2009 Cedar Creek Water Quality Study

Prepared by the Upper Thames River Conservation Authority for the City of Woodstock

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UPPER THAMES RIVER
CONSERVATION AUTHORITY

city of
Woodstock

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1.0 Background

Cedar Creek watershed is 95 square km, with land use comprised of 73% agriculture, 14% urban, and 12% forest. This study focuses on the urban portion of the watershed, in the City of Woodstock.

Over the years, there has been local interest in enhancing Cedar Creek including the Cedar Creek Watershed Project, initiated in 1996 by the Woodstock Environmental Advisory Committee and the Upper Thames River Conservation Authority (UTRCA). A Cedar Creek Watershed Management Strategy was developed in 1998 and a number of objectives of the plan were implemented with a focus to protect groundwater in the headwater area[1].

In recent years many projects have been implemented in Woodstock to enhance Cedar Creek, as outlined in the 2007 Cedar Creek Watershed Report Card[2]. Examples include in-stream riffles installed at Southside Park, and bioengineering in the creek through Cedar Creek Golf Course (the Downs) to improve aquatic habitat.

Since 1964, Cedar Creek has been monitored as part of the Provincial Water Quality Monitoring Network (PWQMN) of the Ontario Ministry of the Environment. This data provides long term trends in water quality at the outlet of Cedar Creek, as summarized in the Woodstock Natural Heritage Inventory[3]. The UTRCA has also conducted aquatic monitoring including benthic invertebrates (since 1997) and fish.

In 2007, based on the provincial watershed report card grading system[4], Cedar Creek watershed received a D grade for surface water quality on the three indicators: benthic invertebrates, total phosphorus, and *E. coli* bacteria[2]. The City of Woodstock and UTRCA initiated the 2009 Cedar Creek Water Quality Study following these water quality results, to further monitor Cedar Creek through Woodstock to assess water quality conditions along the creek and begin to identify any stressors or areas to target remedial work.

2.0 Study Outline

2.1 Purpose

The purpose of this study is to develop a better understanding of the water quality conditions in Cedar Creek at a variety of locations in the subwatershed, focusing on the downstream section through Woodstock. This study was designed to give an assessment of water quality and stream health in Cedar Creek in 2009 through water chemistry sampling, benthic invertebrate analyses and fish community assessment.

2.2 Site Selection and Monitoring

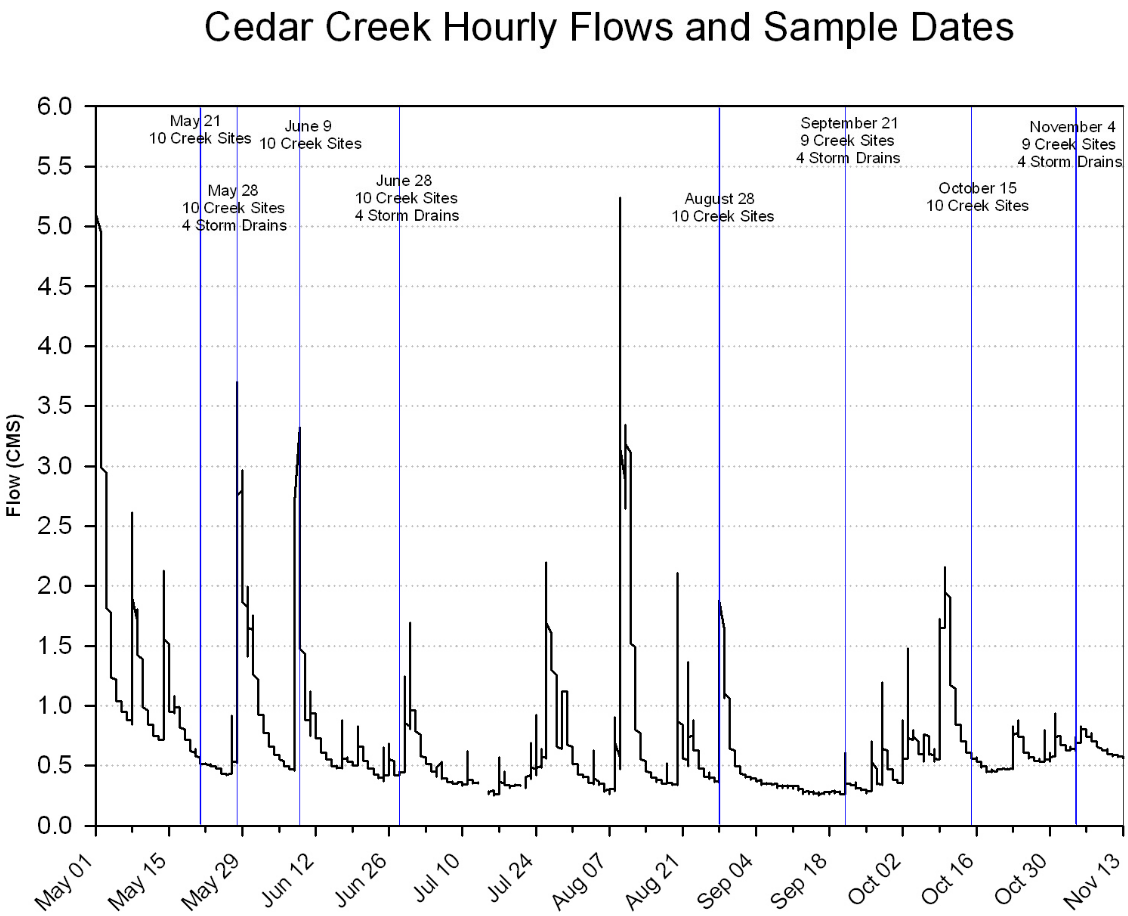
Water Chemistry

Sites were selected in conjunction with the City of Woodstock to represent points along Cedar Creek through the urbanized portion (sites 1 to 7), as well as three creek sites upstream of the City (sites 8, 9 and 10). Four storm drain outlets (A, B, C and D) representing four different stormwater drainage areas in Woodstock were also monitored (Map 1).

Water samples were taken at the 10 creek sites on eight sampling days from May to November, which included five rain event sampling dates. The four storm drains were also monitored on four of the rain dates. Samples were analysed by Maxxam Analytics for the following parameters: Nitrate, Nitrite, Total Kjeldahl Nitrogen, Ammonia-N, Total Phosphorus, Orthophosphate, Chloride, Total Suspended Solids, Total metals and *E. coli*. On-site water quality measurements were taken with a YSI multi-parameter meter for pH, temperature, salinity, TDS, conductivity and dissolved oxygen.

An effort was made to collect samples through a range of flow conditions including low flow and rain events (Figure 1). Storm drains were sampled on four occasions. There was generally a short window of time through a rain event when the four storm drain outlets would all be flowing. One observation of note was the relatively low volume of discharge from storm drain B during rain event monitoring. A number of peak rain events in August to October that occurred on Friday evening and Saturdays were not sampled because of laboratory restrictions in analyzing bacteria samples through the weekend. Site conditions are outlined in Appendix A.

Figure 1. 2009 Sample Dates and Cedar Creek Flows (from flow monitoring station in Southside Park)



Benthic Invertebrate (Benthos) Monitoring

During 2009, 25 benthos samples were conducted at 16 sites (Map 1). Where possible and practical the locations duplicated those sampled for chemical and bacterial parameters. During late May, 15 samples were taken, six from Cedar Creek within Woodstock (North of Highway 401) and nine from upstream reaches of Cedar Creek and headwater tributaries. In late September, the six Woodstock sites were repeated, one additional Woodstock site was sampled where high water levels had prevented spring sampling, and three of the upstream sites were repeated.

