Water Quality in the Long Point Region
A Summary of the 2002-2005 Conditions and Trends

DRAFT

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EXECUTIVE SUMMARY

The purpose of this report is to characterize surface water quality and identify key water quality issues within the watersheds of the Long Point Region. This was accomplished through the analysis of data from the Provincial Water Quality Monitoring Network (PWQMN), and a review of existing literature.

Although the Long Point Region Conservation Authority has participated in the PWQMN for more than thirty years, a water quality report has never been produced for the watershed. To provide a benchmark indicative of the current water quality conditions found within the watersheds of the Long Point Region and to identify potential water quality issues, our analysis investigated the most recent four year contiguous set of data, 2002-2005, for which a total of 10 monitoring sites across four watersheds could be evaluated. To fill in some of the gaps across the region, six historical sites were also analysed within the Nanticoke Creek and two within the Sandusk Creek watershed. In addition, the entire dataset (historical to current) for each of the 18 sites were assessed for preliminary long-term temporal trends where possible.

Water quality sampling within the Long Point Region watershed occurred on a routine basis whereby flow was not always considered. Generally, sampling was performed across a range of flows; however, peak events were missed for some years. This potential bias towards sampling at low to moderate flows indicates that the results from the monitoring data presented here has mainly characterized base-flow and likely has not captured the changes in water quality which occur during high flow events.

Streamflow across the Long Point Region varies widely. Big Otter Creek has the highest flows relative to the other watersheds that were gauged within the region. Those streams whose headwaters originate in the Norfolk Sand Plain (e.g. Big Otter Creek, Big Creek, and Nanticoke Creek) are primarily groundwater fed resulting in a continuous base-flow, whereas those tributaries whose headwaters reside in the Horseshoe Moraine (clayey till) or the Haldimand Clay Plain (e.g. Black Creek or Sandusk Creek) usually have intermittent flow during the summer months.

Although the natural base-flow for those streams within the Norfolk Sand Plain is continuous through the low flow summer months, the numerous permits to take water, online impoundments and tile or municipal drains, could eventually have a negative effect on base-flow levels, which in turn could negatively impact water quality. In order to sustain the current base-flow while still allowing for the numerous water takings, adequate protection of natural recharge areas (such as wetlands and moraines) should be developed.

Across the Long Point Region dissolved oxygen levels have rarely been observed to dip below 6mg/L. While this value is considered to be adequate for aquatic life, samples were generally only taken during the day which would not have accounted for the diurnal fluctuation or the range of values an organism truly experiences. Thus, determining if dissolved oxygen within the Long Point Region was limiting to aquatic organisms could not be accurately assessed with the 2002-2005 sampling regime and diurnal monitoring should be employed as part of future monitoring programs.

Super-saturation of dissolved gases can also be potentially hazardous to aquatic life. Within most of the five watersheds analysed gas saturation levels for dissolved oxygen (DO) have been reported as high as 140 percent. Super-saturation of gases within the water can lead to gas exchange problems in aquatic life such as blood gas trauma in fish (Fidler and Miller, 1994). However, there has yet to be a criteria set for the upper limit of DO for the protection of aquatic life.

The warming trend in summer water temperature values across several watersheds (e.g. Big Otter Creek, Big Creek and Lynn River) is of obvious concern to maintaining the current cool and cold water fisheries.

Many of the tributaries within the Long Point Region (e.g. Big Creek, Big Otter Creek) have been described as thermally stressed. However, there are watersheds within the Long Point Region that have temperatures and habitats suitable to continue supporting the present cold water fisheries (e.g. the Young Creek, Trout Creek and Kent Creek). Although it appears as though the duration of time during which summer temperatures are above the 19 °C threshold for cold water fish has been increasing over time within some of the cold water streams (e.g. Trout Creek).

The inherent geology and current landuse practices appear to be driving some of the chronic surface water quality issues within the Long Point Region. For example, watersheds draining the clay and till plains tend to have the highest non-filterable residue and nutrient concentrations (e.g. Big Otter Creek, and Nanticoke Creek). Several studies (McTavish, 1986; Wilcox, 2005) indicate that there is a strong relationship between land-use practices and surface water quality. Within the watersheds of the Long Point Region most of the land area is designated as agricultural of which a high percentage is row cropped & tile drained. Land-use of this type can result in waterways becoming enriched through runoff of fertilizers and erosion of soils. This relationship is apparent throughout the Long Point Region especially with respect to the elevated nutrient and non-filterable residue concentrations found.

The following is a brief summary of the major water quality issues within each of the six watersheds reviewed in this report.

Big Otter Creek Watershed

Nutrient levels, primarily nitrate and phosphorus, and non-filterable residue concentrations were found to be the major water quality issue within the Big Otter Creek watershed.

Land-use including intensive agricultural production, urban development, water pollution control plant effluents, the underlying geology and the topography within the Big Otter Creek watershed are all likely contributing to the degradation in water quality. The higher nitrate and organic nitrogen concentrations found within Spittler Creek are likely as a result of the intensive agriculture, namely fertilizer run-off and livestock stream access. Fausto & Finucan (1992) found that phosphorus loading within the Big Otter Creek watershed was mainly anthropogenically driven by fertilizers, household effluent, industry and improper milk-house wash water disposal.

Big Otter Creek has been identified as Canada’s largest source of sediment contamination to Lake Erie (Cridland, 1997). Big Otter Creek reacts to event flows extremely quickly and tends to be flashy (Stone, 1993) resulting in increased erosion and sedimentation as indicated by the wide range of values found downstream on BOC (3.0 mg/L - 367.25 mg/L). This phenomenon is also compounded by the soil type, lack of riparian vegetation and the deeply incised banks within the lower portion of the watershed. Other potential non-filterable residue contributions could be due to the upstream water pollution control plants at Norwich and Tillonsburg.

Bacterial concentrations have also been identified as an issue within the Big Otter Creek watershed. Regular beach postings within the watershed prompted the start of the Clean Up Rural Beaches (CURB) program in 1992. Since the implementation of the program bacterial counts have decreased, however, beach postings are still occurring at Port Burwell. It has been hypothesized that some of the bacteria found at the Port Burwell beaches may be originating from the high bacterial concentrations emptying into Lake Erie from Silver Creek in the Catfish Creek watershed (McCarron and McCoy, 1992).

Big Creek Watershed

Generally water quality was better within Trout Creek compared to other sites sampled within the Big Creek watershed. The upper Big Creek region was the most impaired with respect to nitrogen and chloride concentrations, but Venison Creek and lower Big Creek were the most impaired with respect to phosphorus and non-filterable residue concentrations.

The intensive agriculture and fertilizer application within the upper Big Creek watershed is likely responsible for the high nitrate concentrations as well (Figure 12). The relatively low nitrate concentrations found within the downstream tributaries (Trout Creek and Venison Creek) is likely having a positive impact on the water quality within lower Big Creek.

The higher phosphorus inputs found within the lower watershed are a reflection of the upstream cumulative inputs from the Delhi water pollution control plant, the intensive fertilizer application to crops within the watershed, as well as the higher non-filterable residue concentrations occurring in the lower portion of the watershed.

Compared to other watersheds within the Long Point Region Big Creek is not a major contributor of nutrients or non-filterable residue (NFR) to Lake Erie. Flow within Big Creek is partially regulated through several wetlands, reducing flow intensity and acting as a sediment sink thereby reducing the sediment concentrations reaching Lake Erie (Stone, 1993). Due to the wetlands and high degree of riparian cover the Big Creek watershed does not react as quickly to event flows compared to Big Otter Creek.

The Lehman Reservoir (used as a municipal drinking water source for the town of Delhi) is assumed to have fairly good water quality given the fish populations it can support and the quality of the upstream waters. Although water from the Lehman reservoir is tested for a suite of water quality parameters as part of the Ontario drinking water regulations, none of the sites used in our analysis of the Big Creek watershed were situated upstream of the Lehman reservoir to give an indication of the water quality feeding the reservoir.

Lynn River Watershed

Within the Lynn River watershed other tributaries, such as Kent Creek (a groundwater fed creek with minimal urban or agricultural impacts) have significantly better water quality than that found in the lower portion of the Lynn River.

Elevated levels of nitrite, ammonia and phosphorus were found to be the major water quality issues within the Lynn River. Rarely did samples taken on the Lynn River meet the Canadian guideline for nitrite or the PWQO for total phosphorus. High nitrite and unionized ammonia levels found within aquatic systems tend to be associated with organic pollution through the disposal of sewage or organic waste (Hem, 1985; Hydromantis Inc. et al., 2005). Within the Lynn River the high nitrite and unionized ammonia levels are likely a result of the Simcoe WPCP, which is directly upstream of the site sampled. Both unionized ammonia and nitrite are highly toxic to aquatic life which likely is having a negative effect on the fish populations present.

Although the Lynn River below Simcoe appears to have poor water quality, a brown trout fishery does exist within the Lynn River below Brook's Dam. The higher ammonia and nitrite concentrations are likely buffered by the continual groundwater recharge occurring in the river, inputs from other tributaries of better water quality (such as Kent Creek) and the reduced sedimentation occurring as a result of the dam.

Another concern with the high nutrient concentrations occurring within the Lynn River is its ability to continue assimilating effluent from the Simcoe Water Pollution Control Plant. Currently Norfolk County is carrying out an assimilative capacity study to better understand the impact the WPCP is having on the Lynn River (pers. comm. Bob Fields).

Black Creek, another major tributary to the Lynn River near the mouth, was not analysed as part of this study, but was evaluated as part of the state of the Lynn Watershed report. Gangon & Giles, (2004), found that the major water quality issues within Black Creek were high non-filterable residue, intermittent stream flow and low dissolved oxygen.

Nanticoke Creek Watershed

Generally, within the Nanticoke Creek watershed nutrient concentrations significantly increase as the creek flows out of the Norfolk Sandplain and into the Haldimand Clayplain. This increase within the upper portion of the watershed is likely as a result of the cumulative urban impact from the town of Waterford, the WPCP effluent and the transition in soil types within the contributing drainage area from sandy to clay based soils. The headwaters within the Norfolk Sand Plain tend to have better water quality compared to the rest of the creek which resides within the Haldimand Clay Plain (Van De Lande, 1987).

Total phosphorus and non-filterable residue (NFR) inputs are the most significant water quality issues within the Nanticoke Creek watershed and appeared to progressively increase from upstream to downstream (Figures 20 and 21). Although Nanticoke Creek was not historically considered a major contributor of nutrient concentrations to Lake Erie (Long Point Region Conservation Authority, 1979a), our analysis found that median NFR and phosphorus concentrations found near the mouth of Nanticoke Creek were higher than those found for any of the other tributaries evaluated within the Long Point Region. However, the Nanticoke Creek does not appear to be as event driven as Big Otter Creek whose maximum concentrations were much higher.

Dissolved oxygen levels have been found to decrease downstream of Waterford rendering the creek beyond this point unsuitable as cold water fish habitat (Van De Lande, 1987). G. Douglas Vallee Ltd. (2004) speculated that the low dissolved oxygen levels found in the summer were likely as a result of the effluent from the Waterford WPCP making up a substantial percentage of the summer base-flow. Norfolk County has since developed a contingency plan detailing the necessary monitoring and appropriate actions required to mitigate these impacts. Currently an assimilative capacity study is underway to help determine if an upgrade to the Waterford WPCP is required for Nanticoke creek to effectively assimilate its effluent (pers. comm. Bob Fields). Upgrades such as tertiary treatment, or the addition of sand filters and disinfectants could potentially help reduce the level of contaminants within the effluent thus improving the downstream water quality.

Sandusk Creek Watershed

Phosphorus and non-filterable residue levels are the primary water quality issues within the Sandusk Creek watershed, and tend to progressively increase from upstream to downstream. The entire Sandusk Creek watershed resides within the Haldimand Clay Plain which has a natural tendency for higher sedimentation and sediment associated nutrient concentrations, such as phosphorus. There are no natural retention areas within the Sandusk Creek watershed to help augment summer low flows (Morse et al., 1982). Therefore the Sandusk Creek watershed tends to be a 'flashy' system during rain events due to soil type (clay), lack of forest cover and the lack of infiltration capacity of the soils (LPRCA, 1979b). However, given the relatively low flows found within this watershed, it is only considered to be a moderate contributor of nitrate and phosphorus to Lake Erie (LPRCA, 1979b).

Dedrick-Young Creek Watershed

Water quality within the Dedrick Creek and Young Creek watersheds tends to be fairly good and those streams within the Norfolk Sand Plain, such as Young Creek, have been identified as a biologically significant salmonid cold water stream habitat (LPRCA 1979; Bernier & Reynolds 1976). Young Creek tends to be of better water quality compared to Dedrick Creek, which is likely due to the numerous springs along Young Creek that continually recharge, cool and dilute the water (Van de Lande 1987).

The Port Rowan drinking water intake and Water Pollution Control Plant (WPCP) both take and discharge within the same general area in Lake Erie. This is of potential concern for the raw water quality used by the drinking water treatment plant. Norfolk County routinely monitors the raw water quality used to supply the Port Rowan drinking water treatment. Bacterial samples are taken weekly; nitrate, nitrite and THM are sampled for quarterly and a full chemical analysis is done yearly. Norfolk County has also recognized the potential issues related to having a discharge and intake within the same general vicinity and thus have implemented safeguards to reduce the impact on the water quality (pers. comm. Bob Fields). Future raw water analyses at the location of the Port Rowan drinking water treatment plant intake should be performed to ensure the WPCP effluent is not having a negative impact..

Very little information exists on the major reservoirs within the watersheds of the Long Point Region. Historic monitoring data suggests that the Norwich, Little Lake and Sutton reservoirs are eutrophic with very high phosphorus levels in the euphotic zone while the Deer, Waterford and Lehman reservoirs are meso-eutrophic with low to moderate phosphorus levels. The Lehman Reservoir is also used as the municipal drinking water source for the town of Delhi. Although water from the Lehman reservoir is reported to be fairly good and is tested for a suite of water quality parameters as part of the Ontario drinking water regulations, the LPRCA has only recently started monitoring within the tributaries upstream of the Lehman reservoir to give an indication of the water quality feeding this reservoir.

Very little water quality information exists for the other watersheds within the Long Point Region. However, it is generally thought that their nutrient or NFR contributions to Lake Erie are minimal and given that there are no surface drinking water sources or recreational areas within these watersheds, they have not been considered a priority for monitoring.

Spills and water pollution control plant bypasses are a significant threat to downstream water users in the watersheds of the Long Point Region. They represent an acute and immediate impairment to water quality that can compromise recreational uses at public beaches. Therefore, it may be of use to have an effective spills response protocol to mitigate a timely response and notification of downstream users.

The Preliminary trend assessment yielded variable results with respect to whether nutrient levels are decreasing or increasing over time. Generally, at any site across the entire Long Point Region where a discernable trend was evident, nitrate concentrations appeared to be slightly increasing where as phosphorus and NFR appear to be decreasing or staying the same. Nitrite and ammonia concentrations have been dramatically increasing over time just below the Simcoe Water Pollution Control Plant in the Lynn River. However, the most apparent change in water quality overtime has been the increase in chloride levels found at most sites. This is likely as a direct result of an increase in road-salt application. Although, levels across the Long Point Region are still low relative to the Environment Canada benchmark. Re-assessing these trends in the future as more current data becomes available would be helpful in identifying if new trends are emerging. Measures such as improved wastewater treatment, road salt management strategies and targeted implementation of agricultural beneficial management practices are needed to curb these increasing trends.

The primary recommendations from this report include: an increase in the number of samples taken at each of the PWQMN monitoring sites in order to improve statistical analysis; continue sampling at the current Source Water Protection (SWP) monitoring stations to ensure adequate spatial cover of the watershed; incorporation of diurnal and high flow monitoring in order to better assess the total range of conditions; conduct future investigations into the water quality conditions of major reservoirs to build on existing baseline information; promote outreach programs to facilitate rehabilitation of impaired cold water watersheds; conduct future investigations into the connection between local soil conditions and ambient water quality to determine realistic water quality goals; and continue monitoring water temperatures in critical cool and cold water streams.

The analysis of physiochemical water quality data in this report is intended to be used as a benchmark against which future information can be compared. This will allow for the determination of whether water quality within the watershed is improving, degrading, or remaining the same. Similar reports are expected to be compiled at five year intervals as consecutive years of data are obtained

INTRODUCTION

There are approximately 14 watersheds within the Long Point Region Conservation Authority's jurisdiction. The total population of this region is estimated at 102,000 people of which the majority are located within the towns of Norwich, Tillsonburg, Port Burwell, Delhi, Port Rowan, Simcoe, Port Dover, Waterford, Jarvis and Hagersville. The tributaries and reservoirs within the Long Point Region support a variety of uses such as habitat for aquatic life, recreational use, agricultural irrigation, livestock watering, waste assimilation and drinking water (taken from the Delhi Reservoir). Population forecasts have predicted there will be an average 0.95% annual growth for Long Point Region over the next 20-30 years, most of which will occur in Tillsonburg, Simcoe and Norwich. As the pressure on the waterways increases and the already highly agricultural and urbanized areas intensify, there is the potential for the quality of the water within the watershed to decrease if proper precautionary and management measures are not implemented. These concerns along with the current water quality issues within this region highlight the need for baseline and continuous water quality assessment.

It is not only important to monitor water quality, but also to document and report on it so issues can be identified and actions can be recommended to improve the state of the waterways. Within Ontario the Provincial Water Quality Monitoring Network (PWQMN) provides an invaluable source of data and is the primary dataset employed by this report to determine the ambient water quality within the Long Point Region. Therefore, much of this report will focus on characterizing nutrients, non-filterable residue, metals, major ions, and bacteria at the long-term monitoring sites within the watersheds of the Long Point Region.

The purpose of this report is to characterize the chemical and physical aspects of surface water quality and identify the water quality issues which affect Long Point Region through the analysis of historical data and a review of existing literature

Watershed Characteristics

The Long Point Region is located along the north shore of Lake Erie and is bordered by the Catfish Creek Conservation Authority to the west and the Grand River Conservation Authority to the east. The major communities within the region include Port Burwell in Elgin County; Norwich and Tillsonburg in Oxford County; Delhi, Waterford, Simcoe and Port Dover in Norfolk County; and Jarvis and Hagersville in Haldimand County.

For the purposes of this study the Long-Point Region was grouped into nine major watersheds (Figure 1), whose general characteristics are summarized in Appendix A and within the results and discussion section of this report. The following is a brief description of the major characteristics at the regional scale.

The nine major watersheds within the Long-Point Region drain an area of approximately 2,900 km2. The surface elevation ranges from 357 masl in the northwest (west of Norwich), to 173 masl in the southeastern limits of the study area along the Lake Erie shoreline.

There are three distinct physiographic regions within the Long Point Region; the Horseshoe Moraine to along the northwest boundary, the Norfolk Sand Plain within the middle of the region, and the Haldimand Clay Plain within the remainder of the region east of Waterford and Simcoe (Figure 2) (Chapman and Putnam 1984).

Those watersheds within the western portion of the Long Point Region (e.g. Big Otter, Big and Dedrick-Young Creek) contain cold-water fisheries, and a higher number of permits to take water. The Long Point Region Conservation Authority (LPRCA) has among the highest number of surface and ground water takers of any area in southern Ontario.

Land-use in the watershed is primarily agriculture with 20% classified as forest, which is primarily found with the southern portion of the Long Point Region (Figure 3). Forest cover is high within the sand-plain with the highest percentage found within the Dedrich-Young Creek Watershed. The type of agricultural activity present is dependent on the soil and climate conditions within the area. Within the Haldimand Clay Plain, livestock operations and general cash crops (corn, soybeans) are the dominant form of agriculture, whereas within the Norfolk Sand Plain specialty crops (tobacco, ginseng, vegetables and some fruits and nursery crops). These high value specialty crops require very careful management and supplemental water from irrigation at times of moisture stress due to the lack of water retention found within sandy soils.

There are several reservoirs found throughout the region that are used for recreational purposes (e.g. Norwich, Lehman, Backus, Vittoria, Hay Creek, Deer Creek Reservoirs, and the Waterford ponds). However, only the Norwich and Teeterville Reservoirs are also used for both recreation and flood control (Figure 4). There are also several dams across the Long Point Region of which only a select few are illustrated in Figure 4.

Nearly two-thirds of the people residing in the Long-Point Region rely on municipally-operated water supply for their drinking water and other water needs. Of the more than 60,000 residents on municipal water supply, approximately 75 per cent rely on groundwater resources, with the balance serviced by a surface water supply, most of which (6 out of the 7) are located within Lake Erie (Figure 5). The remaining residents throughout the region rely on private wells or private intakes from Lake Erie for their drinking water supply.

There are 11 wastewater treatment facilities servicing municipal populations, which service approximately 60% of the Region's population (Figure 6). The remaining 40% are serviced by on-site wastewater treatment systems (e.g. septic systems). There are also likely other wastewater treatment facilities servicing industrial areas within the Long Point Region (e.g. Nanticoke Industrial Park); however a comprehensive inventory of these does not currently exist.

A combination of the land-use, intrinsic geology and anthropogenic sources (e.g. water pollution control plants, agricultural runoff) all contribute to the water quality issues present in the watersheds of the Long Point Region.

Major Water Uses

Water quality is generally evaluated according to the primary use of the water body. Some of the common designated uses within a watershed include drinking water supplies, habitat for aquatic life, industrial/commercial uses, agricultural uses and contact or non-contact recreational uses.

The tributaries within the Long point region watersheds are primarily used for agricultural irrigation, recreational fishing, waste assimilation and supporting a variety of aquatic habitats including cold-water fisheries within the western watersheds. Although aquatic recreation does occur within the Region, it is limited to the reservoirs and the Lake Erie shoreline and therefore, is not seen as a primary use throughout. Water quality is generally evaluated with respect to provincial objectives, Canadian guidelines, or other criteria for a particular water use. Since there are no such criteria for waste assimilation, evaluation of water quality will be against criteria for the protection of aquatic life.

It is also important to point out that while there is only one surface drinking water intake within the Long-Point Region (Delhi), most of the region's drinking water is taken from Lake Erie into which the nine watersheds of the region drain. Therefore, it is important to evaluate the influence each watershed's water quality may have on Lake Erie.

Figure 1. Long point region watershed characteristics illustrating location of the major urban centres, streams & the 9 major watersheds reported on in this report.

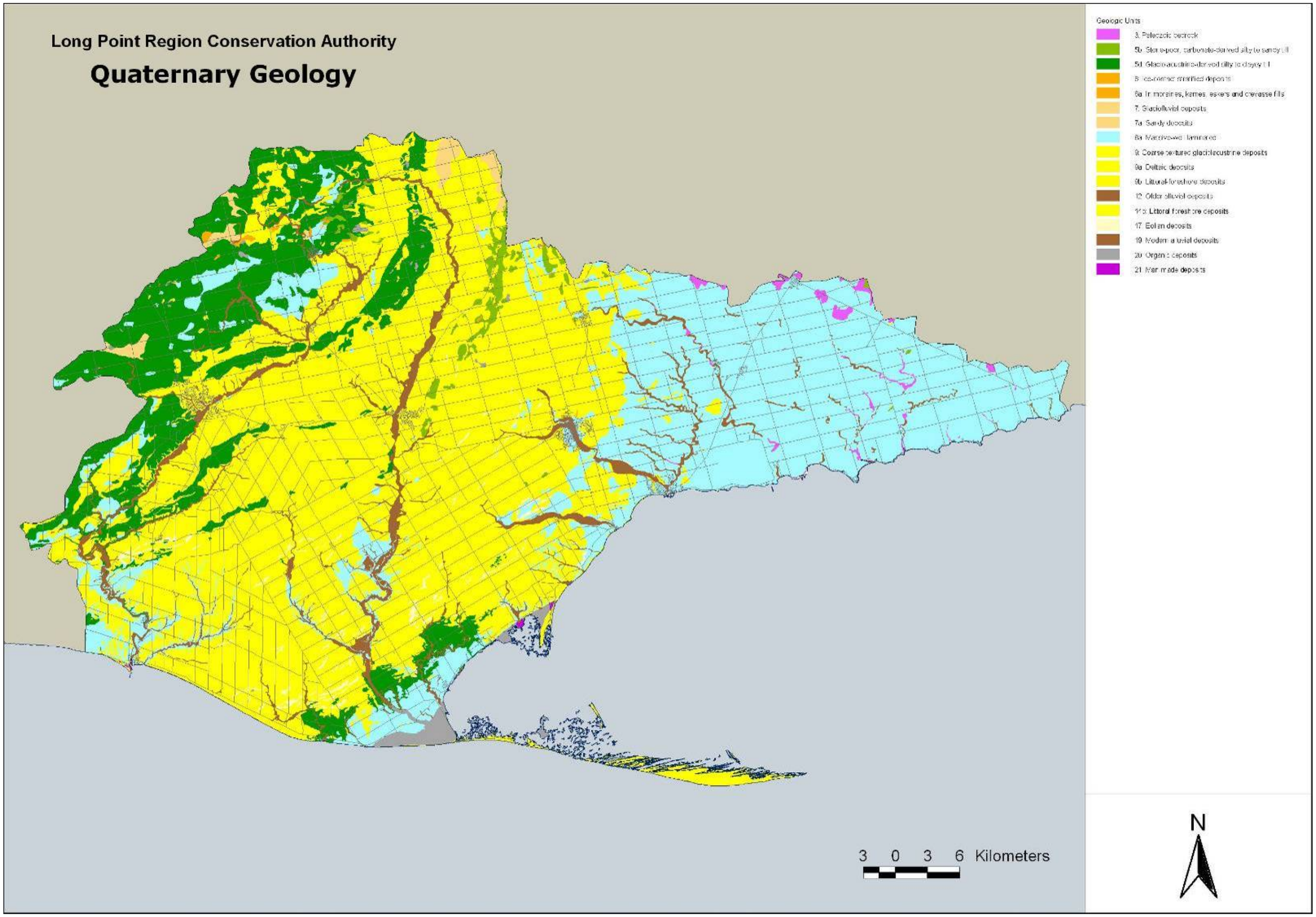


Figure 2. Surficial Geology of the Long point region Watershed

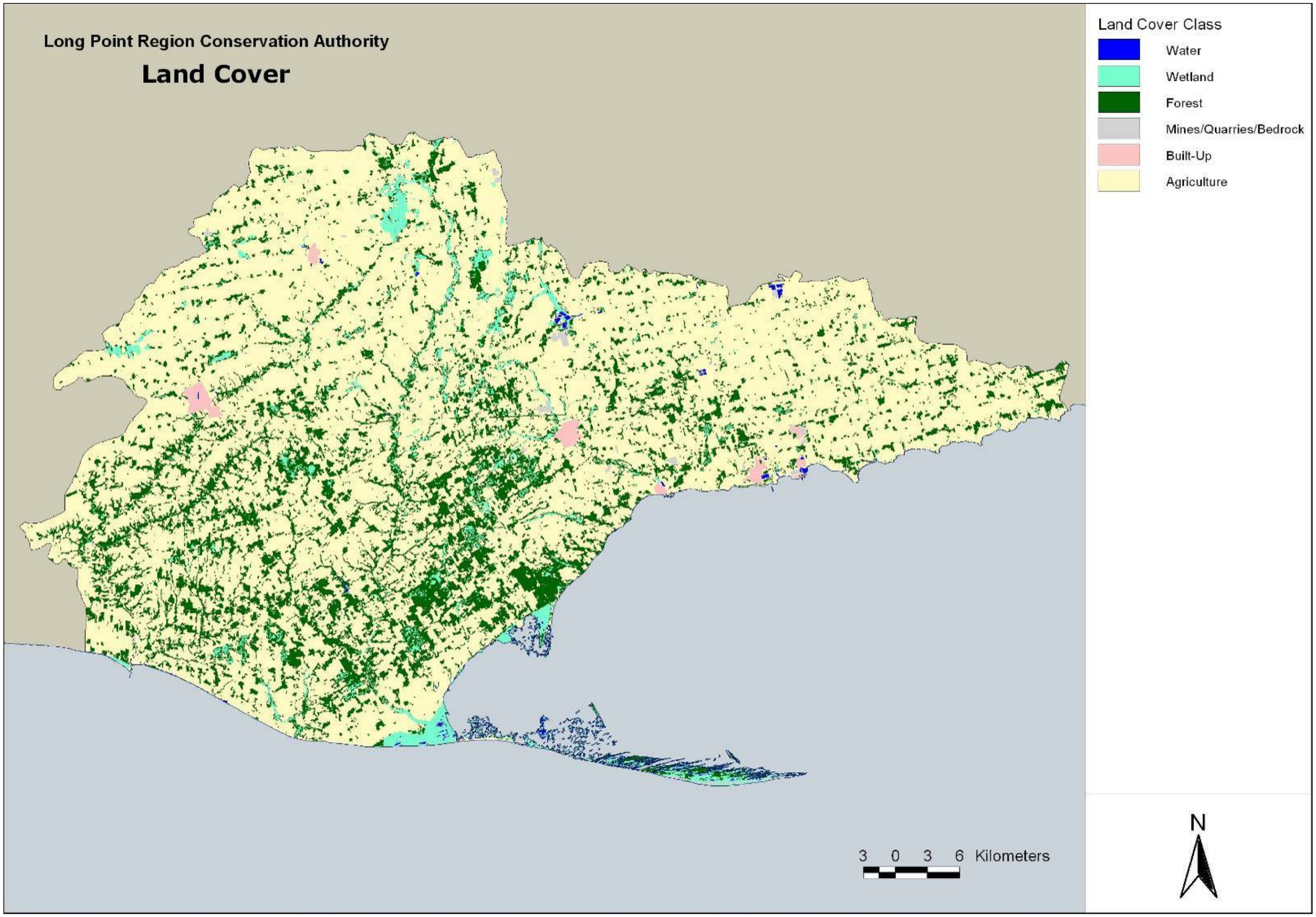


Figure 3. Land cover in the Long point region watershed

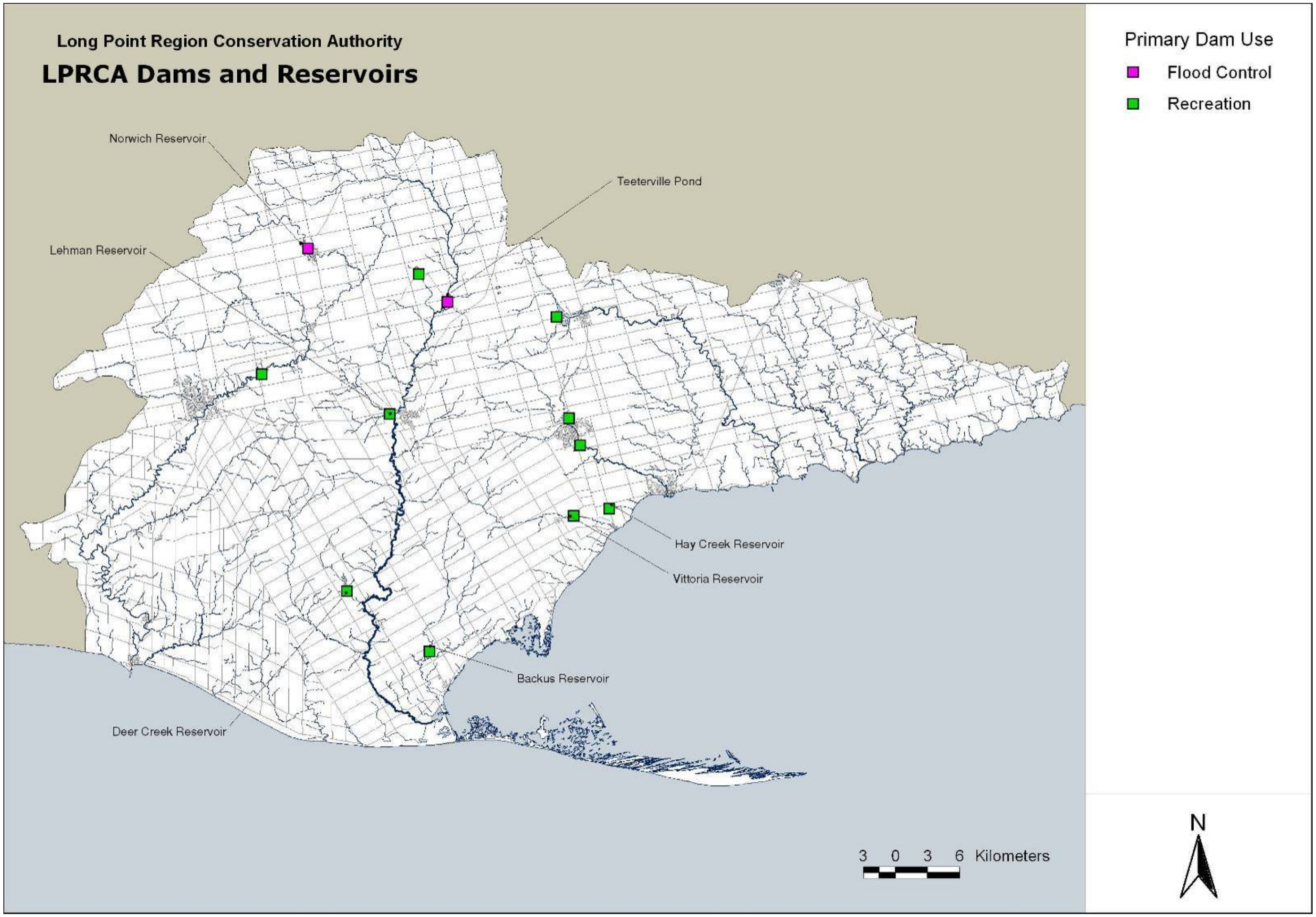


Figure 4. Map illustrating the location of the major reservoirs within the Long-Point Region.

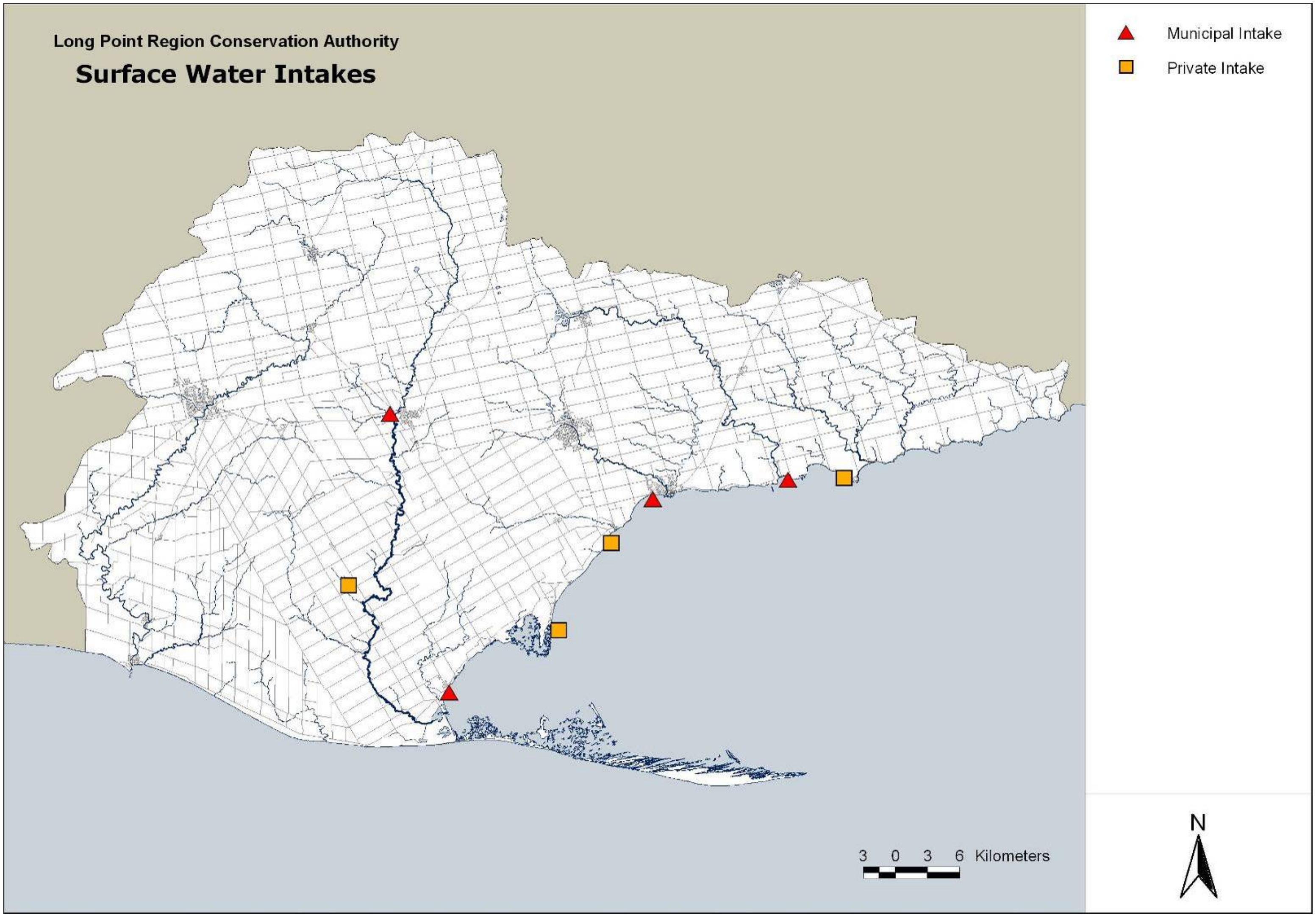


Figure 5. Map illustrating the location of the surface drinking water intakes servicing communities within the Long-Point Region

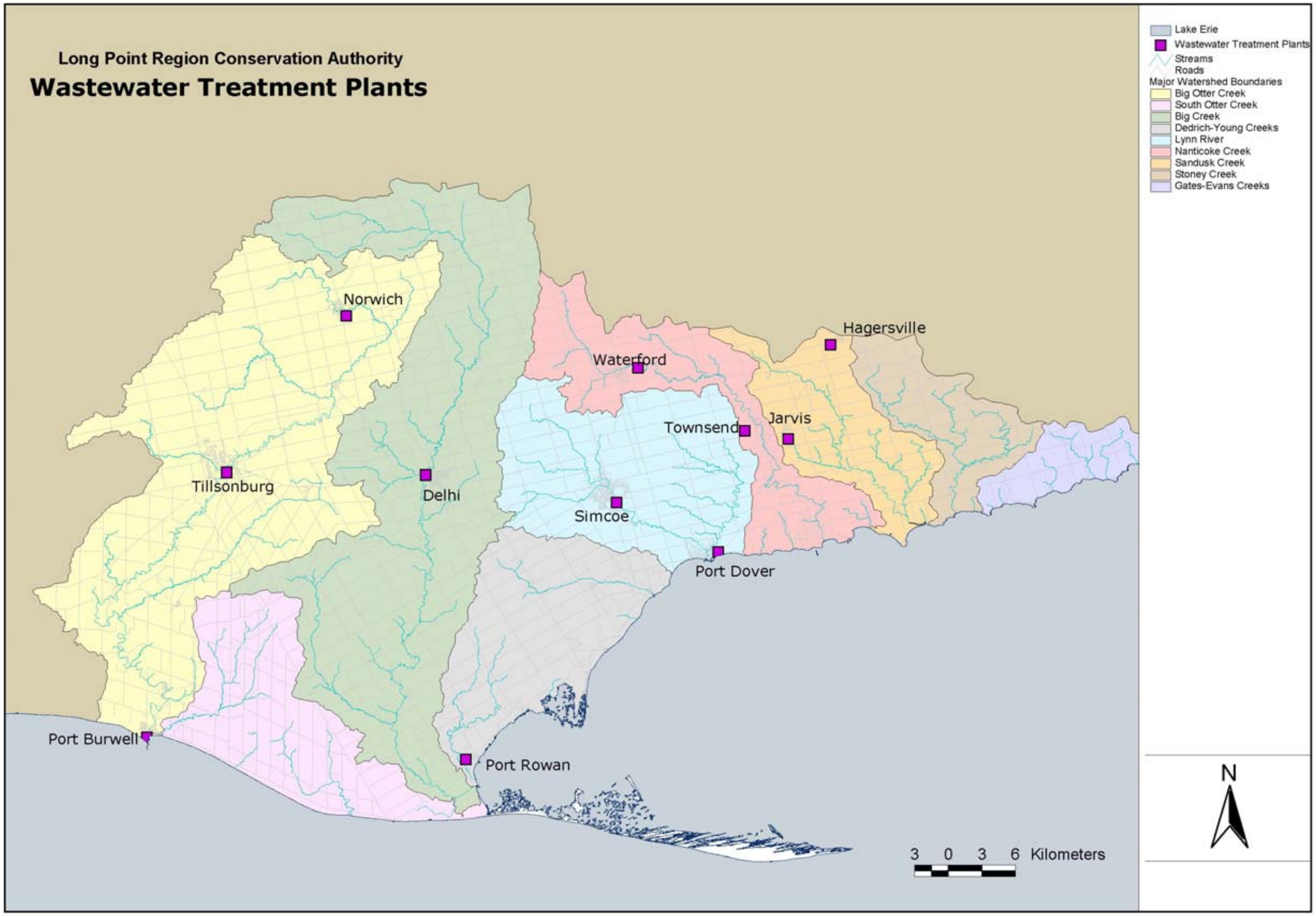


Figure 6. Location of the wastewater treatment facilities within the Long-Point Region

METHODS

Dataset Selection

Surface water quality monitoring has historically focused on characterizing the chemical and physical attributes of the creeks and rivers within a watershed. The Provincial Water Quality Monitoring Network (PWQMN) is an important long term monitoring program for Ontario which facilitates the characterization of the chemical and physical aspects of water quality. However, financial cutbacks by the province over the last decade, along with limited capacity at Conservation Authorities, have resulted in a decrease in the number of sites monitored and the frequency at which they are sampled.

As part of the partnership in the PWQMN program the Ontario Ministry of the Environment (MOE) is responsible for the laboratory analysis while the Conservation Authorities are responsible for collecting the samples. There were 53 historic monitoring sites in the Long Point Region that at some point was part of the provincial network. Appendix B describes the location of the active and inactive PWQMN sampling sites and the period for which samples were taken at each site.

In the Long Point Region, the number of active monitoring sites fell from a high of 25 in 1975 to a low of zero from 1996 to 2000. In 1996 when the MOE cut funding to the PWQMN program, the Long Pont Region Conservation Authority (LPRCA) did not have the internal capacity to continue monitoring on its own leaving a six year data gap for watershed wide sampling from 1996 to 2000. In 2000 and 2001 the LPRCA sporadically sampled at 5 sites within the region. However, starting in 2002 when the MOE started re-building the PWQMN the Long Point Region Conservation Authority reinstated a condensed version of their historical network which is still currently monitored.

The number of annual samples taken per site has also declined over the years. Under the PWQMN program the MOE is responsible for the laboratory analysis while LPRCA is responsible for collecting the samples. Currently the MOE allows for eight samples per year to be taken at each of the PWQMN sites; however, historically a total of 12 samples per year were taken at each of the sites.

Considering this data gap, to provide a benchmark indicative of the current water quality conditions found within the Long Point Region, our analysis investigated the most recent four year contiguous set of data, 2002-2005, for which 10 monitoring sites could be evaluated (Figure 7). Summarizing the most recent contiguous four years of data helps to increase the likelihood of characterizing the full range of flow and climatic conditions. This approach also reduces the strong year-to-year variability from extremes in climate (e.g. wet and dry periods). Although this dataset provides an initial coverage across the Long Point Region there are some significant gaps. Therefore, to address these spatial gaps across the region, additional analyses were performed using historical 5 year data sets (e.g. Nanticoke Creek and Sandusk Creek watersheds) and where no PWQMN data was available, a review of existing literature was performed to provide comment on the potential conditions and trends within those watersheds (e.g. South Otter Creek, Stoney Creek and Gates-Evans Creek watersheds). This resulted in the analysis of 17 PWQMN sites across the Long Point Region within this report.

To provide a preliminary assessment of water quality trends across the region, the entire dataset (historical to current) for each of the 17 sites was also assessed for preliminary long-term temporal trends where possible.

Parameters Analysed

Routine Chemistry, Nutrients, Metals and Pesticides

Water quality samples were analyzed for routine chemistry, nutrients and metals (Table 1). For more information on laboratory methods and detection limits refer to MOE (1994) and Appendix C. Water samples were collected using standard sampling procedures depending on access type. Sites with easy access were sampled directly from the stream with the sample bottle upstream of where they were standing. Sites with bank access were sampled from the shore with a stainless steel bucket attached to an extension rod. Finally, sites with only bridge access were sampled by lowering a stainless steel pail from the bridge into stream. Sample bottles were rinsed three times on site with the sample water prior to filling. Samples were preserved if necessary, stored on ice and couriered to the MOE laboratory.

Pesticides were only sporadically monitored for at a few sites across the Long Point Region. These samples were also collected using the procedure previously described. However, due to the sporadic nature of the data and the limited spatial coverage within each watershed no data analysis was performed. A summary of known issues related to pesticides has been provided in the discussion section of this report.

Dissolved oxygen, conductivity, pH and temperature were monitored in the field at the time of sample collection using an YSI data sonde. Temperature was also additionally monitored throughout the Long Point Region using temperature loggers, which recorded on an hourly basis. Only data from the temperature loggers deployed at the PWQMN sites was analysed in this report.

Table 1. List of water quality variables analyzed in PWQMN stream/river samples.

Water Quality Variable Category	Water Quality Variables
Nutrients	Dissolved Nutrients: ammonia, nitrate, nitrite; phosphate Total Nutrients: Total phosphorus, Total Kjeldahl nitrogen
Solids	Non-filterable residue; Total dissolved solids
Major Ions/Anions	Calcium; Magnesium, Sodium, Potassium; Hardness; Chloride
Routine Chemistry	pH; Alkalinity; Conductivity
Metals	Aluminum; Barium, Beryllium; Cadmium; Chromium, Copper; Iron; Manganese; Molybdenum; Nickel; Lead; Strontium; Titanium; Vanadium; Zinc
Routine Physical	Turbidity; Temperature

Figure 7. Location of the 10 sites sampled from 2002-2005 within the Provincial Water Quality Monitoring Network that were analysed in this study.

Bacteria and Pathogens

Fecal coliforms were once thought to originate exclusively from fecal sources; however, evidence has shown that many types of bacteria in this group can originate from the environment. As a result this group is not the preferred indicator of fecal contamination. *E. coli* is the best indicator of recent fecal contamination in surface water and groundwater (Doyle & Erickson, 2006). Therefore we will only comment on the characteristics of the Ecoli data monitored for within the Long Point Region.

Generally samples for bacteria or pathogens were not routinely collected as part of the long-term PWQMN monitoring program. However, in 2002 the Ministry of Health (MOH) partnered with LPRCA to do additional sampling of *E. Coli* at their PWQMN sites. Considering the historic and sporadic nature of the PWQMN bacterial data, only the MOH data will be presented in this report. Other projects apart from the MOH and PWQMN programs have also investigated the presence of bacteria and/or pathogens within the watersheds of the Long Point Region (e.g. Fausto & Finucan, 1992; Stone, 1993). Relevant results from these investigations will be referred to in the discussion of this report in an attempt to fill in gaps and further substantiate results from our analysis.

Benthic Macroinvertebrates

Historically, no routine monitoring of the benthic macroinvertebrate assemblages within the Long Point Region has been performed. However, in 2002 LPRCA started sampling benthics throughout the Long-Point Region as part of the Ontario Benthos Biomonitoring Network (OBBN). In addition, in 2004 as part of the state of the watershed project, intensive benthic surveys were preformed throughout the Lynn River and Black Creek watersheds (Gagnon & Giles, 2004). The summary of this report will elaborate on the results of these analyses as they relate to water quality within the Long-Point Region.

Reservoirs

Historically, no routine monitoring of the major reservoirs within the Long Point Region has been carried out. However, historical watershed studies have commented on the general characteristics of some reservoirs, which will be discussed in the later sections of this report.

Data Analysis

<u>Streamflow</u>

Streamflow was analyzed to help characterize the study period since water quality in rivers is strongly influenced by the amount and timing of rainfall and snowmelt. There are eight gauge stations located within the watersheds of the Long Point Region (Figure 9). Data from these stations were provided by the Water Survey of Canada (Environment Canada, http://www.wsc.ec.gc.ca/). Recently two stations were re-activated within the Long Point Region. The first station is situated on Venison Creek near the confluence with Big Creek and the second on Big Creek near Kelvin. However, data for these stations were limited and so were not analysed in this report.

At the time of this analysis, the Water Survey of Canada had not released data for the 2004 and 2005 years. Therefore, the historical long-term average annual flow was calculated and compared with the annual average flows for each year from 2000-2003. This comparison indicated whether stream levels were rising or falling signifying a wetter or dryer period than normal.

The strength of the relationship between water quality parameters and streamflow was investigated using the non parametric Kendall Correlation Coefficient (Kendall tau statistic).

<u>Summary Statistics</u>

Box and whisker plots were used to present the data graphically. Box and whisker plots can illustrate the distribution and statistics of a dataset. The box in the box-whisker plot shows the 25th and 75th percentiles of the dataset, called the lower and upper quartiles, and the median (50th percentile) (Figure 8). The whiskers represent the range of the data set to the 90th and 10th percentiles (Sigma Plot 8.0 2002). The circles illustrate outliers beyond the 10th and 90th percentiles (values more than 2 standard deviations from the mean).

A summary of the descriptive statistics, (including the minimum, maximum, mean, and median values), for each water quality parameter analyzed from the 1991-1995 dataset are included in Appendix D.

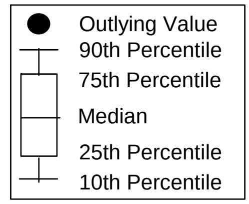


Figure 8. Box and whisker plot illustrating the 5th 25th, 50th (median) 75th and 95th percentiles and outliers of the 2002-2005 dataset.

Figure 9. Location of flow stations currently monitored by the Water Survey of Canada within the watersheds of the Long Point Region.

Comparative Statistics

Statistical methods for detecting spatial and temporal changes in water quality have greatly improved throughout the years (Hirsch, R.M et al 1991). Nonparametric statistical methods can accommodate data that are not normally distributed, have missing data, and are robust against outliers (Hrynkiw et al 2003). These characteristics are typical of water quality data (Trkulja 1997).

Nonparametric regression analyses were carried out, using the Mann-Whitney (differences between two groups) or Kruskal-Wallis tests (differences between more than two groups), to identify differences between PWQMN sites for each water quality parameter (e.g. nutrients, non-filterable residue and chloride) (Analyse-it Software, 2003). Sites were considered to be significantly different if the *p* value resulting from a test was < 0.05 (i.e. 5% significance level). However, it is cautioned that finding a statistically significant result does not necessarily imply that one has found an environmentally significant result (Griffith et al 2001; Trkulja 1997). Results from these analyses can be found in Appendix E.

Compliance with Guidelines

Provincial Water Quality Objectives (PWQO), Federal Guidelines and other relevant criteria were used to evaluate whether stream water quality within the region was meeting the specified levels for protection of aquatic life (Table 2). The level of compliance was determined at each site for each water quality parameter by calculating the percentage or frequency of samples above the objective, guideline or criteria for the data collected between 2002 and 2005. For presentation purposes and relative comparison of compliance levels between sites, results of this analysis were subsequently classed into 5 percentage groups (0%, 1-25%, 26-50%, 51-75%, 76-100%) and each group was assigned a representative colour. Actual values for the percentage of samples above the objective, guideline or criteria for each water quality parameter measured can be found in Appendix F. Results for each sampling site were then graphically represented on maps of the watershed region as coloured dots corresponding to the percentage group previously mentioned. These maps along with similar maps representing the 75th percentile value at each site for each parameter were developed to be used as communication tools for illustrating where the areas for improvement likely are (actual 75th percentile values can be found in Appendix H).

Preliminary Trend analysis (LOWESS)

Although sampling frequency has fluctuated over the years, the long term nature of the PWQMN warrants the evaluation of long term monotonic trends to determine whether conditions are improving or deteriorating. Furthermore, this is one of the objectives of the network (A. Todd, pers. Communication).

