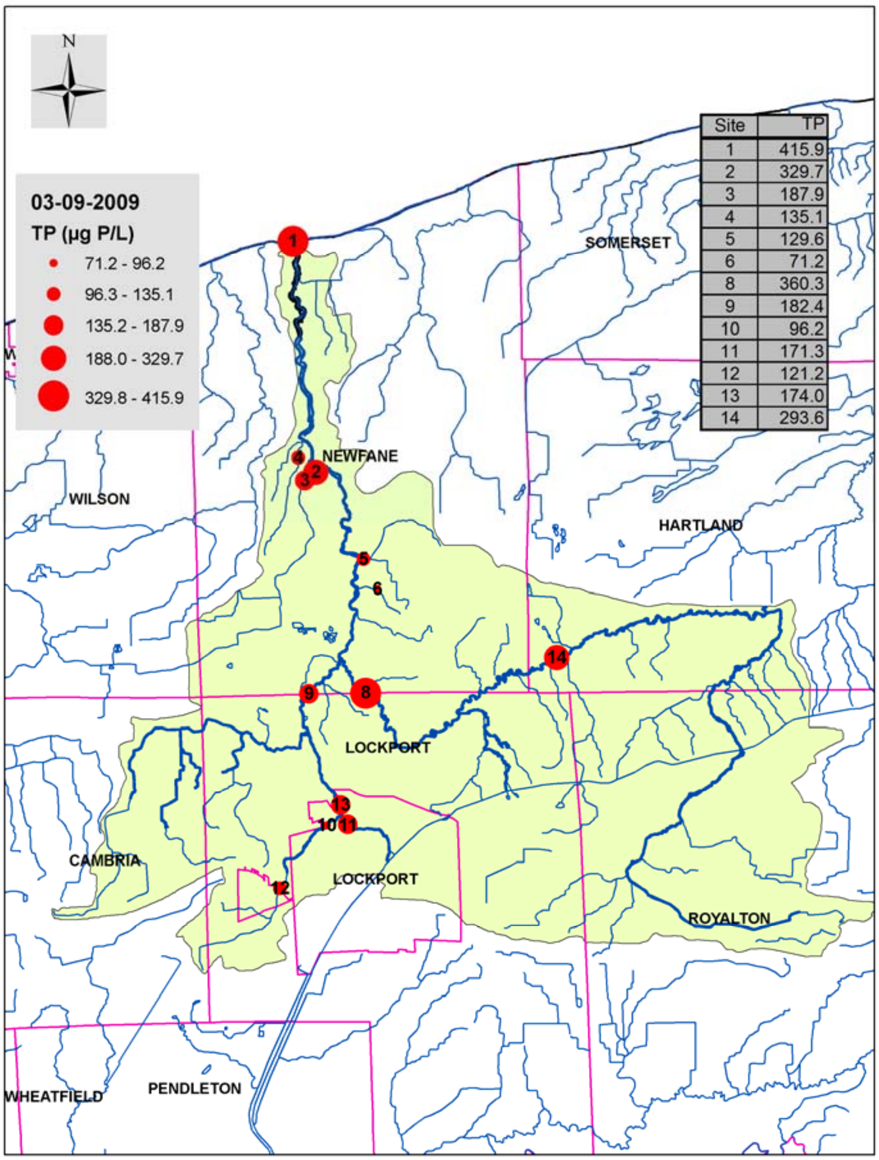


Figure 3. Soluble reactive phosphorus (SRP) concentrations at various sites (red circles) along Eighteenmile Creek on 9 March 2009.

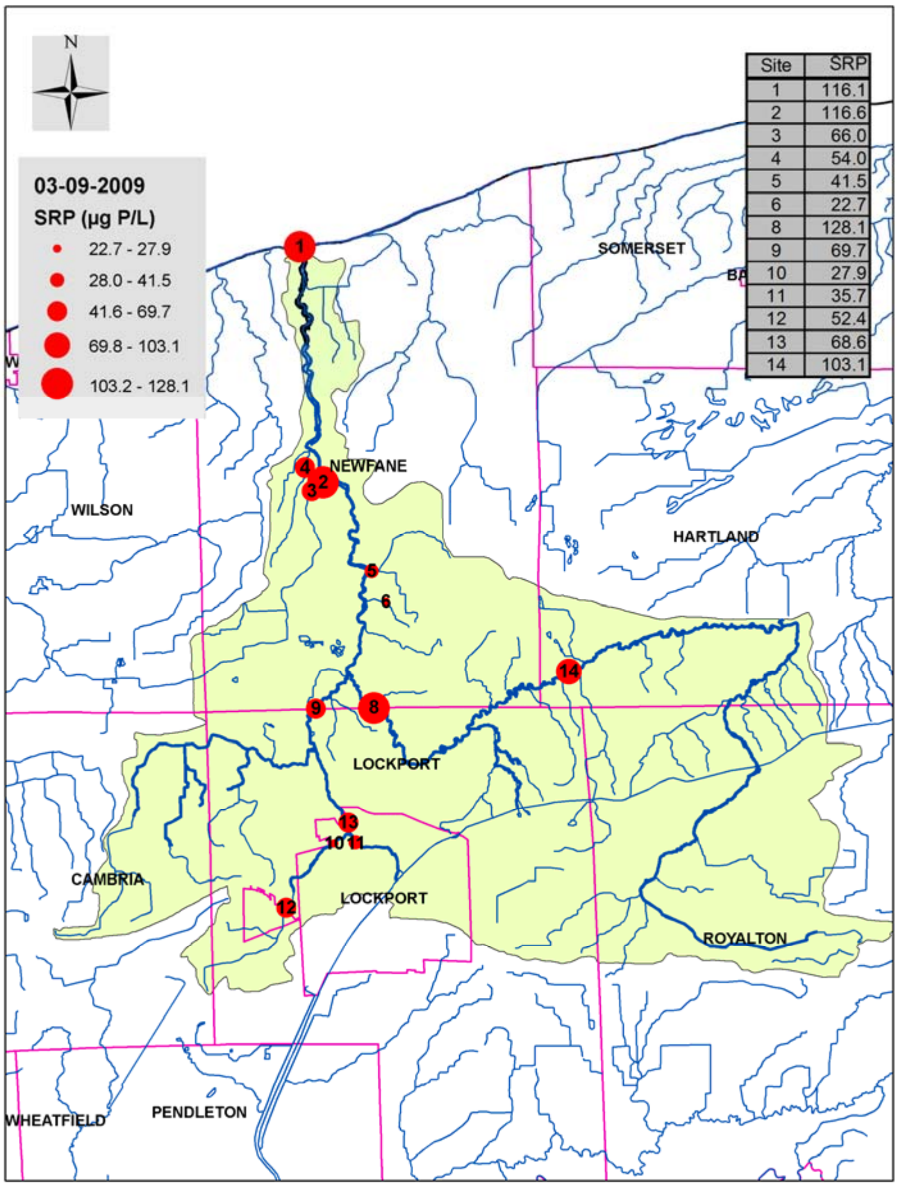


Figure 4. Nitrate concentrations at various sites (red circles) along Eighteenmile Creek on 9 March 2009.

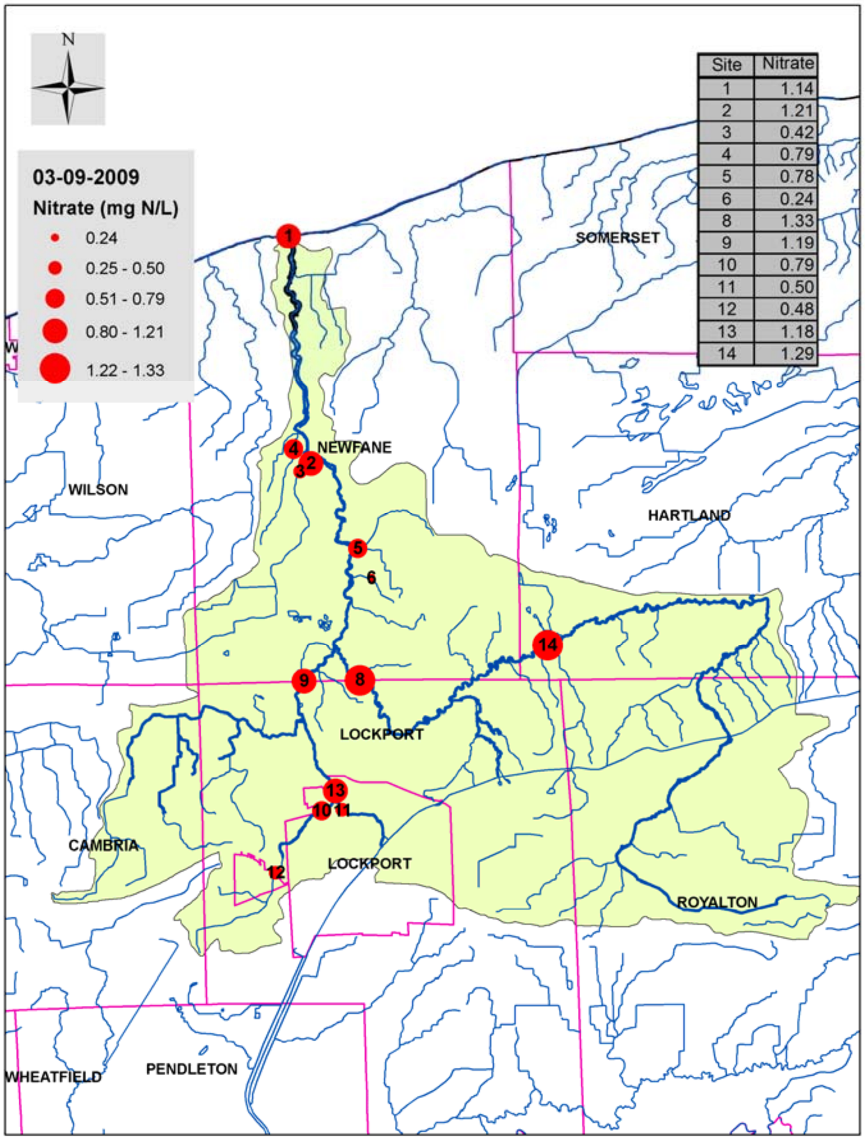


Figure 5. Total Kjeldahl nitrogen (TKN) concentrations at various sites (red circles) along Eighteenmile Creek on 9 March 2009.

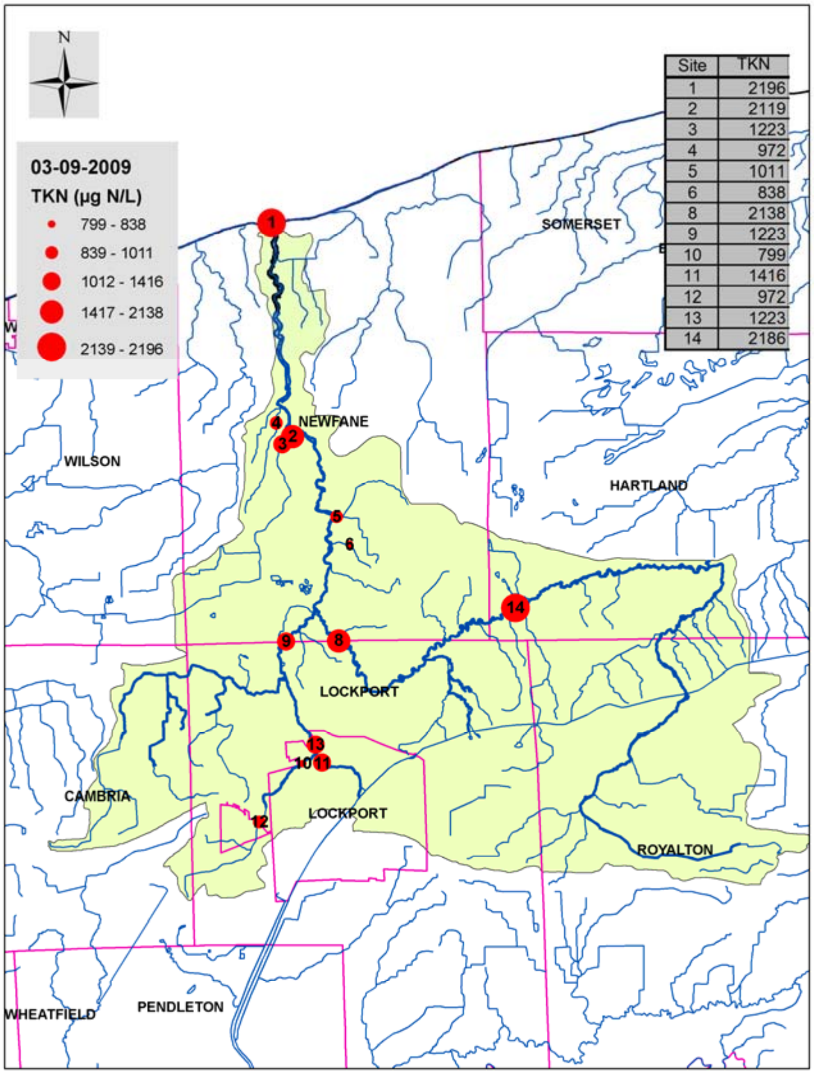
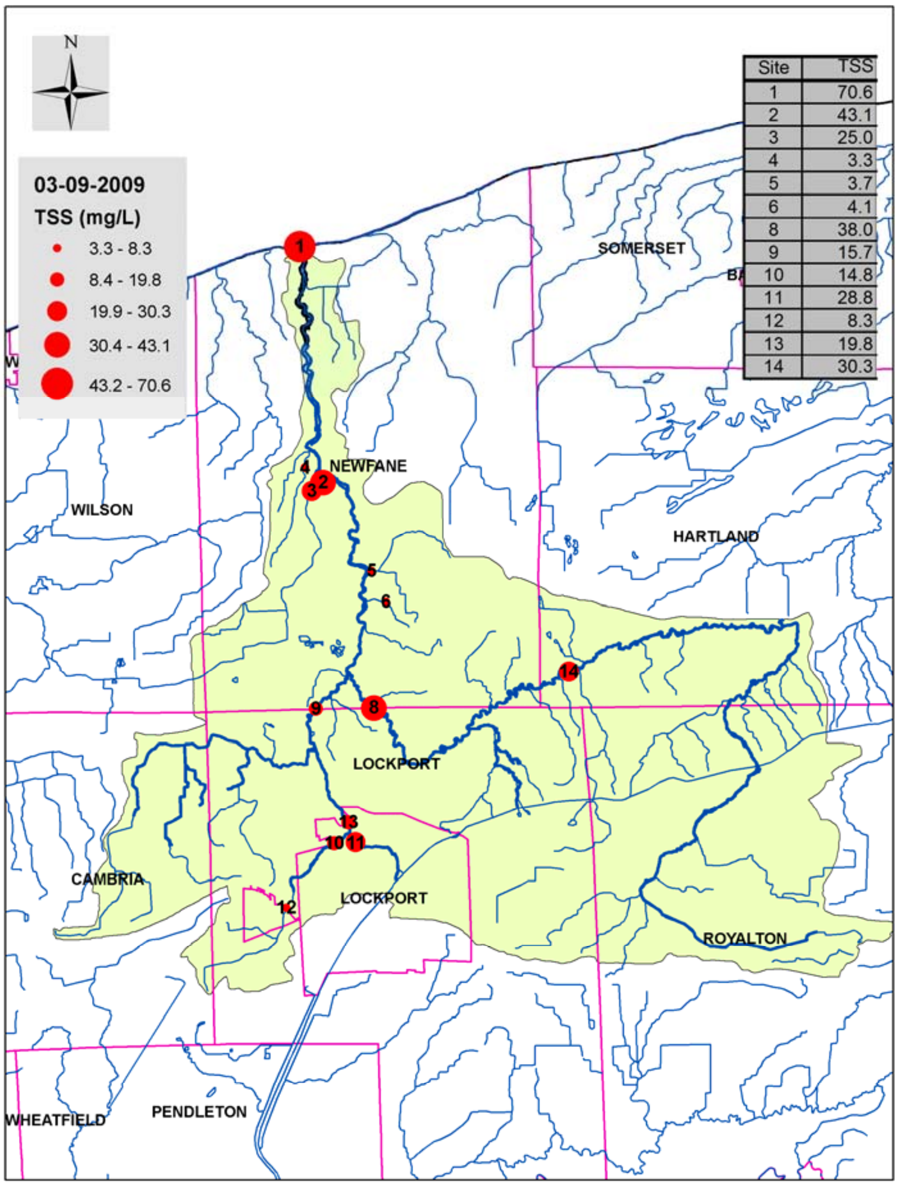
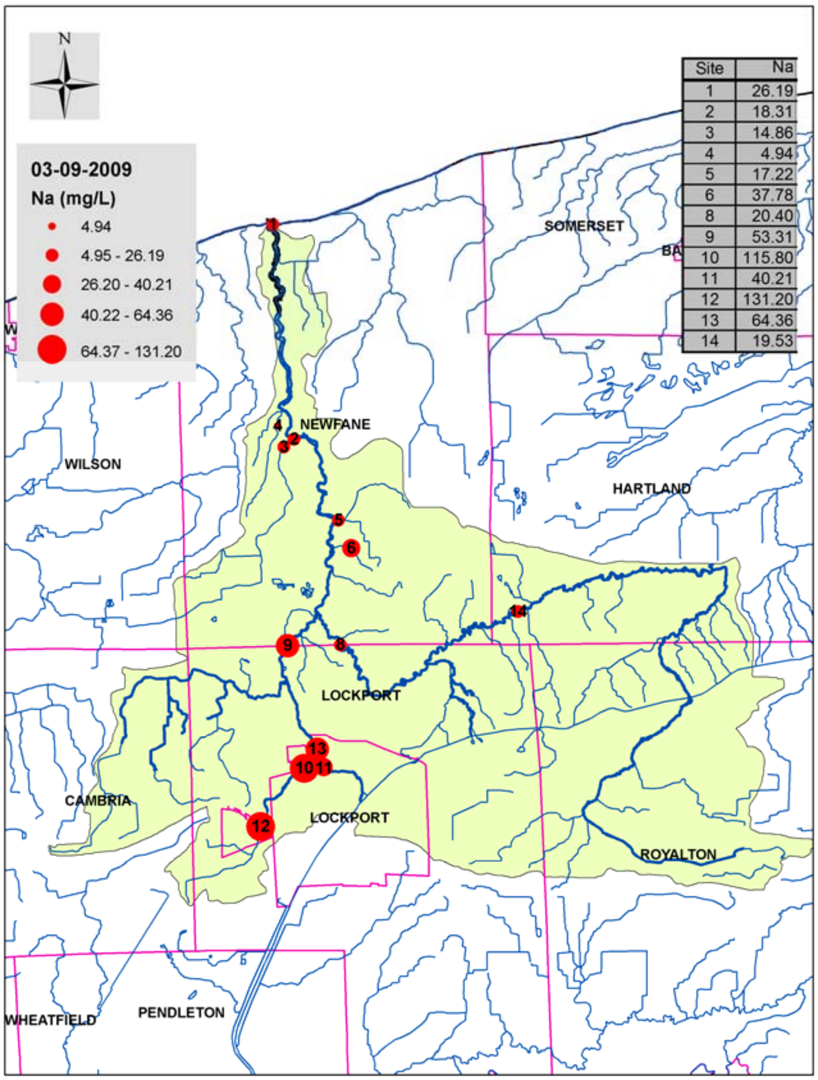