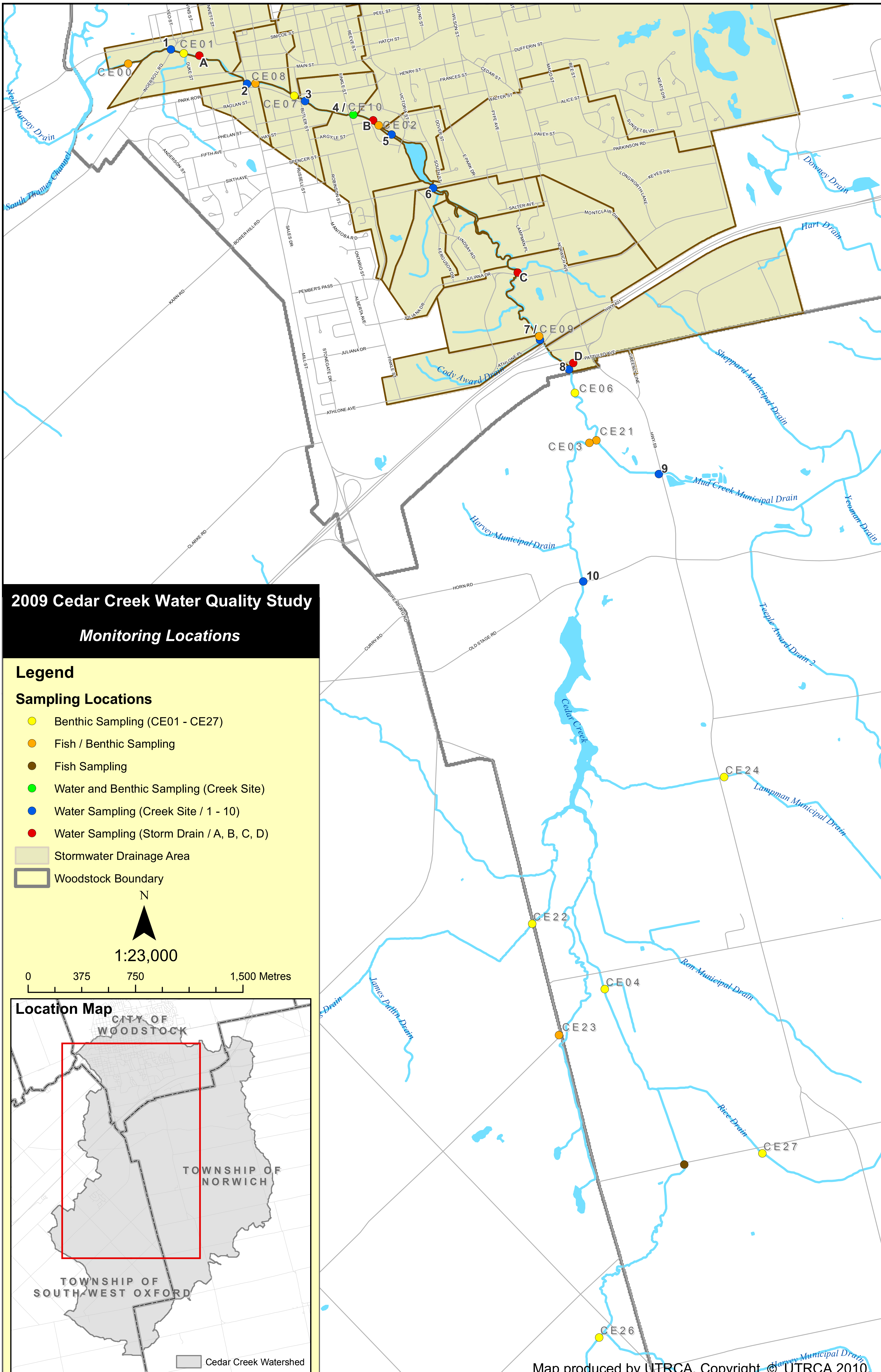
Benthos are benthic macroinvertebrates (BMI), the usually abundant organisms that live in and on the substrate of our streams, rivers and lakes. Included are insects, usually in the larval form, such as caddisflies, mayflies, stoneflies, damselflies, dragonflies, beetles and two-winged flies (i.e., midges, blackflies). Also included are crustaceans, leeches, snails, clams and aquatic worms. The benthos comprising a benthic community is a function of the habitat present and the water quality throughout the lifespan of each organism, being a year or more for many. Some BMI are very sensitive to pollution and habitat disturbance while others are very tolerant. By determining the proportion of intolerant to tolerant BMI, a long term measure of water quality and overall aquatic ecosystem health can be obtained.

Benthos sampling has been conducted by the UTRCA in the Cedar Creek watershed since 1997. Although sampling methods have varied slightly during this time they have been consistent enough to generate comparable results. Initially, sampling followed a version of the US Environmental Protection Agency's (EPA) Benthic monitoring protocol[5], modified by the faculty of the University of Western Ontario Biology Department for local conditions. More recently, minor changes allow compatibility with the Ontario Benthos Biomonitoring Network[6]. Throughout, a timed traveling kick sample using a 0.5 mm mesh D-net was used to collect the BMI sample. Samples were preserved immediately after sampling. Laboratory analyses of these samples consists of identifying randomly selected subsamples to the Family Taxonomic level until a minimum number (currently 300) are selected. An assessment of aquatic and riparian habitat conditions was completed at each site along with measuring and recording basic water chemistry parameters.

Fish Community Monitoring

Fish sampling was conducted at eight locations in the Cedar Creek watershed during the fall of 2009, at four sites in Woodstock, and four Cedar Creek and headwater tributary sites upstream of Highway 401. In addition, fish community data collected by UTRCA and OMNR crews since 1997 and historical data from the Royal Ontario Museum database were utilized.

Sampling was conducted using a backpack electrofisher, which effectively draws fish out of cover and temporarily immobilizes them, permitting their capture. All fish were identified to species level, their relative abundance recorded, and then they were released unharmed. Sampling effort at each site was designed to provide a representative assessment of the fish community present. Occasionally voucher specimens are collected to confirm the identities of unusual or difficult to identify species, but as all species encountered in this study were relatively common and readily identified they were released at the sampling sites.



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Monitoring Locations
Legend
Sampling Locations
Benthic Sampling (CE01 - CE27)
Fish / Benthic Sampling
Fish Sampling
Water and Benthic Sampling (Creek Site)
Water Sampling (Creek Site / 1 - 10)
Water Sampling (Storm Drain / A, B, C, D)
Stormwater Drainage Area
Woodstock Boundary
N
1:23,000
0
375
750
1,500 Metres
Location Map
CITY OF WOODSTOCK
TOWNSHIP OF NORWICH
TOWNSHIP OF SOUTH-WEST OXFORD
Cedar Creek Watershed
Cedar Creek
Cody Award Drain
Sheppard Municipal Drain
Mud Creek Municipal Drain
Harvey Municipal Drain
Yeoman Drain
Teeple Award Drain 2
Lampman Municipal Drain
Ron Municipal Drain
James Pattin Drain
Rice Drain
Harvey Municipal Drain
Hart Drain
Downey Drain
South Thames Channel
Neil Murray Drain
Map produced by UTRCA. Copyright © UTRCA 2010.

3.0 Results

3.1 Results: Water Chemistry and Bacteria

Results are provided for 10 parameters which are related to land use activities and had data exceeding water quality guidelines.

E. coli Bacteria

Fate and behavior: *Escherichia coli* (*E. coli*) are a type of fecal bacteria found in human and animal waste. Their presence in water indicates some fecal contamination. *E. coli* are an indicator for the presence of other pathogens found in human and animal waste, such as *Giardia* and *Cryptospiridium.*
Sources: Potential sources of fecal bacteria include upstream runoff from biosolids/sewage or livestock waste application, faulty private septic systems, and urban stormwater runoff including waste from pets and wildlife.
Standards: The Provincial Water Quality Objective (PWQO) for recreational waters is 100 *E. coli*/100 mL. This guideline is used as a target for comparison, recognizing that Cedar Creek is not monitored as recreational water.
Monitoring Results:

- Concentrations of *E. coli* bacteria are routinely well above the provincial recreational guideline for all stream sites and storm drains, with some high levels (close to 10,000 *E. coli*/100 ml) at all sampled sites on two rain events (May 28 and June 9).
- Higher *E. coli* levels are present during rain/runoff events with 70% of these samples over 1000 *E. coli*/100 ml compared to only 3% of baseflow samples.
- Storm drain B in Southside Park discharged higher concentrations of *E. coli* than levels in Cedar Creek at that location on all four rain event samples but, at time of sampling, the discharge only appears to raise *E. coli* levels in the creek between stations 5 and 4 on November 4th. Storm drains A, C and D discharged *E. coli* levels significantly higher than adjacent creek concentrations on just one of the four sample dates (June 28).
- While *E. coli* levels fluctuate along Cedar Creek, particularly during runoff/rain events, *E. coli* levels from upstream of the City at site 8 are fairly similar to downstream levels at site 1 on each sample date. *E. coli* levels are slightly lower further upstream at site 10.

Figure 2a. ***E. coli*** **Concentrations from Upstream to Downstream for Baseflow Conditions**
(note: log scale used for *E.coli*)