Time series plots were created for each parameter at each of the PWQMN sites analysed for the entire sampling period of record. A LOWESS (LOcally WEighted Scatterplot Smoothing) smoothing algorithm was then applied, to visually inspect the data for potential temporal variability and preliminary trends. However, the results from the LOWESS analysis do not represent a statistical trend analysis and as such are only considered preliminary. With the aforementioned sampling frequency and timing there is the potential for these trend estimates to be incorrect. Trkulja (1997) suggested that trend estimates based on monthly sampling are less reliable than estimates based on daily and weekly sampling schemes. Consequently, more detailed analyses are required to accurately evaluate statistical trends.

Temperature was analysed for trends over time through visual inspection of the time series plots created using the daily maximum temperatures captured by the data loggers. Considering increasing summer temperatures is a concern within the tributaries across the Region, especially those which support good fisheries, we also looked at histogram plots of the daily max summer temperatures from year to year. This allowed us to identify if the was an increasing or decreasing trend number of days temperatures were above a particular threshold (we chose to use 24°C , the upper limit for cold water fish species (Coker et al., 2001) was increasing or decreasing from year to year.

Table 2. Water quality parameters and corresponding Federal Guideline or Provincial Objective.

Water Quality Parameters	Objective or Criteria Used	Jurisdiction
Nitrate	2.93 mg/L	Canadian Environmental Quality Guidelines
Nitrite	0.06 mg/L	Canadian Environmental Quality Guidelines
Total Ammonia	pH and temperature dependant	Ontario Ministry of the Environment
Total Phosphorus	0.030 mg/L	Ontario Ministry of Environment
Non-filterable residue	25.0 mg/L	General criteria[2]
Chloride	250 mg/L	Benchmark identified in Environment Canada report[1]; Drinking Water Quality Guideline
pH	6.5- 8.5	Ontario Ministry of Environment
Dissolved Oxygen	Temperature dependant	Ontario Ministry of Environment
Temperature	Natural thermal regime shall not be altered	Ontario Ministry of Environment

1. Environment Canada. 2001. Priority Substances List Assessment Report: Road Salt. Environment Canada, Health Canada, Ottawa, Ontario, 165p.

2. The Canadian Guideline for NFR or suspended solids for aquatic health involves comparison with background levels (NFR should not exceed 25 mg/L above background for short periods or 5 mg/L above background for long periods, CCME 1999) which in a heavily impacted region such as Long Point is difficult to assess. Therefore, to provide some level of comparison from which to gauge the concentrations found across the Long Point Region, we will use 25 mg/L as a benchmark.

RESULTS AND DISCUSSION

Data Caveats

Sampling Frequency

Historic sampling occurred on a routine basis whereby flow in the stream was not always considered. This is evident when dates of sampling events are graphed against stream flow (Figure 10). Generally, sampling in the past was performed across the range of flow events; however, peak events were missed for some years. This was likely a result of limited manpower and logistical challenges associated with sampling high flow events. However, as part of LPRCA's new water quality monitoring program, efforts have been made to characterize the full range of flow events.

This potential bias towards sampling at low flows and the fact that the results presented here were not corrected for flow should be taken into account when interpreting the data.

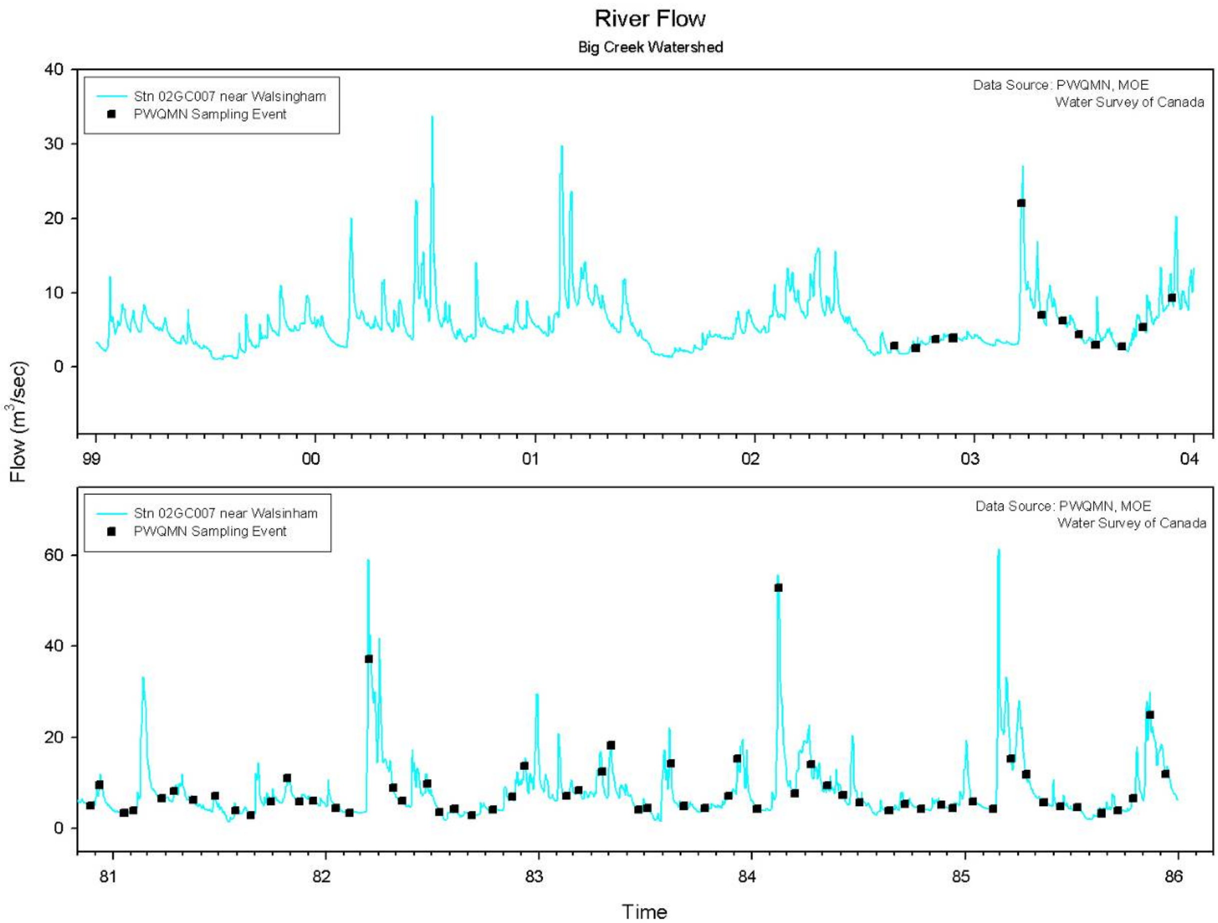


Figure 10. Daily stream flow rates at three locations within the Big Otter Creek watershed plotted with the time of sampling events.

Nutrient Data

Upon first inspection of the nutrient, non-filterable residue, and major ion data, for all of the PWQMN sites within the Long-Point Region, there appeared to be several outliers (data more than 2 standard deviations from the mean as evident from a visual inspection of the box and whisker plots shown in each of the watersheds discussed below). To account for this characteristic of the data when describing the spread of the data, the 95th and 5th percentiles from each PWQMN site will be used (Appendix D). Actual min and max values can also be found in the descriptive statistics table in Appendix D.

Metals Data

Metals data were not fully analyzed in this report due to concerns with historical laboratory detection methods. In 1997 the Ministry of the Environment replaced the historical method for detecting metals in surface water, MET33386 with MET3080. This change replaced the digestion step with an ultrasonic nebulizer to reduce contamination problems previously found (Rusty Moody at MOE personal communication).

Pesticide Data

Pesticide sampling only occurred within three of the Long-Point Region watersheds, Big Otter Creek, Big Creek and the Lynn River. The most extensively monitored area was site 16010900502 on Big Otter Creek near the mouth, which was monitored from 1981-1995. Big Creek had sporadic sampling done during the 1970's while Lynn River had sampling done in the 1970's and on one occasion in the summer of 2002 as part of the Lynn River State of the Watershed Report. Given the historic and sporadic nature of the data collected as part of the PWQMN program no analysis was done as part of this report.

Dissolved Oxygen Data

Dissolved oxygen (DO) levels during the period from 2002-2005 were observed below the critical 4 mg/L threshold for cold water biota at all sites once on Aug 15, 2002. Given that all sites had readings ranging from 2.03-2.78 on the same day but remaining samples throughout the 2002-2005 sampling period never dipped below 6mg/L, is likely an indication that there was a problem with the instrumentation (YSI). This data was believed to be in error and as such was removed from the analysis.

Bacteria and Pathogen Data

Given the inherent variability in sampling and analyzing bacteria in surface waters, we felt that no statistical analyses could be carried out and have only commented on the general characteristics of the bacterial data.

Water Quality Conditions in the Long Point Region

Generally, water quality conditions are described according to chemical and physical characteristics of the stream water. However, biological indicators such as benthic macroinvertebrates and fish species should also be used, in conjunction with chemical and physical characteristics, to further describe the overall health of a watershed. Currently LPRCA monitors at 10 locations for both physiochemical and biological parameters throughout 6 of the watersheds across the region. The physiochemical sampling is carried out as part of the Provincial Water Quality Monitoring Network (PWQMN), benthic monitoring is carried out through the Ontario Benthic Biomonitoring Network and *E.Coli* monitoring is done in partnership with the Local Health Unit. Temperature has been monitored throughout the watershed since 2002, using a series of temperature loggers to determine if temperatures are on the rise within critical areas (e.g. cold water fish habitat).

Throughout subsequent sections of this report, to facilitate the description of results each PWQMN site will be referred to by its truncated PWQMN site name (see Appendix B).

Big Otter Creek Watershed

The Big Otter Creek watershed makes up the western boundary of the Long Point Region and is approximately 712 km^2 in area. Beginning in the north just east of the town of Norwich the Big Otter Creek travels approximately 42 km south towards Port Burwell where it empties into Lake Erie (Figure 11). The topography of this watershed is fairly flat to the north but the creek becomes deeply incised as it travels through the southern portion of the watershed.

The Big Otter Creek watershed drains two main physiographic regions; the Horseshoe Moraine region, along the north and western boundaries, and the Norfolk Sand Plain region across the eastern boundary (Figure 2).

Land-use within the area is primarily agriculture, comprising mainly of cash crop and livestock within the till plain (north and west) and tobacco and ginseng in the sand plain (east and south). The lower portion of the watershed is less agriculturally intense and has fewer livestock operations compared with the upper reaches. There are also three major urban areas within the watershed, Norwich, Tillsonburg and Port Burwell all of which have their own municipal water pollution control plants (WPCP). However, given the close proximity of Port Burwell to Lake Erie, the effects of this town are felt by Lake Erie and not Big Otter Creek. The Port Burwell WPCP also services the smaller towns of Vienna and Stratfordville.

There were three sites sampled as part of the PWQMN program within the Big Otter Creek watershed during the 2002-2005 sampling season (Figure 11). The information from these sites allowed for upstream / downstream comparisons along Big Otter Creek, characterization of the urban influence the village of Norwich has on upper Big Otter Creek, the potential influence Spittler Creek, (a major tributary), has on the water quality found in lower Big Otter Creek and finally the potential contaminant contributions Big Otter Creek may be emptying into Lake Erie.

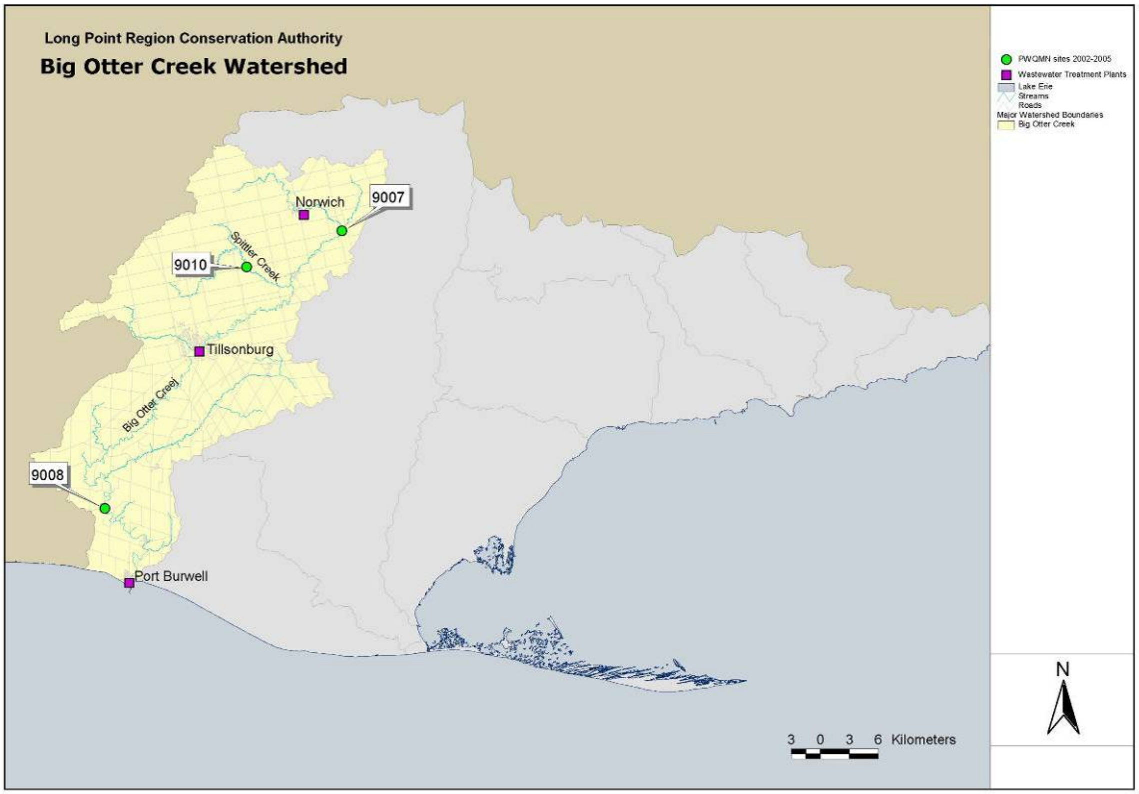


Figure 11. Big Otter Creek watershed illustrating the location of the major urban areas, the water pollution control plants, and the PWQMN sites sampled from 2002-2005.

Physical Conditions

Streamflow

The Big Otter Creek watershed has the highest flows relative to the other watersheds within the region that were gauged. Most of the predominant flow originates in the sand plain and those tributaries in the Horseshoe moraine (clayey till) usually dry up during the summer months. Big Otter Creek reacts to event flows extremely quickly and tends to be flashy (Stone 1993). Likely this is due to the soil type, lack of riparian vegetation and the deeply incised banks within the lower portion of the watershed.

There are three gauge stations situated along the Big Otter Creek (Figure 9). Streamflow for the six year period between 1998 and 2004 increased in magnitude from upstream to downstream (Figure 12). To give an indication of how wet or dry a particular year was relative to the long-term average (40 years from 1960-2004), the average annual flow was calculated for each year data was available during the period from 1960 to 2004 for stations 02GC010, 02GC017 and 02GC026. These yearly averages were then plotted with the 40 year long-term average discharge (Figure 13, 14, & 15). Generally, average annual flows within Big Otter Creek were similar to the long term average in 2003 but below in 2002. Verified flow data for the 2004 and 2005 years has not yet become available so was not plotted here.

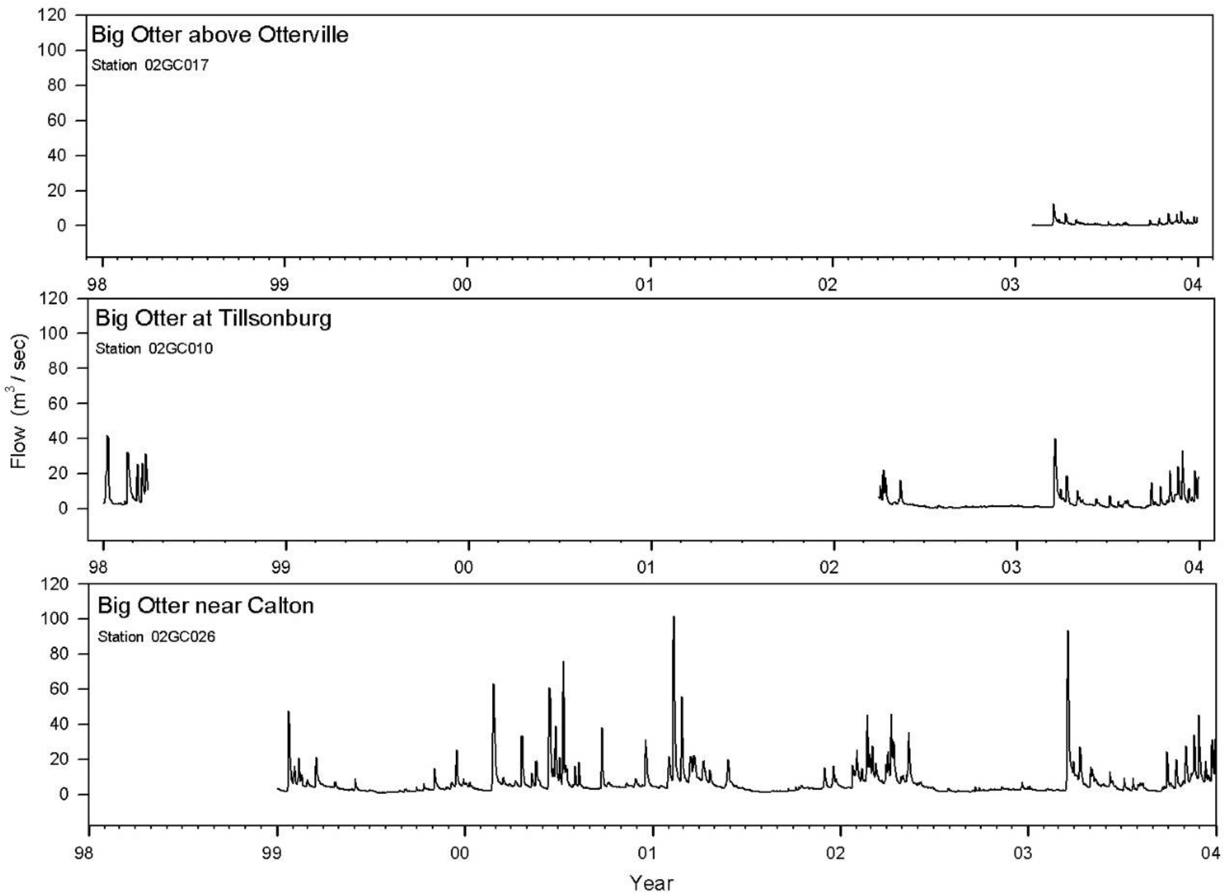


Figure 12. Flow rates at the three Water Survey of Canada gauge stations for the period from 1998-2004 within the Big Otter Creek watershed.

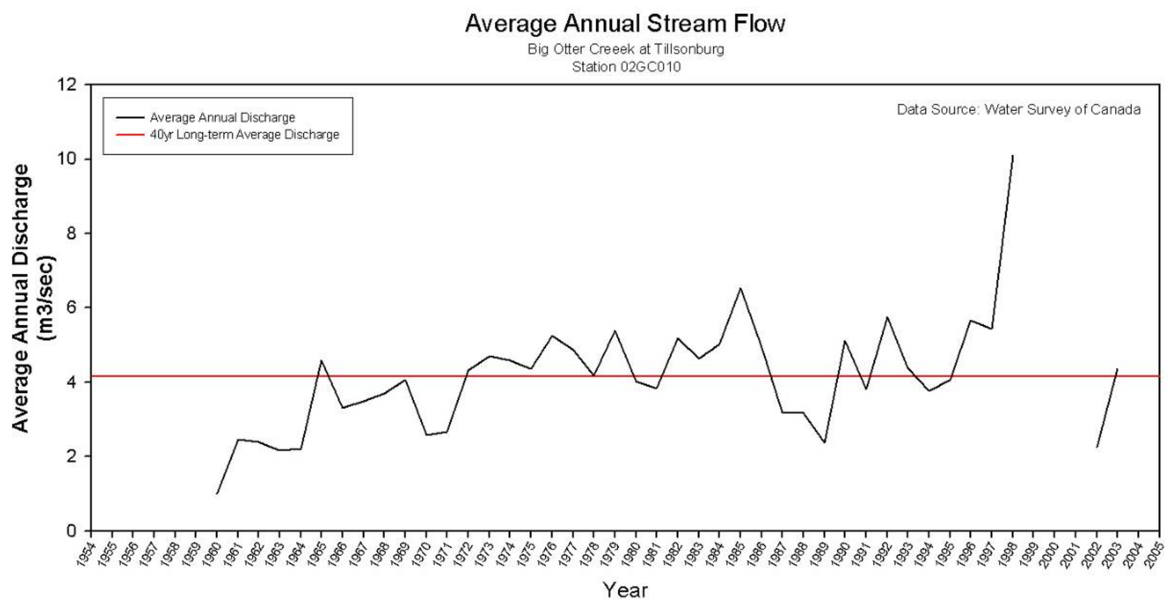


Figure 13. Average annual stream flow from 1960-2004 for station 02GC010 Big Otter Creek at Tillsonburg

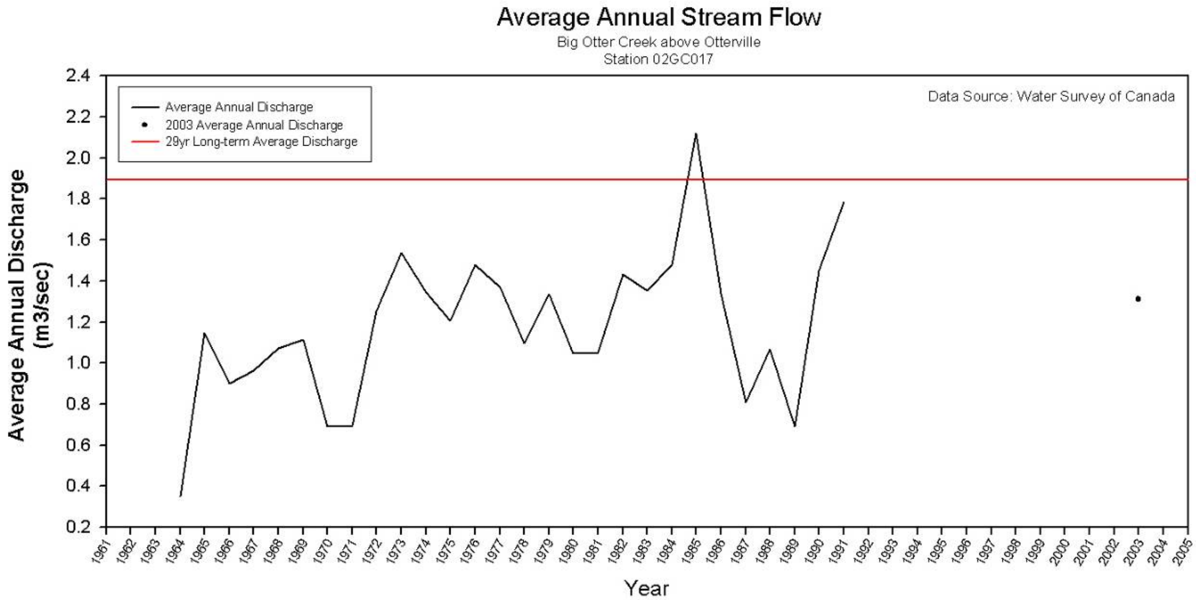


Figure 14. Average annual stream flow from 1964-1992 for station 02GC017 Big Otter Creek above Otterville.

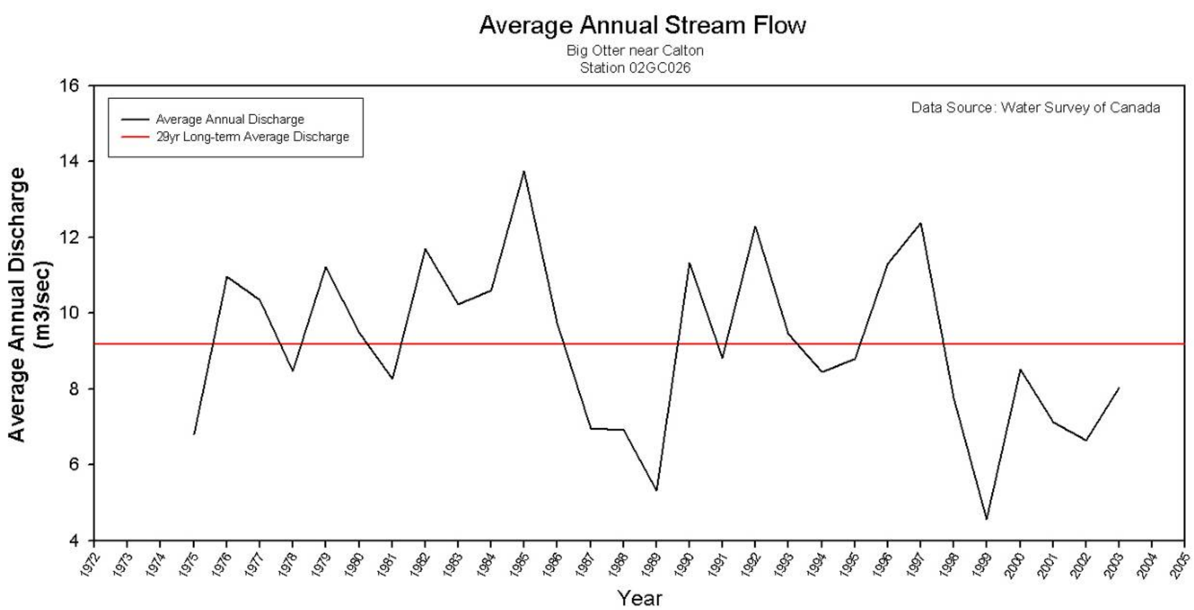


Figure 15. Average annual stream flow from 1964-1992 for station 02GC026 Big Otter Creek near Calton.

PH

The pH values varied only slightly between the three PWQMN sampling sites, and ranged from 6.87 at all sites to 9.29 at site 9008 on lower Big Otter Creek. Although most of the samples had pH values within the range (6.5-8.5) suggested by the Provincial Water Quality Objective (PWQO) to support aquatic life, there were values higher than 8.5 recorded at all of the sites. Site 9008 appeared to have the highest number of observations outside the upper end of the PWQO range. This could be indicative of high levels of photosynthesis (Wurts & Durborow, 1992); however, the high turbidity levels within the creek make it difficult for aquatic vegetation to become established and as such the creek tends to have little aquatic vegetation. .

Dissolved Oxygen

Dissolved Oxygen (DO) within the Big Otter Creek watershed never dipped below the 4 mg/L criteria for cold water fish. However, sampling generally occurred between 9a.m. and 4p.m. and as a result, the data presented here does not characterize the diurnal fluctuations in DO levels. Thus, determining if the range in dissolved oxygen concentration within the Big Otter Creek watershed was limiting to aquatic organisms could not be accurately assessed with the 2002-2005 sampling regime.

During the 2002-2005 sampling period, dissolved oxygen (DO) levels were consistently above 10 mg/L and in 2005 were reported as high as 24.15 mg/L (at site 9010), which when converted to percent saturation was found to be supersaturated (>140%). Super-saturation of gases within the water can lead to gas exchange problems in aquatic life such as blood gas trauma in fish (Fidler & Miller, 1994). However, there has yet to be a criteria set for the upper limit of DO for the protection of aquatic life.

Summer Temperature

Temperature data analysed from the temperature loggers deployed at the three PWQMN sites within the Big Otter Creek watershed indicated that summer (June, July & August) maximum daily temperatures were lowest within upper BOC (site 9007) at 24°C and highest within Spittler Creek (site 9010) at 33°C. Time series plots (Appendix H) indicated that daily maximum temperatures appear to be on the rise and the occurrence of daily maximum temperatures above the 24°C threshold between cool and warm water fish species (Coker et al., 2001; Stoneman and Jones, 1996) is happening more frequently within Big Otter Creek.

Rising temperatures within Big Otter Creek are of concern as it currently supports a rainbow trout run which tend to be extremely sensitive to warm waters. However, the many cold water tributaries and riffle areas within the watershed likely provide refuge for these young coldwater migrants. An increase in water temperatures can also impact oxygen saturation of freshwaters thereby impacting metabolic rates, growth and reproduction of freshwater fish (Gordon et al 1994).

Nutrient Conditions

Nutrient conditions did not vary widely between sites within the Big Otter Creek watershed. No significant differences were found between sites for nitrate, nitrite, ammonia and phosphorus. The consistently high concentrations of nitrate, phosphorus and non-filterable residue throughout the watershed are the primary water quality issues within the Big Otter Creek watershed.

Nitrate

Nitrate levels tend to be high throughout the Big Otter Creek watershed (Figure 16). The highest, 11.64 mg/L, and lowest, 0.004mg/L concentrations were both found within Spittler Creek (Appendix D). The range of variability found within Spittler Creek was noticeably higher than either of the two sites situated on Big Otter Creek.

When all three sites were statistically compared using a Kruskal-Wallis test, no significant differences were found ($p = 0.55$).

Although Spittler Creek was shown to have the highest median nitrate concentration, site 9007 on upper Big Otter Creek was found to have the highest number of samples with values above the Canadian Guideline (Appendix F). This is likely due to either the effluent from the upstream WPCP in Norwich or run-off from agriculture lands. Till plains, found in the northern and western portions of the watershed, tend to have a lower potential for percolation resulting in high run-off rates and as such, these areas, if farmed, are usually heavily tile drained which, can facilitate nitrogen (nitrate) inputs from fertilized lands.

Given the extremely high nitrate levels found within Spittler Creek, agriculture related inputs are likely the major contributors within the upper watershed. The high values seen within the lower watershed, could be from cumulative upstream impacts or agriculture inputs from the till plain region to the west.

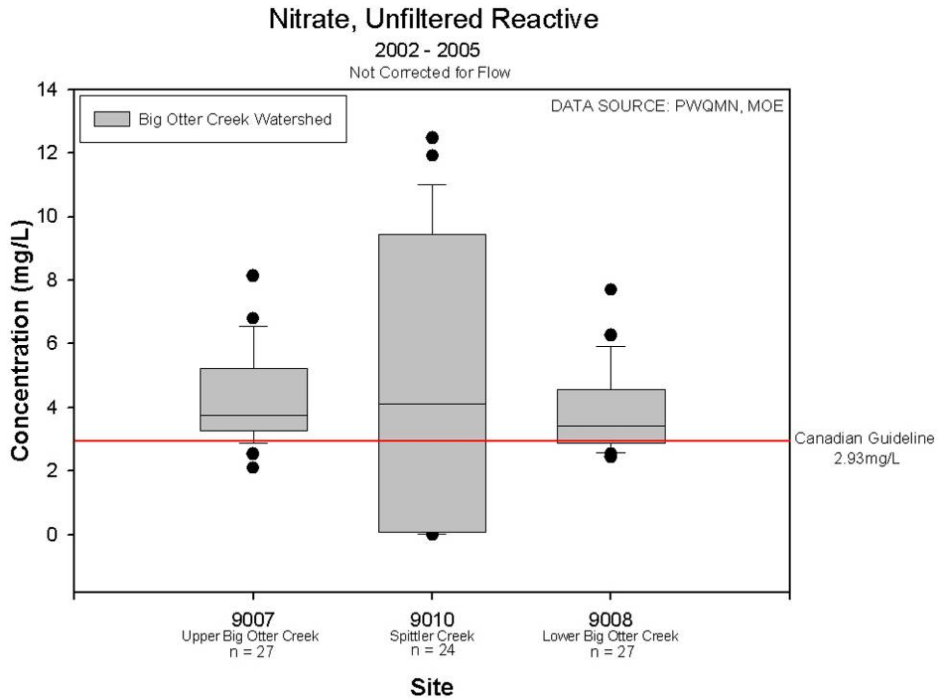


Figure 16. Nitrate concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Big Otter Creek watershed.

Nitrite

Nitrite concentrations ranged from 0.007 mg/L within lower Big Otter Creek to 0.148 mg/L within Spittler Creek (Appendix D, Figure 17). Concentrations appeared to slightly decrease from upstream to downstream within the watershed. However when all three sites were statistically compared using a Kruskal-Wallis test, no significant differences were found ($p = 0.48$). A noticeably wider range of concentrations were found within the samples taken at Spittler Creek compared to either of the two sites along Big Otter Creek (Figure 17).

Generally, nitrite did not appear to be of concern as median values throughout the watershed were well below the Canadian Guideline of 0.06 mg/L. Spittler Creek was found to have the highest number of samples with concentrations above the guideline while site 9008 on lower Big Otter Creek had the lowest (less than 5%) of its samples above the guideline. The higher levels found within Spittler and upper Big Otter Creek are likely associated with the higher number of livestock operations present in the upper portion of the watershed relative to the lower watershed.

Unionized Ammonia

In general unionized ammonia levels did not widely vary and ranged from 2.47 e^{-5} mg/L within lower Big Otter Creek to 0.011mg/L within Spittler Creek (Figure 18). No significant differences were found between any of the three sites analysed within the Big Otter Creek watershed ($p = 0.31$).

Unionized Ammonia was not considered to be a major water quality issue as median values at all three sites were well below the Provincial Water Quality Objective (PWQO); however, a few (less than 5%) samples were found to exceed the PWQO within Spittler Creek.

Total Kjeldahl Nitrogen (TKN)

Total Kjeldahl Nitrogen concentrations across the Big Otter Creek watershed ranged from 0.32 mg/L to 1.91 mg/L, both of which were found at site 9008 downstream on Big Otter Creek (Appendix D, Figure 19).

TKN concentrations between upper and lower Big Otter Creek were not statistically different ($p = 0.62$). However, Spittler Creek was found to have significantly higher TKN concentrations than those found at both the upper and lower sites along Big Otter Creek ($p = 0.0014$ and $p = 0.0004$ respectively).

Total Kjeldahl nitrogen (TKN) is the measure of the total organic nitrogen and ammonia content of a water sample. Considering the total ammonia levels within Spittler Creek are fairly low, it is likely that the elevated TKN levels found are as a result of high levels of organic nitrogen. Organic nitrogen can be indicative of highly productive areas and can also lead to decreased dissolved oxygen levels.

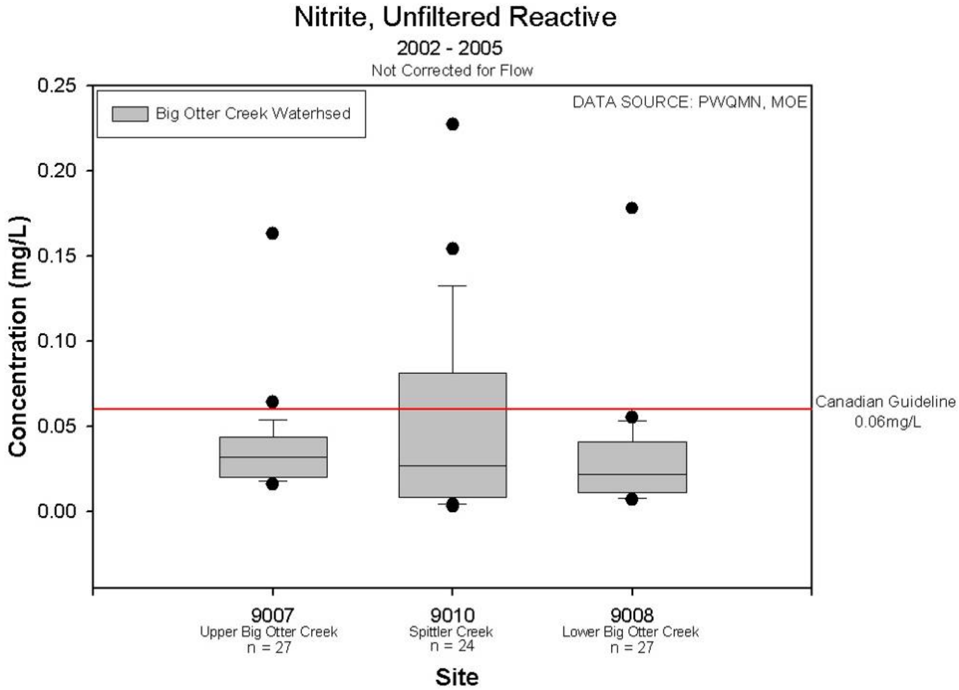


Figure 17. Nitrite concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Big Otter Creek watershed.

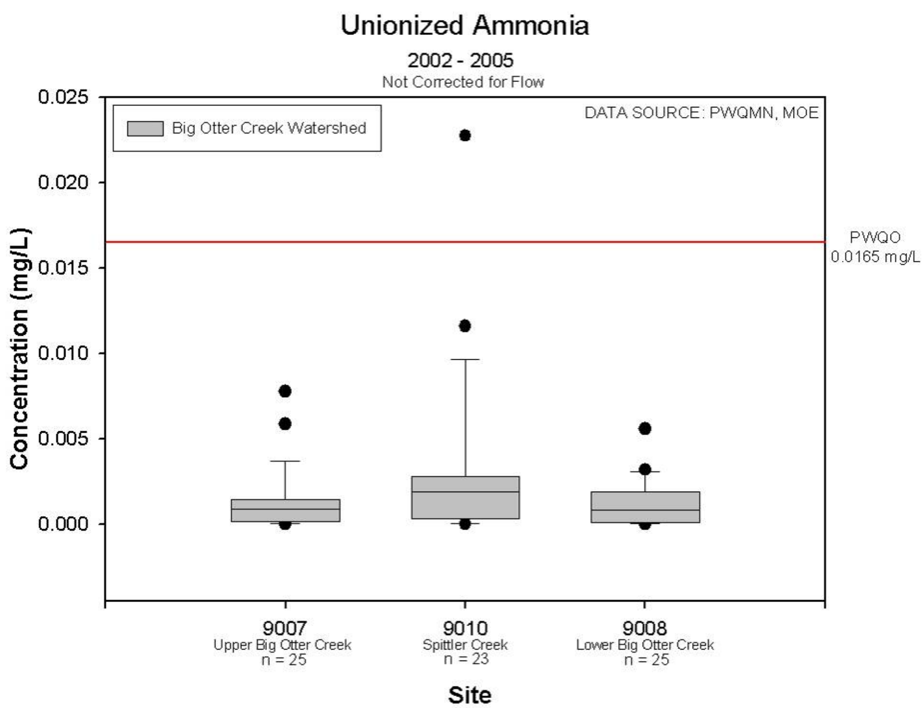


Figure 18. Unionized ammonia concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Big Otter Creek watershed.

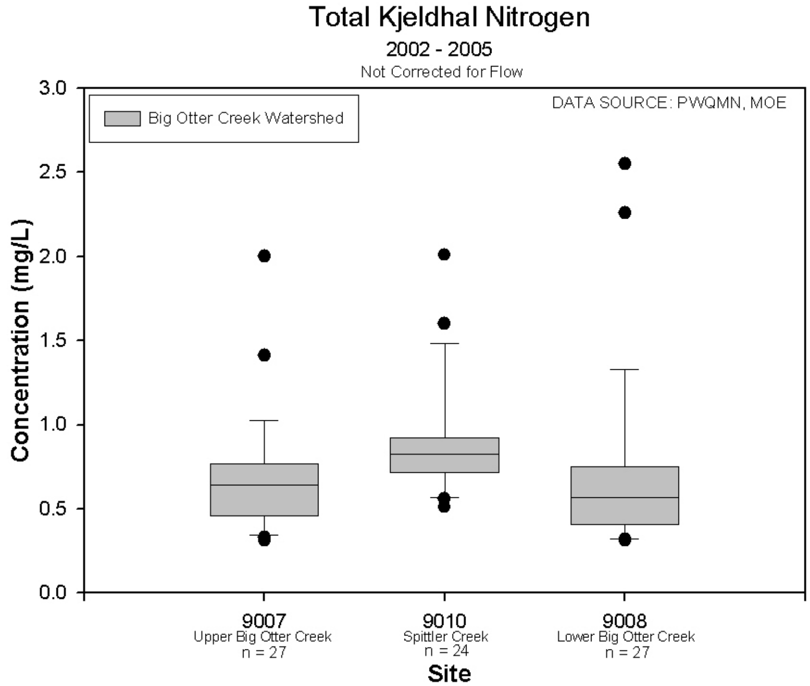


Figure 19. Total kjeldahl nitrogen concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Big Otter Creek watershed.

Total Nitrogen (Nitrate + Nitrite + Kjeldahl Nitrogen)

Total nitrogen is made up of three constituents: nitrate, nitrite and total kjeldahl nitrogen (TN = NO3 + NO2 + TKN) (TKN = NH4 + Organic N). On average nitrates tend to make up greater than 80% of the total nitrogen pool at both PWQMN sites along Big Otter Creek (Figure 20). However, within Spittler Creek only 56% of the total nitrogen was composed of nitrate and 41% was composed of organic nitrogen. Organic nitrogen levels range from 13 % to 42% (Appendix D). The high organic inputs within Spittler Creek are likely due to the high number of agricultural operations where livestock have direct access to the creek, as well as the increased run-off potential from operations within close proximity to the creek. Unionized ammonia levels make up less than 2% of the total nitrogen pool for the entire region ranging from 1% on upper Big Otter Creek to just below 2% on Spittler Creek.

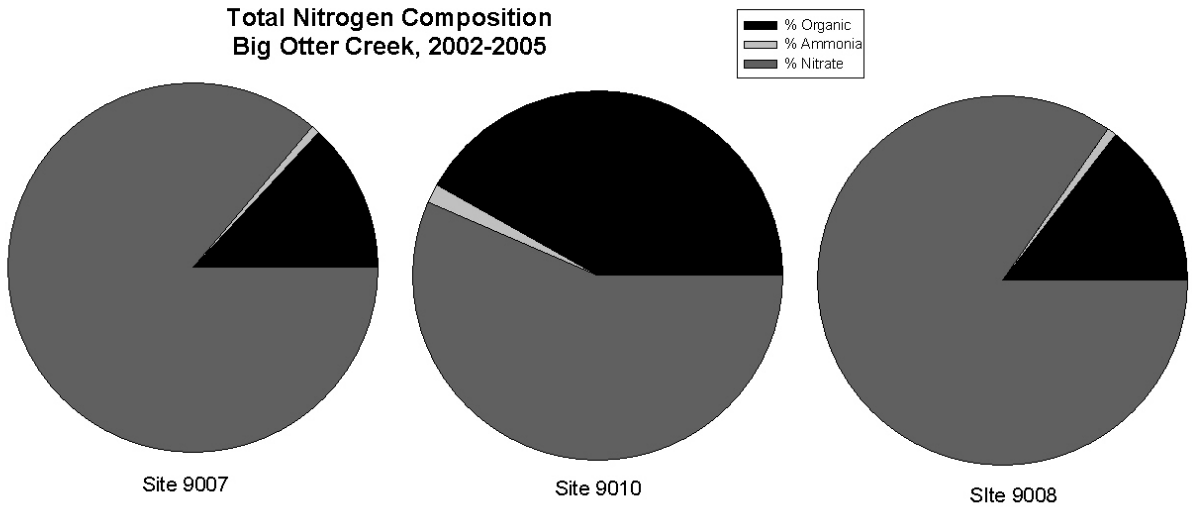


Figure 20. Composition of average total nitrogen concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Big Otter Creek watershed.

Phosphorus

Total phosphorus levels were very high throughout the Big Otter Creek watershed and ranged from 0.02 mg/L within Spittler Creek and lower Big Otter Creek to 0.526 mg/L within lower Big Otter Creek (Appendix D, Figure 21).

A slight increasing trend from upstream to downstream was noted although not significant ($p = 0.32$). Phosphorus levels throughout the watershed were routinely above the provincial objective of 0.03 mg/L. Samples from Spittler Creek were above the objective 71% of the time while samples along Big Otter Creek were above the objective 84% and 96% of the time within the upper and lower reaches respectively.

Generally, high phosphorus levels are seen in areas that drain highly intensive agricultural lands situated with till or clay lands, which is the case for most of the Big Otter Creek watershed. Potential sources within the upper watershed are; run-off from fertilized agricultural lands within the till plain where the run-off potential is high and urban inputs from the village of Norwich (e.g. their water pollution control plant). The levels found within lower Big Otter Creek are likely as a result of cumulative upstream concentrations, run-off inputs and possibly contributions from the town of Tillsonburg. However, none of the PWQMN sites analysed in this report were situated directly downstream of Tillsonburg to accurately assess its influence on Big Otter Creek. Although, the lack of a significant increase from upstream to downstream along Big Otter Creek may be an indication that any major urban influence tends to be localized, Fausto & Finucan (1992) found that phosphorus loading within the Big Otter Creek watershed was mainly anthropogenically driven by fertilizers, household effluent, industry and improper milk-house wash water disposal.

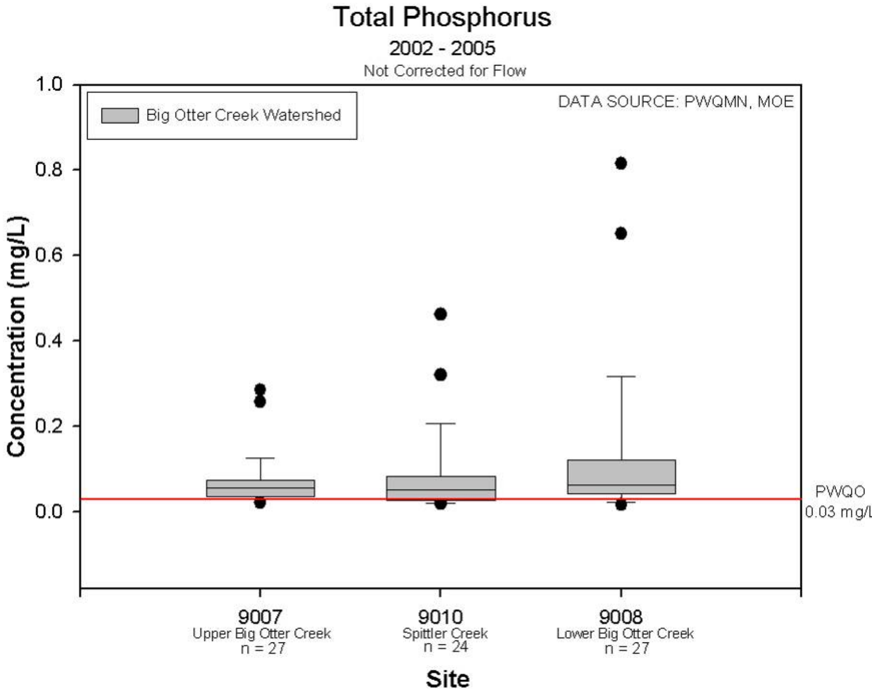


Figure 21. Phosphorus concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Big Otter Creek watershed.

Non-filterable residue (NFR)

Non-filterable residue significantly increased from upstream to downstream along Big Otter Creek (p = 0.0001) and ranged from 2.03 mg/L upstream at site 9007 to 367.25 mg/L downstream at site 9008 (Appendix D, Figure 22). Concentrations within Spittler creek were significantly lower than concentrations found at site 9008, downstream on Big Otter Creek (p = 0.0095).

Occurrences of samples with concentrations above the 25 mg/L benchmark appear to be more of an issue along lower Big Otter Creek compared to the other two sites in the watershed. Site 9007 on upper Big Otter Creek had the lowest number of samples (7 %) which exceeded the benchmark, while site 9008 on lower Big Otter Creek had the highest number of exceedences (54 %). Median concentrations were below the general criteria (25 mg/L) except for site 9008 furthest downstream where the median value was slightly above the criteria (26.9 mg/L).

The significant increase in NFR found downstream is likely due in part to the topography and the deeply incised stream banks. Other potential contributors could be: the upstream WPCPs at Norwich and Tillonsburg; the increased potential for run-off within till and clay soil types; and/or the increased flow velocity within the lower portion of the watershed. NFR loading is one of the major water quality issues within the Big Otter Creek watershed and has been identified by Cridland (1997) as the largest source of sediment contamination to Lake Erie on the Canadian side.

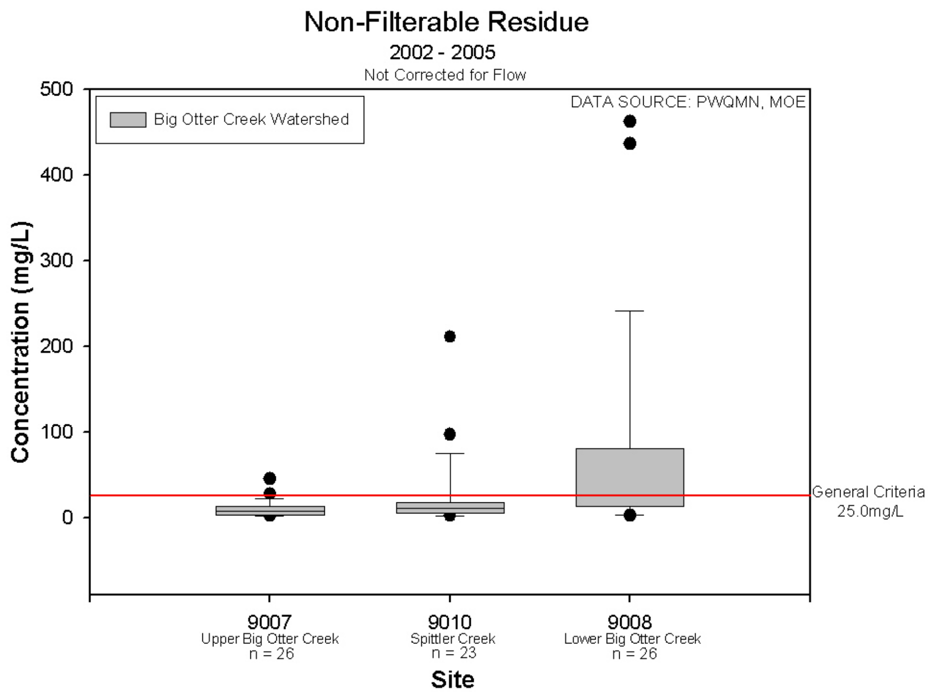


Figure 22. Total non-filterable residue concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Big Otter Creek watershed.

Chloride

Throughout the Big Otter Creek watershed chloride levels were low, relative to the Environment Canada benchmark of 250mg/L, and ranged from 17.45mg/L upstream on Big Otter Creek to 60.75mg/L on Spittler Creek (Appendix D, Figure 23).

There was no significant difference between upstream and downstream concentrations along Big Otter Creek ($p = 0.57$). However, Spittler Creek was found to have significantly higher Chloride concentrations than those found at both the upper and lower sites along Big Otter Creek ($p = 0.004$ and $p = 0.002$ respectively).

Usually excess chloride concentrations within streams can be attributed to road salting in urban areas. However, there are no nearby urban centers influencing Spittler Creek so this is not likely the source. Another potential input could be from faulty septic tanks in the area or feed supplements from nearby farms.

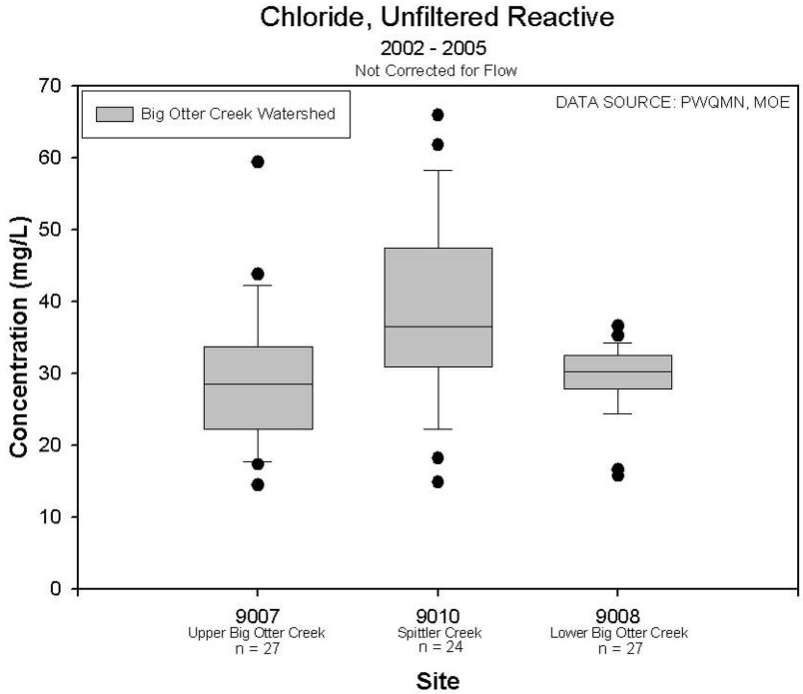


Figure 23. Chloride concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Big Otter Creek watershed.

