# Credit Valley Conservation

## Headwaters Subwatershed Study
## Subwatershed 19

DRAFT: Phase 1 Characterization - Water Quality
August 2009

## 4.6 Water Quality

### 4.6.1 Introduction to Parameters of Concern

For the purposes of this study, water quality is defined as the combined chemical, physical and microbiological properties of the water in relationship to habitat for aquatic biota and recreational use for humans. Through the work on the Water Quality Strategy Phase I Report (CVC *et al*., 2003), Parameters of Concern (POCs) have been identified on a watershed scale for the Credit River watershed. The watershed POCs were used as indicator species for characterization of the subwatershed, in addition to a number of other parameters that were identified to be potential POCs on a subwatershed scale from the results of the Background Report (CVC, 2006). Table 4.6.1 presents the parameters that were chosen for further analysis with a discussion of sources.

**Table 4.6.1 Description of parameters evaluated for Headwaters Subwatershed**

| Type | Parameters | Objective | Sources | Concern / Description |
|---|---|---|---|---|
| Nutrients | Total Phosphorus (TP) | PWQO - 0.03 mg/L (MOEE, 1994) | Urban, Rural and Agricultural Runoff, Water Pollution Control Plant Effluent Erosion of banks and bed | TP and Nitrate can cause excessive aquatic plant growth leading to oxygen depletion Nitrate (also has a drinking water objective), and particularly nitrite and ammonia, can be toxic to aquatic biota. Ammonia can exert oxygen demand similar to BOD (see below) |
| | Nitrate-Nitrogen | CWQG – 2.93 mg/L (CCME, 2003) | | |
| | Un-ionized Ammonia | PWQO - 20 µg/L (MOEE, 1994) | | |
| Oxygen Related | Dissolved Oxygen (DO) | PWQO – 5.0 mg/L (MOEE, 1994) | Urban, Rural and Agricultural Runoff, Water Pollution Control Plant (WPCP) Effluent | Low DO levels can be harmful for fish and other aquatic biota High BOD levels can deplete DO levels |
| | Biochemical Oxygen Demand (BOD) | N/A | | |
| Metals | Aluminum | PWQO –75 µg/L (MOEE, 1994) | Urban Runoff, WPCP Effluent , Natural Groundwater (Mineralization) Inputs | Metals can be directly toxic to aquatic biota In general, the toxicity of metals increase as the pH and alkalinity decreases Some metals such as iron and aluminum are found naturally adsorbed to clay soils |
| | Copper | PWQO –5 µg/L (MOEE, 1994) | | |
| | Iron | PWQO –300 µg/L (MOEE, 1994) | | |
| | Zinc | PWQO –20 µg/L (MOEE, 1994) | | |
| Physical | Suspended Solids (SS) | CWQG - 25 mg/L (CCME, 1999) | Urban, Rural and Agricultural Runoff, WPCP Effluent, Bed and bank erosion | Suspended solids can clog spawning areas Metals, bacteria and TP are readily adsorbed on SS High SS can make recreational uses of water more dangerous (clarity of water decreases) |

<table>
<tr><th>Type</th><th>Parameters</th><th colspan="2">Objective</th><th>Sources</th><th>Concern / Description</th></tr>
<tr><td rowspan="3"></td><td rowspan="3">Water Temperature (WT)</td><td>Absolute Maximum Summer Water Temperature</td><td>Daily Maximum Summer Average Water Temperature</td><td rowspan="3"></td><td rowspan="3">Increases in summer WT can be harmful to fish due to increases in their metabolism and lowered capacity of the water to hold DO<br>Decreases in winter WT can freeze spawning areas and potentially kill fish eggs<br>Ammonia toxicity also increases with increased WT</td></tr>
<tr><td>26 C (coldwater)<br>28 C (mixed water)<br>30 C (warmwater</td><td>20 C (coldwater)<br>23 C (mixed water)<br>26 C (warmwater)</td></tr>
<tr><td colspan="2">Source: Ontario Ministry of Natural Resources and Canadian Department of Fisheries and Oceans</td></tr>
<tr><td>Micro-biological</td><td>E. coli</td><td colspan="2">100 CFU/100mL<br>(MOEE, 1994)</td><td>Urban and Agricultural Runoff<br>WPCP Effluent</td><td>High E. coli levels are indicative of the presence of pathogenic bacteria which can cause respiration and gastrointestinal illnesses in humans</td></tr>
<tr><td>Other</td><td>Chloride</td><td colspan="2">252 mg/L<br>(CEPA, 1999)</td><td>Road Salting<br>WPCP Effluent<br>Septic Systems</td><td>High levels may be toxic to aquatic biota<br>Chloride is a conservative parameter and increasing trends across the Credit River watershed indicate it is accumulating in the environment</td></tr>
</table>

### 4.6.2 Methodology

Five methodologies were used to assess water quality in Subwatershed 19. These are:

- long-term water quality data assessment;
- local 2006 field water quality data assessment;
- local sediment chemistry data assessment;
- diurnal water quality data assessment; and
- water temperature logger deployment and assessment.

The large data sets from the five long-term MOE Provincial Water Quality Monitoring Network (PWQMN) stations on the Credit River allowed for the evaluation of selected parameters for annual statistics, seasonal means, trend analysis, correlation with other water quality parameters and guideline exceedance frequencies. The parameters chosen for these analyses were those identified for need of further study in the 2006 Background Report, which included total phosphorus, nitrate, chloride, suspended solids, six metals (Cu, Fe, Mn, Al, Ni, and Zn), *E. coli*, DO, BOD, and water temperature.

The five PWQMN stations are on the main Credit River portion of the subwatershed, which created a significant spatial gap from the tributaries to the east and west, as identified in the Background Report. Therefore additional water quality data were collected across the subwatershed during the 2006 field season to provide an estimation of water quality conditions throughout the subwatershed. Four additional stations were sampled once a month from June to October for nutrients, metals, BOD, suspended solids, *E. coli*, pH, DO and water temperature. Sediment chemistry monitoring was conducted in the 2004, 2005 and 2006 field season at the five PWQMN sites. This analysis allows a deeper look into the historical chemical compounds employed, their mobility and ability to bioaccumulate in the subwatershed.

These results were then compared with the Provincial Water Quality Objectives (Ministry of the Environment, 1999), Canadian Environmental Quality Guidelines (Canadian Council of Ministers of the Environment, 1999), and CVC's criteria for water temperature for the protection of aquatic biota. Except for water temperature, these guidelines are all based on long-term conditions and chronic toxicity values. Typically, the results of surface water quality measurements are highly variable and therefore many measurements are needed before background conditions can be determined. Therefore, the purpose of the statistical analyses is to look at composite sets of data to determine background water quality conditions to compare to the chronic exposures guidelines.

Another gap identified in the Background Report was the lack of knowledge of diurnal variations in water quality within the subwatershed. Some water quality parameters are known to fluctuate significantly over a 24-hr period, which is problematic since the vast majority of sampling occurs during the daytime hours. Dissolved oxygen and water temperature are of particular concern since the most detrimental levels of these parameters for aquatic biota occur outside of normal working hours. Dissolved oxygen is typically at its lowest point during the early morning hours, before the sun rises and stimulates aquatic plants to start photosynthesizing and producing oxygen. Water temperature is typically highest between 4:30 and 5:30pm, after a full day of adsorbing heat from the sun. Conductivity and pH can also fluctuate through evaporation processes and the production of carbonic acid (from carbon dioxide, affected by algal production and respiration), respectively. To address this gap in the data, water temperatures and dissolved oxygen levels were remotely monitored over 24-hr time periods at 5 stations across the subwatershed. Furthermore, late day water temperatures were measured at all major road crossing after a period of 3 days of extremely hot weather.

### 4.6.3 Data Analyses

#### 4.6.3.1 Long-term Data

The five PWQMN stations on the main Credit River, illustrated in Figure 4.6.1, are sampled on a monthly basis on a randomly chosen day near the end of each month. Monitoring began in 1965 for the north crossing at Hwy 10 station (19-6), in 1976 at the Orangeville Dam (19-1), in 1979 at Melville (19-8) and in 1982 at the South Crossing (19-7).

Most parameters were sampled for the entire time period of existence of the sites, however accurate data for *E. coli*, metals, and nitrate data were not available until after 1994, 1996 and 1994, respectively.

Parameters that were identified for further study from the Background Report underwent the following analyses:

- annual means and geometric means (for *E. coli*);
- annual 75$^{th}$ percentile values;
- percent violation of a standard guideline;
- trend analysis for selected parameters; and
- seasonal means for selected parameters.

The first four statistics were compared against their respective Provincial Water Quality Objectives (PWQOs) (MOE, 1998), Drinking Water Quality Objective (DWQO) for chloride (MOE, 2001) and Canadian Water Quality Guidelines (CWQG) (CCME, 1999) and evaluated for any major spatial trends across the subwatershed.

The medians of common time periods from two long terms stations were then tested using the Wilcoxon Signed Rank test statistical non-parametric test to determine if they were significantly different based on a 5% level of significance. With this type of analysis, it was possible to ascertain whether one station had a statistically significant higher level of a given parameter than the other station.

The non-parametric Spearman rank correlation tests were completed to determine which stations had parameters which were closely associated with suspended solids. The Spearman rank correlation test determines the degree of correlation between values of the parameters potentially associated with the suspended solids and the suspended solids values. Parameters with a high degree of correlation with suspended solids, particularly smaller urban tributaries, are most likely from erosional sources. Parameters with a low degree of correlation with suspended solids may be from point sources, such as urban drainage outlets and water pollution control plants, or groundwater sources.

#### 4.6.3.2 Field Season Data

Water quality sampling was carried out once a month from June to October of the 2006 field season at 4 additional stations. Samples were analyzed for a basic suite of parameters including nutrients, suspended solids, BOD, DO, conductivity, water temperature, pH, *E. coli*, chlorides and metals near urban areas. The stations listed in Table 4.6.2 correspond to the stations presented in Figure 4.6.1. The location of the Orangeville WPCP is also identified on Figure 4.6.1.

**Table 4.6.2 Stations and measured parameters**

| Station ID | Description | Analysis Lab | Length of Record | Diurnal DO Survey | Sediment Sampling |
|---|---|---|---|---|---|
| 19-1 | Credit River at Orangeville Dam | MOE | 1976-2006 | | ✓ |
| 19-2 | Credit River d/s of Island lake | - | - | ✓ | |
| 19-3 | Credit River d/s of Mill Creek | Maxxam | 2002-2006 | | ✓ |
| 19-4 | Credit River d/s of WPCP outfall | Maxxam | 2006 | ✓ | ✓ |
| 19-5 | Credit River at Hwy 9 | - | - | ✓ | |
| 19-6 | Credit River at the North Crossing of Hwy 10 | MOE | 1965-2006 | | ✓ |
| 19-7 | Credit River at the South Crossing of Hwy 10 | MOE | 1982-2006 | ✓ | |
| 19-8 | Credit River at Melville | MOE | 1979-2006 | | ✓ |
| 19-9 | East Tributary 1 of Island Lake | Maxxam | 2006 | | ✓ |
| 19-10 | Mill Creek u/s of Townline | Maxxam | 2006 | | ✓ |
| 19-11 | Monora Creek at Cemetery | Maxxam | 2006 | | ✓ |

The highlighted stations indicate the long term data records. The results from these samples were compared against their respective PWQOs, and CWQGs and were evaluated for any major spatial trends across the subwatershed.

#### 4.6.3.3 Diurnal Data

The 72-h collection of basic water quality parameters, including water temperature, pH, DO and conductivity, was completed twice during the 2006 field season. The first survey was completed in late June when aquatic plant growth is typically at its peak and the second survey was undertaken in August, to observe the fluctuation in water quality under low flow conditions. Hydrolab MiniSonde® water quality loggers were deployed at the 4 stations listed below and portrayed in Figure 4.6.1:

- Station 19- 2:Credit River d/s of Island Lake;
- Station 19-4: Credit River d/s WPCP outfall;
- Station 19-5: Credit River at Hwy 9; and
- Station 19-7: Credit River at the South Crossing of Hwy 10.

The results were compared to PWQOs and critical water temperatures outlined for fishery types in the Credit River Management Strategy (Beak et al., 1992). In addition, the degrees of fluctuations in the parameters measured were examined for obvious trends or atypical results.

#### 4.6.3.4 Temperature Logger Deployment

Water temperature is one of the most critical water quality parameters for the health of fisheries and can determine what species of fish can survive and thrive in a watercourse. Higher water temperatures are also associated with lower dissolved oxygen concentrations. Continuous monitoring of water temperature took place in the 2006 field season with Hydrolab and temperature logger deployment. Seventeen sites throughout the subwatershed had water temperature loggers that recorded temperature every half-hour. The absolute maximum summer temperatures recorded in the 2006 field season are illustrated in Figure 4.6.2.

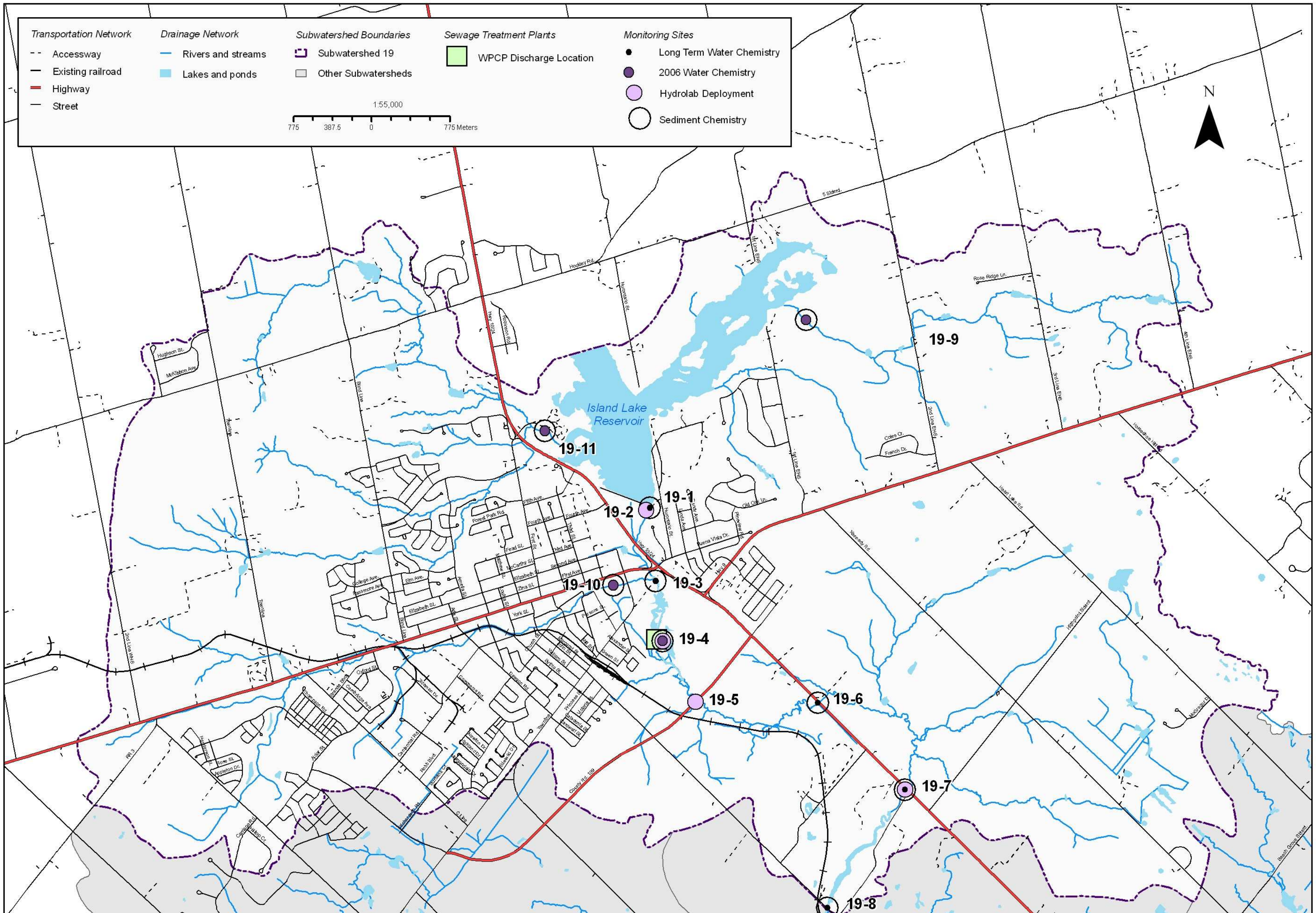



Figure 4.6.1 Long Term Water and Sediment Chemistry Stations

Sources: Drainage (OMNR, 1982; CVC, 1999); Monitoring Stations (CVC, 2006); Transportation Network (OMNR, 1982; CVC, 1999)

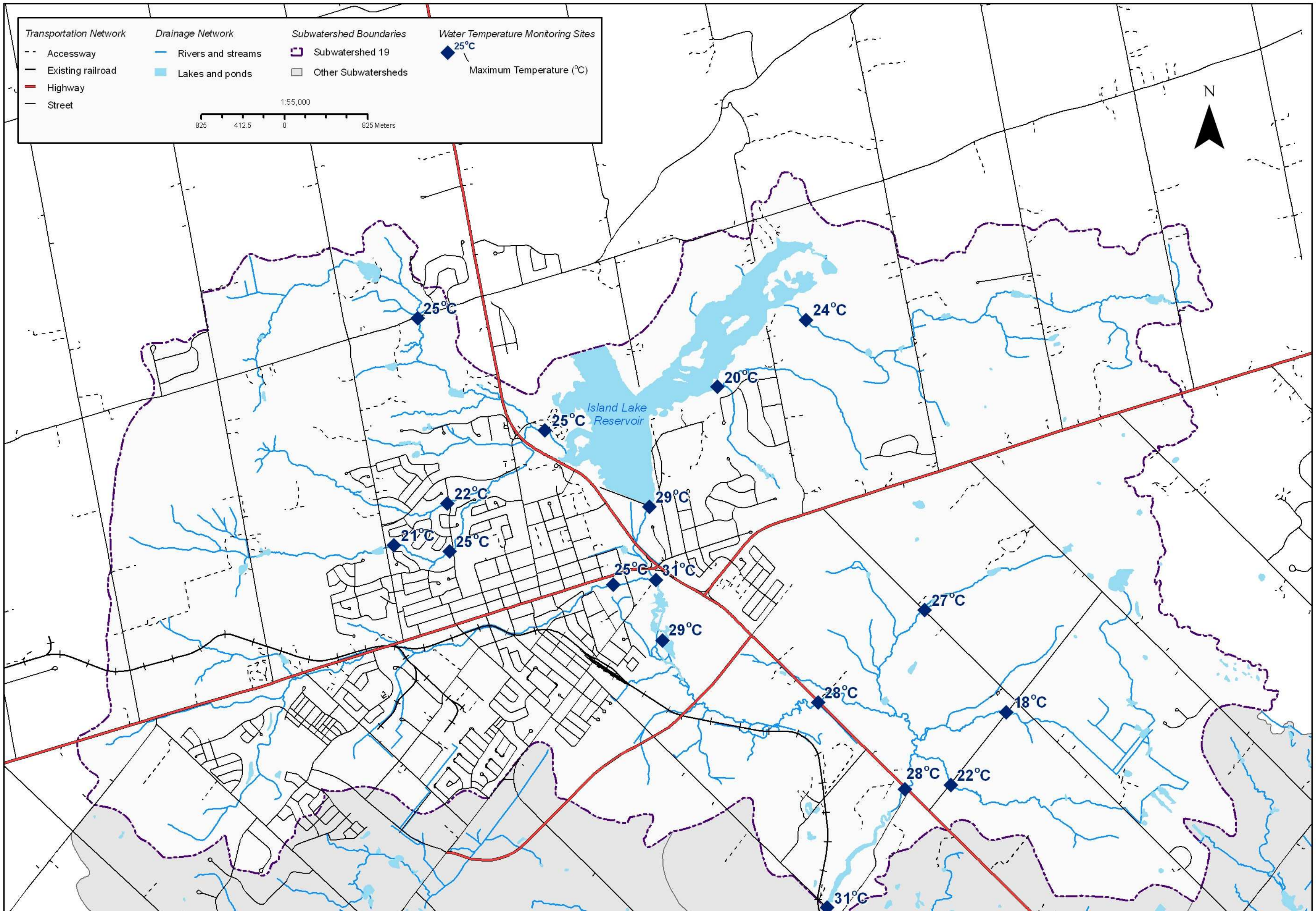



Figure 4.6.2 Water Temperature Sampling Locations

Sources: Drainage Network (OMNR, 1982; CVC, 1999); Transportation Network (OMNR, 1982; CVC, 1999); Monitoring Sites (CVC, 1997; 2006)

## 4.6.4 Results and Discussion

### 4.6.4.1 Nutrients

Many watercourses in southern Ontario are considered to be Policy 2, with respect to Total Phosphorus. Total phosphorus is a limiting nutrient for aquatic plants and high levels can lead to excessive plant growth which, in turn, can lead to depleted dissolved oxygen levels. Policy 2 is a designation by MOE, which states that no further degradation of water quality is permissible and all practical steps must be taken to upgrade water quality (MOE, 1999). A watercourse is typically considered to be Policy 2 if the 75$^{th}$ percentile value of the dataset, which represents a worse case long-term exposure scenario, is above the PWQO.

From April to June 2001, the Orangeville Water Pollution Control Plant (WPCP) experienced an upset condition resulting in exceedences of the plant's Certificate of Approval effluent limit. The upset occurred as a result of sludge management problems, combined with high flows and warm weather. The Water Pollution Control Plant returned to compliance in July 2001. Sewage sludge in the plant exceeded acceptable levels, resulting in final effluent X exceedences of CofA limits for:

1. Biological oxygen demand in April and May 2001
2. Total Phosphorus in June 2001
3. Ammonia Nitrogen in both May and June 2001

The long-term MOE data indicates that the Credit River is a Policy 2 watercourse in terms of Total Phosphorus both upstream and downstream of the Orangeville WPCP. The non-parametric statistical test for the differences between the medians demonstrated that the station downstream of the Orangeville WPCP at the north Crossing of Hwy 10 had significantly higher phosphorus concentration when compared to the upstream station at the Orangeville Dam. The results of these analyses are shown in portrayed in Figure 4.6.3. This graph illustrates that a significant source of phosphorus loadings is to due to inputs from the wastewater treatment plant.