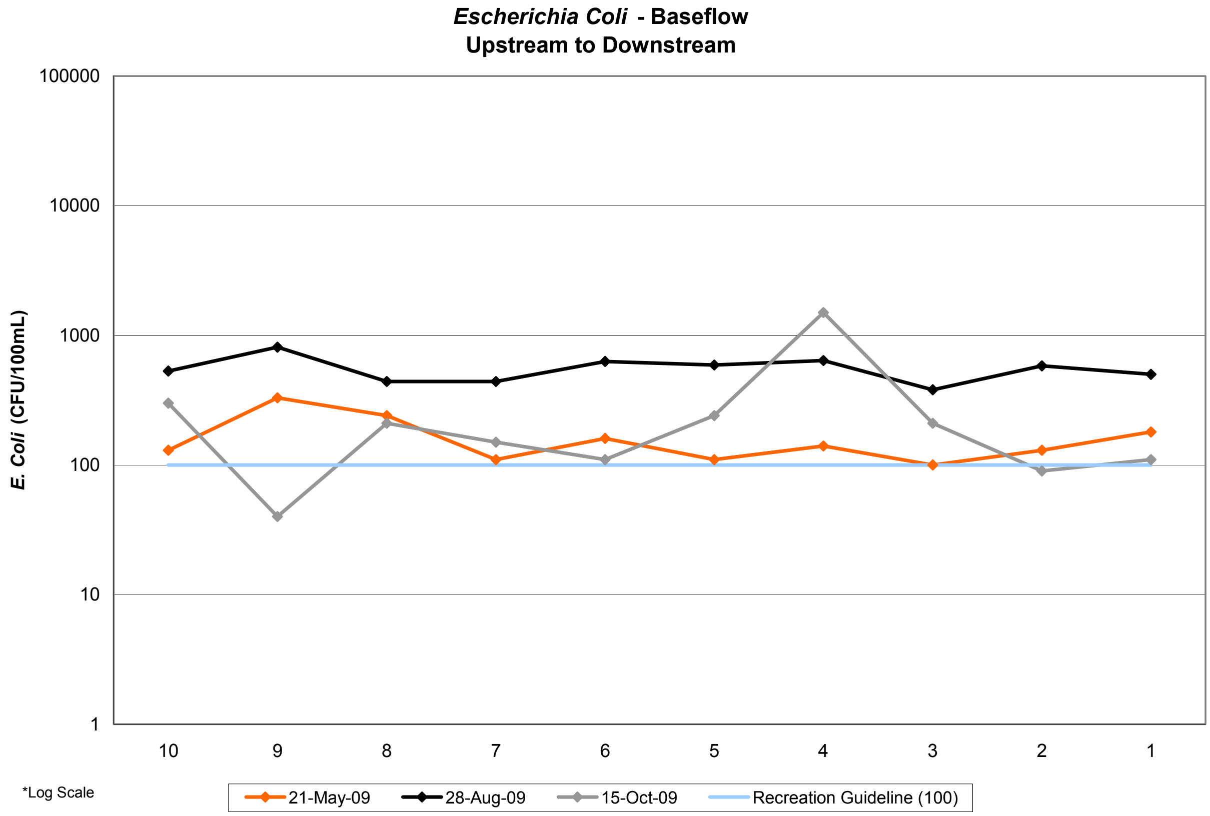
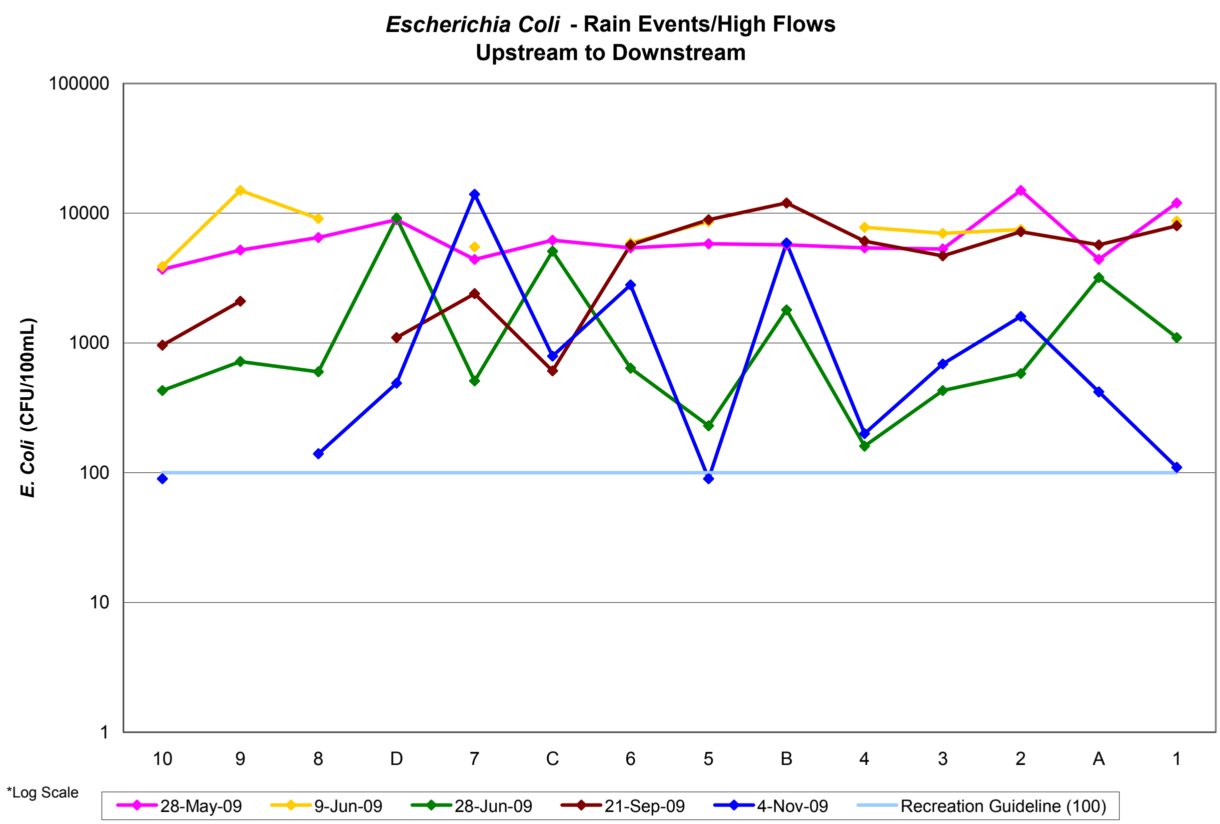


Figure 2b. ***E. coli*** **Concentrations from Upstream to Downstream for Rain Event Conditions**



Total Phosphorus

Fate and Behavior: Phosphorus is not directly toxic to aquatic life, but elevated concentrations can lead to undesirable changes in a watercourse including excess plant growth, reduced oxygen levels, and reduced biodiversity. Orthophosphate, which is a form of phosphorus most biologically available to plants, was also measured.

Sources: Phosphorus sources include commercial fertilizers, animal waste, and domestic and industrial wastewater including soaps and cleaning products. Phosphorus binds to soil and is readily transported to streams with eroding soil.

Standards: Ontario has an interim Provincial Water Quality Objective of 30 *u*g/L of total phosphorus to prevent the nuisance growth of algae.

Monitoring Results:

- Concentrations of total phosphorus routinely exceed the Provincial Objective for the protection of aquatic life at all sampled sites for baseflow conditions (concentrations one to four times PWQO) and rain event conditions (one to 13 times PWQO).
- Storm drain B in Southside Park discharged higher concentrations of total phosphorus than levels in Cedar Creek at that location on three of four rain event samples but, at time of sampling, samples do not show storm drain B raising total phosphorus levels in the creek between stations 5 and 4. Storm drains A, C and D discharged total phosphorus levels significantly higher than adjacent creek concentrations on two of the four sample dates.
- While total phosphorus levels fluctuate along Cedar Creek, particularly during runoff/rain events, total phosphorus levels from upstream of the City at site 8 are fairly similar to downstream levels at site 1 on each sample date.
- Samples taken upstream and downstream of Southside Pond show a small decrease in total phosphorus, indicating some nutrient retention/uptake in the pond.
- Orthophosphate levels show particular peaks at storm drain A and at site 9, indicating inorganic sources of phosphorus which are more biologically available to plants (e.g., fertilizer).

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Figure 3a. Total Phosphorus Concentrations from Upstream to Downstream for Baseflow Conditions

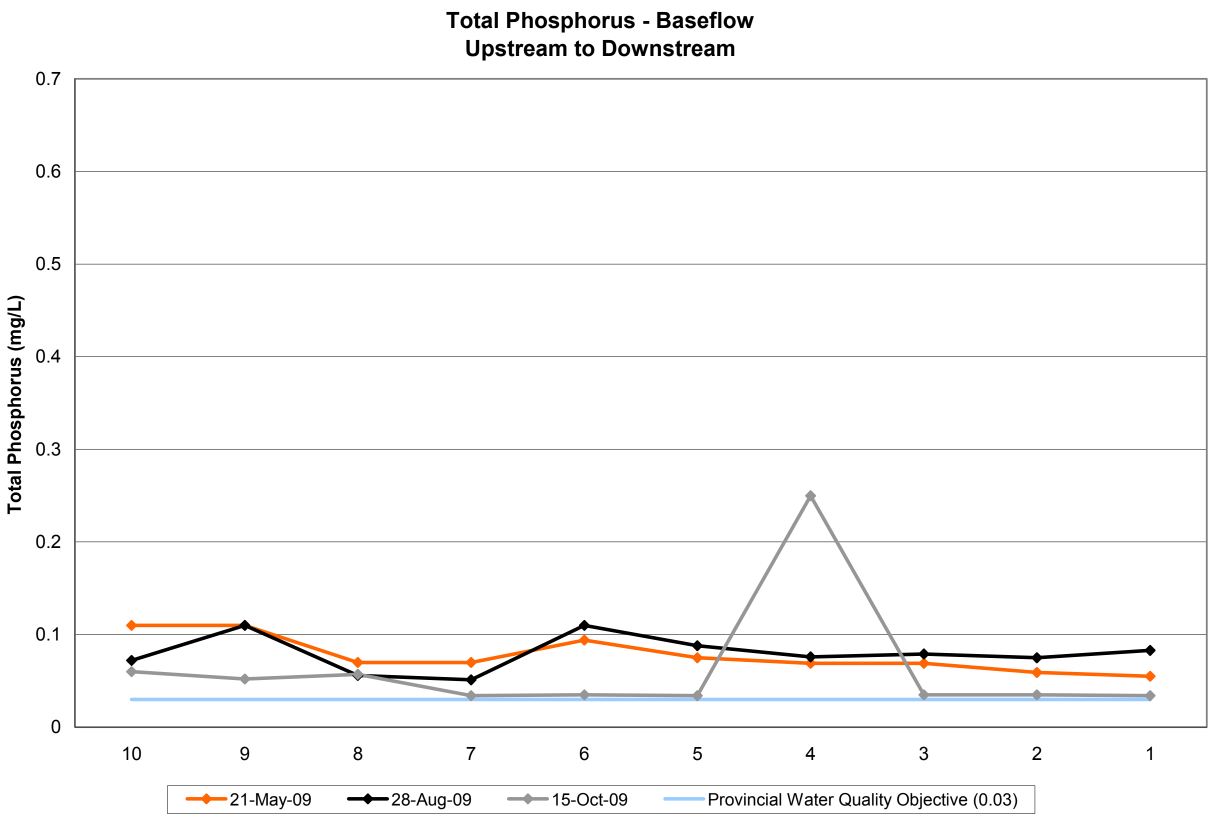
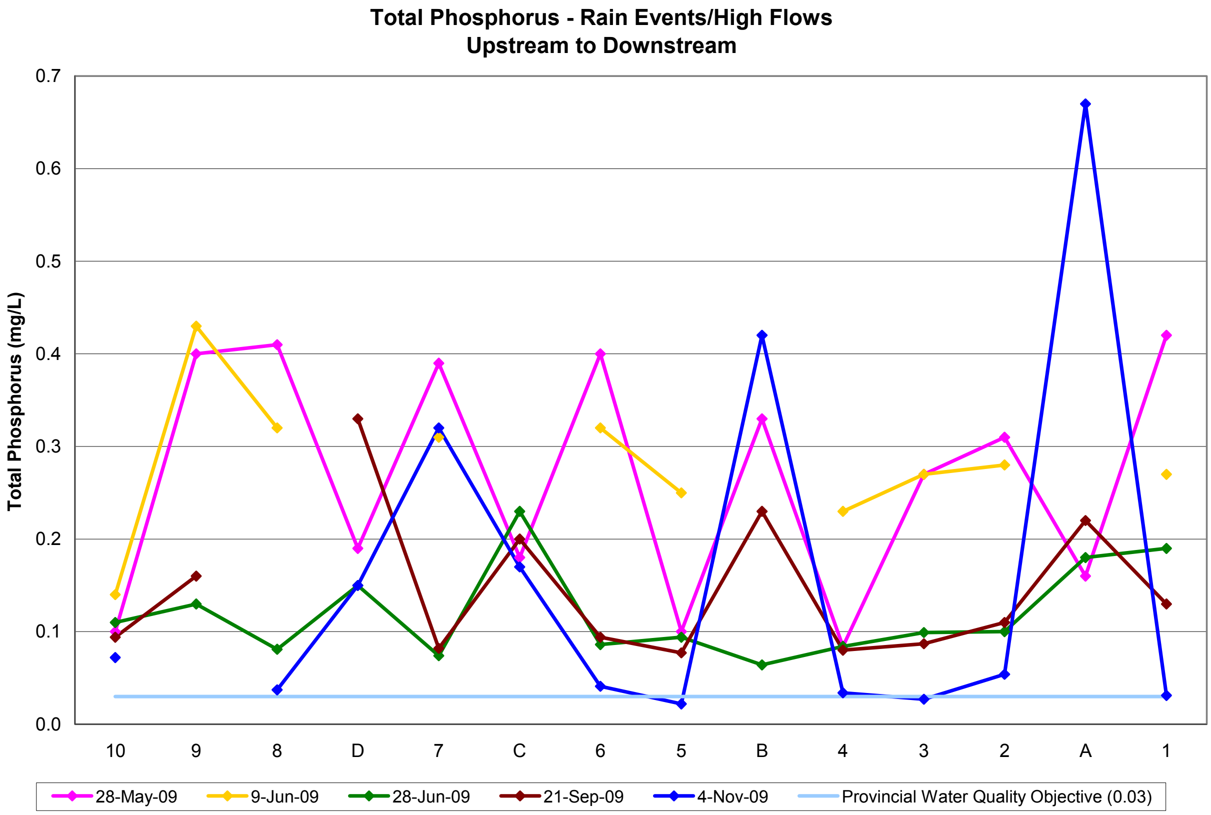