Bacterial Conditions

The widest range in *Escherichia coli* counts was found furthest downstream on Big Otter Creek at site 9008 (10-5100 counts/100mL). However, this site did not display the highest median value, which was found on Spittler Creek at site 9010 (Figure 24).

The higher median level found within Spittler Creek could be as a result of the higher percentage of livestock operations within this area compared to the lower portion of the watershed. However, the methods used for enumerating and quantifying bacteria and pathogen levels in natural waters have a large degree of error associated with them and should be interpreted with this in mind.

Studies characterizing the bacterial levels at the Port Burwell Beach found that levels were regularly above the ministry of health guidelines and can be very high (Fausto & Finucan, 1992; Cridland 1997). The littoral drift within Lake Erie (from west to east) generally transports bacterial concentrations found at Port Burwell towards Long Point (Cridland 1997). Cridland (1997) also found that bacterial levels were high throughout the watershed and attributed this to high flow events and pulse loading form large point sources such as WPCPs.

Upon implementation of the Clean Up Rural Beaches (CURB) program an improvement in *E. coli* levels throughout the watershed was apparent (Fausto & Finucan, 1992). It was also found that the tributaries had higher concentrations compared to the main branch. However, this could be as a result of the higher natural flow within Big Otter resulting in a dilution effect (Fausto & Finucan, 1992). During 2000 and 2001 the villages of Eden, Staffordville and Vienna were upgraded from being on septic systems to having their waste processed through the Port Burwell WPCP.

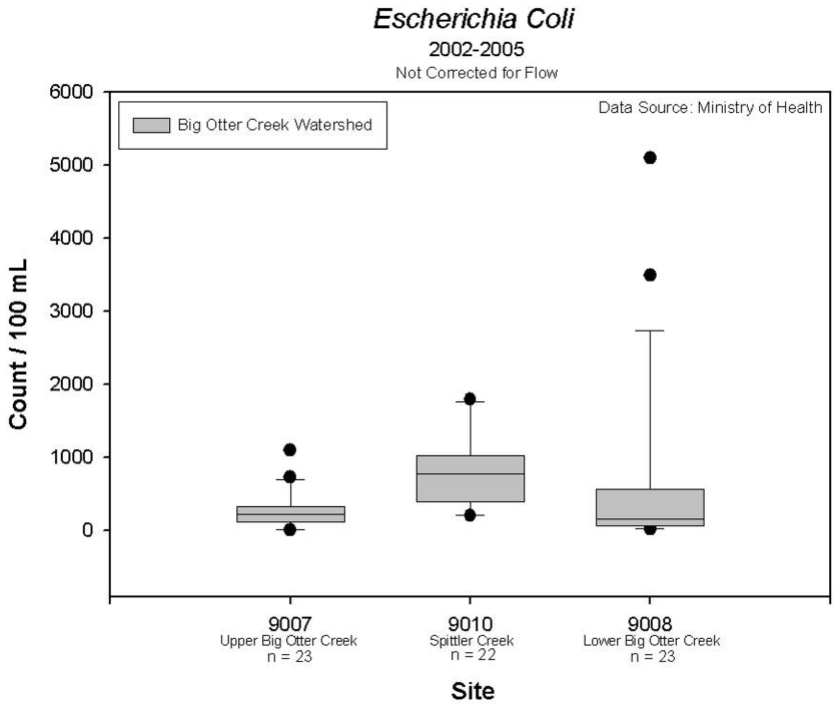


Figure 24. *Escherichia coli* concentrations from 2002 to 2005 at the currently monitored PWQMN sites in the Big Otter Creek watershed.

Reservoir Conditions

There is one major reservoir within the Big Otter Creek watershed, the Norwich reservoir, which is used for recreation, flow augmentation and flood control. Although there were no PWQMN sites situated within the reservoir, previous studies characterizing the reservoir's general water quality have been performed and their major findings are discussed below.

Water quality within the Norwich reservoir in the past has been characterized as poor, with high nutrients, high turbidity and poor clarity (Cridland, 1997; Van De Lande, 1987). This is likely due to the high stream bank erosion from the inflow and the soil type within the area (clay and till) as well as the resident carp populations which tend to re-suspend the benthic sediments. Dissolved oxygen and temperature have been reported to vary only slightly throughout the year but summer temperatures have been on the rise, which could be as a result of the minimal bank vegetation to provide shade (Van De lande, 1987). The aquatic life within this reservoir tends to be limited to hearty fish species, mainly carp, although some large mouth bass have been found.

In addition to the Norwich reservoir there are three main dam structures within the Big Otter Creek watershed, Otterville dam (downstream of where the East Big Otter Creek Branch meets the main Big Otter Creek branch), Rockmills dam (east of RR13) and Blacksbridge dam (near Tillsonburg). These dams interrupt the natural stream flow by decreasing velocity and increasing the stream width behind the dam. The slower shallower waters are likely attributing to the recent increase in daily maximum temperatures recently found within the watershed. Besides creating thermal regimes more conducive to warm water fish species such as carp, these dams also create barriers for migratory cold-water fish populations.

Big Creek Watershed

The Big Creek watershed is approximately 725km^2 spanning 90km north to south and approximately 21-36km east to west with a drop in elevation of approximately 1.4m / km. The headwaters are located in Oxford County southwest of Woodstock near the Ingersol Moraine. The Big Creek primarily drains one physiographic region, the Norfolk Sand Plain, with the exception of a small section of the Horseshoe Moraine region in the northwest and the Haldimand Clay Plain at the southern tip of the watershed.

Agricultural production is said to be around 71% of the land-use within this area (Stone 1993), which is dominated by specialty crops such as market vegetables and ginseng. The agricultural land-use is less intense within the southern half of the watershed where there is a higher percentage of forest cover. The town of Delhi is the only major urban centre within the Big Creek watershed, which has its own water pollution control plant (WPCP).

There were four sites sampled within the Big Creek watershed as part of the PWQMN program during the 2002-2005 sampling season (Figure 25). The information from these sites allowed for upstream / downstream comparisons along Big Creek, the potential influence Trout and Venison Creeks may have on the water quality found in lower Big Creek and the potential contaminant contributions Big Creek may be emptying into Lake Erie.

Within the Big Creek watershed there is one municipal drinking water system, the Delhi Water Treatment Plant, which is a combination surface and ground water supply system. The surface water intake is located within the Lehman reservoir (a surface water impoundment on North Creek, a tributary to Big Creek). This drinking water system supplies approximately 1/3 of the population which resides in the Big Creek watershed.

Physical Conditions

Streamflow

Streamflow within the Big Creek Watershed is lower compared to that of Big Otter Creek but higher than other watersheds across the Long Point Region. Flow is partially regulated through several wetlands, reducing flow intensity and acting as a sediment sink thereby reducing the sediment loads reaching Lake Erie (Stone, 1993). Due to an increased number of wetlands, the high degree of riparian cover and the higher percentage of sandy soil allowing for good infiltration, the Big Creek watershed does not react as quickly to event flows compared to Big Otter Creek.

Streamflow for the six year period between 1999 and 2004 was fairly consistent as it moved downstream from station 02GC006 near Delhi to station 02GC007 near the village of Walsingham further downstream (Figure 26). To give an indication of how wet or dry a particular year was relative to the long-term average (49 years from 1955-2004), the average annual flow was calculated for each year data was available during the 1955 to 2004 period for stations 02GC006 and 02GC007. These yearly averages were then plotted with the 49 year long-term average discharge (Figure 31 & 32). Average annual flows within Big Otter Creek were above or approaching the 49 year long term average in 2000 and 2003 but below in 2001, and 2002 (Figure 27 & 28).

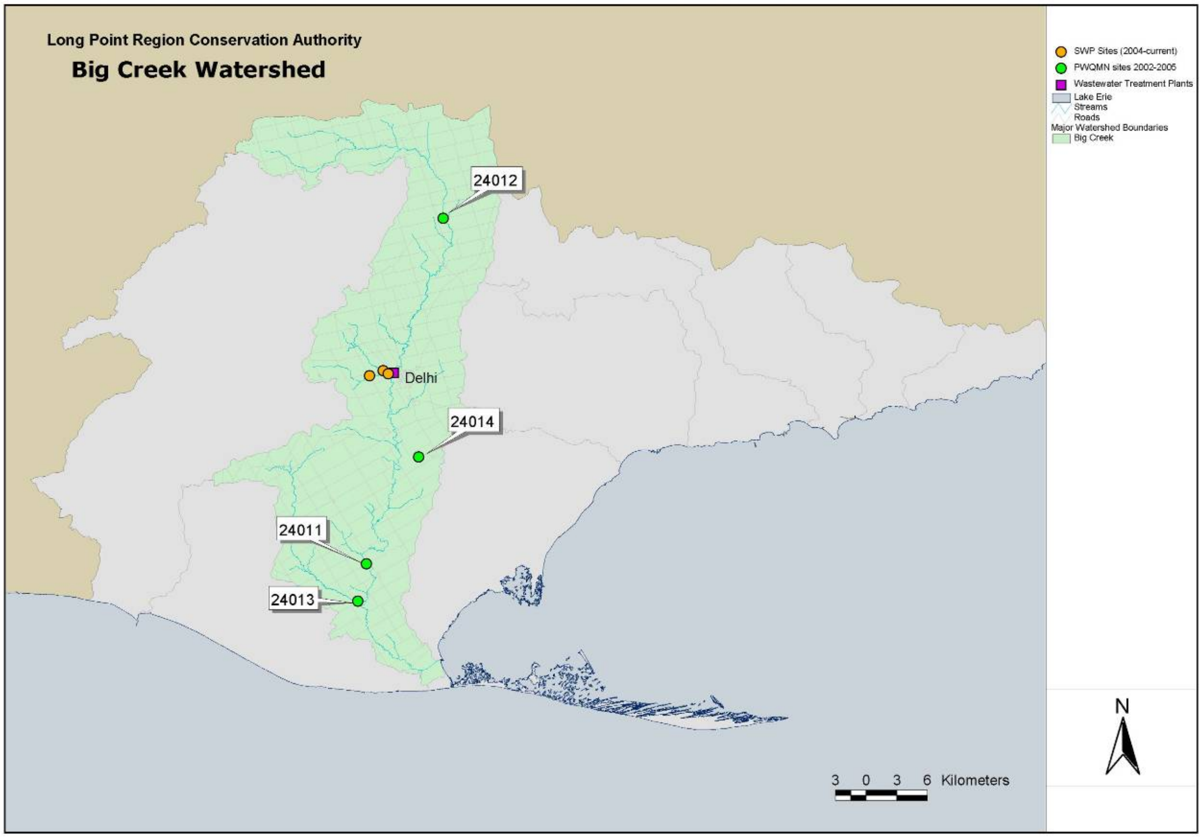


Figure 25. Big Creek watershed illustrating the location of the major urban areas, the water pollution control plants, the new monitoring sites under source water protection (SWP) and the PWQMN sites sampled from 2002-2005.

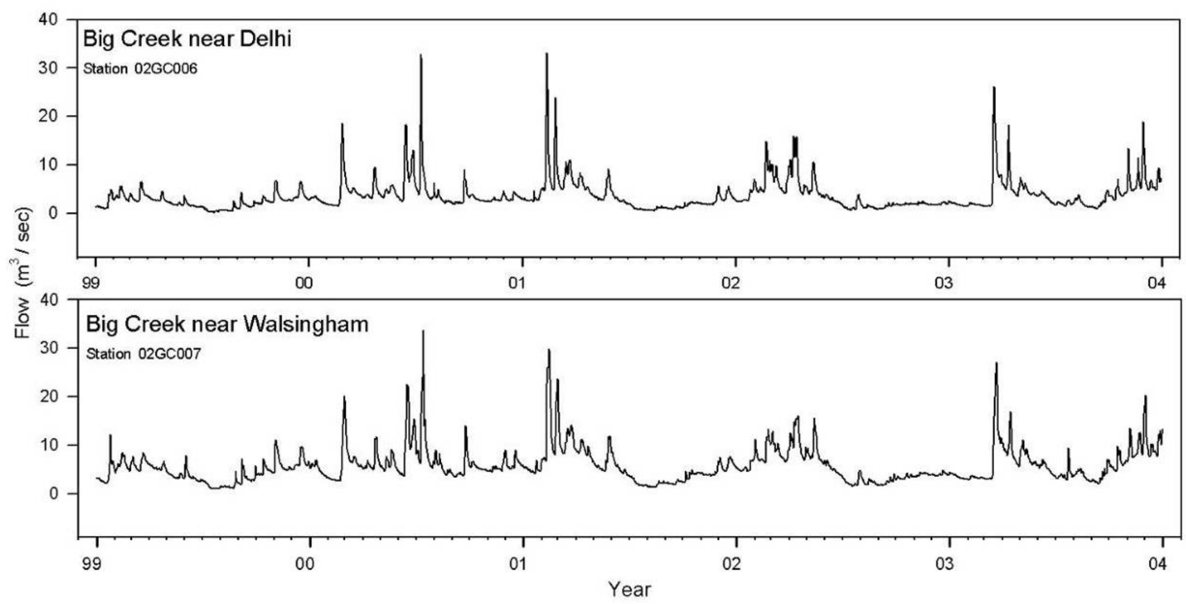


Figure 26. Flow rates at the two Water Survey of Canada gauge stations for the period from 1999-2004 within the Big Creek watershed.

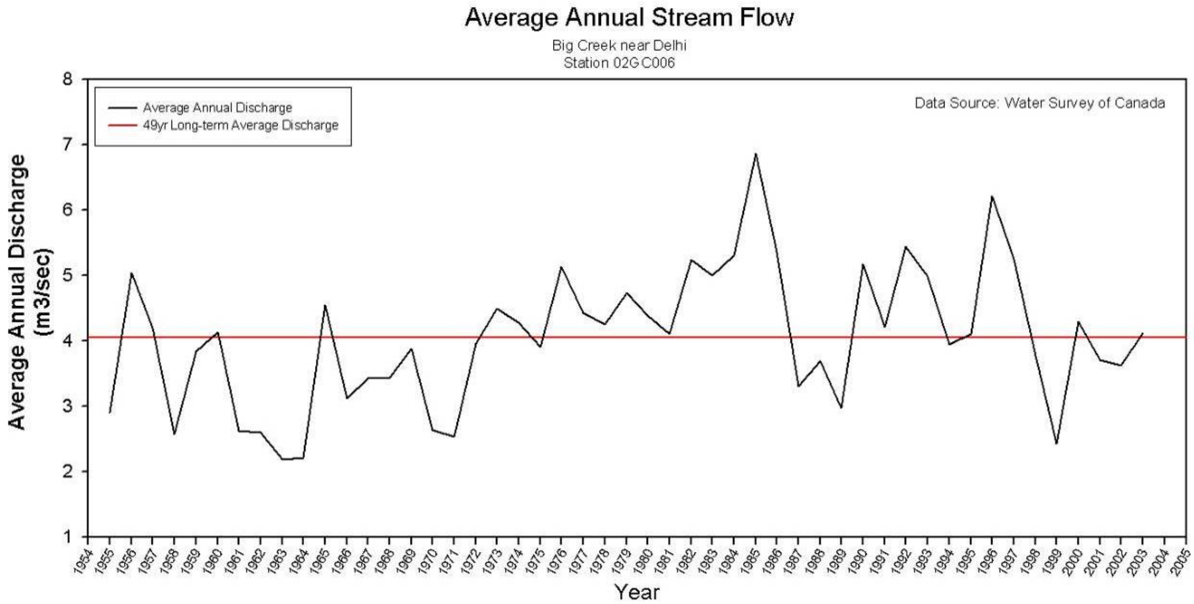


Figure 27. Average annual stream flow from 1955-2004 for station 02GC006 Big Creek near Delhi

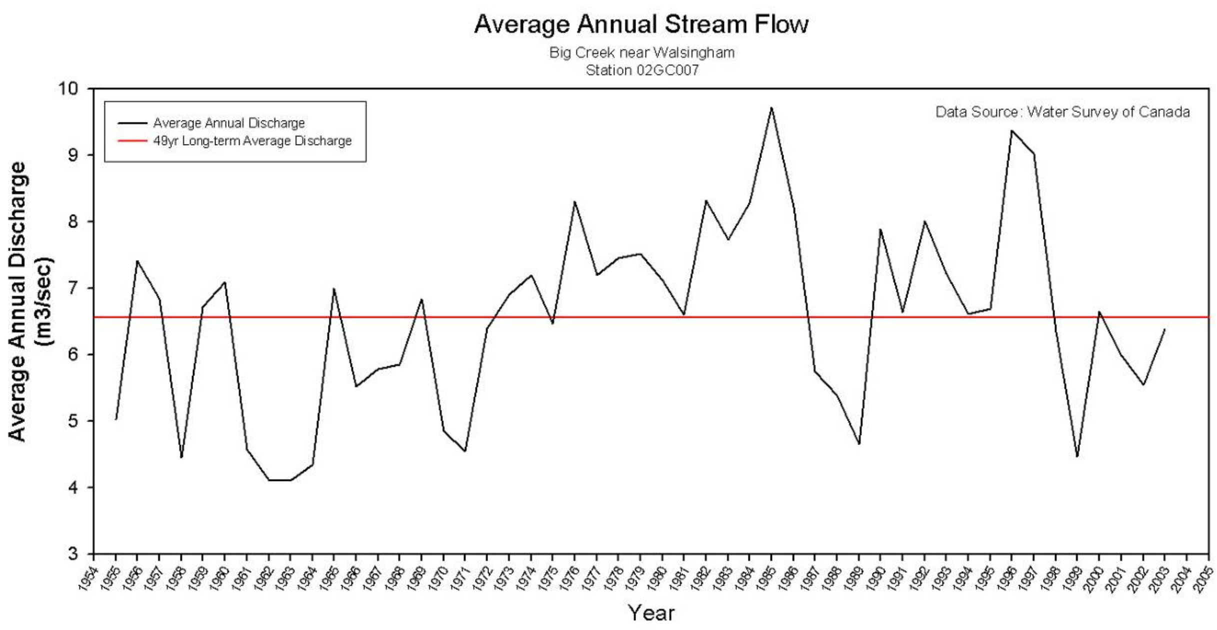


Figure 28. Average annual stream flow from 1955-2004 for station 02GC007 Big Creek near Walsingham.

PH

The pH values varied only slightly between the four PWQMN sites ranging from 6.87 at all sites along Big Creek and Venison Creek (sites 24012, 24011 & 24013) to 9.15 at site 24014 on Trout Creek. The Provincial Water Quality Objective (PWQO) for aquatic health indicates that pH should be maintained between 6.5 and 8.5. Site 24014, on Trout Creek, appeared to have the highest number of observations outside the upper end of this range, which can be indicative of high productivity. However, nutrient concentrations are among the lowest in the watershed so this is likely not the case (see nutrient section).

Dissolved Oxygen

Dissolved Oxygen (DO) within the Big Creek watershed never dipped below the 4 mg/L criteria for cold water fish. However, sampling generally occurred between 9a.m. and 4p.m. and as a result, the data presented here does not characterize the diurnal fluctuations in DO levels. Thus, determining if the range in dissolved oxygen concentration within the Big Otter Creek watershed was limiting to aquatic organisms could not be accurately assessed with the 2002-2005 sampling regime.

During the 2002-2005 sampling period, dissolved oxygen (DO) levels were consistently above 10 mg/L and in 2005 were reported as high as 20.16 mg/L (at site 24014), which when converted to percent saturation was found to be supersaturated (>140%). Super-saturation of gases within the water can lead to gas exchange problems in aquatic life such as blood gas trauma in fish (Fidler & Miller, 1994). However, there has yet to be a criteria set for the upper limit of DO for the protection of aquatic life.

Summer Temperature

Temperature data analysed from the temperature loggers deployed at the four PWQMN sites within the Big Creek watershed indicated that summer (June, July & August) maximum daily temperatures are lowest within Trout Creek (site 24014) at 18.9°C and highest within upper Big Creek (site 24012) at 25.1°C.

Time series plots (Appendix H) indicated that daily maximum temperatures appear to be on the rise but the occurrence of daily maximum temperatures above the 24°C threshold between cool and warm water fish species (Coker et al., 2001; Stoneman and Jones, 1996) only appears to be happening more frequently within Big Creek. Trout Creek, a cold water stream had temperatures approaching the 19°C cold water threshold but summer maximum temperature were generally below 18°C. Venision Creek had temperatures generally above the 19°C cold water threshold but well below the 24°C warm water classification.

Nutrient Conditions

Generally water quality was better within Trout Creek compared to other sites sampled within the Big Creek watershed. The upper Big Creek region was the most impaired with respect to nitrogen and chloride levels, likely as a result of the heavier soils in the upper watershed. However, Venison Creek and lower Big Creek were the most impaired with respect to phosphorus and total non-filterable residue (NFR) concentrations. Compared to other watersheds within the Long Point Region, Big Creek is not a major contributor of nutrients or NFR to Lake Erie.

Nitrate

Nitrate levels are the most serious water quality issue within upper Big Creek. Across the entire watershed nitrate concentrations ranged from 2.09 mg/L within Venison Creek (site 24013) to 6.32 mg/L upstream on Big Creek at site 24012 (Appendix D, Figure 29).

When the four PWQMN sites within the Big Creek watershed were statistically analyzed using a Kruskal-Wallis test it was determined that median values significantly differed between sites (p = <0.0001). To spatially determine where within the watershed these differences occurred, a series of Mann-Whitney tests were carried out. Significant differences were found between all sites (Appendix E). Median nitrate concentrations within Big Creek were found to significantly decrease from upstream to downstream and were significantly higher than levels found in both Trout Creek and Venison Creek. Venison Creek was found to have significantly lower median nitrate concentrations than all other sites within the watershed.

The number of times a sample did not meet the Canadian Guideline for nitrate (2.93 mg/L) was highest (74 %) at site 24012 on upper Big Creek. Nitrate levels within lower Big Creek exceeded the guideline less frequently than the upper reaches of Big Creek, but exhibited a higher percentage of samples with concentrations above the guideline than either Trout or Venison Creeks (Appendix F). Overall Venison Creek exceeded the guideline the fewest number of times with only 11% of the samples taken at this site being greater than 2.93 mg/L.

The higher nitrate values found within the upper watershed are likely as a result of run-off from the till and clay soils found within the northwestern corner of the watershed. There is also a higher percentage of livestock operations within the upper watershed that could also be contributing to the elevated nitrate levels found. The better water quality entering lower Big Creek from the major tributaries (Trout and Venison, which are groundwater fed) is likely having a positive effect on Big Creek's water quality which has resulted in an improvement of water quality as the creek runs from upstream to downstream.

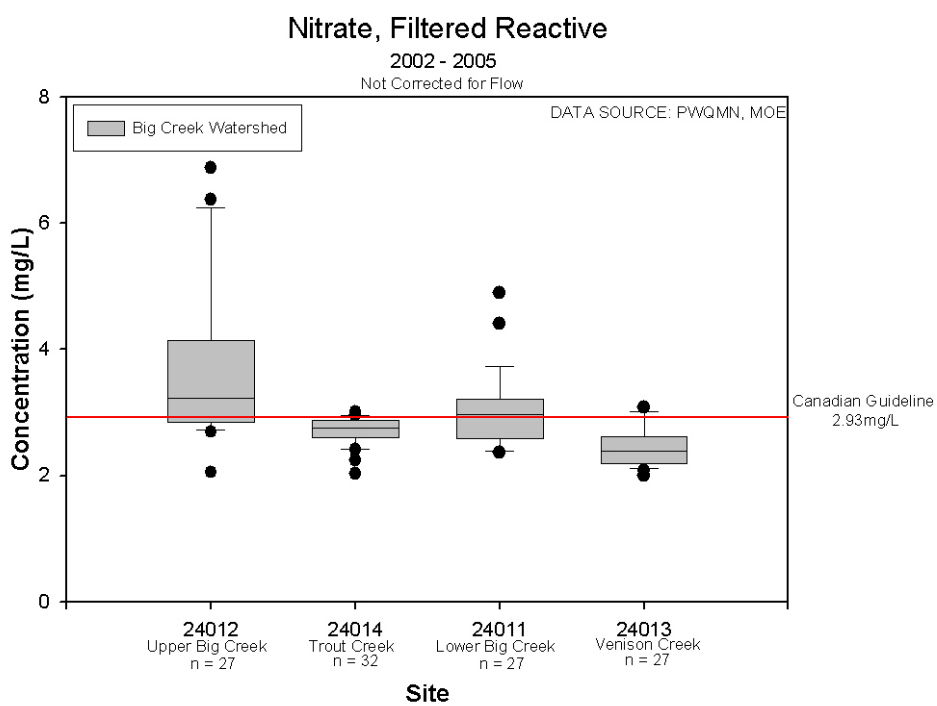


Figure 29. Nitrate concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Big Creek watershed.

Nitrite

Nitrite concentrations were generally low and did not appear to be a problem within the Big Creek watershed as samples taken rarely had concentrations that were above the Canadian guideline of 0.06 mg/L (Appendix F).

Within the Big Creek watershed nitrite concentrations ranged from 0.005mg/L on Trout Creek (site 24014) to 0.055 mg/L on upper Big Creek (site 24012) (Figure 30). Generally, nitrite concentrations were statistically similar throughout the watershed with the exception of Trout Creek (site 24014), where significantly lower concentrations were found (Appendix E).

Unionized Ammonia

Unionized ammonia concentrations were also very low, ranging from $1.2e^{-5}$ mg/L on Trout Creek (site 24014) to $6.4e^{-3}$ mg/L on upper Big Creek (site 24012) (Appendix D, Figure 31). Median concentrations between sites were statistically similar except for Trout Creek, which had significantly lower unionized ammonia concentrations with respect to all other sites within the Big Creek watershed (Appendix E). None of the PWQMN sites analysed within the Big Creek watershed had concentrations above the PWQO, indicating that unionized ammonia concentrations are likely not a water quality concern.

Total Kjeldahl Nitrogen (TKN)

Total Kjeldahl nitrogen (TKN) varied widely across the watershed ranging from 0.15 mg/L in Trout Creek (site 24014) to 1.22 mg/L at site 24012 in upper Big Creek (Appendix D, Figure 32).

Significantly higher TKN values were found upstream on Big Creek relative to all other sites in the watershed (Appendix E). Concentrations within lower Big Creek (site 24011) and Venison Creek (site 24013) did not significantly differ from each other but were found to be significantly higher than site 24014 on Trout Creek which had the lowest median concentrations in the watershed (Appendix D & E). Considering ammonia levels within the watershed are fairly low, it is likely that the elevated TKN levels found are as a result of high levels of organic nitrogen reaching the creeks.

Total Nitrogen (Nitrate + Nitrite + Kjeldahl Nitrogen)

Total nitrogen is made up of three constituents: nitrate, nitrite and total kjeldahl nitrogen (TN = NO3 + NO2 + TKN) (TKN = NH4 + Organic N). Generally nitrates tended to make up greater than 84% of the total nitrogen pool at all four PWQMN sites within the Big Creek watershed (Figure 33). Organic nitrogen levels range from approximately 8% to 15%. Unionized ammonia levels generally made up less than 1% of the total nitrogen pool for the entire region ranging from 0.33% to 1%.

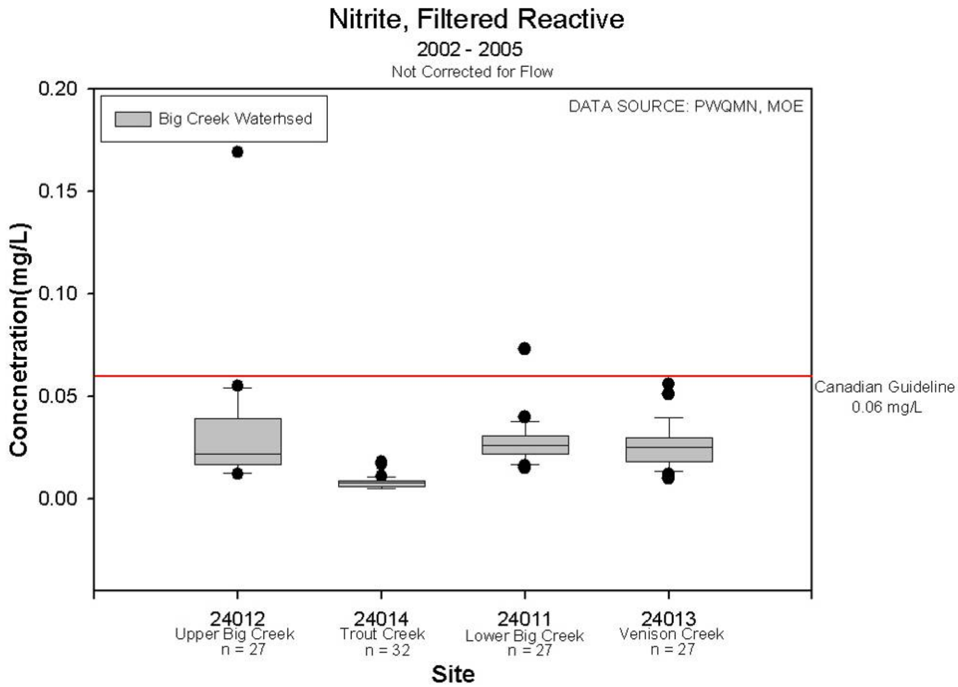


Figure 30. Nitrite concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Big Creek watershed.

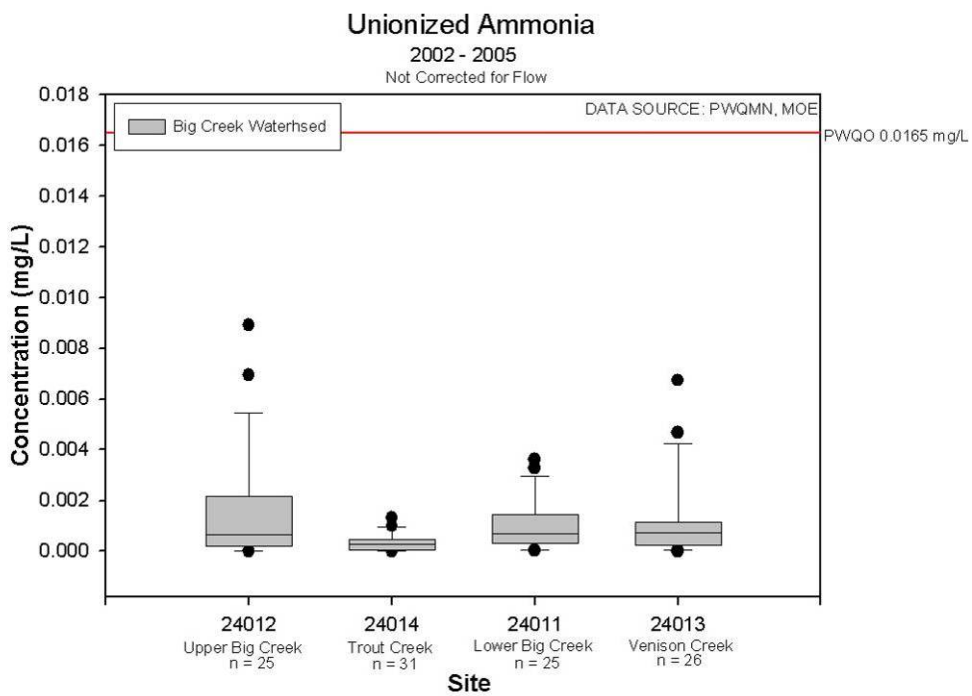


Figure 31. Unionized ammonia concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Big Creek watershed.

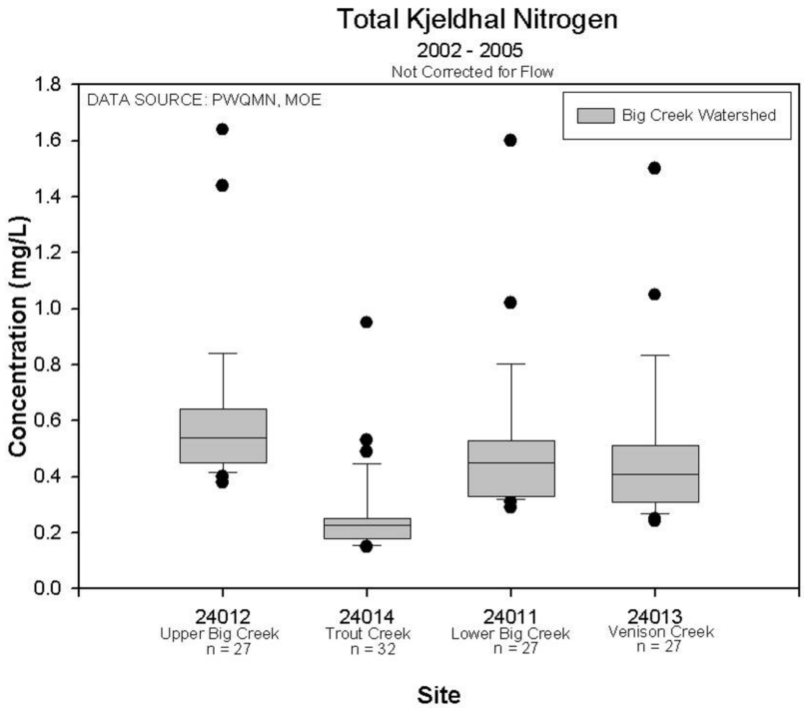


Figure 32. Total Kjeldahl nitrogen concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Big Creek watershed.

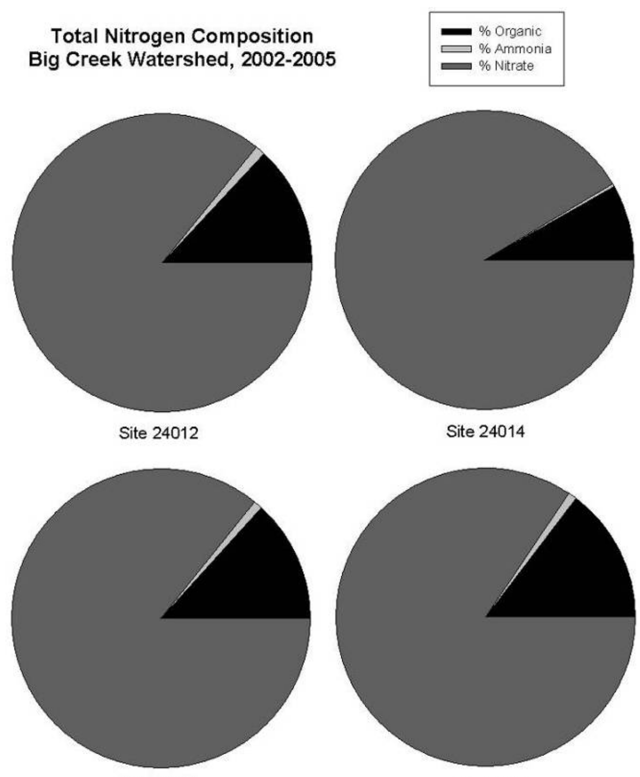


Figure 33. Composition of average total nitrogen concentrations from 2002 - 2005 at four PWQMN monitoring sites within the Big Creek watershed.

Phosphorus

Phosphorus levels within the Big Creek watershed are quite high and ranged from 0.014 mg/L within both Trout Creek and lower Big Creek to 0.2 mg/L within lower Big Creek at site 24011 (Appendix D, Figure 34). Phosphorus concentrations are more of a concern within the lower portion of the watershed indicated by the high percentage of samples (74%) with concentrations above the Provincial Water Quality Objective (PWQO) found at both site 24011 on lower Big Creek and site 24013 on Venison Creek (Appendix F).

When spatial trends were evaluated across the watershed, a significant increase from upstream to downstream along Big Creek was found ($p = 0.02$). No significant differences were found between upper Big Creek and Trout Creek ($p = 0.31$) or between lower Big Creek and Venison Creek ($p = 0.83$). Both sites within the upper portion of the watershed (site 24012 & 24014) had median concentrations significantly lower than those found within either of the lower watershed sites (24011 & 24013) (Appendix E).

The higher phosphorus concentrations found downstream are likely as a result of cumulative upstream sources. Urban contributions from Delhi may be a potential source; however, no PWQMN site was situated directly downstream of Delhi to properly assess this. Stone (1993) found that the phosphorus present in both Big and Big Otter Creeks was mainly composed of absorbed phosphorus (i.e. attached to the sediment) which is not surprising given that phosphorus and `non-filterable residue (NFR) concentrations are usually positively correlated (Wall et al. 1996).

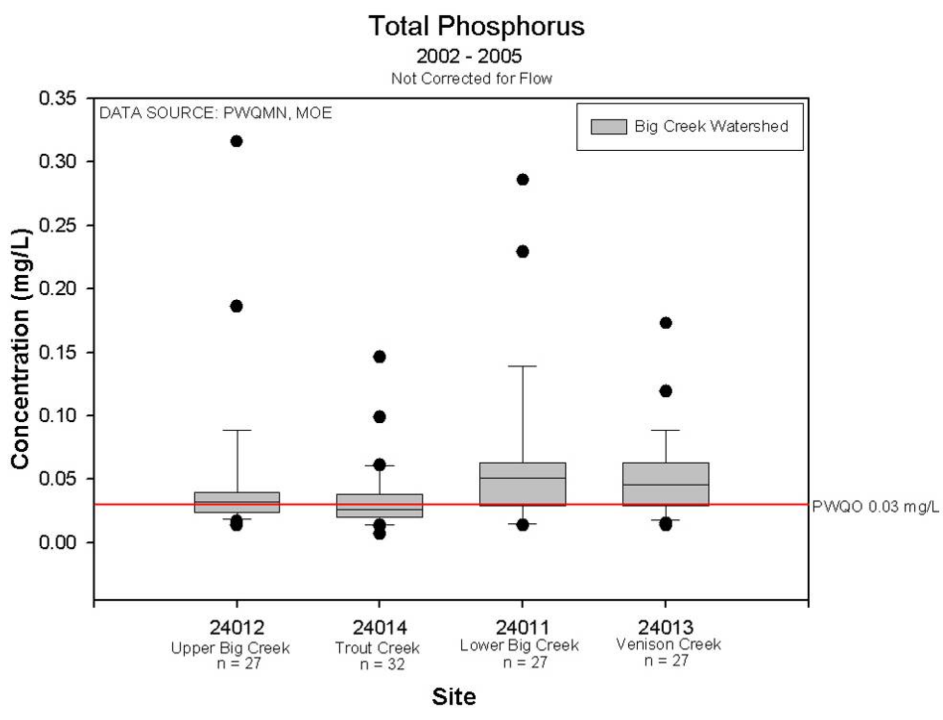


Figure 34. Phosphorus concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Big Creek watershed.

Non-filterable residue (NFR)

Non-filterable residue concentrations ranged from 1.3 mg/L at site 24012 on upper Big Creek to 95.23 mg/L at site 24011 on lower Big Creek. Median concentrations along Big Creek significantly increased from upstream to downstream. In fact, concentrations found within lower Big Creek were significantly higher than all other sites within the watershed (Appendix E, Figure 35). Trout Creek had NFR levels significantly higher than upper Big Creek (p = <0.0001) but lower than both Venison Creek and lower Big Creek (p = 0.0026 and p = 0.0027 respectively).

Occurrences of samples with concentrations above the benchmark (25 mg/L) appeared to be more of an issue within the lower portion of the watershed (lower Big Creek, 35% and Venison Creek, 27%). Within the upper watershed there were no samples within site 24012 on upper Big Creek and only a small percentage (10%) of samples taken within Trout Creek that had concentrations above the benchmark.

The higher NFR concentrations found downstream on Big Creek are likely from cumulative upstream sources and could potentially be as a result of urban inputs from the Delhi WPCP. However, with no PWQMN site situated directly downstream of Delhi, this can not be properly assessed. The lower NFR loads entering Lake Erie via Big Creek relative with other similar sized creeks in the Long Point Region (e.g. Big Otter Creek), is likely due to the increased wetland and riparian cover as well as the lower potential for runoff from the sandy soils within the Big Creek watershed. Stone (1993) found that the stream flow within the Big Creek watershed was partially regulated through several wetlands, reducing flow intensity and acting as a sediment sink thereby reducing the sediment loads reaching Lake Erie.

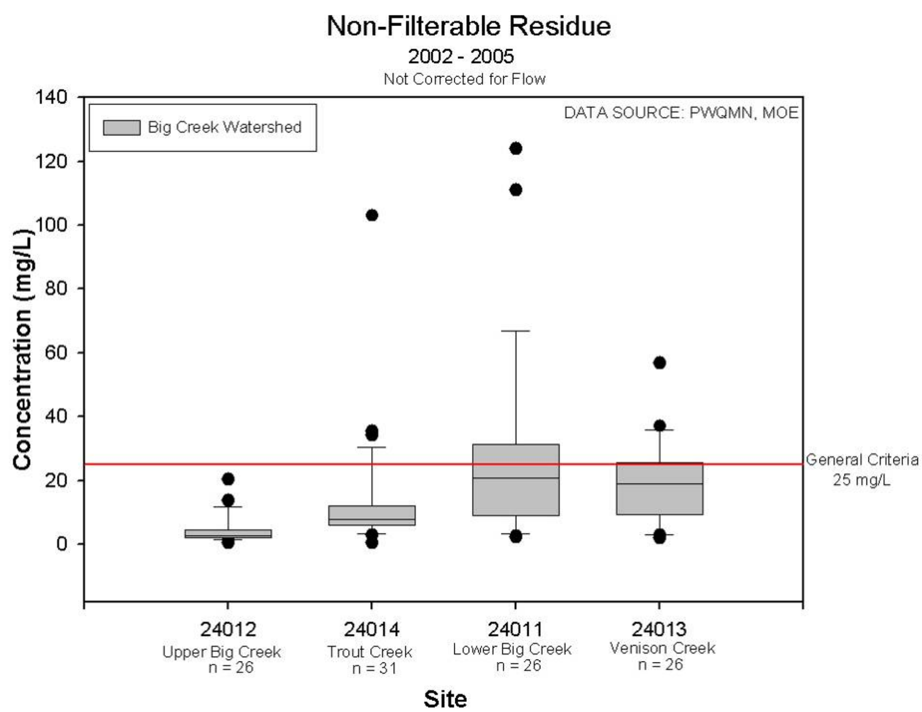


Figure 35. Non-filterable residue concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Big Creek watershed.

Chloride

Chloride levels within the Big Creek watershed do not appear to be a problem as they were well below the Environment Canada benchmark of 250 mg/L at all sites sampled. Chloride levels in the Big Creek watershed during the 2002-2005 sampling season ranged from 10.35 mg/L in Venison Creek to 30.94 mg/L in upper Big Creek at site 24012 (Appendix D, Figure 36).

Significantly higher chloride concentrations were found within Big Creek compared to concentrations within both Trout Creek and Venison Creek (Appendix E). Along Big Creek median levels appeared to slightly increase from upstream to downstream although this was not significant ($p = 0.27$). Venison Creek had the lowest median chloride concentration and values were significantly lower than all other sites in the watershed (Appendix E).

The most common source of chloride inputs is from road salting. Therefore it is likely that even higher concentrations may be found directly downstream of Delhi. However, the PWQMN sites analysed along Big Creek are likely too far downstream to capture this influence.

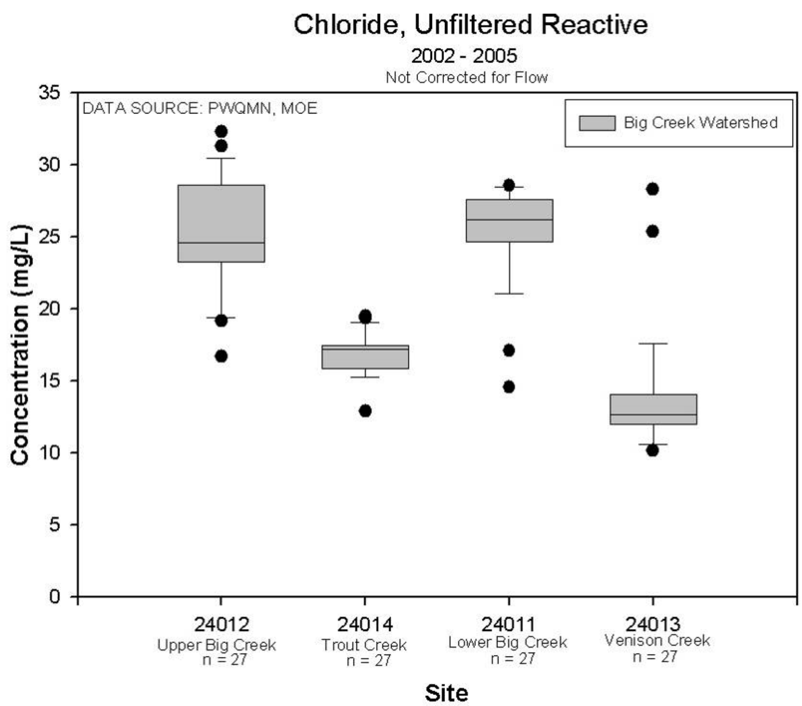


Figure 36. Chloride concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Big Creek watershed.

Bacterial Conditions

A general increasing trend from upstream to downstream in *Escherichia coli* counts was found along Big Creek. *E. coli* counts were highly variable with the widest range, 18-1400 occurring at site 24013 on Venison Creek (Figure 37). The lower bacterial counts found along Trout Creek at site 24014 could be due to the relatively low number of livestock operations within close proximity to this creek and the influence of the groundwater fed headwaters.

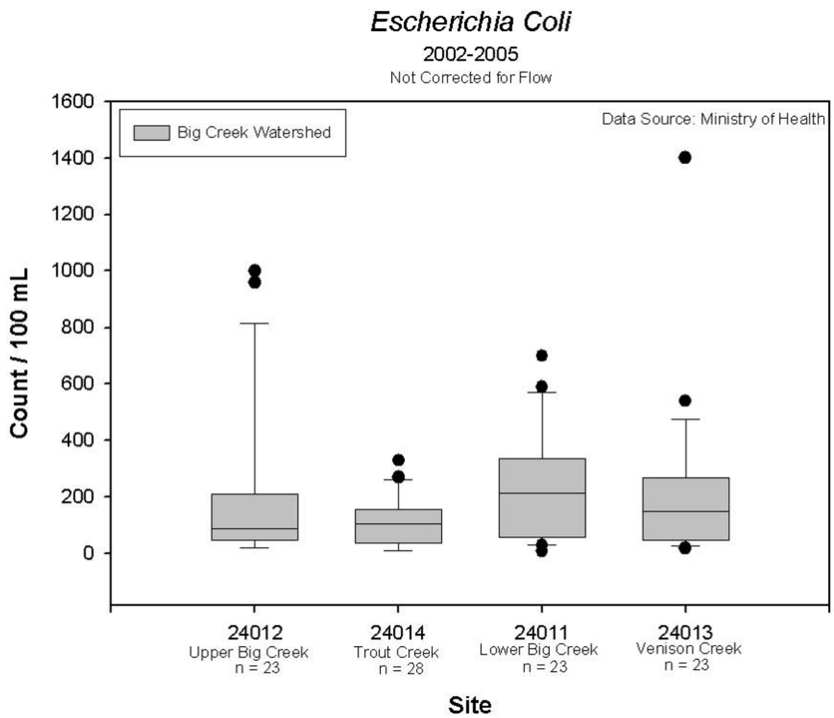


Figure 37. ***Escherichia coli*** **concentrations between 2002 and 2005 at the currently monitored PWQMN sites in the Big Creek watershed.**

Reservoir Conditions

There are four major reservoirs within the Big Creek watershed; Little Lake, Teeterville, Lehman and Deer Creek. The following discussion will be based on existing studies of water quality within the reservoirs as none of the reservoirs are routinely monitored as part of the PWQMN.

The Lehman Dam Reservoir was built to supply the Town of Delhi with a municipal drinking water system. The reservoir itself is situated on North Creek, a tributary to Big Creek, and is equipped with an operational dam but it is not used for flood control. The reservoir is also fed by South Creek which similar to North Creek has a good rainbow and brown trout fishery. Spawning has been noted to occur within both South and North Creek so the dam on North Creek has been fitted with a fish ladder to accommodate for this. The water quality within the Lehman reservoir is fairly good and meets the Canadian water quality guidelines for all parameters (nitrate, nitrite, phosphorus, dissolved oxygen, pH, and temperature) except turbidity within the deeper sections of the reservoir (Gagnon 1995). The reservoir is thermally stratified and as a result the bottom waters tend to be anoxic. Large algal blooms have been evident indicating the potential for high productivity within the reservoir. However, the presence of a good panfish fishery within the Lehman reservoir and the upstream trout spawning along both North and South Creek indicates that the water quality feeding the reservoir and the upper water column of the reservoir is likely fairly good.

Deer Creek Reservoir located within the lower part of the watershed is known for its fisheries indicated by the high fishing effort present. This reservoir is classified as a cold water reservoir and has fairly good water quality and although the habitat is able to support salmonids, most fish present are coarse and tolerant fish species (Van De Lande 1987). The most common fish is rockbass and bluegill although largemouth bass and pumpkinseed can also be found in high quantities (Gagnon 1995).

Little Lake Reservoir is used for recreation but the water quality tends to be poor. There are elevated levels of total phosphorus and turbidity; frequent algal blooms; low dissolved oxygen levels within the deeper waters and poor clarity throughout (Gagnon 1995).

Teeterville Reservior is used for both recreation and flood control. This reservoir is an old mill pond that now has a well established wetland feature in its upper reaches. Temperature loggers were deployed downstream of the Teeterville Reservoir to help characterize the impact it may be having on Big Creek. However, this data was not analysed as part of this report.

Lynn River

The area generally described as the Lynn River watershed (Figure 38) includes both the Lynn River and Black Creek watersheds. As part of the current (2002-2005) PWQMN sampling program for the LPRCA, there are no sites situated within Black Creek. However, a site at the confluence of Black Creek and the Lynn River was added in 2004 under the source water protection program. Unfortunately there is not enough data collected to date to properly analyse this site within Black Creek.

The Lynn River and Black Creek watersheds combine to cover an area of approximately 288km^2. It spans approximately 16km form north to south and 23km from east to west. The Lynn River originates just north of the town of Simcoe and is fed by three major tributaries; Davis Creek, Patterson Creek and Kent Creek (LPRCA, 1979). Black Creek originates within the eastern part of the watershed in the Galt Moraine and flows south towards Port Dover were it converges with the Lynn River before emptying into Lake Erie. Catfish Creek is the major contributing tributary while the other smaller tributaries within the Black Creek watershed are often intermittent (LPRCA, 1979).

The Lynn River and its tributaries reside mainly in the Norfolk Sand Plain while the Black Creek watershed is entirely within the Haldimand Clay Plain. This results in very different inherent water quality characteristics within these regions.

The major land-use practices within the two watersheds are also quite different. Within the Lynn River watershed specialty crops and cereals are the primary form of agriculture, where as livestock operations dominate the Black Creek watershed. There are two major urban centres within the Lynn/Black region; the Towns of Simcoe and Port Dover, both of which are within the Lynn River watershed. Both Simcoe and Port Dover have municipal water pollution control plants (WPCP); however, the proximity of the one at Port Dover to Lake Erie results in little influence on the Lynn River watershed.

There were two sites sampled as part of the PWQMN program within the Lynn River watershed during the 2002-2005 sampling season (Figure 38). The information from these sites allowed for a comparison of the Lynn River and one of its cold water tributaries, Kent Creek, as well as the potential influence the Town of Simcoe may be having on the Lynn River. In 2004, three sites were added under the source water protection program but data from these sites were not analysed (Figure 38).

To fill in the spatial gaps and compliment the findings from our analysis, a review of the findings from the 2004 state of the watershed study for the Lynn River-Black Creek watershed will also be discussed here (Gagnon & Giles, 2004).