Figure 6. Total suspended solids (TSS) concentrations at various sites (red circles) along Eighteenmile Creek on 9 March 2009.



Site	TSS
1	70.6
2	43.1
3	25.0
4	3.3
5	3.7
6	4.1
8	38.0
9	15.7
10	14.8
11	28.8
12	8.3
13	19.8
14	30.3

Figure 7. Sodium (Na) concentrations at various sites (red circles) along Eighteenmile Creek on 9 March 2009.



Site	Na
1	26.19
2	18.31
3	14.86
4	4.94
5	17.22
6	37.78
8	20.40
9	53.31
10	115.80
11	40.21
12	131.20
13	64.36
14	19.53

Figure 8. Total phosphorus (TP) concentrations (µg P/L) at various sites (red circles) along Eighteenmile Creek on 6 April 2009.

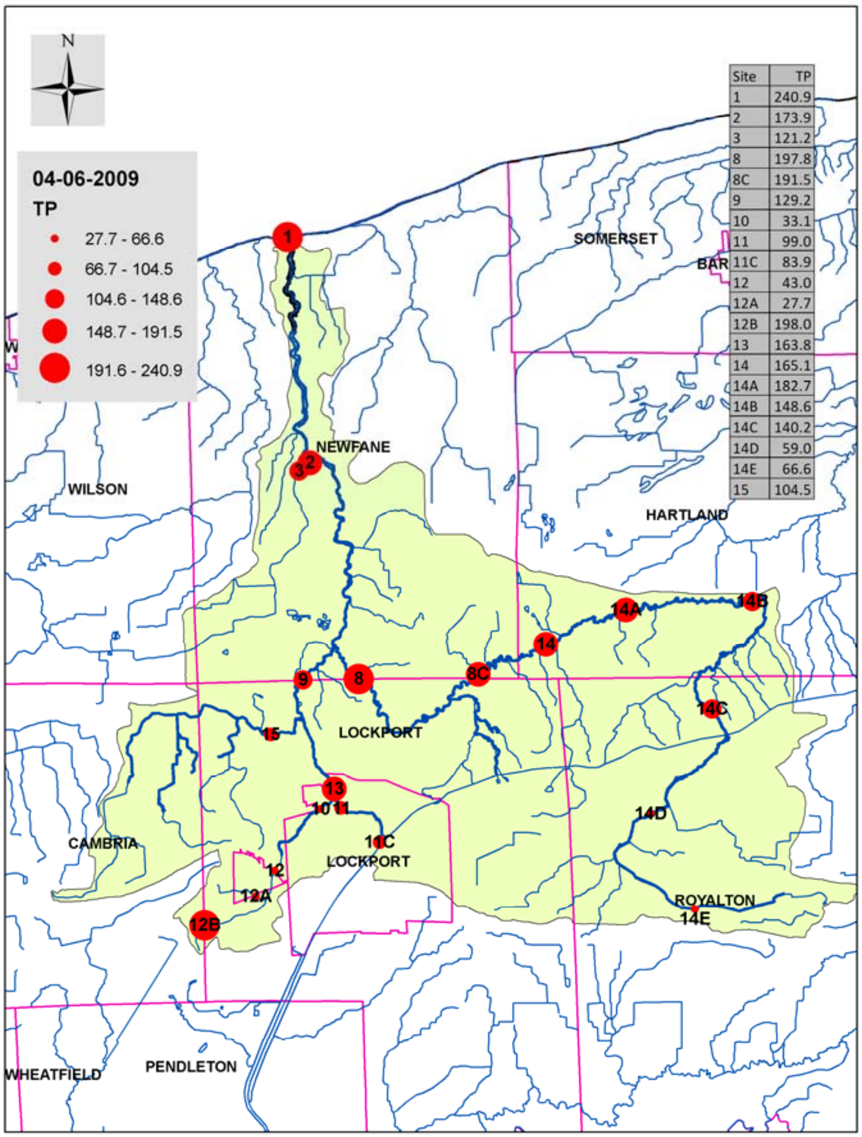


Figure 9. Soluble reactive phosphorus (SRP) concentrations (µg P/L) at various sites (red circles) along Eighteenmile Creek on 6 April 2009.

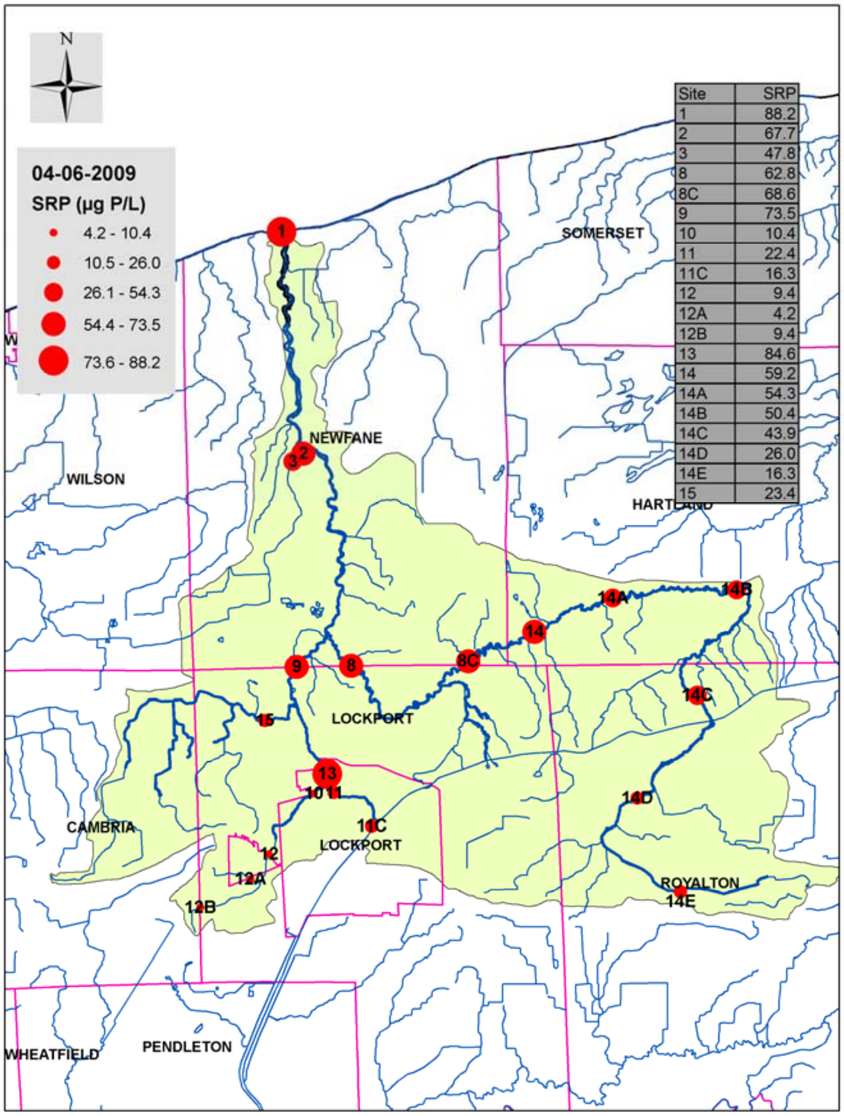


Figure 10. Nitrate concentrations (mg N/L) at various sites (red circles) along Eighteenmile Creek on 6 April 2009.

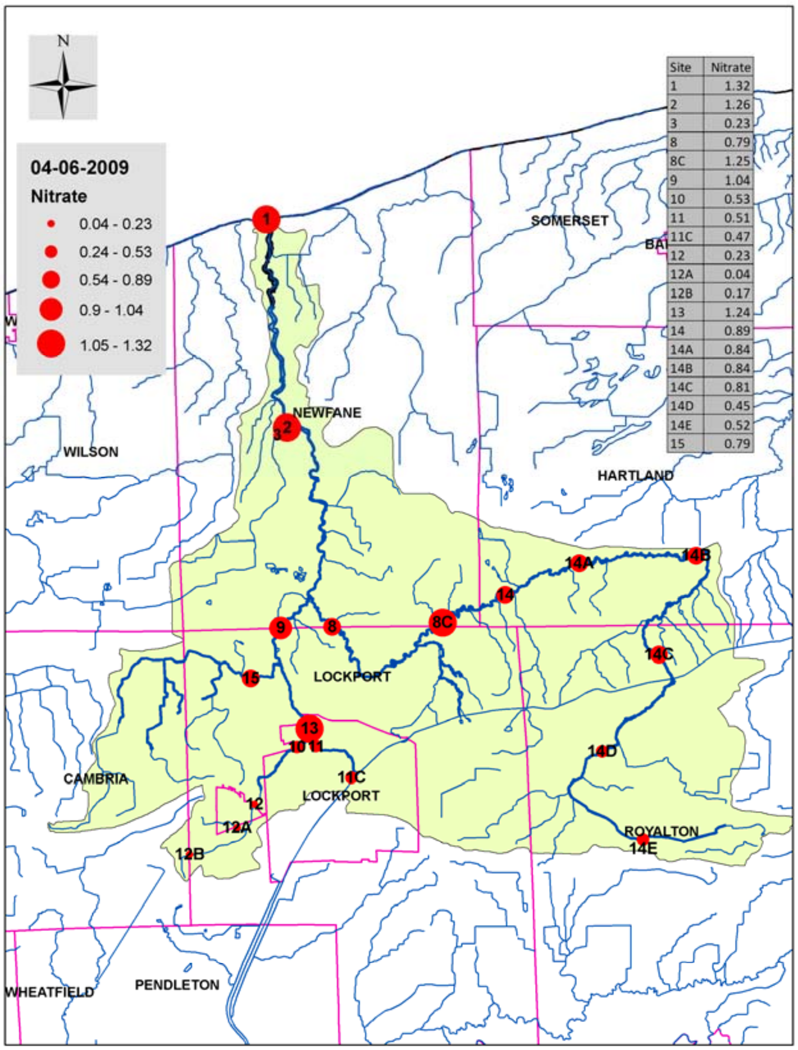


Figure 11. Total Kheldahl nitrogen (TKN) concentrations (µg N/L) at various sites (red circles) along Eighteenmile Creek on 6 April 2009.

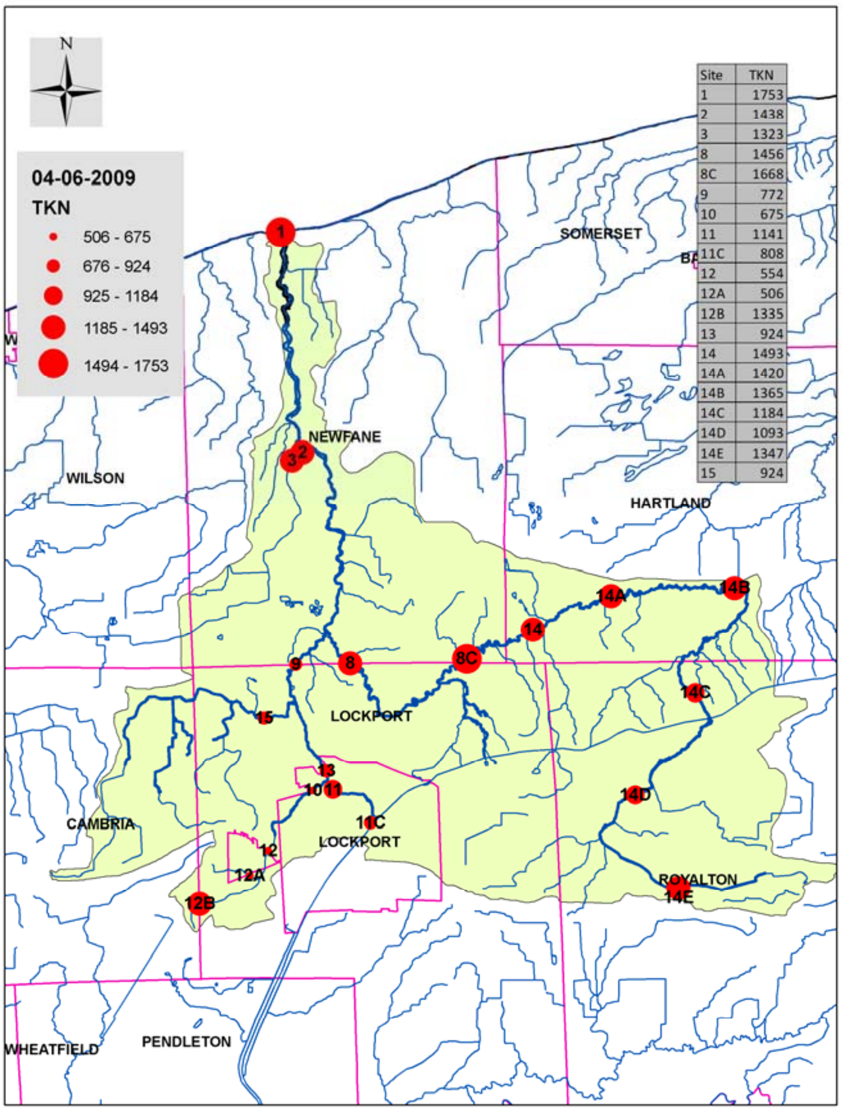


Figure 12. Total suspended solids (TSS) concentrations (mg/L) at various sites (red circles) along Eighteenmile Creek on 6 April 2009.