Figure 3b. Total Phosphorus Concentrations from Upstream to Downstream for Rain Event Conditions



Nitrate and Ammonia

Fate and Behaviour: Nitrate is a nutrient that does not adsorb to sediment and moves readily through surface runoff to streams and through soil into groundwater. Elevated levels in a watercourse can be toxic to aquatic organisms, especially amphibians. Ammonia is highly soluble in water. Ammonia in surface water is naturally converted to nitrate. This conversion, in addition to increasing nitrate concentration, removes oxygen from the water, which can adversely affect fish and invertebrates[7].

Sources: Nitrate and ammonia sources can include sewage/animal waste, commercial fertilizers, septic systems, atmospheric deposition and natural decomposition of organic wastes.

Standards: Ontario does not have a Provincial Water Quality Objective for aquatic life but the Canadian Environmental Quality Guideline to protect aquatic life from direct toxicity to nitrate is 2.93 mg/L. The PWQO for total ammonia is 0.02 mg/L.

Monitoring Results:

- Storm drains A, B, C and D all show low nitrate levels, below the aquatic life guideline and lower than creek concentrations. However the ammonia data shows the reverse with peaks in ammonia levels at the storm drains. It is expected that nitrogen in the form of ammonia is high in storm drain runoff and is converting to nitrate in the creek.
- 70% of the creek nitrate samples are above the aquatic life guideline but are generally lower compared to many sites across the UTRCA[8]
- There is relatively low overall change in nitrate levels from upstream (site 8) to downstream (site 1).

Figure 4a. **Nitrate Concentrations from Upstream to Downstream for Baseflow Conditions**

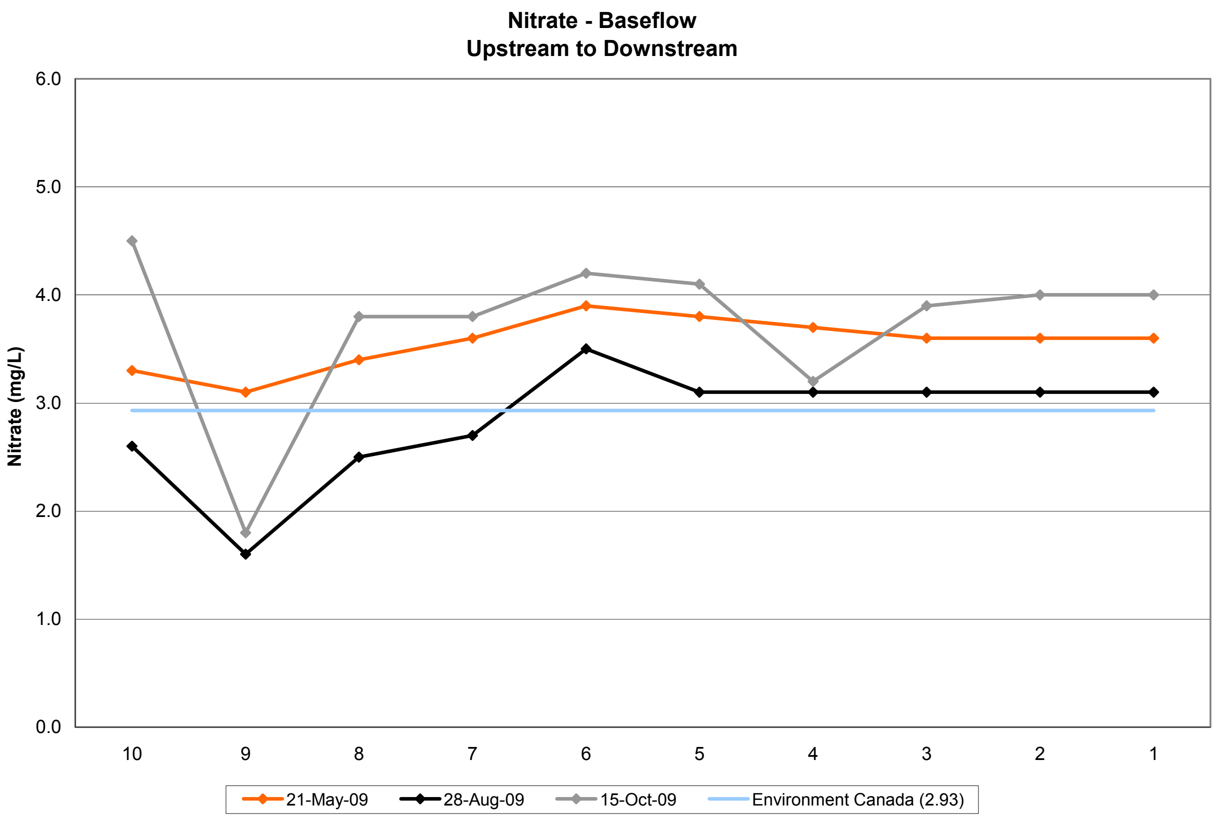


Figure 4b. **Nitrate Concentrations from Upstream to Downstream for Rain Event Conditions**

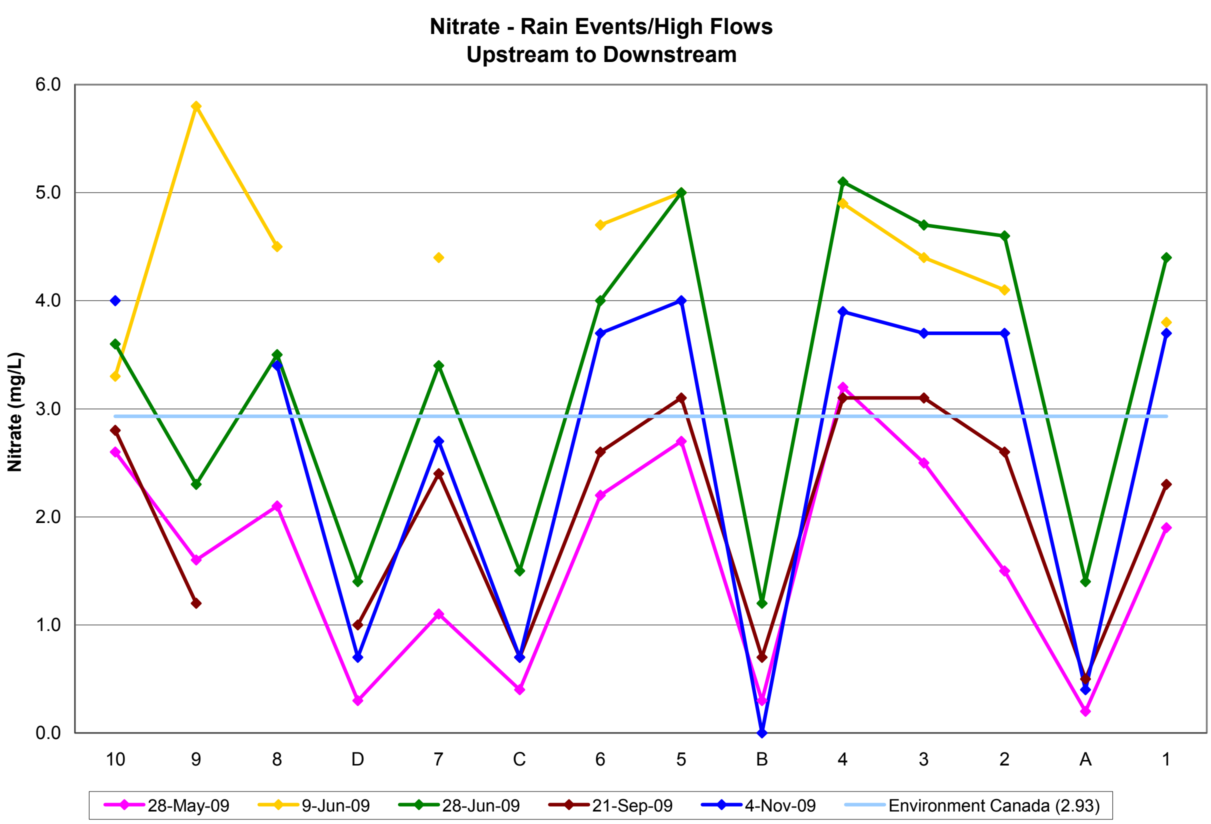


Figure 5a. Ammonia Concentrations from Upstream to Downstream for Baseflow Conditions