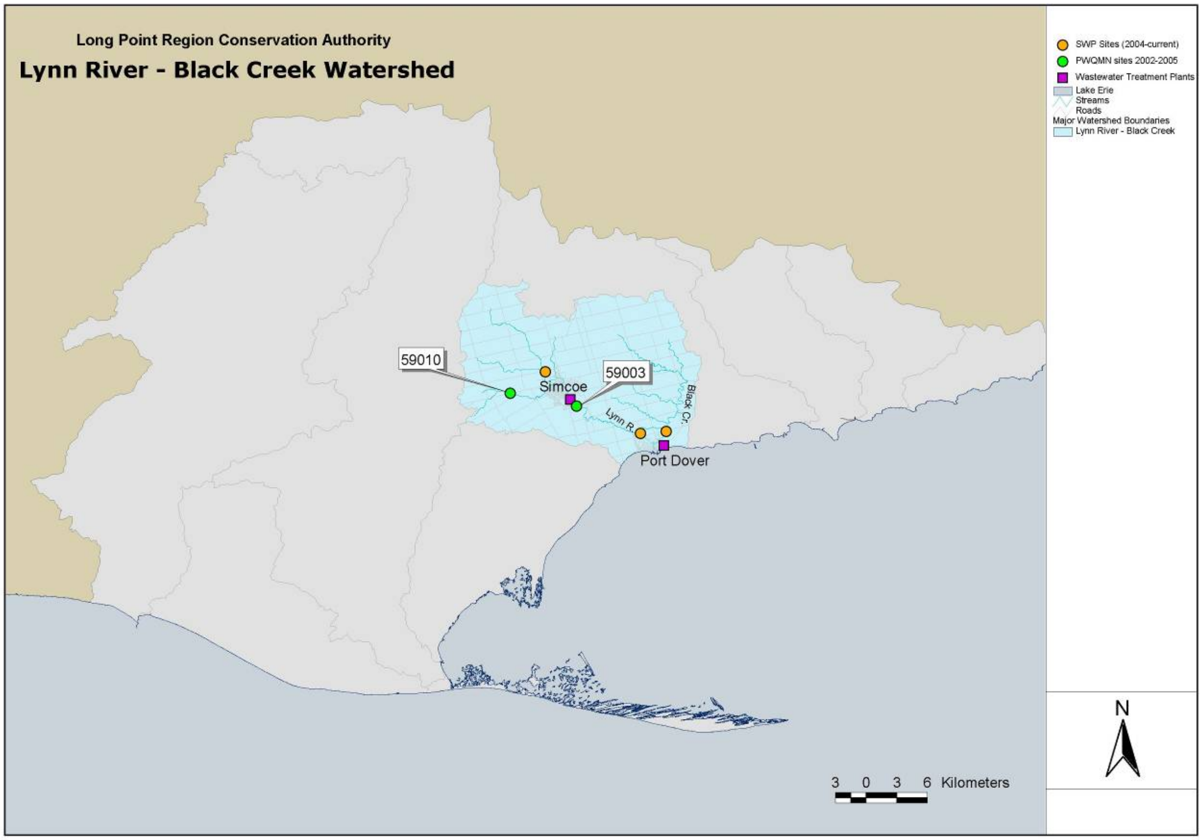


Figure 38. Lynn River – Black Creek watershed illustrating the location of the major urban areas, the water pollution control plants, the new monitoring sites under source water protection (SWP) and the PWQMN sites sampled from 2002-2005.

Physical Conditions

Streamflow

Within the Lynn and Black watersheds there is only one streamflow gauge (station 02GC008) located on the Lynn River downstream of Simcoe. Flow within the Lynn River watershed tends to be continuous and is mainly fed by ground water springs. Within the Black Creek watershed flow can be intermittent in the summer months resulting in standing pools (LPRCA, 1979). Streamflow for the six year period between 1999 and 2004 was relatively low compared with other gauge stations throughout the watersheds of the Long Point Region (Figure 39).

To give an indication of how wet or dry a particular year was relative to the long-term average (47 years from 1957-2004), the average annual flow was calculated for each year data was available during the period from 1957 to 2004. The yearly averages were then plotted with the 47 year long-term average discharge (Figure 40). Average annual flows within Lynn River were above the 47 year long term average in 2000 but below in 2001, 2002, and 2003 (Figure 40).

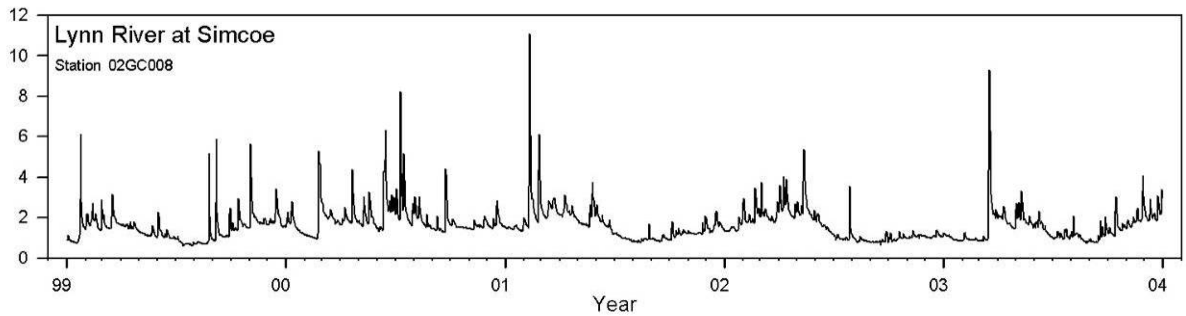


Figure 39. Flow rates at the only Water Survey of Canada gauge stations for the period from 1999-2004 within the Lynn River watershed.

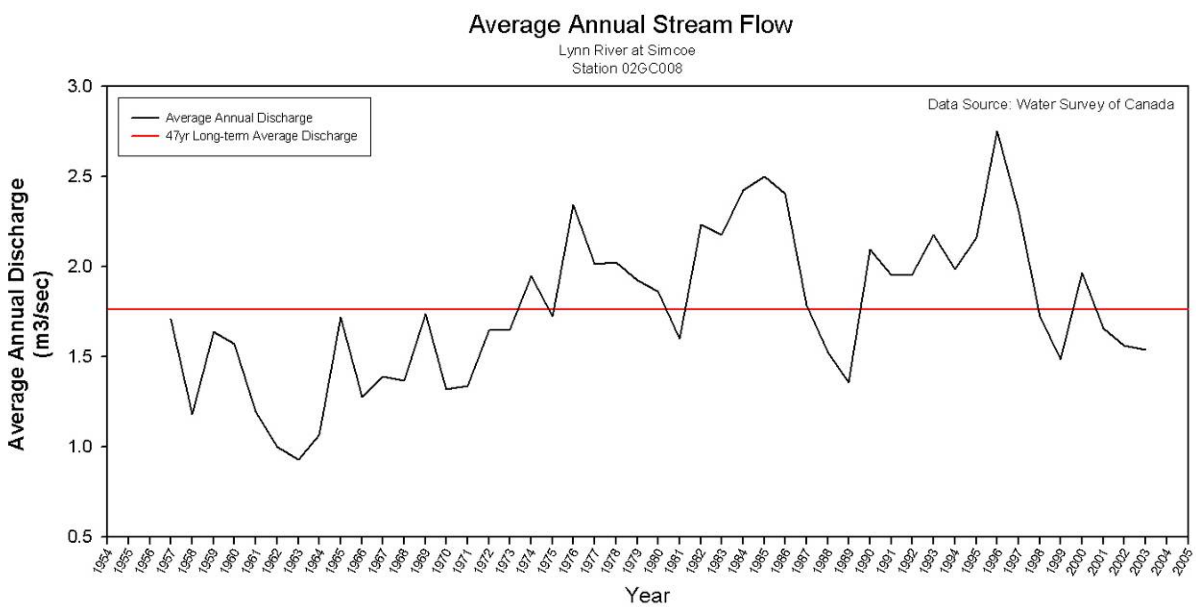


Figure 40. Average annual stream flow from 1957-2004 for station 02GC008 Lynn River at Simcoe.

PH

The pH values within the Lynn River watershed varied only slightly between the two PWQMN sampling sites and ranged from 7.2 on Kent Creek to 8.95 on the Lynn River (Appendix D). The provincial water quality objective (PWQO) for aquatic health indicates that pH should be maintained between 6.5 and 8.5. The pH levels were generally within this range and don't appear to be indicative of high productivity.

Dissolved Oxygen

Dissolved Oxygen (DO) within the Lynn River watershed never dipped below the 4 mg/L criteria for cold water fish. However, sampling generally occurred between 9a.m. and 4p.m. and as a result, the data presented here does not characterize the diurnal fluctuations in DO levels. Thus, determining if the range in dissolved oxygen concentration within the Big Otter Creek watershed was limiting to aquatic organisms could not be accurately assessed with the 2002-2005 sampling regime.

During the 2002-2005 sampling period, dissolved oxygen (DO) levels were consistently above 10 mg/L and in 2005 were reported as high as 20.64 mg/L at site 59010 along Kent Creek, which when converted to percent saturation was found to be supersaturated (>140%). Super-saturation of gases within the water can lead to gas exchange problems in aquatic life such as blood gas trauma in fish (Fidler & Miller, 1994). However, there has yet to be a criteria set for the upper limit of DO for the protection of aquatic life.

Summer Temperature

Temperature data analysed from the temperature loggers deployed at the two PWQMN sites within the Lynn River watershed indicated that summer (June, July & August) maximum daily temperatures are lowest within Kent Creek (site 59010) at 22.7°C and highest within upper the Lynn River (site 59003) at 24.5°C.

Time series plots (Appendix H) indicated that daily maximum temperatures at site 59003, downstream of Simcoe, appeared to decrease from 2002-2004 but increase in 2005. However, the occurrence of daily maximum temperatures above the 24°C threshold between cool and warm water fish species (Coker et al., 2001; Stoneman and Jones, 1996) appears to have decreased within the Lynn River at site 59003. Summer temperatures within Kent Creek were never above the 24°C threshold.

Nutrient Conditions

Generally Kent Creek (a groundwater fed creek with minimal urban or agricultural impacts) had good water quality and was significantly less impaired compared to the Lynn River. Nitrite, unionized ammonia and phosphorus concentrations were routinely high and are of particular concern within the Lynn River downstream of Simcoe. Gagnon & Giles (2004) performed a comprehensive watershed study for both the Lynn River and Black Creek watersheds, in which they found the Lynn River to have the highest nutrient loads. However, tributaries within the Black Creek watershed were still found to have higher NFR and lower DO levels relative to some of the cold water creeks within the Lynn River watershed (e.g. Kent Creek) (Gagnon & Giles 2004).

Nitrate

Nitrate levels within the Lynn River watershed ranged from 2.0 mg/L within Kent Creek to 4.2 mg/L within the Lynn River downstream of Simcoe (Appendix D, Figure 41). The concentrations found within the Lynn River downstream of Simcoe were significantly higher than those found within Kent Creek (p = 0.0007). Samples taken at site 59003 on the Lynn River had concentrations above the Canadian guideline 44% of the time which was almost twice the number of exceedences observed at site 59010 within Kent Creek (26%)

The major source of nitrate is likely run-off from fertilized lands surrounding Simcoe or from field tile drainage entering the river system. LPRCA (1979) found that nitrate levels were higher within the Lynn River compared to the Black River and generally increased along the Lynn River from upstream to downstream which they also attributed to fertilizer inputs.

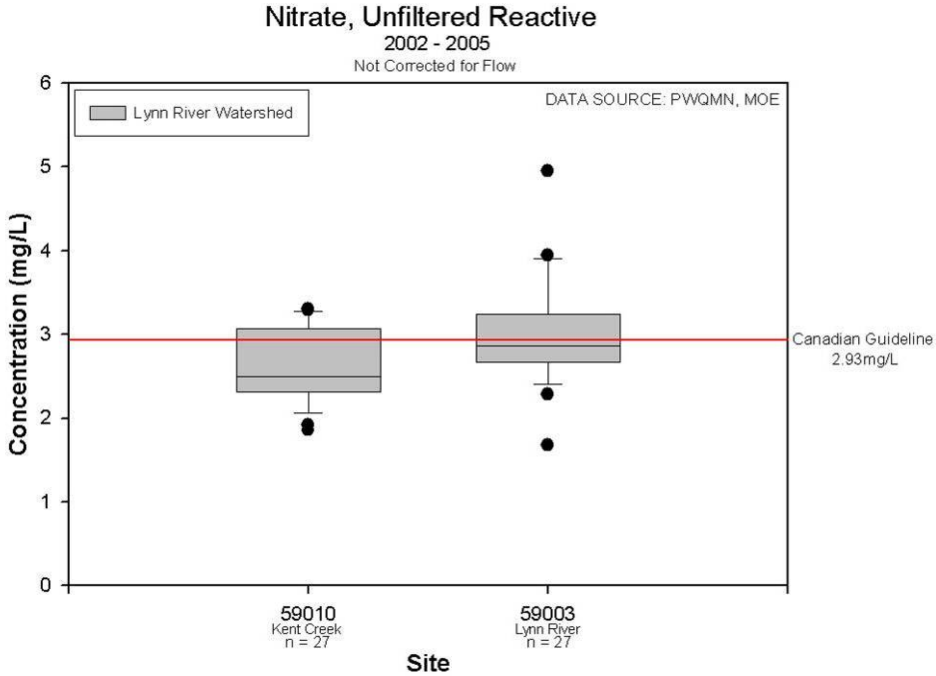


Figure 41. Nitrate concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Lynn River watershed.

Nitrite

Nitrite concentrations ranged from 0.01 mg/L at site 59010 on Kent Creek to 0.31 mg/L at site 59003 on Lynn River (Appendix D Figure 42). Median nitrite levels significantly varied between the two sites (p = <0.0001). Nitrite levels within the Lynn River, downstream of Simcoe, were found to be almost an order of magnitude higher than those within Kent Creek. Samples with concentrations above the Canadian guideline were only found within the Lynn River. Continually high nitrite concentrations such as those found within the Lynn River are a major concern as levels above the guideline are considered to be extremely toxic to aquatic life.

High nitrite concentrations tend to be indicative of organic pollution through the disposal of sewage or organic waste (Hem, 1985; Hydromantis Inc. et al. 2005).

Unionized Ammonia

Unionized ammonia levels varied widely between the Lynn River and Kent Creek sites. Concentrations ranged from $1.5e^{-5}$ mg/L within Kent Creek to 0.06 mg/L in Lynn River which is well above the 0.0165 mg/L provincial water quality objective (Appendix D, Figure 43).

Generally unionized ammonia values within Kent Creek were an order of magnitude lower than those found within the Lynn River, which had significantly higher concentrations. Samples taken from Kent Creek were never observed above the PWQO; however, 35% of the samples taken within the 2002-2005 season at site 59003 on the Lynn River had recorded concentrations above the objective.

Similar to nitrite, the likely source of the elevated unionized ammonia levels is upstream organic pollution.

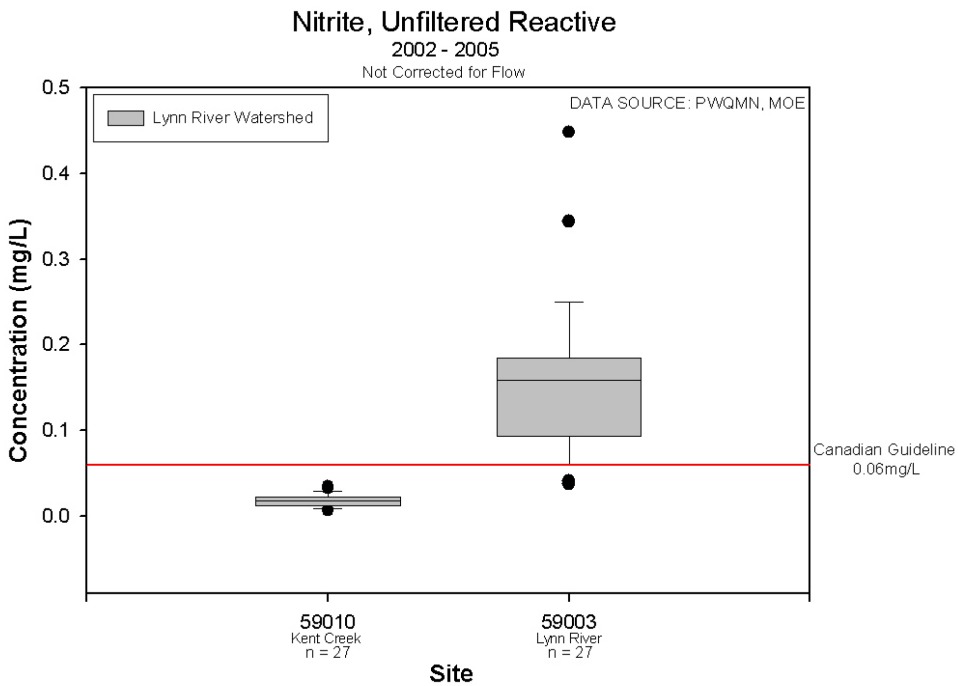


Figure 42. Nitrite concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Lynn River watershed.

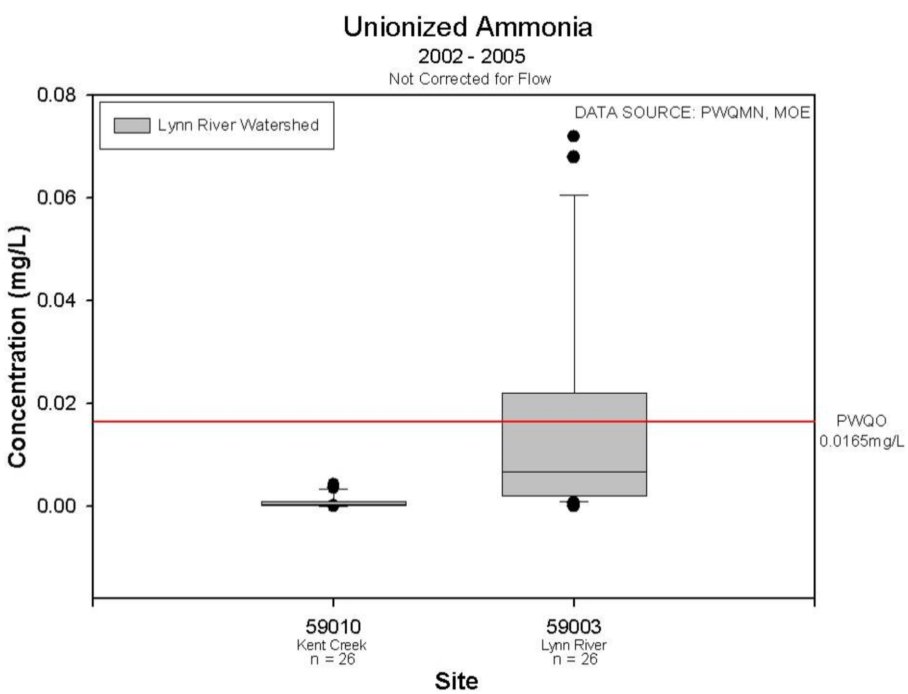


Figure 43. Unionized ammonia concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Lynn River watershed.

Total Kjeldahl Nitrogen (TKN)

Total Kjeldahl nitrogen is the combined total of organic nitrogen and ammonium. TKN concentrations varied widely within and between both sites, ranging from 0.27 mg/L within Kent Creek to 1.53 mg/L within the Lynn River (Appendix D, Figure 44). Again, levels within the Lynn River were significantly higher than those found within Kent Creek (p = <0.0001). Similar findings were also observed by Gagnon & Giles (2004).

The TKN concentrations within the Lynn River are among the highest found across the entire Long Point Region. This is likely due to the elevated unionized ammonia levels also found within the Lynn River.

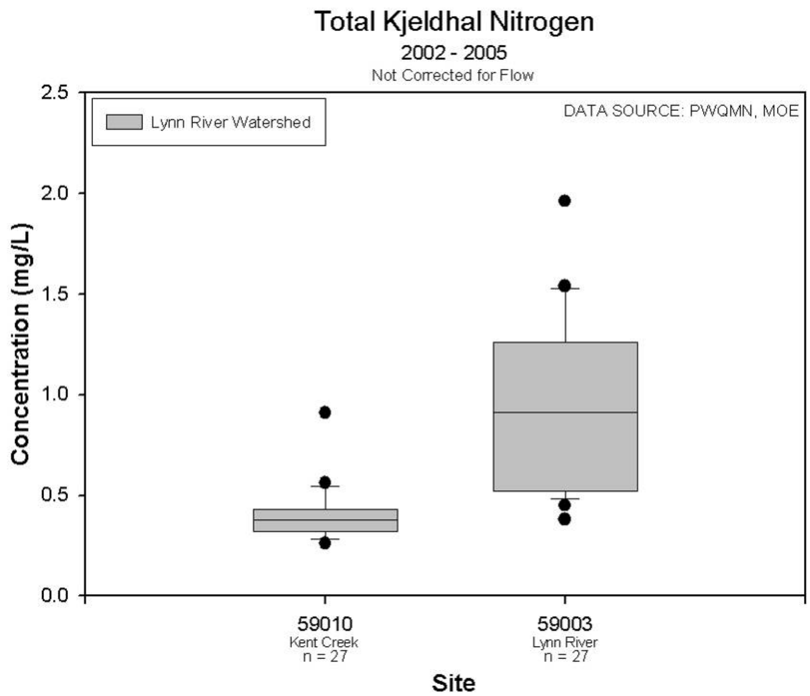


Figure 44. Total Kjeldahl nitrogen concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Lynn River watershed.

Total Nitrogen (Nitrate + Nitrite + Kjeldahl Nitrogen)

Total nitrogen is made up of three constituents: nitrate, nitrite and total Kjeldahl nitrogen (TN = NO_3 + NO_2 + TKN) (TKN = NH_4 + Organic N). On average nitrates tend to make up greater than 75% of the total nitrogen pool at both PWQMN sites within the Lynn River watershed (Figure 45). Organic nitrogen levels were moderate and ranged from approximately 12% to 14%. Unionized ammonia levels made up less than 1% of the total nitrogen pool at site 59010 on Kent Creek; however, at site 59003 within the Lynn River ammonia comprised 10% of the nitrogen pool, which was orders of magnitude higher than any other site sampled across the entire Long Point Region.

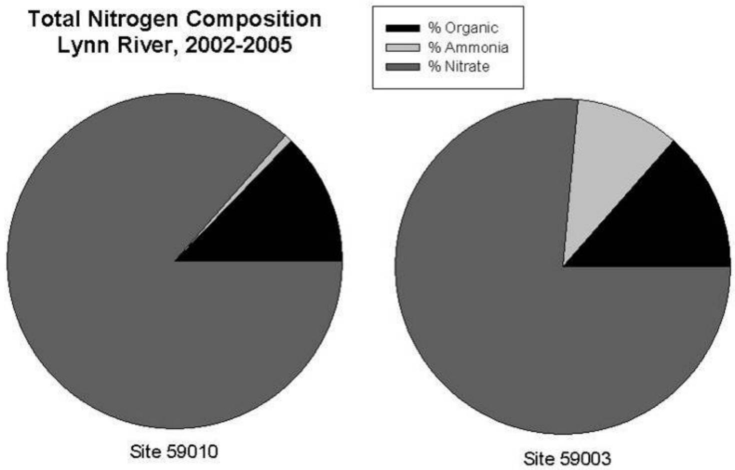


Figure 45. Composition of average total nitrogen concentrations from 2002 - 2005 at two PWQMN monitoring sites within the Lynn River watershed.

Phosphorus

Phosphorus concentrations within the Lynn River were significantly higher than those found in Kent Creek (p = <0.0001), with levels ranging from 0.03 mg/L to 0.17 mg/L (Appendix D, Figure 46). Phosphorus levels within the Lynn River were routinely above the PWQO (93% of the samples were above) during the 2002-2005 sampling season. Phosphorus concentrations within Kent Creek ranged from 0.01mg/L to 0.04 mg/L and were found to be above the PWQO 18% of the time during the 2002-2005 sampling season.

The significantly higher concentrations found within the Lynn River are likely as a result of urban inputs from the town of Simcoe as well as cumulative inputs from upstream agricultural practices.

Compared to other Lake Erie tributaries the Lynn River does not appear to be a major contributor of total phosphorus to Lake Erie, which was also found during the 1979 study of the watershed (LPRCA, 1979). However, high levels of phosphorus have been found within Crystal Lake along the upper Lynn River (above Simcoe). It is therefore thought that these water features are potentially acting as a buffer to the movement of phosphorus downstream due to their influence on sediment movement (LPRCA 1979). The same is also thought for Silver Lake near Port Dover.

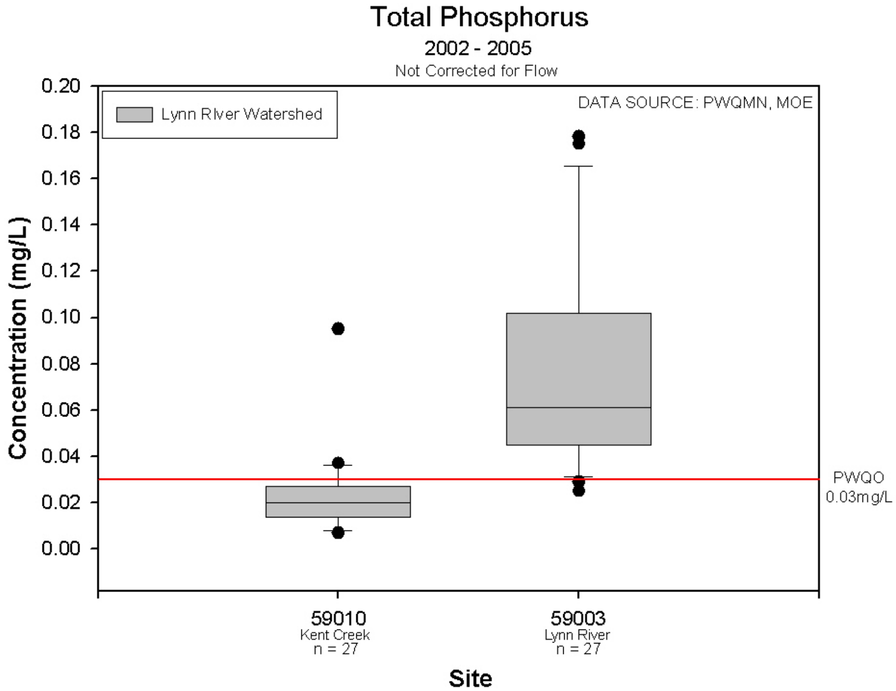


Figure 46. Phosphorus concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Lynn River watershed.

Non-filterable residue (NFR)

Non-filterable residue does not appear to be elevated within either Kent Creek or the Lynn River and ranged from 0.67 mg/L within Kent Creek to 29.08 mg/L within the Lynn River (Appendix D, Figure 47). However, Brooks Dam, situated upstream of the sampling site on the Lynn River, could be acting as a sediment sink and biasing results. Currently this dam is being decommissioned so future results may indicate if this was in fact the case. NFR levels within the Lynn River downstream of Simcoe were significantly higher than those found in Kent Creek (p = <0.0001). NFR levels in Kent Creek never exceeded the criteria for aquatic health (25 mg/L) and remains at suitable levels for the continued support of a cool-cold water fisheries (CCME, 1999).

Erosion is of concern throughout both the Lynn River and Black Creek watersheds. The Lynn River tends to be susceptible to wind erosion across the sand plain and urban erosion during high flow events (i.e. storm water from urban drains tend to increase flows). Within the Black Creek watershed sheet and stream bank erosion are more prevalent due to the clay soils, lack of vegetative cover and the high percentage of livestock operations in the area with stream bank access and other poor farming practices (LPRCA, 1979; Gagnon & Giles, 2004). Gagnon & Giles (2004) also found that NFR concentrations were higher within Black Creek and its tributaries relative to the levels generally found within the Lynn River watershed.

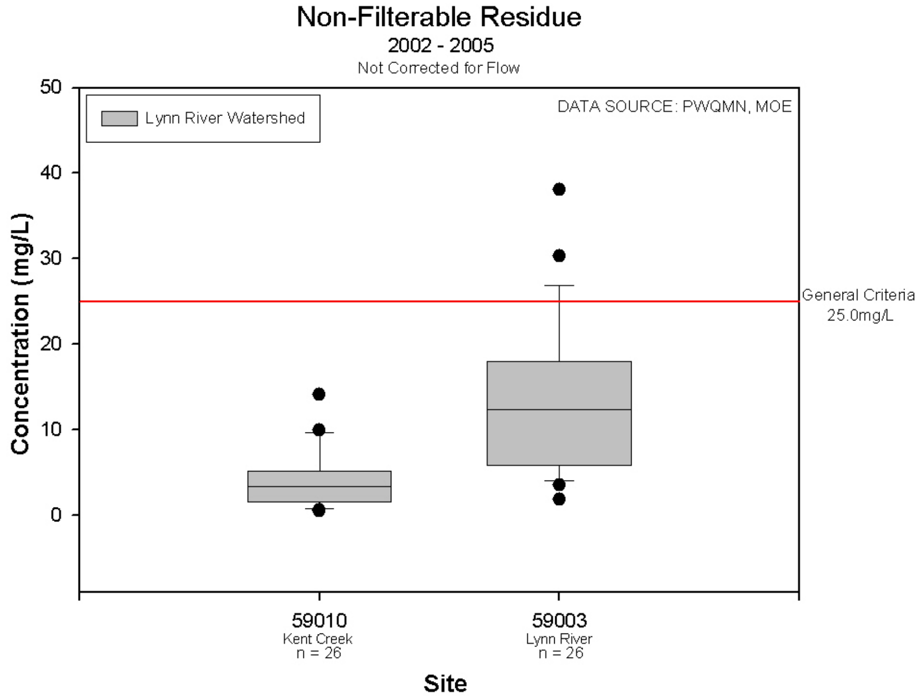


Figure 47. Total non-filterable residue concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Lynn River watershed.

Chloride

Chloride levels within both Kent Creek and the Lynn River were well below the 250 mg/L benchmark and as such do not appear to currently be a concern (Figure 48). Chloride levels were significantly higher downstream of Simcoe on the Lynn River compared to the concentrations found within Kent Creek (p = <0.0001). This is likely as a result of localized road salting within the town of Simcoe. In fact median chloride within the Lynn River was the highest across the entire Long-Point Region, likely due to the sampling site's closer proximity to a major urban area compared to other sites across the region.

Pesticides

As part of the Lynn River State of the Watershed study, pesticides were sampled once on August 28, 2002 along four tributaries within the watershed, Kent Creek, Patterson Creek, Davis Creek, and Lynn River. All samples had concentrations less than the detection limit for each of the pesticides analysed for.

Bacterial Conditions

Escherichia Coli counts were quite variable along the Lynn River ranging from 10-4000 counts/100mL at site 59003 (Figure 49). A much smaller range of values were found within Kent Creek (10-350 counts/100mL). The higher values found within the Lynn River are likely influenced by the upstream water pollution control plant in the town of Simcoe as well as nearby wildlife populations and runoff from surrounding livestock operations. Other sources could include nearby livestock operations with stream access or run-off from nearby manure pads.

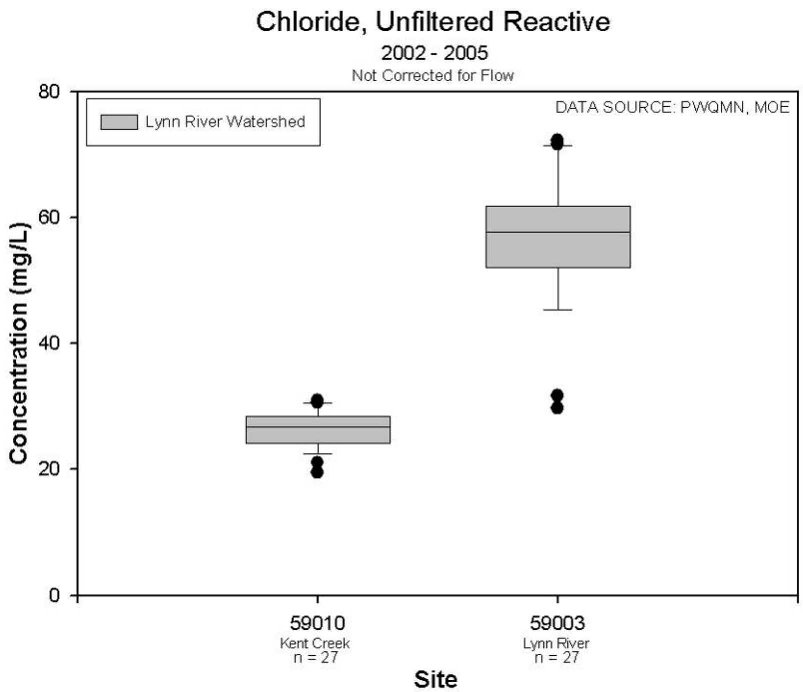


Figure 48. Chloride concentrations between 2002 and 2005 at three PWQMN monitoring sites in the Lynn River watershed.

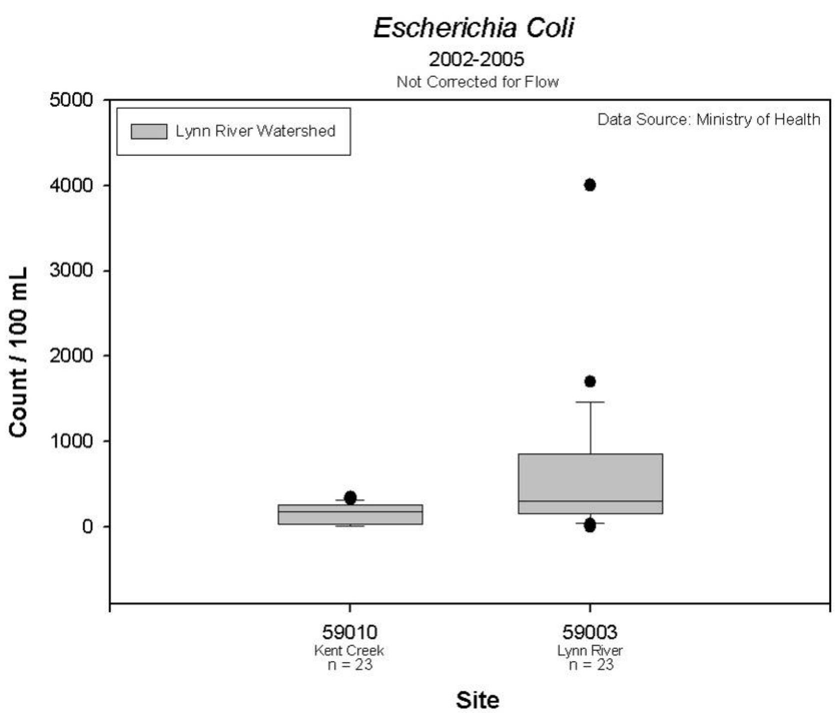


Figure 49. *Escherichia coli* concentrations between 2002 and 2005 at the currently monitored PWQMN sites in the Lynn River watershed.

Reservoirs

Historically there were two main reservoirs in the town of Simcoe, Sutton Pond and Lake George. In the past Sutton Pond was known to be a sediment sink so was likely high in phosphorus and NFR. However, in May of 2004 this pond was permanently drawn down and is now re-establishing itself as a watercourse. Lake George, created by Quance Dam, is used for recreation and due to its shallow nature tends to have a warming influence on the Lynn River.

Within Port Dover a privately owned dam (Misner Dam) has created a large reservoir known as Silver Lake, which is currently used for recreation.

Nanticoke Creek

The Nanticoke Creek watershed is approximately 180 km^2. The watershed begins just south of the hamlet of Scotland and travels south approximately 10km to the town of Waterford. The Creek then travels east for 11km at which point it turns south and travels 16km to where it empties into Lake Erie near the village of Nanticoke (Figure 50). The total length of the creek is approximately 43km with an average drop in elevation of 1.44 m/km (LPRCA 1979).

The Nanticoke Creek drains two physiographic regions, the Norfolk Sand Plain in the northeastern corner, where the headwaters originate, and the Haldimand Clay Plain comprising the rest of the watershed. The headwaters are groundwater fed so tend to supply the creek with a continuous base-flow (LPRCA 1979).

The major urban centres within the Nanticoke Creek watershed are the town of Waterford and the village of Townsend both of which have there own water pollution control plant (WPCP). Agriculture within the northern portion of the watershed is predominately tobacco, peanuts and rotating grains, where as livestock operations are the dominant agriculture practice within the rest of the watershed. There is also a small industrial area within the village of Nanticoke near the Lake Erie shore.

There was only one site sampled as part of the PWQMN program within the Nanticoke Creek watershed during the 2002-2005 sampling season (Figure 7). This did not allow for any comparisons throughout the watershed but can provide insight into the cumulative effect the watershed is having on the downstream water quality and potentially Lake Erie. To better understand where within the watershed potential inputs and sources of contaminations are, historic data from 1982-1986 was also analysed. Within the 1982-1986 sampling season there were six PWQMN sites monitored (Figure 50). The information from these sites allowed for upstream / downstream comparisons along Nanticoke Creek, the investigation of the potential influence from the town of Waterford and the village of Townsend (including the WPCPs), and the potential influence Nanticoke Creek may having on Lake Erie.

Physical Conditions

Streamflow

The Nanticoke Creek watershed only has one streamflow gauge station, located downstream near the mouth of the creek. Streamflow for the six year period between 1999 and 2004 on Nanticoke Creek was of similar magnitude to that found within Big Creek (Figure 51 & 26).

To give an indication of how wet or dry a particular year was relative to the long-term average (35 years from 1969-2004), the average annual flow was calculated for each year data was available during the period from 1969 to 2004 for station 02GC022. The yearly averages were then plotted with the 35 year long-term average discharge (Figure 52). Average annual flows within Nanticoke Creek were slightly above the 35 year long term average in 2000 but below in 2001, 2002 and 2003 (Figure 52).

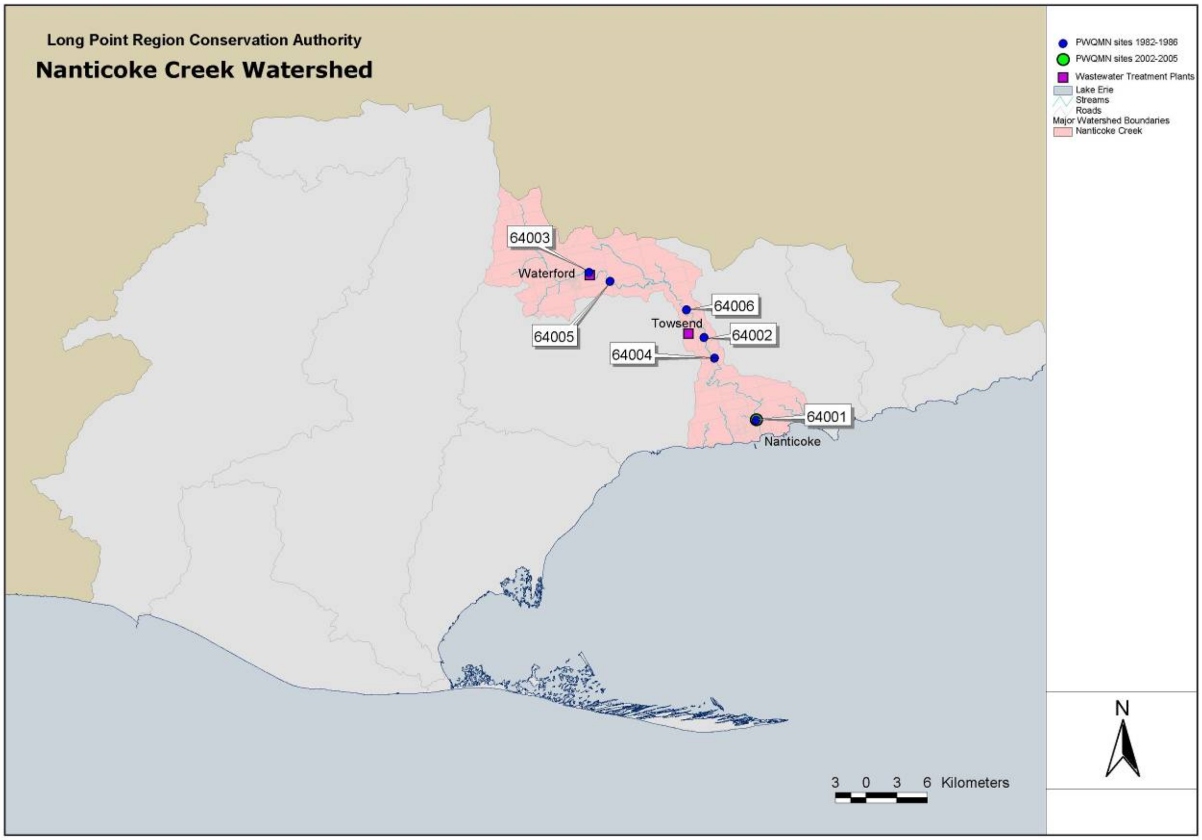


Figure 50. Nanticoke Creek watershed illustrating the location of the major urban areas, the water pollution control plants, and the PWQMN sites sampled from 1982-1986 and 2002-2005.

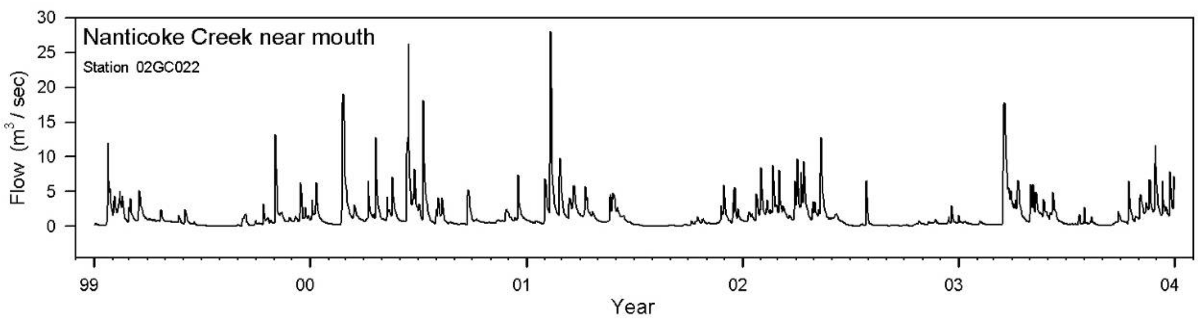


Figure 51. Flow rates at the only Water Survey of Canada gauge stations for the period from 1999-2004 within the Nanticoke Creek watershed.

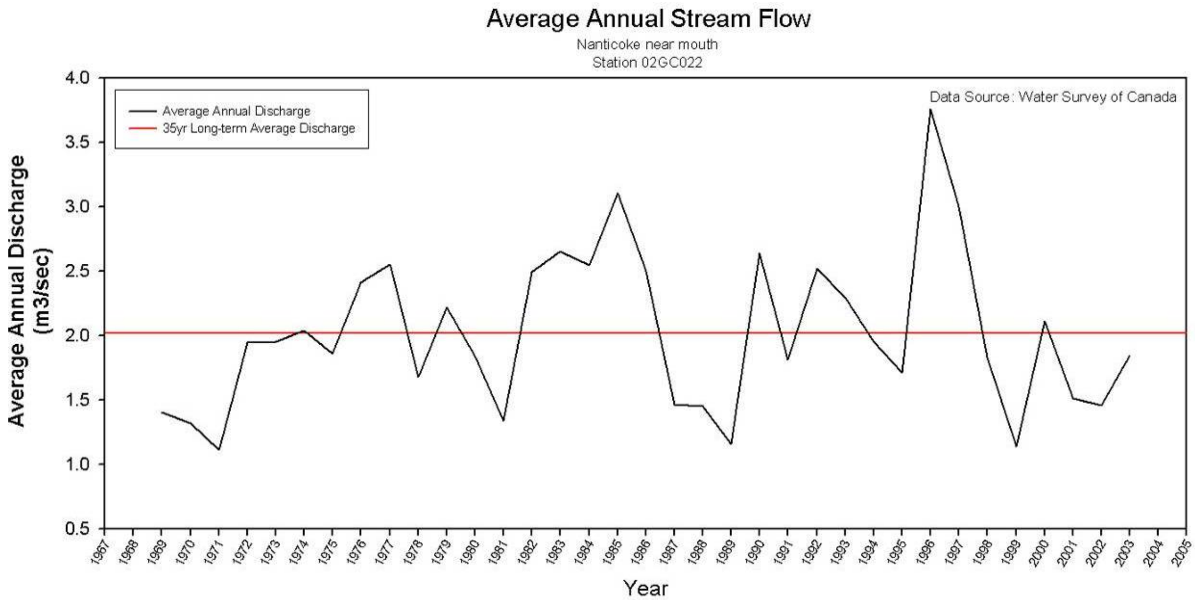


Figure 52. Average annual stream flow from 1960-2004 for station 02GC022 Nanticoke Creek near creek mouth at Port Dover.

PH

The pH values varied only slightly between the six PWQMN sampling sites and ranged from 6.8 at site 64001 furthest downstream on Nanticoke Creek to 8.7 also at site 64001 and 8.6 at all other sites within the watershed (Appendix D). The Provincial Water Quality Objective (PWQO) for aquatic health indicates that pH should be maintained between 6.5 and 8.5. The pH values throughout the Nanticoke Creek watershed appeared to be closer to the upper end of the range and between one and three samples taken at all sites had values above the recommended range. pH values higher than 8.5 can be indicative of productivity.

Dissolved Oxygen

Dissolved Oxygen within the Nanticoke Creek watershed never dipped below the 4 mg/L criteria for cold water biota and ranged from 4.9 mg/L at site 64004 to 14.0 mg/L at site 64005 (Appendix D). Median and maximum DO levels were much higher within site 64001 for the 2002-2005 monitoring period, relative to the 1982-1986 data for the same site indicating that DO levels have generally been increasing over time. Dissolved oxygen concentrations were reported as high as 20.06 mg/L at site 64001 during the 2002-2005 seasons, which when converted to percent saturation was found to be supersaturated (>140%).. Super-saturation of gases within the water can lead to gas exchange problems in aquatic life such as blood gas trauma in fish (Fidler & Miller, 1994). However, there has yet to be a criteria set for the upper limit of DO for the protection of aquatic life.

However, sampling generally occurred between 9a.m. and 4p.m. and as a result, the data presented here does not characterize the diurnal fluctuations in DO levels. Thus, determining if the range in dissolved oxygen concentration within the Big Otter Creek watershed was limiting to aquatic organisms could not be accurately assessed with either the 1982-1986 or 2002-2005 sampling regime.

Nanticoke Creek starts in the northern part of the watershed as a cold water system which drains over a portion of the Norfolk Sandplain. Once the creek travels through Waterford, it begins to drain the Haldimand Clay Plain and water temperatures begin to rise. Decreasing dissolved oxygen levels have been found downstream of Waterford beyond which point the Creek has been identified as no longer suitable habitat for cold water fish (Van De Lande, 1987). G. Douglas Vallee Ltd (2004) speculated that the low dissolved oxygen levels found in the summer were likely as a result of the high percentage of summer base-flow being comprised of the effluent from the Waterford WPCP, which is then compounded by the higher BOD concentrations of the effluent. Norfolk County has since developed a contingency plan detailing the necessary monitoring and appropriate actions required to mitigate these impacts.

Summer Temperature

Temperature data analysed from the temperature loggers deployed at the current PWQMN sites within the Nanticoke Creek watershed indicated that summer (June, July & August) maximum daily temperatures were quite high and ranged between 26°C to 30°C. A time series plot (Appendix H) indicated that daily maximum temperatures appear to be on the rise.

Nutrient Conditions

The Nanticoke Creek watershed is not considered to be a major contributor of nutrient loads to Lake Erie (LPRCA 1979). The headwaters within the Norfolk Sand Plain tend to have better water quality compared to the rest of the Creek which resides within the Haldimand Clay Plain (Van De Lande 1987).

Total phosphorus and non-filterable residue concentrations are the most significant water quality issues within the Nanticoke Creek watershed and appeared to progressively increase from upstream to downstream.

Generally, within the Nanticoke Creek watershed nutrient concentrations significantly increase as the creek flows out of the Norfolk Sandplain and into the Haldimand Clayplain. The Waterford Water Pollution Control Plant (WPCP) located on the clay plain likely adds to this. This increase within the upper portion of the watershed is likely as a result of the cumulative urban impact from the town of Waterford, the WPCP effluent and the transition in soil types within the contributing drainage area from sandy to clay based soils.

Nitrate

Nitrate concentrations within the Nanticoke Creek watershed ranged from 0.13 mg/L at site 64001 near the mouth of Nanticoke Creek to 4.17 mg/L also at site 64001(Appendix C, Figure 53).

Median nitrate concentrations were highest midway along the Nanticoke Creek at site 64006 after which point concentrations generally decrease as the creek flowed downstream; however, this trend was not significant (Figure 53). When median values for the six PWQMN sites sampled during the 1982-1986 monitoring season were statistically analysed using a Kruskal-Wallis test, a significant difference was found ($p = 0.01$). To spatially determine where within the watershed these differences occurred, a series of Mann-Whitney tests were carried out. As previously mentioned, no significant difference was found between sites 64006, 64002, 64004 & 64001, which are situated within the middle and lower portions of the watershed. The significant increase in nitrate concentrations between sites 64005 and site 64006 indicates that there is an additional source of nitrate besides the Waterford WPCP effluent occurring between these sites. Likely the change in geology of the surrounding lands from a clay and sand mix to only clay has allowed for an increase in the run-off from fertilized lands to reach the creeks, thereby increasing the amount of nitrate that enters as well. Earlier studies found that there was a seasonal pattern to nitrate loading within Nanticoke Creek, which generally peaked during the spring and fall run-off events (LPRCA, 1979). Within upper Nanticoke Creek site 64003 (furthest upstream), had a lower median concentration than site 64005 downstream of the Waterford WPCP, although this increase was not significant. However, concentrations found upstream at site 64003 and 64005 had significantly lower nitrate concentrations than sites 64006 and 64002 midway along the Creek.

Median nitrate concentrations at all sites sampled from 1982-1986 were below the Canadian Guideline. The number of times a sample was recorded above the Canadian Guideline for nitrate, 2.93 mg/L, was highest downstream of Townsend and its WPCP at site 64002 and site 64004, with 26% of the samples above the guideline at both sites. The lowest exceedances were found upstream at sites 64003 (no samples with concentrations above the guideline) and 64005 (5% of samples above).

The lower concentrations found within the upstream waters is likely as a result of the geology within which the headwaters reside, (the Norfolk Sand Plain), the lower degree of run-off and the fewer urban influences. Within the upper watershed there is only the influence of one WPCP compared with the cumulative influence of 3 within the lower watershed.

When median concentrations for site 64001, furthest downstream on Nanticoke Creek, during the 1982-1986 and the 2002-2005 sampling seasons were compared, no statistical differences were found. However, the median concentration found during the 2002-2005 season was lower than that for the 1982-1986 season and the lack of a significant difference may be due to the extreme variation in nitrate values observed for the 2002-2005 period.

Nitrite

Nitrite levels within the watershed varied only slightly between sites and ranged from 0.002 mg/L at the site 64003, furthest upstream on Nanticoke Creek to 0.12 mg/L at site 64005 directly downstream of the Waterford WPCP (Appendix D, Figure 54).

No significant differences were found for nitrite concentrations between the six sites along the Nanticoke Creek. Median nitrite levels were highest in the upper portion of the watershed at site 64005 just downstream of the Waterford WPCP. Beyond site 64005 nitrite concentrations progressively decreased as the creek flowed towards the mouth. Although slightly higher median nitrite values were found at site 64001 during the 2002-2005 season, concentrations did not significantly change over time.

Median nitrite levels at all sites are well below the Canadian Guideline (0.06 mg/L). Site 64005, directly downstream of the Waterford WPCP had the greatest number of samples (29%) with concentrations above the Guideline, where as all other sites had between 14% and 16% of their samples above the guideline (Appendix F).