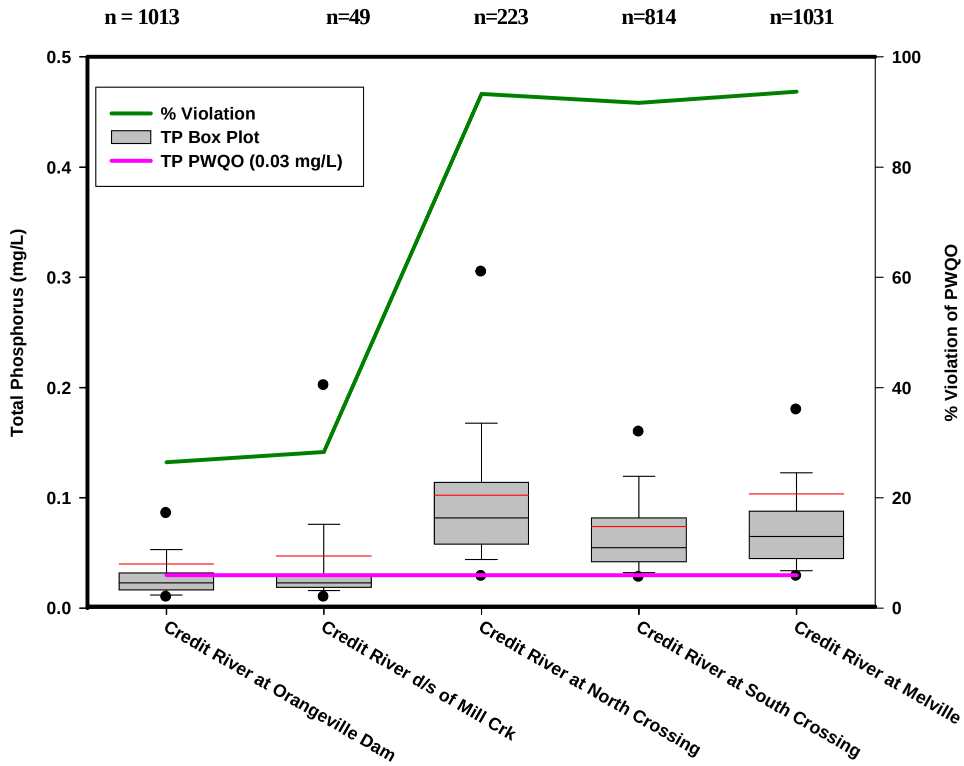



**Figure 4.6. 3** **Box Plot of Total Phosphorus concentrations at long term water chemistry stations**

Total Phosphorus trend analyses show that for the entire data set (which is available back to 1965 at some stations) is that levels have generally declined in the watershed from the 1970s. It is generally accepted that the introduction of phosphorus-free detergents and significant improvements in phosphorus treatment at WPCPs has resulted in a decrease in phosphorus levels which stabilized in the 1980s. Recent trend analysis (based on 1993-2003 data) show that the phosphorus levels below the Orangeville WPCP at the Credit River at Melville Dam are significantly ($p < 0.10$) increasing at a rate of 2.6 ug/L per year. All of the other long term stations did not reveal significant trends due to the variability in the data.

Total phosphorus has a high affinity for clay soils and can readily be adsorbed onto suspended solids. The Spearman correlation test was performed for the total phosphorus (dependent variable) and suspended solids (independent variable) data points from a common time period. Total phosphorus did not show a strong correlation with suspended solids at the Orangeville Dam, Mill Creek or Melville stations but was significantly correlated with suspended solids at the North and South Crossing of Highway 10 sites.

The total phosphorus data collected through the subwatershed fieldwork in 2006 revealed that the phosphorus levels are generally below the PWQO on the smaller tributaries and on the Credit River upstream of the Orangeville WPCP. The Credit River station 50m downstream of the Orangeville WPCP exceeded the PWQO on 4 out of 5 occasion and portrayed a 75$^{th}$ percentile of 39 mg/L, as presented in Figure 4.6.4. The complete dataset for all measured parameters is presented in Appendix D.

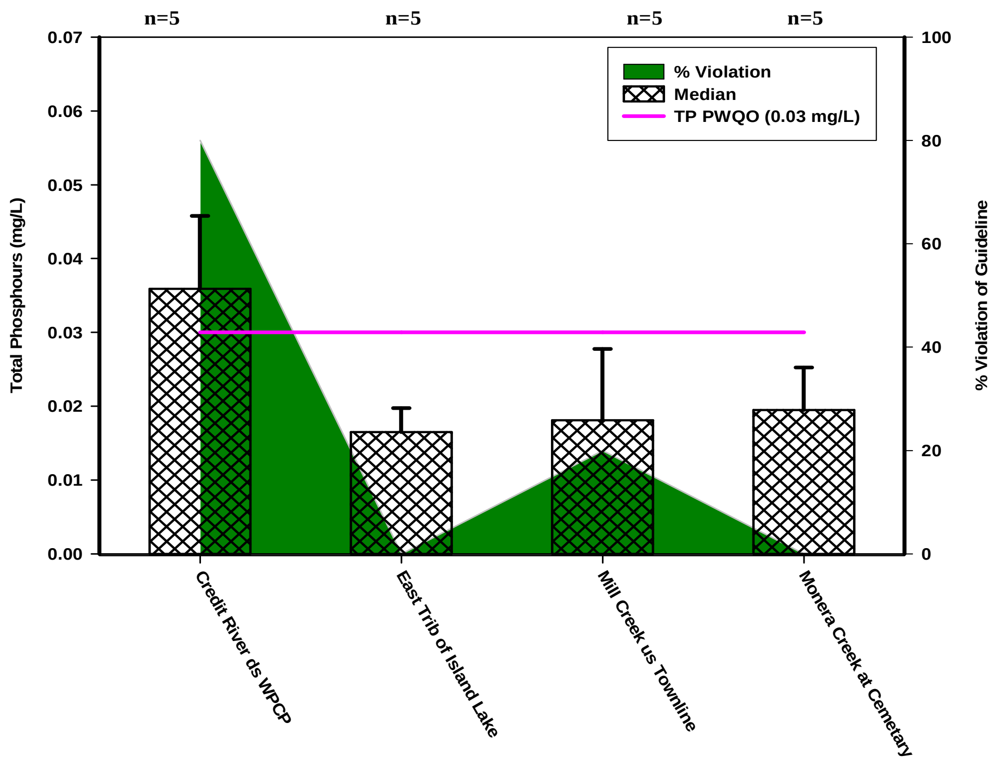



**Figure 4.6.4** **Total Phosphorus results from 2006 fieldwork**

### 4.6.4.2 Nitrate

Nitrate is a dissolved nitrogen species that can act as a nutrient to stimulate aquatic plant growth and be directly toxic to aquatic biota at elevated levels. Excessive aquatic plant growth can lead to an unhealthy dissolved oxygen regime, since nighttime DO levels will be reduced by plant respiration. Many fertilizers, including chemical-based, manure and biosolids fertilizers, contain high levels of nitrate or of other nitrogen species that are eventually converted to nitrate. Because nitrate is a dissolved species of nitrogen, any nitrogen used to fertilize agricultural or residential lands that are not taken up by plants can readily infiltrate to the local groundwater. In addition, septic systems contribute to nitrate loading to directly to groundwater and indirectly to surface waters from groundwater upwellings. WPCPs are also a source of nitrogen contribution to surface water at point sources. Denitrification, a microbiological process that typically requires anaerobic (low or no oxygen) conditions and a carbon source, can convert nitrate into nitrogen gas, which is naturally abundant in the atmosphere. However, if nitrate loading rates are higher than dilution and denitrification rates, nitrate can build up in the groundwater and surface waters.

Figure 4.6.5 below illustrates a box plot of the nitrate nitrogen concentrations found at the long term water quality stations. Most readings are below the CCME guideline due to tertiary treatment including nitrification and denitrification which the effluent undergoes at the Orangeville WPCP. The Orangeville Marsh (aka Melville Marshes) also facilitates a natural uptake of nutrients which aids in assimilating nutrients from many contributing sources from Mill Creek to Melville Dam.

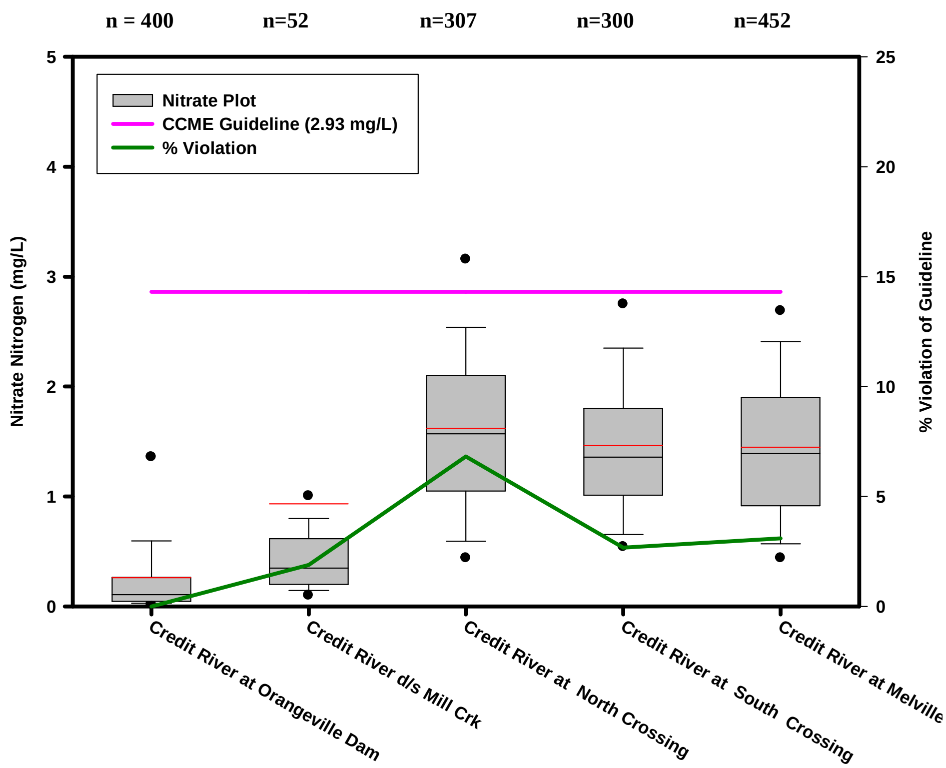



**Figure 4.6.5 Box Plot of Nitrate Nitrogen concentrations at the long term stations**

Trend analysis indicates a significant decreasing trend in nitrates in the upper watershed, possibly the results of improved wastewater tertiary treatment and stormwater management practices. Sites downstream of the Orangeville WPCP outfall do not show significantly increasing trends of nitrate nitrogen as the treatment processes in the Orangeville WPCP include a nitrogen removal step (nitrification followed by de-nitrification). The Certificate of Approval for the Orangeville WPCP limits the concentration and load of nitrogen from the plant. Accordingly, even with increased flows from population growth, the load and thus the instream concentration have not increased, and even may be diluted by increased flows.

Nitrate results from the 2006 fieldwork indicated low nitrate levels for all of the additional stations in the headwaters study (Figure 4.6.6). There were no incidents of violation of the CCME nitrate guideline in the 20 samples taken at these additional stations. The medium values from these 4 stations were below 1 mg/l, with the 75$^{th}$ percentile downstream of the WPCP at 1.7 mg/L. Low levels are due to the high level of nitrogen treatment that effluent undergoes at the WPCP and limited intensive agricultural practices in the subwatershed.

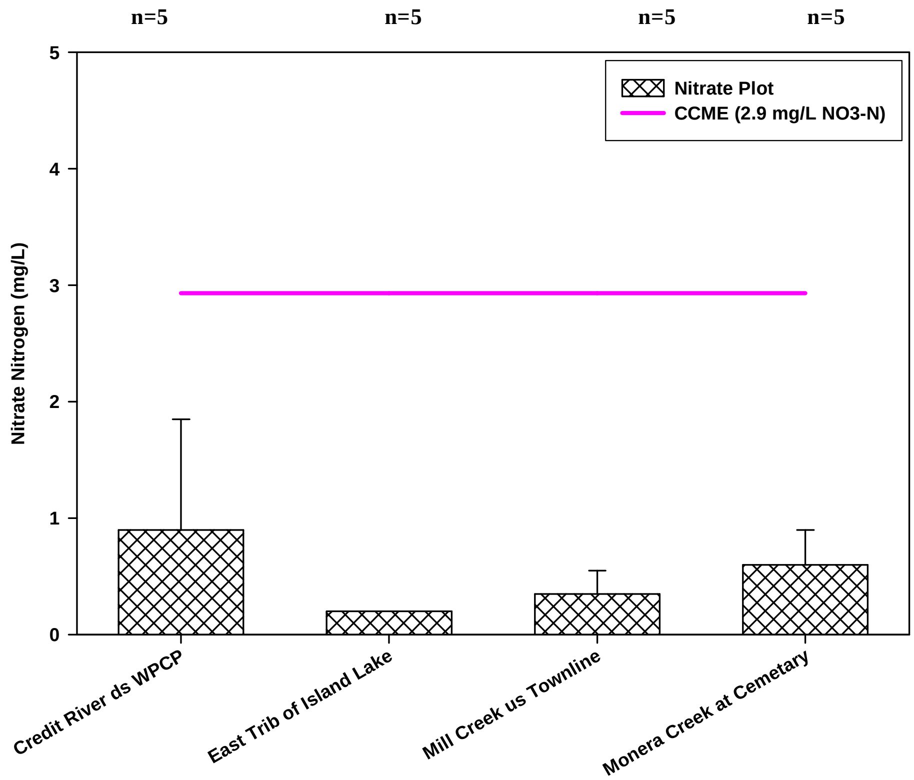



**Figure 4.6.6 Median nitrate results and 75 percentile (error bars) from the 2006 fieldwork**

The 2006 Background Report noted that both ammonia (un-ionized ammonia as calculated based on temperature and pH was below the PWQO of 0.02 mg/l) and nitrite levels observed at the PWQMN stations were well below their PWQO and CCME respectively. The nitrite and ammonia results across the subwatershed from the fieldwork for 2006 further confirmed that these parameters are not currently at levels harmful to aquatic biota.

### 4.6.4.3 Metals

Most metals can be found naturally in soils and in the watercourses that discharge from these soils. Elevated levels of specific metals in watercourses and in soils can occur from naturally higher levels in geologic formations and from human activities, which can effectively concentrate metals directly and indirectly through urban, agricultural and aggregate land uses, as shown in Table 4.6.3.

**Table 4.6.3 Examples of metal contributions to watercourses from natural causes and human activities**

| | Natural | Aggregate | Urban | Agricultural |
|---|---|---|---|---|
| Direct | NA | NA | Discharge of wastewater or stormwater with elevated metals (i.e., from industrial inputs)<br>Landfills | Application of metals, such as calcium, potassium, magnesium, sodium or other minerals/trace metals for crop nutrients or soil amendments |
| Indirect | Naturally high deposits of metals can increase soil, groundwater and surface water concentrations of the given metal | Exposure of geologic formations to oxygen, which can release metals that would other-wise be ‘locked’ into the rock | Increased flows eroding bed and bank soils with naturally high metal content | Where a cover crops are not used, erosion of clay soils with naturally high metal content |

Statistical analysis of the dataset indicates that all of the downstream Main Credit stations are in Policy 2 with respect to aluminum concentrations in the water column (Figure 4.6.7). The correlation analysis performed for the Mill Creek station indicates a strong relationship between aluminum and total suspended solids (Figure 4.6.14). These elevated levels suggest that the Main Credit is being influenced by stormwater and wastewater effluents. Trend analysis determined an increasing trend in aluminum at Mill Creek at a rate of 22.6 ug/L/year for the period of 2002 to 2006,

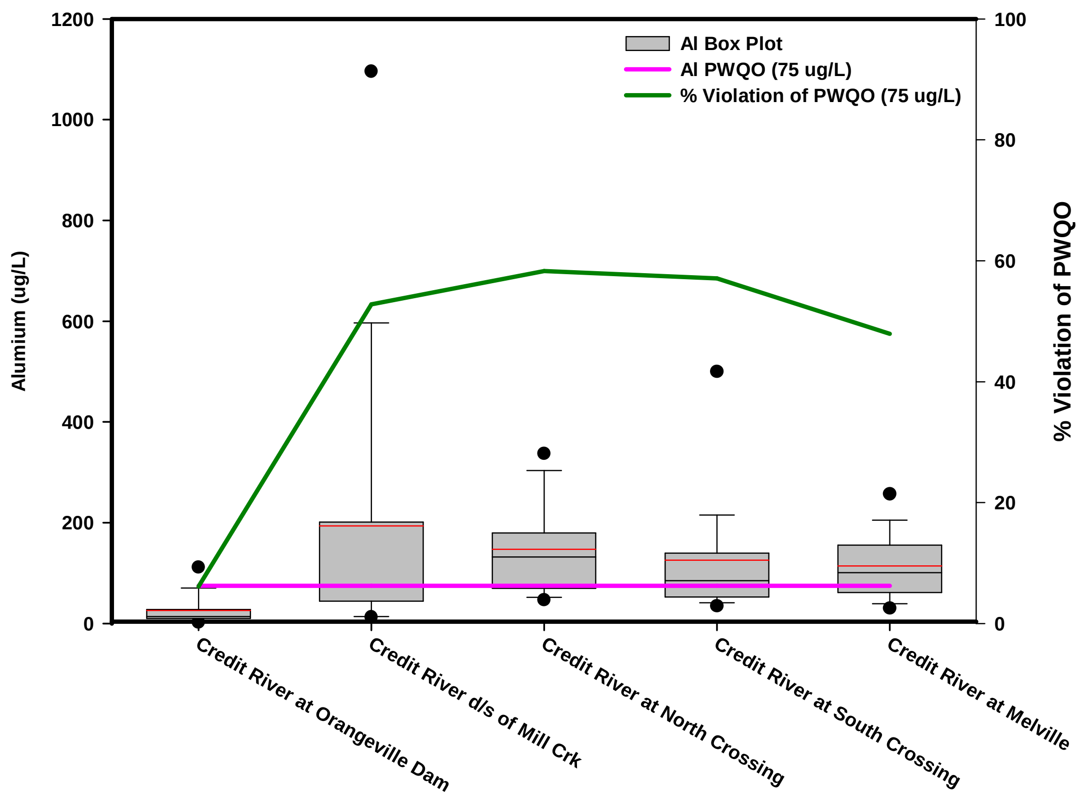



**Figure 4.6.7** **Box Plot of Alumium concentrations, compared against the PWQO and percentage of violation of this objective at the long terms stations**

The aluminum results from the 2006 field season showed lower aluminum levels, in general, in tributaries of Island Lake as compared to the Main Credit stations as seen in Figure 4.6.8. These smaller tributaries have a lower population density and less impervious area and therefore it would be expected that this area would produce less stormwater runoff.

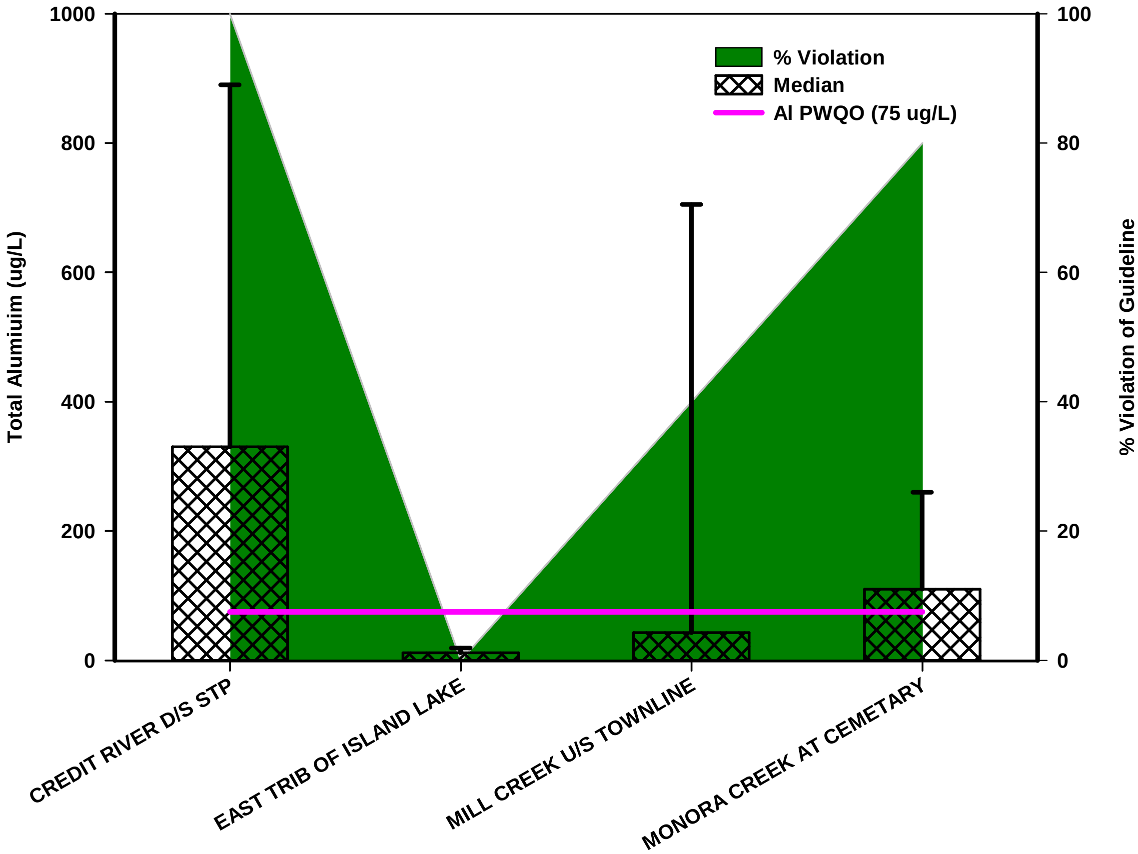



**Figure 4.6.8 Median aluminum and % Violation of the PWQO results from 2006 fieldwork**

Copper, Iron and zinc were sampled at all sites throughout the subwatershed and are detailed in Table 4.6.4. All of these parameters showed a similar trend with metal concentrations generally higher downstream of WPCPs, urbanized areas and in areas without stormwater management controls. This is further illustrated by the violation percentage of respective PWQOs in Figure 4.6.9.