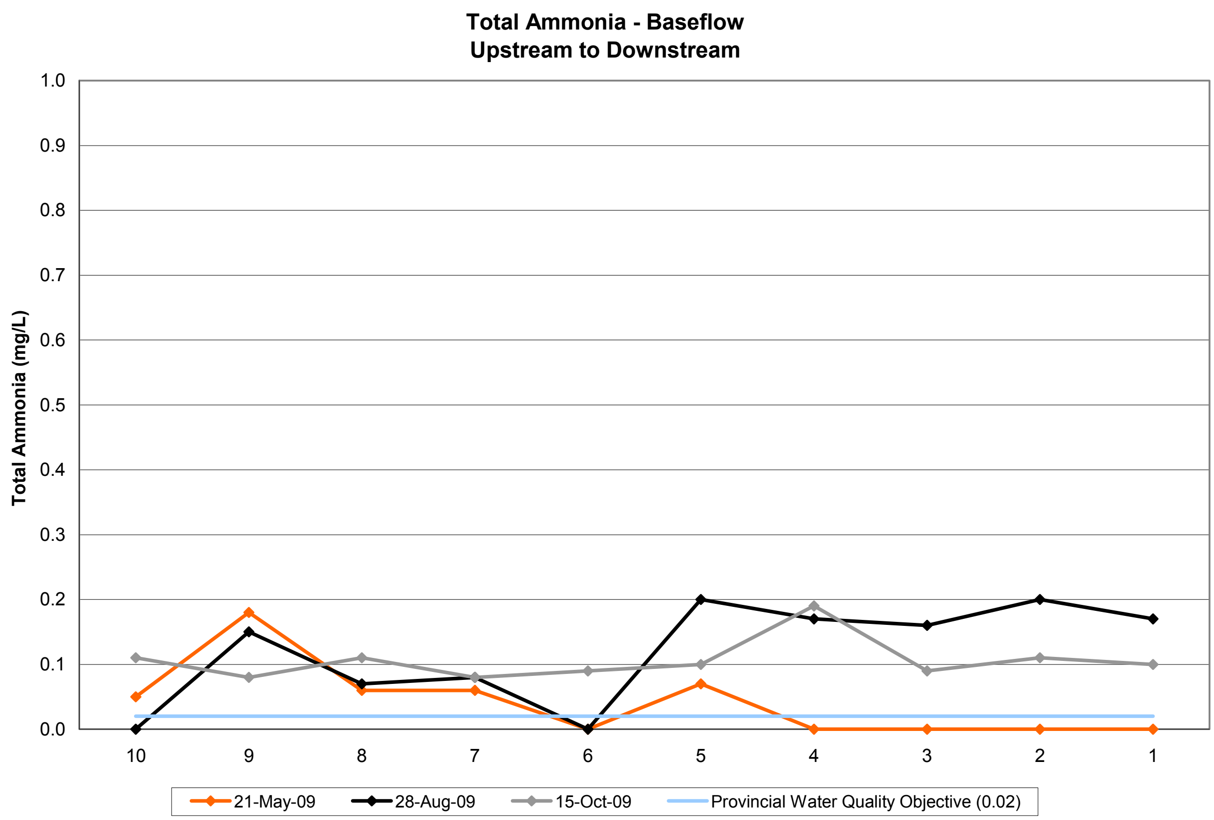
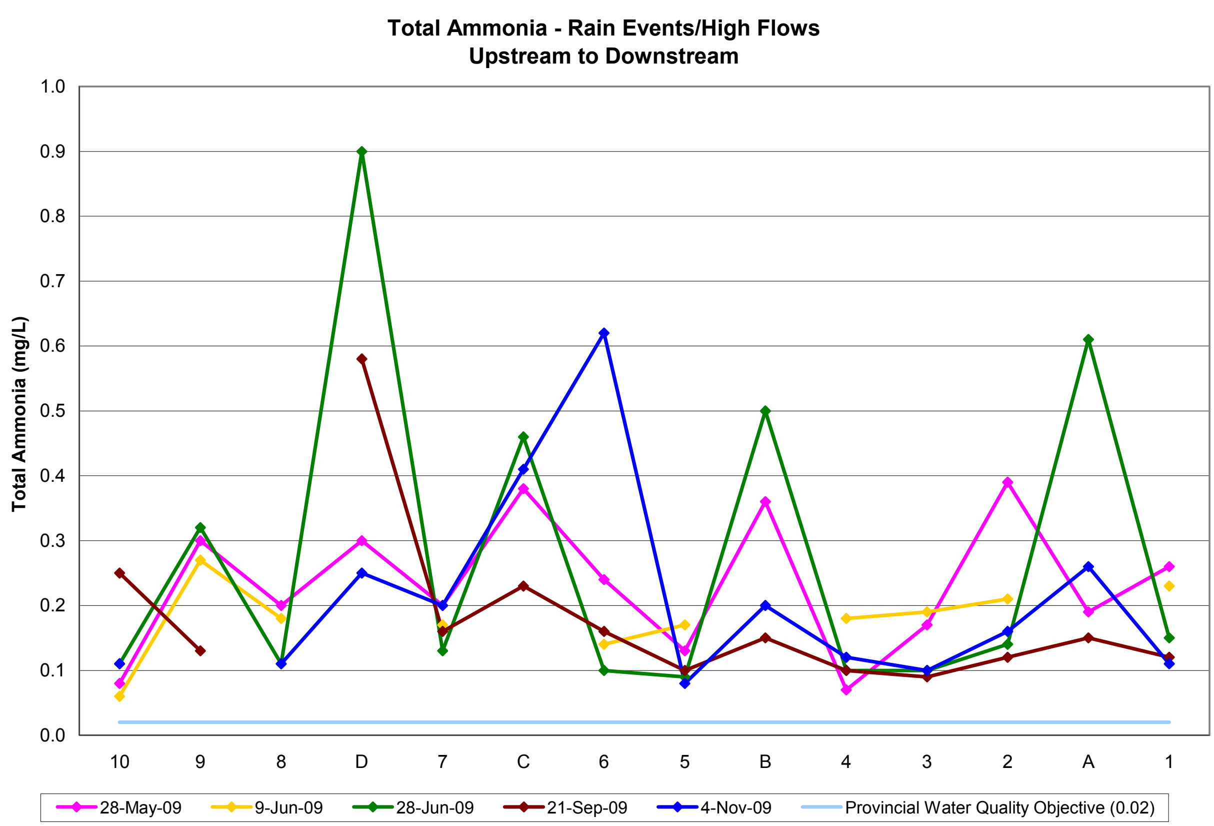


Figure 5b. Ammonia Concentrations from Upstream to Downstream for Rain Event Conditions



Chloride

Fate and Behaviour: Chloride moves easily with water and persists in the river system. Nearly all chloride added to the environment will eventually migrate to surface water or groundwater. Chloride can be toxic to aquatic organisms at high concentrations.
Sources: The highest loadings of chloride are typically associated with the application and storage of road salt (e.g., calcium chloride). Urban streams tend to have the highest chloride concentrations.
Standards: Ontario does not have a Provincial Water Quality Objective for aquatic life. An Environment Canada/Health Canada assessment report (2001) documents toxicity for sensitive aquatic species at 210 mg/L.
Monitoring Results:

- All samples had concentrations well below the Environment Canada toxicity guideline.
- For the majority of samples, the storm drains had much lower chloride levels than the main creek.
- There were fairly consistent creek concentrations from upstream (site 8) to downstream (site 1). The lowest chloride levels were in upstream site 10.
- The timing of sampling for this study does not provide data for winter or early spring runoff when chloride levels would be expected to be highest as a result of road salt runoff. Since the 1980s, chlorides have been increasing in Cedar Creek, a trend seen in many locations locally and across Ontario.