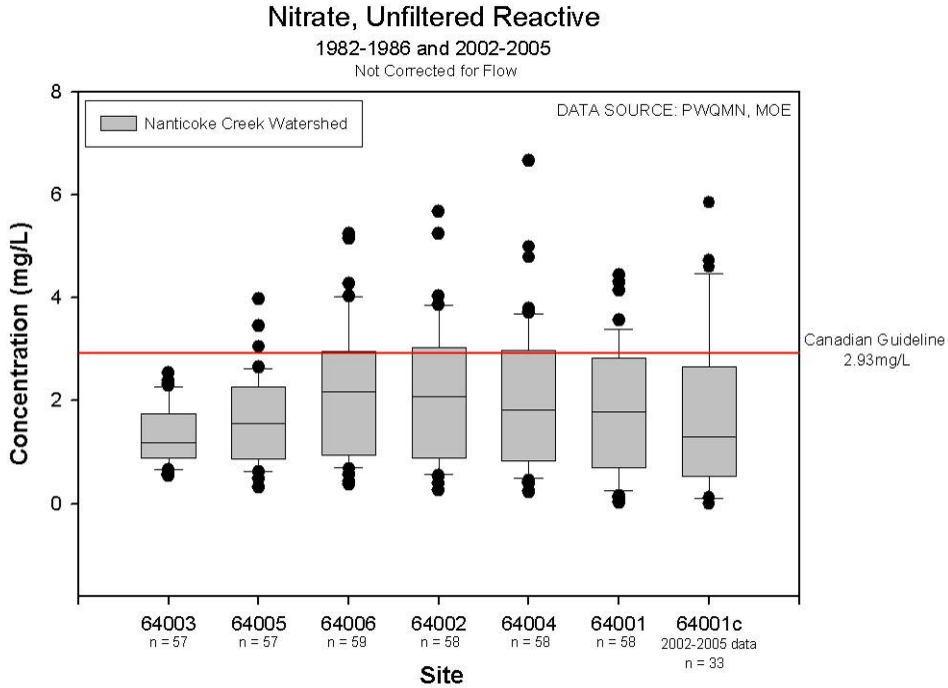


Figure 53. Nitrate concentrations between 1982 and 1986 at six PWQMN monitoring sites in and from 2002-2005 at one PWQMN monitoring site (64001) within the Nanticoke Creek watershed.

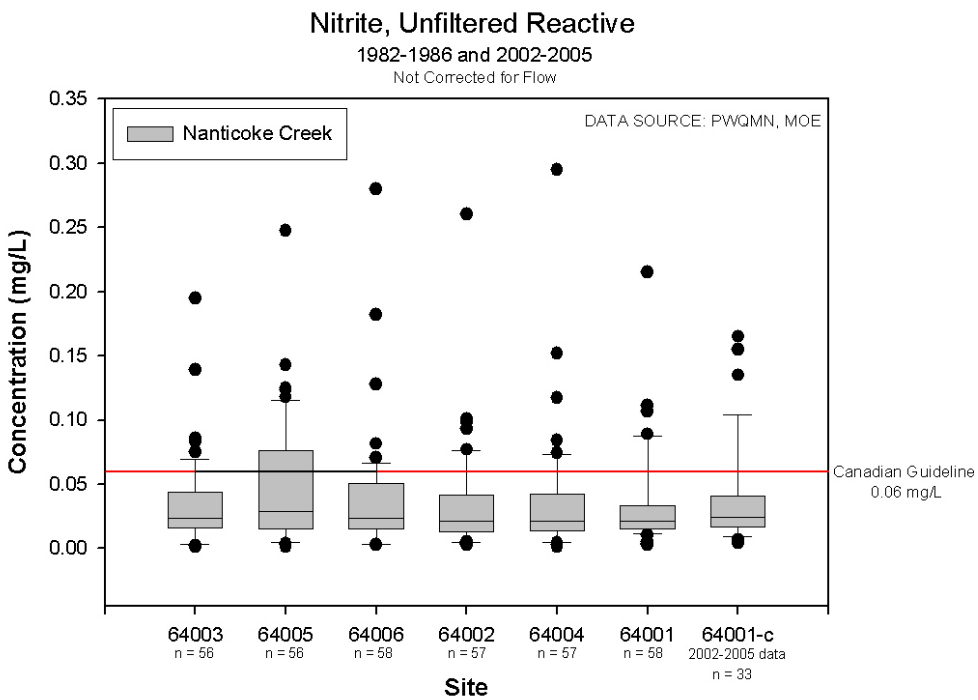


Figure 54. Nitrite concentrations between 1982 and 1986 at six PWQMN monitoring sites in and from 2002-2005 at one PWQMN monitoring site (64001) within the Nanticoke Creek watershed.

Unionized Ammonia

Unionized Ammonia concentrations within Nanticoke Creek varied only slightly between sites and did not appear to be an issue, as most values were well below the PWQO for ammonia (0.0165 mg/L) (Appendix D, Figure 55). Median unionized ammonia levels ranged from 7.86 e^{-5} mg/L at site 64002, to 0.012 mg/L found in the upper portion of the watershed at site 64005 just downstream of the Waterford WPCP. Downstream of site 64005 unionized ammonia concentrations appeared to remain fairly constant.

A study characterizing the environmental impact of the Waterford WPCP indicated that during the spring, effluent from the WPCP accounts for 2-4% of the base-flow while during the summer it accounts for 28-89% (G.Douglas Vallee LTD. 2004). It was also found that during the summer months unionized ammonia concentrations were above the PWQO but only appeared to affect the immediate mixing zone (G.Douglas Vallee LTD. 2004). This may also explain the extreme variation in nitrite concentrations found (Figure 64) downstream of the Waterford WPCP at site 64005, as nitrite is an intermediate step in the breakdown of ammonium to nitrate.

Median unionized ammonia values found at site 64001 significantly increased over time from those found 1982-1986 season to those found within the 2002-2005 sampling season.

Total Kjeldahl Nitrogen (TKN)

Within the Nanticoke Creek watershed TKN concentrations ranged from 0.40 mg/L within site 64003 furthest upstream at site 64003 to 1.65 mg/L at site 64001 furthest downstream (Appendix D, Figure 56).

Generally, TKN concentrations tended to increase from upstream to downstream. Concentrations significantly increased between site 64003 upstream of the Waterford WPCP and site 64005 downstream of the WPCP. This is likely due to the WPCP effluent which tends to be high in organic nitrogen and ammonium. All sites within the watershed downstream of the WPCP had similar concentrations and were not found to significantly differ from each other. These sites downstream of the WPCP are also directly influenced by both the Waterford and Townsend WPCPs which discharge into the Nanticoke Creek.

Over time TKN concentrations at the mouth of the creek (site 64001) have not significantly changed, although a slightly higher median concentration was found during the 2002-2005 sampling season.

Total Nitrogen (Nitrate + Nitrite + Kjeldahl Nitrogen)

Total nitrogen is made up of three constituents: nitrate, nitrite and total kjeldahl nitrogen (TN = NO3 + NO2 + TKN) (TKN = NH4 + Organic N). On average nitrates tend to make up greater than 57% of the total nitrogen pool at both PWQMN sites within the Nanticoke Creek watershed (Figure 57). Ammonium generally made up a higher percentage of the nitrogen pool compared with other watersheds in the Long Point Region and ranged from approximately 2% to 5%. Organic nitrogen levels made up between 30 % and 38 % of the total nitrogen pool which was higher than most other watersheds across the Long Point Region. Over time there does not appear to have been much change in the composition of the total nitrogen pool (Figure 58).

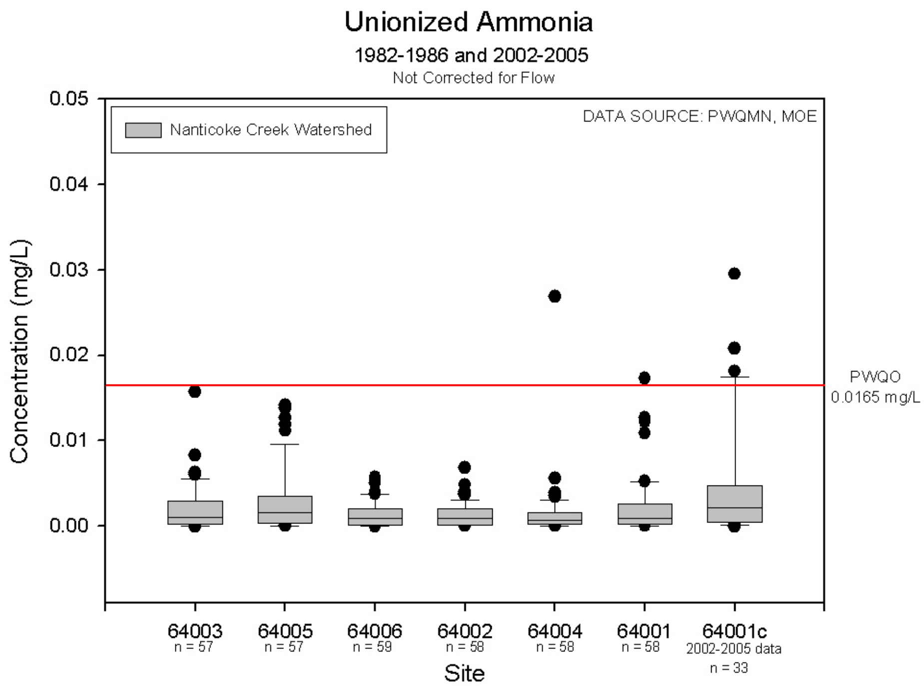


Figure 55. Unionized ammonia concentrations between 1982 and 1986 at six PWQMN monitoring sites in and from 2002-2005 at one PWQMN monitoring site (64001) within the Nanticoke Creek watershed.

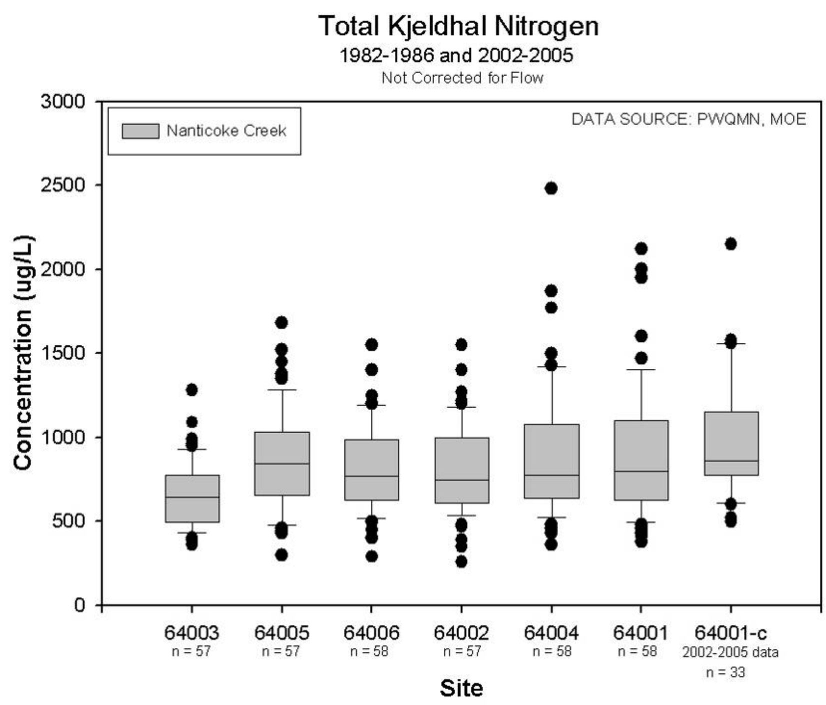


Figure 56. Total Kjeldahl nitrogen concentrations between 1982 and 1986 at six PWQMN monitoring sites in and from 2002-2005 at one PWQMN monitoring site (64001) within the Nanticoke Creek watershed.

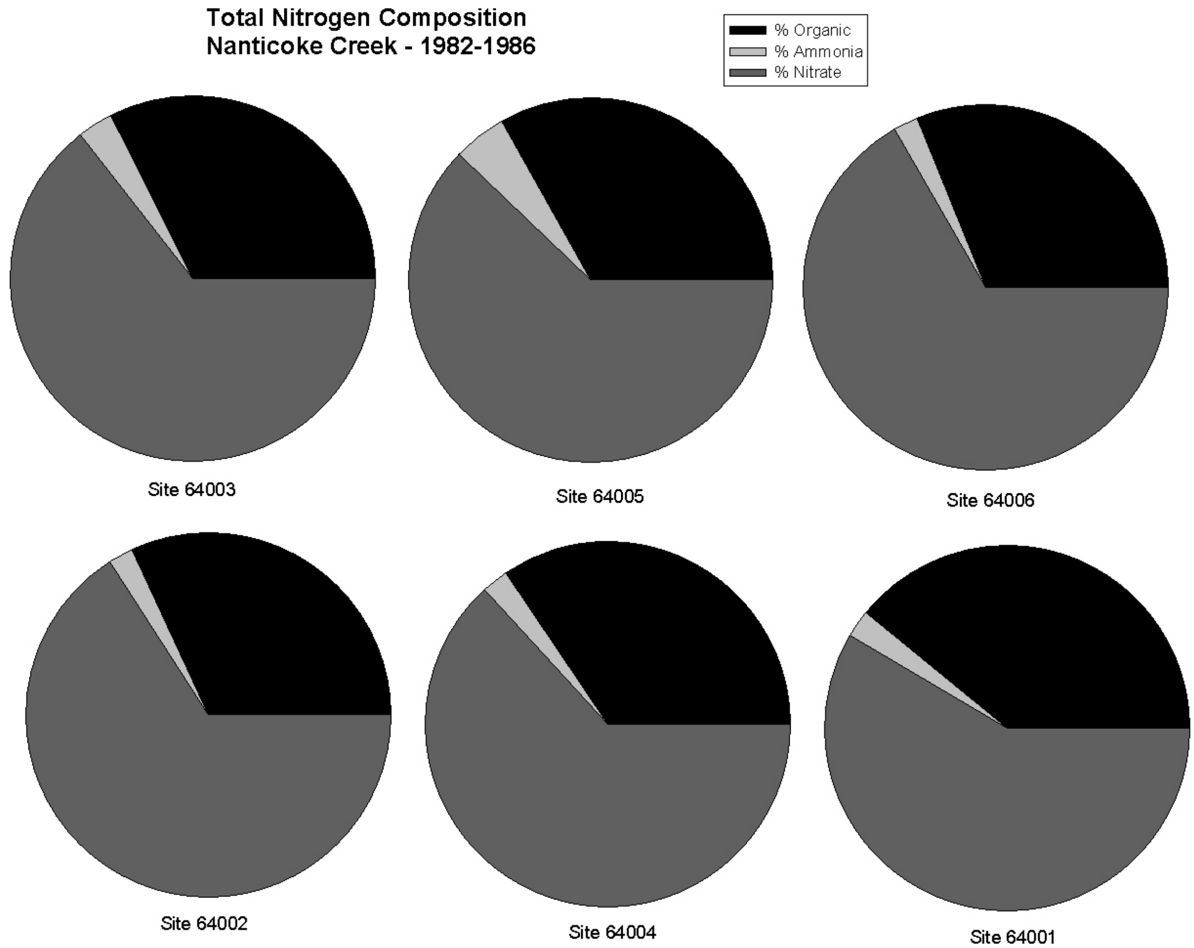


Figure 57. Composition of average total nitrogen concentrations from 1982-1986 at six PWQMN monitoring sites within the Nanticoke Creek watershed.

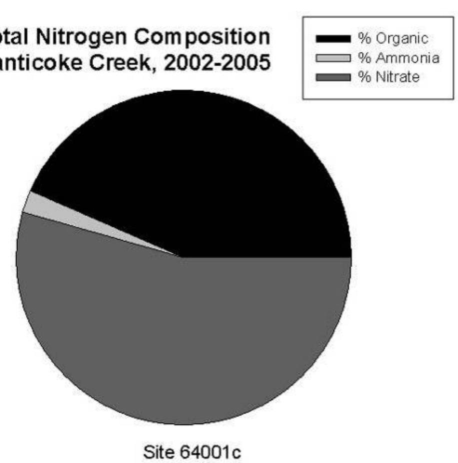


Figure 58. Composition of average total nitrogen concentrations from 2002 - 2005 at one PWQMN site also historically monitored within the Nanticoke Creek watershed.

Phosphorus

Total phosphorus is a significant water quality issue within the Nanticoke Creek watershed. Phosphorus levels during the 1982-1986 monitoring season ranged from 0.017 mg/L at site 64003 furthest upstream to 0.5 mg/L at site 64001 furthest downstream (Appendix D, Figure 59). Phosphorus samples throughout the Nanticoke watershed were routinely above the provincial water quality objective of 0.03 mg/L. Site 64003 had the fewest number of samples with concentrations above the objective (68%) while all other sites had between 93% and 98% of their samples taken with recorded concentrations above the objective (Appendix F).

Phosphorus levels were significantly lower at site 64003 upstream of the Waterford WPCP relative to any of the other sites within the watershed. Those sites downstream of the Waterford WPCP all had similar median concentrations and did not significantly differ. The significant increase in phosphorus concentrations between site 64003 and 64005 was likely due to high levels within the WPCP effluent. Considering that phosphorus levels remained high downstream of the Waterford WPCP there are likely additional inputs resulting from fertilized land run-off and sedimentation occurring between these two sites.

G.Douglas Vallee Ltd (2004) also found that total phosphorus levels within the Nanticoke Creek increased below the Waterford WPCP outfall and could be up to 13 times the PWQO during August when the effluent accounted for 89% of the base-flow. However, during the 1979 watershed study carried out by the Long Point Region Conservation Authority, (LPRCA 1979), the highest levels of total phosphorus were found just above the village of Townsend. This was likely due to a combination of fertilizer inputs from field run-off and urban inputs from the town of Waterford.

Median concentrations remained high at site 64001 during the 2002-2005 sampling season but have not significantly increased over time.

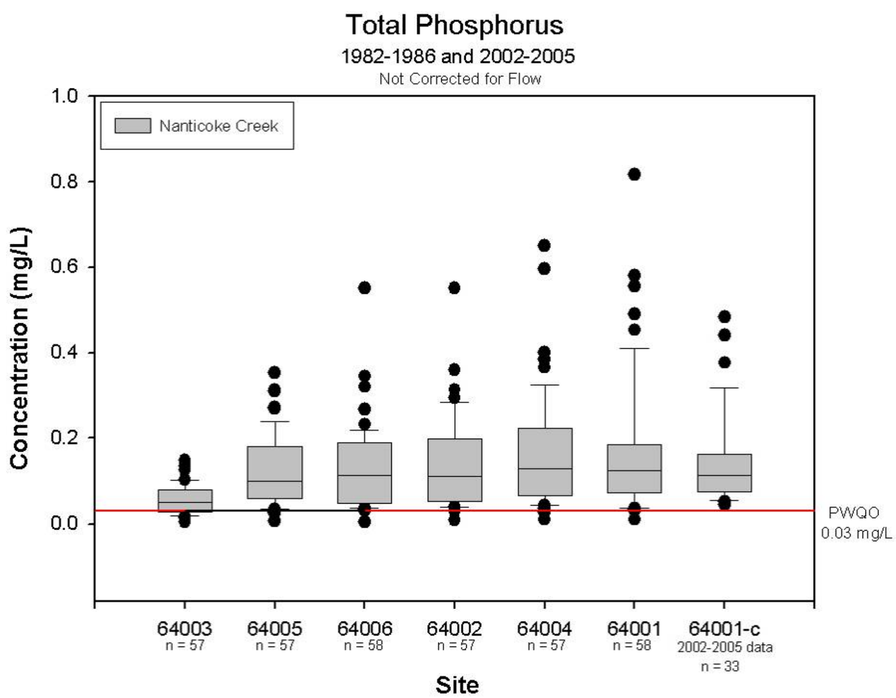


Figure 59. Phosphorus concentrations between 1982 and 1986 at six PWQMN monitoring sites in and from 2002-2005 at one PWQMN monitoring site (64001) within the Nanticoke Creek watershed.

Non-filterable residue (NFR)

Across the watershed NFR concentrations ranged from 3.40 mg/L at site 64003 furthest upstream to 244.30 mg/L at site 64001 furthest downstream (Appendix D, Figure 60).

Similar to the trends exhibited for phosphorus, NFR concentrations were significantly lower upstream of the Waterford WPCP at site 64003 compared to all other sites within the watershed. The remaining five sites located downstream of the Waterford WPCP had statistically similar median values.

The significant change in NFR concentrations between site 64003 and 64005 is likely in part due to the WPCP effluent as well as the change in soil types. Turbidity tends to increase as the soil type changes form sand to clay, which is known to erode more easily (Van De Lande 1987). Erosion is of primary concern within the Haldimand clay plain region of this watershed, which is compounded by the number of livestock operations with stream bank access and the very little permanent vegetation cover along the creek (LPRCA 1979). However, over time there has been a decrease in the NFR concentrations found near the mouth of the creek (Figure 60 site 64001c).

All sites within the Nanticoke Creek watershed, with the exception of site 64003, had median values above the 25 mg/L benchmark. The percentage of samples above the 25mg/L benchmark generally progressively increased from upstream to downstream (Appendix F). Site 64003, furthest upstream, had the fewest number of samples with concentrations above the benchmark, 29%, while site 64001 furthest downstream had the highest number, 77%.

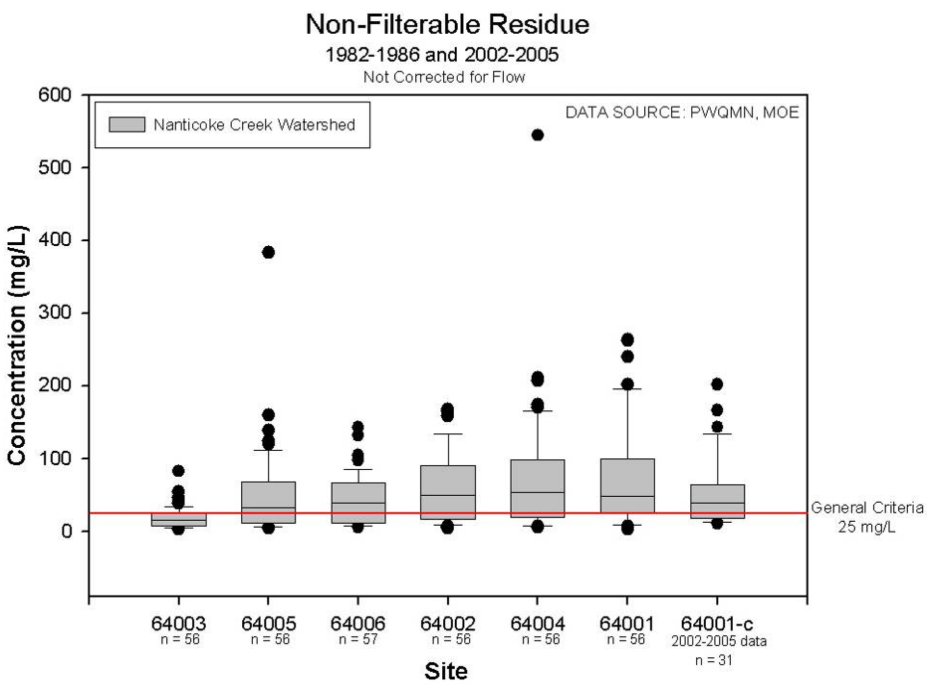


Figure 60. Total non-filterable residue concentrations between 1982 and 1986 at six PWQMN monitoring sites in and from 2002-2005 at one PWQMN monitoring site (64001) within the Nanticoke Creek watershed.

Chloride

Generally chloride levels within Nanticoke Creek were not seen as a problem as none of the PWQMN sites examined had samples with concentrations above the 250 mg/L Environment Canada benchmark. Chloride concentrations across the watershed were quite low ranging from 9.74 mg/L at site 64002 to 58.15 mg/L at site 64004 downstream of Townsend and southwest of Jarvis (Appendix D, Figure 61).

Chloride levels did not vary significantly between sites along Nanticoke Creek downstream of Waterford, but significantly increased between sites 64003 (upstream of Waterford) and 64005 (downstream of the Waterford WPCP). This was likely due to site 64005 being located downstream of the Waterford city center.

When comparing chloride concentrations at site 64001 near the mouth of the Creek, a significant increase was found between the 1982-1986 dataset and the 2002-2005 dataset ($p < 0.0001$). This is likely a reflection of the city growth and an increase in the level of road salt application.

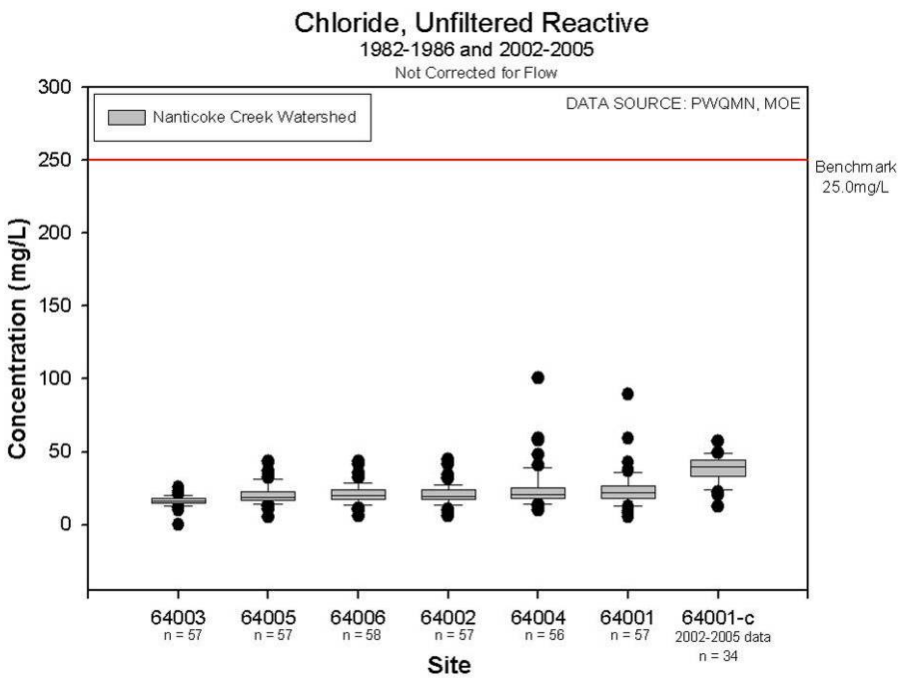


Figure 61. Chloride concentrations between 1982 and 1986 at six PWQMN monitoring sites in and from 2002-2005 at one PWQMN monitoring site (64001) within the Nanticoke Creek watershed.

Bacterial Conditions

During the 2002-2005 sampling period *Escherichia coli* counts varied from 4 to 1800 counts/100mL at the only site monitored within Nanticoke Creek (site 64001 close to the mouth of Nanticoke Creek) (Figure 62). The median *E. coli* count at the mouth of the creek was above the Health Canada recreational guideline of 100 counts/100 ml, which could indicate a significant impact to the downstream beaches (Figure 62). Compared to other watersheds across the region, median counts were lower than those found within the Lynn River or Big Otter Creek but higher than those found within the Big Creek watershed and Kent Creek within the Lynn River watershed.

Other watershed studies also found that bacterial loads were high within the central region of the Nanticoke Creek watershed, but indicate that they could be attributed to both the Waterford WPCP as well as the concentration of most of the watershed's livestock operations within this region (LPRCA 1979; G.Douglas Vallee LTD. 2004).

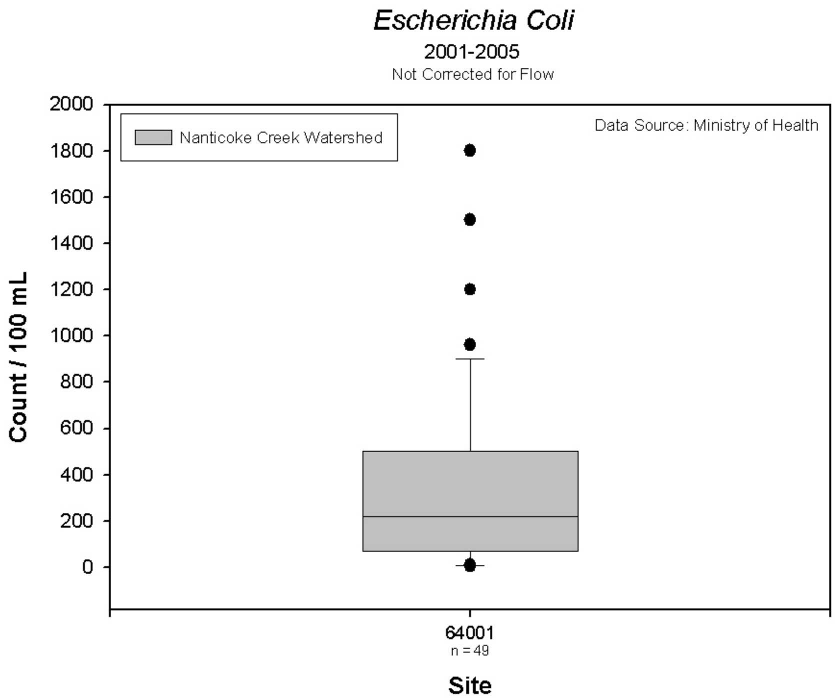


Figure 62. *Escherichia coli* concentrations between 2002 and 2005 at the currently monitored PWQMN site in the Nanticoke Creek watershed.

Reservoirs

There are several lakes and ponds within the northern part of the Nanticoke Creek watershed, which make up the Waterford Lake System. There are a total of 12 water features within the system of which five are owned by the LPRCA. Eight of the ponds were created from abandoned gravel pits while the remaining 4 were created from dam impoundments. Warm water fish species tend to dominate the watershed and are frequently stocked within the Waterford Lake System. The ponds and lakes within the Waterford Lake System have been shown to have fair water quality and support a good warm water fishery and other recreational activities (e.g. swimming, boating) (LPRCA 1979).

Sandusk Creek

The headwaters for Sandusk Creek originate just west of Hagersville and then travel south 32.7km towards Lake Erie where it empties east of Peacock Point. The entire watershed is within the Haldimand Clay Plain and has a relatively flat landscape with undefined stream valleys generally 3.5m deep (LPRCA 1979).

There are two wastewater treatment facilities within the Sandusk Creek watershed, the Hagersville Water Pollution Control Plant (WPCP) and the Jarvis sewage lagoons. The Hagersville WPCP discharges continuously into Sandusk Creek, while the Jarvis sewage lagoons discharge only twice a year into Sandusk Creek. The Hagersville WPCP currently operates at 85% of its capacity and is projected to be upgraded within the near future (Brian Pett pers. communication 2005)

Landuse in the area is mainly agriculture in the form of livestock operations, pasture land and grain cash cropping. Most of the recreational activity within this watershed occurs along the Lake Erie shore.
The Sandusk Creek watershed tends to be limited to coarse / tolerant fish species due to the low flow, low dissolve oxygen (DO), nutrient pollution and natural characteristics of the clay plain (LPRCA 1979).

Sites samples as part of the PWQMN within the Sandusk Creek watershed were not routinely monitored after 1986. Considering the existing literature describing the watershed's water quality dates back to 1979 an analysis of two sites for the three year period from 1984-1986 was performed to comment on the most current information (Figure 63). The analysis from 1984-1986 allowed for upstream / midstream comparisons along Sandusk Creek, as well as the potential influence the town of Hagersville may be having on the watershed.

Physical Conditions

Streamflow

There are no streamflow gauge stations that monitor streamflow within the Sandusk Creek watershed. However, it is generally accepted that adequate flow within the watershed is lacking in most streams, which dry to a series of standing pools during the summer months (LPRCA 1979). There are no natural retention areas, such as headwater swamps or wetlands, within the Sandusk Creek watershed to help augment summer low flows (Morse et al. 1982). Therefore the Sandusk Creek watershed tends to be a 'flashy' system during rain events due to soil type (clay), lack of forest cover and the lack of infiltration capacity (LPRCA 1979).

PH

The pH values varied only slightly between the two PWQMN sites and ranged from 7.2 at both sites to 9.6 at site 70003 on Sandusk Creek (Appendix D). The Provincial Water Quality Objective (PWQO) for aquatic health indicates that pH should be maintained between 6.5 and 8.5. Although most of the samples had pH values within this range, there were values higher than 8.5 within all of the sites, which could be indicative of high levels of photosynthesis (Wurts & Durborow, 1992). Site 70003 appeared to have the highest number of observations outside the upper end of the PWQO range.

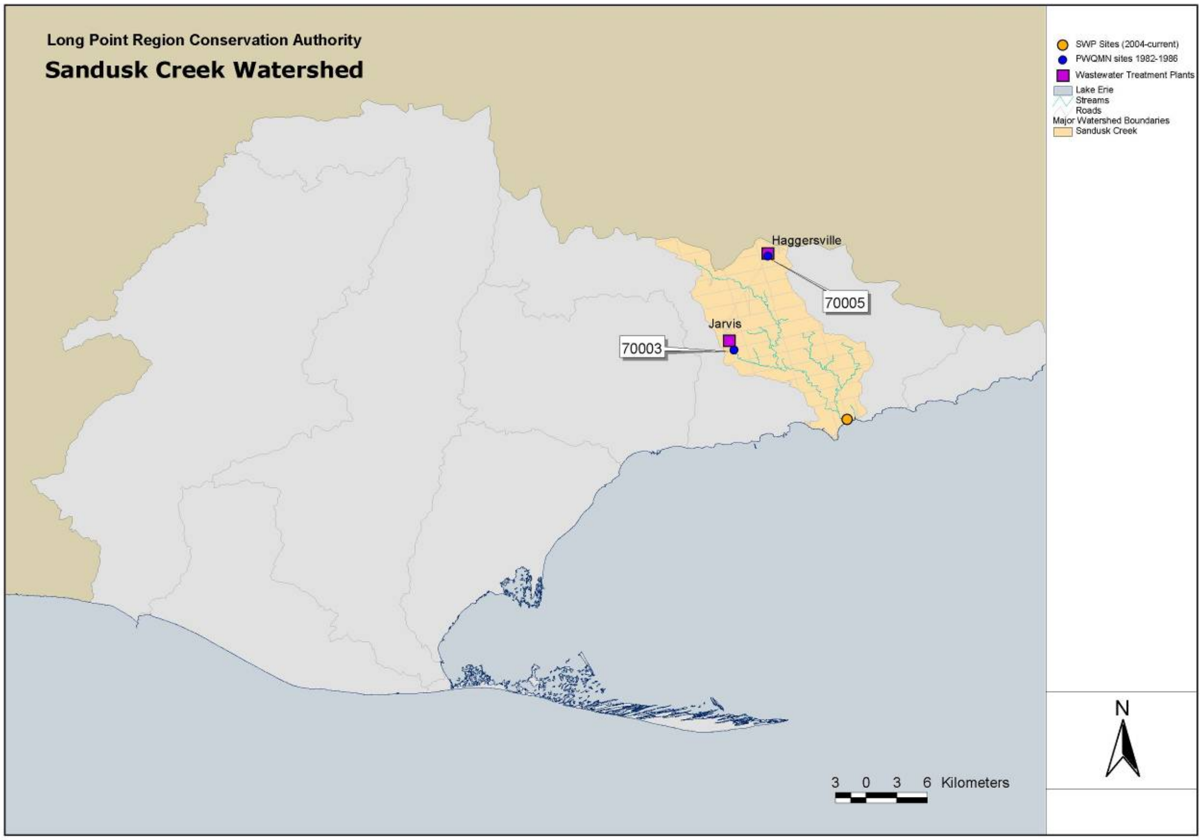


Figure 63. Sandusk Creek watershed illustrating the location of the major urban areas, the water pollution control plants, the new monitoring sites under source water protection (SWP) and the PWQMN sites sampled from 1984-1986.

Dissolved Oxygen

Dissolved Oxygen within the Sandusk Creek watershed rarely dipped below the 4 mg/L criteria for cold water fish. Concentrations ranged from 3.9 mg/L to 14.2 mg/L at site 70003 southeast of Jarvis, and 5.3 mg/L to 14.0 mg/L at site 70005 on upper Sandusk Creek (Appendix D). However sampling generally occurred between 8 a.m. and 1 p.m. and as a result, the data presented here does not represent diurnal fluctuations in DO levels. Therefore the true range in DO concentrations experienced by organisms can not be determined.

Temperature

Temperature loggers were not deployed within the Sandusk Creek watershed during the 2002-2005 sampling period. Therefore historical data from 1984-1986 is discussed here. Ambient water temperatures within the Sandusk Creek watershed tend to follow a seasonal pattern ranging from approximately 1 °C during the winter to 24.5 °C in the summer. Temperatures appeared to be slightly higher within the upper watershed at site 70005 downstream of Haggersville. This could potentially be as a result of the continuous WPCP effluent discharge in to the creek directly upstream of site 70005.

Nutrient Conditions

Phosphorus and non-filterable residue concentrations are the primary water quality issue within the Sandusk Creek watershed. Compared to other watersheds within the Long Point Region, Sandusk Creek is a moderate contributor of nitrate and phosphorus to Lake Erie (LPRCA 1979). However, this same study noted that Sandusk Creek was a significant contributor of atrazine (a common pesticide) to Lake Erie (LPRCA 1979).

Nitrate

Within the Sandusk Creek watershed nitrate concentrations were low relative to the Canadian guideline. In fact, less than 7% of the samples taken from both sites had concentrations above the guideline.

Nitrate concentrations within the two PWQMN sites sampled during the 1984 to 1986 sampling period ranged from 0.014 mg/L to 3.27 mg/L both at site 70003 furthest downstream (Appendix D, Figure 64). Median nitrate was significantly higher at site 70005 just downstream of the Hagersville WPCP (p = 0.01). During the 1979 watershed study major nitrate loading was shown to occur during run-off events and was likely as a result of excessive fertilizer application (LPRCA 1979).

Nitrite

Nitrite concentrations within the Sandusk Creek watershed were extremely variable within site 70003 and ranged from 0.012 mg/L to 0.5 mg/L (Appendix D, Figure 65). Concentrations within site 70005 were typically lower, less variable and ranged from 0.02 mg/L to 0.16 mg/L.

Median nitrite levels at both sites were approaching the Canadian guideline of 0.06 mg/L and both sites had a high percentage of samples with concentrations reported above the guideline (Appendix F). Although the number of samples with concentrations above the guideline was higher at site 70003 (43%) than site 70005 (37%), no significant difference in concentrations was found between the two sites on Sandusk Creek (p = 0.56).

Likely the effluent from the WPCP in Hagersville and the sewage lagoon in Jarvis are elevating the nitrite levels within Sandusk Creek. This watershed is also dominated by livestock operations, which could be a secondary source of nitrite inputs

Unionized Ammonia

Unionized ammonia concentrations within the Sandusk Creek watershed were extremely variable within site 70003 and ranged from 0.0001 mg/L to 0.66 mg/L (Appendix D, Figure 66). The extremely high 95^{th} percentile reported here could be as a result of effluent from the Haggersville WPCP or livestock access near the sampling site. Concentrations within site 70005 were typically lower, less variable and ranged from $3.4e^{-4}$ mg/L to 0.026 mg/L.

Median unionized ammonia levels within this watershed were below the PWQO (0.0165 mg/L), however, there were reported values above the guideline at both sites. A higher percentage of samples had concentrations above the guideline at site 70003 (26%) downstream of Jarvis compared to site 70005 (9%) further upstream near Haggersville. No significant difference in median concentrations was found between the two sites (p = 0.40). However, a higher median concentration was found at site 70003, which was likely as a result of the cumulative upstream inputs from the Haggersville WPCP, nearby livestock operations, and potential inputs from the Jarvis sewage lagoons.

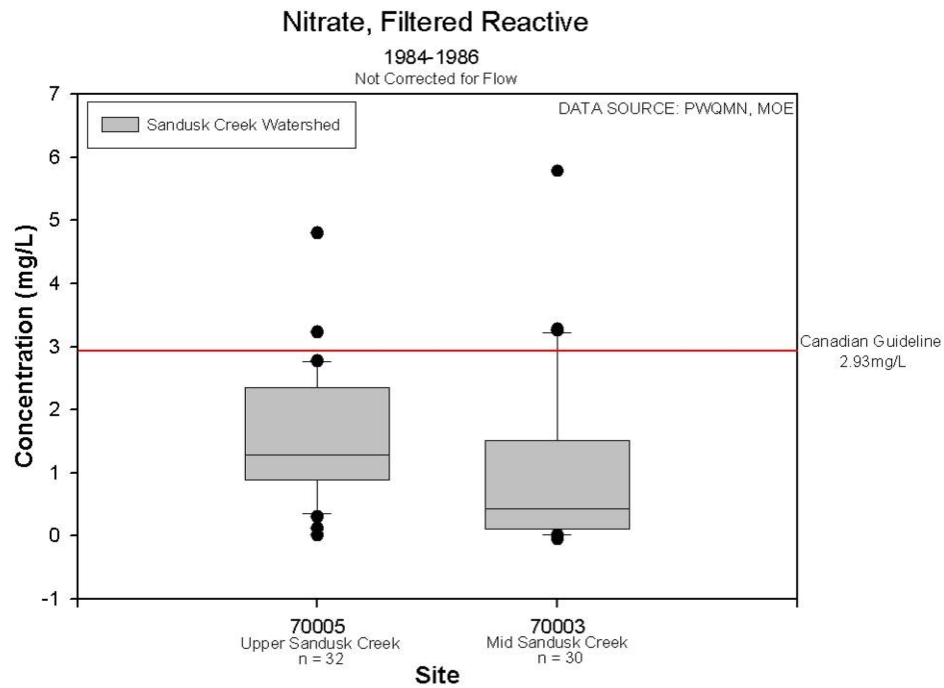


Figure 64. Nitrate concentrations between 1984 and 1986 at two PWQMN monitoring sites within the Sandusk Creek watershed.

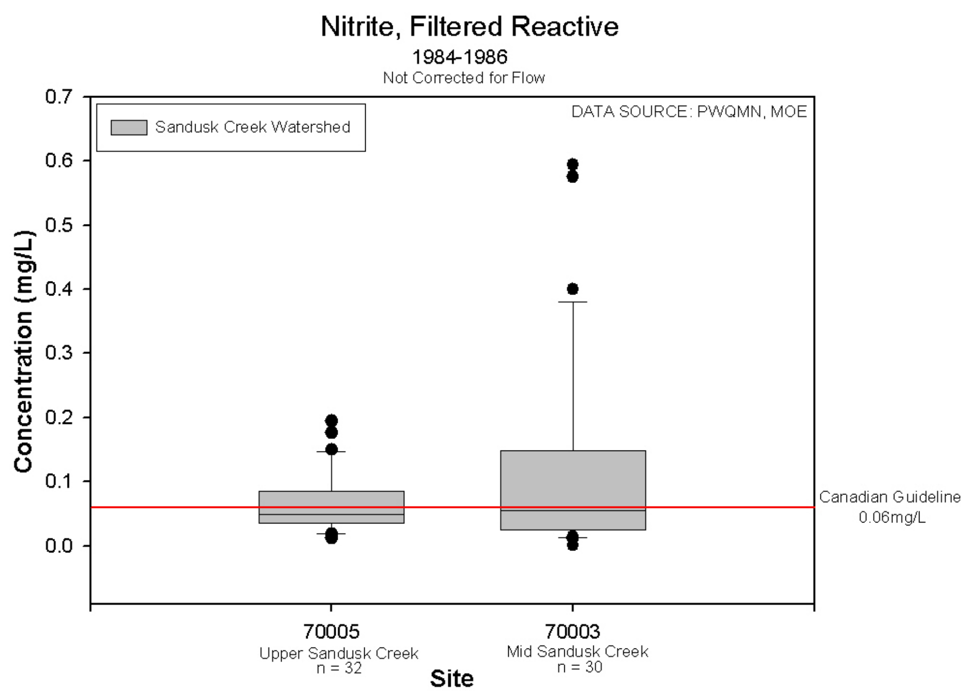


Figure 65. Nitrite concentrations between 1984 and 1986 at two PWQMN monitoring sites within the Sandusk Creek watershed.

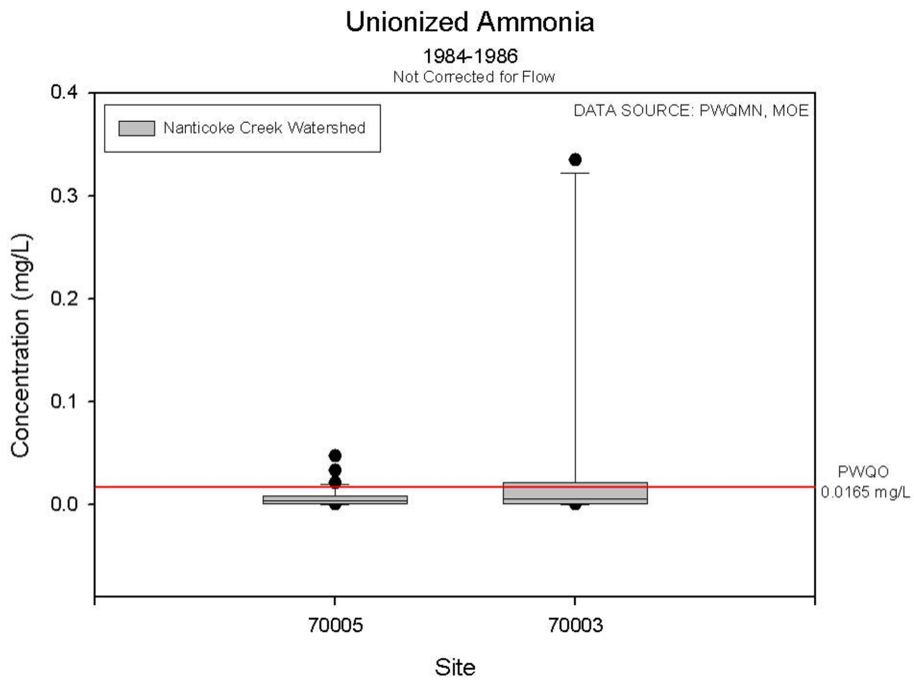


Figure 66. Unionized ammonia concentrations between 1984 and 1986 at two PWQMN monitoring sites within the Sandusk Creek watershed.

Total Kjeldahl Nitrogen (TKN)

Total Kjeldahl Nitrogen concentrations were more variable within site 70003, midway along Sandusk Creek and ranged from 0.83 mg/L to 7.95 mg/L (Appendix D, Figure 67). When the two sites were statistically compared using a Mann-Whitney test, site 70003 further downstream on Sandusk Creek was found to have significantly higher TKN concentrations compared to the upstream site, 70005 (p = 0.01). In fact, TKN concentrations at site 70003 were the highest relative to all other watersheds across the entire Long Point Region. The higher ammonia concentrations previously noted may be driving the elevated TKN concentrations found. However, since no significant difference in median concentrations for ammonia was found, there is likely an additional organic nitrogen input at site 70003 as well. The organic nitrogen is also likely from the sewage lagoon discharge.

Total Nitrogen (Nitrate + Nitrite + Kjeldahl Nitrogen)

Total nitrogen is made up of three constituents: nitrate, nitrite and total kjeldahl nitrogen (TN = NO_3 + NO_2 + TKN) (TKN = NH_4 + Organic N). Site 70003 near Jarvis had a higher percentage of ammonia and organic nitrogen contributing to the total nitrogen pool relative to site 70005, downstream of Hagersville (Figure 68). This is likely indicative of a sewage input either from poorly treated lagoon effluent, faulty septic systems or livestock waste.

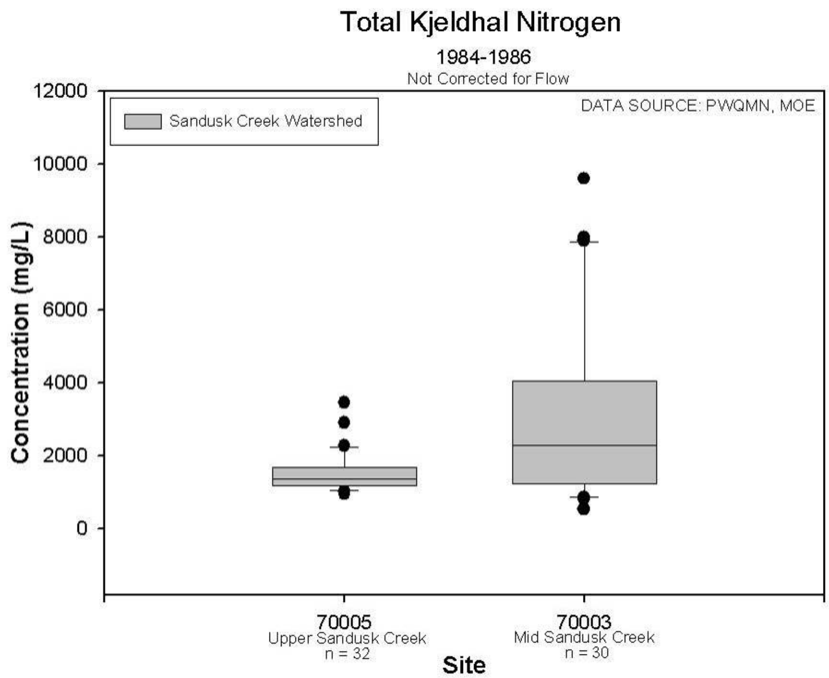


Figure 67. Total Kjeldahl nitrogen concentrations between 1984 and 1986 at two PWQMN monitoring sites within the Sandusk Creek watershed.

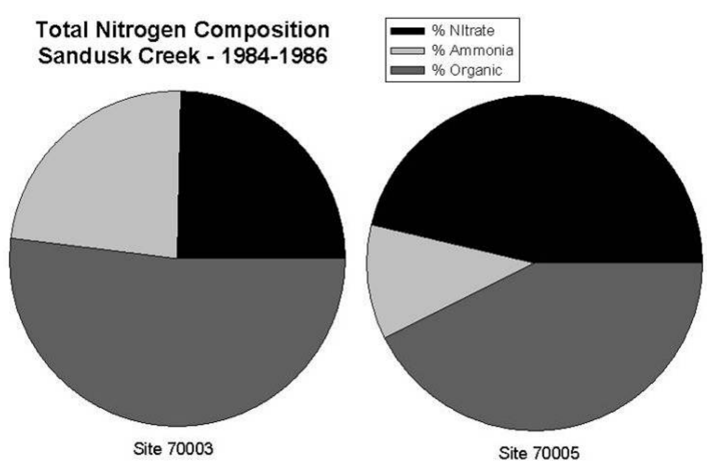


Figure 68. Composition of average total nitrogen concentrations from 1984-1986 at two PWQMN monitoring sites within the Sandusk Creek watershed.

Phosphorus

Phosphorus concentrations were extremely high at both sites within Sandusk Creek and ranged from 0.094 mg/L at the site 70005, upstream, to 0.91 mg/L at site 70003 further downstream (Appendix D, Figure 69). Median concentrations significantly increased from upstream to downstream ($p = 0.01$) and were continually (100% of the time) above the provincial water quality objective of 0.03 mg/L during the 1984-1986 sampling period.

During the 1979 watershed study, total phosphorus levels were found to be elevated downstream of Jarvis relative to the rest of the watershed (LPRCA, 1979). This along with the findings from the PWQMN site directly downstream of Jarvis (70003) could be an indication that run-off from fertilized fields within the area or urban inputs from the village of Jarvis and its sewage lagoon, are potentially contribution to the elevated phosphorus levels found.

Non-filterable residue (NFR)

Non-filterable residue concentrations are also extremely high within the Sandusk Creek watershed and ranged from 18.0 mg/L at site 70005 to 251.3 mg/L at site 70003 (Appendix D, Figure 70). NFR concentrations are routinely above the general criteria of 25 mg/L, with 84% and 90% of the samples taken at sites 70005 and 70003 respectively having concentrations above the 25 mg/L benchmark. Although there was a slight decreasing trend evident from upstream to downstream, no significant difference was found between median NFR concentrations for the two sites along Sandusk Creek ($p = 0.2$).

The higher NFR concentrations found within the upstream site (70003) could potentially be due in part to the WPCP and sewage lagoon effluent. However, erosion is prevalent within the Sandusk Creek watershed and is mainly attributed to soil type, lack of vegetative cover and unrestricted livestock access to stream banks (LPRCA, 1979). Severe sheet erosion due to row cropping and over grazing of pastures has also occurred increasing the sediment loading to nearby creeks (Morse et al. 1982).

Chloride

Generally, chloride concentrations are well below the Environment Canada benchmark of 250 mg/L and are not considered a water quality problem within the Sandusk Creek watershed. Chloride concentrations did not statistically differ between the two sites on Sandusk Creek ($p = 0.24$) and ranged from 10.8 mg/L at site 70005 to 178.95 mg/L at site 70003 further downstream (Appendix D, Figure 71).

Bacterial Conditions

Within the Sandusk Creek watershed bacterial concentrations were not routinely monitored at any of the historic PWQMN sites. *Escherichia coli* was only monitored from 1988-1991 at site 70005 and more recently at site 70006 (near the mouth of Sandusk Creek) from 2001-2002. In general *E. coli* counts were highly variable and did not appear to substantially differ between sites (Figure 72).