**Table 4.6. 4 Results of statistical analyses for Copper, Iron and Zinc at long term stations**

| Parameter | Copper | | | | | Iron | | | | | Zinc | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | 19-1 | 19-3 | 19-6 | 19-7 | 19-8 | 19-1 | 19-3 | 19-6 | 19-7 | 19-8 | 19-1 | 19-3 | 19-6 | 19-7 | 19-8 |
| Count | 196 | 46 | 208 | 178 | 219 | 44 | 47 | 48 | 48 | 49 | 44 | 47 | 48 | 48 | 49 |
| PWQO (µg/l) | 5 | | | | | 300 | | | | | 25 | | | | |
| Median (µg/l) | 1 | 1.2 | 3.6 | 2.6 | 3 | 32 | 390 | 230 | 164.5 | 213 | 0.6 | 10 | 17.1 | 12.7 | 13.4 |
| 75th Percentile (µg/l) | 3 | 2.2 | 6 | 5 | 5 | 75.6 | 580 | 323 | 273.8 | 306 | 1.08 | 17 | 20.9 | 15 | 15.6 |
| Min (µg/l) | 0.11 | 0.5 | 0.5 | 0.5 | 0.5 | 0.8 | 96 | 117 | 88.3 | 83.3 | 0.05 | 5 | 5.73 | 4.63 | 3.67 |
| Max (µg/l) | 23 | 10.1 | 44 | 49 | 30 | 335 | 6720 | 1000 | 1270 | 656 | 3.24 | 132 | 33.5 | 26.2 | 28 |
| % Violation of PWQO | 12.9 | 8.7 | 31.9 | 24.7 | 20.2 | 4.1 | 67.9 | 30.6 | 16.7 | 26.5 | 2.0 | 12.8 | 4.2 | 4.2 | 2.0 |

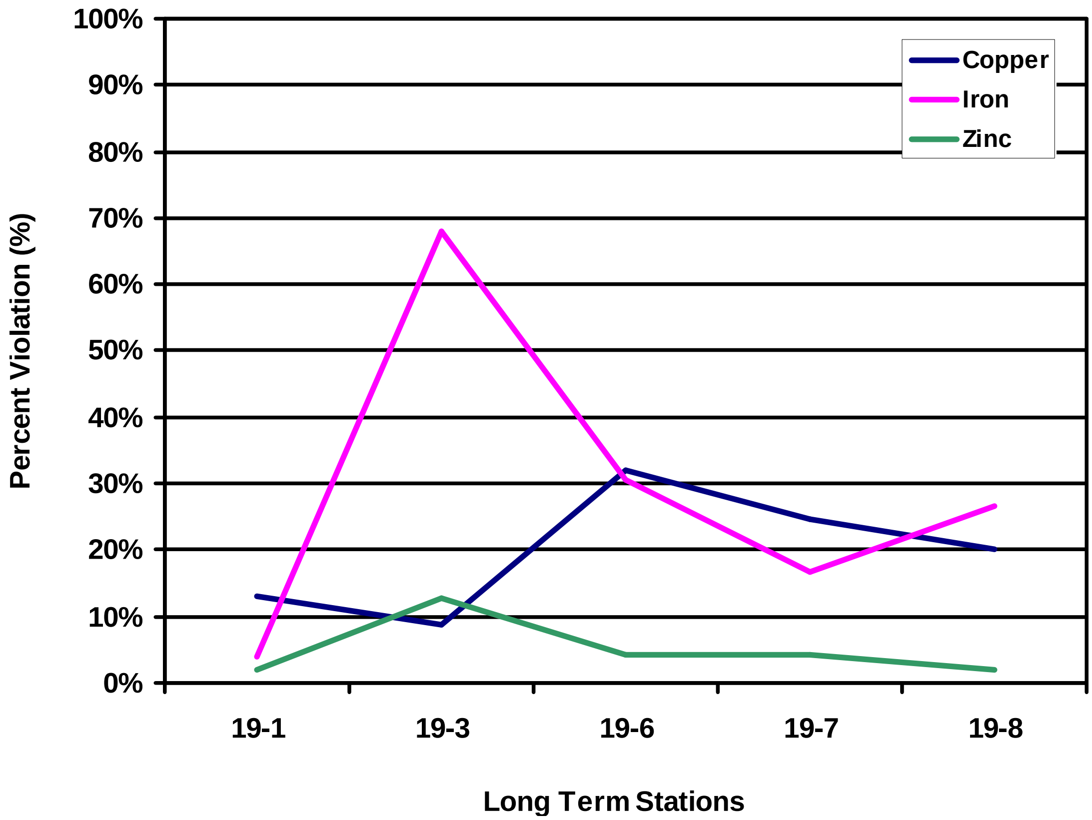



Figure 4.6.9 Results of Percent Violation of the PWQO for copper, nickel and zinc

### 4.6.4.4 Oxygen Related Parameters

A healthy dissolved oxygen regime is critical for fisheries and other aquatic biota. The PWQO for dissolved oxygen is 5 to 6 mg/L for coldwater fisheries and 4 to 5 mg/L for warmwater, within the temperature range of 10 °C to 25°C. As opposed to most parameters, the standard for dissolved oxygen is a minimum, and therefore observed values should be above the PWQO. Oxygen levels are a function of many variables including:

- oxygen demanding parameters including carbonaceous, nitrogenous and benthic sediment oxygen demand (increased oxygen demand will decrease dissolved oxygen);
- water temperature and decreases in atmospheric pressure (increased water temperatures and decreased pressure will decrease the amount of oxygen the water can hold);
- re-aeration (increased re-aeration will increase dissolved oxygen when levels are below saturation and will decrease levels when above saturation); and
- plant photosynthesis and respiration processes (photosynthesis processes produce oxygen while respiration processes consume oxygen).

***Diurnal Monitoring***

Although dissolved oxygen (DO) is measured during the PWQMN runs, these measurements are almost always taken during daylight hours and do not capture the period of lowest dissolved oxygen. Night time measurements of DO are important because if significant aquatic plant growth is present, DO levels can drop below healthy levels for fish just before dawn. During the day, aquatic plants use the sun's energy to photosynthesize, a process that produces oxygen, and therefore increases the dissolved oxygen levels for fish. However, aquatic plants respire continuously, a process that consumes dissolved oxygen in the water. Therefore at night, plant respiration can cause a depletion of dissolved oxygen, which can stress or even kill fish. Water temperature, reaeration rates, and the amount of oxygen demanding material in the water can also affect the dissolved oxygen levels. Sediment oxygen demand, carbonaceous biological oxygen demand, and nitrogenous oxygen demand can remove dissolved oxygen in the water column. Warmer water holds less oxygen than colder water and also increases fish metabolism, which thereby increases the amount of oxygen needed by the fish. Higher reaeration rates in turbulent, high gradient, fast moving water can reduce the impact on dissolved oxygen from aquatic plants and oxygen demanding materials. Because of the number of variables that can impact DO levels, diurnal surveys for dissolved oxygen are needed to measure both daytime and night time dissolved oxygen levels.

Two sets of diurnal monitoring tests for dissolved oxygen, pH, conductivity and water temperature were completed at 4 stations across the subwatershed, one in late June and one in late August. Figure 4 6.10 illustrates DO concentrations over the five days of Hydrolab deployment. All concentrations surpassed the minimum DO objective of 5 mg/L at Credit River 100m downstream of Orangeville dam (19-2). Stations downstream of the urban influences of Mill Creek and the WPCP exhibited DO concentrations that approach or slightly exceed the PWQO during early morning monitoring (Figure 4.6.10). The large variation seen in the Credit River at Hwy 10 south crossing is typical of the dissolved oxygen impacts from excess plant growth and respiration.

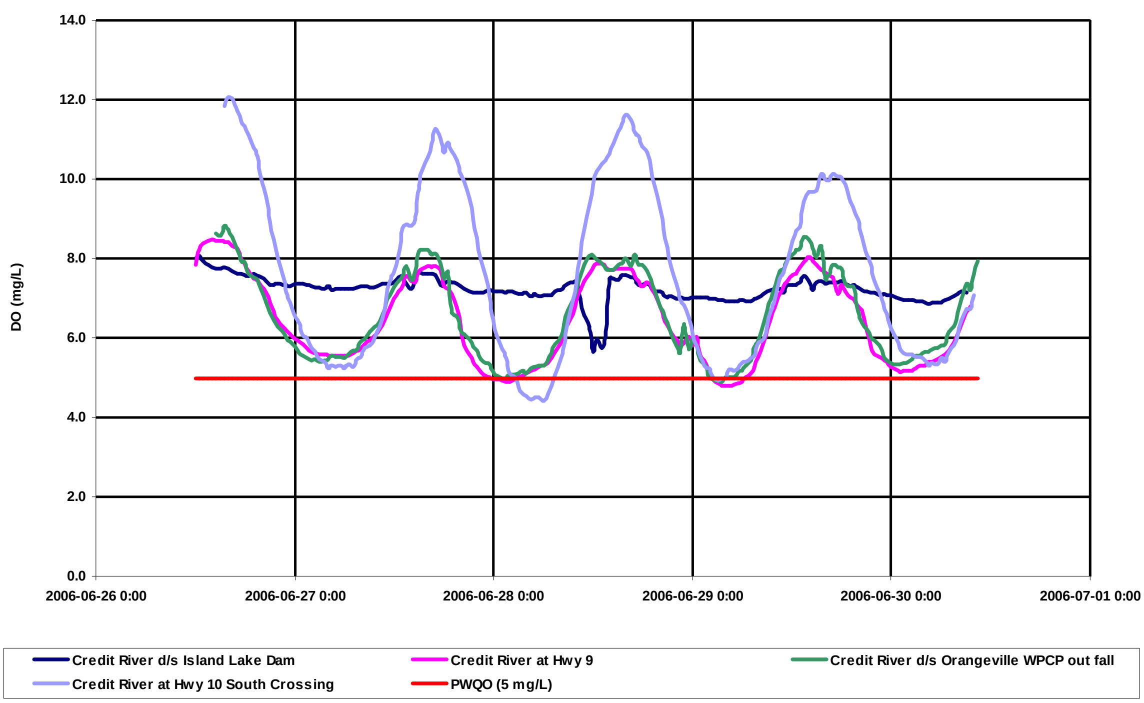



**Figure 4.6. 10 Diurnal survey dissolved oxygen results for Credit River stations in June**

The second diurnal sampling was taken in late August 2007, during a period of low flow conditions and warmer water temperatures. Some mechanical difficulty was experienced with the probe directly downstream of the WPCP and therefore no measurements were recorded at this station. The DO profile showed similar trends to June, with the DO exceeding the PWQO minimum objective at Hwy 9 for a significant portion of each morning (Figure 4.6.11). This could be due to elevated water temperatures and plant respiration.

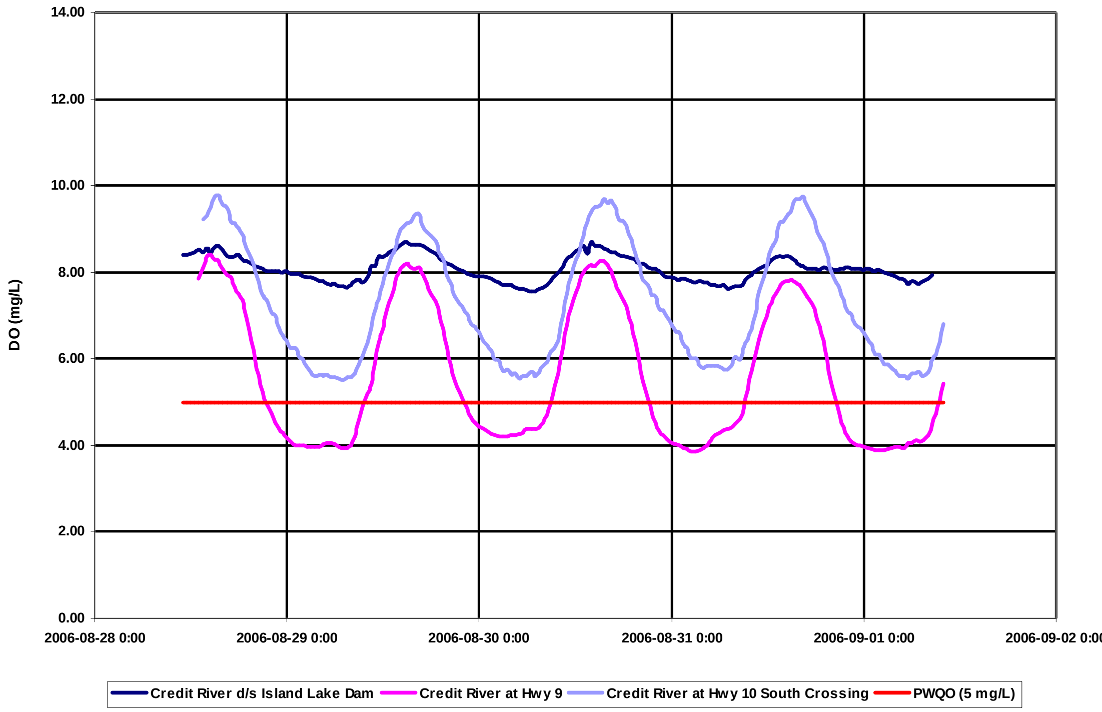



**Figure 4.6.11 Diurnal survey dissolved oxygen results for Credit River stations in September**

### 4.6.4.5 Physical Parameters

The type and concentration of suspended matter controls the turbidity and transparency of water. Suspended matter includes silt, clay, fine particles of organic and inorganic matter, soluble organic compounds and microscopic organisms. Total Suspended Solids (TSS) are defined as undissolved particles that vary in size from approximately 10 nm to 0.1 mm in diameter, containing both biotic and abiotic components. Anthropogenic activities such as forest harvesting, road building, construction, dredging, and gravel pit operations can cause marked changes in the physical, chemical, and biological characteristics of the watercourses nearby, and areas downstream. Other major sources of anthropogenic sediment loading in streams include construction, agriculture, industrial and municipal wastewater discharge. Urban runoff contributes dust and dirt collected on impervious surfaces. Also the increased rate of runoff from urban areas due to the impervious surfaces and construction of efficient collection system of roadside curbs and gutters, catch basins and sewers can increase channel erosion in natural stream banks and add to the TSS in streams during runoff events.

There is no PWQO for suspended solids but it is recognized that high levels can clog critical spawning areas for fish, increase sediment oxygen demand (SOD) which can deplete DO levels, and result in poor water clarity for aquatic life and recreational uses. The CWQG for suspended solids suggests that during clear flow conditions suspended solids levels should not increase from anthropogenic activities to over 25 mg/l of background levels for a 24-hr period and 5 mg/l for period of longer-term exposure (24-hr to 30 d).

Suspended solids measurements are spot measurements similar to water temperature and can vary widely from wet to dry conditions (Figure 4.6.12). These data suggest that the Main Credit River downstream of Orangeville may occasionally receive large sediment loads through either erosion, the WPCP effluent or stormwater flows.

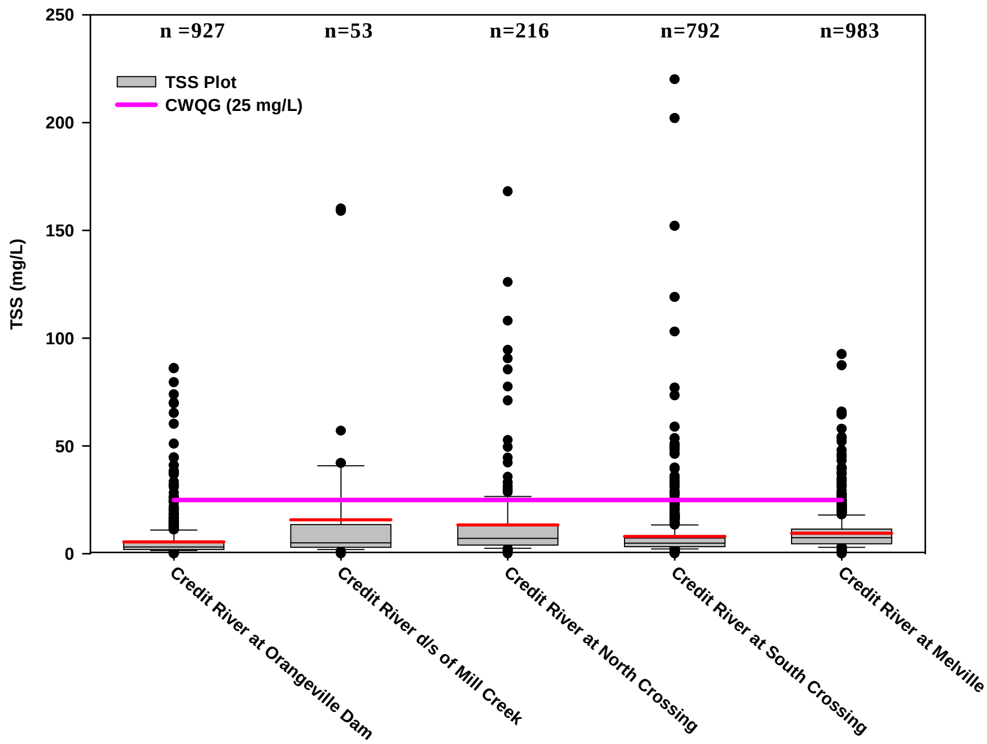



**Figure 4.6. 12 Results of statistical analyses for Suspended Solids compared to the CWQG**

Correlation analyses between suspended solids and all of the Parameters of Concern were carried out for 10 years of data (1993 – 2003), with significant correlations observed for four parameters – total phosphorus, aluminum, copper and iron. A significant correlation was observed ($p<0.05$) between total phosphorus and suspended solids in Mill Creek, one of the main tributaries of the Credit River (Figure 4.6.13). This suggests a very close association between the two parameters that may be a result of phosphorus entering the Main Credit attached to sediment and stormwater runoff.

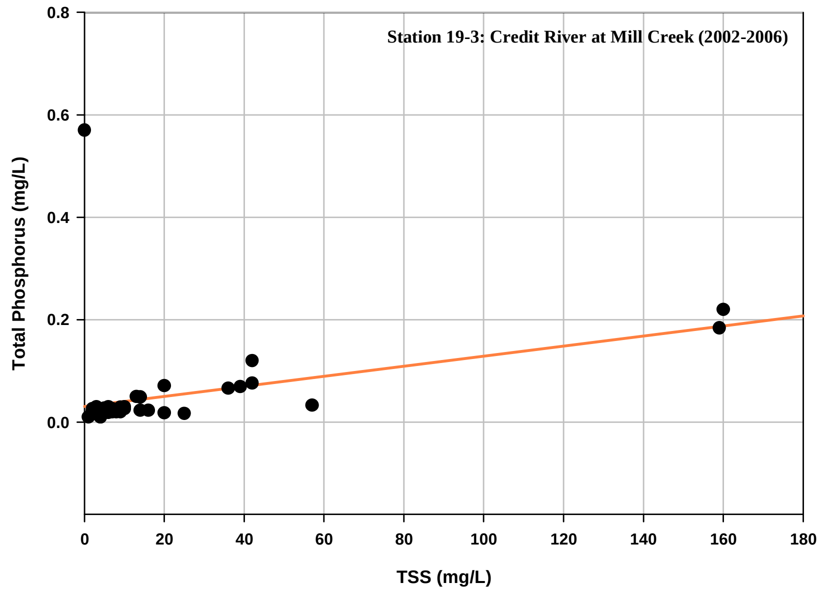



**Figure 4.6. 13 Correlation analysis of TSS vs. Total Phosphorus for the Credit River at Mill Creek**

Correlation analysis also indicates a strong relationship to aluminum, copper and iron in the Credit River downstream of Orangeville indicating possible inputs from the stormwater management facilities (Figure 4.6.14).

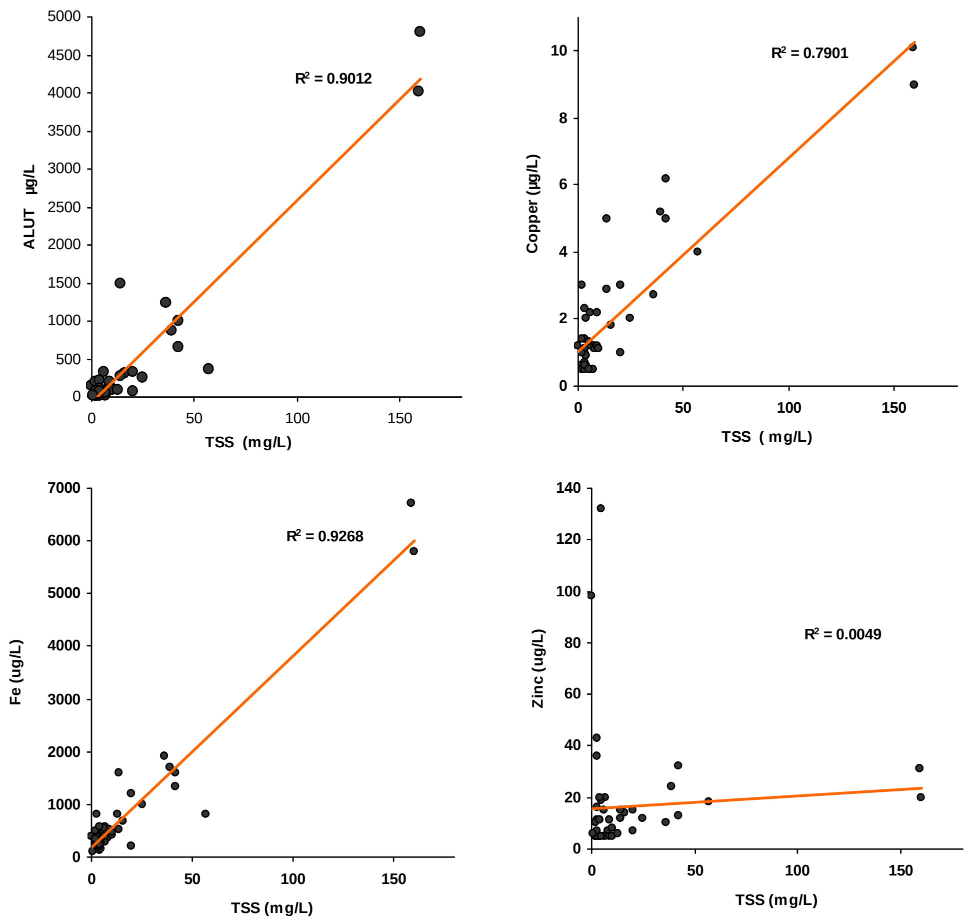



**Figure 4.6. 14 Correlation analysis for Suspended solids verses metals on the Credit River at Mill Creek.**

Suspended solids levels also appear to be elevated under winter and spring conditions when ice jams or spring runoff events may be increasing loadings to the creek (Figure 4.6.15.)

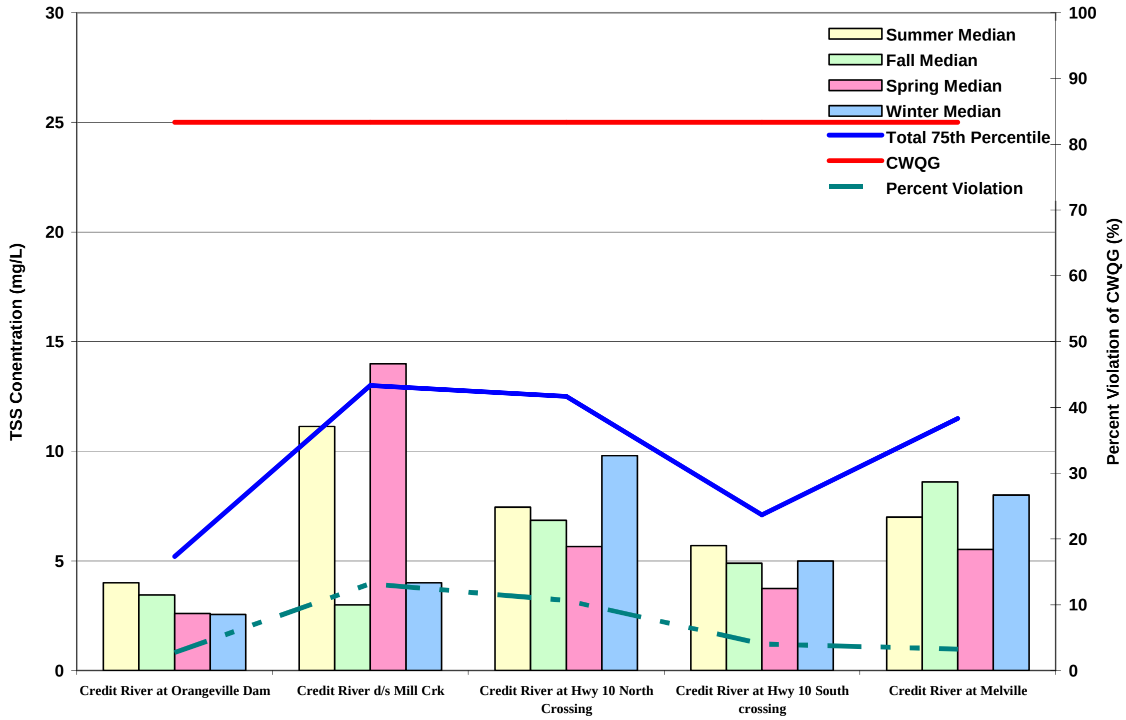



**Figure 4.6.15 Season Medians for long term stations compared with percent violation of CWQG guideline**

The 2006 field season data showed that that there is often a high variability in suspended solids data and many of the stations and five sample events may not been sufficient to accurately characterize the stations. Short terms results showed elevated levels downstream of the WPCP outfall resulting in a percent violation of 40% of the Canadian Water Quality Guideline.

**Table 4.6.5 Average Suspended Solids results from the 2006 fieldwork**

| Station ID | Description | Number of Samples | Median (mg/l) | 75th Percentile (mg/l) | Percent Violation of CWQG |
|---|---|---|---|---|---|
| 19-4 | Credit River d/s of WPCP outfall | 5 | 17 | 31.0 | 40% |
| 19-9 | East Tributary 1 of Island Lake | 5 | 3 | 19.0 | 20% |
| 19-10 | Mill Creek u/s of Townline | 5 | 7.5 | 10.75 | 0% |
| 19-11 | Monera Creek at Cemetery | 5 | 7 | 11.0 | 0% |

### Chlorides and Conductivity

Sources of chlorides ($Cl^-$) include loadings from WPCP effluents and road salting for ice in the winter (NaCl), use of a dust suppressant ($CaCl_2$) on dirt roads in the summer, and water softeners. Because chloride has a high solubility and is a conservative parameter, it can readily move through groundwater systems and into surface waters through runoff or groundwater discharges (Bowen and Hinton, 1998). Chloride does not have freshwater guideline for the protection of aquatic biota, however the current aesthetic drinking water quality objective for chloride is 250 mg/l (MOE, 2001) which is within the range of the lowest concentrations observed to be harmful to aquatic biota (Environment and Health Canada, 2000). Based on the figure below, it is likely that the source of chlorides in the Main Credit is either stormwater inputs, which may have elevated chlorides levels from road salting, or the Orangeville WPCP effluent.