Figure 6a. Chloride Concentrations from Upstream to Downstream for Baseflow Conditions

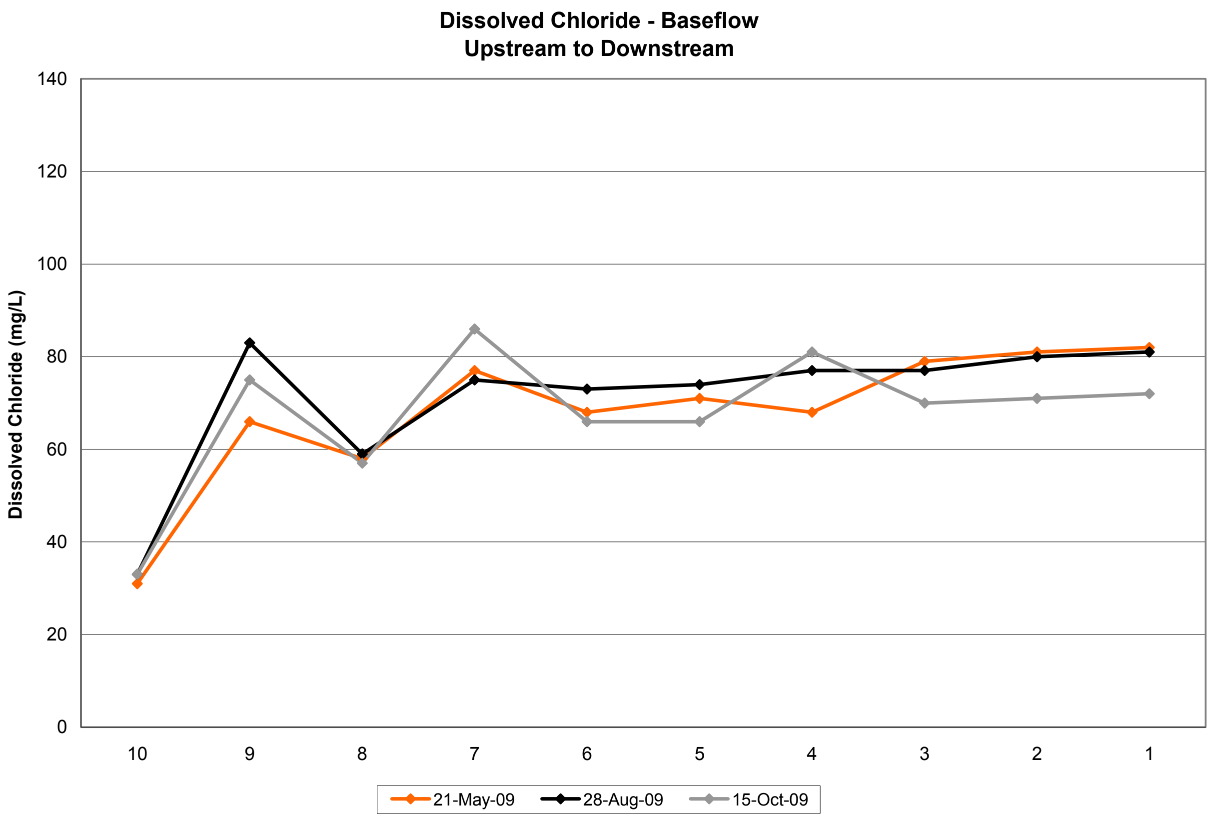
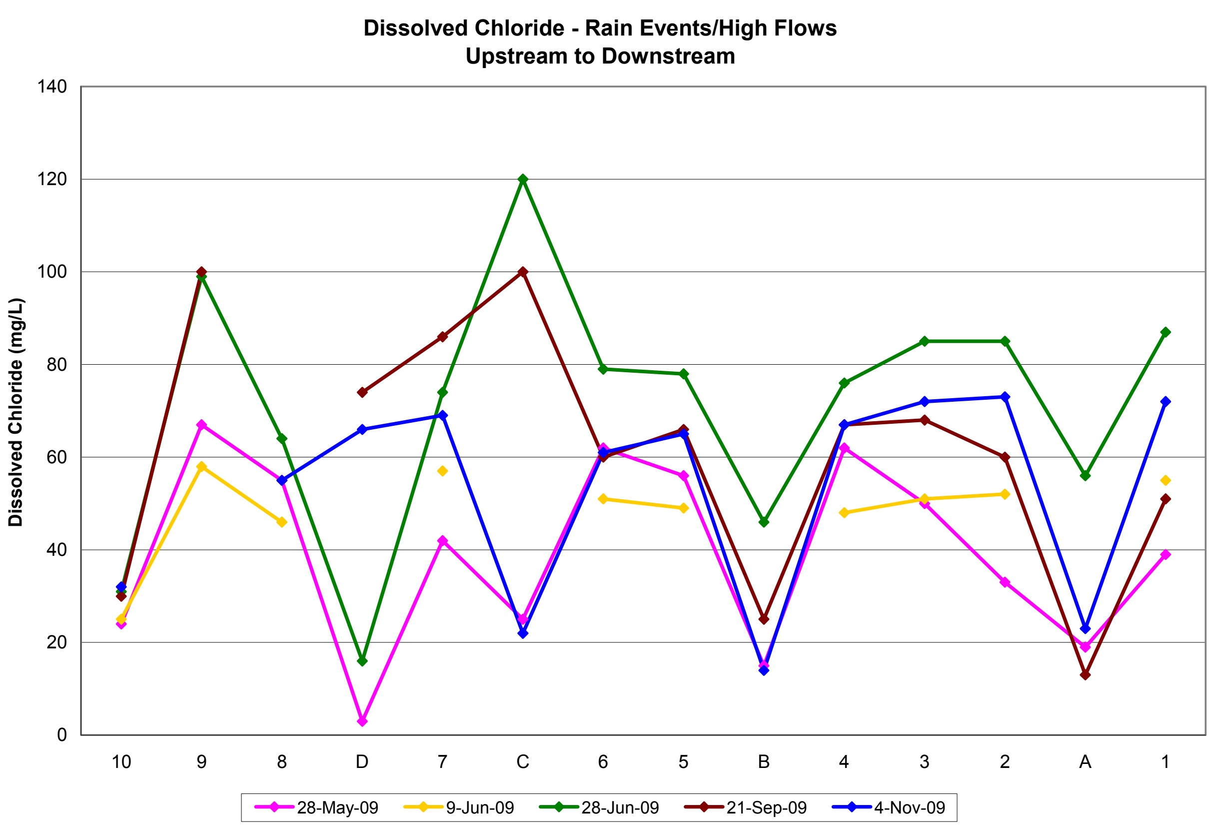


Figure 6b. Chloride Concentrations from Upstream to Downstream for Rain Event Conditions



Metals

An extensive suite of metals was tested in each sample as part of standard laboratory tests. Metals are long lasting in the environment where they tend to accumulate in streambed sediments. Metals can bio-accumulate in fish and wildlife and can be toxic to aquatic life at elevated levels. Following is an assessment of those metals with some occurrence above guideline levels.

Copper

Sources: Some sources that can impact on water quality include plumbing fixtures and pipes, textile manufacturing, paints, electrical conductors, wood preservatives, pesticides, fungicides and sewage treatment plant effluent.
Standards: The PWQO for copper is 5 ug/L for aquatic life.
Monitoring Results:

- Copper concentrations exceeded the Provincial Water Quality Objective for 57% of the rain/runoff event samples and 10% of the base flow samples, indicating sources delivered by runoff. Concentrations were higher at most of the storm drain discharge samples(for all samples at storm drain B) as well as site 7, which was over six times the guideline on May 28.
- The lowest copper concentrations were in upstream Site 10.

Figure 7a. Copper Concentrations from Upstream to Downstream for Baseflow Conditions