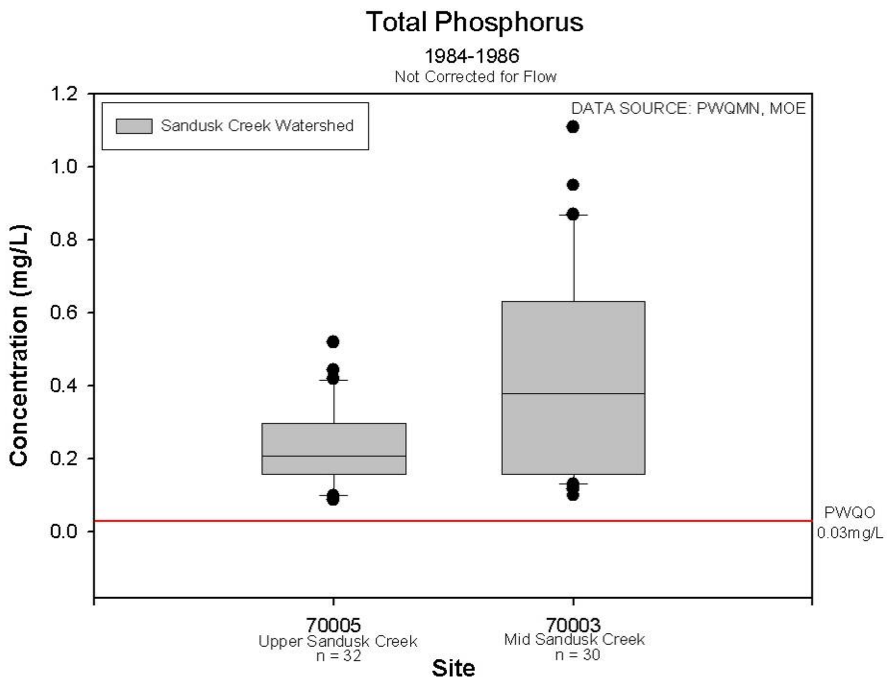


Figure 69. Phosphorus concentrations between 1984 and 1986 at two PWQMN monitoring sites within the Sandusk Creek watershed.

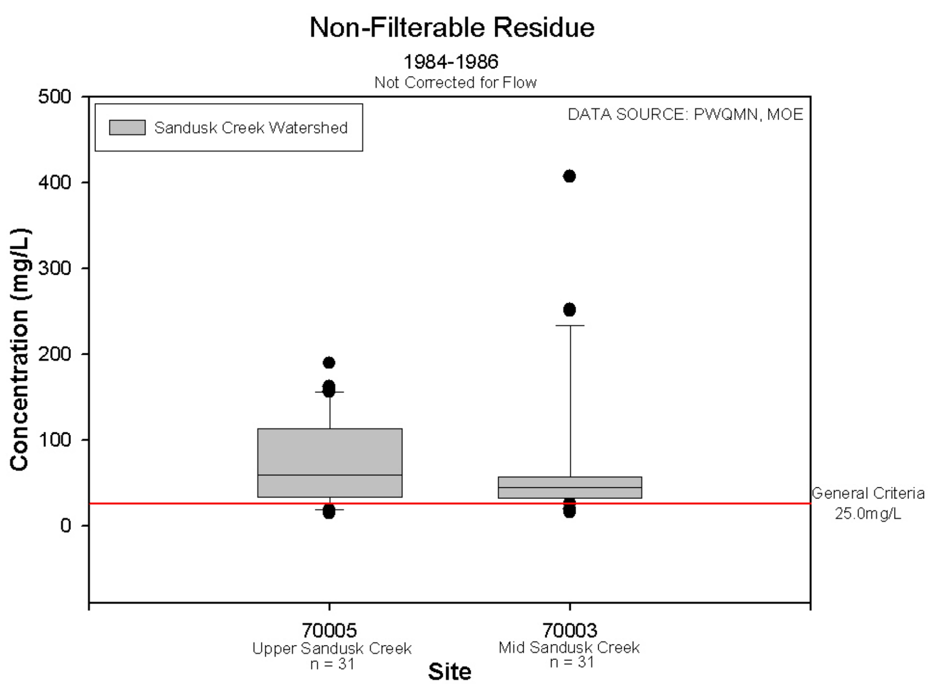


Figure 70. Total non-filterable residue concentrations between 1984 and 1986 at two PWQMN monitoring sites within the Sandusk Creek watershed.

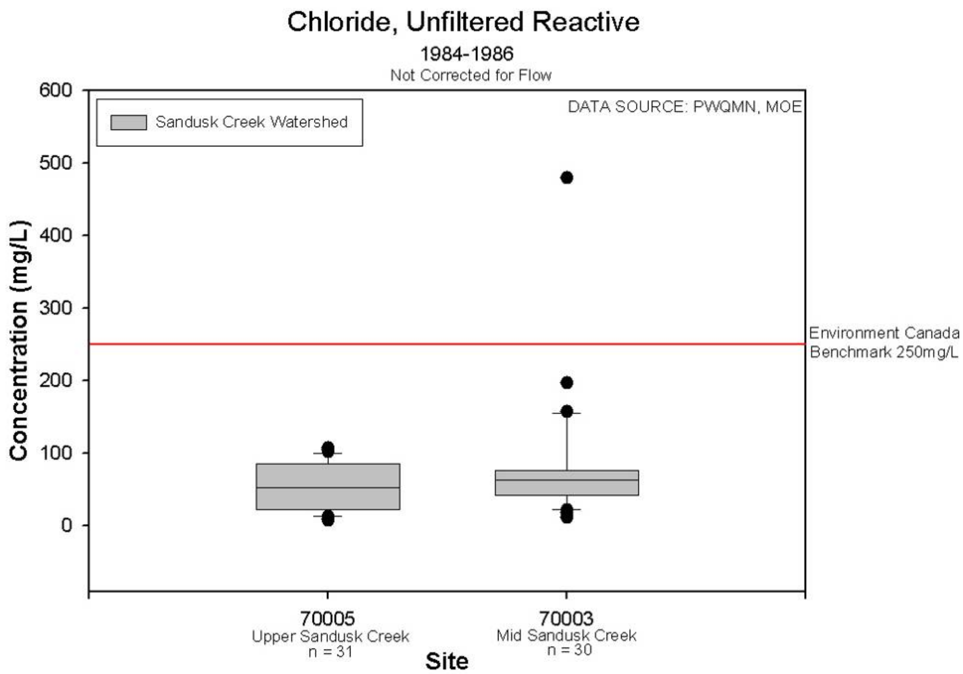


Figure 71. Chloride concentrations between 1984 and 1986 at two PWQMN monitoring sites within the Sandusk Creek watershed.

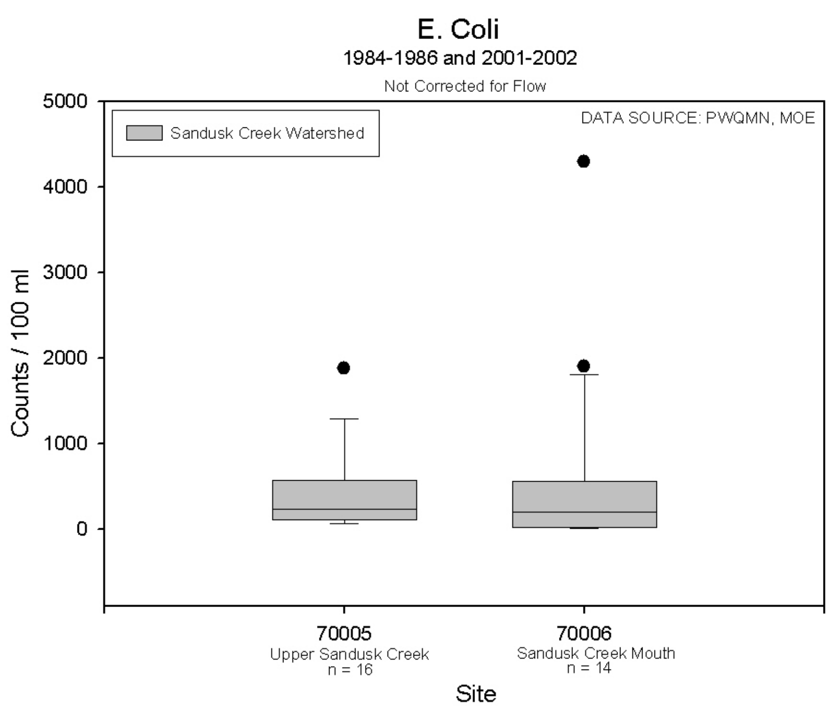


Figure 72. ***Escherichia coli*** **concentrations between 1984 and 1986 at two historically monitored PWQMN sites in the Sandusk Creek watershed.**

Dedrick-Young Creek

The Dedrick-Young watershed is drained by a total of eight streams of which Dedrick Creek and Young Creek are the most prominent (Figure 73). Most streams in the watershed are considered to be cold-water and support healthy fisheries (e.g. Lawrence and Hay Creeks have resident brook trout populations). The watershed area is approximately 209 km^2 spanning 19km north to south and 26km east to west. Dedrick Creek is situated within the western portion of the watershed and empties into Lake Erie at Port Rowan with an average decrease in elevation of 2.8m/km. Young Creek is situated within the eastern portion of the watershed and empties into Lake Erie at Port Ryerse with an average decrease in elevation of 3.6m/km.

Majority of the watershed region is within the Norfolk Sand Plain except for a small portion in the southwest and southeast corners of the watershed, which are dominated by a till/clay plain physiographic region. This watershed has the highest percentage of forest cover compared with all other watersheds across the Long Point Region. Major landuse within the region is tobacco, which in recent years has been switching to other specialty crops such as ginseng. There are very few livestock operations, which tend to be concentrated near Port Rowan and Port Ryerse. There is a small area of market gardening within the southwest corner of the watershed within the clay plain. Streams tend to be deeply incised throughout the watershed. Special natural features within this watershed include the Turkey Point Marsh, which is a resting site for migratory waterfowl.

Port Rowan and Turkey Point are the major urban communities within the Dedrick-Young watershed. Both of these two communities have small populations and are located along the north shore of Lake Erie. As such any urban sources of contamination tend to have a greater influence on Lake Erie than any of the tributaries within the watershed.

Only one site along Dedrick Creek has historically been sampled within the Dedrick-Young watershed. However, sampling at this station was discontinued after 1986. Given this, no analysis of the PWQMN data was performed and instead a review of the existing literature follows.

Physical Conditions

Flow within the Dedrick-Young Creek watershed is continuous year-round as it is ground water fed. As with most of the watersheds in the Norfolk Sand plain, the demand for irrigation is great. This is re-inforced by the numerous dams and dugouts on-line. These numerous water takings, which are more prevalent in Young Creek, could potentially place pressure on the water course and influence water quality (LPRCA 1979).

A historical stream gauge within Young Creek, which was taken off-line in 1979, was re-instated in 2002. Therefore within the next few years a better understanding of the flow within the creek and the potential influence the numerous water takings are having on the base-flow can be ascertained.

Historically temperature was not considered to be a problem within this watershed, which is known to support several cold water fisheries (Bernier & Reynolds 1976). However, recent temperature logger data indicates that daily maximum temperatures within Dedrick Creek are reaching the critical 24°C threshold between cool and warm water fish species during the summer months (Appendix E) (Coker et al., 2001; Stoneman and Jones, 1996).

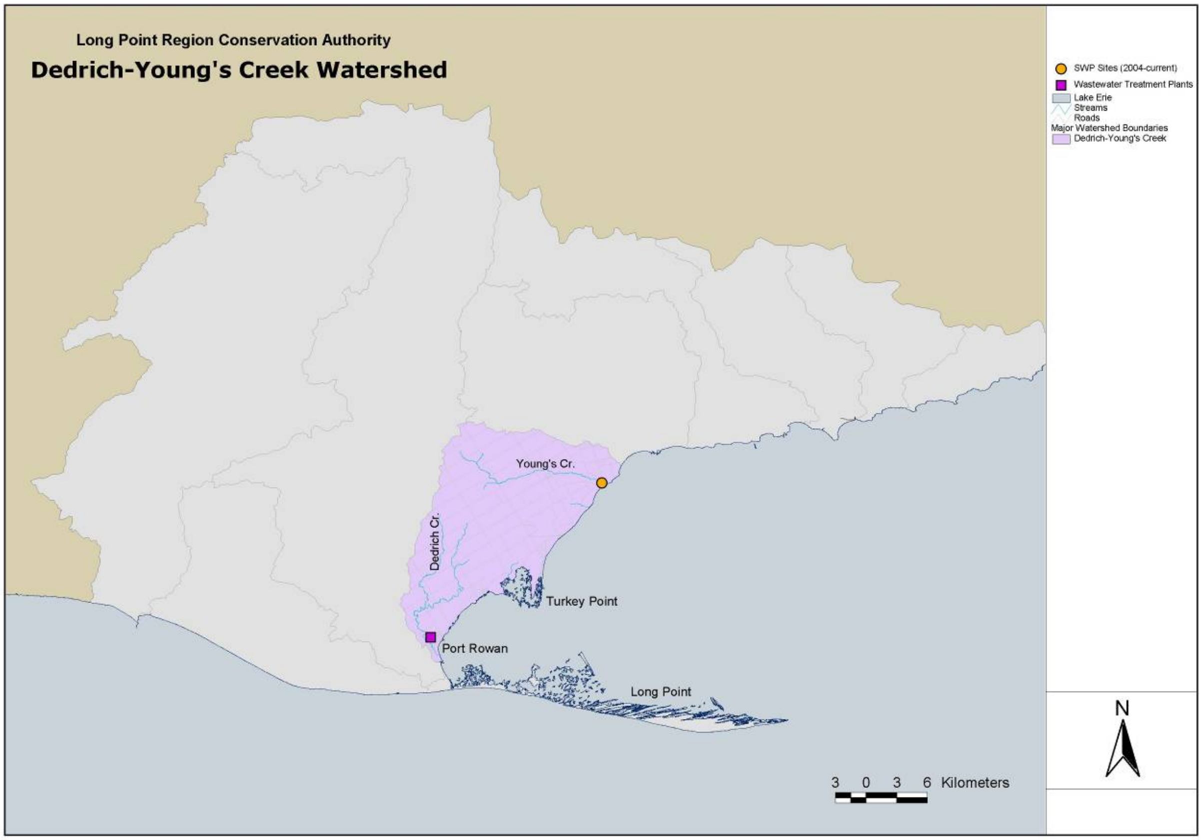


Figure 73. Dedrich-Young Creek watershed illustrating the location of the major urban areas, the water pollution control plants, and the new monitoring sites under source water protection (SWP).

Nutrient Conditions

Water quality within this watershed tends to be fairly good and the streams within the sand plain have been identified as biologically significant stream habitat for cold water salmonids (LPRCA 1979; Bernier & Reynolds 1976). Young Creek tends to be of better water quality compared to Dedrick Creek, which is likely due to the numerous springs along Young Creek that continually recharge, cool and dilute the water (Van de Lande 1987).

The better water quality found within Young Creek has resulted in it being considered one of the best cold water streams within this watershed but historically was thought to be lacking sufficient gravel for spawning areas (LPRCA 1979; Morse et al. 1982). Currently, the gravel appears to be sufficient to support spawning areas and does not appear to be a limiting factor, rather the increasing temperatures found over the past few years is of more concern to the health of the cold-water fisheries in the area. The increased temperatures are likely as a result of the Vittoria Dam decreasing flow and creating pooling areas with a larger surface area to heat up. Fishers Creek is also located within the Dedrick-Young Creek watershed and has been noted as the best cold water stream in the area. This is likely a direct result of it primarily draining a pristine forested area. Other creeks (Hay & Dedrick) have been affected by the increase in the agricultural intensity during the 70's which has resulted in a decrease in fish numbers (LPRCA, 1979).

Nutrient contributions to Lake Erie are relatively low compared to other tributaries within the Long Point Region. NFR tends to be the most significant water quality issue within this watershed (Bernier & Reynolds 1976), which can silt over spawning beds. Wind erosion is high across the sand plain and bank erosion tends to occur from recreational hiking. Most of the non-filterable residue inputs come from tributaries within the watershed that are not as heavily forest covered (e.g. Mud Creek, Hay Creek and Dedrick Creek) (LPRCA 1979). Nitrate concentrations tend to fluctuate seasonally with peaks during the late fall and early spring run-off events (LPRCA 1979). The source of the nitrate concentrations within the watershed is likely from the over application of fertilizers on agricultural crop lands (LPRCA 1979).

Bacterial Conditions

Livestock related bacterial contamination is not widespread within this watershed due to the relatively few operations present (LPRCA 1979). In 2005 best management practices were initiated in Dedrick Creek, such as fencing, to prevent cattle access to the creek and improve water quality. There is only one water pollution control plant within the watershed situated on Dedrick Creek near Port Rowan. However, due to its proximity to Lake Erie, it may be having more of an influence on Lake Erie compared to Dedrick Creek.

Reservoirs

There are four major reservoirs within the Dedrick-Young watershed; St. Williams, Backus, Hays and Vittoria. All four reservoirs have turbidity and clarity values that exceed the Canadian guidelines. Likely the high turbidity is in part due to the numerous carp uprooting plants and disturbing the sediments as well as the high sedimentation occurring due to erosion (Gagnon 1995). Hay Creek Reservoir had the highest nutrient levels in 1994 where as Vittoria Creek Reservoir on Young Creek had the lowest (Gagnon 1995; Morse et al. 1982). Backus Reservoir tends to rapidly fill with sediments and has been increasing in temperature over the years. A recent dredging project, in which an offline warm water system was formed, deepened and decreased the surface area of the reservoir to hopefully reduce the reservoir's water temperature.

South Otter Creek, Stoney Creek & Gates Creek Watersheds

The PWQMN monitored two sites within the South Otter Creek watershed and one site within the Stoney Creek watershed during the 1960's and 70's. No monitoring as part of the PWQMN program has ever been done within the Gates Creek watershed. Given the historic nature and lack of data, no data from these watersheds was analysis for this report.

Unfortunately, very little information regarding the water quality of the South Otter Creek, Stoney Creek or Gates Creek watersheds is available. South Otter Creek primarily drains the Norfolk Sand Plain east of Port Burwell, while both Stoney and Gates Creeks drain the Haldimand Clay Plain and as such the creeks tend to be intermittent during the summer. South Creek has permanent flow but has issues with increasing temperatures and a lack of spawning habitat for cold-water fish populations. This is likely as a result of the numerous online ponds along the creek.

Preliminary Trends in the Long Point Region

Although trend analyses were performed for the seven key water quality variables over a minimum 10 year period using the LOWESS technique, these results should be considered preliminary. With the aforementioned sampling frequency and timing there is the potential for these trend estimates to be incorrect. Trkulja (1997) suggested that trend estimates based on monthly sampling are less reliable than estimates based on daily and weekly sampling schemes. Consequently, more detailed analyses are required to accurately evaluate statistical trends. Therefore, only a preliminary analysis to explore the data for temporal variability is provided.

Time series plots were created for each water quality parameter at the PWQMN sites for which there was at least 10 years of data available. A LOWESS (LOcally WEighted Scatterplot Smoothing) smoothing algorithm was then applied to visually assess preliminary trends (Appendix G).

Preliminary Trends Big Otter Creek Watershed

Generally, to accurately assess trends a minimum of 10 years of data is needed. Within the Big Otter Creek watershed only one of the three currently monitored sites also has historical data, site 9007 on upper Big Otter Creek. Therefore, sites 9010 and 9008 were not analysed for trends; however, to give an indication of how water quality has changed within the downstream portion of the watershed over time, historic data from site and 9005 (near the town of Vienna) was also analysed for trends.

Nitrate concentrations appeared to be increasing within both sites from the 1970's to the late 1990's and have continued to increase at site 9007 from 2002-2005 (Appendix G). Nitrite, unionized ammonia, TKN, TP and NFR all appeared to be fairly consistent over time at both sites except for the slight increase within site 9005 for TKN. Chloride concentrations displayed the most prominent trend with an increase from the 1980's to the late 1990's which then appeared to level off within site 9007 from the late 1990's to 2005.

Preliminary Trends Big Creek Watershed

None of the PWQMN sites monitored during the 2002-2005 season were historically sampled. Therefore to assess the changes in parameter concentrations over time, data from both an upstream and downstream sites along Big Creek with at least 10 years of historical data were used to explore preliminary trends. Site 24009 (near Delhi) was routinely sampled from 1979 to 1998 and site 24003 (near Port Rowan) was sampled from 1972-1992 for most parameters.

Nitrate and nitrite both displayed an increasing trend which appeared to begin during the early 1980's (Appendix G). Both phosphorus and NFR appeared to be slightly decreasing with time from the mid 1980's to the early 1990's. The most prominent trend found was for chloride concentrations which appeared to have been progressively increasing over time at both sites. No discernable trends were evident for unionized ammonia or TKN.

Preliminary Trends Lynn River

There were no historic or current datasets for Black Creek watershed that had at least 10 years of data. Therefore no trend analyses were preformed.

Only one of the two PWQMN sites within the Lynn River watershed monitored during the 2002-2005 season was historically sampled (site 59003). Therefore to assess the changes in parameter concentrations over time throughout the Lynn River, data from a downstream site (59001), was also used to explore preliminary trends. Site 59003, just downstream of Simcoe, was routinely sampled from 1975 to 2005 and site 59001, at the Lynn River mouth, was sampled from 1964-1982.

Nitrate and chloride concentrations appeared to be increasing over time both within the upper and lower part of the Lynn River watershed (Appendix G). There is an increasing trend displayed for nitrite within the upstream site (59003) which appears to have occurred from 1990-2005. However within the downstream site (59001) there does not appear to be a trend for nitrite present which could be due to the time frame monitored (stopped in the early 80's before the trend seen in the upstream sites). Unionized ammonia was quite variable and no discernable trend was evident in the upstream site. However a decreasing trend was evident for ammonia downstream near the Lynn River mouth. TKN appeared to have decreased from the late 60's to the mid 80's within both sites, after which there appeared to be an increase in TKN concentrations within the upstream site. No discernable trend was evident within the upstream site for either TP or NFR. However, both TP and NFR appeared to be decreasing since the early 70's through to the mid 80's at site 59001, near the Lynn River mouth.

Preliminary Trends Nanticoke Creek

Only one of the PWQMN sites within the Nanticoke Creek watershed was monitored both historically and during the 2002-2005 sampling season (site 64001 at the mouth). Therefore to assess the changes in water quality over time throughout the Nanticoke Creek, data from two upstream sites (64003 and 64005) were also explored for preliminary trends. Site 64003 is situated upstream of the Waterford WPCP and 64005 is situated downstream of the Waterford WPCP. Both sites were monitored for the 13yr period from 1975-1988.

Nitrate levels appeared to be increasing within both upstream and downstream sites from the 1970's to the mid 1980's after which a slight decreasing trend was apparent (Appendix G). From the 1990's to 2005 site 64001 displayed a slight increase in nitrate concentrations. Nitrite appeared to be increasing within the two upstream sites but remained fairly constant within site 64001 at the mouth of the Nanticoke Creek. TKN concentrations appeared to generally decrease from the 1970's to the late 1980's at all sites and after which there was an increase, except at site 64001, near the Creek mouth, which remained fairly constant through to 2005. Both chloride and TP appeared to decrease downstream of the Waterford WPCP from the late 1970's to the late 1980's. However from the late 1980's to 2005 chloride concentrations appeared to increase within site 64001. No discernable trends were found for ammonia or non-filterable residue.

Preliminary Trends Sandusk Creek

Most of the historic water quality sampling that has occurred within Sandusk Creek has been sporadic and usually for less than 10 consecutive years. Currently only one site near the mouth of Sandusk Creek is monitored, which began as part of the source water protection program in 2004. Given the lack of a long-term dataset, trends were not evaluated for the Sandusk Creek watershed.

Spills

Spills can be defined as releases of pollutants into the natural environment originating from a structure, vehicle, or other container and are abnormal in light of all circumstances. All spills must be reported to the Ministry of the Environment so the necessary remedial actions and protection measures can be taken. According to the Norfolk Groundwater Study, there were approximately 300 reported spills within Norfolk County for the 2003 year (WHI et al., 2003).

Although spills are not considered to be a chronic water quality problem they can still have a tremendous impact on aquatic health and are of potential risk to drinking water if the spill is substantial enough to cause contamination of the Lake Erie intake waters. There is also the risk of transportation related spills that could impact the municipal water supply in Delhi which is in close proximity to Hwy 3, a major route between Detroit and Windsor and Buffalo and Niagara.

Given the inherent risk to the region’s drinking water supply and the limited response time in the event of a spill emergency, it is imperative that spill response protocols are in place. Recently a time of travel study within North and South Creeks was performed as part of the source water protection planning process. The purpose of this study was to determine a two hour time of travel from the Delhi municipal surface water intake within the Lehman Reservoir. The information from this study will help to refine any response protocols that are currently in place.

SUMMARY & CONCLUSIONS

Data Limitations

Environmental monitoring is imperative to good environmental decision-making (ECO 1997). However, the interpretation of results from monitoring programs can be strongly influenced by the quality of data gathered. Therefore it is important to be transparent about the limitations of the data used in decision-making. This is not to say that investigating an issue should be postponed until better data presents itself. On the contrary, using the best available data at the time of investigation allows gaps in our existing datasets to be identified and thus better direct future data gathering expeditions.

Two of the most common data limitations found in environmental studies are the quantity (number of samples taken spatially and temporally) and quality (time and location of sampling event) of the data available.

Data Quantity Limitations

Historically, the Long Point Region Conservation Authority (LPRCA) carried out water quality sampling on a variety of scales. These included site specific studies (such as Lynn River State of the Watershed study) and region wide studies (such as the Provincial Water Quality Monitoring Network). Due to financial cutbacks by the province and the limited internal capacity of the Conservation Authority, there has been a drastic reduction in water quality monitoring since 1996. Across Ontario the PWQMN was reduced from 730 sampling sites to 350 sampling sites in 1996 (A.Todd pers. communication), but has currently increased to 240 sites starting in 2000 (ECO, 2000). The decrease in spatial coverage of the Provincial Water Quality Monitoring Network within the Long Point Region (from a high of 24 sites to the current 10 sites) and the reduction of yearly samples taken at each site (from 12 to 8) has limited the ability to conduct comprehensive spatial and temporal analyses at the watershed scale.

Water quality is highly variable and is sensitive to season, time of day, temperature, flow-stage, spills, soil types, basin topography and many other factors. Due to this, water quality samples must be collected over a range of stream-flows that are representative of the stream at the sample-collection site (ECO, 2002; Painter *et al* 2000). Consequently, many samples are required to adequately characterize water quality over a range of environmental conditions. Painter *et al* (2000) recommends that at least 10 samples be taken per year to adequately characterize ambient surface water quality in streams, while Maybeck *et al* (1996) suggest 12 samples per year for a multipurpose monitoring program, such as the PWQMN. The current eight samples per year per site limits the network's ability to characterize water quality over a full range of environmental conditions such as low and high flows or the effects of seasonality (e.g. under ice conditions).

Data Quality Limitations

Historically, water quality samples collected at sites in the Long Point Region were mainly collected during low to moderate flows (e.g. Figure 11). This was likely a result of limited manpower and of the logistical challenges of sampling high flow events. However, in recent years an effort has been made to sample a full range of flows including high flow events.

The determination of contaminant loads or 'fluxes' is critical for understanding the contribution of non-point sources of contaminants to a water body since most of these contaminants are mobilized during runoff events. It is not uncommon for 80-90% of the annual load to be delivered during 10% of the time when the highest discharges are occurring (Richards, 2002). As a result, it is important that water quality sampling be targeted to characterize both high and low flows. Painter *et a.,l* (2000) suggests that as few as 30 to as many as 75 or more samples may be used to estimate river loads using various estimator techniques, such as, statistical or regression approaches. However, censored data must be kept to a minimum of 50 percent.

Since only eight samples per year are collected at the PWQMN sites and generally at low to moderate flows, accurate annual loads cannot be made with any certainty. More frequent and targeted sampling of both high and low flows over the long term is required to adequately characterize both ambient water quality and contaminant fluxes within sub-basins.

The approach used in this report whereby the most recent contiguous four years of data was summarized helped to increase the likelihood of characterizing the full range of flow and climatic conditions. This approach also reduces the strong year-to-year variability from extremes in climate (e.g. wet and dry periods).

The use of non-parametric statistics to anlayse the data also allowed our analysis to accommodate for the inherent characteristics of water quality data (i.e. non-normal distribution, outliers, missing data) (Hrynkiw et al 2003; Trkulja, 1997). However a numerical statistical difference does not always translate into an ecologically significant difference

Physiochemical Characteristics across the Long Point Region

Streamflow across the Long Point Region varies widely. Big Otter Creek has the highest flows relative to the other watersheds that were gauged within the region. Both Big Creek and Nanticoke Creek have similar stream flows, which were lower that those found in Big Otter Creek but higher than other streams across the Long Point Region, such as the Lynn River and Young Creek. Those streams whose headwaters originate in the Norfolk Sand Plain (e.g. Big Otter Creek, Big Creek, and Nanticoke Creek) are primarily groundwater fed resulting in a continuous base-flow, whereas those tributaries whose headwaters reside in the Horseshoe Moraine (clayey till) or the Haldimand Clay Plain (e.g. Black Creek or Sandusk Creek) usually have intermittent flow during the summer months.

Although the natural base-flow for those streams within the Norfolk Sand Plain remains continuous throughout the low flow summer months, the numerous permits to take water, online impoundments and tile or municipal drains, could eventually have a negative effect on base-flow levels, which in turn could negatively impact water quality. In order to sustain the current base-flow while still allowing for the numerous water takings, there needs to be adequate recharge of the aquifers within the region. Therefore, it is important that nearby wetlands and moraines are protected.

Dissolved oxygen is an important indicator of the river's ability to sustain aquatic life. Within the Long Point Region dissolved oxygen levels have rarely been observed to dip below 6 mg/L, which is above the 4 mg/L lower threshold for cold water biota and is considered to be adequate for aquatic life. However, samples were generally only taken during the day which would not have accounted for the diurnal fluctuation or the range of values an organism truly experiences. Thus, determining if dissolved oxygen within the Long Point Region was limiting to aquatic organisms could not accurately be assessed with the 2002-2005 sampling regime and diurnal monitoring should be employed as part of future monitoring programs.

Super-saturation of dissolved gases can also be potentially hazardous to aquatic life. Within most of the five watersheds analysed gas saturation levels for dissolved oxygen (DO) have been reported as high as

140 percent. Super-saturation of gases within the water can lead to gas exchange problems in aquatic life such as blood gas trauma in fish (Fidler and Miller, 1994). However, there has yet to be a criteria set for the upper limit of DO for the protection of aquatic life.

The pH levels across the entire Long Point Region were fairly consistent and generally were within the range given by the Provincial Water Quality Objective (6.5-8.5). However there were a few cases in which pH values were above 8.5 which can indicate high levels of photosynthesis (Wurts & Durborow, 1992).

The warming trend of summer water temperatures across several watersheds (e.g. Big Otter Creek, Big Creek and Lynn River) is of obvious concern (Figure 8). High temperatures can limit the diversity of aquatic species present as well as impact dissolved oxygen saturations. Twenty four degrees is generally the temperature threshold between cool and warm water fish species (Stoneman and Jones, 1996; Coker et al. 2004). Prolonged periods of time during which temperatures are above 24 °C creates stress for cold or cool water species thus limiting the ability for them to inhabit these areas of the creek. Increased water temperatures can also impact oxygen saturation of freshwaters thereby impacting metabolic rates, growth and reproduction of freshwater fish (Gordon, 1996). Many of the tributaries within the Long Point Region (e.g. Big Creek, Big Otter Creek) have been described as thermally stressed. However, there are watersheds within the Long Point Region that have temperatures and habitats suitable to continue supporting the present cold water fisheries (e.g. the Young Creek, Trout Creek and Kent Creek).

The inherent geology and current landuse practices within the Long Point Region appear to be driving some of the chronic surface water quality issues. For example, watersheds draining the clay and till plains tend to have the highest non-filterable residue and nutrient concentrations (e.g. Big Otter Creek, and Nanticoke Creek). Several studies (McTavish, 1986; Wilcox, 2005) have indicated that there is a strong relationship between land-use practices and surface water quality. Within the watersheds of the Long Point Region most of the land area is designated as agricultural of which a high percentage is row cropped & tile drained. Land-use of this type can result in waterways becoming enriched through runoff of fertilizers and erosion of soils. This relationship is apparent throughout the Long Point Region especially with respect to the elevated nutrient and non-filterable residue concentrations found.

Very little information exists on the major reservoirs within the watersheds of the Long Point Region. Historic monitoring data suggests that the Norwich, Little Lake and Sutton reservoirs are eutrophic with very high phosphorus levels in the euphotic zone, while Deer, Waterford and Lehman reservoirs are meso-eutrophic with low to moderate phosphorus levels. The Lehman Reservoir is also used as the municipal drinking water source for the town of Delhi. Although water from the Lehman reservoir is reported to be fairly good and is tested for a suite of water quality parameters as part of the Ontario drinking water regulations, the LPRCA has only recently started monitoring within the tributaries upstream of the Lehman reservoir to give an indication of the water quality feeding this reservoir.

The major tributaries within the watersheds of the Long Point Region are improving with respect to some nutrients but deteriorating with respect to others. Generally, at any site across the entire Long Point Region where a discernable trend was evident, nitrate concentrations appeared to be slightly increasing where as phosphorus and NFR levels appeared to be decreasing or staying the same. Nitrite and ammonia concentrations have been dramatically increasing over time in the Lynn River just below the Simcoe Water Pollution Control Plant (Appendix G). However, the most apparent change in water quality overtime has been the increase in chloride levels found at most sites across the Long Point Region. This is likely as a direct result from an increase in road-salt application. Although, levels across the Long Point Region are still low relative to the Environment Canada benchmark. Re-assessing these trends in the future as more current data becomes available would be helpful in identifying if new trends are emerging. Measures such as improved wastewater treatment, road salt management strategies and targeted implementation of agricultural beneficial management practices are needed to curb these increasing trends.

Although the characterization of the water quality within this analysis focused mainly on chemical and physical data from the Provincial Water Quality Monitoring Network, (PWQMN), other sources and types of data should ideally be incorporated to create a more integrative approach to monitoring and assessing water quality within a watershed. Biological indices as water quality assessment tools should ideally be used in conjunction with traditional chemical and physical water quality monitoring. Future correlation analyses between the PWQMN, Source Water Protection and Ontario Benthic Biomonitoring Network data gathered by LPRCA should be performed to see if these datasets identify the same areas as impaired. An integrative approach such as this is far more powerful than either alone and can act as a 'quality assessment' of these variables as surrogates to describe surface water quality.

The following is a brief summary of the major water quality issues within each of the six watersheds reviewed in this analysis.

Big Otter Creek Watershed

Nitrate and phosphorus concentrations within the Big Otter Creek watershed were consistently above the Canadian guideline and PWQO and as a result are the most serious nutrient issues within the Big Otter Creek watershed. In fact, median nitrate levels within Spittler Creek were among the highest across the entire Long Point Region. Spittler Creek was the most impaired area within the watershed with respect to all water quality parameters tested, except for phosphorus and total non-filterable residue levels, which were higher downstream on lower Big Otter Creek.

Land-use including intensive agricultural production, urban development, water pollution control plant effluents, and the underlying geology and the topography within the Big Otter Creek watershed are all likely contributing to the degradation in water quality. The higher nitrate and organic nitrogen concentrations found within Spittler Creek are likely as a result of the intensive agriculture, namely fertilizer run-off and livestock stream access. Fausto & Finucan (1992) found that phosphorus inputs within the Big Otter Creek watershed were mainly anthropogenically driven by fertilizers, household effluent, industry and improper milk-house wash water disposal.

Big Otter Creek has been identified as Canada's largest source of sediment contamination to Lake Erie (Cridland, 1997). Although median values were just over the 25 mg/L benchmark, the 95th percentile value (367.25 mg/L) indicated that there were times when significant inputs did occur (Figure 11). Big Otter Creek reacts to event flows extremely quickly and tends to be flashy (Stone, 1993) resulting in increased erosion and sedimentation. This phenomenon is also compounded by the soil type (clayey-till), lack of riparian vegetation and the deeply incised banks within the lower portion of the watershed. Other potential non-filterable residue contributions could from the upstream water pollution control plants at Norwich and Tillonsburg.

Bacterial concentrations have also been identified as an issue within the Big Otter Creek watershed. Regular beach postings within the watershed prompted the start of the CURB (Clean Up Rural Beaches) program in 1992. As a result of this study, tributaries within the upper watershed were found to have higher bacterial counts relative to the main branch, and therefore improvement measures were focused within those areas (e.g. Spittler Creek). Since the implementation of the program bacterial counts have decreased, however, beach postings are still occurring at Port Burwell. It has been hypothesized that some of the bacteria found at the Port Burwell beaches may be originating from the high bacterial concentrations emptying into Lake Erie from Silver Creek in the Catfish Creek watershed (McCarron and McCoy, 1992).

Big Creek Watershed

Generally water quality was better within Trout Creek compared to other sites sampled within the Big Creek watershed. The upper Big Creek region was the most impaired with respect to nitrogen and chloride concentrations (Figures 12, 13 and 14) but Venison Creek and lower Big Creek were the most impaired with respect to phosphorus and non-filterable residue concentrations (Figures 15, 16).

The intensive agriculture and fertilizer application within the upper portion of the Big Creek watershed is likely contributing to the high nitrate concentrations as well (Figure 12). The relatively low nitrate concentrations found within the downstream tributaries (Trout Creek and Venison Creek) is likely having a positive impact on the water quality within lower Big Creek, which is potentially why nitrogen levels are lower downstream.

Phosphorus was routinely above the provincial objective (0.03 mg/L) within the lower portion of the watershed (lower Big Creek and Venison Creek) (Figure 8). Likely these inputs are a reflection of the upstream cumulative inputs from the Delhi Water Pollution Control Plant, and the intensive fertilizer application to crops within the watershed. Also these higher phosphorus levels are likely associated with the higher non-filterable residue concentrations also occurring in the lower portion of the watershed.

Compared to other watersheds within the Long Point Region Big Creek is not a major contributor of nutrients or non-filterable residue (NFR) to Lake Erie. Flow within Big Creek is partially regulated through several wetlands, reducing flow intensity and acting as a sediment sink thereby reducing the sediment concentrations reaching Lake Erie (Stone, 1993). Due to the wetlands and high degree of riparian cover the Big Creek watershed does not react as quickly to event flows relative to Big Otter Creek.

The Lehman Reservoir (used as a municipal drinking water source for the town of Delhi) is assumed to have fairly good water quality given the fish populations it can support and the quality of the upstream waters. Although water from the Lehman reservoir is tested for a suite of water quality parameters as part of the Ontario drinking water regulations, none of the sites used in our analysis of the Big Creek watershed were situated upstream of the Lehman reservoir to give an indication of the water quality feeding the reservoir. However, two sites were added in 2004 under the source water protection program to monitor the quality of the water entering the Lehman reservoir via North Creek and South Creek. It will be important to continue monitoring the water entering and within the Lehman Reservoir as it remains the primary drinking water source for the town of Delhi.

Lynn River Watershed

The impact of urban development on the Lynn River is reflected by the extremely high concentrations of nitrite, ammonia and phosphorus found within the River directly downstream the town of Simcoe (Figures 17, 18 and 19).

Within the Lynn River watershed other tributaries, such as Kent Creek (a groundwater fed creek with minimal urban or agricultural impacts) have significantly better water quality than that found in the lower portion of the Lynn River. Rarely do samples taken on the Lynn River, downstream of the Water Pollution Control Plant (WPCP), meet the Canadian guideline for nitrite or the PWQO for total phosphorus. High nitrite and unionized ammonia levels found within aquatic systems tend to be associated with organic pollution through the disposal of sewage or organic waste (Hem, 1985; Hydromantis Inc. et al., 2005). Within the Lynn River the high nitrite and unionized ammonia levels are likely a result of the Simcoe WPCP. Both unionized ammonia and nitrite are highly toxic to aquatic life which likely is having a negative effect on the fish populations present.

Non-filterable residue (NFR) did not appear to be an issue within the Lynn River; however, the numerous impoundments upstream of the monitoring site along the Lynn River may be acting as sediment sinks.

Although the Lynn River below Simcoe does not appear to have the best water quality it does support a very good brown trout fishery downstream of Simcoe and below Brook's Dam. The higher ammonia and nitrite concentrations are likely buffered by the continual groundwater recharge occurring in the river and the reduced sedimentation occurring as a result of the dam likely provides the necessary gravel substrate. Other tributaries within the Lynn River watershed are fairly good cold water streams (e.g. Kent & Patterson Creeks), the Lynn River has water quality restrictions mainly stemming from WPCP effluent from Simcoe, dam obstruction, and an increase in erosion (LPRCA 1979).

The better water quality found within Kent Creek is likely having a positive influence on the Lynn River further downstream of its confluence and thereby improving the quality of the water reaching Lake Erie.

Another concern with the high nutrient concentrations occurring within the Lynn River is its limited assimilative capacity especially in light of the population growth forecasted for the town of Simcoe. Increasing the WPCPs capacity may be enough to have the treatment process run more effectively and decrease some of contaminant levels within the effluent. Currently Norfolk County is carrying out an assimilative capacity study to better understand the Lynn River's ability to effectively assimilate the WPCP effluent from the Simcoe Plant (pers. comm. Bob Fields).

Black Creek, another major tributary to the Lynn River near the mouth, was not analysed as part of this study, but was evaluated as part of the state of the Lynn Watershed report. Gangon & Giles, (2004), found that the major water quality issues within Black Creek were high NFR, intermittent stream flow and low dissolved oxygen.

Nanticoke Creek Watershed

Generally, within the Nanticoke Creek watershed nutrient concentrations significantly increase as the creek flows out of the Norfolk Sandplain and into the Haldimand Clayplain. This increase within the upper portion of the watershed is likely as a result of the cumulative urban impact from the town of Waterford, the WPCP effluent and the transition in soil types within the contributing drainage area from sandy to clay based soils. The headwaters within the Norfolk Sand Plain tend to have better water quality compared to the rest of the creek which resides within the Haldimand Clay Plain (Van De Lande, 1987).

Total phosphorus and non-filterable residue (NFR) inputs are the most significant water quality issues within the Nanticoke Creek watershed and appeared to progressively increase from upstream to downstream (Figures 20 and 21). Phosphorus has been shown to historically increase during the summer low flow season which could be as a direct result of the increased NFR accumulation that also occurs during this time (Long Point Region Conservation Authority, 1979a). Although Nanticoke Creek was not historically considered a major contributor of nutrient concentrations to Lake Erie (Long Point Region Conservation Authority, 1979a), recent data indicates that the highest median NFR and phosphorus concentrations are found near the mouth of Nanticoke Creek relative to other tributaries within the Long Point Region. However, the Nanticoke Creek does not appear to be as event driven as Big Otter Creek whose maximum concentrations for NFR and phosphorus were much higher. Again the high concentrations found within the lower reaches of the Nanticoke Creek are likely a combination of upstream impacts from urban and WPCP effluent, the increased erosion due to higher base flows, the natural topography and increased livestock access to streams.

Dissolved oxygen levels have been found to decrease downstream of Waterford rendering the creek beyond this point unsuitable cold water fish habitat (Van De Lande, 1987). G. Douglas Vallee Ltd. (2004) speculated that the low dissolved oxygen levels found in the summer were likely as a result of the effluent from the Waterford WPCP making up a substantial percentage of the summer base-flow. Norfolk County has since developed a contingency plan detailing the necessary monitoring and appropriate actions required to mitigate these impacts. Currently an assimilative capacity study is underway to help determine if an upgrade to the Waterford WPCP is required for Nanticoke creek to effectively assimilate its effluent (pers. comm. Bob Fields). Upgrades such as tertiary treatment, or the addition of sand filters and disinfectants could potentially help reduce the level of contaminants within the effluent thus improving the downstream water quality.

Sandusk Creek Watershed

Phosphorus and non-filterable residue levels are the primary water quality issues within the Sandusk Creek watershed, and tend to progressively increase from upstream to downstream (Figures 22 and 23). The entire Sandusk Creek watershed resides within the Haldimand Clay Plain which has a natural tendency for higher sedimentation and sediment associated nutrient concentrations, such as phosphorus. There are no natural retention areas within the Sandusk Creek watershed to help augment summer low flows (Morse et al., 1982). Therefore the Sandusk Creek watershed tends to be a 'flashy' system during rain events due to soil type (clay), lack of forest cover and the lack of infiltration capacity of the soils (LPRCA, 1979b). However, given the relatively low flows found within this watershed, it is only considered to be a moderate contributor of nitrate and phosphorus to Lake Erie (LPRCA, 1979b).

However, this same study noted that Sandusk Creek was a significant contributor of atrazine (a common pesticide) to Lake Erie (LPRCA 1979). Future pesticide sampling at the new source water protection site near the mouth of Sandusk Creek should be performed to confirm if atrazine levels are still high within the Creek.

Dedrick-Young Creek Watershed

Water quality within the Dedrick - Young Creek watershed tends to be fairly good and some streams within the Norfolk Sand Plain, such as Young Creek, have been identified as a biologically significant salmonid cold water stream habitat (LPRCA 1979; Bernier & Reynolds 1976). Young Creek tends to be of better water quality compared to Dedrick Creek, which is likely due to the numerous springs along Young Creek that continually recharge, cool and dilute the water (Van de Lande 1987).

The Port Rowan drinking water intake and Water Pollution Control Plant (WPCP) both take and discharge within the same general area in Lake Erie. This is of potential concern for the raw water quality taken up by the drinking water intake. Norfolk County routinely monitors the raw water quality used to supply the Port Rowan drinking water treatment. Bacterial samples are taken weekly; nitrate, nitrite and THM are sampled for quarterly and a full chemical analysis is done yearly. Norfolk County has also recognized the potential issues related to having a discharge and intake within the same general vicinity and thus have implemented safeguards to reduce the impact on the water quality (pers. comm. Bob Fields). Future raw water analyses at the location of the Port Rowan drinking water treatment plant intake should be performed to ensure the WPCP effluent is not having a negative impact.

Other Watersheds

Very little water quality information exists for the other watersheds within the Long Point Region. However, it is generally thought that their nutrient or NFR contributions to Lake Erie are minimal and given that they are not used for recreation or as a drinking water source, they have not been considered a priority for monitoring.

Spills

Spills and water pollution control plant bypasses are a significant threat to downstream water users in the Long Point Region. Although spills are not considered to be a chronic water quality problem they can still have a tremendous impact on aquatic health and are of potential risk to drinking water supplies if the spill is within close proximity to an intake. There is also the risk of transportation related spills that could impact the municipal water supplies in Delhi which are is in close proximity to Highway 3, a major route between Detroit and Windsor and Buffalo and Niagara. Given the inherent risk to the region's drinking water supply and the limited response time in a spill emergency, it is imperative that spill response protocols are in place.

Preliminary Trends

The Preliminary trend assessment yielded variable results with respect to whether nutrient levels are decreasing or increasing over time. Generally, at any site across the entire Long Point Region where a discernable trend was evident, nitrate concentrations appeared to be slightly increasing where as phosphorus and NFR appeared to be decreasing or staying the same. Nitrite and ammonia concentrations have been dramatically increasing over time just below the Simcoe Water Pollution Control Plant in the Lynn River. However, the most apparent change in water quality overtime has been the increase in chloride levels found at most sites. This is likely as a direct result of an increase in road-salt application. Although, levels across the Long Point Region are still low relative to the Environment Canada benchmark. Re-assessing these trends in the future as more current data becomes available would be helpful in identifying if new trends are emerging. Measures such as improved wastewater treatment, road salt management strategies and targeted implementation of agricultural beneficial management practices are needed to curb these increasing trends.

RECOMMENDATIONS

To improve our understanding of the water quality conditions within the Long Point Region watersheds, the following recommendations are made:

Sampling Regime

1. At a minimum, 12 samples per year should be taken at each long term monitoring site to characterize ambient water quality conditions. However, this will require additional financial resources.
2. The sampling regime should be designed so that the range of flow conditions is continued to be sampled. For example, additional high flow samples should be targeted during spring runoff and summer rainfall events. This will characterize the range of environmental conditions that exist in the watershed.
3. Diurnal sampling of dissolved oxygen, pH and temperature should be carried out to adequately capture the range of values organisms are truly experiencing within a day.

Monitoring

1. Continue monitoring chemical and physical parameters within the watershed under the provincial water quality monitoring network and the source water protection programs.
2. Additional long term monitoring sites are needed to gain better spatial coverage, at the watershed scale, so that upstream/downstream and tributary comparisons can be made. Additional recommended sites include:
    i. Big Otter Creek downstream of Tillsonburg
    ii. Big Creek downstream of Delhi
    iii. Nanticoke Creek downstream of Waterford
3. Continue to sample benthic macroinvertebrates under the OBBN program at each of the PWQMN sites and continue to develop an integrative monitoring program that combines chemical, physical and biological (e.g. benthic macroinvertebrate, fish community) data.
4. Monitor for pesticide contamination pre and post application and target high flow events within smaller agricultural tributaries across the Long Point Region.

Reporting

1. Identify specific long term indicators that can be used for progress measurement. Target monitoring activities so that these indicators will be collected annually. Incorporate these indicators into the monitoring design.
2. Annual high-level reporting of current conditions to report on progress should be carried out
3. Future analysis of data should be corrected for flow to determine if this is a confounding variable that is resulting in a misinterpretation of the water quality results such as bacterial concentrations.
4. Every five years, prepare an in-depth technical report.
5. Future statistical trend analyses should be carried out upon completion of a current 5 year set of sampling data. This is to properly assess if areas within the watershed are improving or deteriorating over time.

Future Investigations

1. Investigate the linkage between an area's underlying geology and 'ambient' nutrient concentrations to predict basin specific natural benchmarks (however current land-use practices and alterations must be taken into consideration as these may have amplified the natural relationship)
2. Investigate the linkage between land-use and water quality to help modify best practices for agriculture and pasture lands (for example the introduction of buffer or riparian zones to decrease sedimentation).
3. Investigate potential point and non-point sources of nutrient and sediment loading within the major watersheds of the Long Point Region (e.g. Big Otter, Big, Lynn, Nanticoke & Sandusk). This could include a mass load analysis to estimate loads from both point and non-point sources (e.g. sediment budget analysis within Big Otter Creek to determine where the loading within Port Burwell is coming from).
4. Conduct an analysis characterizing the current water quality conditions within the major recreational reservoirs
5. Investigate the potential to protect recharge areas through reforestation and redesign of a more efficient municipal drainage system which could decrease the number of active drains.
6. Conduct site specific investigation(s) evaluating the potential for maintaining or rehabilitating cold water creeks currently supporting native fisheries (e.g. Young Creek).
7. Investigate the potential for liquid manure injected into the ground to reach nearby surface waters during high flow events.
8. Investigate potential ways in which to control sedimentation across the region, especially in Big Otter Creek.
9. Conduct future outreach initiatives, such as rural outreach for implementation of waterway fencing and buffer zones to decrease nutrient loading and sediment loading through erosion, to promote and facilitate rehabilitation of the impaired watersheds (Big Otter Creek, Big Creek and Lynn River)
10. Conduct a comprehensive survey and inventory of good cold water tributaries within the LPR and potential management plans to ensure their continued good water quality.
11. Conduct a comprehensive inventory of all dams and reservoirs within the Long Point Region
12. Conduct a comprehensive analysis of all temperature logger data to investigate frequency of days and duration at maximum temperatures as well as the resiliency of the system to recover from very hot air temperature spikes.

REFERENCES

Analyse-it Software, Ltd. 2005. Analyse-it statistical analysis software for Microsoft Excel. (http://www.analyse-it.com)

Bernier, L. and J.K. Reynolds. 1976. The Young Creek Watershed Study: The Jr. Conservationist Award Program. Ministry of Natural Resources, Toronto ON. 75pgs.

CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment, Winnipeg.

Cridland, W. 1997. Shoreline Water Quality Study Port Burwell to Long Point, Lake Erie. Long Point Conservation Authority, Environment Canada Great Lakes 2000 Clean Fund. Simcoe ON. 18pgs.

Doyle M.P. and M.C. Erickson. 2006. Closing the Door on the Fecal Coliform Assay. Microbe. 1(4): 162-163.