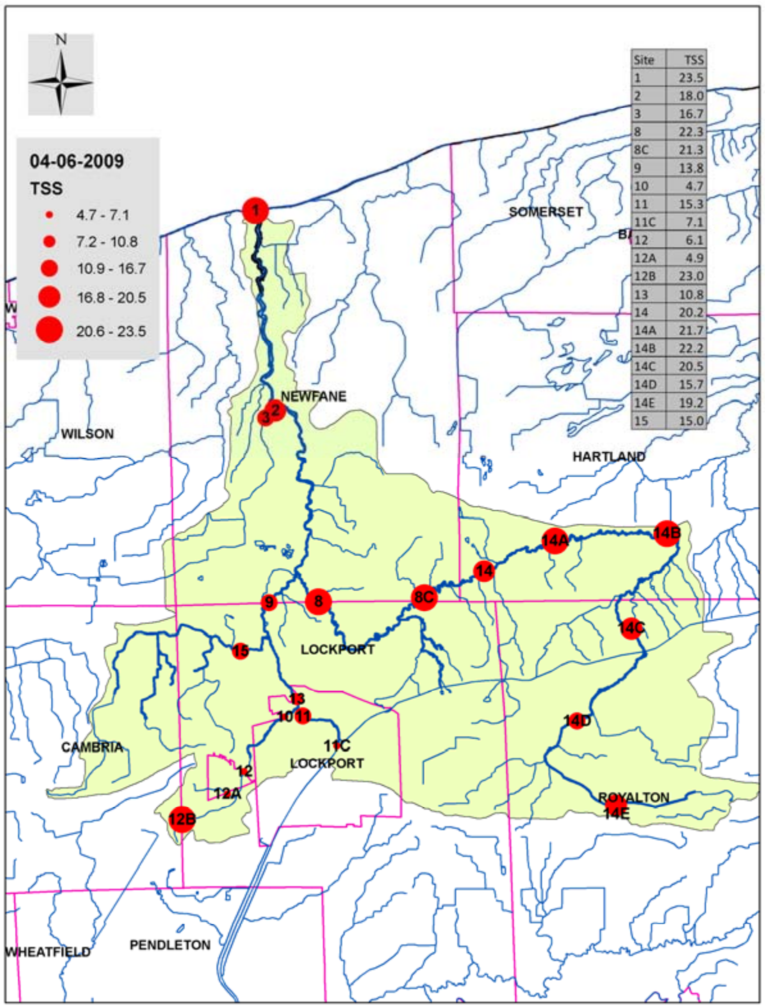
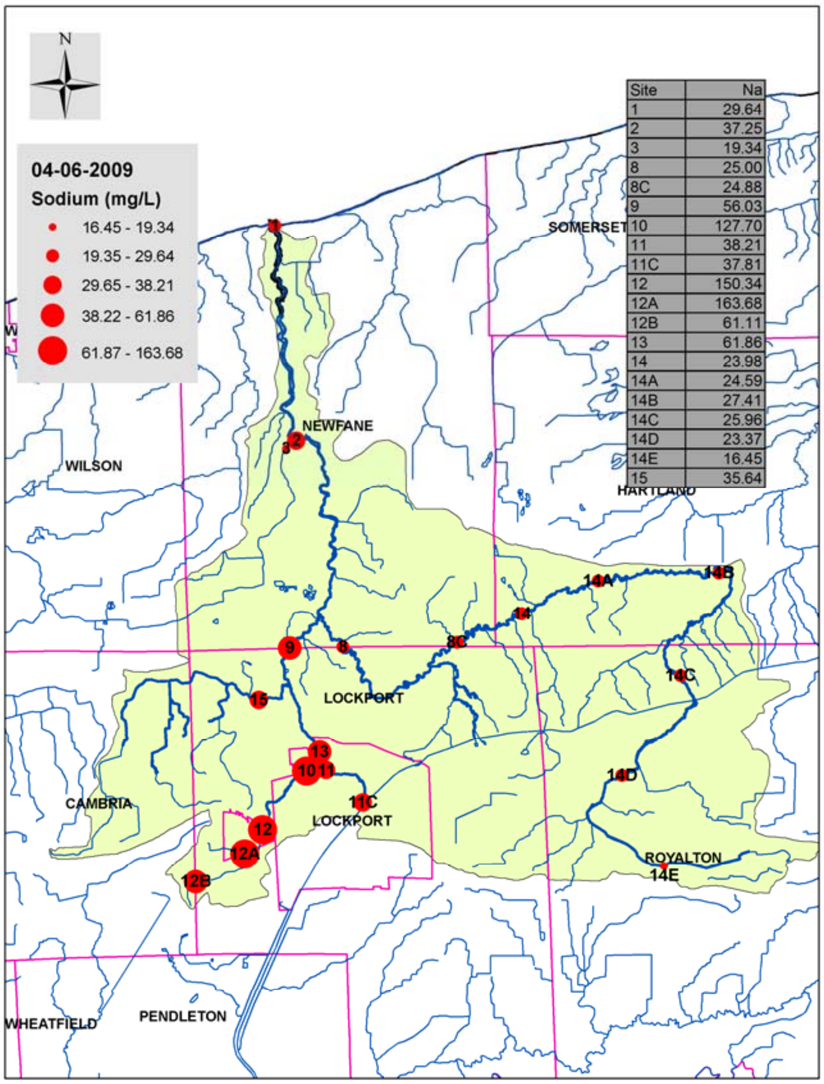


Figure 13. Sodium (Na) concentrations (mg/L) at various sites (red circles) along Eighteenmile Creek on 6 April 2009.



Site	Na
1	29.64
2	37.25
3	19.34
8	25.00
8C	24.88
9	56.03
10	127.70
11	38.21
11C	37.81
12	150.34
12A	163.68
12B	61.11
13	61.86
14	23.98
14A	24.59
14B	27.41
14C	25.96
14D	23.37
14E	16.45
15	35.64

Figure 14. Total phosphorus (TP) concentrations (µg P/L) at various sites (red circles) along Eighteenmile Creek on 8 April 2009.

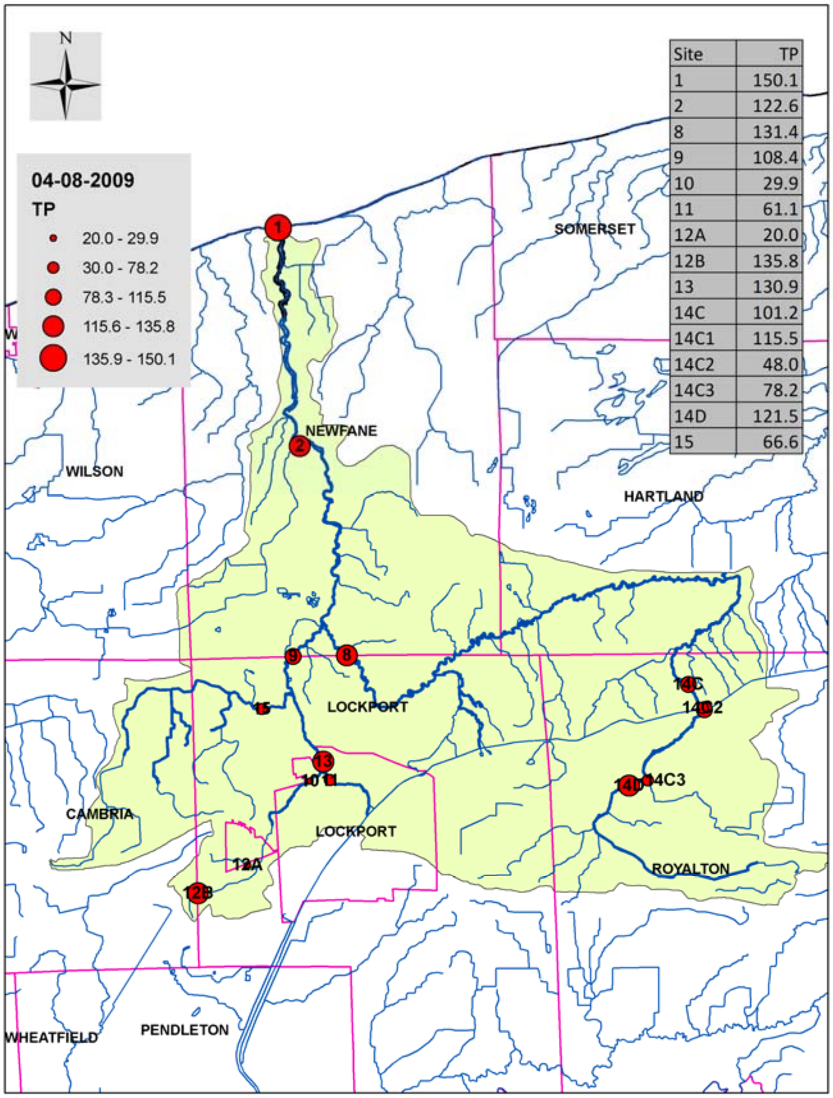


Figure 15. Soluble reactive phosphorus (SRP) concentrations (µg P/L) at various sites (red circles) along Eighteenmile Creek on 8 April 2009.

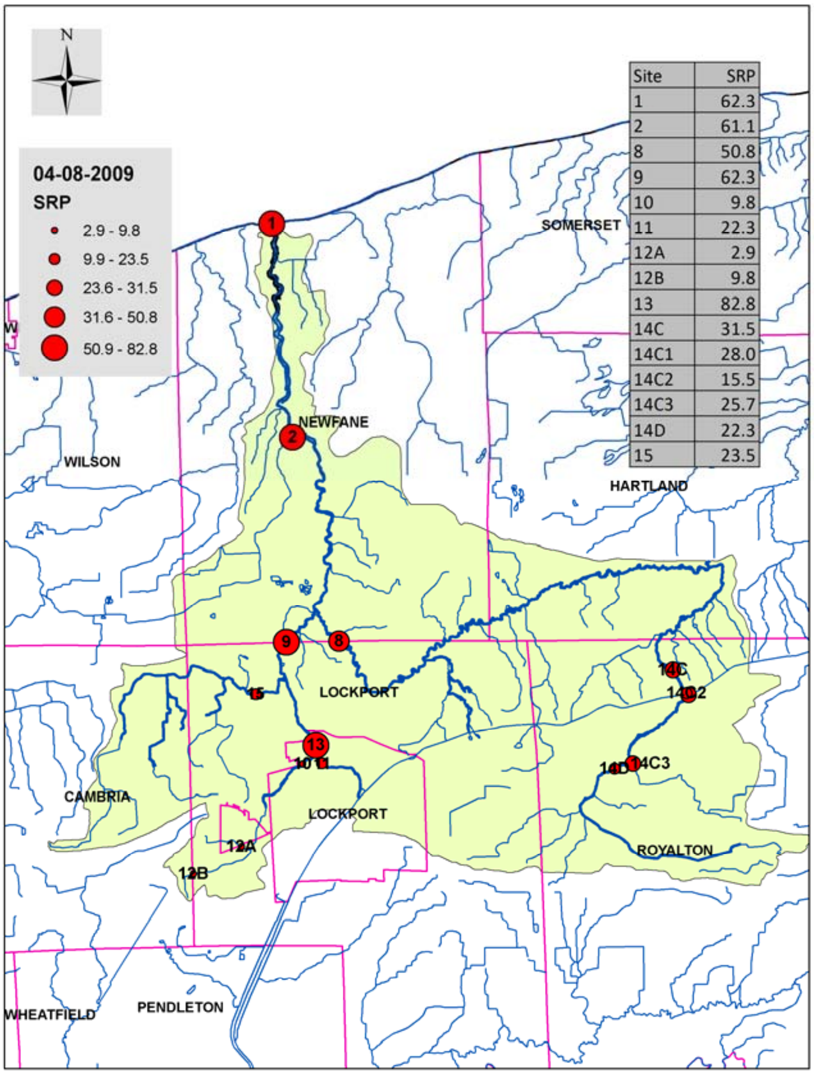


Figure 16. Nitrate concentrations (mg N/L) at various sites (red circles) along Eighteenmile Creek on 8 April 2009.

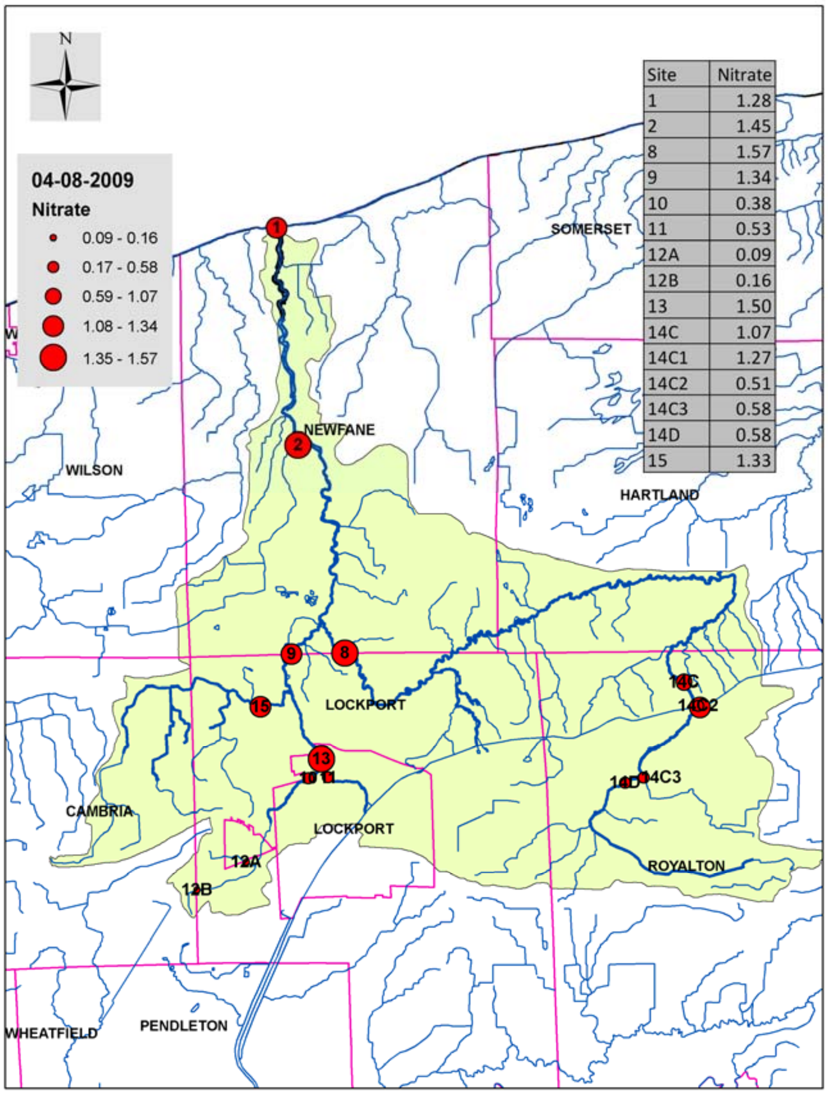


Figure 17. Total Kjeldahl nitrogen (TKN) concentrations (µg N/L) at various sites (red circles) along Eighteenmile Creek on 8 April 2009.

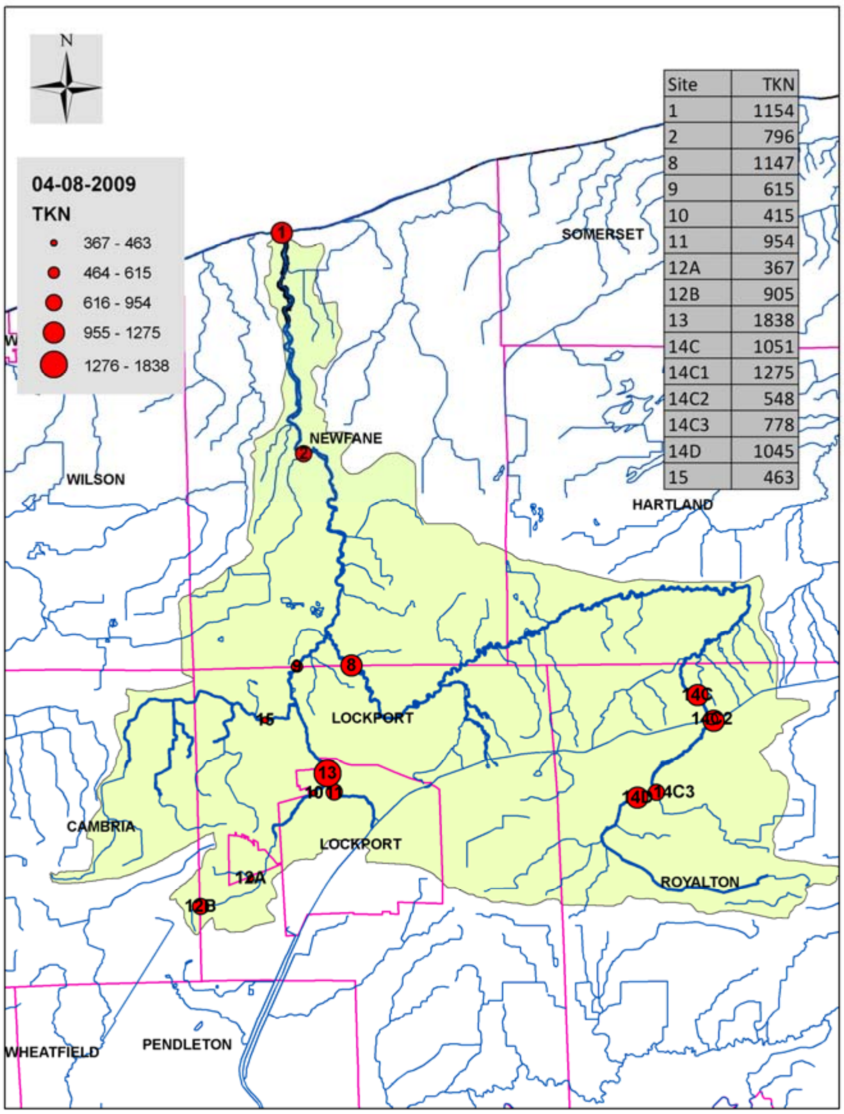


Figure 18. Total suspended solids (TSS) concentrations (mg/L) at various sites (red circles) along Eighteenmile Creek on 8 April 2009.