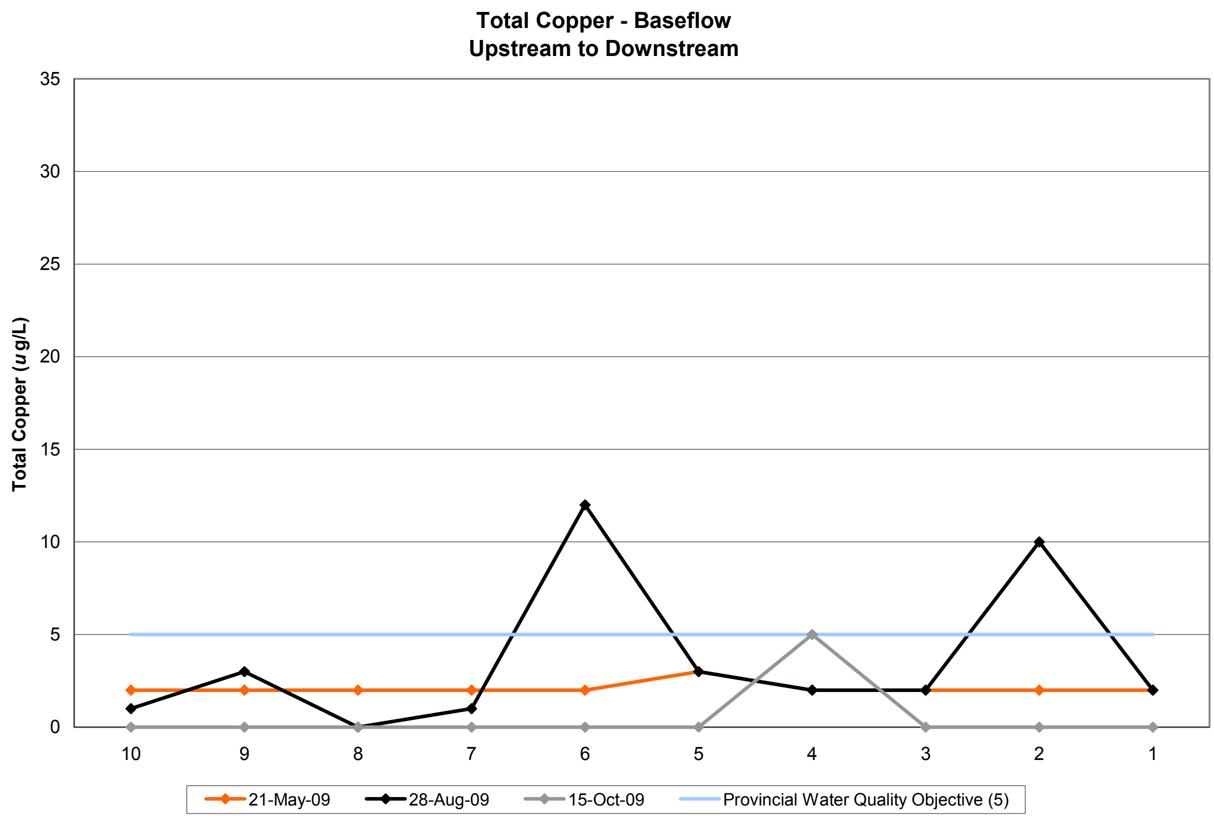
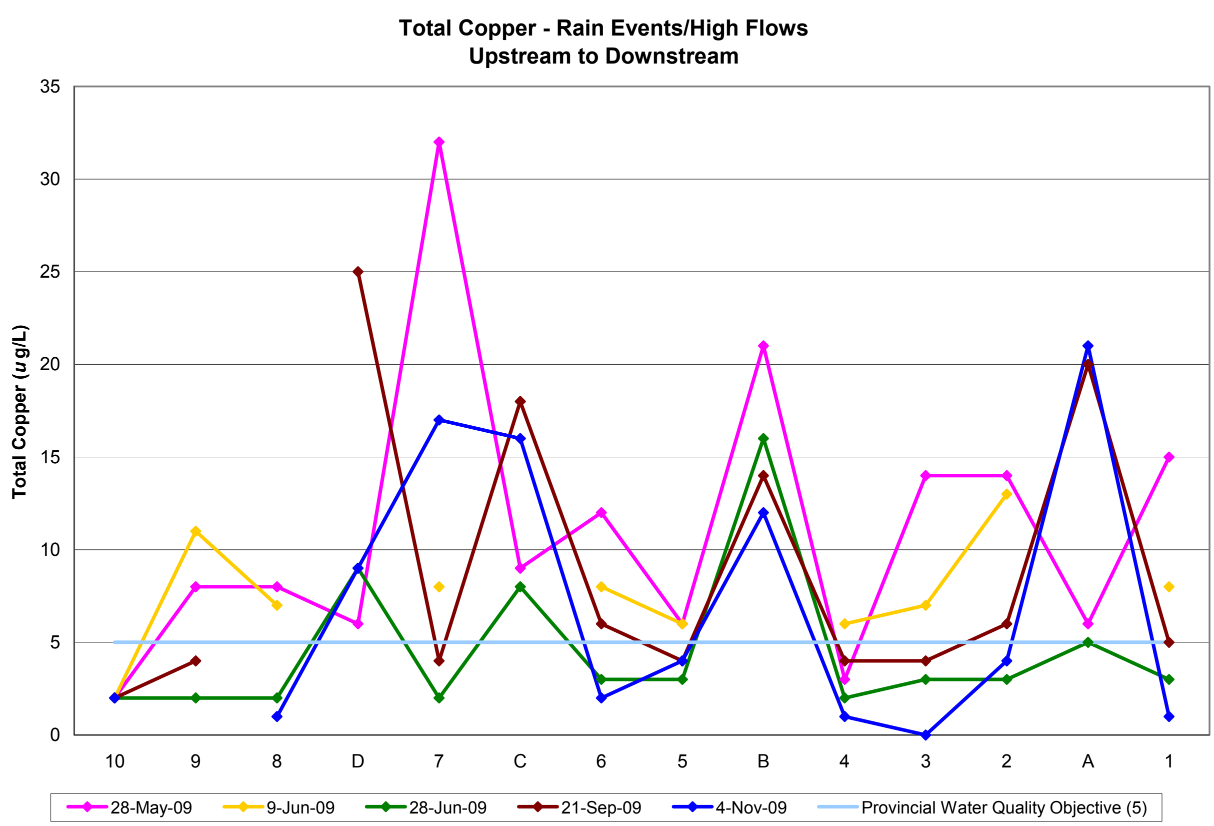


Figure 7b. Copper Concentrations from Upstream to Downstream for Rain Event Conditions



Lead

Sources: Sources of lead in the environment can include the production of batteries, metal products (solder, pipes, electronics), the manufacturing of electronic parts, plastics, rubbers and metals, ceramics, and flame retardants. Sources also include burning of fossil fuels, phosphate fertilizers and certain pesticides.
Standards: PWQO of 5 ug/L for aquatic life.
Monitoring Results:

- Lead concentrations exceeded the Provincial Water Quality Objective for 25% of the rain/runoff event samples and only 7% of the base flow samples, indicating some sources delivered by runoff. Concentrations were higher at most of the storm drain discharge samples (for all samples at storm drain B) than the adjacent creek sites. The May 28 runoff event had the highest concentrations of lead, especially at downstream sites 1, 2 and 3.
- The lowest lead concentrations were in upstream Site 10.

Figure 8a. Lead Concentrations from Upstream to Downstream for Baseflow Conditions

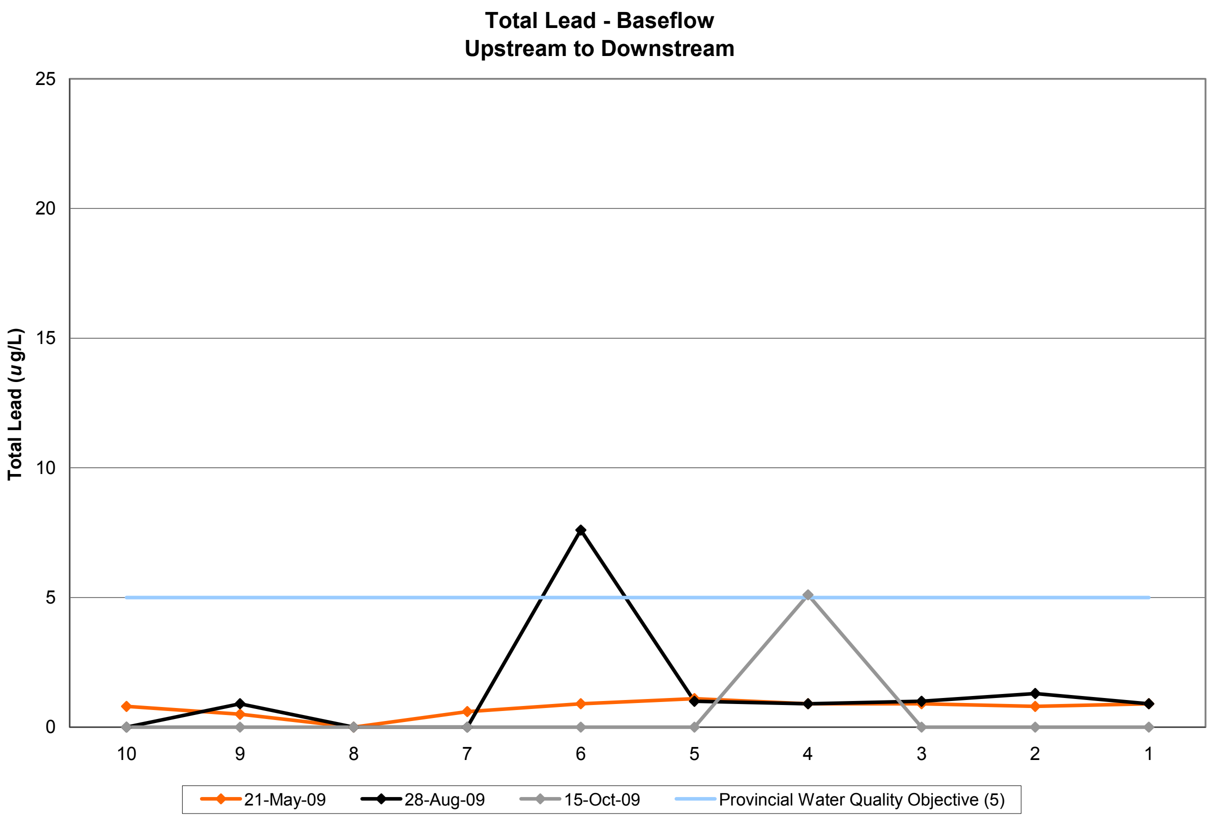
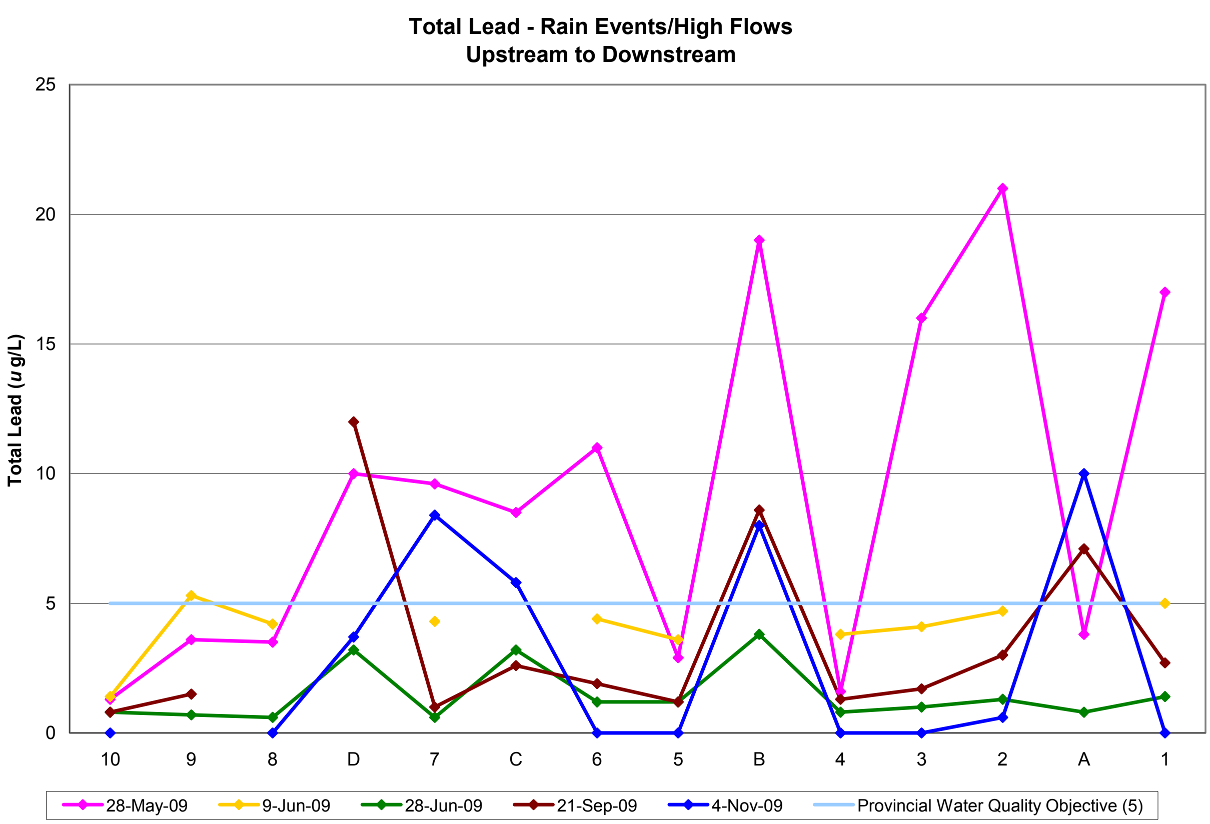