Environment Canada. 2001. Priority Substances List Assessment Report: Road Salt. Environment Canada, Health Canada, Ottawa, Ontario, 165p.

Environmental Commissioner of Ontario. 1997. Open Doors- Ontario's Environmental Bill of Rights. 1997 Annual Report. Environmental Commissioner of Ontario, Toronto, Ontario. 100p.

Environmental Commissioner of Ontario (ECO). 2002. Developing Sustainability. 2001-2002 Annual Report. Environmental Commissioner of Ontario, Toronto, Ontario. 191p.

Francy, D.S. and R.A. Duner. 1998. Factors Affecting *Escherichia coli* Concentrations at Lake Erie Public Bathing Beaches. Water-Resources Investigation Report 98-4241 USGS. 41 pgs.

Fausto, J.A. and S.D. Finucan. 1992. Clean Up Rural Beaches: CURB Plan for Hay, Dedrich and Big Otter Creek Watersheds. Long Point Conservation Authority, Simcoe ON. 84p.

Fidler, L.E. and S.B. Miller. 1994. British Columbia Water Quality Guidelines for Dissolved Gas Supersaturation. Report for BC Environment. Aspen Applied Sciences Ltd., Valemount BC. Pgs. 110.

G. Douglas Vallee Ltd. 2004. Environmental Impact Study Waterford Water Pollution Control Plant. G.D.Vallee Ltd., Simcoe ON. 20pgs.

Gagnon, P. 1995. Fisheries Management Report, 1994 Reservoir Monitoring Program for Long Point Region Conservation Authority Reservoirs. Simcoe ON 49pgs.

Gagnon, P. and E. Giles. 2004. Lynn River State of the Watershed Project: Final Report. Long Point Region Conservation Authority. Simcoe, Ontario. 232pgs.

Gordon, L. 1996. Big Otter Creek CURB Program Annual Report. Long Point Region Conservation Authority. Simcoe, ON. 28p.

Griffith, L.M., R.C. Ward, G.B. McBride, and J.C. Loftis. 2001. Data Analysis Considerations in Producing 'Comparable' Information for Water Quality Management Purposes'. Technical Report 01-01, National Water Quality Monitoring Council, USGS, Reston, Virginia. (http://water.usgs.gov/wicp/acwi/monitoring/pubs/tr/nwqmc0101.pdf)

Helsel, D.R. and R.M. Hirsch. 2002. Techniques in Water Resources Investigations of the United States Geological Survey. Book 4 Hydrologic Analysis and Interpretation. Chapter A3. Statistical Methods in Water Resources. U.S. Department of the Interior, United States Geological Survey. (http://water.usgs.gov/pubs/twri/twri4a3/)

Hirsch, R.M, R.B. Alexander, and R.A. Smith. 1991. Selection of Methods for the Detection and Estimation of Trends in Water Quality. Technical Memorandum. (http://water.usgs.gov/admin/memo/BSA/BSA91.01.pdf)

Hrynkiw, T., T. Viraraghavan, and G. Fuller. 2003. Analysis of Trends in Water Quality of Buffalo Pound Lake. Canadian Water Resources Journal 28(3):337-357.

LPRCA. 1979. Background Study: Lynn River - Black Creek Waterhsed. Long Point Region Conservation Authority, Simcoe ON. 102pgs.

LPRCA. 1979. Background Study: Nanticoke Creek Waterhsed. Long Point Region Conservation Authority, Simcoe ON. 97pgs.

LPRCA. 1979. Background Study: Sandusk Creek Watershed. Long Point Region Conservation Authority, Simcoe ON. 81pgs.

LPRCA. 1979. Background Study: Dedrick - Young Creek Waterhsed. Long Point Region Conservation Authority, Simcoe ON. 115pgs.

McCarron J. & McCoy K. 1992. Silver Creek Water Quality Inventory CCCA publication 37 p.

McTavish, D.A. 1986. Relationships between Land Use and Water Quality in Southwestern Ontario. Gartner Lee and Associates and Ministry of the Environment Southwestrn Region Technical Support Section, Ontario.

Meybeck, M, V. Kimstach, and R. Helmer. 1996. Chapter 2. Strategies for water quality assessment. In Water Quality Assessments – A guide to use of biota, sediments and water in Environmental Monitoring. Second Edition, UNESCO/WHO/UNEP (http://www.who.int/water_sanitation_health/resourcesquality/wqachapter2.pdf)

Morse, A., B. Janssen and T. VanOostrom. 1982. Young Creek / Sandusk Creek Watershed Study. Long Point Region Conservation Authority, Simcoe ON. 96pgs.

MNR. 1977. Big Otter Creek Watershed Study, the senior conservationist award program. MNR, Toronto ON. 43p.

Stone, F.A. 1993. Sediment and Nutrient Transport Dynamics in Tow Lake Erie Tributaries: Implications for External Phosphorus Loading Estimates. PhD Thesis. University of Waterloo Department of Geography. Waterloo Ontario. 156p.

Painter, S., D.N. Myers, J. Letterhos. 2000. Lake Erie Lakewise Management Plant (LaMP) Technical Report Series. Characterization of Data and Data Collection Programs for Assessing Pollutants of Concern to Lake Erie. Lake Erie Lakewide Management Plan. Environment Canada, Burlington. 62p.

Pett, Brian. 2005. Personal Communication.

Richards, P.R. 2002. Estimation of pollutant loads in rivers and streams: A guidance document for NPS programs. Report to the U.S. Environmental Protection Agency-Region VIII. Heidelberg College Water Quality Laboratory, Tiffin, Ohio. 134p.

Sigma Plot 8.0. 2002. Users Guide. SPSS, Chicago Il.

Stoneman, C. L. and M. L. Jones. 1996. A simple method to classify stream thermal stability with single observations of daily maximum water and air temperatures. N. Am. J. Fisheries Management 16:728-737.

Trkulja, J. 1997. Stochastic modeling and trend analysis of phosphorus in the Grand River. Maters of Science, University of Guelph, Guelph, Ontario. 156p.

Van De Lande, R. 1987. Water Quality Report. Long Point Region Conservation Authority, Simcoe ON. 34pgs.

Wilcox, B. 2005. Dodd Creek Community Based Watershed Strategy. Lake Erie Bi-national Public Forum, Ontario.

Wurts, W.A. and Durborow, R.M. 1992. Interactions of pH, Carbon Dioxide, Alkalinity and Hardness in Fish Ponds. Southern Regional Aquaculture Centre. Publication no. 469. Stoneville Mississippi. 4p.

APPENDICES

Appendix A. Summary of general characteristics for the 9 major watersheds within the Long-Point Region.

Major Watershed	*Drainage Area (km^2)*	*Physiography*	*Land-Use*	*Major Water-Use*	*Topography & Major tribs.*	*No. of WPCP*
Big Otter Creek (LPRCA 1979. Big Otter Watershed Study)	712	Moraine till to the north and along the western boundary Norfolk Sand through the middle and eastern portion of the watershed	Livestock operations and cash crops in the Moraine till Tobacco and ginseng in the Sand Plain Lower watershed is less agriculturally intense Major urban centres include; Norwich, Tillsonburg, and Port Burwell	Aquatic habitat Waste Assimilation Agricultural irrigation Recreation - Port Burwell beach	Elevation drop of 145km Mainly flat within the northern reaches and deeply incised to the south Major tributaries include; Spittler, Little Otter Creeks	3
South Otter Creek	217	Norfolk Sand mainly throughout Haldimand Clay in a small part of the southeast corner	Mainly specialty crops such as fruits and vegetables	Aquatic habitat		
Big Creek (Stone 1993)	725	Norfolk Sand mainly throughout Moraine Till in the northeast corner Haldimand Clay in the southern tip	Mainly specialty crops such as tobacco, ginseng and Major urban centres include Delhi	Aquatic habitat Waste Assimilation Agricultural irrigation	Average fall in elevation is 1.4m/km Major tributaries include; Trout Creek and Venison Creek	1
Dedrick-Young Creek (LPRCA 1979. Background Study Dedrich-Young; Bernier & Reynolds 1976; Morse et al. 1982))	263	Norfolk Sand mainly throughout Haldimand clay in the south west corner and eastern corner near Young Creek	Major urban centres include Port Rowan and Turkey Point	Aquatic habitat Mainly tobacco and rotational grains Fishing – Young creek supports a cold water fishery Recreation along the Lake Erie shore Very high forest cover	Total eleveation fall is 62m with an average gradient of 3.6m/km and 2.8m/km for Young and Dedrich Creeks respectively Streams are deeply incised Dedrick Creek is located near the western watershed boundary whereas Young Creek is located near the eastern watershed boundary	1
Lynn River (includes Black	288	Norfolk sand in the northwestern portion of the	Mainly tobacco, cereal, corn, and ginseng in the	Aquatic habitat	Average change in elevation of 13ft/mile	2

Creek) (LPRCA 1979. Background Study; CD report)		watershed Haldimand clay in the rest of the watershed east of Simcoe and all of Black Creek Two physiographic regions above are separated by the Galt Moraine	Sand Plain High percentage of livestock operations and cash crops within the Haldimand Clay of the Black Creek watershed Major urban centres include Simcoe and Port Dover	Waste Assimilation Fishing – in Lynn River tributaries, Kent Creek supports a brook trout fishery	Major tributaries of Lynn River include; Davis, Paterson and Kent Creeks Major tributaries to Black Creek include; catfish creek	
Nanticoke Creek (LPRCA 1979, background Study)	180	Haldimand clay mainly throughout Norfolk sand in the northeast portion of the watershed, west of Waterford Two physiographic regions above are separated by the Galt Moraine	Mainly tobacco, peanuts and rotational grains in Sand plain Livestock dominates through the Galt Moraine and Haldimand clay Industrial Park – in the village of Nanticoke near Lake Erie shore Major urban centres include Waterford, Townsend, and Nanticoke	Aquatic habitat Waste Assimilation Recreation within the Waterford Ponds	Total fall in elevation is 62m with an average gradient of 1.44m/km	2
Sandusk Creek (LPRCA 1979. background study Sandusk-Stondy)	158	Haldimand clay throughout	Mainly grains, pasture and livestock Major urban centres include Hagersville and Jarvis	Aquatic habitat Waste Assimilation	Fairly flat	2
Stoney Creek (LPRCA 1979. background study Sandusk-Stondy)	118	Haldimand clay throughout	Livestock operations, pasture and cash crops	Aquatic habitat		
Gates-Evans Creek	89	Haldimand clay throughout	Livestock operations, pasture and cash crops	Aquatic habitat		
Note: WPCP = water pollution control plant						

Appendix B. Table of Provincial Water Quality Monitoring Network (PWQMN) Sites within Long Point Region watersheds.

Surface Water Quality Monitoring Sites

Station Number	Truncated Name	Tributary	Location	Current Program	FIRST YEAR	LAST YEAR	MISSED YEARS
16010900102		Big Otter Creek	Cnty Rd 42, W of Cnty Rd 19, Port Burwell		1964	2000	28
16010900202		Big Otter Creek	Main St, W of Plank Rd, N of Vienna		1966	1971	0
16010900302		Big Otter Creek	Union Ln , upstrm Tillsonburg		1966	1971	0
16010900402	9004	Big Otter Creek	Eden Line, 3km E. of Hwy 3, SE of Tillsonberg		1972	1995	0
16010900502	9005	Big Otter Creek	Plank Rd, Vienna		1972	1995	0
16010900602		Little Jerry Creek	Hwy 3, E of Springer Hill Rd, E of Aylmer		1974	1974	0
16010900702	9007	Big Otter Creek	Maple Dell Rd, E of Base Line	PWQMN	1980	present	6
16010900802	9008	Big Otter Creek	Calton Ln, Calton	PWQMN	2002	present	0
16010900902		Big Otter Creek	John Pound Rd, dwnstrm Tillsonburg		2002	0	0
16010901002	9010	Spittler Creek	Milldale Rd, W of Otterville	PWQMN	2002	present	0
16011000102		South Otter Creek	Lakeshore Line, E of Port Burwell		1964	1971	0
16011100102		Clear Creek	Lake Rd, W of Conc Rd 8, SW of Port Rowan		1964	1976	0
16012400102		Big Creek	Hwy 59, S of Port Rowan		1964	1989	16
16012400202		Big Creek	Western Ave, W of Hwy 3, Delhi		1982	1995	7
16012400302	24003	Big Creek	Lakeshore Rd (Cnty Rd 42), SW of Port Rowan		1972	2000	7
16012400402		Big Creek	Hwy 3, W of Hwy 59, W of Delhi	SWP	1974, 2004	present	0
16012400502		Venison Creek	Conc 8, Walsingham Twp, S of Langton (AG-2)		1975	1977	0
16012400602		Venison Creek	Conc. 12 Rd (Norwich Rd), E of Norwich		1975	1976	0
16012400702		Venison Creek	Townline Rd, W of Hwy 59, SE of Tillsonburg		1975	1976	0
16012400802		Venison Creek	Bostick Rd, W of Hwy 59, SE of Tillsonburg		1975	1976	0
16012400902	24009	Big Creek	William St, W of Hwy 3, Delhi		1979	1995	3
16012401002		Big Creek	1st Conc, Walsingham Twp		2001	2003	0
16012401102	24011	Big Creek	Conc 7, W of Hwy 59, NW of Walsingham	PWQMN	2002	present	0
16012401202	24012	Big Creek	Conc 2, Windham Twp, S of Kelvin	PWQMN	2002	present	0
16012401302	24013	Venison Creek	Reg Rd 60, W of Springarbour	PWQMN	2002	present	0
16012401402	24014	Trout Creek	Massecar Rd, W of Pine Grove	PWQMN	2002	present	0
16012600102		Dedrich Creek	Front Rd, E of Hwy 59, SW of Port Rowan		1964	1995	8
16015900102		Lynn River	Hwy 6, Port Dover		1964	1982	1
16015900202		Lynn River	Lynn Valley Rd, E of Hwy 24, SE of Simcoe		1969	1980	0
16015900302	59003	Lynn River	DeCou Rd, Simcoe	PWQMN	1975	present	14
16015900402		Lynn River	Queensway E (Hwy 3), E of Norfolk, Simcoe		1975	1975	0

		Tributary					
16015900502		Kent Creek	S of Cedar St, W of Norfolk St, Simcoe		1975	1975	0
16015900602		Davis Creek Tributary	14 St W, W of Norfolk St, N of Simcoe		1975	1975	0
16015900702		Patterson Creek	14 St W, W of Norfolk St (Hwy 24), N of Simcoe	SWP	1975, 2004	present	0
16015900802	59008	Lynn River	Victoria St, S. of Queensway (Hwy 3), Simcoe		1977	1995	7
16015900902	59009	Lynn River	Queen St, W of Cnty Rd 5, Port Dover	SWP	1981, 2000,2004	present	12
16015901002	59010	Kent Creek	Hwy 3, W of Simcoe	PWQMN	2002	present	0
16016200102		Foley Creek	New Lake Shore Rd, E of Port Dover		1975	1978	0
16016300102		Centre Creek	New Lakeshore Rd, E of Hwy 6, E of Port Dover		1976	1995	2
16016400102	64001 & 64001c	Nanticoke Creek	Reg Rd 3, Nanticoke	PWQMN	1964	present	6
16016400202	64002	Nanticoke Creek	S of Conc 14, W of Jarvis off Hwy 3		1975	1995	7
16016400302	64003	Nanticoke Creek	Mechanic St, E of Waterford		1975	1995	8
16016400402	64004	Nanticoke Creek	Hwy 6, SW of Jarvis		1977	1995	8
16016400502	64005	Nanticoke Creek	Cockshutt Rd, Nanticoke Rd 5, E of Waterford		1977	1995	7
16016400602	64006	Nanticoke Creek	Bloomsburg Rd, Conc 12, NW of Jarvis		1977	1995	8
16017000102		Sandusk Creek	Cheapside Rd, S of Cnty Rd 3, Woodlawn Park	SWP	1964-1975, 2004	present	0
16017000202		Sandusk Creek	Reg Rd. 3, E. of Sandusk Road, N of Peacock Point		1978	1995	10
16017000282		Sandusk Creek	Reg Rd. 3, E of Sandusk Road, N of Peacock Point		1975	2000	21
16017000302	70003	Sandusk Creek	Con Rd 6, E of Hwy 6, SE of Jarvis		1975	1995	8
16017000402		Sandusk Creek	Hwy 3, W of Sandusk Rd (Cnty Rd 18), E of Jarvis		1975	1995	16
16017000502	70005	Sandusk Creek	Cnty Rd 9, E of Cnty Rd 74, W of Hagersville		1984	1995	3
16017000602	70006	Sandusk Creek	Brooklyn Sideroad, S of Rainham Rd		2001	2002	0
16017300102		Stoney Creek	Reg Rd 53, S of Reg Rd 3, S of Selkirk		1964	1976	0
SWP		North Creek	Old Mill Rd, W of Delhi	SWP	2004	present	0
SWP		South Creek	Schafer side Rd, W of Delhi	SWP	2004	present	0
SWP		Yonge Creek	Front Rd, near mouth of Younge Creek	SWP	2004	present	0
SWP		Black Creek	Conc 2, NE of Port Dover	SWP	2004	present	0

current provincial water quality monitoring network (PWQMN) sites, 2002-2005 data analysed
new source water protection (SWP) sites
historical sites used for full analysis
additional sites analysed for bacterial data

Appendix C. Current method detection limit at MOE laboratory for various water quality variables.

Variable	Detection Limit	Units
Alkalinity - TFE	0.2	mg/L as CaCO3
Ammonia nitrogen	0.002	mg/L as N
Calcium	0.05	mg/L
Conductivity, 25C	1	mS/cm
Copper	0.0002	mg/L
Dissolved Solids	2	mg/L
Hardness	0.2	mg/L
Lead	0.0005	mg/L
Magnesium	0.02	mg/L
Nickel	0.0005	mg/L
Nitrate + Nitrite Nitrogen	0.005	mg/L as N
Nitrite nitrogen	0.001	mg/L as N
Potassium	0.01	mg/L
Reactive Phosphorus	0.0005	mg/L as P
Sodium	0.02	mg/L
Non-filterable residue	1	mg/L
Total Kjeldahl Nitrogen	0.02	mg/L as N
Total Phosphorus	0.002	mg/L as P
Total Solids	2	mg/L
Zinc	0.0005	mg/L

SOURCE:

Appendix D. Summary statistics for the 2002-2005 dataset for all the water quality parameters at the 10 long term PWQMN monitoring sites in the Long Point Region watersheds.

Nitrates, Total Summary Statistics

	9007	9010	9008	24012	24014	24011	24013	59010	59003	64001
5th	2.67	0.00	2.56	2.70	2.33	2.38	2.09	1.98	2.33	0.07
10th	2.99	0.01	2.66	2.73	2.44	2.43	2.13	2.11	2.54	0.14
25th	3.31	0.08	2.90	2.96	2.62	2.63	2.21	2.34	2.69	0.58
Median	3.76	4.13	3.43	3.23	2.76	2.97	2.39	2.49	2.86	1.31
75th	5.11	9.12	4.39	4.14	2.87	3.20	2.57	3.00	3.21	2.50
90th	6.25	10.01	5.51	6.03	2.95	3.51	2.92	3.23	3.84	4.21
95th	6.70	11.64	6.14	6.32	2.96	4.15	3.05	3.28	3.93	4.65
Mean	4.26	4.72	3.81	3.79	2.71	3.04	2.44	2.60	3.01	1.82
Std dev	1.44	4.49	1.28	1.26	0.22	0.58	0.31	0.43	0.64	1.59
Std err	0.28	0.92	0.25	0.24	0.04	0.11	0.06	0.08	0.12	0.28
Min	2.10	0.00	2.43	2.05	2.03	2.36	2.00	1.86	1.68	0.00
Max	8.12	12.47	7.70	6.88	3.01	4.89	3.08	3.30	4.95	5.86
n	27	24	27	27	32	27	27	27	27	33

Nitrite Summary Statistics

	9007	9010	9008	24012	24014	24011	24013	59010	59003	64001
5th	0.018	0.004	0.007	0.012	0.005	0.016	0.013	0.009	0.049	0.008
10th	0.018	0.005	0.008	0.014	0.005	0.018	0.014	0.011	0.073	0.009
25th	0.021	0.009	0.013	0.018	0.006	0.023	0.019	0.014	0.099	0.018
50th	0.032	0.027	0.022	0.022	0.008	0.026	0.025	0.018	0.159	0.024
75th	0.042	0.076	0.040	0.039	0.009	0.031	0.030	0.022	0.185	0.038
90th	0.051	0.107	0.052	0.047	0.010	0.035	0.035	0.028	0.218	0.057
95th	0.060	0.148	0.054	0.055	0.014	0.039	0.047	0.032	0.309	0.143
Mean	0.037	0.050	0.032	0.032	0.008	0.028	0.025	0.019	0.159	0.037
Std dev	0.028	0.056	0.033	0.030	0.003	0.011	0.011	0.007	0.087	0.039
Std err	0.005	0.011	0.006	0.006	0.001	0.002	0.002	0.001	0.017	0.007
Min	0.016	0.003	0.007	0.012	0.005	0.015	0.010	0.007	0.038	0.004
Max	0.163	0.227	0.178	0.169	0.018	0.073	0.056	0.035	0.448	0.165
n	27	24	27	27	32	27	27	27	27	33

Ammonia Summary Statistics

	9007	9010	9008	24012	24014	24011	24013	59010	59003	64001
5th	2.9E-05	2.5E-05	2.5E-05	2.3E-05	1.2E-05	4.5E-05	2.7E-05	1.5E-05	7.0E-04	9.8E-05
10th	3.3E-05	3.8E-05	4.1E-05	3.2E-05	2.5E-05	5.5E-05	4.4E-05	3.9E-05	1.2E-03	2.6E-04
25th	2.9E-04	3.1E-04	9.2E-05	2.5E-04	7.7E-05	4.5E-04	3.0E-04	1.6E-04	2.0E-03	7.3E-04
50th	8.9E-04	1.9E-03	8.0E-04	6.6E-04	2.8E-04	6.9E-04	7.4E-04	4.7E-04	6.7E-03	2.4E-03
75th	1.4E-03	2.6E-03	1.2E-03	1.5E-03	4.6E-04	1.4E-03	1.0E-03	8.3E-04	2.1E-02	4.8E-03
90th	2.2E-03	6.7E-03	3.0E-03	4.1E-03	7.6E-04	2.7E-03	3.7E-03	3.3E-03	4.8E-02	1.4E-02
95th	5.1E-03	1.1E-02	3.1E-03	6.4E-03	1.0E-03	3.2E-03	4.5E-03	3.5E-03	6.5E-02	2.0E-02
Mean	1.2E-03	3.1E-03	1.2E-03	1.6E-03	3.4E-04	1.1E-03	1.3E-03	9.3E-04	1.6E-02	5.1E-03
Std dev	1.8E-03	5.1E-03	1.4E-03	2.3E-03	3.3E-04	1.0E-03	1.7E-03	1.2E-03	2.1E-02	7.2E-03
Std err	3.6E-04	1.1E-03	2.8E-04	4.5E-04	6.0E-05	2.1E-04	3.3E-04	2.4E-04	4.1E-03	1.4E-03
Min	2.5E-05	1.3E-05	1.5E-05	7.4E-06	4.9E-06	4.4E-05	9.2E-06	7.2E-06	7.6E-05	1.1E-05
Max	7.8E-03	2.3E-02	5.6E-03	8.9E-03	1.3E-03	3.6E-03	6.7E-03	4.3E-03	7.2E-02	2.9E-02
n	25	23	25	25	31	25	26	26	26	26

Kjeldahl Summary Statistics

	9007	9010	9008	24012	24014	24011	24013	59010	59003	64001
5th	0.34	0.56	0.32	0.41	0.15	0.31	0.26	0.27	0.46	0.57
10th	0.36	0.58	0.34	0.43	0.16	0.32	0.27	0.29	0.50	0.63
25th	0.48	0.75	0.41	0.47	0.18	0.34	0.32	0.33	0.54	0.78
50th	0.64	0.83	0.57	0.54	0.23	0.45	0.41	0.38	0.91	0.86
75th	0.74	0.89	0.74	0.63	0.25	0.53	0.51	0.43	1.21	1.08
90th	0.91	1.27	0.96	0.68	0.33	0.72	0.66	0.50	1.48	1.52
95th	1.27	1.57	1.91	1.22	0.51	0.94	0.97	0.55	1.53	1.57
Mean	0.68	0.89	0.71	0.61	0.26	0.51	0.47	0.40	0.92	0.97
Std dev	0.35	0.34	0.53	0.28	0.15	0.27	0.27	0.13	0.42	0.36
Std err	0.07	0.07	0.10	0.05	0.03	0.05	0.05	0.02	0.08	0.06
Min	0.31	0.51	0.31	0.38	0.15	0.29	0.24	0.26	0.38	0.50
Max	2.00	2.01	2.55	1.64	0.95	1.60	1.50	0.91	1.96	2.15
n	27	24	27	27	32	27	27	27	27	33

Phosphorus Summary Statistics

	9007	9010	9008	24012	24014	24011	24013	59010	59003	64001
5th	0.029	0.020	0.020	0.018	0.014	0.014	0.016	0.008	0.030	0.051
10th	0.031	0.021	0.024	0.020	0.015	0.018	0.023	0.010	0.037	0.060
25th	0.040	0.028	0.044	0.025	0.020	0.030	0.032	0.014	0.045	0.077
50th	0.057	0.053	0.063	0.032	0.027	0.051	0.046	0.020	0.061	0.113
75th	0.071	0.082	0.119	0.039	0.038	0.061	0.063	0.026	0.100	0.143
90th	0.094	0.092	0.214	0.056	0.059	0.090	0.073	0.035	0.159	0.232
95th	0.208	0.287	0.526	0.149	0.078	0.195	0.108	0.037	0.171	0.402

Mean	0.070	0.081	0.128	0.048	0.035	0.062	0.052	0.022	0.081	0.141
Std dev	0.061	0.101	0.184	0.062	0.027	0.061	0.033	0.017	0.047	0.107
Std err	0.012	0.021	0.035	0.012	0.005	0.012	0.006	0.003	0.009	0.019
Min	0.022	0.018	0.016	0.014	0.007	0.014	0.014	0.007	0.025	0.044
Max	0.286	0.463	0.815	0.316	0.146	0.286	0.173	0.095	0.178	0.483
n	27	24	27	27	32	27	27	27	27	33

NFR Summary Statistics

	9007	9010	9008	24012	24014	24011	24013	59010	59003	64001
5th	2.03	2.22	3.00	1.30	2.85	2.90	3.03	0.68	3.75	11.95
10th	2.10	2.70	4.65	1.70	4.50	4.65	4.70	1.05	4.30	14.50
25th	3.63	6.35	14.90	2.15	6.05	9.28	10.23	1.60	6.50	18.75
50th	7.60	11.30	26.90	2.70	7.70	20.75	18.80	3.35	12.40	38.40
75th	12.15	17.60	77.78	4.25	11.85	30.98	25.28	4.78	17.70	63.15
90th	19.20	41.00	152.50	10.10	15.70	46.95	32.95	8.05	24.35	95.80
95th	25.80	90.97	367.25	13.03	34.80	95.23	36.60	9.88	29.08	154.50
Mean	10.05	25.08	73.57	4.43	12.68	27.30	19.38	3.94	13.52	51.28
Std dev	9.55	45.34	118.40	4.46	18.35	29.42	12.48	3.20	8.71	46.12
Std err	1.87	9.45	23.22	0.88	3.30	5.77	2.45	0.63	1.71	8.28
Min	1.90	1.80	2.30	0.50	0.50	2.20	2.00	0.50	1.90	10.30
Max	45.40	211.00	463.00	20.20	103.00	124.00	56.80	14.10	38.10	201.00
n	26	23	26	26	31	26	26	26	26	31

Chloride Summary Statistics

	9007	9010	9008	24012	24014	24011	24013	59010	59003	64001
5th	17.45	19.40	19.51	17.45	15.30	18.60	10.35	21.61	36.83	24.62
10th	18.40	26.23	26.36	19.38	15.36	22.28	10.82	23.04	50.12	28.48
25th	22.30	31.70	28.00	23.25	16.00	24.85	12.00	24.15	52.25	34.80
50th	28.50	36.45	30.30	24.50	17.20	26.20	12.70	26.80	57.70	39.60
75th	33.35	45.55	32.45	28.35	17.45	27.55	13.90	28.20	61.40	44.10
90th	38.72	54.11	34.00	30.10	18.52	28.50	15.64	30.32	71.10	48.32
95th	43.23	60.75	34.84	30.94	19.28	28.57	22.49	30.57	71.61	49.44
Mean	29.25	38.59	29.59	25.23	16.90	25.50	13.78	26.36	57.07	38.02
Std dev	9.62	12.58	4.74	3.88	1.41	3.32	4.07	2.97	10.08	9.20
Std err	1.85	2.57	0.91	0.76	0.27	0.64	0.78	0.57	1.94	1.58
Min	14.40	14.80	15.70	16.70	12.90	14.60	10.20	19.50	29.70	12.20
Max	59.40	65.90	36.60	32.30	19.50	28.60	28.30	31.00	72.20	57.30
n	27	24	27	27	27	27	27	27	27	33

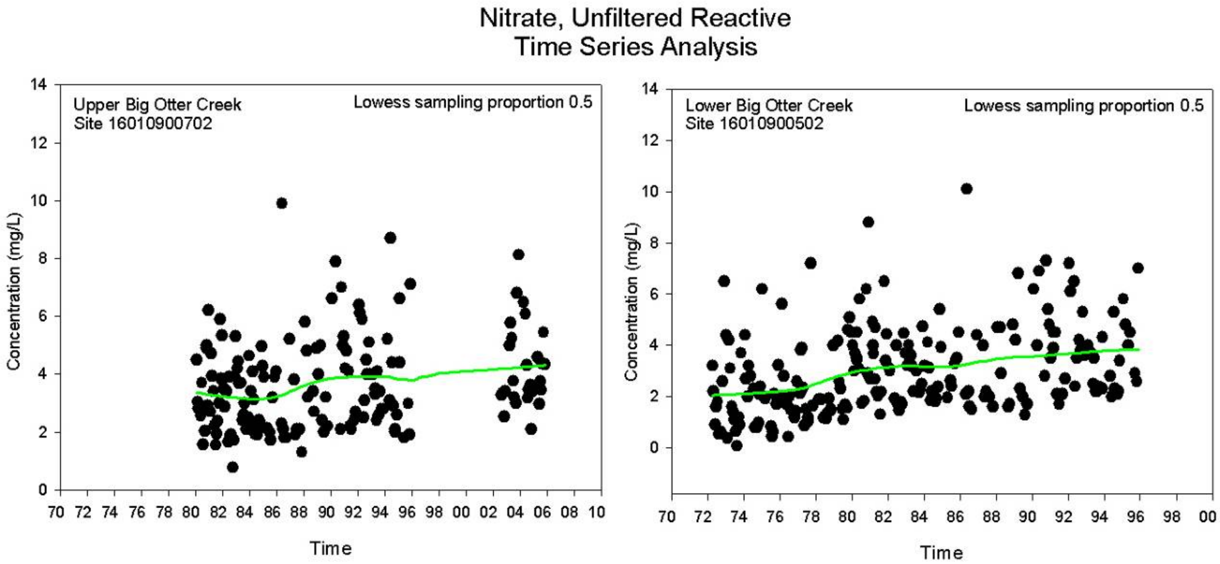
Appendix E. Nonparametric regression statistics for comparison of each water quality parameter between the PWQMN sites within the 9 watersheds analysed in the Long Point Region.

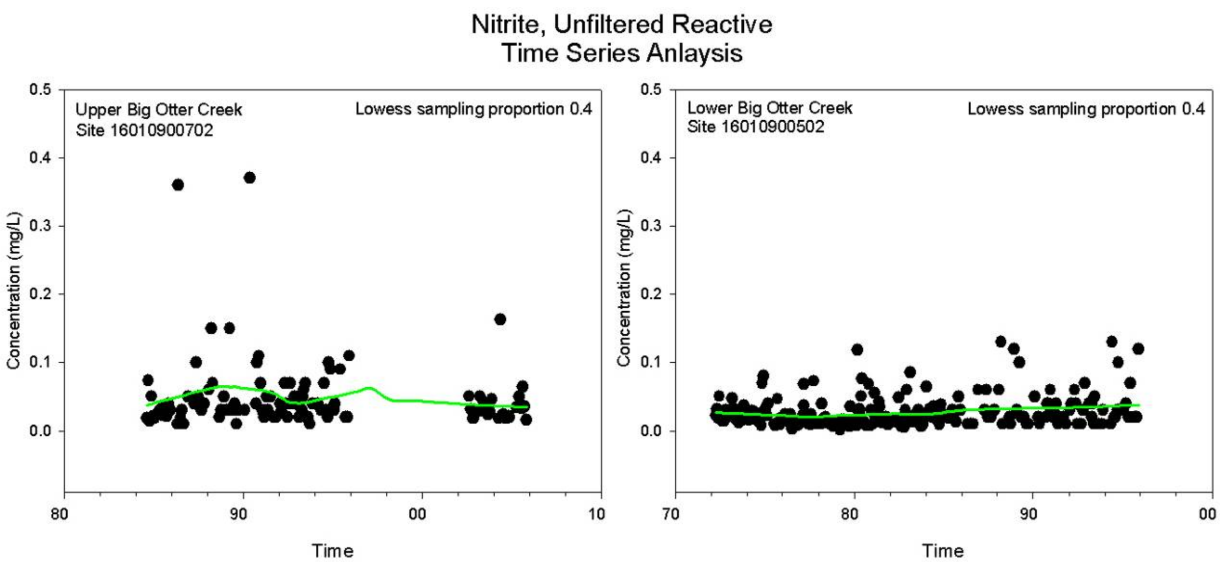
Parameter		Total Nitrate	Total Nitrite	Unionized Ammonia	Total Kjeldahl Nitrogen	Total Phosphorus	Non-filterable residue	Chloride
Big Otter Creek Watershed								
all	*p*	0.5478	0.4756	0.3093	**0.0005**	0.3194	**0.0003**	**0.0028**
702 / 802	*p*				0.6158		**0.0001**	0.5739
702 / 1002	*p*				**0.0014**		0.1491	**0.0039**
802 / 1002	*p*				**0.0004**		**0.0095**	**0.0022**
Big Creek Watershed								
all	*p*	**<0.0001**	**<0.0001**	**0.0013**	**<0.0001**	**0.0019**	**<0.0001**	**<0.0001**
24011 / 24012	*p*	**0.0102**	0.7553	0.7784	**0.0099**	**0.0218**	**<0.0001**	0.2718
24011 / 24013	*p*	**<0.0001**	0.2565	0.7775	0.2223	0.8354	0.5643	**<0.0001**
24011 / 24014	*p*	**0.0069**	**<0.0001**	**0.0004**	**<0.0001**	**0.0044**	**0.0027**	**<0.0001**
24012 / 24013	*p*	**<0.0001**	0.5445	0.9249	**0.0008**	**0.0143**	**<0.0001**	**<0.0001**
24012 / 24014	*p*	**<0.0001**	**<0.0001**	**0.0052**	**<0.0001**	0.3113	**<0.0001**	**<0.0001**
24013 / 24014	*p*	**0.0007**	**<0.0001**	**0.0023**	**<0.0001**	**0.0027**	**0.0026**	**<0.0001**
Lynn River Watershed								
59003 / 59010	*p*	**0.0007**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**

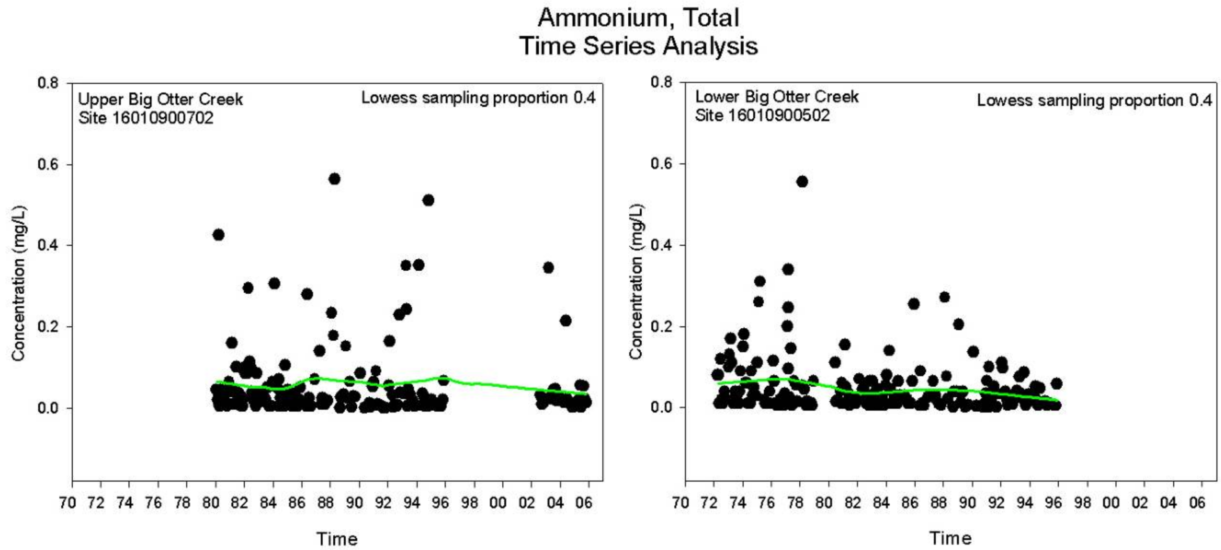
Appendix F. . Percentage of samples per site with values greater than the provincial objective or Canadian guideline.

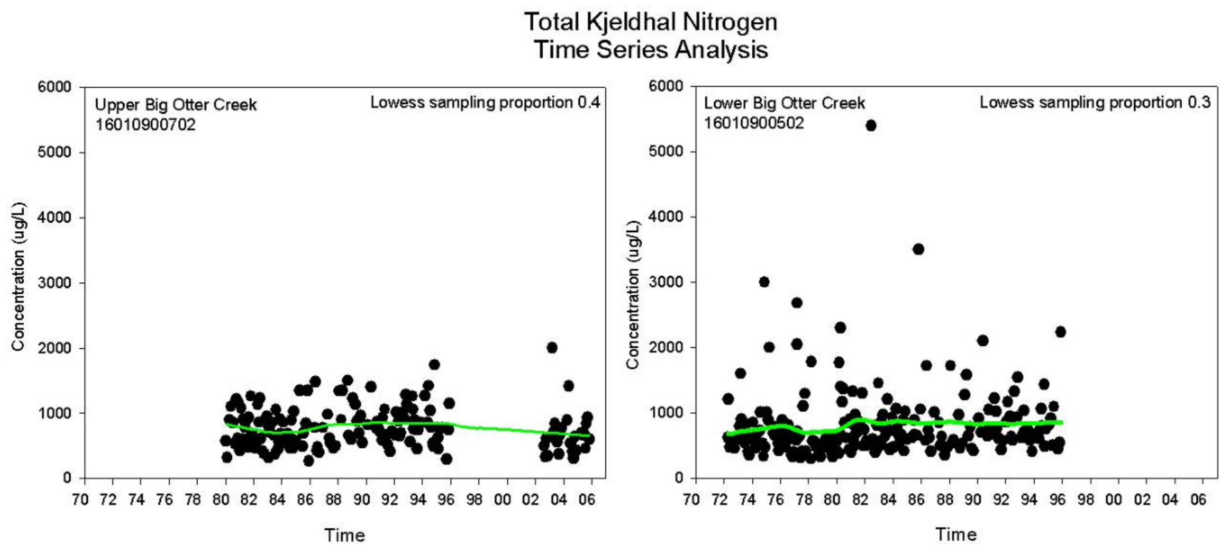
Percent of Samples That Do Not Meet Guidelines or Objectives							
Site	**Tributary**	**Nitrate**	**Nitrite**	**Unionized Ammonia**	**Total Phosphorus**	**Non-filterable residue**	**Chloride**
	Objective	2.93 mg/L	0.060 mg/L	0.0165 mg/L	0.030 mg/L	25.0 mg/L	250.0 mg/L
9007	Upper Big Otter Creek	92.59	7.41	0.00	96.30	7.41	0.00
9010	Spittler Creek	66.67	33.33	4.35	70.83	21.74	0.00
9008	Lower Big Otter Creek	59.26	4.17	0.00	85.19	53.85	0.00
24012	Upper Big Creek	74.07	4.17	0.00	51.85	0.00	0.00
24014	Trout Creek	12.50	0.00	0.00	43.75	9.68	0.00
24011	Lower Big Creek	59.26	4.17	0.00	74.07	34.62	0.00
24013	Venison Creek	11.11	0.00	0.00	74.07	26.92	0.00
59010	Upper Kent Creek	25.93	0.00	0.00	81.48	0.00	0.00
59003	Lynn River	44.44	92.59	34.62	92.59	11.54	0.00
64001	Nanticoke Creek	21.21	9.10	11.54	0.00	61.29	0.00

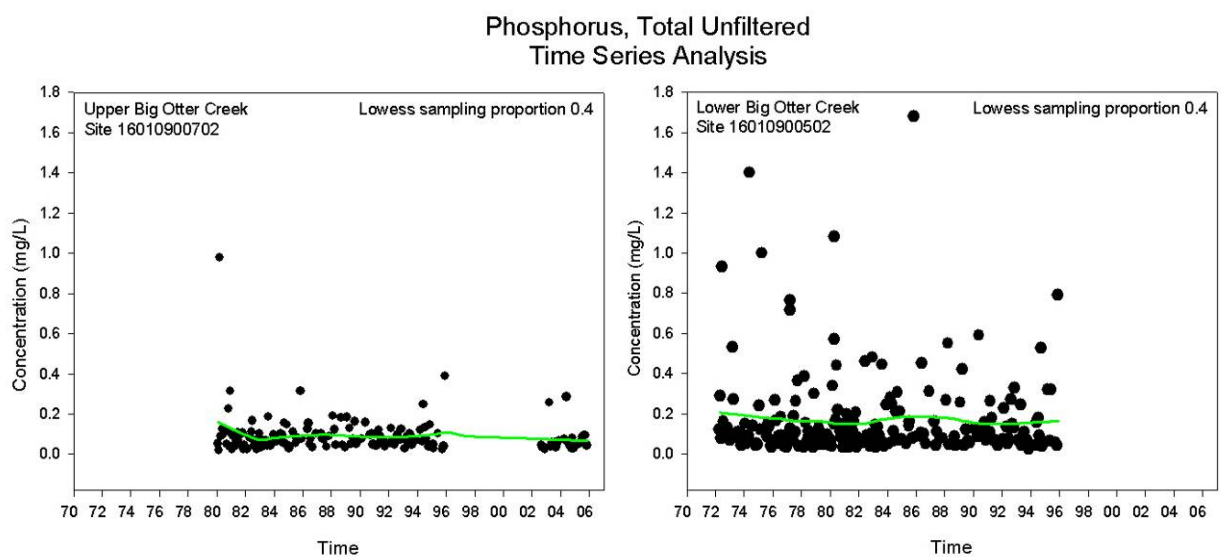
Appendix G. Time-series plots for each of the watersheds with long-term data within the Long Point Region.



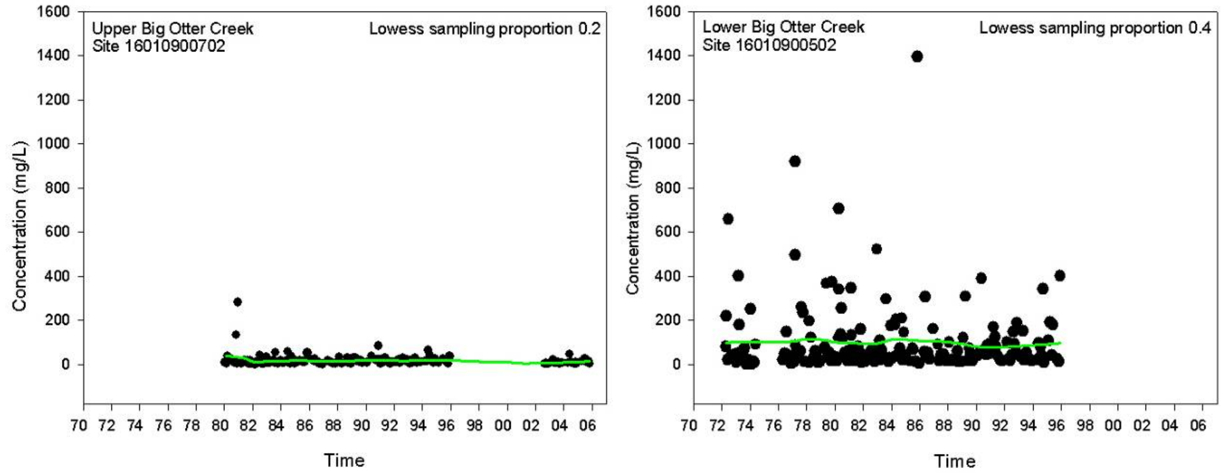



Ammonium, Total
Time Series Analysis
Upper Big Otter Creek
Site 16010900702
Lowess sampling proportion 0.4
Lower Big Otter Creek
Site 16010900502
Lowess sampling proportion 0.4
Concentration (mg/L)
Time

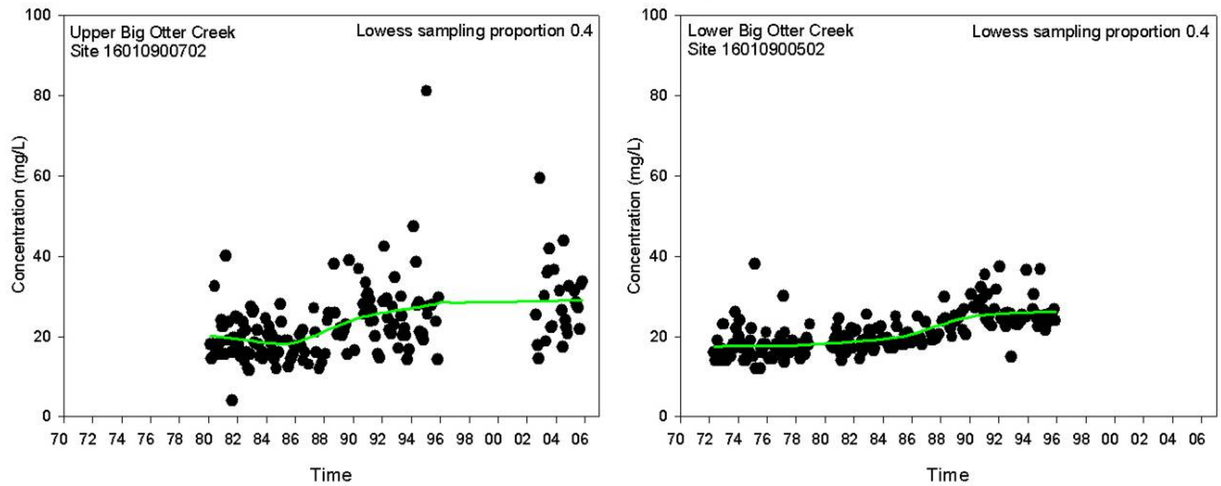

Total Kjeldhal Nitrogen
Time Series Analysis
Upper Big Otter Creek
16010900702
Lowess sampling proportion 0.4
Lower Big Otter Creek
16010900502
Lowess sampling proportion 0.3
Concentration (ug/L)
Time


Phosphorus, Total Unfiltered
Time Series Analysis
Upper Big Otter Creek
Site 16010900702
Lowess sampling proportion 0.4
Lower Big Otter Creek
Site 16010900502
Lowess sampling proportion 0.4
Concentration (mg/L)
Time

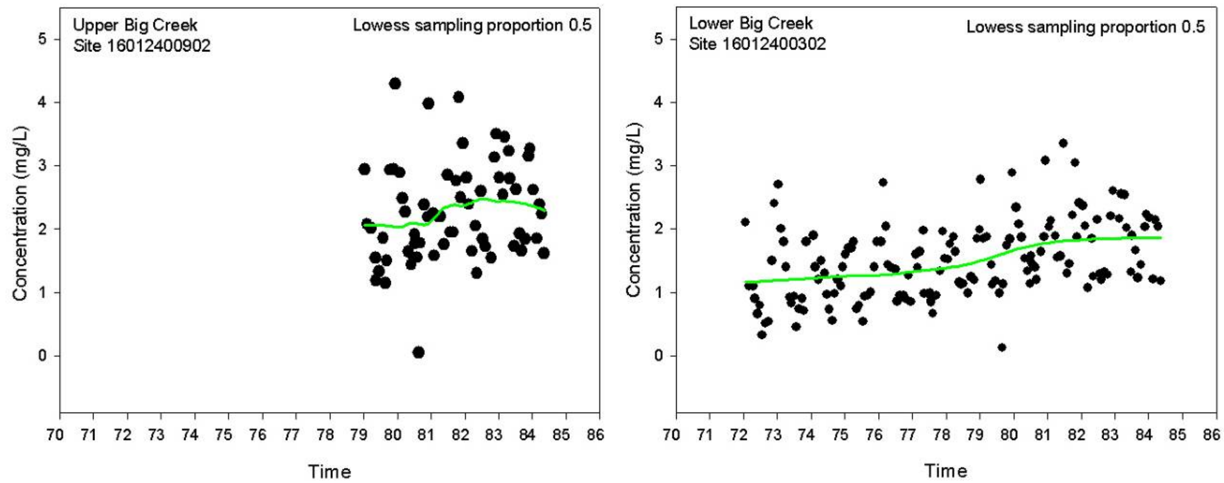
Non-Filterable Residue
Time Series Analysis



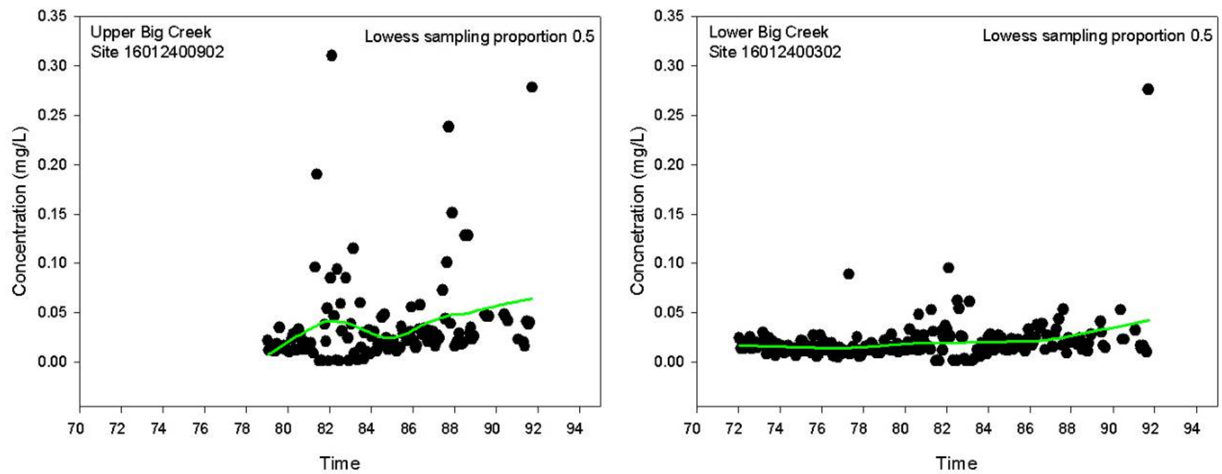
Chloride, Unfiltered Reactive
Time Series Analysis