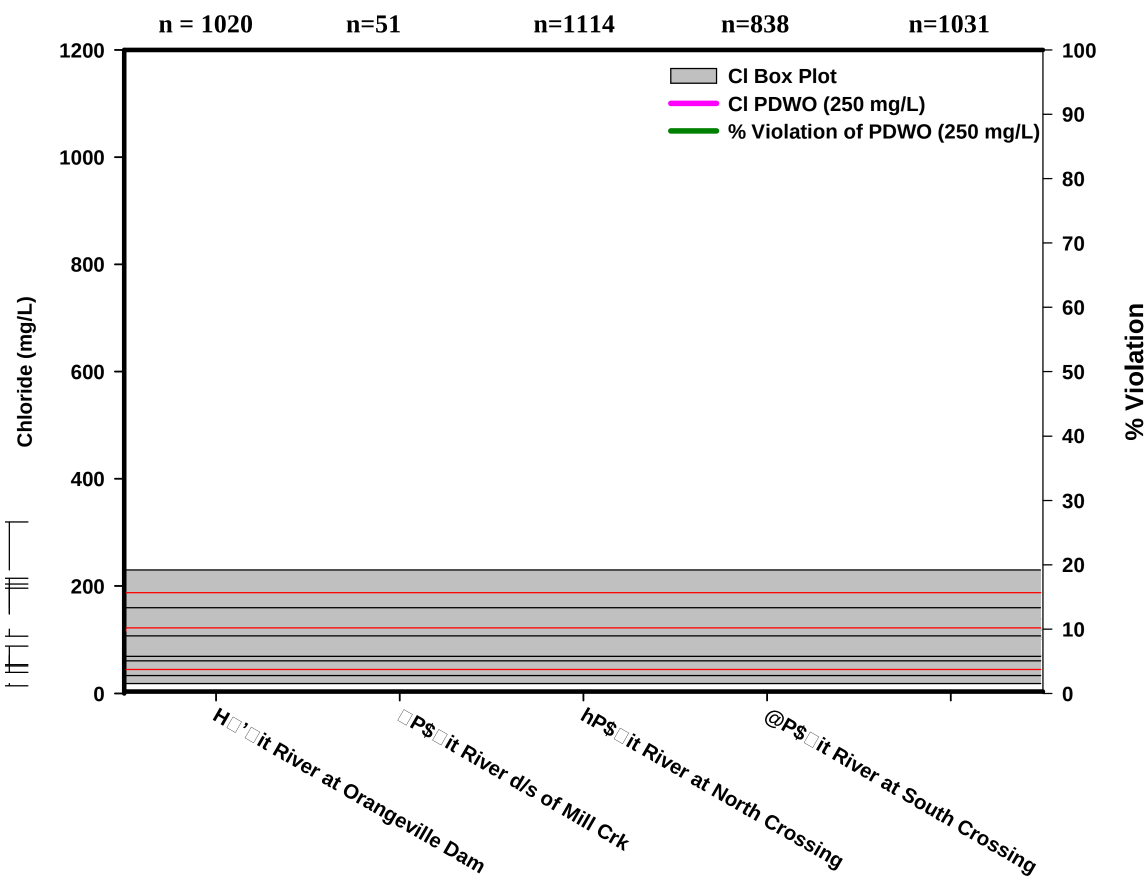
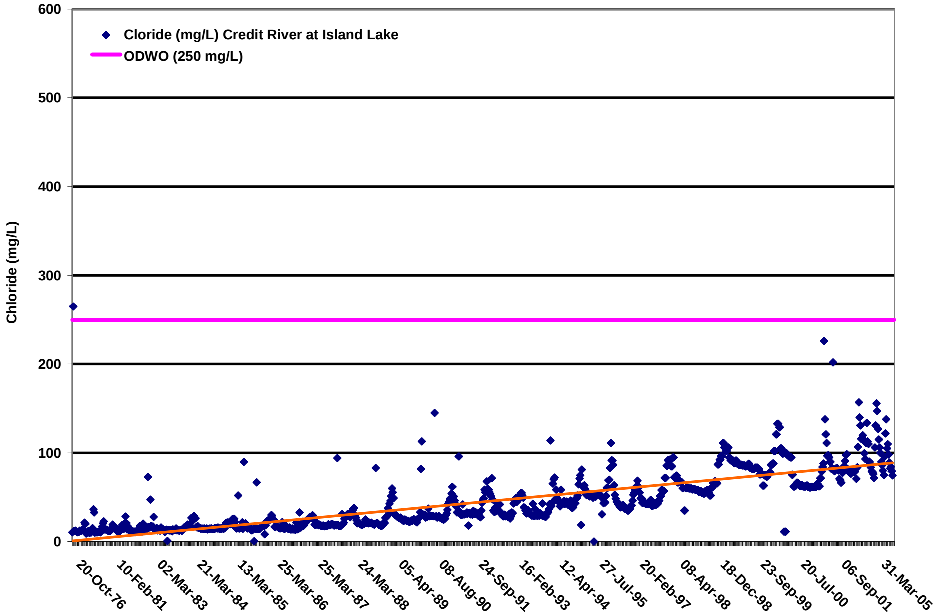



**Figure 4.6.16 Box plot of Chloride Concentrations at the long term stations compared with the ODWO**

The 2006 Background Report observed that Headwaters subwatershed had an increasing trend for chlorides, which is a common trend across the Credit River watershed. Chlorides are typically a good indicator of urban development with significant inputs coming from road salting and WPCP inputs. This is evident from the significant trends portrayed in Figure 4.6.17 both at the upstream station of Credit River at Island Lake and downstream of Orangeville at North crossing of Hwy 10.



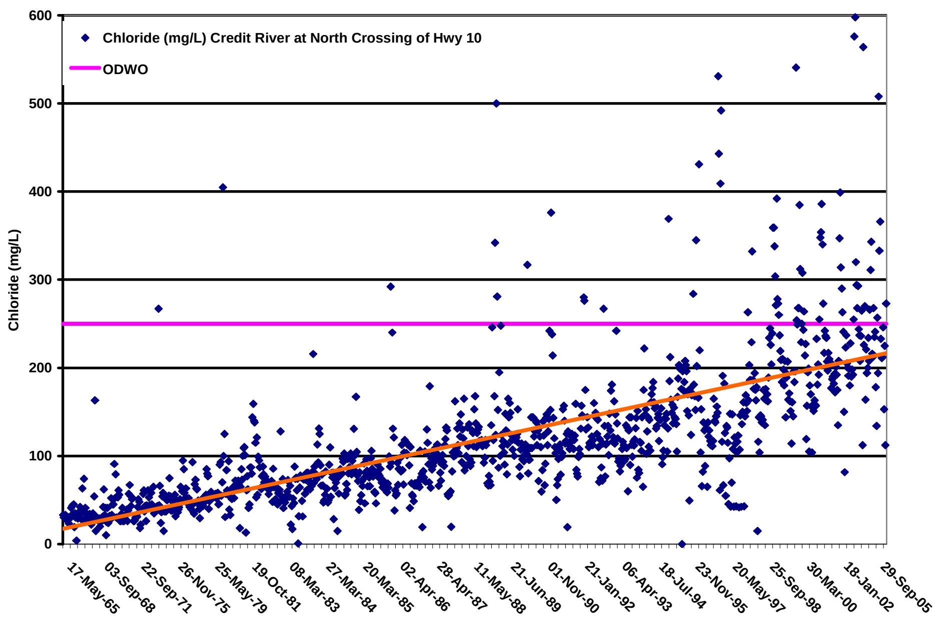




**Figure 4.6.17 Long term chloride concentrations downstream of Island Lake Reservoir (above) and Credit River at North Crossing of Hwy 10 (below).**

Application of road salt in the winter months on paved roads and highways results in elevated chloride concentrations at all stations in the winter months. Chloride concentrations in urbanized Mill Creek catchments are depicted in Figure 4.6.18. Chloride levels are highest during the winter months. This is interpreted to be associated with road salt application and reduced baseflow, which has the potential to help dilute high chloride concentrations in the surface water. Chloride concentrations then decrease during the summer months, with the lowest values recorded during the fall, after most of the winter road salts are flushed off road surfaces during rain events or associated with the spring freshet.

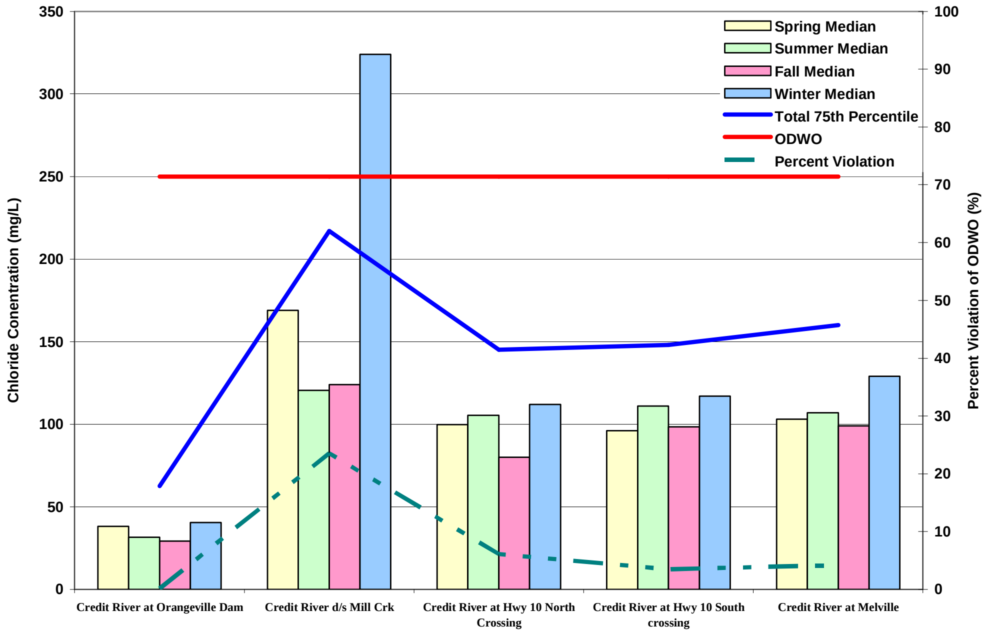



**Figure 4.6.18 Seasonal results of Chloride seasonal mean compared with the Ontario Drinking Water Objective and the Percent violation of this objective**

The chloride results from the 2006 field season showed lower chloride levels, in general, in tributaries of Island Lake as compared to the Main Credit stations as seen in Figure 4.6.19. These smaller tributaries have a lower population density and therefore fewer roads would require salting and it would be expected that this area would be subject to lower loads of salt.

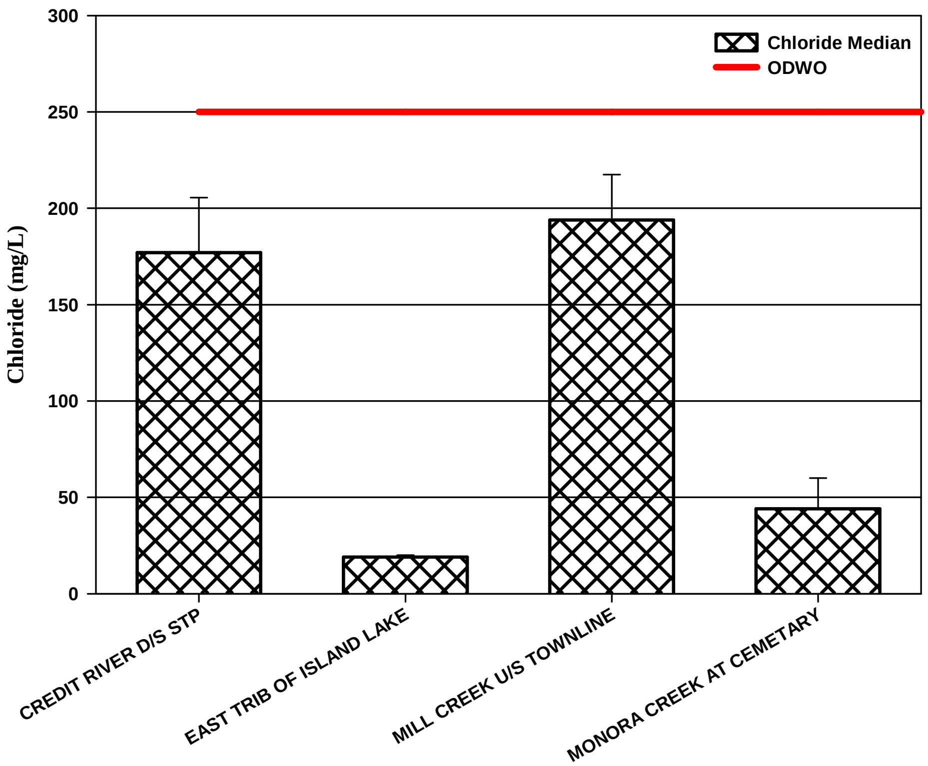



**Figure 4.6.19 Average chloride results from the 2006 fieldwork**

### 4.6.4.6 Microbiological

Although bacteria levels are typically more of a concern for the health of humans than fisheries, high bacteria levels can be indicative of an impaired watercourse. Livestock, wildlife, pets, septic systems and treated and untreated sewage are the main sources of bacteria in the Credit River and tributaries. Levels of *E. coli* are used as a surrogate indicator for the presence of pathogenic bacteria and nitrogenous waste that impair human uses of the water. The PWQO for *E. coli* is set for the safety of recreational uses, such as swimming and other water sports, and is therefore not necessarily an appropriate objective for fisheries health. However, since the previously mentioned sources of elevated bacteria levels can also contribute excessive nutrients and oxygen demanding materials, *E. coli* can still be considered a secondary indicator for fisheries health. In addition, the PWQO is meant to be compared to the geometric mean of five samples taken simultaneously. Geometric means (or geomeans) are used to measure ‘average’ bacteria values since this bacterial growth occurs at a logarithmic scale. For this analysis, long-term geometric mean results are compared to the PWQO for comparison of bacterial levels between stations. In general, the geometric mean values for *E. coli* are below the PWQO of 100 counts/100 mL however very high *E. coli* levels, assumed to have been associated with precipitation and urban runoff, have been observed for all stations (Figure 4.6.20).

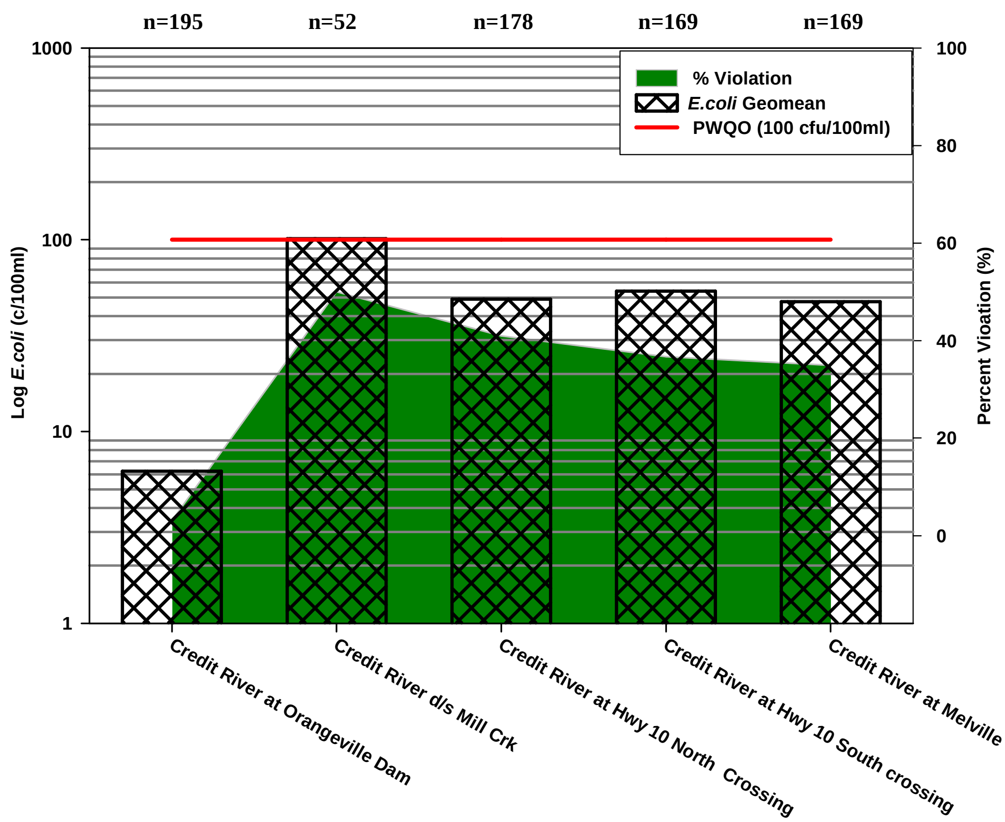



**Figure 4.6.20 Log *E. coli* Geomean and Percent Violation compared with PWQO**

The statistical results from the *E. coli* dataset are presented in the figure above and illustrate little variability between the four long term stations below Orangeville. Mill Creek experienced an approximate 45% frequency of exceeding the PWQO. This indicates that urban stormwater runoff is the major contributing source rather than WPCP inputs. Higher values for all short terms stations were observed in the summer which would be expected due to phenomena such as increased biological activity in the summer from warmer temperatures and the practice of moving livestock outside to graze in the warmer months (Figure 4.6.21).

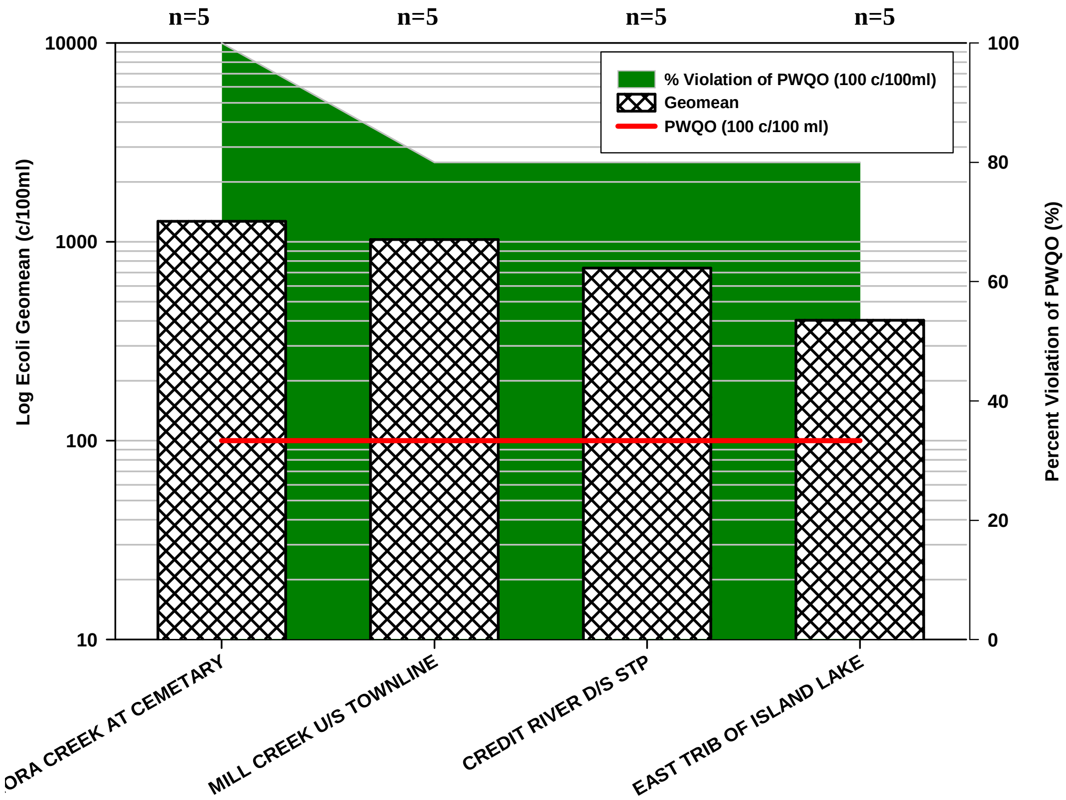



**Figure 4.6. 21** **Log of short term stations *E.coli* Geomean and Percent Violation compared with PWQO**

The county of Dufferin Public Health Unit samples the public beach at Island Lake Conservation Area weekly throughout the summer months (June-August). A public beach is posted with unsafe water quality conditions after two consecutive geomeans that are measured greater than the PWQO of 100 counts/100ml. From the period from 2000 – 2008, the Island Lake CA was posted as unsafe water quality for a total of 8 weeks. During this period, 35 out of the 102 sampling events were found to be above the PWQO (Figure 4.6.22).

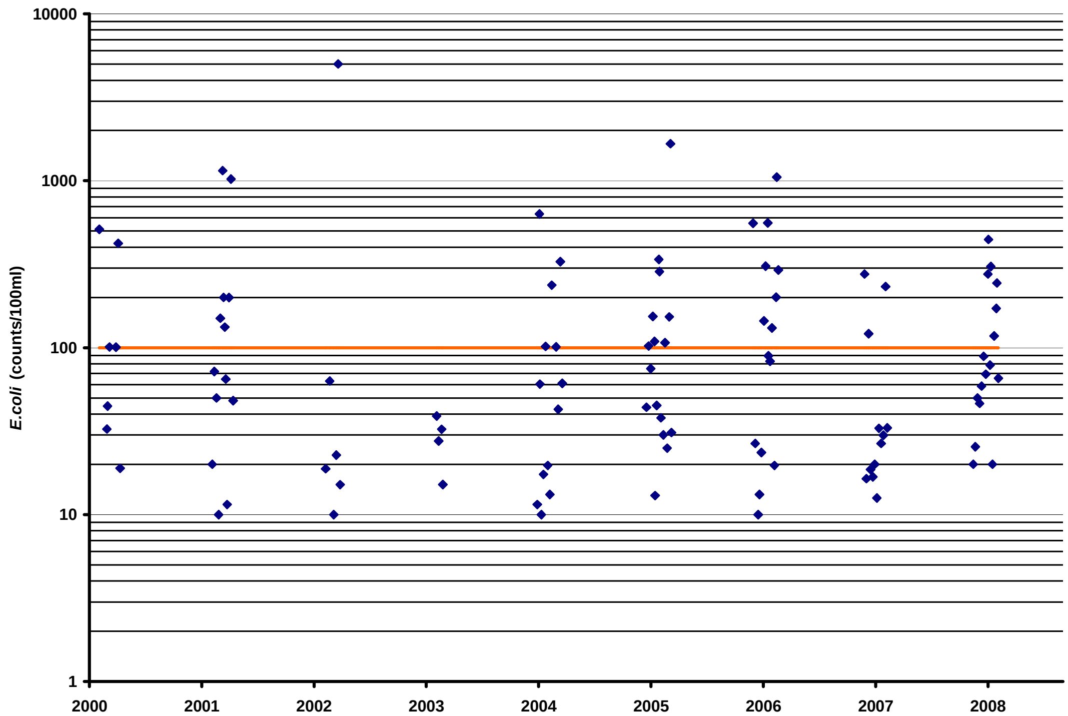



**Figure 4.6.22** ***E.coli*** **Geomean concentrations found at the Island Lake Beach sampled by Dufferin Health Department from 2000-2008, compared against the PWQO of 100 cts.per100ml.**

## 4.6.5 Comparison with Original Subwatershed Study

The Water Quality component of the 1997 Subwatershed 19 study was intended to:

- determine existing water quality (baseline conditions) throughout Subwatershed 19;
- determine the impacts of future land use change on surface water quality; and
- determine the effectiveness of potential best management practices (BMPs) in mitigating the impacts of land use change on water quality.