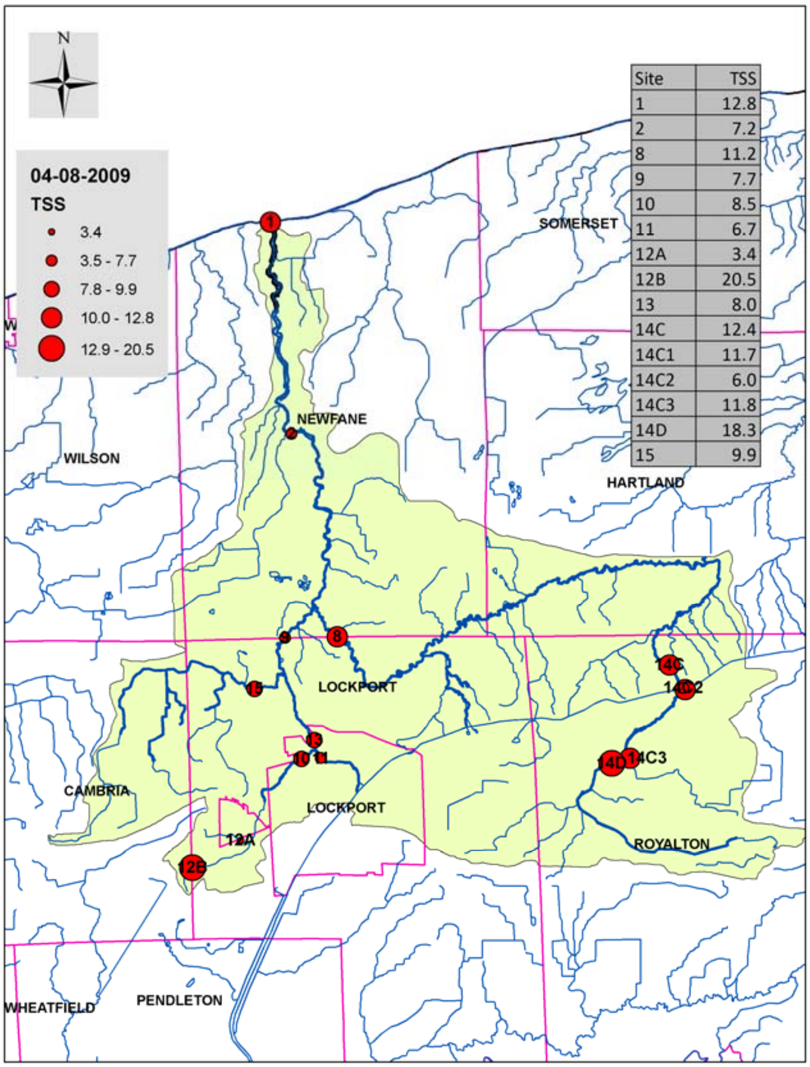


Figure 19. Sodium (Na) concentrations (mg/L)at various sites (red circles) along Eighteenmile Creek on 8 April 2009.

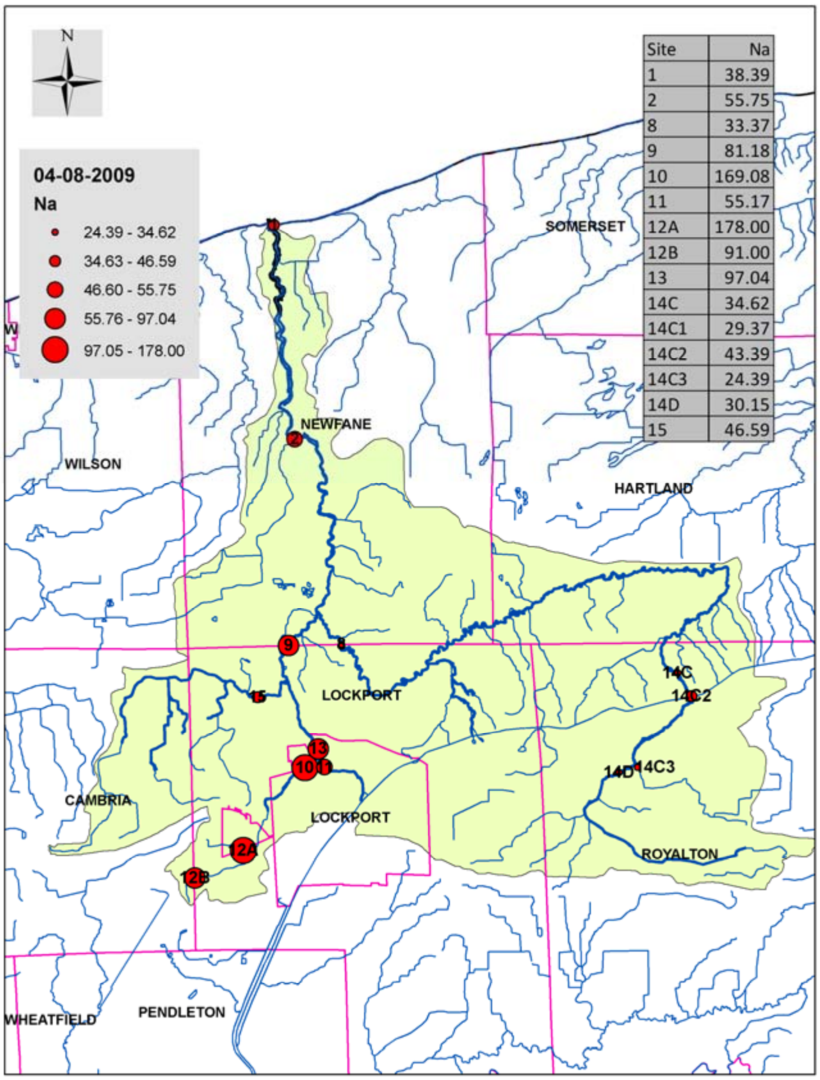


Figure 20. Total phosphorus (TP) concentrations at various sites (red circles) along Eighteenmile Creek on 29 May 2009.

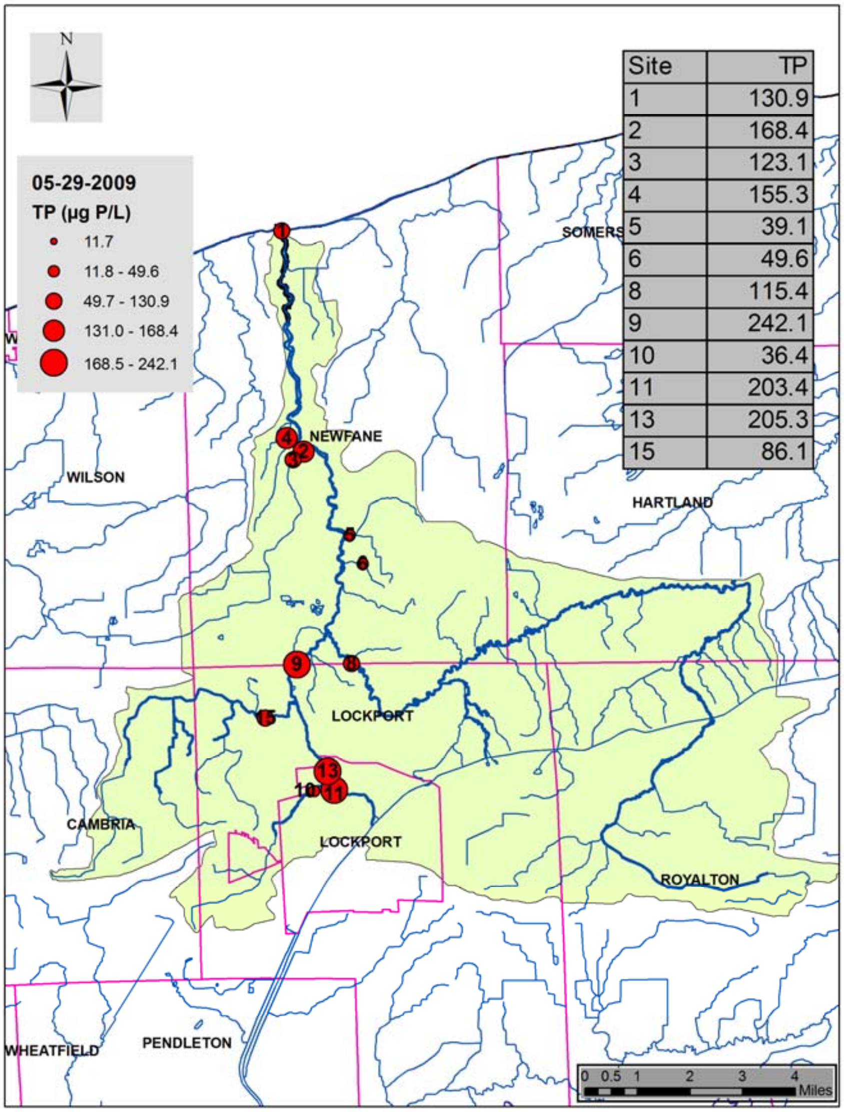
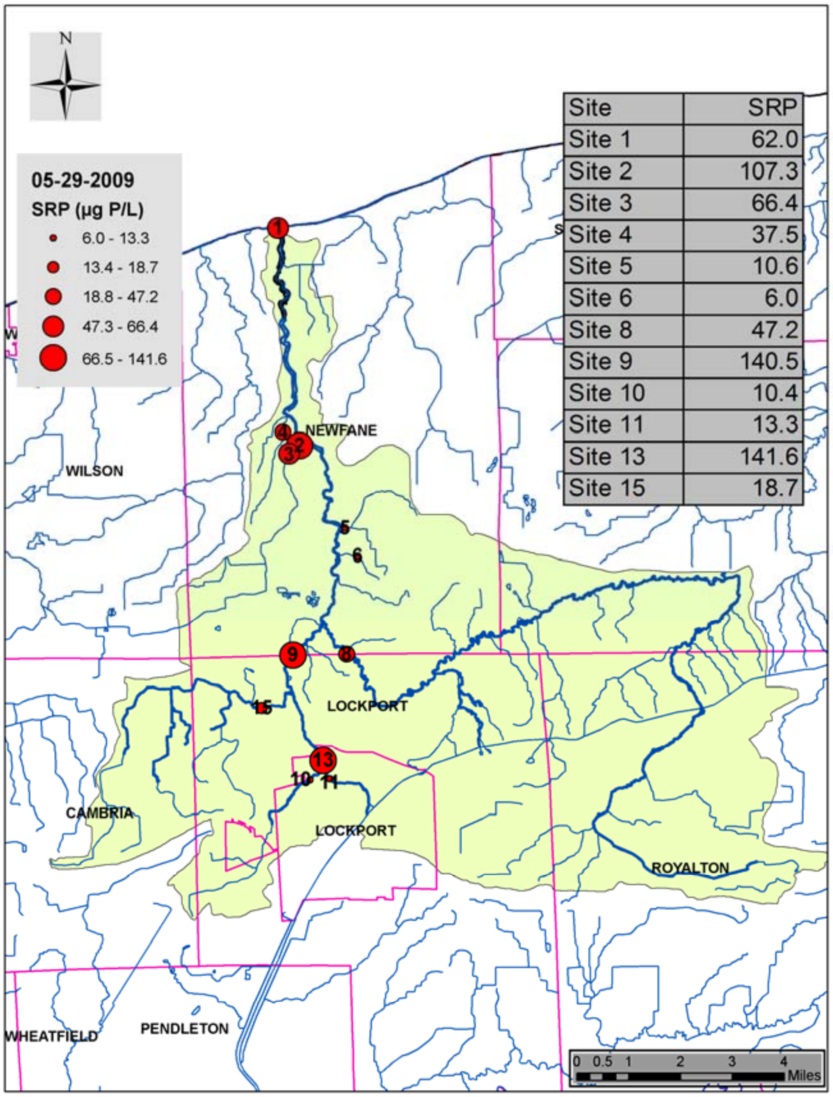
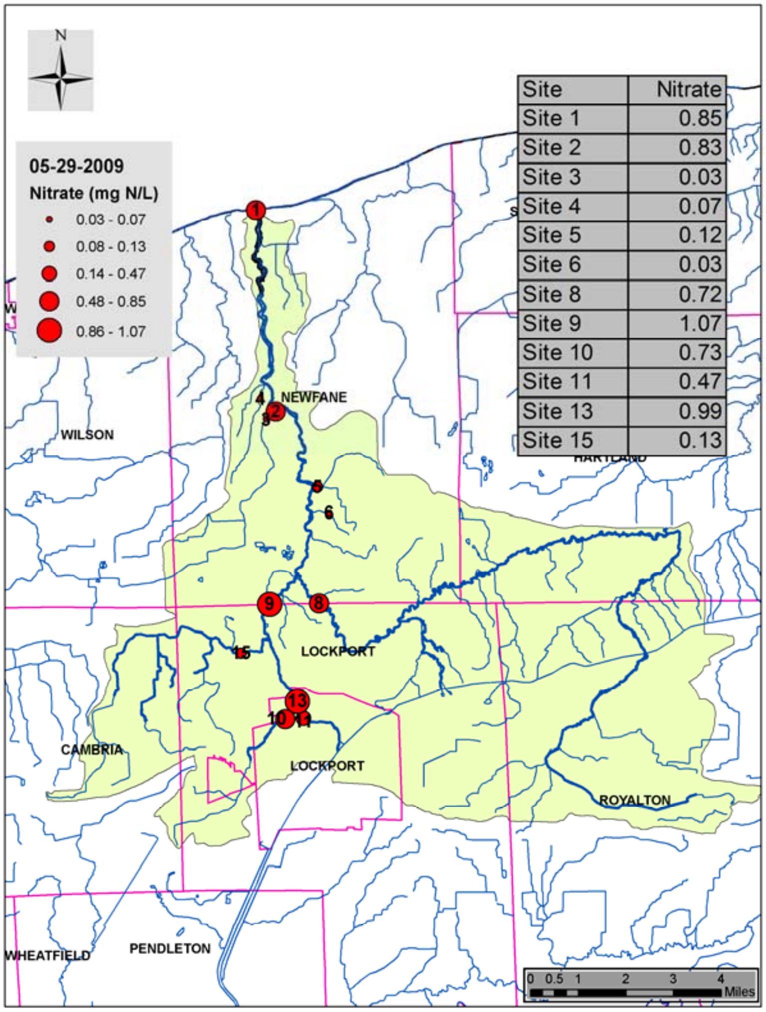


Figure 21. Soluble reactive phosphorus (SRP) concentrations at various sites (red circles) along Eighteenmile Creek on 29 May 2009.