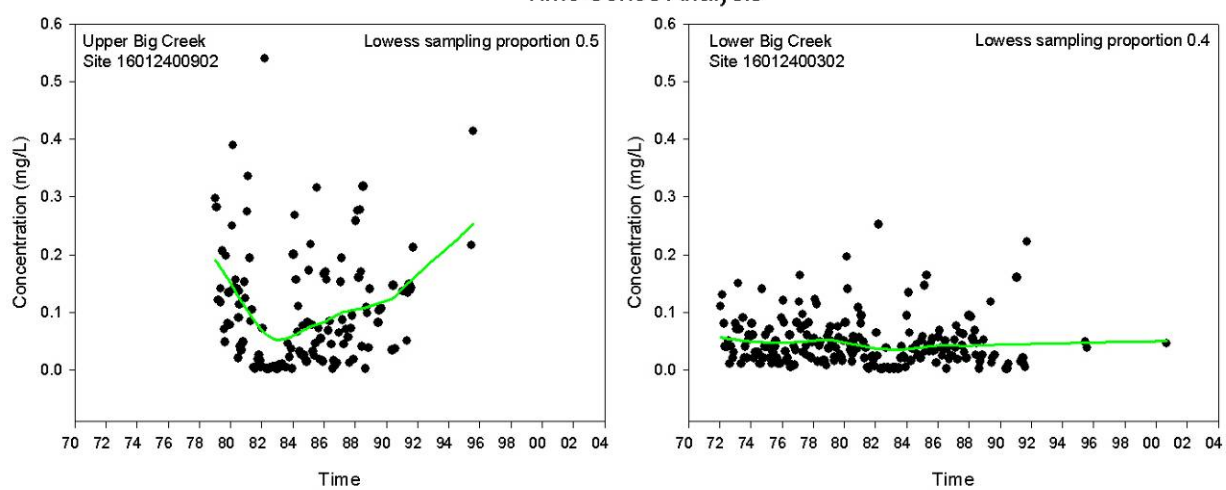
Nitrate, Filtered
Time Series Analysis



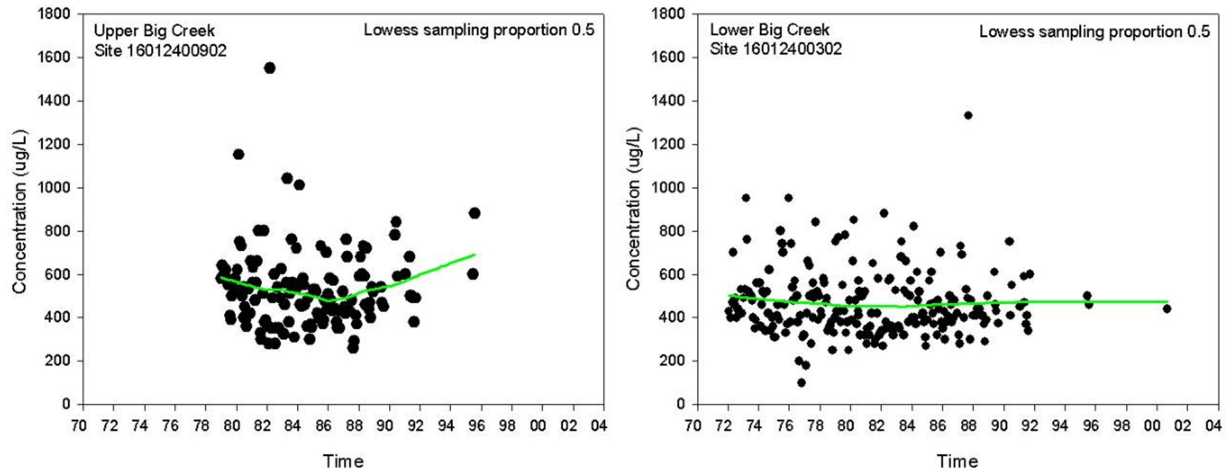
Nitrite, Filtered
Time Series Analysis



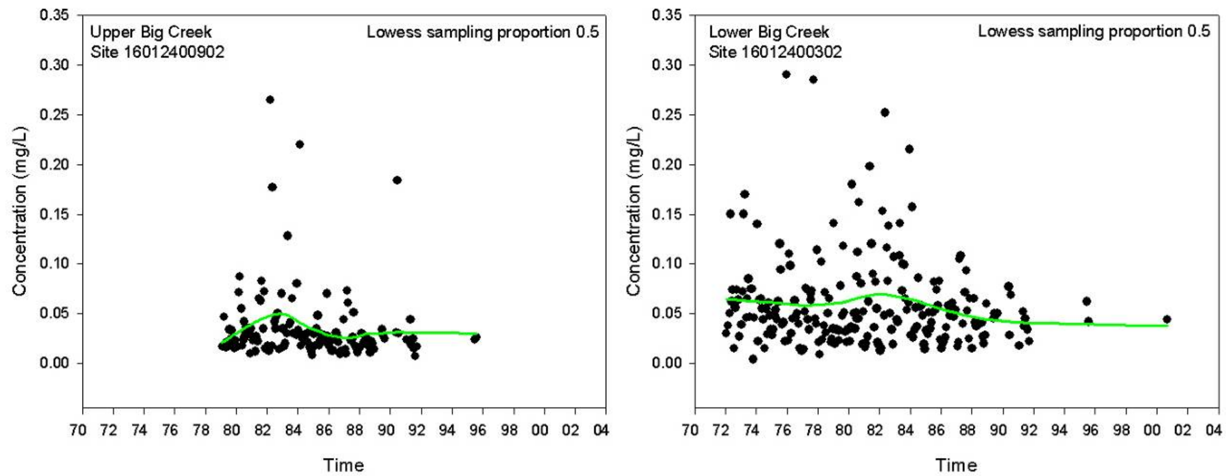
Ammonium, Total
Time Series Analysis



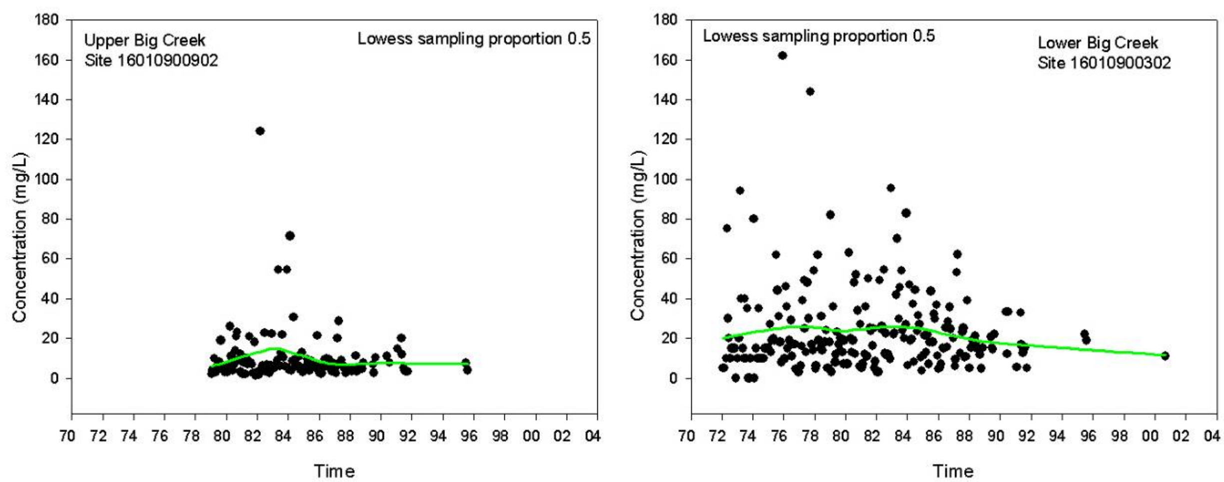
Total Kjeldhal Nitrogen
Time Series Analaysis



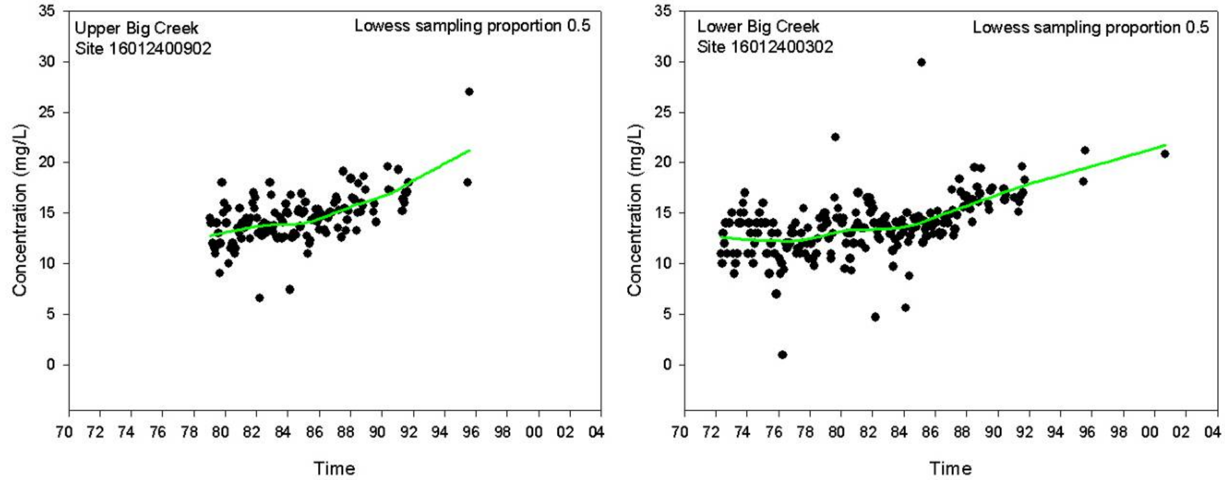
Phosphorus, Total Unfiltered
Time Series Analysis



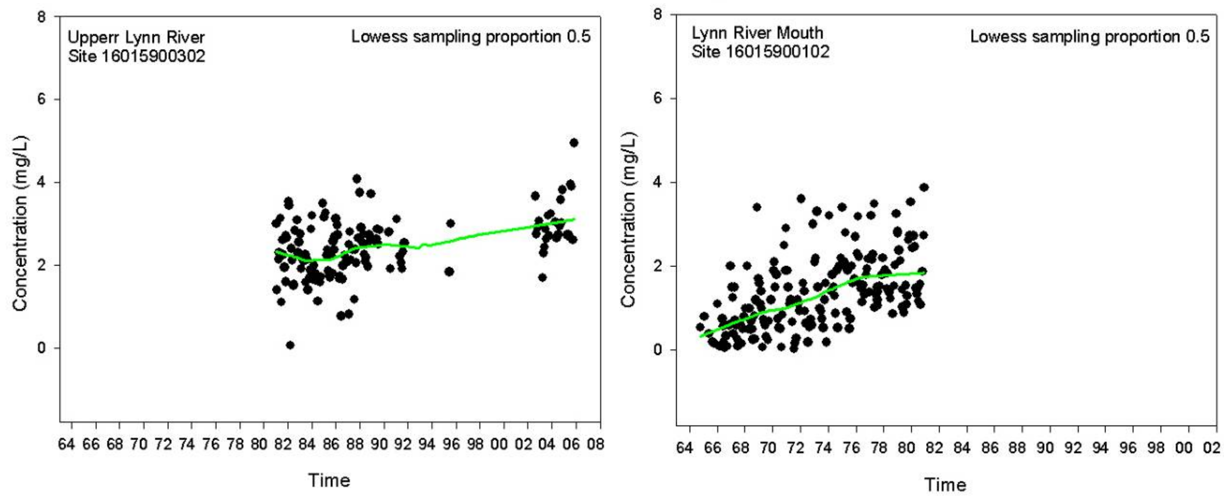
Non-Filterable Residue
Time Series Analysis



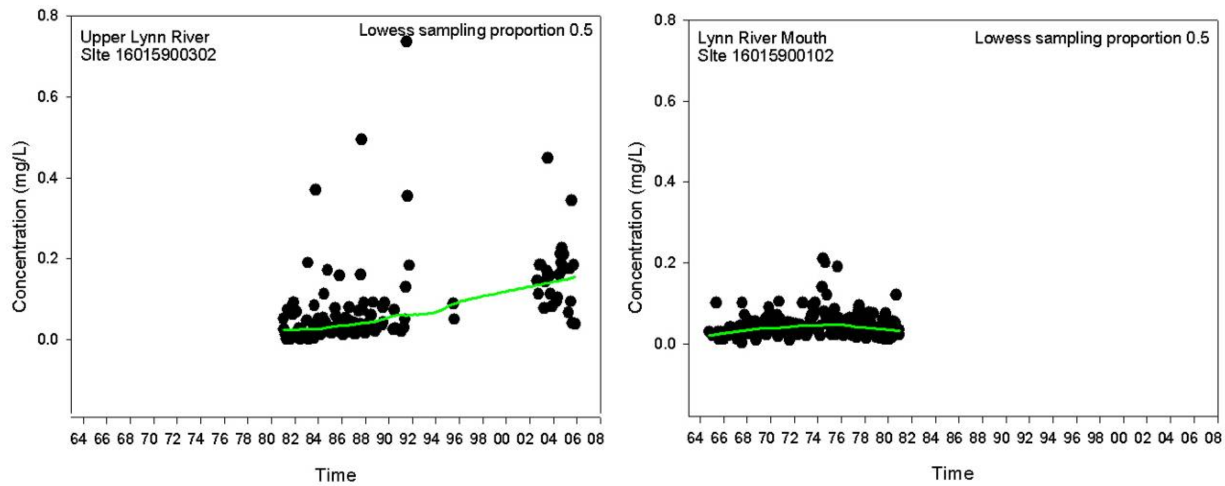
Chloride, Unfiltered
Time Series Analysis



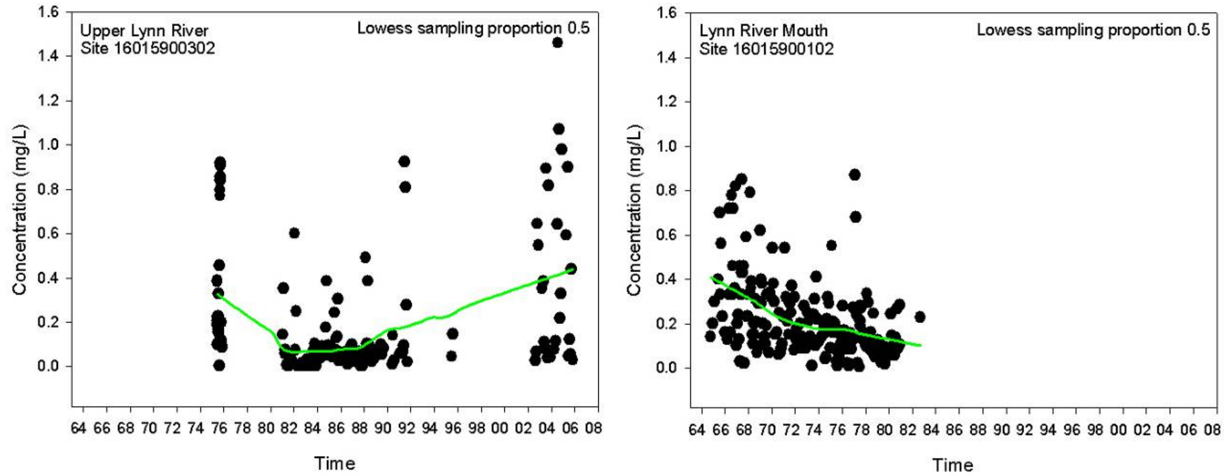
Nitrate, Filtered & Unfiltered
Time Series Analysis



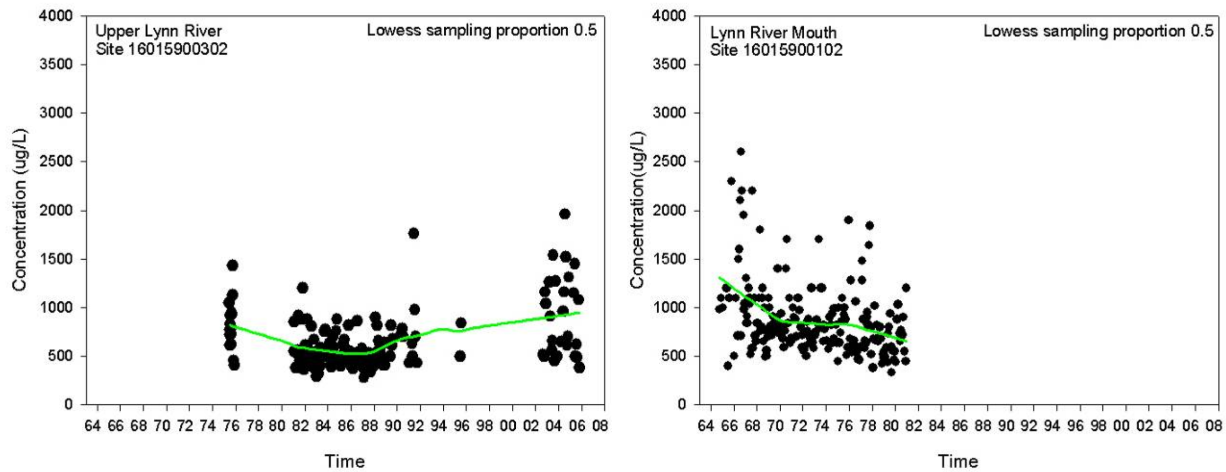
Nitrite, Filtered & Unfiltered
Time Series Analysis



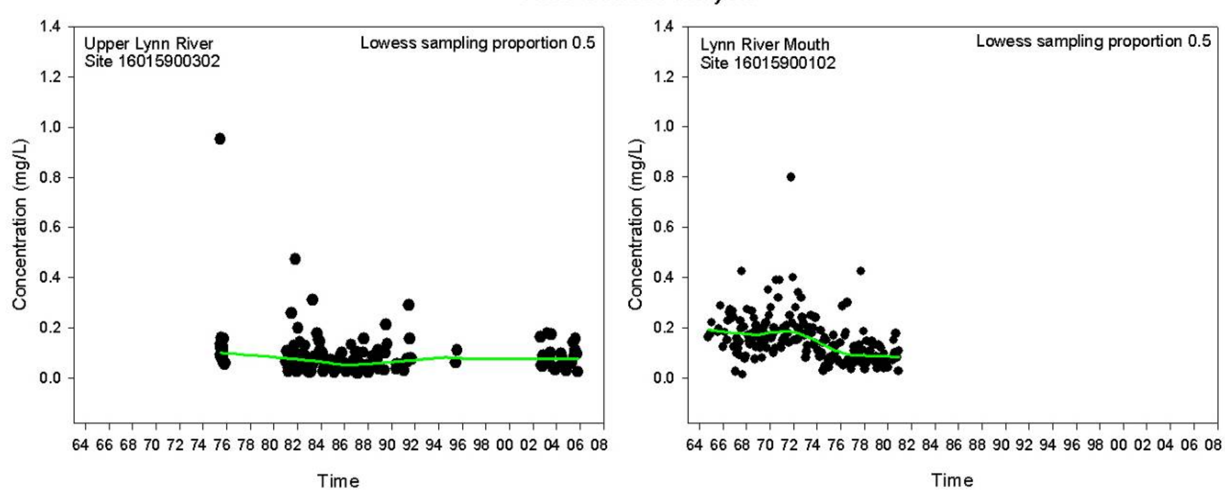
Ammonium, Total
Time Series Analysis



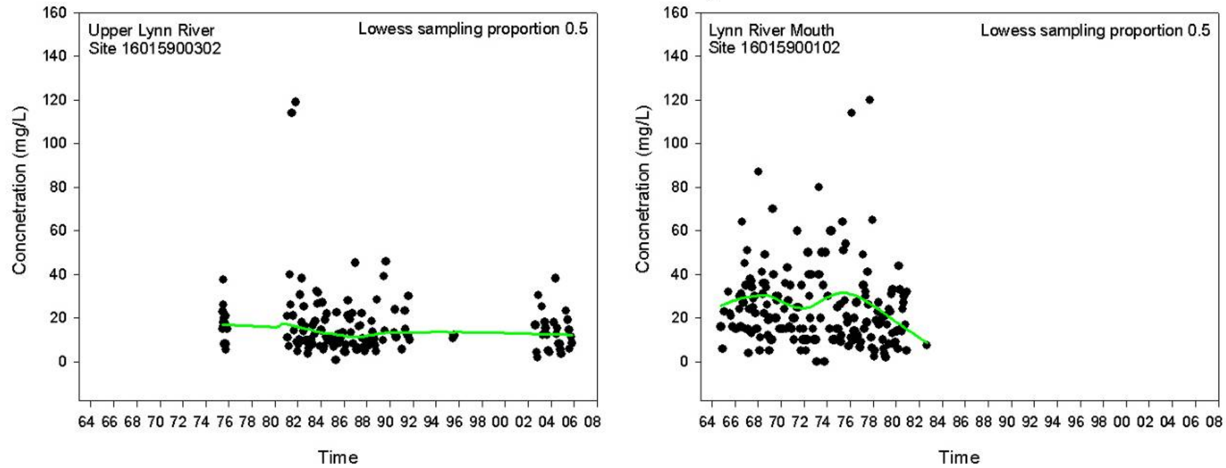
Total Kjeldhal Nitrogen
Time Series Analysis



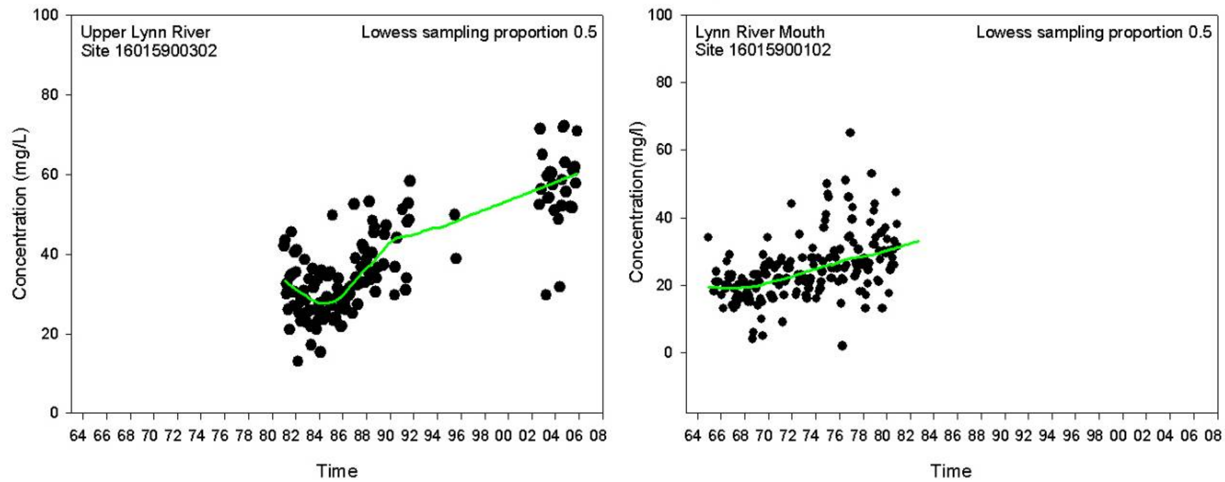
Phosphorus, Unfiltered & Filtered
Time Series Analysis



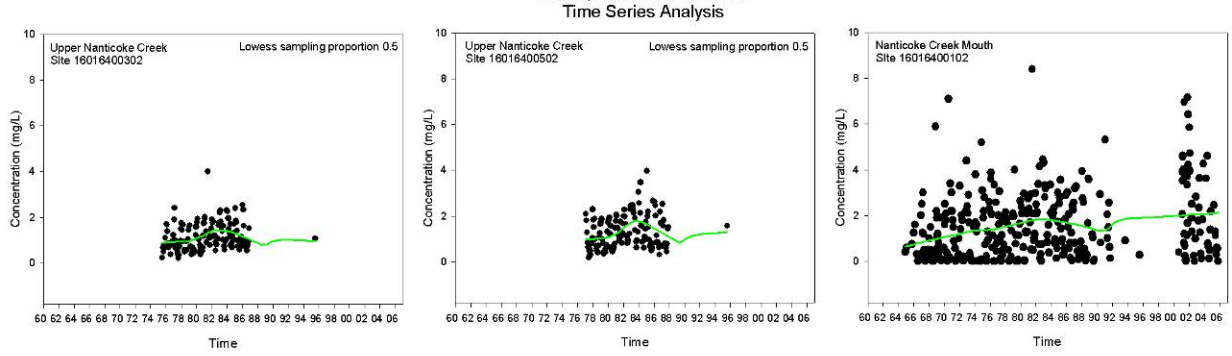
Non-Filterable Residue
Time Series Analysis



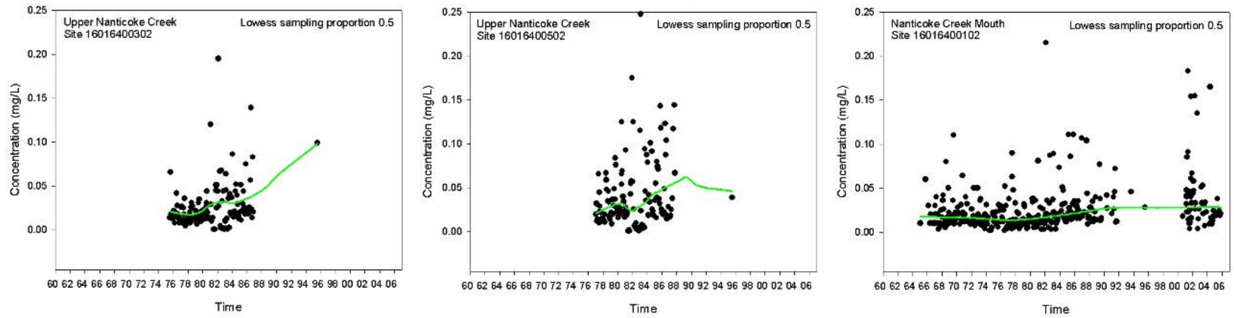
Chloride, Unfiltered & Filtered
Time Series Analysis



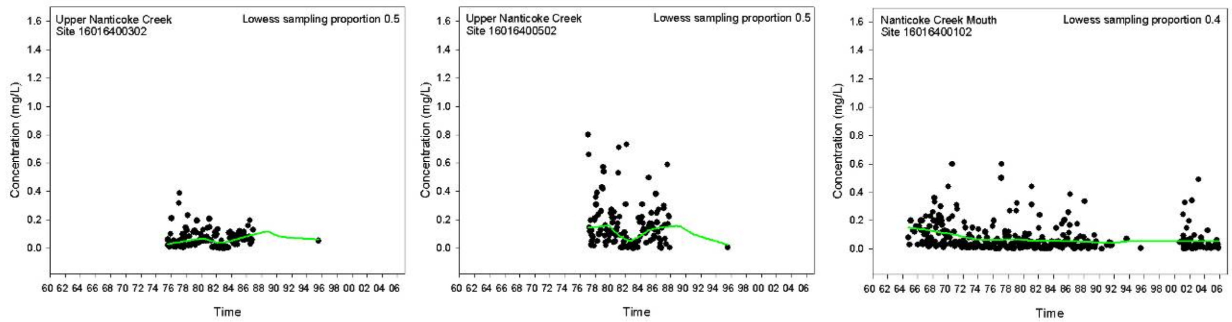
Nitrate, Filtered & Unfiltered
Time Series Analysis



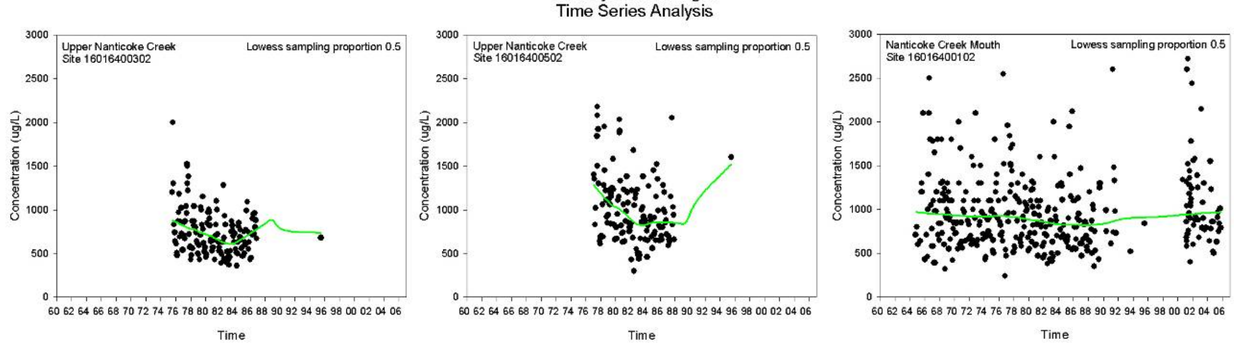
Nitrite, Filtered & Unfiltered
Time Series Analysis



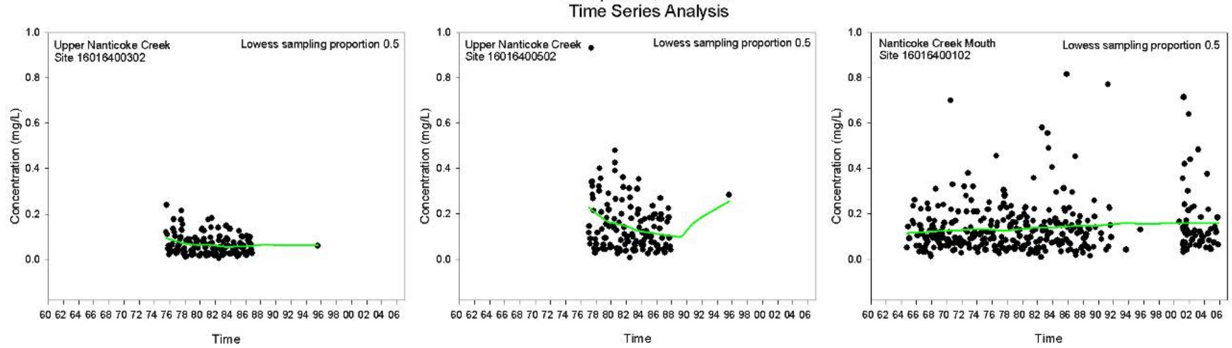
Ammonium, Total
Time Series Analysis



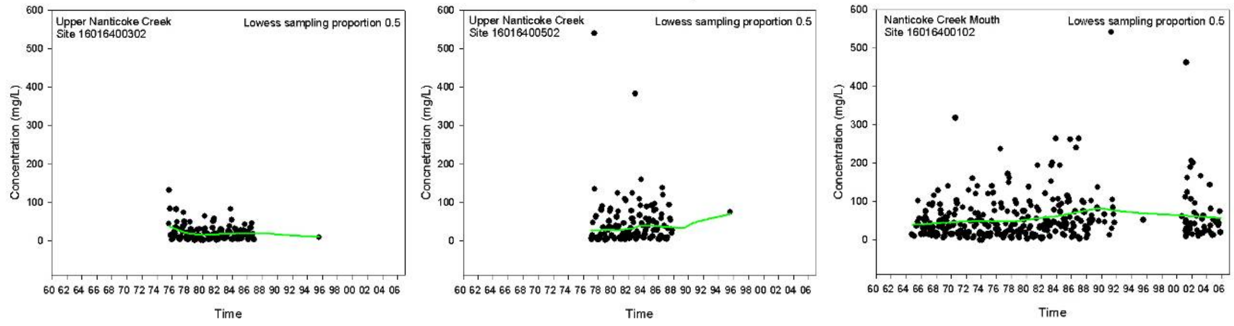
Total Kjeldhal Nitrogen
Time Series Analysis



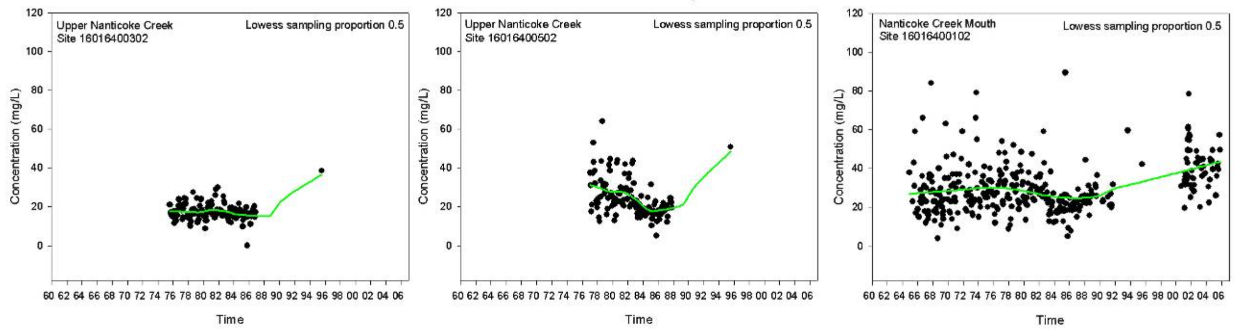
Phosphorus, Unfiltered
Time Series Analysis



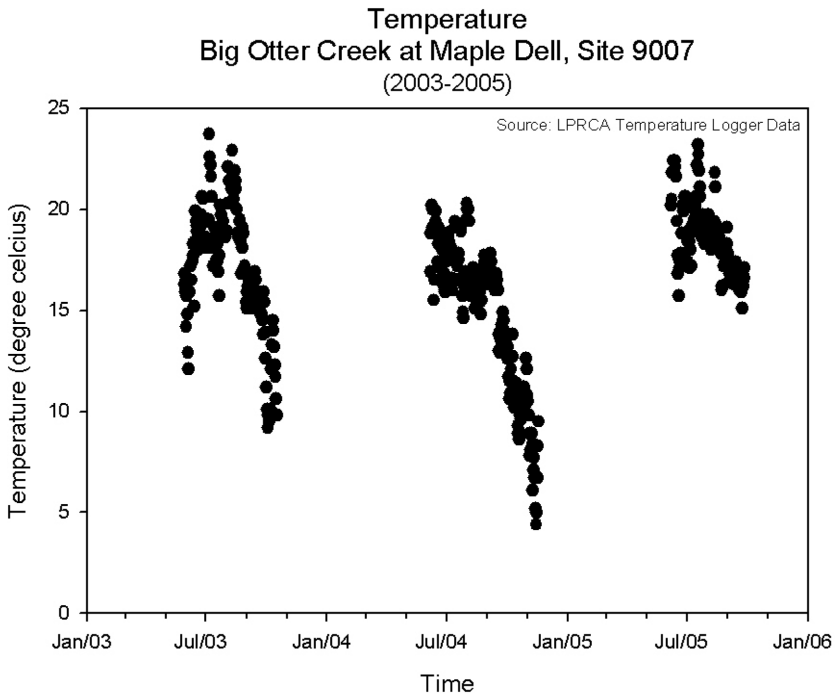
Non-Filterable Residue
Time Series Analysis

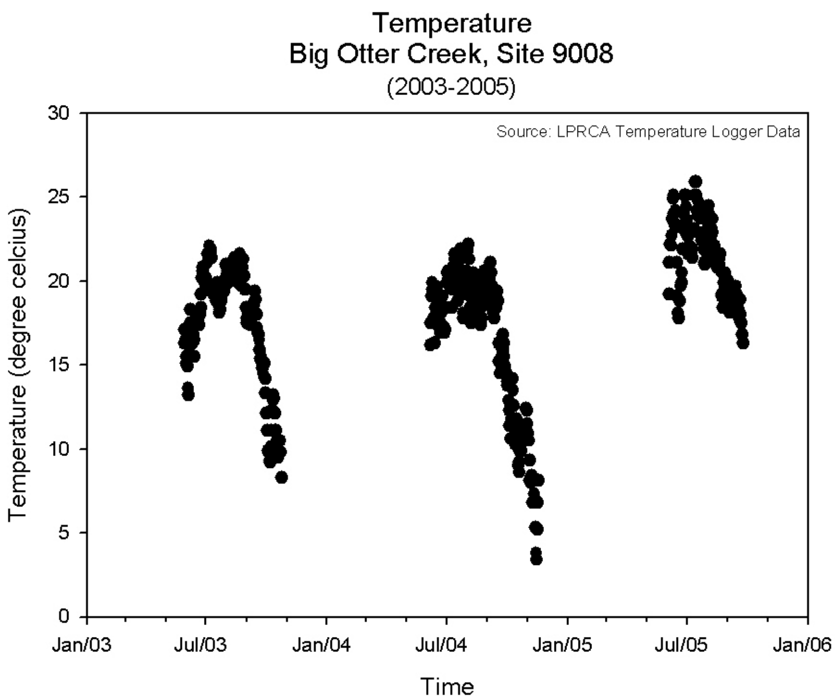


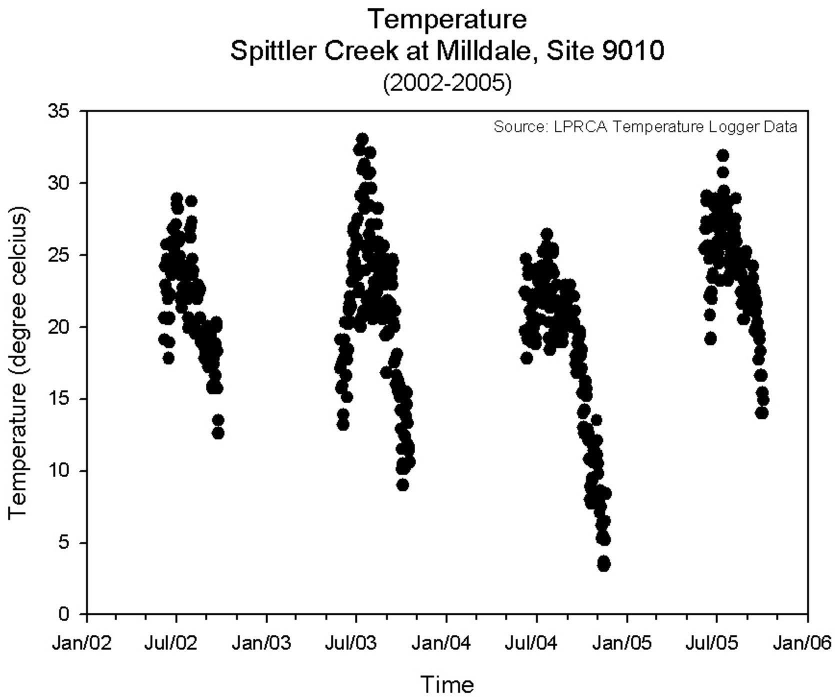
Chloride, Unfiltered
Time Series Analysis

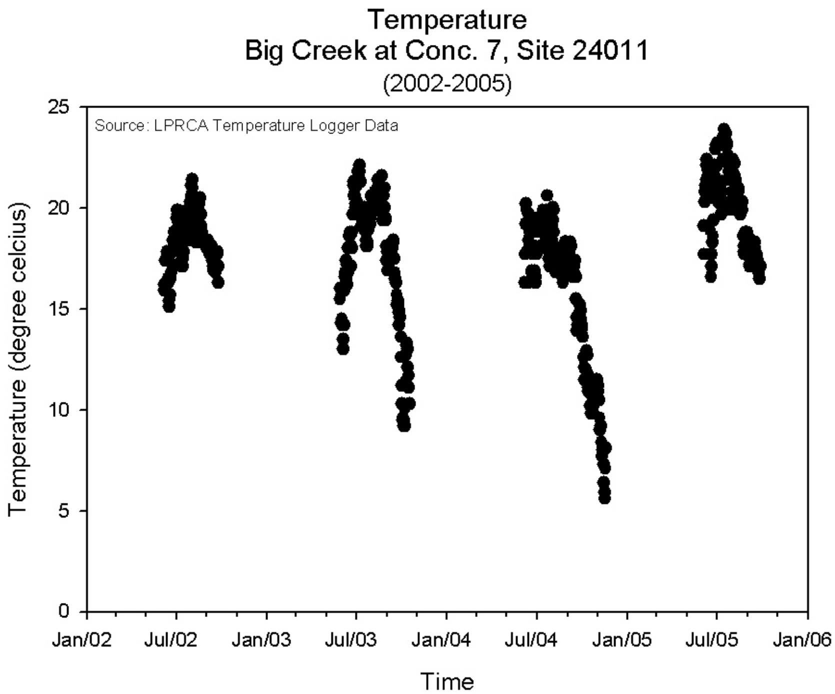


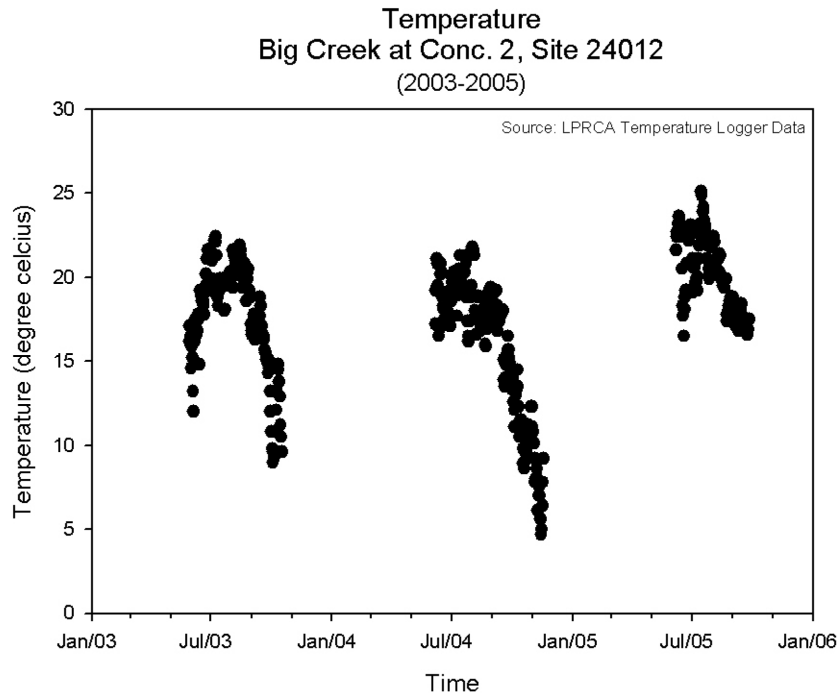
Appendix H. Temperature

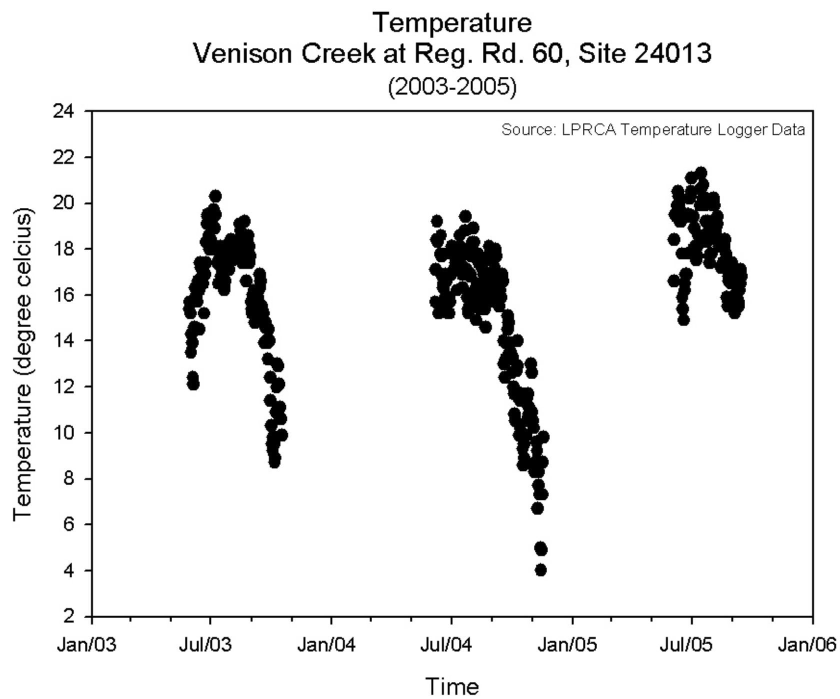


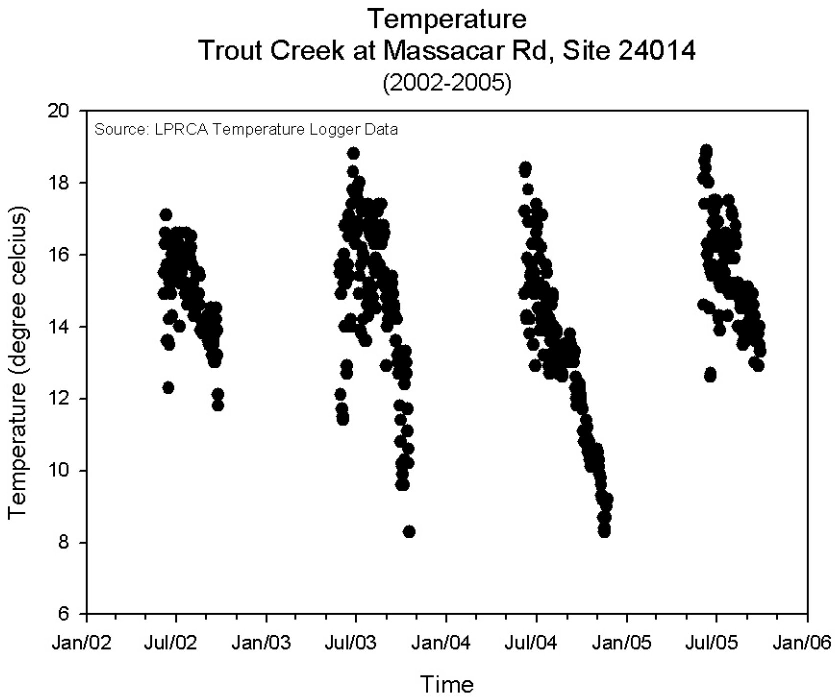


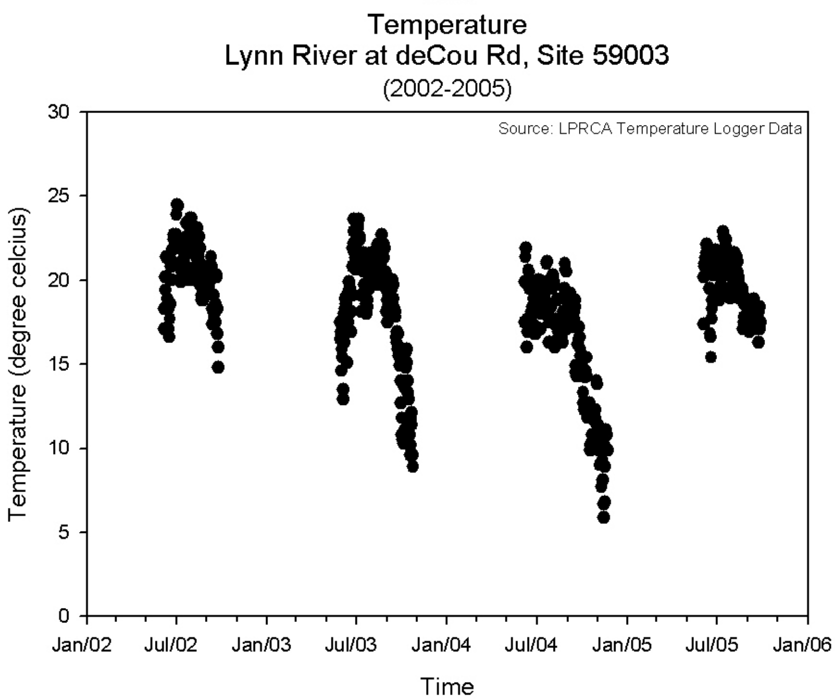

Temperature
Spittler Creek at Milldale, Site 9010
(2002-2005)
Source: LPRCA Temperature Logger Data
Temperature (degree celcius)
35
30
25
20
15
10
5
0
Jan/02
Jul/02
Jan/03
Jul/03
Jan/04
Jul/04
Jan/05
Jul/05
Jan/06
Time


Temperature
Big Creek at Conc. 7, Site 24011
(2002-2005)
Source: LPRCA Temperature Logger Data
Temperature (degree celcius)
25
20
15
10
5
0
Jan/02
Jul/02
Jan/03
Jul/03
Jan/04
Jul/04
Jan/05
Jul/05
Jan/06
Time

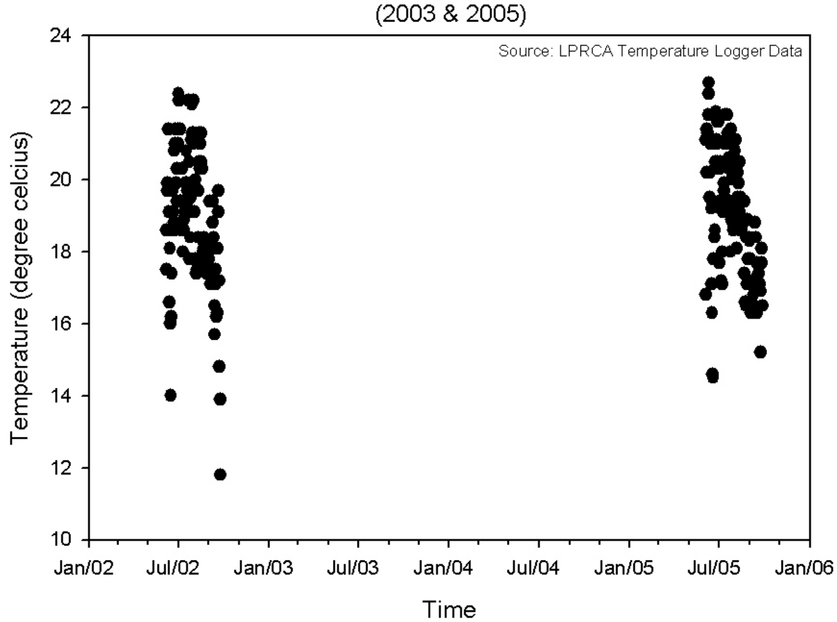

Temperature
Big Creek at Conc. 2, Site 24012
(2003-2005)
Source: LPRCA Temperature Logger Data
Temperature (degree celcius)
0
5
10
15
20
25
30
Jan/03
Jul/03
Jan/04
Jul/04
Jan/05
Jul/05
Jan/06
Time


Temperature
Venison Creek at Reg. Rd. 60, Site 24013
(2003-2005)
Source: LPRCA Temperature Logger Data
Temperature (degree celcius)
2
4
6
8
10
12
14
16
18
20
22
24
Jan/03
Jul/03
Jan/04
Jul/04
Jan/05
Jul/05
Jan/06
Time

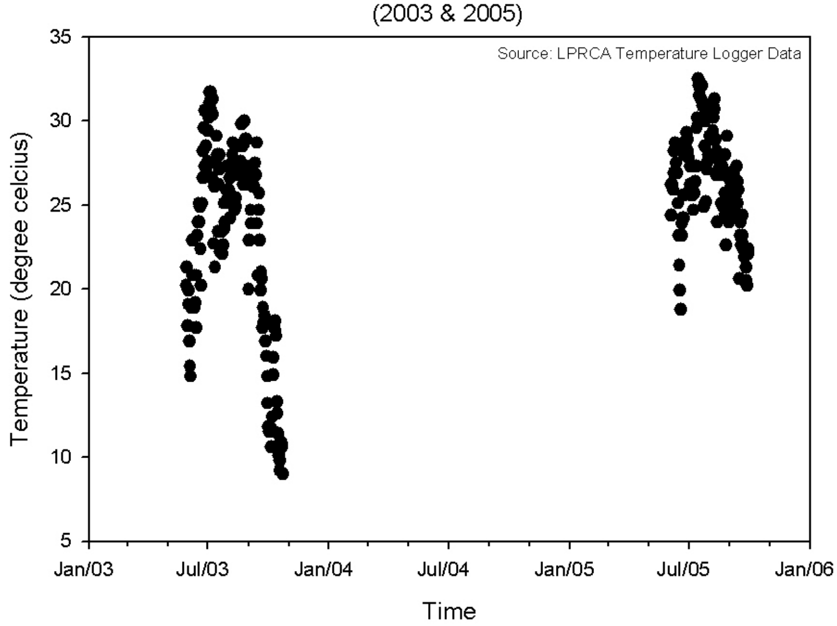

Temperature
Trout Creek at Massacar Rd, Site 24014
(2002-2005)
Source: LPRCA Temperature Logger Data
Temperature (degree celcius)
20
18
16
14
12
10
8
6
Jan/02
Jul/02
Jan/03
Jul/03
Jan/04
Jul/04
Jan/05
Jul/05
Jan/06
Time


Temperature
Lynn River at deCou Rd, Site 59003
(2002-2005)
Source: LPRCA Temperature Logger Data
Temperature (degree celcius)
30
25
20
15
10
5
0
Jan/02
Jul/02
Jan/03
Jul/03
Jan/04
Jul/04
Jan/05
Jul/05
Jan/06
Time

Temperature
Kent Creek at Hwy 3, Site 59010
(2003 & 2005)



Temperature
Nanticoke Creek at Reg. Rd. 3, Site 64001
(2003 & 2005)



Appendix I. Maps of the LPR watersheds illustrating how the 75th percentile value for each site ranks against the provincial water quality objective or Canadian Guideline.