This phase of the Subwatershed Study focused on the determination of baseline conditions throughout Subwatershed 19. Phase 2 of this study will determine impacts of future land use changes and effectiveness of BMPs.

The original subwatershed study classified the existing water quality throughout Subwatershed 19 as good, and determined that water quality was not considered to be a limiting factor in the health of the aquatic communities. The updated Subwatershed Study classified the water quality in Headwaters subwatershed as variable in terms of supporting healthy aquatic biota. In general, the tributaries that flow into Island Lake are fair while the results of the Water Quality Index designate the long term Main Credit stations experience marginal water quality.

## 4.6.6 Water Quality Characterization

### 4.6.6.1 Summary of Surface Water Chemistry Data

***Water Quality Index***

A water quality index provides a convenient method of mathematically summarizing complex arrays of multivariate water quality data into simple water quality descriptors that facilitates easy communication of the water's status to general audiences.

While numerous water quality indexing systems are in use throughout Canada and the United States, none provide the power and versatility seen in the Canadian Council of Ministers of the Environment, Water Quality Index (CCME WQI). The CCME Water Quality Index is based on 3 analytical factors that compare water quality data with their associated provincial or federal objectives or guidelines for each parameter:

- the number of variables whose objectives are not met (Scope – $F_1$);
- the frequency with which the objectives are not met (Frequency – $F_2$); and
- the amount by which the objectives are not met (Amplitude – $F_3$).

As noted previously, a list of chemical and physical "Parameters of Concern" was identified during the development of the CVC Water Quality Strategy. Those parameters provide the most relevant information pertaining to surface water quality changes relative to land use practices throughout the Watershed. Since some of the identified parameters do not have provincial or federal "Objectives" they are not included in the index calculations (Table 4.1). Parameters included in the water quality index include: total phosphorus, nitrate-nitrogen, aluminum, zinc, copper, iron, chloride and *E.coli*. Indexing at least 6 parameters per site is recommended by CCME. However, those parameters without provincial or federal objectives/guidelines are profiled separately.

***Results***

The WQI analysis is based on a ten year record of data collected from 1996 to 2006. The WQI generates a score between 0 and 100, whereby a score of zero indicates poor water quality and 100 indicates ideal water quality. Results from the analysis of the WQI rank the main stem Credit River Stations as generally good to marginal (Figure 4.6.23).

Overall, the water quality in upper portion of the Headwaters subwatershed is good to fair in terms of impact to the health of aquatic biota. In the mid to lower portions of the subwatershed, the influence of highways, urban land use and high population density is apparent with median concentrations of the total phosphorus, aluminum and chlorides in the main Credit River markedly greater than those at other sampling locations in the subwatershed. Results of the Water Quality Index indicate that main Credit stations water quality is generally marginal.

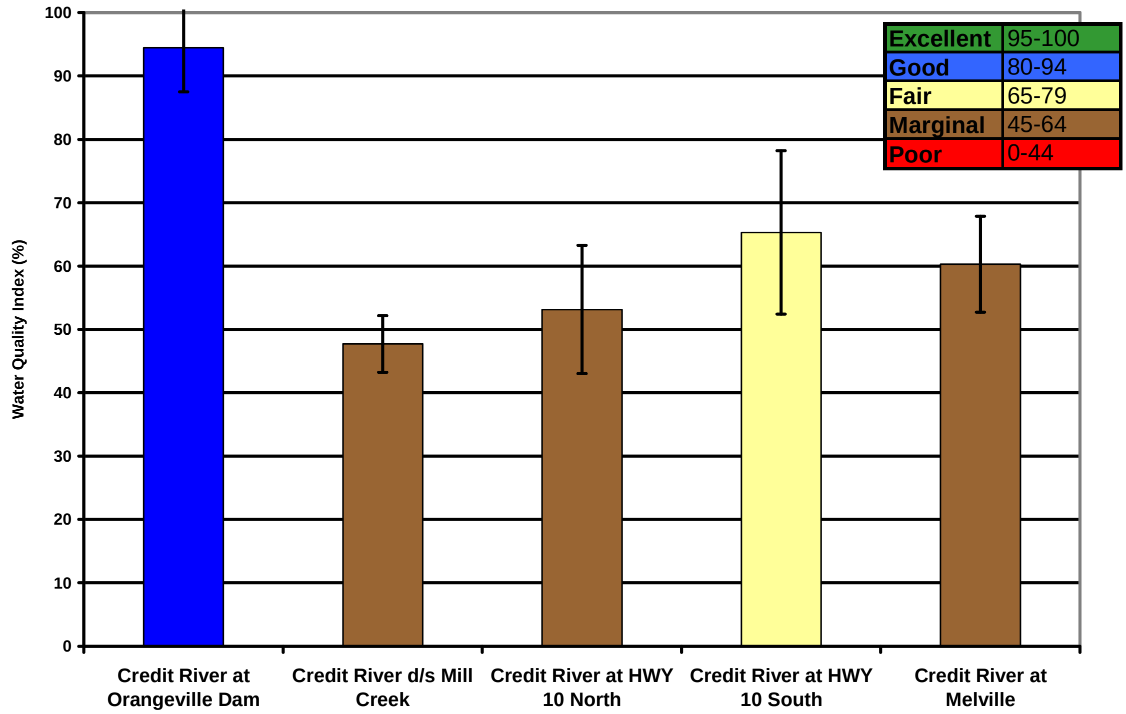



**Figure 4.6.23** **Average of Water Quality Index with standard deviation results for long term stations for the period of 1996-2006**

### 4.6.6.2 Summary of Sediment Chemistry Data

Sediment chemistry monitoring was conducted in the 2006 field season at eight sites in Sub 19 illustrated in Figure 4.6.1. Eight sites were sampled throughout Subwatershed 19 on smaller tributaries that lead to the main Credit River and the Credit River itself.

Sediment Chemistry analysis allows a deeper look into the historical chemical compounds utilization, their mobility and ability to bioaccumulate. Bioaccumulation occurs in the sediments which are consumed by benthic macroinvertebrates. These benthic invertebrates are then consumed by larger predators such as fish that are then consumed by carnivorous animals and humans. Bioaccumulation occurs with metals, Polychlorinated Biphenyls (PCBs), Phenanthrene (PAHs), and Organo-Chlorides (OC), all of which were analyzed for in this study. These results are compared against 4 standards described below:

- **Federal Probable Effect Level (PEL)** - level above which adverse effects are expected to occur frequently (CCME. 1999);
- **Federal Threshold Effect Level (TEL)** – concentration below which adverse biological effects are expected to occur rarely (CCME 1999);
- **Provincial Severe Effect Level (SEL)** – level in sediments that could potentially eliminate most of the benthic organisms (MOE, 1993); and
- **Provincial Lowest Effect Level (LEL)** – level at which actually ecotoxic effects become apparent. It is derived using field based data on the co-occurrence of sediment concentrations and benthic species (MOE, 1993).

### *Polychlorinated Biphenyls (PCBs)*

PCBs were commonly used as a number of consumer products and as ballast in electrical equipment such as transformers and capacitors due to their chemical stability. Although the use of PCBs has been severely restricted in North America over the last two decades, the main sources for aquatic environments continue to be leaks, spills, municipal and industrial effluents, runoff from contaminated soils, leachate from unsecured landfills, and atmosphere deposition (WHO, 1992). Like many other organochlorine compounds, PCBs are persistent, bioaccumulative and toxic. Once released into the environment PCBs tend to change composition and bind to sediments. The majority of PCBs that are introduced into the aquatic environment are eventually incorporated into bed sediments (Baker et al., 1985). Therefore, sediment represents an important exposure route for aquatic biota to PCBs. They are the cause of most of the fish consumption advisories in the Great Lakes and are considered a priority pollutant by many authorities.

While there were no PCBs detected at any of the tributary stations in 2006, Total PCBs were detected at the Orangeville Dam and at the North Crossing of Hwy 10 (Figure 4.6.24). Levels at the Orangeville Dam were above the Probable Effect Levels.

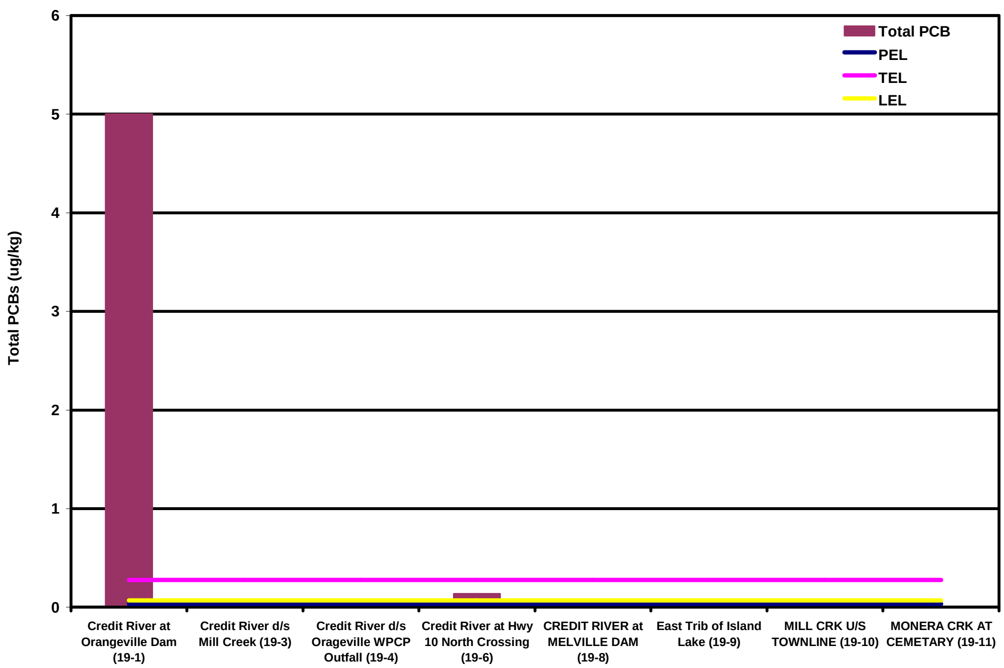



**Figure 4.6. 24 Total PCBs concentration measured in the Headwaters Subwatershed in 2006**

### *Polycyclic Aromatic Hydrocarbons (PAHs)*

Polycyclic aromatic hydrocarbons are produced during the incomplete combustion of organic substances, most commonly the combustion of fossil fuels. As an indicator of human industrial activities, PAH contamination is relatively widespread throughout the Great Lake Basin. This study included an analysis of 16 different PAH chemicals. Eleven PAHs were detected at 3 of the 4 sites in the subwatershed, with the East tributary of Island lake found no detections. The indicator species Phenanthrene was chosen as a representative species. Mill Creek upstream of town line site, had concentrations that were above the Threshold Effect Level (Figure 4.6.25).

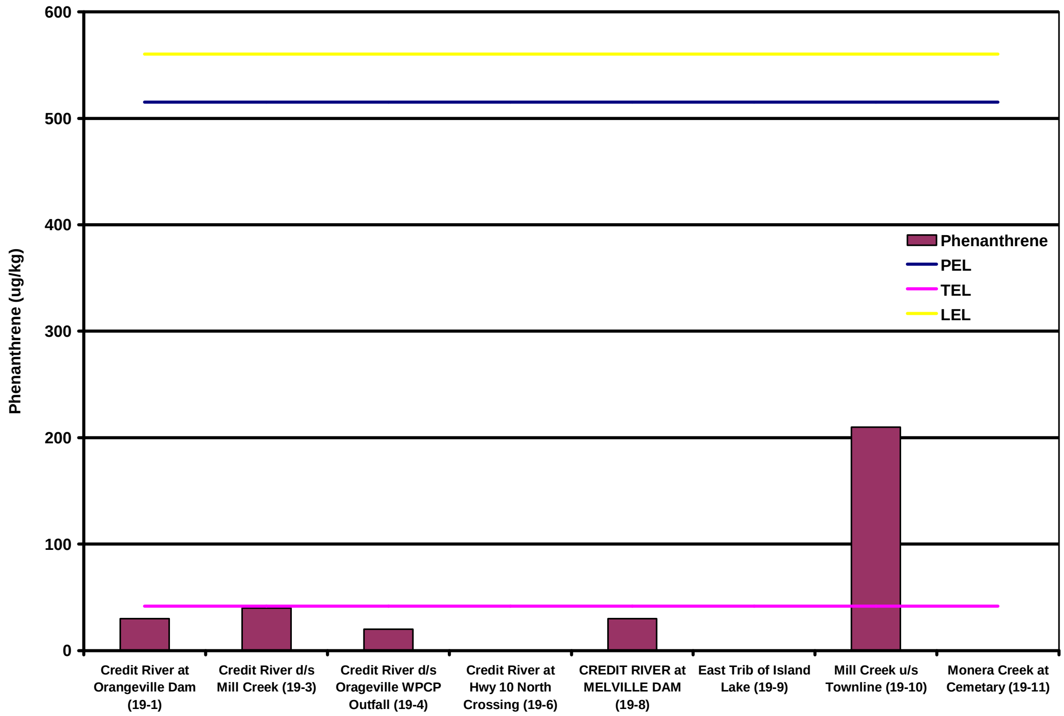



**Figure 4.6.25 Phenanthrene concentration measured in the Headwaters Subwatershed in 2006**

### *Organochlorines (OC)*

The study also tested for a broad range of organochlorines including DDT and metabolites, and other common pesticides (Dieldrin, Chlordane, Endosulfate, Lindane and Mirex). These chemicals were all utilized for their pesticide properties, ranging from a broad spectrum pesticide to specific target receptors. There was only one detect for one species of DDT (p,p'-DDE) that was found at the East Tributary of Island Lake station (Figure 4.6.26).

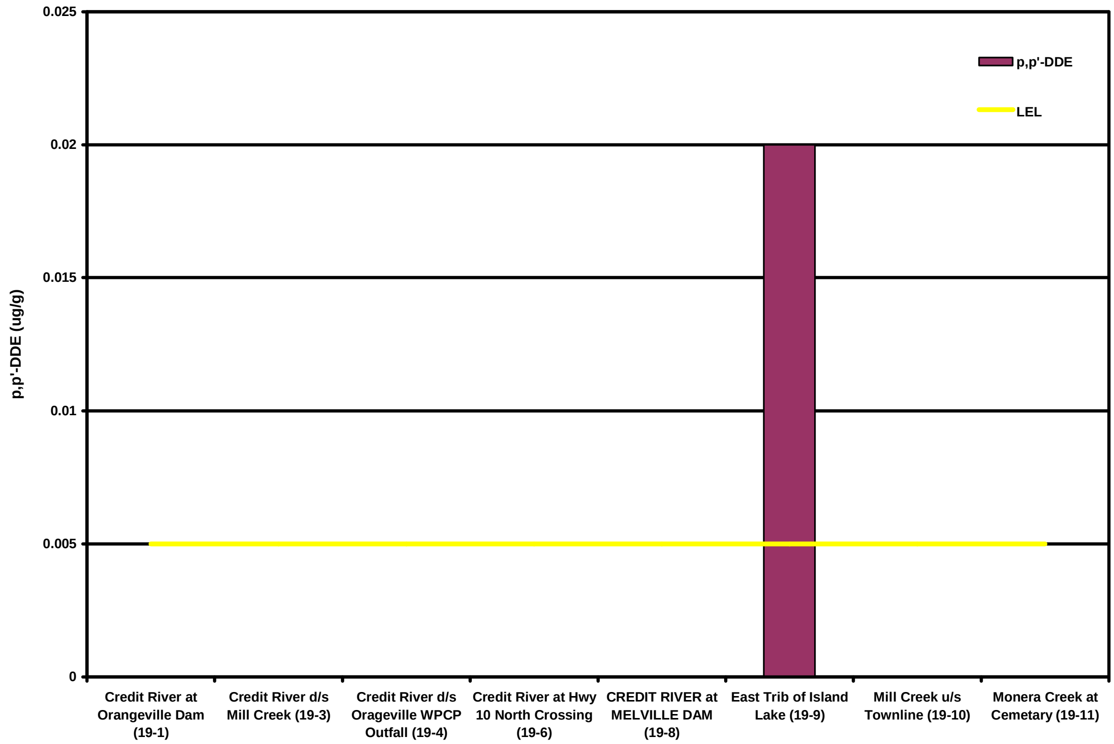



**Figure 4.6. 26 p,p'-DDE concentration measured in the Headwaters Subwatershed in 2006. A black value indicates a non-detect**

### *Metals*

Total metal concentrations for a suite of commonly analyzed metals including aluminum, copper, iron and zinc were analyzed in the sediment samples. Elevated total metal levels may be from domestic and/or industrial wastewater, landfill leachate, erosional processes and both rural and urban runoff. Iron and aluminum are typically found in clay soils and can be present in other geologic formations. Leaching minerals from rock and both the natural and anthropogenic erosion of clay soils can increase aluminum and iron concentrations in the local watercourse. There were five metals detected above the Threshold Effects Levels across the subwatershed -- copper, lead, zinc, mercury and cadmium.

## 4.6.7 Summary

Overall, the water quality in Headwaters subwatershed is variable in terms of supporting healthy aquatic biota. In general, the tributaries that flow into Island Lake are fair. These smaller tributaries have a lower population density and fewer roads and it would be expected that this area would be subject to lower loads of stormwater runoff. In the mid to lower portions of the subwatershed, the influence of highways, urban land use and high population density is apparent with median concentrations of the total phosphorus, aluminum and chlorides in the main Credit River markedly greater than at other sampling locations in the subwatershed.

Results of the Water Quality Index suggest that water quality at the long-term Main Credit stations is marginal. The long-term monitoring data indicate that Main Credit stations are a Policy 2 watercourse with respect to total phosphorus, as concentrations were consistently above the PWQO set by MOE. Elevated total phosphorus and temperature levels are resulting in negative impacts on the dissolved oxygen regime in the main Credit River in the Melville Marsh, with exceedances to the PWQO occurring in August. Nitrate levels across the subwatershed were rarely measured above the CCME guideline and violations of the un-ionized ammonia PWQO (based on chronic exposure) are non-existent.

In the subwatershed, chlorides are below values thought to be hazardous to aquatic biota but the increasing trends observed in the long-term data and the higher values observed in the more urbanized portion of the subwatershed are a concern for future urban development.

Statistical analysis of the metals dataset indicates that all of the downstream Main Credit stations are in Policy 2 with respect to aluminum concentrations in the water column. Downstream of the urban tributaries, zinc, nickel, and copper values appear to be elevated but only occasionally exceed their PWQOs. Copper may be of particular concern under future conditions since it can be highly toxic to aquatic biota and was found to be at levels close to its PWQO.

Bacterial levels, as indicated by *E. coli*, in the main branch and tributaries of Headwaters subwatershed were above what is considered to be acceptable levels for recreational uses, particularly during the summer. The water temperature regime is relatively healthy within the subwatershed, with the coolest water temperatures occurring in the upper portion of the subwatershed and in the groundwater fed tributaries. The warmest water temperatures were observed to be in the lower main branch of Headwaters and the tributary that drained a wetland (Station 11-13).

Sediment Chemistry results were generally indicative of a healthy aquatic environment with minimal point source impacts. There was no indication of heavy metals or hydrocarbon accumulation in the subwatershed. PCB's were found at one site above the Probable Effect Level which indicates adverse effects are expected. Exact sources of the PCBs are difficult to determine as they persist and accumulate in the sediment over long time periods.

# 5.0 INTEGRATION – CHARACTERIZING THE SUBWATERSHED

## 5.1 What is integration?

Integration is a mechanism by which the parts of a system and their structure are examined and provide an understanding of their functioning.

Subwatershed integration is the process of synthesizing, interpreting and developing a systemic understanding of the subwatershed. Integration is needed because the total (the watershed with its air, water, land, humans and other living things) is greater than the sum of its parts. In order to study a complex system, we often must take the system and break it into its constituent parts (physical, chemical, biological, etc.) for analyses. However, in order to truly understand how the system functions, we need to reconstitute these pieces in order to understand the whole. Studying the component parts of a watershed — streams, water quality, groundwater, aquatic systems, terrestrial systems, human uses — in isolation from each other does not allow us to adequately characterize the existing system, or make predictions about the future.

In terms of future planning, decision-makers need to know how streamflow <u>and</u> water quality <u>and</u> aquatic communities <u>and</u> recharge to our water supply <u>and</u> recreational use of water resources are connected. Each of these components is interconnected in complex, subtle, and sometimes unknown ways. In order to make sound decisions, we need to understand the interrelationships of the physical, biological and chemical components of watersheds through integration of information across all scientific disciplines

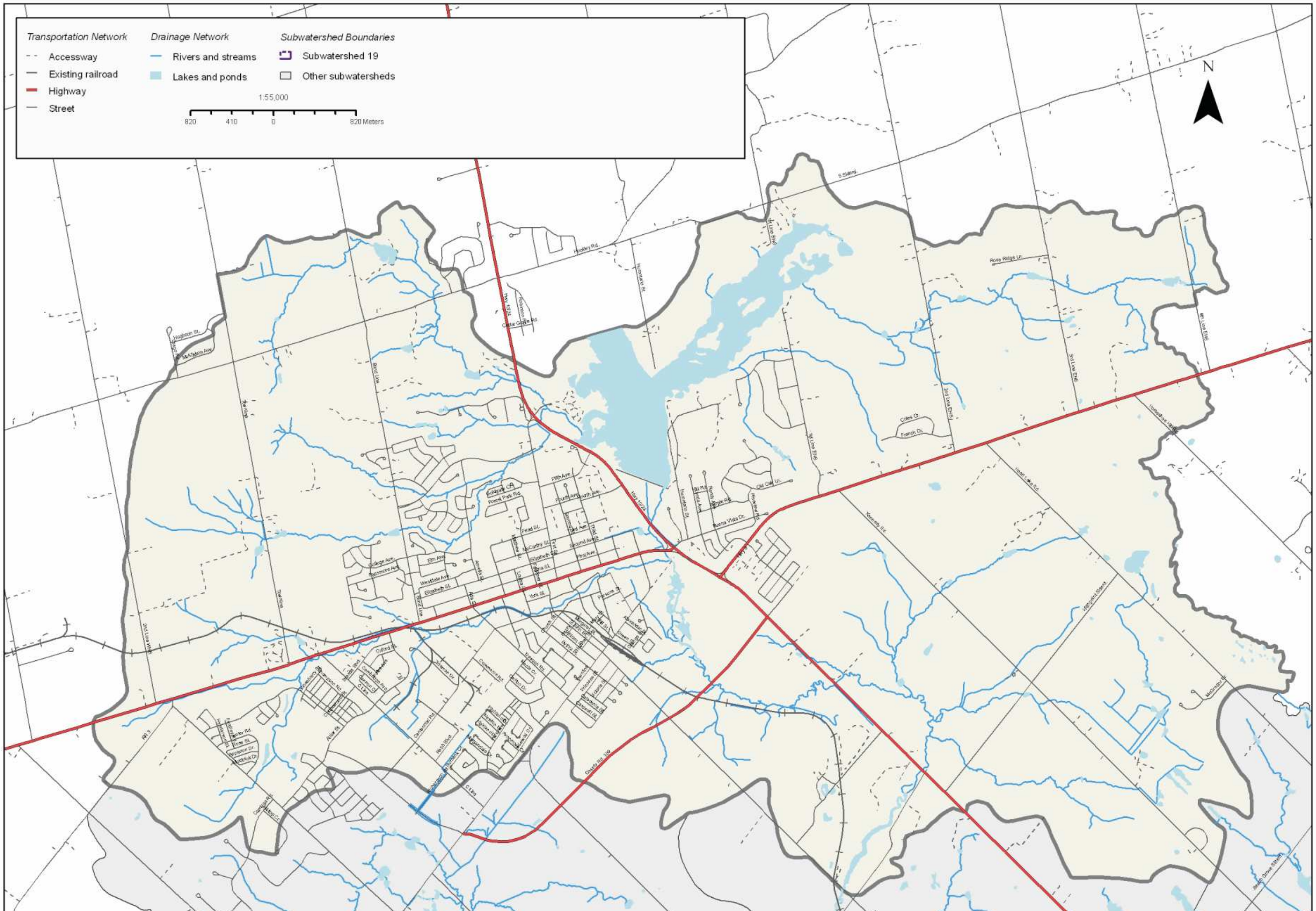



Figure 5.2.3 Conceptual Water Linkages

Sources: Drainage Network (OMNR, 1982; CVC, 1999); Transportation Network (OMNR, 1982; CVC, 1999); Water Taking (County of Dufferin, 2005; Region of Peel, 2005)

## 5.2 Headwaters Subwatershed Integration

Within the Headwater subwatershed, the distribution of the geological materials and their influence on water, nutrients and sediment movements have a major influence on the functioning of the biotic components of the watershed. This section uses the "bucket and pipe" model (i.e. Figure 5.2.3) to explain how the major elements of geology, topography and elevation affect the structure, composition and functioning of the biophysical components of the subwatershed ecosystems.