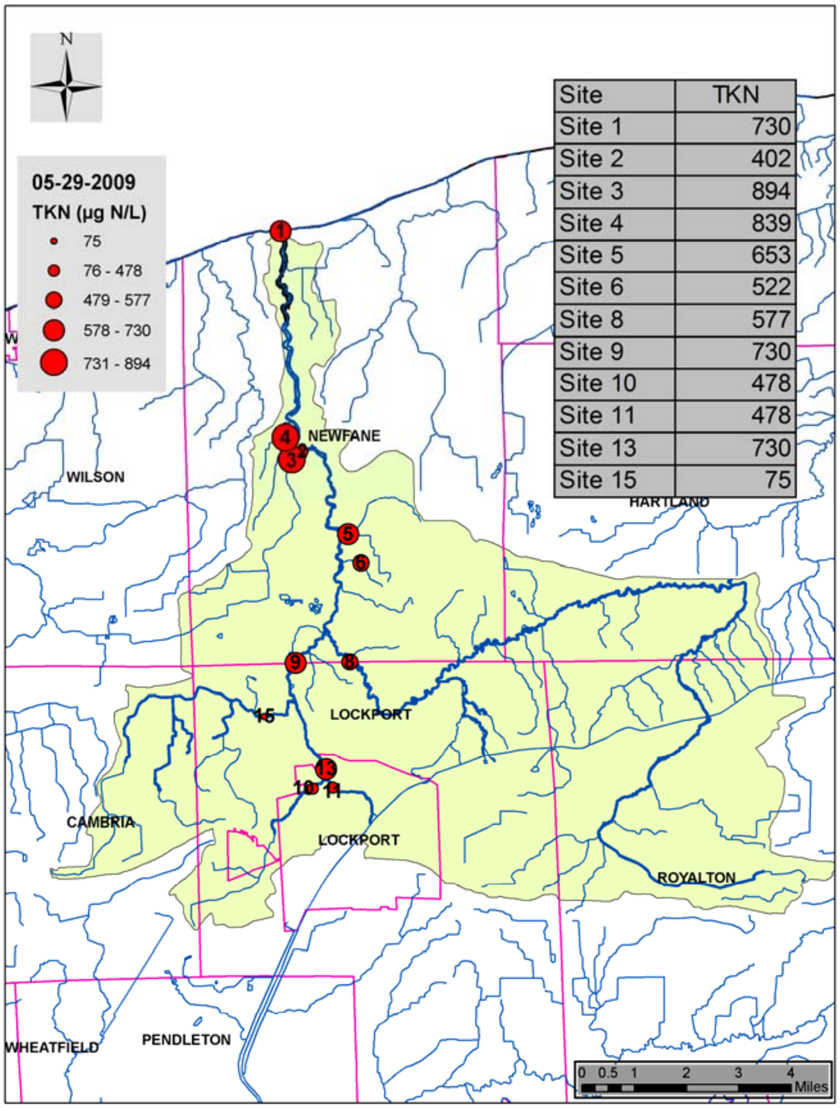
Site	SRP
Site 1	62.0
Site 2	107.3
Site 3	66.4
Site 4	37.5
Site 5	10.6
Site 6	6.0
Site 8	47.2
Site 9	140.5
Site 10	10.4
Site 11	13.3
Site 13	141.6
Site 15	18.7

Figure 22. Nitrate concentrations at various sites (red circles) along Eighteenmile Creek on 29 May 2009.



Site	Nitrate
Site 1	0.85
Site 2	0.83
Site 3	0.03
Site 4	0.07
Site 5	0.12
Site 6	0.03
Site 8	0.72
Site 9	1.07
Site 10	0.73
Site 11	0.47
Site 13	0.99
Site 15	0.13

Figure 23. Total Kjeldahl nitrogen (TKN) concentrations at various sites (red circles) along Eighteenmile Creek on 29 May 2009.



Site	TKN
Site 1	730
Site 2	402
Site 3	894
Site 4	839
Site 5	653
Site 6	522
Site 8	577
Site 9	730
Site 10	478
Site 11	478
Site 13	730
Site 15	75

Figure 24. Total suspended solids (TSS) concentrations at various sites (red circles) along Eighteenmile Creek on 29 May 2009.

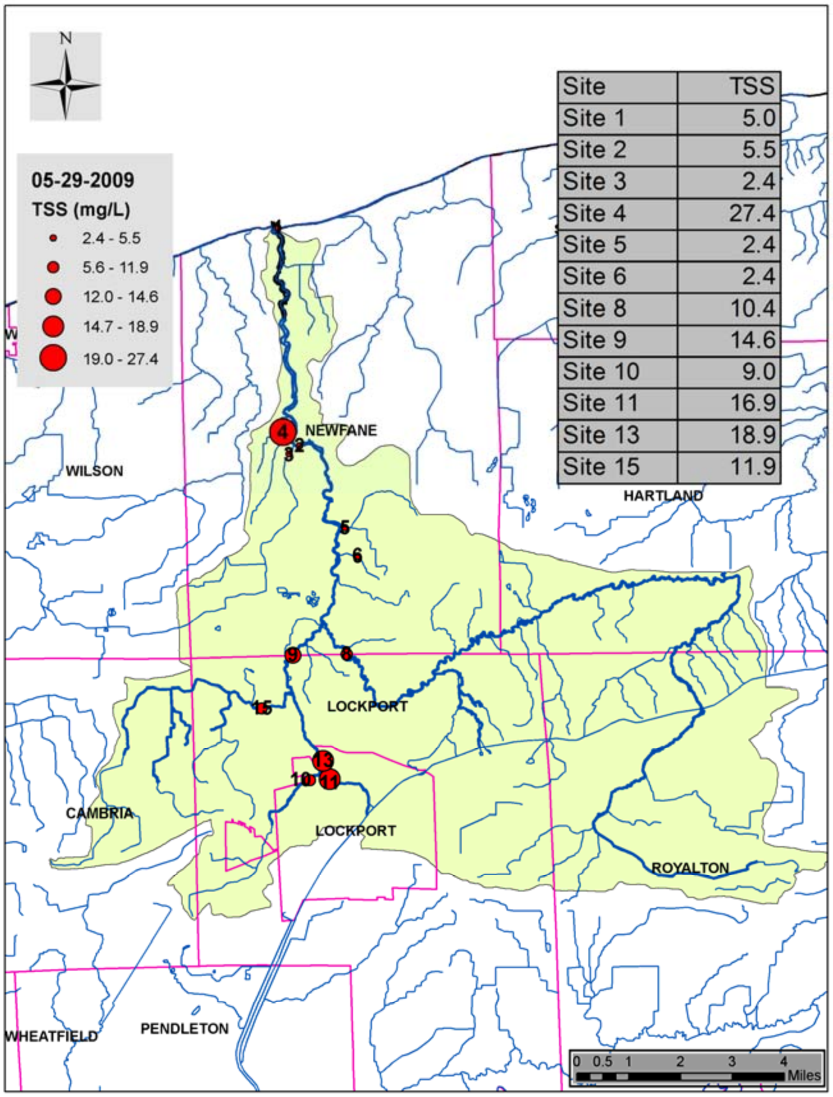
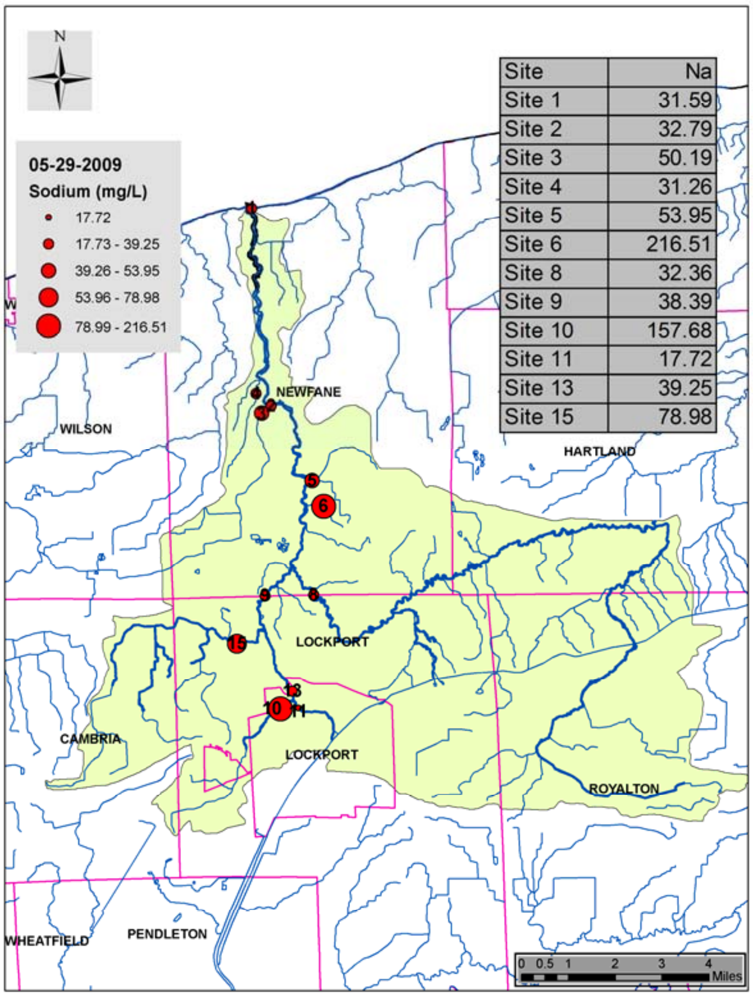
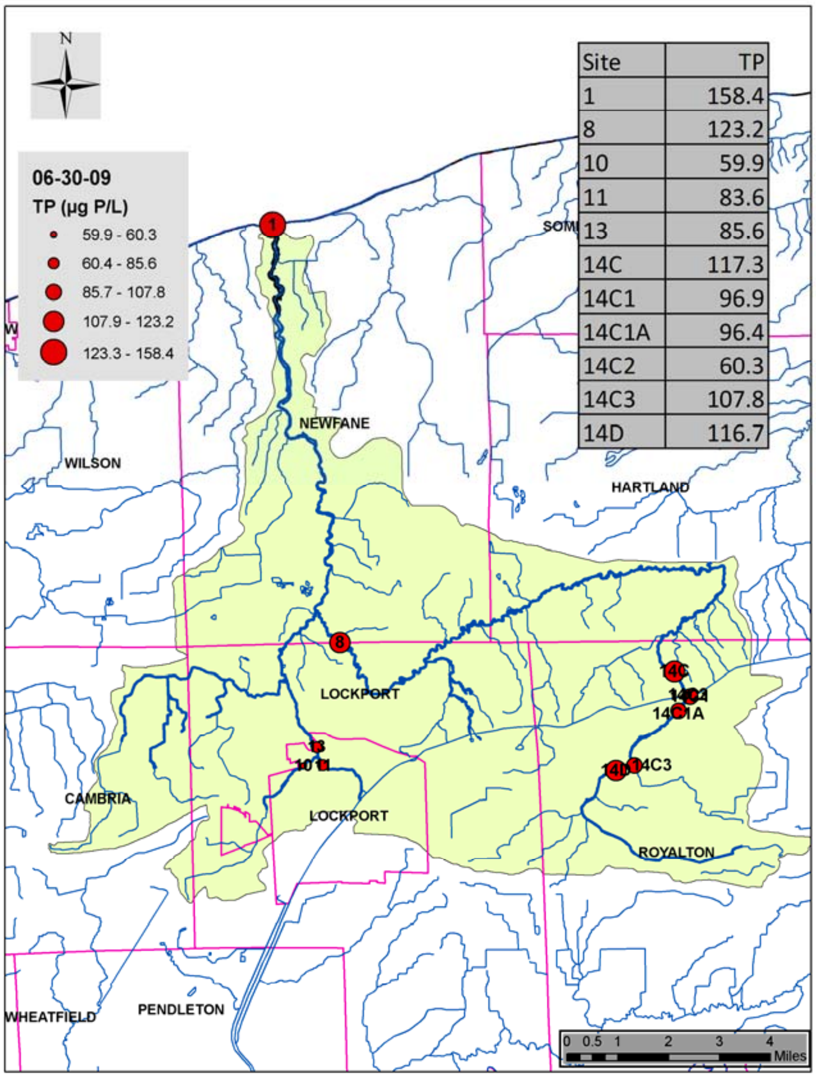


Figure 25. Sodium (Na) concentrations at various sites (red circles) along Eighteenmile Creek on 29 May 2009.



Site	Na
Site 1	31.59
Site 2	32.79
Site 3	50.19
Site 4	31.26
Site 5	53.95
Site 6	216.51
Site 8	32.36
Site 9	38.39
Site 10	157.68
Site 11	17.72
Site 13	39.25
Site 15	78.98

Figure 26. Total phosphorus (TP) concentrations at various sites (red circles) along Eighteenmile Creek on 30 June 2009.



Site	TP
1	158.4
8	123.2
10	59.9
11	83.6
13	85.6
14C	117.3
14C1	96.9
14C1A	96.4
14C2	60.3
14C3	107.8
14D	116.7

Figure 27. Soluble reactive phosphorus (SRP) concentrations at various sites (red circles) along Eighteenmile Creek on 30 June 2009.

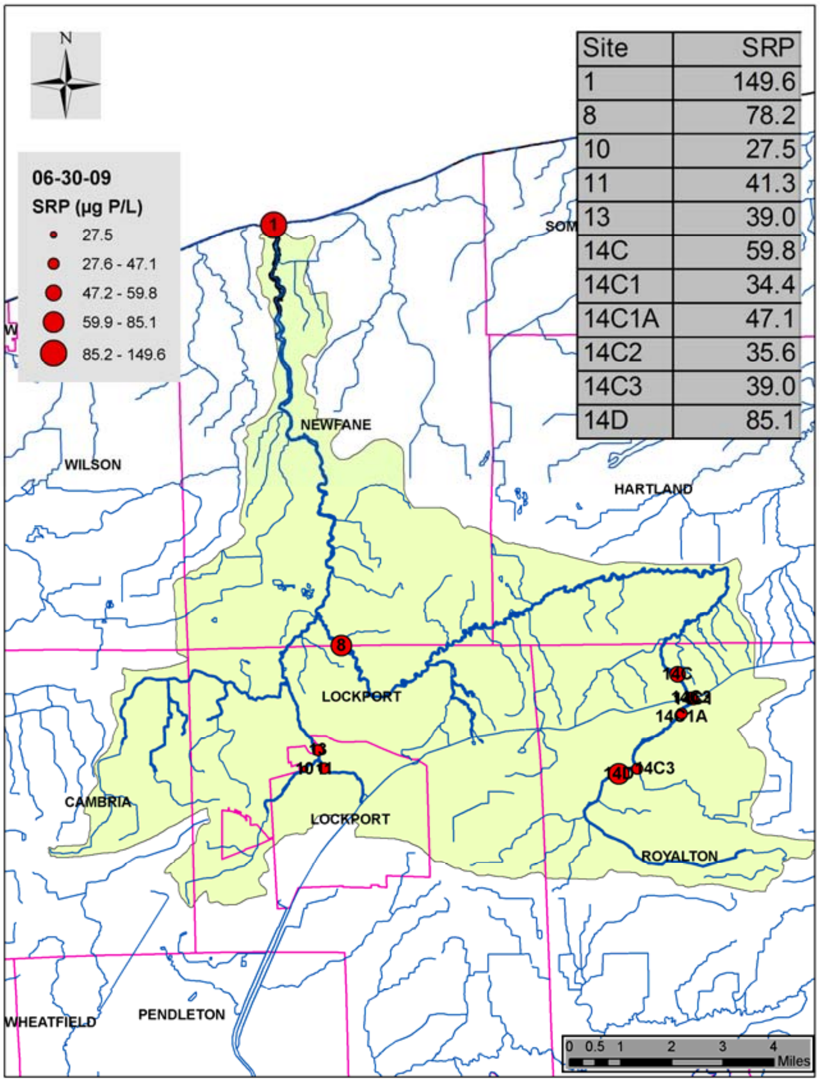


Figure 28. Nitrate concentrations at various sites (red circles) along Eighteenmile Creek on 30 June 2009.