The subwatershed has been broken into five zones: Monora Creek, Mill Creek, Credit River, Caledon Tributaries, Eastern Tributaries, and Island Lake. Please refer to section 3.3 for descriptions of the each of these zones, and Figure 3.3.1 for the boundaries of each of these zones.

### 5.2.1 Hydrogeology Characterization

The following section provides more detailed information or the conceptual water pathway per zone.

***Monora Creek***

The Monora Creek catchment is generally a high recharge area due to its location atop the Orangeville Moraine. The Orangeville Moraine is largely comprised of coarse grained (i.e., sand and gravel) ice contact stratified drift deposits that promote groundwater recharge. Groundwater recharge is further enhanced by the hummocky topography that tends to reduce runoff and encourage infiltration and the large unsaturated zone (i.e., deeper water table) that occurs in the upper reaches of the catchment.

Groundwater discharge occurs along almost all the reaches of Monora Creek, and particularly along both branches of Lower Monora and along Upper Monora. Groundwater discharge occurs where the water table intersects ground surface, so the topographic transition from higher elevations in the upper reaches to lower elevations in the lower reaches would be expected to encourage groundwater discharge. Groundwater discharge in this catchment is also supported by the large amount of groundwater recharge occurring in the catchment, plus the fact that groundwater flows into the catchment from the Grand River watershed to the west, which increases the amount of groundwater available for discharge within the catchment and helps to offset groundwater losses to municipal pumping and outflow towards the Nottawasaga River watershed.

Overall, this zone is considered to have high groundwater recharge potential and the overall hydrogeologic condition is good.

***Mill Creek***

The upper reaches of Mill Creek also occur atop the Orangeville Moraine and these are areas of higher groundwater recharge as identified in the Monora Creek catchment. In the middle and lower reaches of the catchment the surficial geologic deposits are less permeable till, and these deposits along with the greater amounts of urbanization tend to decrease groundwater recharge. Overall the Mill Creek area loses significant water to municipal pumping; however, large groundwater inflows from the Grand River watershed offset some of these losses.

The upper reaches of Mill Creek have the same characteristics of the Monora Creek catchment that promote groundwater discharge (e.g., high groundwater recharge, groundwater flow in from the Grand River watershed, decreasing topography) and there are significant groundwater discharge zones identified. Further downstream in the catchment groundwater discharge conditions are less prevalent due to generally flatter topography and lower groundwater recharge due to less permeable soil types and the impacts of urbanization.

The overall hydrogeologic condition is generally moderate to good, although poorer conditions exist in the lower reaches where groundwater discharge generally does not occur.

***Credit Catchment***
The Credit catchment occurs at lower topographic elevations relative to the contributing catchments and groundwater flow from the east and west is generally directed towards the Credit. This inflow of groundwater into the catchment, combined with the generally high recharge conditions in the catchment, contribute to groundwater discharge occurring along the main Credit, particularly between the two main crossings of Highway 10. Groundwater discharge conditions are generally indicated by piezometer and flow monitoring stations; however, some of the groundwater discharge may not be apparent in baseflow measurements because of the water lost to evapotranspiration as the Credit flows along a wide channel surrounded by wetland vegetation.

Although the high rates of baseflow would suggest good hydrogeologic conditions in this catchment, since the vast majority of baseflow is provided by Island Lake outflows, WPCP discharges, and baseflows from Mill Creek and the Orangeville Marsh (aka Melville Marshes), the overall hydrogeologic condition is only moderate in recognition of the identified groundwater discharge locations.

***Caledon Tributaries***
A large portion of the Caledon Tributaries occurs among moraine deposits and therefore exhibits the same general groundwater recharge and discharge trends as the Monora Creek catchment (i.e., generally showing both higher groundwater recharge and groundwater discharge rates). While characteristics are generally similar to the Monora Creek catchment, overall groundwater discharge is less for a number of reasons. Firstly, while there is some groundwater inflow from the Eastern Tributaries catchment to the north, the Caledon Tributaries do not receive a large influx of groundwater from outside the catchment as the Monora Creek and Mill Creek catchments receive from the Grand River watershed to the west. Also, while moraine deposits are prevalent in the Caledon Tributaries catchment there are also some lower permeability till deposits in the southern headwaters of the catchment that tend to reduce groundwater recharge relative to the coarser grained moraine deposits. Peak flows are reduced naturally by streambank vegetation, flat topography and wetlands in the area.

The overall hydrogeologic condition is moderate due to intermittent headwater baseflows in the summer and the lower baseflows in the catchment that reflect its smaller size and the lack of groundwater inflows from other subcatchments.

### *Eastern Tributaries*

This catchment generally has moderate groundwater recharge due to the larger amounts of till deposits occurring in the catchment and flatter topography relative to other catchments in the subwatershed. While some of the groundwater recharge that occurs does show up as groundwater discharge in the tributaries, there is also a large component of groundwater flow out of the catchment towards the Nottawasaga Valley, and this portion of groundwater flow is therefore unavailable for groundwater discharge to support baseflow in the tributaries. There is also a smaller component of groundwater that flows out of the catchment towards the main Credit and towards the Caledon Tributaries catchment.

Groundwater discharge along the easternmost of the tributaries generally occurs in the upper reaches, with isolated discharge occurring intermittently in the lower reaches. Throughout the middle reaches of the easternmost tributary decreasing baseflow was consistently observed, and this flow loss could be attributed to water lost to evapotranspiration as the tributary flows through the wetland feature. Groundwater discharge was observed along the other tributaries in this catchment; however, fewer monitoring locations along these tributaries make it difficult to characterize where the discharge occurs. Peak flow is minimized by high infiltration.

Overall hydrogeologic condition is poor to moderate due to overall low baseflow, although perennial baseflows are observed in some limited areas.

### *Island Lake*

Island Lake has high evaporative losses, storage losses due to seepage through the North dam, and modest inflow (except for Monora Creek) due to trans boundary groundwater losses to the Nottawasaga from the Eastern Tributaries. As a result, the hydrogeologic condition for Island Lake is considered to be poor, although its primary relevance is as a hydrologic feature that augments flows downstream.

**Table 5.2.1 Hydrogeology Characterization**

| General | Hydrogeologic Conditions |
|---|---|
| **Zone** | **Overview of Groundwater Discharge/Recharge** |
| Monora Creek Tributaries (1197 ha) | Upper Monora Creek generally shows groundwater discharge conditions, although recharge conditions are noted along some shorter reaches; Middle Monora Creek shows some groundwater discharge conditions, but perhaps not in significant discharge quantities, with some smaller areas of groundwater recharge particularly in the upper reaches. |
| Mill Creek (867.3 ha) | Significant groundwater discharge occurs in the upper reaches of Mill Creek. Groundwater discharge and recharge conditions generally alternate along reaches in the middle and lower portions of Mill Creek. |

| General Zone | Hydrogeologic Conditions Overview of Groundwater Discharge/Recharge |
|---|---|
| Credit River (1317.6 ha) | Groundwater discharge does occur along reaches of the main Credit, however, water temperature and flow measurments do not always indicate the occurrence of groundwater discharge because the wide channel promotes higher water temperatures and evaporation. |
| Caledon Tributaries (1201.6 ha) | Significant groundwater discharge occurs along these tributaries, particularly for the middle and southern Caledon tributaries. Small amounts of groundwater discharge occur in the northern tributary. |
| Eastern Tributaries (1268 ha) | Groundwater discharge conditions are prevalent along both tributaries, however groundwater recharge conditions occur through the middle reaches of the eastern most tributary. |
| Island Lake Reservior (168.8 ha) | Groundwater discharge occurs in the tributaries that drain into Island Lake, and previous reports indicate observations of groundwater springs in some areas of the lake bottom. Groundwater seepage losses from the reservoir occur just downstream of the South Dam. Overall groundwater flow conditions indicate that groundwater recharge occurs along the northern portion of the reservoir, with flow lost to NVCA. |

### 5.2.2 Surface Water Characterization and Functions

Subwatershed 19 is located in the headwaters of the Credit River Watershed. To the east lies the Humber River Basin, to the west lies the Grand River Basin, and to the north lies the Upper Nottawasaga Subwatershed.

The total drainage area of the watershed at the outlet of the main branch of the Credit River is 62.2 $km^2$. This represents 10% percent of the Upper Credit River watershed above Norval, and 6% percent of the Credit River watershed discharging to Lake Ontario.

The main branch of the Credit River within Subwatershed 19 is approximately 14.5 km in length, with an average channel gradient of 2.9 m/km. The Subwatershed elevations vary from 500 m to 410 m. However, more than half the watershed is at an elevation of the 450 m contour (Figure 4.3.16).

Specific characteristics found in Subwatershed 19 impose a dominant influence on the flow response in these areas. The dominant characteristics identified here include:

- significant wetlands (or closed drainage) systems;
- limited municipal drainage (predominantly within the Eastern and Caledon tributaries);
- significant floodplain storage;
- high percentage of forest cover;
- the prevalence of high infiltration soils; and
- the presence of aggregate extraction activities.

The presence of wetland areas within Subwatershed 19 has resulted in large areas with either no surface drainage outlet or restricted outlets, predominantly along the main branch of the Credit River. These areas are referred to as closed drainage systems. Precipitation is retained in these areas, and either recharges the groundwater aquifers or evaporates. Closed drainage systems such as wetlands and marshes account for about 4 % of the area in Subwatershed 19.

Channel floodplain storage is a dominant feature of Subwatershed 19, where the Credit River follows a broad glacial spillway. The broad floodplains and flat channel gradients associated with these spillways result in considerable floodplain storage, which greatly attenuates flood flows in the headwaters of the Credit River, this process is further extenuated by the presence of wetlands and forests within the floodplain creating additional storage and increasing evapotranspiration. Based on the watercourse inventory the channel gradients for many of the Tributaries are relatively steep particularly at the confluence with Credit River (as in the case of Mill Creek and the Caledon Tributaries), leading to high runoff volumes and velocities. However the pockets of forest cover along the tributaries tend to act against this influence by slowing runoff and increasing infiltration.

16% of Subwatershed 19 is covered by forest. The high infiltration associated with soils under forest cover restricts the amount of precipitation appearing as runoff for entry to the surface drainage network. In addition, snowmelt in heavily forested areas melts much later than agricultural areas. The delayed snowmelt reduces the potential for flooding and provides additional opportunities for groundwater recharge.

The presence of on-line and off-line ponds within Subwatershed 19 has created additional storage opportunities for the purpose of controlling post-development flows to pre-development levels and in the process increasing surface water detention times. Another important characteristic of Subwatershed 19 is the presence of areas with aggregate extraction activities. Aggregate pits can alter the surface water/ground water patterns through withdrawals and diversions, and the increased evaporation rates caused by ponds on site.

The following comments per zone relate to Hydrologic and Hydraulics conditions, assuming recharge and flood potential are the key to these metrics:

***Monora Creek***

Monora Creek area loses significant water to municipal pumping wells and to groundwater flux to the Nottawasaga River watershed. However, high groundwater recharge and inflow from the Grand River offsets these losses. Peak flows are increased by urbanization in the area. Overall hydrologic condition is good except in headwaters near wells where baseflow may be intermittent. Hydraulic conditions are in good condition and there is low flood potential due to high channel slopes and infiltration rates.

***Mill Creek***

Mill Creek area loses significant water to municipal pumping wells. High groundwater inflows from the Grand River offset these losses.  Groundwater recharge is high in the area. Urbanization increases peak flows. Overall hydrologic condition is moderate to good except near headwater area wells. Hydraulic conditions are moderate to poor due to the effects of urbanization on peak flows and flat slopes in downstream reaches.

***Credit River***

Credit River baseflows are sustained by Island Lake outflows, WPCP discharges and baseflows from Mill Creek and the Orangeville Marsh (aka Melville Marshes). Baseflows are reduced by high Island Lake evaporation and low resulting outflows as well as high evaporation in the Marsh. Peak flows are greatly attenuated by the Reservoir and the marsh. Overall hydrologic condition is moderate to good. Hydraulic conditions are good due to baseflow and peak flow stabilizing effects of upstream the reservoir, the WPCP inflows and the surrounding Marsh.

***Caledon Tributaries***

This area has moderate groundwater recharge and minimal intrabasin exchange. Summer headwater baseflows are intermittent. Peak flows are reduced naturally by streambank vegetation, flat topography and wetlands in the area. Overall hydrologic condition is poor due to low baseflow. Hydraulic conditions are moderate and are aggravated by moderate infiltration in the area, agricultural drainage improvements and flat slopes.

***Eastern Tributaries***

The area has high recharge, however very significant losses of groundwater to the Nottawasaga result in low and intermittent baseflow. Peak flow is minimized by high infiltration. Overall hydrologic condition is poor due to low baseflow. Hydraulic conditions are good due to high infiltration and slopes and low baseflow.

***Island Lake***

Island Lake has good hydraulic conditions as inflows are generally minimal while evaporation and outflow are high. Water levels are often under stress, providing high flood storage potential. The overall effect of the lake is to provide steady baseflow, attenuate peak flows and lose water to the Nottawasaga and the atmosphere.

**Table 5.2.2 Hydrology and Hydraulics Characterization**

| General | Hydrologic/Hydraulic Condition | |
|---|---|---|
| Zone | Overall Hydrologic Condition | Overall Hydraulic Condition |
| Monora Creek Tributaries (1197 ha) | good[1] | good[7] |
| Mill Creek (867.3 ha) | moderate to good[2] | poor to moderate[8] |
| Credit River (1317.6 ha) | moderate to good[3] | good[9] |
| Caledon Tributaries (1201.6 ha) | poor[4] | poor to moderate[10] |
| Eastern Tributaries (1258 ha) | poor[5] | good[11] |
| Island Lake Reservoir (163.8 ha) | poor[6] | good[12] |

### 5.2.3 Terrestrial Characterization

The following comments per zone relate to the terrestrial conditions, assuming woodlands include forest and plantations, wetlands include swamps and marshes; and successional includes cultural meadows, savannas, thickets, and woodlands.

***Monora Creek***

As shown in Table 5.2.3, the predominant land uses within the Monora drainage area are urban (28%) and agriculture (30%). As mentioned above, these land uses have an impact on hydrogeology and hydrology varying from potential groundwater losses (due to municipal pumping wells) to higher peak flows in Middle and Lower Monora Creek (due to urbanization), however high groundwater recharge and inflow from the Grand River offsets these losses. The land uses also have an impact on woodland and wetland cover -- Middle Monora Creek and the lower section of Lower Monora have been encroached upon by urban development and are considered to be highly impacted. Impacts in the remainder of the corridors within Monora Creek drainage area are considered to be low. While woodland coverage is below Environment Canada's target of 30%, Monora Creek does support three older growth forests, and thirteen occurrences of 100 m core interior forest habitat. Amphibian species richness is considered moderate to low with all identified populations existing outside of the current extent of urban development. The majority of natural areas are well connected, experiencing minor fragmentation.

Wetland coverage of 6% meets Environment Canada targets. The Orangeville Wetland Complex is classified as a Provincially Significant Wetland. Wetland clusters are well-connected with minor fragmentation between clusters. These wetlands help to retain precipitation, which is eventually released through groundwater recharge or evapotranspiration.

Overall, 33% of the landscape is estimated to provide high ecosystem services based on CVC's Terrestrial Ecosystem Enhancement Model (TEEM).

**Table 5.2. 3 Landscape Statistics – Monora Creek Tributaries**

| Land Use | Percentage |
|---|---|
| Urban | 27.9% (331.6 ha) |
| Agriculture | 30.4% (361.9 ha) |
| Aggregate | 4.8% (57.6 ha) |
| Woodland | 11.4% (135.9 ha) |
| Wetland | 6.3% (74.6 ha) |
| Successional | 18.6% (221.6 ha) |
| Aquatic | 0.6% (6.9 ha) |

***Mill Creek***

As shown in Table 5.2.4, the predominant land uses within the Mill Creek drainage area are urban (51.5%) and agriculture (35.9%). As mentioned above, these land uses have an impact on hydrogeology and hydrology varying from higher peak flows (due to urbanization) to potential groundwater losses (due to municipal pumping wells), however high groundwater recharge and inflow from the Grand River offsets these losses. The land uses also have an impact on terrestrial features -- the majority of corridors within the urban landscape are considered to be highly or moderately impacted, in comparison to corridors on the outskirts of the urban area, which are considered to have low impact. All corridors connect to high priority patches with the exception of a few corridors in the south which are likely human-made. Natural areas are fragmented and the transportation network has created barriers to wildlife movement. Woodlands are considered to be highly fragmented while wetlands are considered moderately fragmented with roadways exacerbating impacts.

In comparison to Monora Creek there are no older growth forests found within Mill Creek and only one occurrence of 100 m core interior forest habitat. Amphibian richness is considered low to moderate with very few occurrences, likely due to the lack of suitable habitat. Mill Creek is home to the Eastern milk snake, which is listed as Special Concern under both provincial and national Species at Risk legislation. Woodland and wetland coverage is well below Environment Canada targets at 3 and 2.8% respectively.

Overall, only 7.6% of the Mill Creek landscape is estimated to provide high ecosystem services based on CVC's Terrestrial Ecosystem Enhancement Model (TEEM).

**Table 5.2.4 Landscape Statistics – Mill Creek**

| Land Use | Percentage |
|---|---|
| Urban | 51.5% (443 ha) |
| Agriculture | 35.9% (308.8 ha) |
| Aggregate | 0.8% (6.5 ha) |
| Woodland[1] | 3.0% (26.1 ha) |
| Wetland[2] | 2.8% (24.3 ha) |
| Successional[3] | 6.1% (52.2 ha) |
| Aquatic | 0% (0 ha) |

***Credit River***

As mentioned above, baseflows within the main Credit River branch are sustained by Island Lake outflows, WPCP discharges and baseflows from Mill Creek and the Orangeville Marsh (aka Melville Marsh). Evapotranspiration is high as the Credit flows along a wide channel surrounded by wetland vegetation. The Orangeville Wetland Complex and Melville Marshes perform a vital water storage and evapotranspiration function within the Credit River drainage area, and it is largely for these reasons that they have been designated as Provincially Significant Wetland and Environmentally Significant Area.

While the predominant land use within the Credit River drainage area is urbanization (see Table 5.3.5), the majority of natural areas are large and well connected with minor fragmentation. The majority of woodlands are also connected. While there are no older growth forests, there are nine occurrences of 100 m core interior forest habitat and one occurrence of 200 m core. There are also six vegetation communities with three or more CVC/Peel rare species, and the Eastern milk snake, which is listed as Special Concern both provincially and nationally. Amphibian species richness was considered low, as there were relatively low numbers of frog populations; however this may be explained by the difficulty in accessing the wetlands via road and therefore more research is needed to locate populations.

Wetlands are well-connected with the exception of the Orangeville Bypass, which has fragmented a complex of large wetlands.

Overall, 42.0 % of the landscape is estimated to provide high ecosystem services based on CVC's Terrestrial Ecosystem Enhancement Model (TEEM).

**Table 5.2.5 Landscape Statistics – Credit River**

| Land Use | Percentage |
|---|---|
| Urban | 44.8% (582.5 ha) |
| Agriculture | 12.8% (166.4 ha) |
| Aggregate | 0% (0 ha) |
| Woodland | 15.0% (195 ha) |
| Wetland | 5.1% (66.6 ha) |
| Successional | 21.5% (280.3 ha) |
| Aquatic | 0.8% (10.7 ha) |

***Caledon Tributaries***

The predominant land use within the Caledon Tributaries is agriculture (46.9%). As mentioned previously, this area has moderate groundwater recharge and minimal intrabasin exchange. Summer headwater baseflows are intermittent and peak flows are reduced naturally by streambank vegetation, flat topography and wetlands in the area.

There is a high percentage of agriculture in this area, yet natural areas tend to be well connected with minor fragmentation in comparison to the predominately urbanized Mill Creek. Caledon Tributaries also contain well-connected woodlands which are experiencing moderate fragmentation. Corridors are considered to have little to no impact and most are connected to high priority natural areas. Furthermore, there are seven vegetation communities providing habitat for three or more CVC/Peel rare species and one Older Growth Forest. There are thirteen occurrences of 100 m core interior forest habitat but no deep core (200 m) forest habitat. Amphibian species richness is considered moderate to high in the area and frog populations are abundant.

The majority of wetlands are well-connected. Speersville Wetland Complex and Orangeville Wetland Complex are located within the Caledon tributaries and are considered Provincially Significant Wetlands. Rosehill Swamp is considered an Environmentally Significant Area (ESA).

Overall, 52.7 % of the landscape is estimated to provide high ecosystem services based on CVC's Terrestrial Ecosystem Enhancement Model (TEEM).

**Table 5.2.6 Landscape Statistics – Caledon Tributaries**

| Land Use | Percentage |
|---|---|
| Urban | 6.4% (76 ha) |
| Agriculture | 46.9% (555 ha) |
| Aggregate | 0.5% (6.2 ha) |
| Woodland[1] | 13.8% (162.8 ha) |
| Wetland[2] | 6.9% (81.6 ha) |
| Successional[3] | 25% (296.4 ha) |
| Aquatic | 0.5% (5.6 ha) |

***Eastern Tributaries***

Similar to the Caledon Tributaries, the predominant land use within the Eastern tributaries is agriculture (at 50%) (see Table 5.2.7). The area has high recharge, but very significant losses of groundwater to the Nottawasaga watershed result in low and intermittent baseflow. Peak flow is minimized by high infiltration. The majority of wetlands are well-connected along the tributaries which contribute to good hydraulic conditions. The Orangeville Wetland Complex is considered a Provincially Significant Wetland and the Orangeville Reservoir is considered an Environmentally Significant Area.

Due to the high percentage of agriculture in this area, natural areas tend to be well connected with minor fragmentation in comparison to Mill Creek which is predominately urbanized. There are areas of well-connected woodlands and areas experiencing moderate fragmentation. There is little to no impact on the corridor system and most corridors connect to high priority natural areas. Furthermore, there are two vegetation communities supporting three or more CVC/Peel rare species and two older growth forests. There are five occurrences of 100 m core interior forest habitat but no deep core (200 m) forest habitat. Amphibian species richness is considered high and frog populations are abundant.

Overall, 38.8% of landscape is estimated to provide high ecosystem services based on CVC's Terrestrial Ecosystem Enhancement Model (TEEM).

**Table 5.2.7 Landscape Statistics – Eastern Tributaries**

| Land Use | Percentage |
|---|---|
| Urban | 0.9% (9.6 ha) |
| Agriculture | 50.0% (538 ha) |
| Aggregate | 0.2% (2.5 ha) |
| Woodland[1] | 17.2% (185.6 ha) |
| Wetland[2] | 5.2% (56 ha) |
| Successional[3] | 26.1% (280.8 ha) |
| Aquatic | 0.4% (4.6 ha) |

### *Island Lake*

The Island Lake zone is predominately reservoir (94.6%) with only 0.1% urban and agriculture (see Table 5.2.8). The overall effect of Island Lake is to provide steady baseflow, attenuate peak flows and discharge water to the Nottawasaga and the atmosphere through evaporation. The Orangeville Wetland Complex within the Island Lake Zone is considered a Provincially Significant Wetland. Woodlands within this zone are restricted to the islands within Island Lake and they are not large enough to provide neither 100 m core interior forest habitat, nor deep core (200 m) habitat. Amphibian surveys were conducted near the edge of the reservoir, reflecting the edge wetlands, not the lake interior. From those sites surveyed, species richness was moderate.

**Table 5.2.8 Landscape Statistics – Island Lake Reservoir**

| Land Use | Percentage |
|---|---|
| Urban | 0.1% (0.3 ha) |
| Agriculture | 0.1% (0.1 ha) |
| Aggregate | 0% (0 ha) |
| Woodland[1] | 4.8% (8.1 ha) |
| Wetland[2] | 0.3% (0.4 ha) |
| Successional[3] | 0.1% (0.2 ha) |
| Aquatic | 94.6% (160.7 ha) |

**Table 5.2.9a Terrestrial Characterization**

| Zone | Landscape Feature | | Special Features | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Feature | Stats | Provincially Significant Wetlands (PSW) | Environmentally Significant Areas (ESA) | Areas of natural and Scientific Interest (ANSI) | Species at Risk | Communities with significant numbers of rare species | Older growth forests | Interior forest habitat | Amphibians |
| Monora Creek Tributaries (1197 ha) | Urban | 27.9% (331.6 ha) | Orangeville wetland complex | A very small portion of Orangeville Reservoir ESA | None | None | 1 community with three or more CVC/Peel rare species | Three communities | 13 occurences of 100 m core interior forest habitat. NO deep core (200 m) forest habitat | Moderate to low species richness. All identified populations exist outside of current extent of urban development |
| | Agriculture | 30.4% (361.9 ha) | | | | | | | | |
| | Aggregate | 4.8% (57.6 ha) | | | | | | | | |
| | Woodland | 11.4% (135.9 ha) | | | | | | | | |
| | Wetland | 6.3% (74.6 ha) | | | | | | | | |
| | Successional | 18.6% (221.6 ha) | | | | | | | | |
| | Aquatic | 0.6% (6.9 ha) | | | | | | | | |
| Mill Creek (867.3 ha) | Urban | 51.5% (443 ha) | None | None | None | Eastern milk snake, which is listed as Special Concern both provincially and nationally | None | None | 1occurence of 100 m core interior forest habitat. No deep core (200 m) forest habitat | Low to moderate species richness with very few occurrences, likely due to the lack of suitable habitat |
| | Agriculture | 35.9% (308.8 ha) | | | | | | | | |
| | Aggregate | 0.8% (6.5 ha) | | | | | | | | |
| | Woodland | 3.0% (26.1 ha) | | | | | | | | |
| | Wetland | 2.8% (24.3 ha) | | | | | | | | |
| | Successional | 6.1% (52.2 ha) | | | | | | | | |
| | Aquatic | 0%(0 ha) | | | | | | | | |
| Credit River (1317.6 ha) | Urban | 44.8% (582.5 ha) | Orangeville Wetland Complex | Melville Marshes ESA | None | Eastern milk snake, which is listed as Special Concern both provincially and nationally | 6 vegeration communities with three or more CVC/Peel rare species | None | 9 occurences of 100 m core interior forest habitat. 1 occurrence of 200 m core, however it is very small (approx. 6 m x 33 m) | Low species richness. Relatively low numbers of frog populations, howevern more research needed to locate populations. |
| | Agriculture | 12.8% (166.4 ha) | | | | | | | | |
| | Aggregate | 0% (0 ha) | | | | | | | | |
| | Woodland | 15.0% (195 ha) | | | | | | | | |
| | Wetland | 5.1% (66.6 ha) | | | | | | | | |
| | Successional | 21.5% (280.3 ha) | | | | | | | | |
| | Aquatic | 0.8% (10.7 ha) | | | | | | | | |

| Zone | Landscape Feature | | Special Features | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Feature | Stats | Provincially Significant Wetlands (PSW) | Environmentally Significant Areas (ESA) | Areas of natural and Scientific Interest (ANSI) | Species at Risk | Communities with significant numbers of rare species | Older growth forests | Interior forest habitat | Amphibians |
| Caledon Tributaries (1201.6 ha) | Urban | 6.4% (76 ha) | Speersville Wetland Complex, Orangeville Wetland Complex | Rosehill Swamp | None | None | 7 vegetation communities with three or more CVC/Peel rare species | One community | 13 occurences of 100 m core interior forest habitat. No deep core (200 m) forest habitat. | Moderate to high species richness. Abundant frog populations |
| | Agriculture | 46.9% (555 ha) | | | | | | | | |
| | Aggregate | 0.5% (6.2 ha) | | | | | | | | |
| | Woodland | 13.8% (162.8 ha) | | | | | | | | |
| | Wetland | 6.9% (81.6 ha) | | | | | | | | |
| | Successional | 25% (296.4 ha) | | | | | | | | |
| | Aquatic | 0.5% (5.6 ha) | | | | | | | | |
| Eastern Tributaries (1258 ha) | Urban | 0.9% (9.6 ha) | Orangeville Wetland Complex | Orangeville Reservior ESA | None | None | 2 vegetation communities with three or more CVC/Peel rare species | Two communities | 5 occurences of 100 m core interior forest habitat. No deep core (200 m) forest habitat | High species richness. Abundant frog populations. |
| | Agriculture | 50.0% (538 ha) | | | | | | | | |
| | Aggregate | 0.2% (2.5 ha) | | | | | | | | |
| | Woodland | 17.2% (185.5 ha) | | | | | | | | |
| | Wetland | 5.2% (56 ha) | | | | | | | | |
| | Successional | 26.1% (280.8 ha) | | | | | | | | |
| | Aquatic | 0.4% (4.6 ha) | | | | | | | | |
| Island Lake Reservoir (163.8 ha) | Urban | 0.1% (0.3 ha) | Orangeville Wetland Complex | None | None | None | None | None | There are no occurrences of 100 m core habitat, nor is there any deep core (200 m) within the reservoir. | Surveys were conducted near the edge of the reservoir, for which we might loosely interpret the data. Therefore, survey may not reflect the lake, but conditions of surrounding wetlands instead |
| | Agriculture | 0.1% (0.1 ha) | | | | | | | | |
| | Aggregate | 0% (0 ha) | | | | | | | | |
| | Woodland | 4.8% 8.1 ha) | | | | | | | | |
| | Wetland | 0.3% (0.4 ha) | | | | | | | | |
| | Successional | 0.1% (0.2 ha) | | | | | | | | |
| | Aquatic | 94.6% (160.7 ha) | | | | | | | | |

**Table 5.2.9 b Terrestrial Characterization**

| Zone | Landscape Feature | | Connectivity | | | Corridors | | | Ecosystem Function |
|---|---|---|---|---|---|---|---|---|---|
| | **Feature** | **Stats** | **Natural Areas** | **Woodlands** | **Wetlands** | **Provincial Scale Corridors** | **Watershed Scale Corridors** | **Subwatershed Scale Corridors** | **Ecosystem Services*** |
| Monora Creek Tributaries (1197 ha) | Urban | 27.9% (331.6 ha) | Majority of natural areas are well connected Minor fragmentation | Areas of well connected woodlands. Experiencing minor fragmentation. | Clusters of well-connected wetlands. Minor fragmentation between clusters. | None | Island Lake to Grand River | Middle Minora Creek and lower section of Lower monora have been encroached upon by urban development (highly impacted). The remainder of the corridor have low impact. All are highly connected with the exeption of a few man-made drainage features located in the Upper Monora area, which are dominated by agriculture. | 33.0% of landscape provides high ecosystem services. |
| | Agriculture | 30.4% (361.9 ha) | | | | | | | |
| | Aggregate | 4.8% (57.6 ha) | | | | | | | |
| | Woodland | 11.4% (135.9 ha) | | | | | | | |
| | Wetland | 6.3% (74.6 ha) | | | | | | | |
| | Successional | 18.6% (221.6 ha) | | | | | | | |
| | Aquatic | 0.6% (6.9 ha) | | | | | | | |
| Mill Creek (867.3 ha) | Urban | 51.5% (443 ha) | Natural areas are fragmented. While some are still in close proximity, roads act as a barrier. | Highly fragmented | Moderate fragmentation (effects exaggerated by roads) | None | None | Majority of corridors have high or moderate impact, corridors on the outskirts of the urban area have low impact. All corridors connect to high priority patches with the exception of a few corridors in the south, which are likely man-made. | 7.6% of landscape provides high ecosystem services. |
| | Agriculture | 35.9% (308.8 ha) | | | | | | | |
| | Aggregate | 0.8% (6.5 ha) | | | | | | | |
| | Woodland | 3.0% (26.1 ha) | | | | | | | |
| | Wetland | 2.8% (24.3 ha) | | | | | | | |
| | Successional | 6.1% (52.2 ha) | | | | | | | |
| | Aquatic | 0% (0 ha) | | | | | | | |
| Credit River (1317.6 ha) | Urban | 44.8% (582.5 ha) | Majority of natural areas are well connected. Minor fragmentation. | Majority of woodlands are connected. | Wetlands well-connected. The Orangeville Bypass has fragmented a complex of large wetlands. | Credit River Valley | Caledon Lake Corridor, Alton Corridor | Majority of corridors have little to no impact, moderate impact to tributary corridor in proximity of Orangeville. All corridors are connected to high priority natural areas. | 42.0% of landscape provides high ecosystem services. |
| | Agriculture | 12.8% (166.4 ha) | | | | | | | |
| | Aggregate | 0% (0 ha) | | | | | | | |
| | Woodland | 15.0% (195 ha) | | | | | | | |
| | Wetland | 5.1% (66.6 ha) | | | | | | | |
| | Successional | 21.5% (280.3 ha) | | | | | | | |

| Zone | Landscape Feature | | Connectivity | | | Corridors | | | Ecosystem Function |
|---|---|---|---|---|---|---|---|---|---|
| | Feature | Stats | Natural Areas | Woodlands | Wetlands | Provincial Scale Corridors | Watershed Scale Corridors | Subwatershed Scale Corridors | Ecosystem Services* |
| | Aquatic | 0.8% (10.7 ha) | | | | | | | |
| Caledon Tributaries (1201.6 ha) | Urban | 6.4% (76 ha) | Majority of natural areas are well connected. Minor fragmentation. | Areas of well-connected woodlands. Experiencing | Majority of wetlands are well-connected | None | Speersville corridor (connects Speersville Wetland complex to Credit River) | Little to no impact, high connectivity (most are connected to high priority natural areas) | 52.7% of landscape provides high ecosystem services. |
| | Agriculture | 46.9% (555 ha) | | | | | | | |
| | Aggregate | 0.5% (6.2 ha) | | | | | | | |
| | Woodland | 13.8% (162.8 ha) | | | | | | | |
| | Wetland | 6.9% (81.6 ha) | | | | | | | |
| | Successional | 25% (296.4 ha) | | | | | | | |
| | Aquatic | 0.5% (5.6 ha) | | | | | | | |
| Eastern Tributaries (1258 ha) | Urban | 0.9% (9.6 ha) | Majority of natural areas are well connected. Minor fragmentation | | Wetlands well-connected along tributaries | None | Mono Mills Corridor, Hockley Valley Corridor | Little to no impact. High connectivity (most are connected to high priority areas) | 38% of landscape provides high ecosystem services. |
| | Agriculture | 50.0% (538 ha) | | | | | | | |
| | Aggregate | 0.2% (2.5 ha) | | | | | | | |
| | Woodland | 17.2% (185.5 ha) | | | | | | | |
| | Wetland | 5.2% (56 ha) | | | | | | | |
| | Successional | 26.1% (280.8 ha) | | | | | | | |
| | Aquatic | 0.4% (4.6 ha) | | | | | | | |
| Island Lake Reservoir (163.8 ha) | Urban | 0.1% (0.3 ha) | n/a | n/a | n/a | n/a | n/a | n/a | n/a |
| | Agriculture | 0.1% (0.1 ha) | | | | | | | |
| | Aggregate | 0% (0 ha) | | | | | | | |
| | Woodland | 4.8% (8.1 ha) | | | | | | | |
| | Wetland | 0.3% (0.4 ha) | | | | | | | |
| | Successional | 0.1% (0.2 ha) | | | | | | | |

| Zone | Landscape Feature | | Connectivity | | | Corridors | | | Ecosystem Function |
|---|---|---|---|---|---|---|---|---|---|
| | **Feature** | **Stats** | **Natural Areas** | **Woodlands** | **Wetlands** | **Provincial Scale Corridors** | **Watershed Scale Corridors** | **Subwatershed Scale Corridors** | **Ecosystem Services*** |
| | Aquatic | 94.6% (160.7 ha) | | | | | | | |

***Ecosystem services was based on ecosystem functional analysis provided by Terrestrial Ecosystem Enhancement Model (TEEM)**

### 5.2.4 Geomorphic Characterization

Results of these analyses indicate that Stream Morphology in Subwatershed 19 is generally in balance with prevailing reach hydrologic and physiographic conditions. Historic agricultural practices have altered many channels from former natural state, however, contemporary channel adjustments tend to be localized in urban and developing areas.

Overall trends for the area included high gradient, low sinuosity headwaters within the northwest section of the watershed which contrast with the low gradient, moderately sinuous headwaters of the northeast portion of the watershed. These low order streams culminate in a main channel which features a low gradient, moderately sinuous channel. The main channel is highly sensitive due to the abundance of sandy material in the watershed and corridor, as well as the influences of Large Woody Debris. For other tributary channels, the potential sensitivities are associated with steep gradient reaches and abundance of sandy materials. See Table 5.2.10 for a summary.

The following comments per zone relate to the geomorphic conditions, based on riparian corridors, sediment barriers and depositional environments and sediment sources.

***Monora Creek***

As shown in Table 5.2.3, the predominant land uses within the Monora drainage area is urban (28%) and agriculture (30%). Upper Monora Creek is predominately wooded or agricultural grassland while the Middle and Lower Monora Creek branches have been encroached upon by urban development and are considered mixed suburban green corridor, locally narrow from a geomorphic perspective (impacted from a terrestrial perspective). The natural depositional environment is predominately riverine meadow/marsh. In Middle and Lower Monora Creek artificial sediment barriers include ponds and flood control structures in the urban areas.

Sediment sources can generally be classified as basin or channel sources. Basin Sources are usually finer sediments (silt/sand) derived from upland and headwater landscape surfaces via sheet flow and rill wash. Channel Sources are sediments in the channel derived from erosion of bed, banks, terraces, valley walls; essentially channel erosion within the corridor (i.e., main branches of tributaries and Credit).

Lower order systems are usually dominated by basin sources as they are closer to the headwaters with less stream power available to provide much channel erosion.

The overall geomorphological condition within the Monora Creek drainage area is stable to moderately stable. There is moderate stability in the Upper and Middle Branches, and local instability on the Lower Branch (Widening, Degradational).

***Mill Creek***

As shown in Table 5.2.4 the predominant land uses within the Monora drainage area are urban (at 51.5%) and agriculture (at 35.9%). The headwaters of Mill Creek are predominately wooded or agricultural while the main Channel is a mixed urban corridor, with riparian vegetation locally absent from a geomorphic perspective (impacted from a terrestrial perspective). Some depositional environments are located in the upper reaches due to flood control structures and riverine meadow/marshes, however lower reaches are characterized by variable channel erosion processes.

The overall geomorphological condition for the headwaters of Mill Creek is Moderately Stable (Aggradational), in comparison to the mid-Lower reach which is Moderately Stable to Unstable (Widening, Degradational).

***Credit River***

As mentioned above, baseflows within the main Credit River branch are sustained by Island Lake outflows, WPCP discharges and baseflows from Mill Creek and the Orangeville Marsh (aka Melville Marshes). Evapotranspiration is high as the Credit flows along a wide channel surrounded by wetland vegetation. The Orangeville Wetland Complex and Melville Marshes play a key storage and evapotranspiration function within the Credit River drainage area. The Overall riparian condition is predominantly grass. In the Upper reach it is predominately marshland while in the Mid-Lower it is mixed grass / wooded. The natural depositional environment is riverine meadow/marsh while the artificial sediment barrier is Melville reservoir. The channel provides a minor source for sediment in comparison to tributary inputs from Mill Creek and the Caledon Tributaries.

The overall geomorphological condition for the Credit River is Stable to Moderately Stable (Aggradational).

***Caledon Tributaries***

The predominant land use within the Caledon Tributaries is agriculture (46.9%). As mentioned above, this area has moderate groundwater recharge and minimal intrabasin exchange. Summer headwater baseflows are intermittent and peak flows are reduced naturally by streambank vegetation, flat topography and wetlands in the area. This yields poor to low baseflow and moderate hydraulic conditions which are aggravated by moderate infiltration in the area, agricultural drainage improvements and flat slopes. Natural areas tend to be well connected with minor fragmentation Corridors are considered to have little to no impact (most are connected to high priority natural areas). Riparian conditions alternate between wooded and agricultural grass conditions.

The natural depositional environment is riverine meadow/marsh while the artificial sediment barrier is a pond in tributary 1. Headwater / basin contribute to the dominate source of sediment. Along tributary 2, bedrock is locally exposed contributing to sediment.

The overall geomorphological condition for the Caledon Tributaries is Stable to Moderately Stable (Variable processes)

***Eastern Tributaries***

Like the Caledon Tributaries, the predominant land use within the Eastern tributaries is agriculture (at 50%) (see Table 5.2.7). The area has high recharge, but very significant losses of groundwater to the Nottawasaga result in low and intermittent baseflow. Peak flow is minimized by high infiltration. The majority of wetlands are well-connected along the tributaries which contribute to good hydraulic conditions.

The riparian condition alternates between wooded and agricultural grassland conditions. The natural depositional environment is riverine meadow/marsh while the artificial are ponds that act as sediment barriers. The overall geomorphological condition for the Eastern Tributaries is Stable to Moderately Stable (Aggradational).

**Table 5.2.10 Geomorphic Characterization**

| Zone | Geomorphology and Physical Condition | | | | | |
|---|---|---|---|---|---|---|
| | **Stream Bed Type** | **Stream Channel Type/Definition** | **Riparian Condition** | **Sediment Barriers and Depositional Environments** | **Dominant Sediment Source** | **Overall Geomorphological Condition** |
| Monora Creek Tributaries (1197 ha) | Overall: Dominantly Sa<br>Uppoer: Sa<br>Mid-lower: Cb, Gr<br>Outlet: Sa, Si, Organics | Defined Channel=40%<br>Swale = 26%<br>Roadside Ditch = 1%<br>Intermit. Watercourse = 6%<br>Wetland Flow = 19%<br>Pond = 8% | Headwaters & Upper Branch: Wooded or agricultural grassland<br>Lower & Middle Branches: Mixed suburban green corridor, locally narrow. | Artificial: Ponds and flood control structures<br>Natural: Riverine Meadow/ Marsh | Dominantly headwater/ basin source. Some local channel sources. | Stable to moderately stabled (variable processes)<br>Local unstable on lower branch (widening, degradational) |
| Mill Creek (867.3 ha) | Overall: Cb, Gr, Debris<br>Uppoer: Sa, Gr<br>Mid-lower: Cb, Gr<br>Outlet: Sa, Si, Organics | Defined Channel = 22%<br>Swale = 25%<br>Roadside Ditch = 16%<br>Intermit. Watercourse = 3%<br>Wetland Flow = 33%<br>Pond = 1% | Headwaters: Wooded or agricultural<br>Main Channel: Mixed urban corridor, riparian vegetation locally absent | Artificial: Ponds and flood control structures<br>Natural: Riverine Meadow/ Marsh | Extensive channel sources and headwater/ basin sources | Upper: Moderately stable (aggradational)<br>Mid-Lower: Moderately stable to unstable (widening, degradational) |
| Credit River (1317.6 ha) | Overall: Dominantly Sa<br>Upper: Sa, Organics<br>Mid-lower: Sa, minor Gr, Cb<br>Outlet: Si, Sa | Defined Channel = 21%<br>Swale = 9%<br>Roadside Ditch = 16%<br>Intermit. Watercourse = 1%<br>Wetland Flow = 52%<br>Pond = 1% | Overall: Dominantly grass<br>Upper: Marshland<br>Mid-lower: Mixed grass/wooded | Artificial: Melville Reservoir<br>Natural: Riverine Meadow/ Marsh | Minor channel sources. Dominantly tributary inputs (Mill and Caledon Tributaries) | Stable to moderately stable (aggradational) |
| Caledon Tributaries (1201.6 ha) | Tributaries 1 & 3: Dominantly Sa<br>Tributary 2:<br>Upper: Sa, Si<br>Mid-lower: Cb, Bedrock<br>Outlet: Cb, Gr, Sa | Defined Channel = 24%<br>Swale = 23%<br>Roadside Ditch = 20%<br>Intermit. Watercourse = 3%<br>Wetland Flow = 27%<br>Pond = 3% | Overall: Alternating wooded and agricultural grassland conditions | Artificial: Pond (Tributary 1)<br>Natural: Riverine Meadow/ Marsh | Dominantly headwater/ basin sources. Bedrock locally exposed on Tributary 2 | Stable to moderately stable (variable processes) |
| Eastern Tributaries (1258 ha) | Tributaries 1 & 2A: Dominantly Sa<br>Tributary 2B: Variable Sa, Cb | Defined Channel = 21%<br>Swale = 18%<br>Roadside Ditch = 1%<br>Intermit. Watercourse = 7%<br>Wetland Flow = 50%<br>Pond = 3% | Overall: Alternating wooded and agricultural grassland conditions | Artificial: Ponds<br>Natural: Riverine Meadow/ Marsh/Wetland | Dominantly headwater/ basin sources | Stable to moderately stable |
| Island Lake Reservoir (163.8 ha) | n/a | Pond = 100% | n/a | Artificial: Island Lake Reservoir | n/a | n/a |

### 5.2.5 Surface Water Quality Characterization

The study uses two approaches for the assessment of subwatershed water quality, chemical data and benthic data. In general, both approaches suggest a subwatershed with fair water quality with some exceptions. Table 5.2.11 provides a summary of water quality characterization per zone.

The following paragraphs describe the water chemistry condition by subwatershed zone, followed by the descriptions of benthic conditions.

#### 5.2.5.1 Chemistry

Overall, the water quality in Headwaters subwatershed is variable in terms water quality conditions. In general, the tributaries that flow into Island Lake are fair. These smaller tributaries have a lower population density and fewer roads and it is expected that this area would be subject to lower loads of stormwater runoff. In the mid to lower portions of the subwatershed, the influence of highways, urban land use and high population density is apparent with median concentrations of the total phosphorus, aluminum and chlorides in the main Credit River markedly greater than those at other sampling locations in the subwatershed.