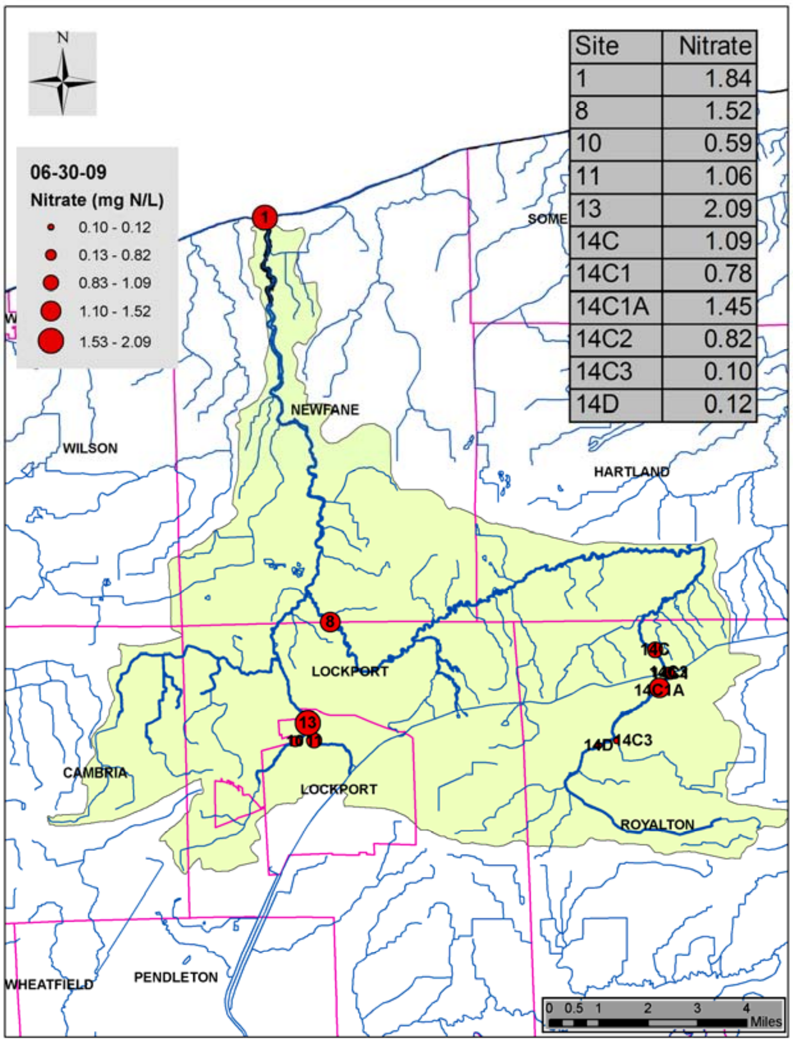


Figure 29. Total Kjeldahl nitrogen (TKN) concentrations at various sites (red circles) along Eighteenmile Creek on 30 June 2009.

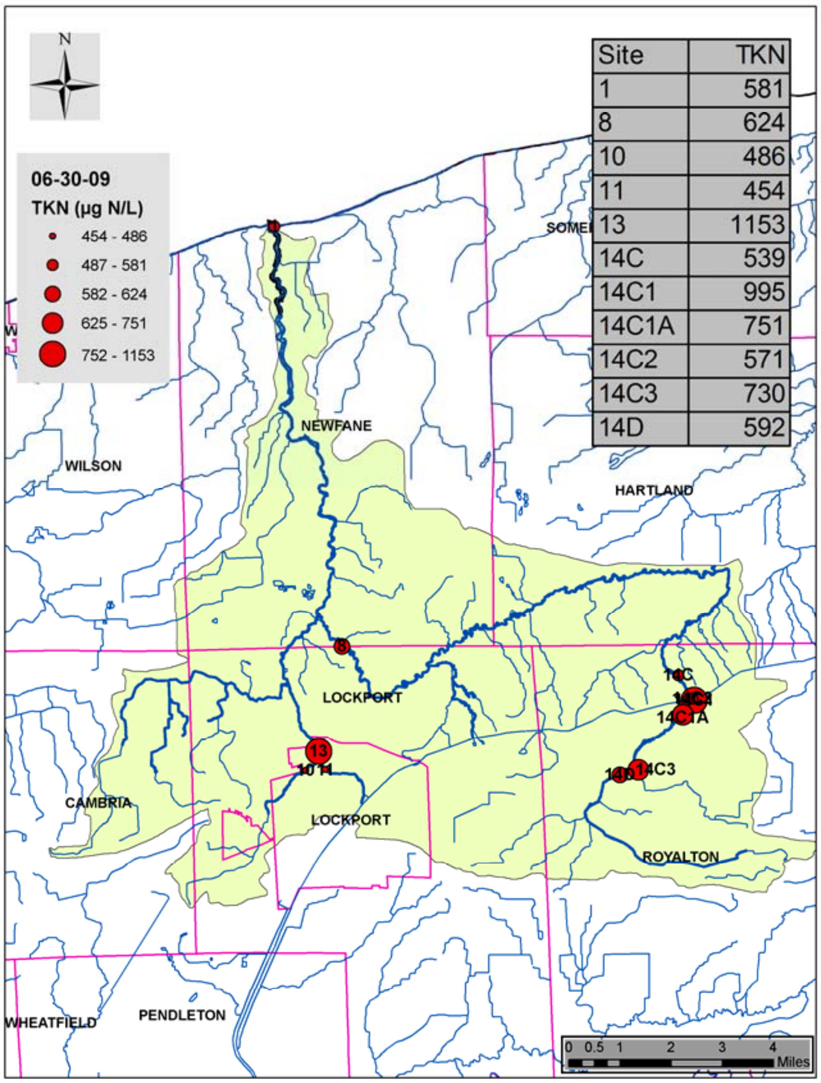


Figure 30. Total suspended solids (TSS) concentrations at various sites (red circles) along Eighteenmile Creek on 30 June 2009.

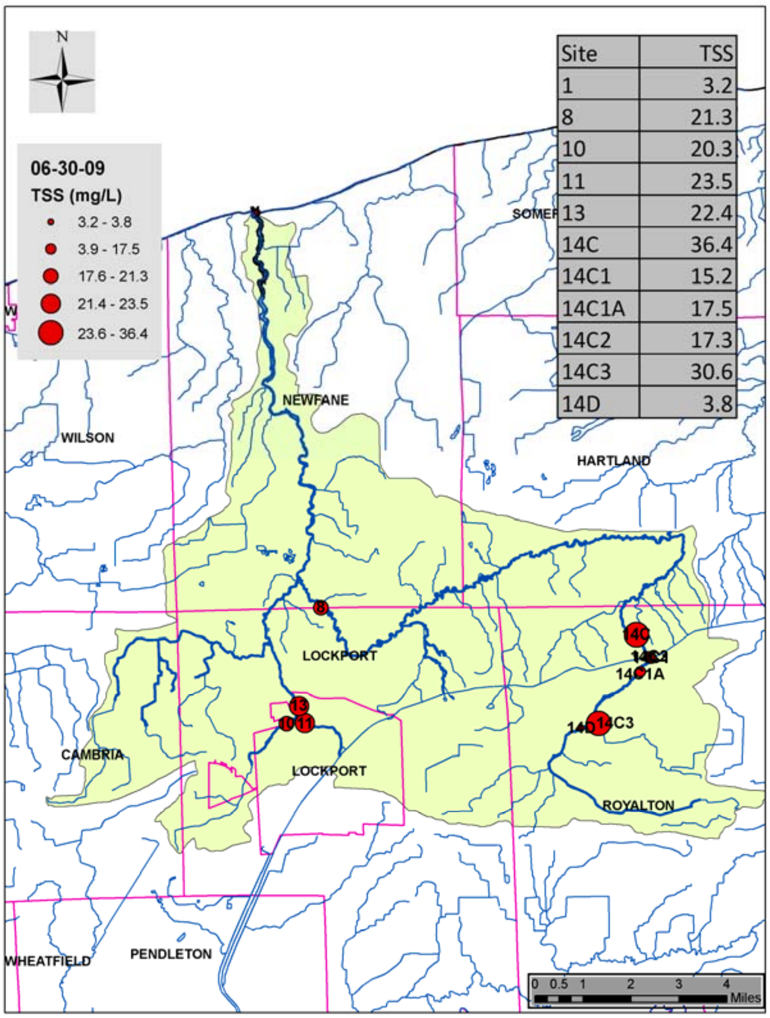
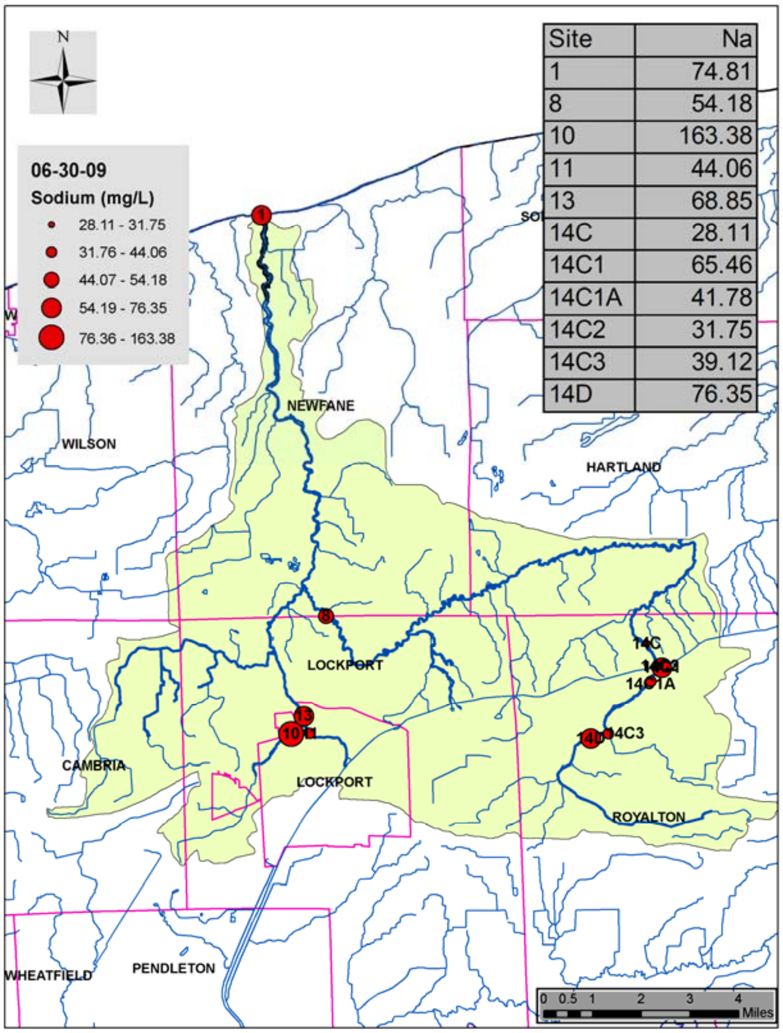
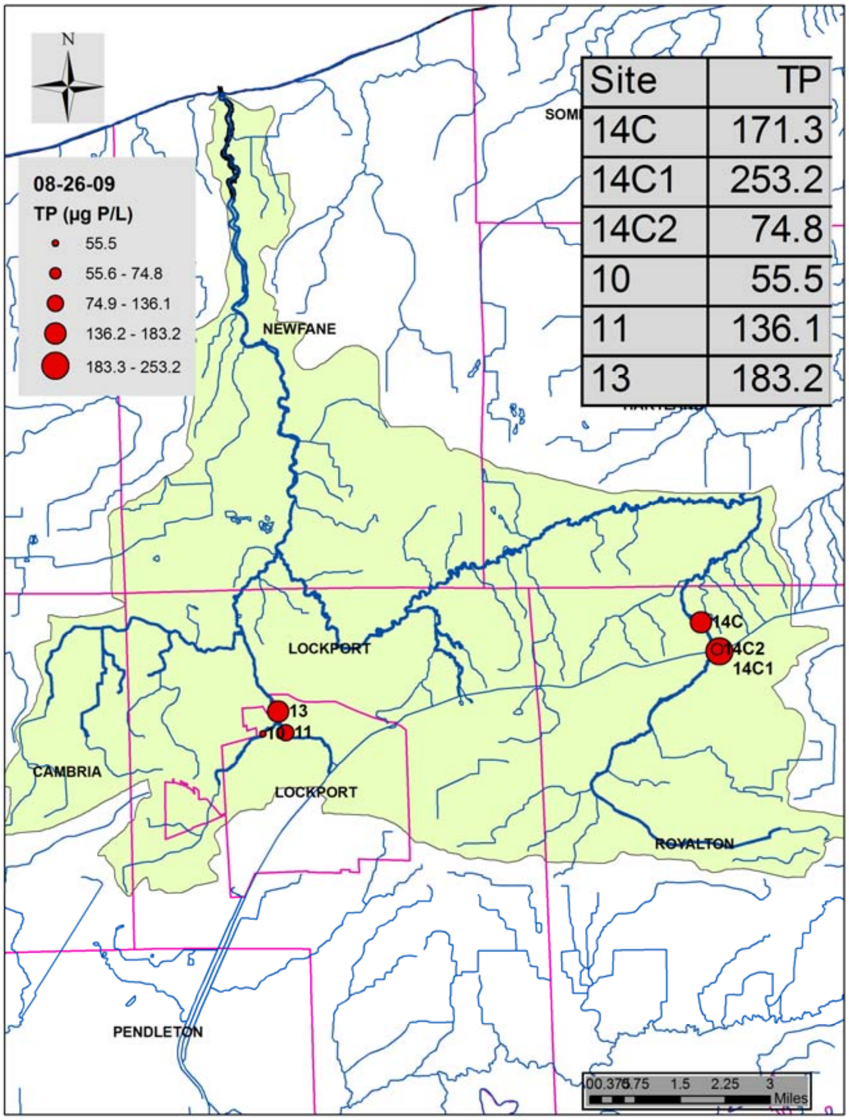


Figure 31. Sodium (Na) concentrations at various sites (red circles) along Eighteenmile Creek on 30 June 2009.



Site	Na
1	74.81
8	54.18
10	163.38
11	44.06
13	68.85
14C	28.11
14C1	65.46
14C1A	41.78
14C2	31.75
14C3	39.12
14D	76.35

Figure 32. Total phosphorus (TP) concentrations at various sites (red circles) along Eighteenmile Creek on 26 August 2009.



Site	TP
14C	171.3
14C1	253.2
14C2	74.8
10	55.5
11	136.1
13	183.2

Figure 33. Soluble reactive phosphorus (SRP) concentrations at various sites (red circles) along Eighteenmile Creek on 26 August 2009.