Sediment Chemistry results were generally indicative of a healthy aquatic environment with minimal point source impacts. There was no indication of heavy metals or hydrocarbon accumulation in the subwatershed. PCB’s were found at one site above the Probable Effect Level which indicates adverse effects could be expected. Exact sources of the PCBs are difficult to determine as they persist and accumulate in the sediment over long time periods.

***Monora Creek***

One station was sampled at the downstream end of Monora Creek, before the confluence with Island Lake. The Water Quality Index indicated generally “Good” water quality conditions although high concentrations of *E.coli* were found, possibly due to urban runoff. A good water quality ranking indicates water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.

***Mill Creek***

One station was sampled at the downstream end of Mill Creek, before the confluence with the Main Credit River. Results of the Water Quality Index designate the Mill Creek station as “marginal” water quality. This means that the water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels. Elevated chloride, metal and *E.coli* concentrations were consistently measured at this site. These contaminants are indicative of urban runoff due minimal storm water management in this catchment.

***Credit River***

Five water chemistry stations were sampled along the Main Credit River in the Headwaters. Results of the Water Quality Index designate the long term Main Credit stations as having overall “marginal” water quality. This means that the water quality is frequently threatened or impaired and conditions often depart from natural or desirable levels.

The long-term monitoring data indicate that total phosphorus concentrations are consistently above the PWQO set by MOE. Chlorides are below values thought to be hazardous to aquatic biota but the increasing trends observed in the long-term data and the higher values observed in the more urbanized portion of the subwatershed are a concern for future urban development.

Elevated total phosphorus and temperature levels have shown negative impacts on the dissolved oxygen regime in the main Credit River in the Melville Marsh, with exceedances to the PWQO occurring in August. Nitrate levels across the subwatershed were rarely measured above the CCME guideline and violations of the un-ionized ammonia PWQO (based on chronic exposure) are non-existent.

***Caledon Tributaries***
No water chemistry sampling was conducted on the Caledon tributaries.

***Eastern Tributaries***
One station was sampled at the downstream end of the Eastern Tributaries, before the confluence with Island Lake. The Water Quality Index indicated generally “Fair” water quality conditions due to elevated concentrations of *E.coli* and Total Suspended Solids, possibly due to agricultural runoff. A Fair water quality ranking indicates water quality is usually protected but occasionally threatened or impaired and that conditions sometimes depart from natural or desirable levels.

#### 5.2.5.2 Benthic Invertebrates
The benthic macroinvertebrate communities in the Headwaters subwatershed indicate possibly impaired to unimpaired water quality conditions. Most locations within the subwatershed show high taxa richness and diversity, although some communities are dominated by more tolerant forms, including oligochaetes and chironomids. Additionally, the Hilsenhoff Biotic Index (HBI) suggests organic enrichment may be contributing to impaired water quality in key areas.

The following paragraphs describe the benthic macroinvertebrate community condition by subwatershed zone, and is found in Table 5.2.11.

***Monora Creek***
Two stations were sampled within the Monora Creek catchment area. The first, Lower Monora Creek upstream of First Street, was found to be possibly impaired. The macroinvertebrate community in the Lower branch is dominated by pollution-tolerant taxa, with very few of the more sensitive forms as indicated by the EPT index. It appears that the Lower branch is impacted by urban land uses within the catchment area. The second station, Monora Creek at Cemetery, showed no significant impairment. This station is located at the bottom end of the catchment area, downstream of the confluences of the Upper, Middle, and Lower branches. The benthic community within this area has a

relatively high EPT index and there appears to be no significant organic enrichment as evidenced by the HBI. While there were no benthic sampling locations on the Upper branch of Monora Creek, because this branch is largely rural it is expected its contributions are having a positive impact on the downstream benthic communities.

***Mill Creek***

Both locations sampled on Mill Creek showed possible impairment according to the benthic macroinvertebrate community. The low EPT index and high proportions of chironomids and oligochaetes suggests there are sources of impact in the catchment area of Mill Creek. Urban land uses in the middle to lower reaches of the tributary within Mill Creek are likely causing some impairment to the benthic community. These impacts may include reduced baseflows, loss of riparian cover and non-point source pollutants.

***Credit River***

Four benthic stations were sampled along the Main Credit River in the Headwaters. The benthic macroinvertebrate communities along the main Credit River generally indicate unimpaired conditions, with one exception. Most stations had relatively high proportions of EPT taxa and lower proportions of pollution-tolerant species. Impairment is suspected immediately downstream of the WPCP, where very high proportions of chironomids and the nearly absent EPT taxa suggest possible impact from the WPCP. Further downstream on the Credit River at the south crossing of Hwy 10, the benthic community shows an improvement. With the exception of the area immediately downstream of the WPCP, the main Credit River in the Headwaters appears to have significant amount of flow to buffer anthropogenic impacts.

***Caledon Tributaries***

No benthic sampling was conducted on the Caledon tributaries.

***Eastern Tributaries***

One station was sampled in this zone, at the easternmost tributary of Island Lake. This station could only be sampled once as the creek went dry in the second year, likely a result of the decreasing baseflows from the middle reaches of the creek. Overall, this station ranked as unimpaired, however high proportions of chironomids suggest there may be some degree of impact, possibly from upstream agricultural land uses.

**Table 5.2.11 Surface Water Quality Characterization**

| General | Water Quality | | |
|---|---|---|---|
| **Zone** | **Water Chemistry** | **Benthic Invertebrate Health** | **Overall Water Quality Condition** |
| Monora Creek Tributaries (1197 ha) | good (85%) (high E.coli) | unimpaired/possibly impaired | good |
| Mill Creek (867.3 ha) | marginal (60%) (high E.coli and Cu concentration) | possibly impaired | marginal |
| Credit River (1317.6 ha) | marginal (57%) (high nutrient, Cl, TSS, Zn and E.coli) | unimpaired in most of the catchment area; possibly impaired immediately d/s of WPCP | fair |
| Caledon Tributaries (1201.6 ha) | No information available | No information available | No information available |
| Eastern Tributaries (1258 ha) | fair/good (75%) (mid E.coli and high TSS concentration) | unimpaired | good |
| Island Lake Reservoir (163.8 ha) | very good (94.5%) | no reservoir data available, but d/s of dam indicates unimpaired | excellent |

***Water Chemistry Notes:***

Excellent: (CCME WQI Value 95-100) – water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels.

Good: (CCME WQI Value 80-94) – water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.

Fair: (CCME WQI Value 65-79) – water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.

Marginal: (CCME WQI Value 45-64) –Poor: (CCME WQI Value 0-44) – water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

***Benthic Notes:***

Benthic ranking was based on several indices. Overall condition is assigned as "Unimpaired", "Possibly impaired" or "Impaired".

### 5.2.6 Aquatic Characterization

In summary, the streams and river within Subwatershed 19 can be characterized as being (or historically being) a coldwater brook trout fishery.

The eastern tributaries contain some reaches dominated by wetland marshes and this naturally limits some coldwater habitats. Brook trout are isolated by Island Lake and the amount of stream habitat is also limited given the small size of these subcatchments. Recent impacts from land use changes and new proposals are an issue.

Mill Creek also has a limited amount of coldwater habitat. Historical areas of coldwater habitat have likely been lost because of the impacts of human settlement. The last remaining coldwater reach is small and isolated and recent observations indicate continued degradation.

Monora Creek supports good populations of brook trout in the face of recent urbanization and has probably benefited from good groundwater supplies and knowledge of coldwater habitats for protection purposes. There has also been monitoring and some restoration efforts in partnership with the Town of Orangeville in this area.

In the upper reaches of the Credit River within Subwatershed 19, brook trout may have disappeared due to the construction of the reservoir and impacts of the Orangeville WPCP. Other impacts from urbanization and water taking are likely cumulatively affecting this reach. The wetland reaches of the Melville Marshes naturally present some constraints but a historical fish kill did confirm the former presence of brook trout.

In the lower reaches of the Credit River, groundwater inputs especially from the 3 Caledon tributaries provide a high quality fishery with spawning and refuge habitats. This population once extended downstream of the Melville Dam that now acts as a barrier and increases the sensitivity of this isolated population.

Mill Creek, the Eastern tributaries and most of the main river have restricted numbers of brook trout with a poor health rating. Conditions in Monora Creek (with a mostly excellent health rating), the Caledon tributaries (which are generally in good condition) and a short reach of the Credit River (which is excellent in terms of fisheries), are encouraging to fishery managers.

The warmwater fishery of Island Lake is characterized by lacustrine and wetland features and functions. The lake provides a very productive fishery dominated by bass and pike as top predators.

Fish community classifications and relative health using an IBI score are provided in section 4.8, where representatives of each area are further described and related to a variety of habitat factors. Observations and past surveys can be referenced from fisheries files including pool-riffle ratios, riparian conditions, woody cover, aquatic plants and substrate. More accurate measurements and characterizations are provided in the geomorphology component (section 4.5) that also reviewed past fish habitat surveys. The water quality component (4.6 Water Quality) also documents water chemistry and in particular dissolved oxygen as it relates to aquatic plants and fish. Wetland habitats (4.4.2), Aquatic (4.4.3.1) and Riparian (4.4.3.2) are also described as part of the terrestrial component (4.4 Terrestrial). These disciplines have also provided summaries that are selectively reiterated here to describe fish habitat. For interpretive purposes recall that:

- Coldwater communities depend on good groundwater discharge and can be naturally limited in some warmer low gradient wetland reaches or impoundments with finer sediments and lower oxygen. Warmwater species can represent healthy fish communities in these conditions.
- All stream fish depend on relatively stable geomorphic regimes. Dams and on-line ponds degrade habitat and genetically isolate fish populations or prevent re-colonization after critical events.
- Increased peak flows stress fish and erode habitats.
- Coldwater fish need cold water temperatures and high oxygen levels. Nutrients are generally lower in coldwater reaches. Toxic substances can either cause fish kills or accumulate over time causing stress and disease.
- Natural land uses (forests and wetlands) promote ensure a healthy water cycle and fish. Some studies suggest fish health can begin showing stress at 15% impervious cover.
- Riparian land uses more directly influence fish habitat such that 30 m buffers are commonly recommended to be in natural vegetation.

***Monora Creek***

Groundwater discharge occurs along almost all the reaches of Monora Creek, and particularly along both branches of Lower Monora and along Upper Monora. Groundwater discharge in this catchment is also supported by the large amount of groundwater recharge occurring in the catchment, plus the fact that groundwater flows into the catchment from the Grand River watershed to the west, which increases the amount of groundwater available for discharge within the catchment and helps to offsets groundwater losses to municipal pumping and outflow towards the Nottawasaga River watershed.

Peak flows are increased by urbanization in the area. Overall condition is good except in headwaters near wells where baseflow may be intermittent. Good condition/low flood potential due to high channel slopes and infiltration rates.

The predominate land uses within the Monora drainage area is urban (28%) and agriculture (30%). Middle Monora Creek and lower section of Lower Monora have been encroached upon by urban development and are considered highly impacted. The remainder of the corridors within Monora Creek drainage area are considered to be low impacted. Wetland coverage of 6% meets Environment Canada targets.

Upper Monora Creek is predominately wooded or agricultural grassland while the Middle and Lower Monora Creek branches have been encroached upon by urban development and are considered mixed suburban green corridor, locally narrow from a geomorphic perspective (impacted from a terrestrial perspective). The natural depositional environment is predominately riverine meadow/marsh. In Middle and Lower Monora Creek artificial sediment barriers include ponds and flood control structures in the urban areas. The overall Geomorphological condition within the Monora Creek drainage area is stable to moderately stable. There is moderate stability in the Upper and Middle Branches, and local instability on the Lower Branch (Widening, Degradational).

Coldwater communities are found throughout the Upper and Lower tributaries of Monora Creek. Lower Monora Creek (6yrs / 22.3=0.57x + b / R2 0.14 / SD+- 9.7) is in excellent health and ranks 9$^{th}$ within the Credit watershed and can be attributed to the dominance of brook trout that is a sensitive indicator.

***Mill Creek***

The upper reaches of Mill Creek also occur atop the Orangeville Moraine and these are areas of higher groundwater recharge as identified in the Monora Creek catchment. In the middle and lower reaches of the catchment the surficial geologic deposits are less permeable till, and these deposits along with the greater amounts of urbanization tend to decrease groundwater recharge and discharge. Overall the Mill Creek area loses significant water to municipal pumping, but large groundwater inflows from the Grand River offset some of these losses.

Mill Creek has moderate to poor hydraulic conditions due to the impacts of urbanization on peak flows and flat slopes in downstream reaches.

As shown in Table 5.2.3, the predominate land uses within the Monora drainage area is urban (51.5%) and agriculture (35.9%). Woodland and wetland coverage is well below Environment Canada targets at 3 and 2.8% respectively. Natural areas are fragmented with roads acting as barriers.

The headwaters of Mill Creek are predominately wooded or agricultural while the main Channel is a mixed urban corridor, with riparian vegetation locally absent from a geomorphic perspective (i.e., it is impacted from a terrestrial perspective). The natural depositional environment in the headwaters is predominately riverine meadow/marsh. In the main channel artificial sediment barriers include ponds and flood control structures in the urban areas. The overall Geomorphological condition for the headwaters of Mill Creek is Moderately Stable (Aggradational), in comparison to the mid-Lower reach which is Moderately Stable to Unstable (Widening, Degradational).

Some intermittent headwaters support some warmwater minnows and may even be used seasonally by brook trout found up and downstream of C Line. This population was also historically isolated by urbanization in lower Mill Creek where a more tolerant warmwater fish community is found. Some of the middle reaches (Dawson Rd) are also intermittent and pass through floodplain wetlands.

Mill Creek @ Amanda St. (6yrs / 3.7=0.34x + b / R2 0.22 / SD+- 1.3) is located in the lower reaches that have been historically urbanized and eroded. Station health is considered poor and comparable to other impacted streams on the Credit. This site on Mill Creek, however, has been more relatively stable over time.

***Credit River***

Groundwater flow from the east and west is generally directed towards the Credit. This inflow of groundwater into the catchment, combined with the generally high recharge conditions in the catchment, contribute to groundwater discharge occurring along the main Credit, particularly between the two main crossings of Highway 10.

Evapotranspiration and a wide channel surrounded by wetland vegetation may account for some loss in baseflow but the vast majority of baseflow is provided by Island Lake outflows, the WPCP discharges, and baseflows from upstream tributaries.

Peak flows are greatly attenuated by the Reservoir and the marsh. There are good hydraulic conditions due to baseflow and peak flow stabilizing effects of upstream reservoir, the WPCP inflows and the surrounding Marsh.

Wetlands are well-connected with the exception of the Orangeville Bypass which has fragmented a large wetland dominating this reach.

The overall riparian condition is predominantly grass. In the upper reach it is predominately marshland while in the Mid-Lower it is mixed grass / wooded.
The natural depositional environment is riverine meadow/marsh while the artificial sediment barrier is Melville reservoir. The overall geomorphological condition for the Credit River is Stable to Moderately Stable (Aggradational).

The upper Credit River from Island Lake downstream near Hwy 10 is classified as mixed water as coldwater components are likely impacted by the reservoir and WPCP. The Credit River in the vicinity of Hwy 10 benefits from known coldwater contributions, and the presence of a few aerating riffles that contains a very productive brook trout population. The Melville Pond is a backwater upstream of a private dam. The Pond has experienced extensive siltation and has poorly oxygenated warm waters that are not suitable for trout and are dominated by bullhead catfish and other warmwater species.

Credit River below Orangeville Reservoir Dam (3yrs / 8.0=mx + b / R2 / SD) indicate good health but in 2006 the IBI was rated poor resulting in an overall rating of fair. Credit River below Orangeville WPCP (2yrs / 0.36=mx + b / R2 / SD) represents the poorest score in the entire Credit watershed. Credit River u/s South Crossing Hwy 10 (6yrs / 30.8=-3.6x + b / R2 0.49 / SD+- 9.7) in contrast to the WPCP site, is considered one of the healthiest in the Credit watershed having excellent scores consistently over the years that are statistically significant. The last sampling however found all brook trout had disappeared. Credit River @ Melville (3yrs / 6.7 =mx + b / R2 / SD) IBI indicate high variability with a fair rating overall.

***Caledon Tributaries***

A large portion of the Caledon Tributaries occur atop the Orangeville Moraine deposits and therefore exhibit good groundwater recharge and discharge. There is some groundwater inflow from the Eastern Tributaries catchment to the north. There are also some lower permeability till deposits in the southern headwaters of the catchment that would tend to reduce groundwater recharge. Peak flows are reduced naturally by streambank vegetation, flat topography and wetlands in the area. The hydrogeologic condition is moderate due to intermittent headwater baseflows in the summer.

Peak flows are reduced naturally by streambank vegetation, flat topography and wetlands in the area. Moderate hydraulic conditions are aggravated by agricultural drainage improvements and flat slopes.

The predominate land use within the Caledon Tributaries is agriculture (46.9%). The majority of wetlands are well-connected. Speersville Wetland Complex and Orangeville Wetland Complex (6.9%) are located within the Caledon tributaries and are considered Provincially Significant Wetlands.

Riparian conditions alternate between wooded and agricultural grass conditions.
The natural depositional environment is riverine meadow/marsh while the artificial sediment barrier is a pond in tributary 1. Along tributary 2, bedrock is locally exposed contributing to sediment. The overall geomorphological condition for the Caledon Tributaries is Stable to Moderately Stable (Variable processes).

The Hwy 10 brook trout population is directly associated with access to refuge, spawning and nursery habitat found in the 3 Caledon tributaries. The upper reaches of these tributaries are intermittent or associated with palustrine wetlands harbouring either coolwater or warmwater species.

***Eastern Tributaries***
This catchment generally has moderate groundwater recharge due to the larger amounts of till deposits occurring in the catchment and flatter topography relative to other catchments in the subwatershed. There is a large component of groundwater flow out of the catchment towards the Nottawasaga Valley and a smaller component of groundwater that flows out of the catchment towards the main Credit and towards the Caledon Tributaries catchment. Groundwater discharge along the easternmost of the tributaries generally occurs in the upper reaches, with isolated discharge occurring intermittently in the lower reaches. Throughout the middle reaches of the easternmost tributary decreasing baseflow was consistently observed, and this flow loss could be attributed to water lost to evapotranspiration as the tributary flows through the wetland feature.

Peak flow is minimized by high infiltration. Hydraulic conditions are good due to high infiltration and slopes and low baseflow.

The predominant land use within the Eastern tributaries is agriculture (at 50%). The Orangeville Wetland Complex (6.9%) is considered a Provincially Significant Wetland and the Orangeville Reservoir is considered an Environmentally Significant Areas. Woodlands represent 17.2% of the zone, with another 26.1% being successional vegetation.

The riparian condition alternates between wooded and agricultural grassland conditions. The natural depositional environment is riverine meadow/marsh while the artificial are ponds that act as sediment barriers. The overall geomorphological condition for the Eastern Tributaries is Stable to Moderately Stable (Aggradational).

The Eastern tributary of Island Lake does support a brook trout population in its lower reaches. Historical observations in the upper reaches also suggest brook trout. Coolwater and warmwater species associated with Island Lake and other wetland habitats are common throughout. The Island Lake South-Eastern tributary supports brook trout. The main tributary supports use by coolwater species as far up as 1$^{st}$ Line but is predominantly intermittent upstream.

***Island Lake***

Island Lake has high evaporative losses, storage losses due to seepage through the North dam, and modest inflow (except for Monora Creek) due to trans boundary groundwater losses to the Nottawasaga from the Eastern Tributaries.

Overall the lake provides steady baseflow, attenuates peak flows and loses water to the Nottawasaga and the atmosphere.

Within Subwatershed 19 only Island Lake is classified as a large warmwater habitat. This artificial impoundment was stocked with bass and pike.

**Table 5.2. 12 Aquatic Characterization**

| General | Fisheries Condition | | |
|---|---|---|---|
| **Zone** | **Habitat Type: Existing/Mngt. Potential** | **Level of Habitat Condition (all disciplines)/Fish Community Health** | **Overall Fisheries Condition** |
| Monora Creek Tributaries (1197 ha) | cold / cold | fair/good | good |
| Mill Creek (867.3 ha) | cold and warm/ more cold and less warm | poor/ poor | poor |
| Credit River (1317.6 ha) | warm and cold/ more cold | fair/ poor to good | poor to good d/s |
| Caledon Tributaries (1201.6 ha) | warm to cold/ more cold | fair to good/ fair to good | fair to good d/s |
| Eastern Tributaries (1258 ha) | warm and cold/ more cold | fair to good/fair | Fair |
| Island Lake Reservoir (163.8 ha) | lacustrine warm | good / good | good |

### 5.3.7 Summary and Conclusions

Appendix ## provides a summary by discipline of each zone discussed above. Listed below is a brief summary of the headwater features and functions:

While some zones within Subwatershed 19 shows signs of stress and degradation as described above, overall the subwatershed appears to be relatively healthy and productive. In light of new growth targets and stresses such as climate change, monitoring of subwatershed ecosystem health indicators will play a critical role in subwatershed management to ensure subwatershed goals and objectives are met. Critical subwatershed ecosystem health indicators include:

- maintaining recharge areas;
- protecting major wetlands;
- maintaining a contiguous and healthy riparian zone;
- protecting critical discharge areas;
- maintaining channel structures that for the most part are still in equilibrium; and
- maintaining the existence of heritage species (e.g., brook trout)
- maintaining or enhancing water quality
- improving connections between natural areas and maintaining corridors at a subwatershed, watershed and regional scale.

Key functions provided by these indicators are outlined in Table 5.3.13. Recharge areas as identified in Section 4.2.2.4 and illustrated in Figure 4.2.20 are relatively intact.

**Table 5.2.13 Key Functions of the Watershed**

| Structure and Composition | Functions |
|---|---|
| Recharge Areas | • Water supply protection<br>• Water storage (reduce floods) |
| Discharge Areas | • Maintenance of riparian wetlands<br>• Water quality management<br>• Creation of unique habitats<br>• Maintenance of coldwater fisheries |
| Stable Channel systems | • Reduction in bank erosion,<br>• Maintain or enhance water quality conditions<br>• Convey floodwater and sediments<br>• Maintain fish habitat |
| Terrestrial corridors | • Movement of wildlife laterally and longitudinally |
| Table Land Forests | • Water budget management - infiltration, transpiration<br>• Interior species habitat |
| Riparian Systems | • Help maintain stable stream channels;<br>• Capture nutrients and manage for good water quality;<br>• Stabilize banks and reduce excessive erosion;<br>• Provide diverse terrestrial habitat and migration routes;<br>• Provide for good fish habitat |

Major wetlands (Orangeville Wetland Complex and Speersville Wetland Complex) still existing in the subwatershed are protected, but many of the small riparian wetlands are not protected and therefore could be at risk of loss due to urbanization.

Fortunately the subwatershed does have a fairly extensive linear riparian corridor which is protected in some areas through the ESA designation, but like recharge and discharge areas is presently not specifically identified as an important feature of the health of the subwatershed.

The persistence of coldwater and mixed water fish communities and the relatively healthy benthic community suggests that the subwatershed still has resiliency and with clear goals and objectives, the system can be maintained and restored.

The relative health of the Headwater Subwatershed can be summarized in the following points:

- key linkages are still largely intact;
- the riparian system is relatively intact and is a major determinant of continued health;
- protection of recharge areas, wetlands and forest cover will play a strong role in the flow stability, flow volumes and water quality of the system;
- recharge:discharge patterns are part of the key to improving the health of the system;
- fair to marginal surface water quality due to influences from urban and agricultural land uses;
- linkages between Tableland Forests and riparian corridors are weak;
- the sensitivity of key parameters (e.g., stream stability) to change suggests that the subwatershed is sensitive to change; and
- changes to land use must be managed given the high sensitivity of the subwatershed's key features and functions to change.