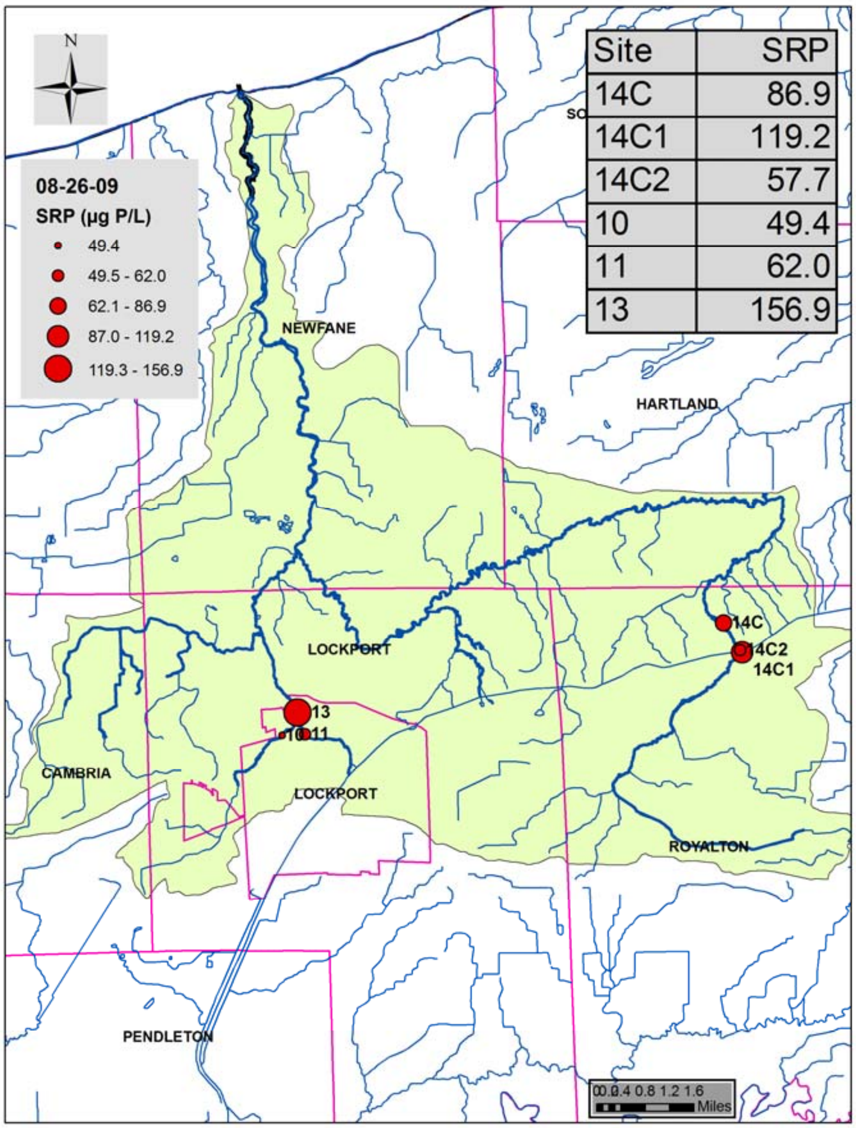
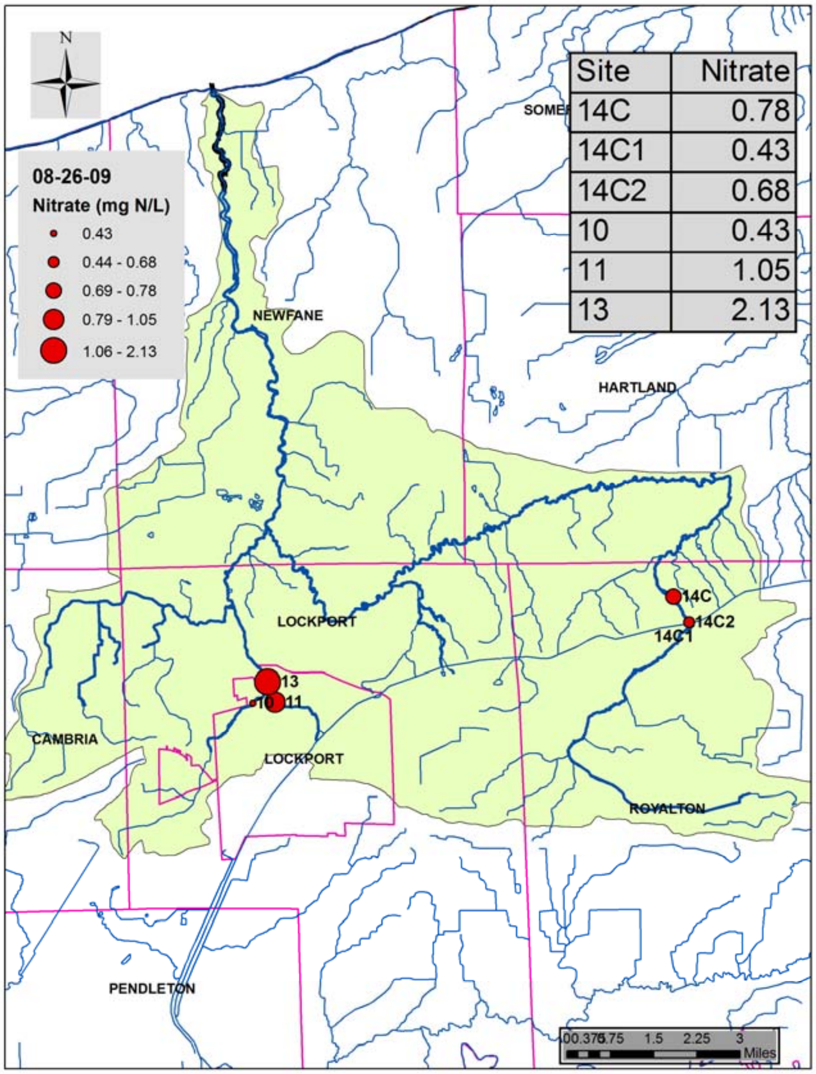
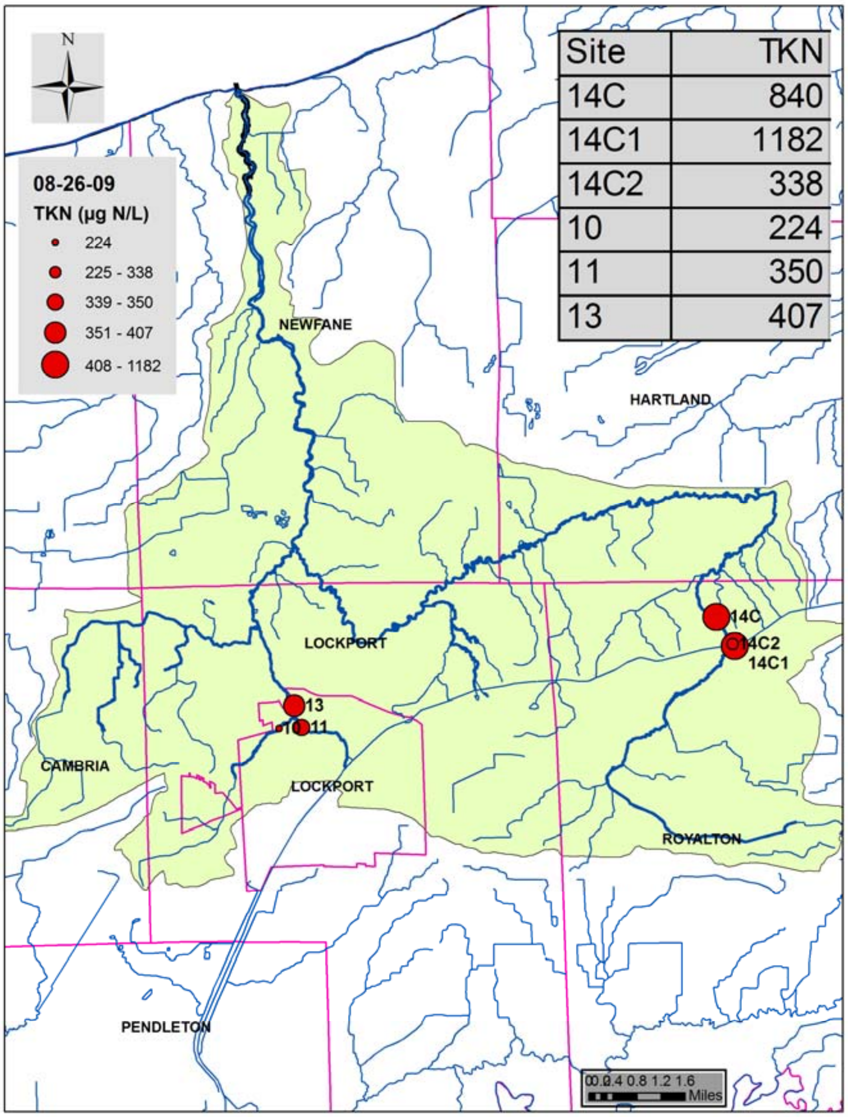


Figure 34. Nitrate concentrations at various sites (red circles) along Eighteenmile Creek on 26 August 2009.



Site	Nitrate
14C	0.78
14C1	0.43
14C2	0.68
10	0.43
11	1.05
13	2.13

Figure 35. Total Kjeldahl nitrogen (TKN) concentrations at various sites (red circles) along Eighteenmile Creek on 26 August 2009.



Site	TKN
14C	840
14C1	1182
14C2	338
10	224
11	350
13	407

Figure 36. Total suspended solids (TSS) concentrations at various sites (red circles) along Eighteenmile Creek on 26 August 2009.

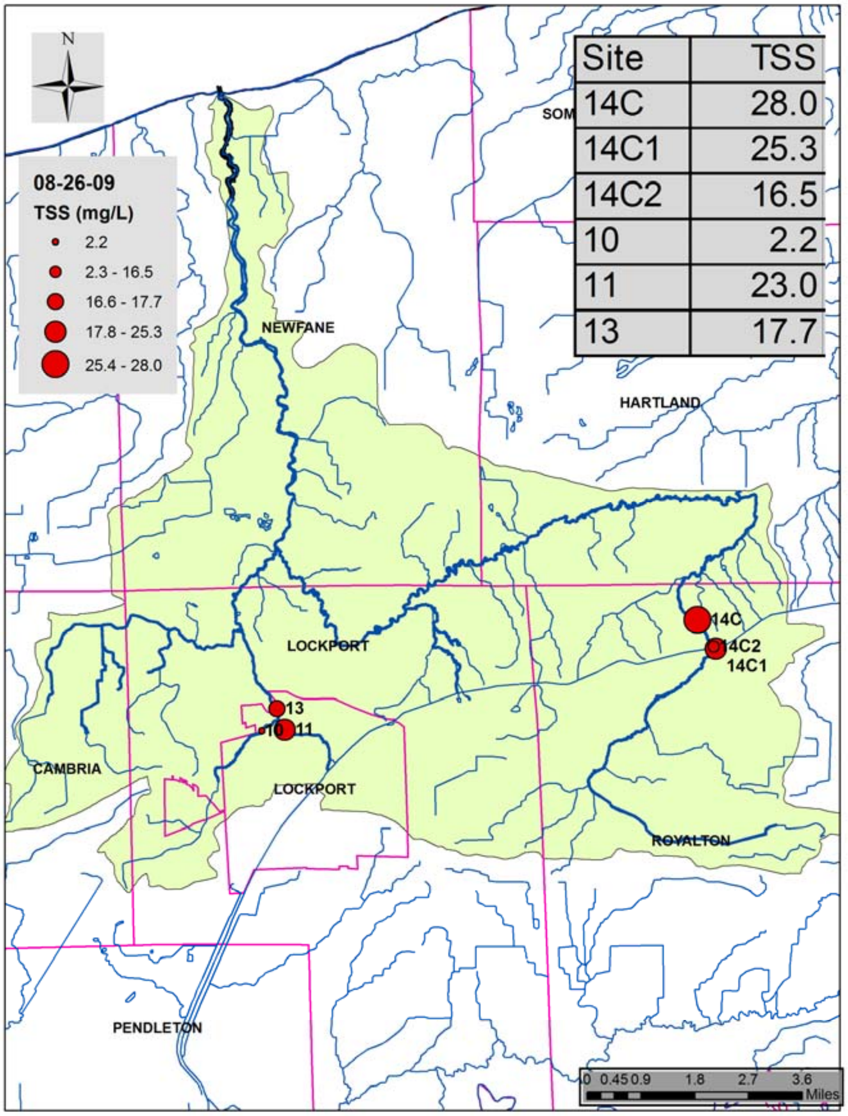
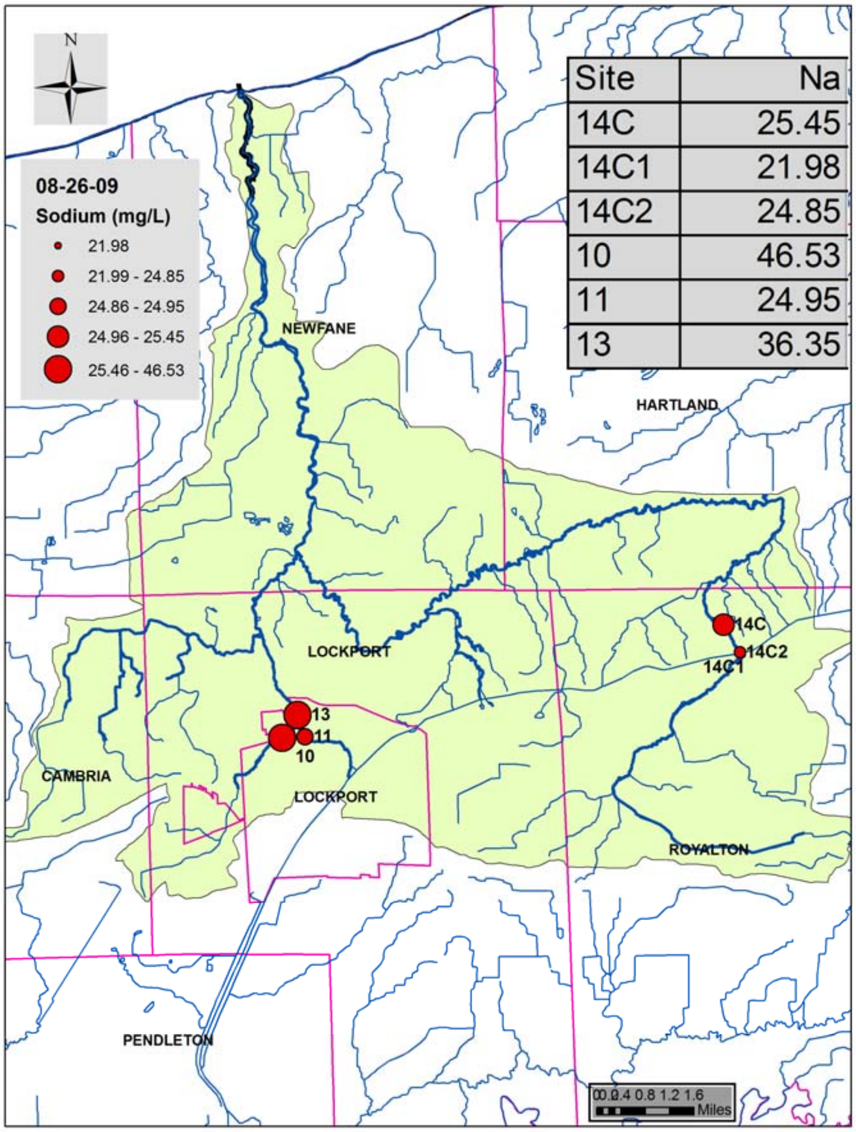


Figure 37. Sodium (Na) concentrations at various sites (red circles) along Eighteenmile Creek on 26 August 2009.



Site	Na
14C	25.45
14C1	21.98
14C2	24.85
10	46.53
11	24.95
13	36.35

Figure 38. Total phosphorus (TP) concentrations at various sites (red circles) along Eighteenmile Creek on 3 December 2009.

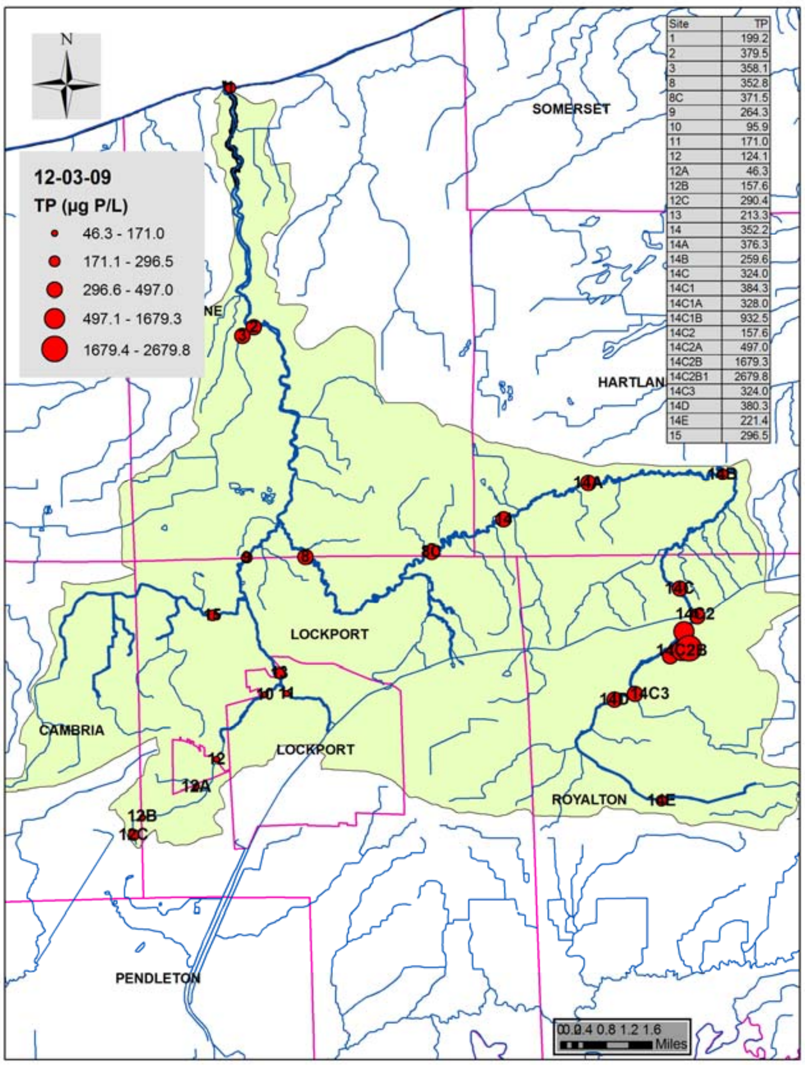
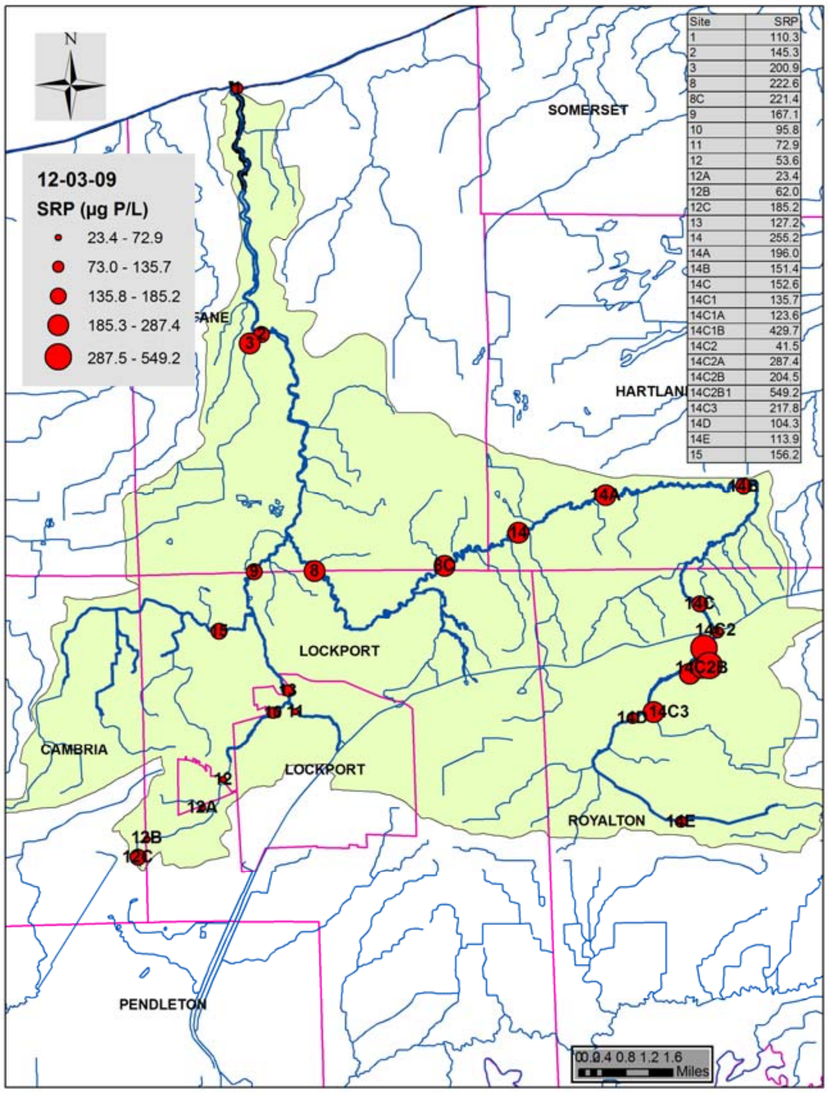


Figure 39. Soluble reactive phosphorus (SRP) concentrations at various sites (red circles) along Eighteenmile Creek on 3 December 2009.



Site	SRP
1	110.3
2	145.3
3	200.9
8	222.6
8C	221.4
9	167.1
10	95.8
11	72.9
12	53.6
12A	23.4
12B	62.0
12C	185.2
13	127.2
14	255.2
14A	196.0
14B	151.4
14C	152.6
14C1	135.7
14C1A	123.6
14C1B	429.7
14C2	41.5
14C2A	287.4
14C2B	204.5
14C2B1	549.2
14C3	217.8
14D	104.3
14E	113.9
15	156.2

Figure 40. Nitrate concentrations at various sites (red circles) along Eighteenmile Creek on 3 December 2009.

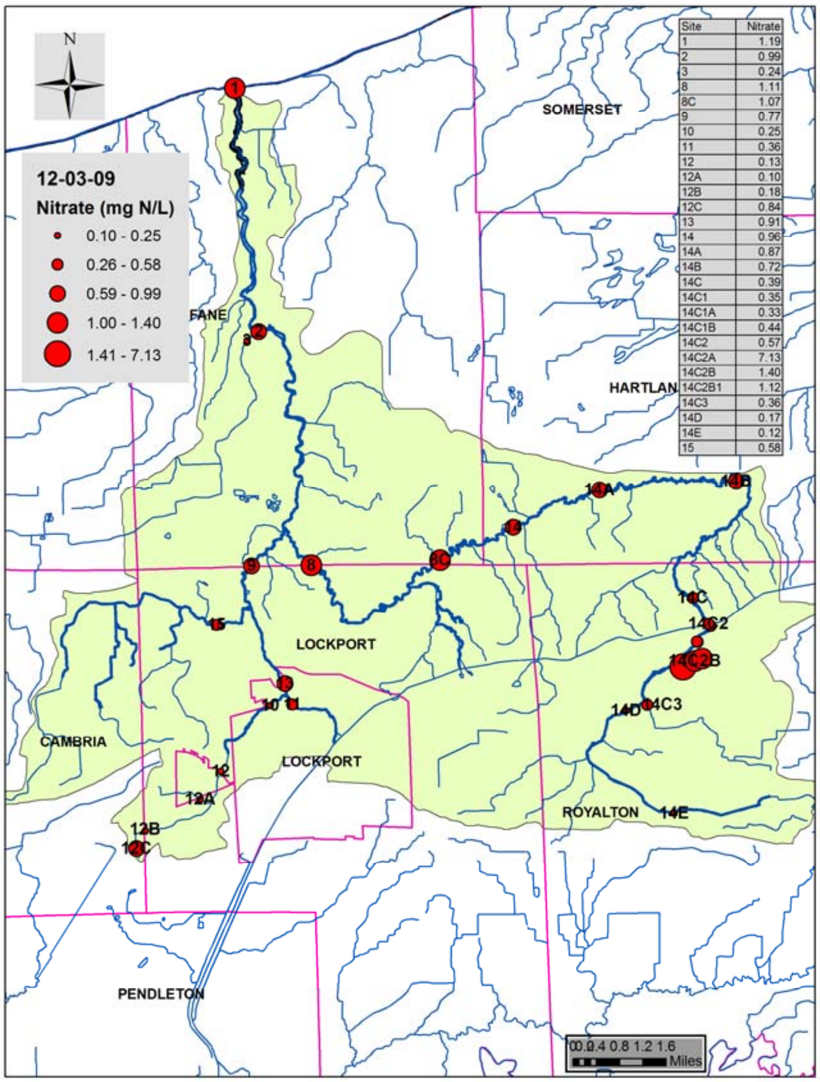
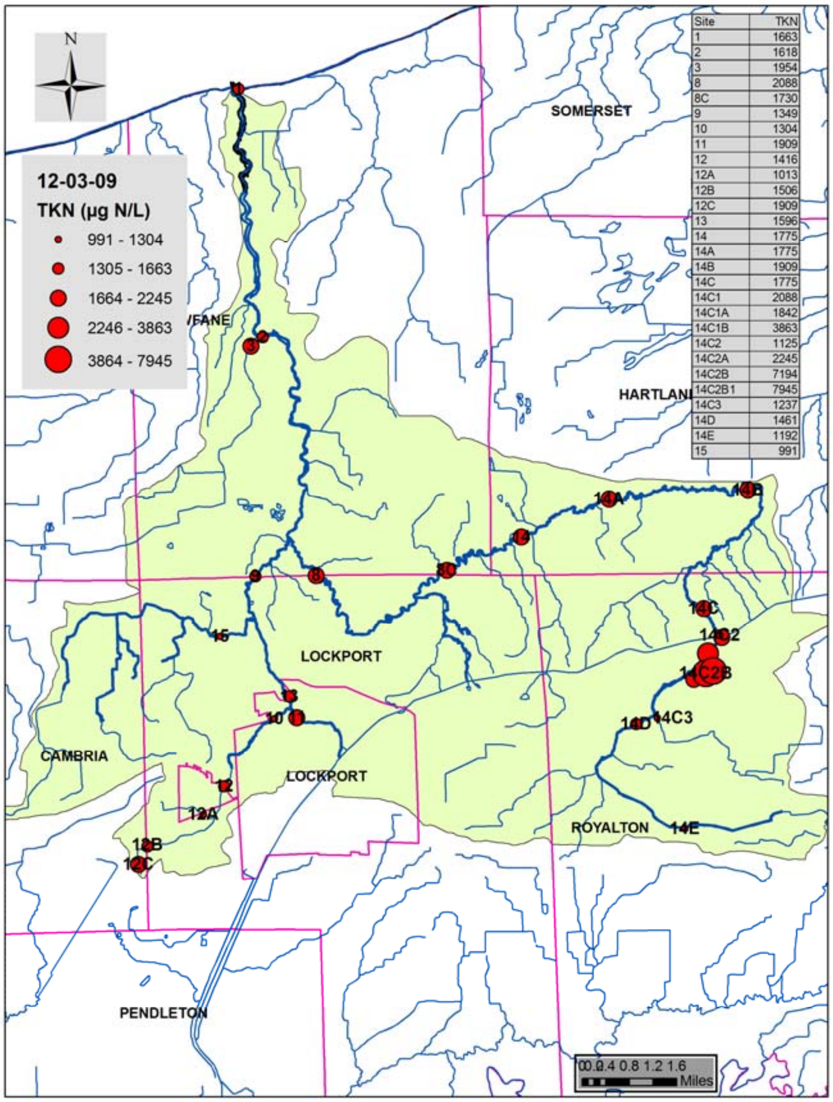


Figure 41. Total Kjeldahl nitrogen (TKN) concentrations at various sites (red circles) along Eighteenmile Creek on 3 December 2009.



Site	TKN
1	1663
2	1618
3	1954
8	2088
8C	1730
9	1349
10	1304
11	1909
12	1416
12A	1013
12B	1506
12C	1909
13	1596
14	1775
14A	1775
14B	1909
14C	1775
14C1	2088
14C1A	1842
14C1B	3863
14C2	1125
14C2A	2245
14C2B	7194
14C2B1	7945
14C3	1237
14D	1461
14E	1192
15	991

Figure 42. Total suspended solid (TSS) concentrations at various sites (red circles) along Eighteenmile Creek on 3 December 2009.

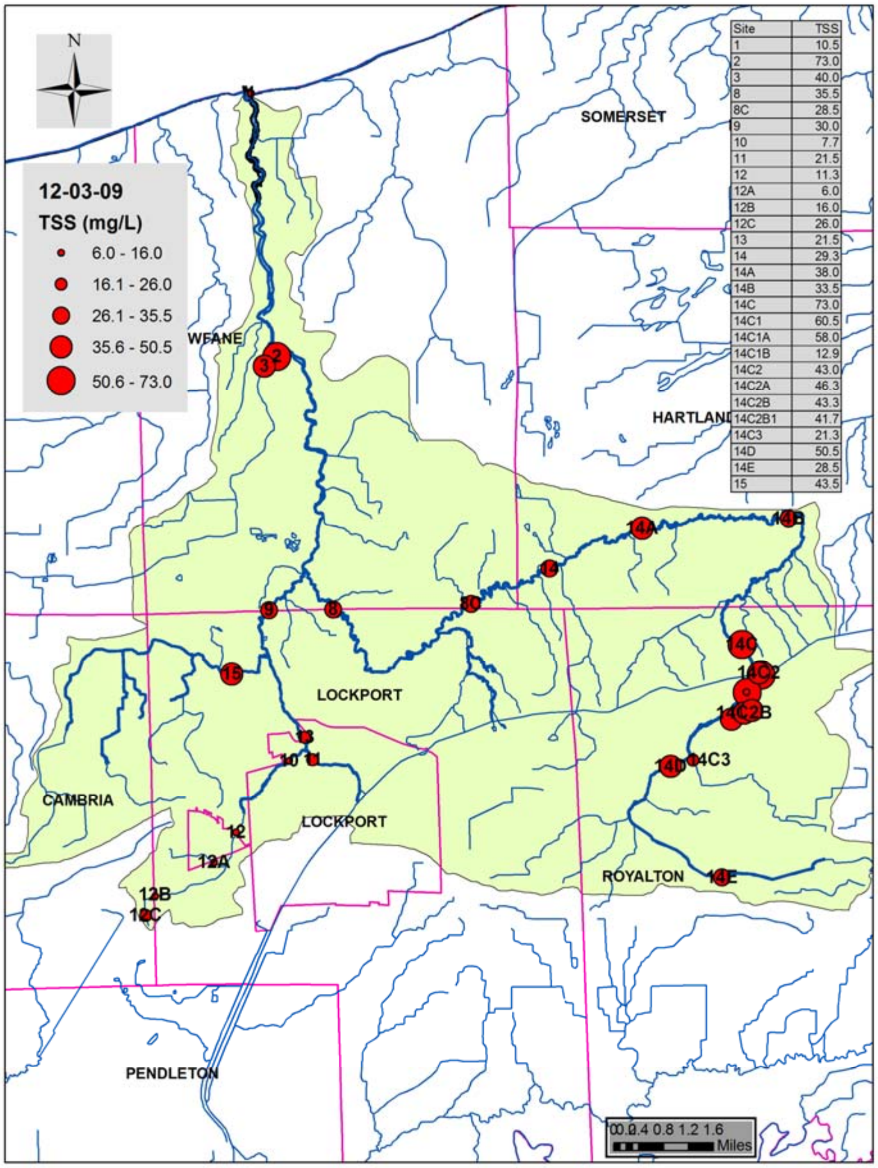


Figure 43. Sodium (Na) concentrations at various sites (red circles) along Eighteenmile Creek on 3 December 2009.

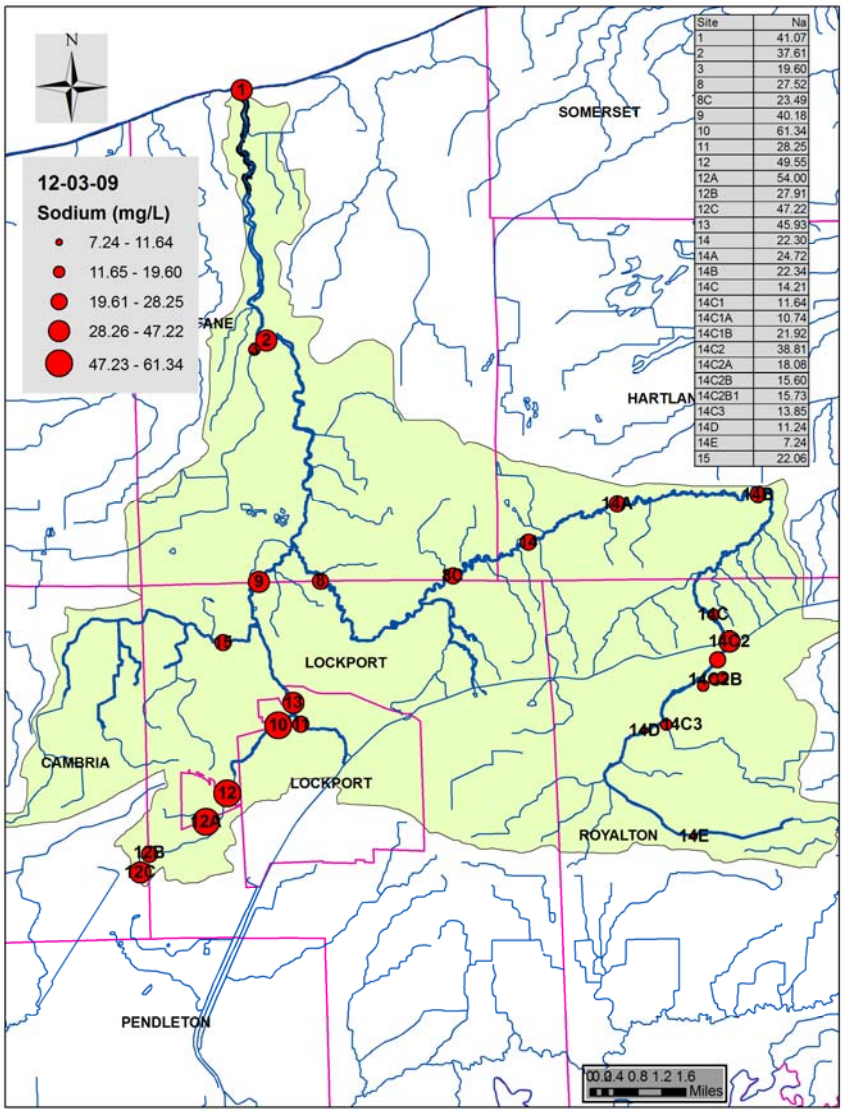


Figure 44. .   Areas in yellow represent suspected sources of nutrients, soil, and sodium to Eighteenmile Creek.