Figure 8b. Lead Concentrations from Upstream to Downstream for Rain Event Conditions



Iron

Sources: Sources of iron include the corrosion of iron or steel products, steel making and metal fabricating, burning of fossil fuels, and the weathering of rocks and soils.
Standards: PWQO of 300 ug/L for aquatic life.
Monitoring Results:

- Iron concentrations exceeded the Provincial Water Quality Objective for 91% of samples with elevated levels occurring across all sample locations. Base flow concentrations were generally lower than runoff concentrations.
- While concentrations at storm drain B were higher than adjacent creek samples, this was not the case for storm drains A, C and D.
- Peak iron levels occurred at creek sites 6, 7 and 9, particularly on three rain event dates.

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Figure 9a. Iron Concentrations from Upstream to Downstream for Baseflow Conditions

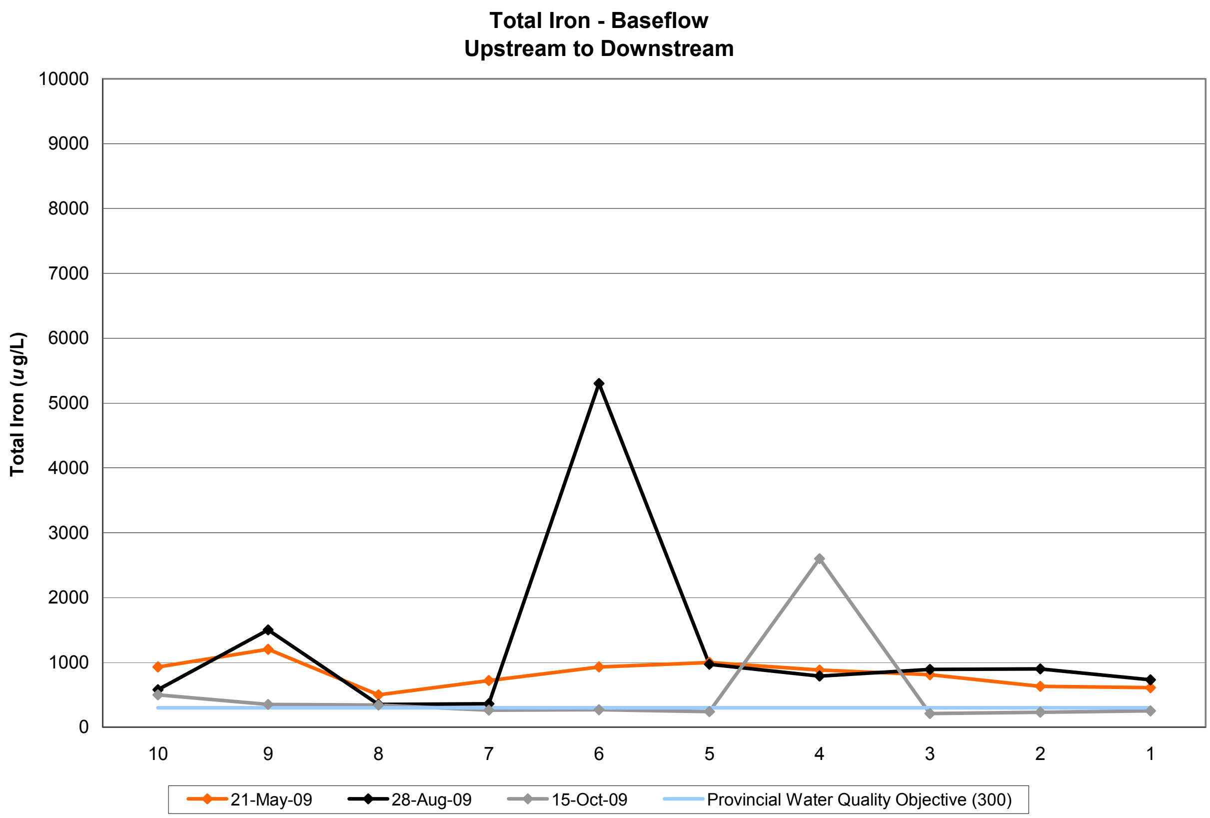
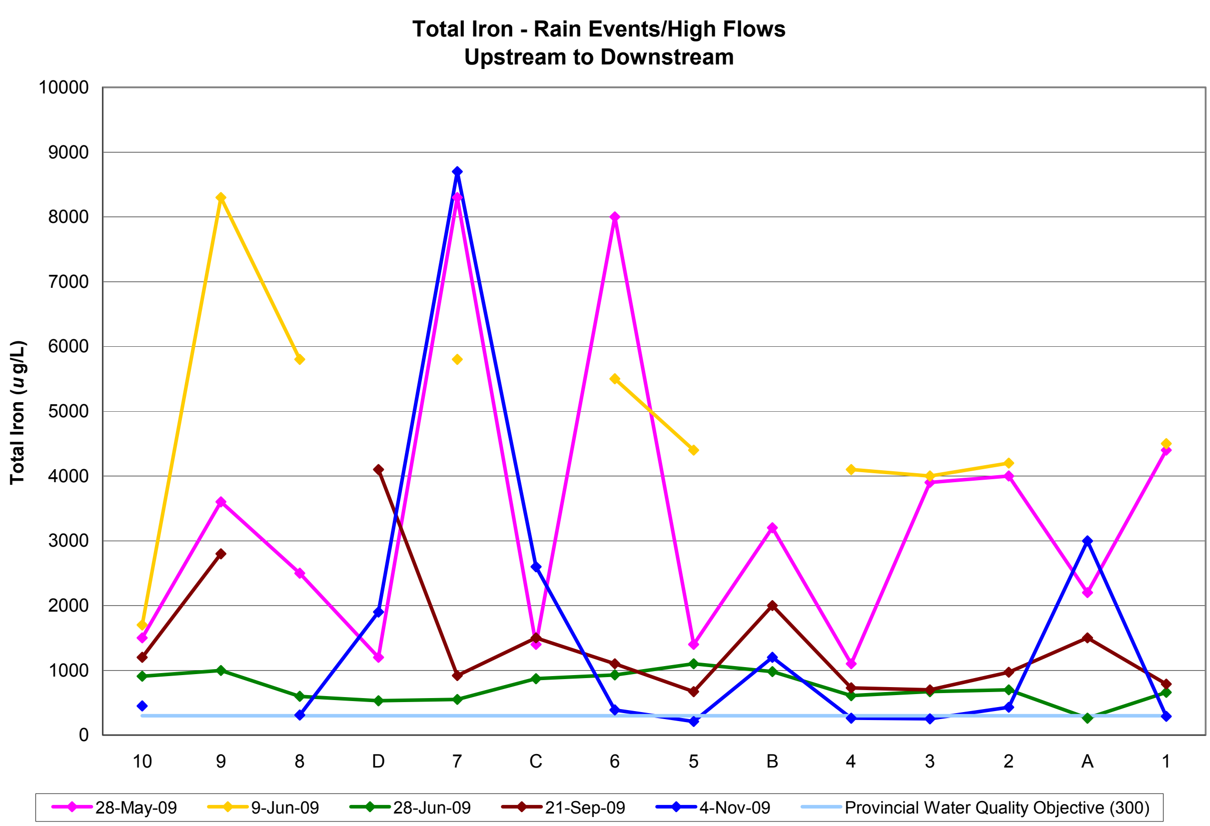


Figure 9b. Iron Concentrations from Upstream to Downstream for Rain Event Conditions



Zinc

Sources: Sources of zinc can include protective coating for iron and steel (galvanizing), production of zinc alloys, electroplaters, combustion of fossil fuels, wood preservatives, herbicides, domestic and industrial wastewater, road surface runoff, and soil erosion.
Standards: PWQO of 20 ug/L for aquatic life.
Monitoring Results:

- Zinc concentrations at the 10 creek sites exceeded the Provincial Water Quality Objective for 42% of rain/runoff event samples and only 7% of the base flow samples, indicating some sources delivered by runoff.
- All four storm drain sites showed peaks in zinc levels and all storm drain samples exceeded the provincial guideline. While concentrations were higher at all of the storm drain samples, creek samples upstream and downstream of monitored storm drains did not show significant change in zinc concentrations at the time of monitoring.

Figure 10a. Zinc Concentrations from Upstream to Downstream for Baseflow Conditions

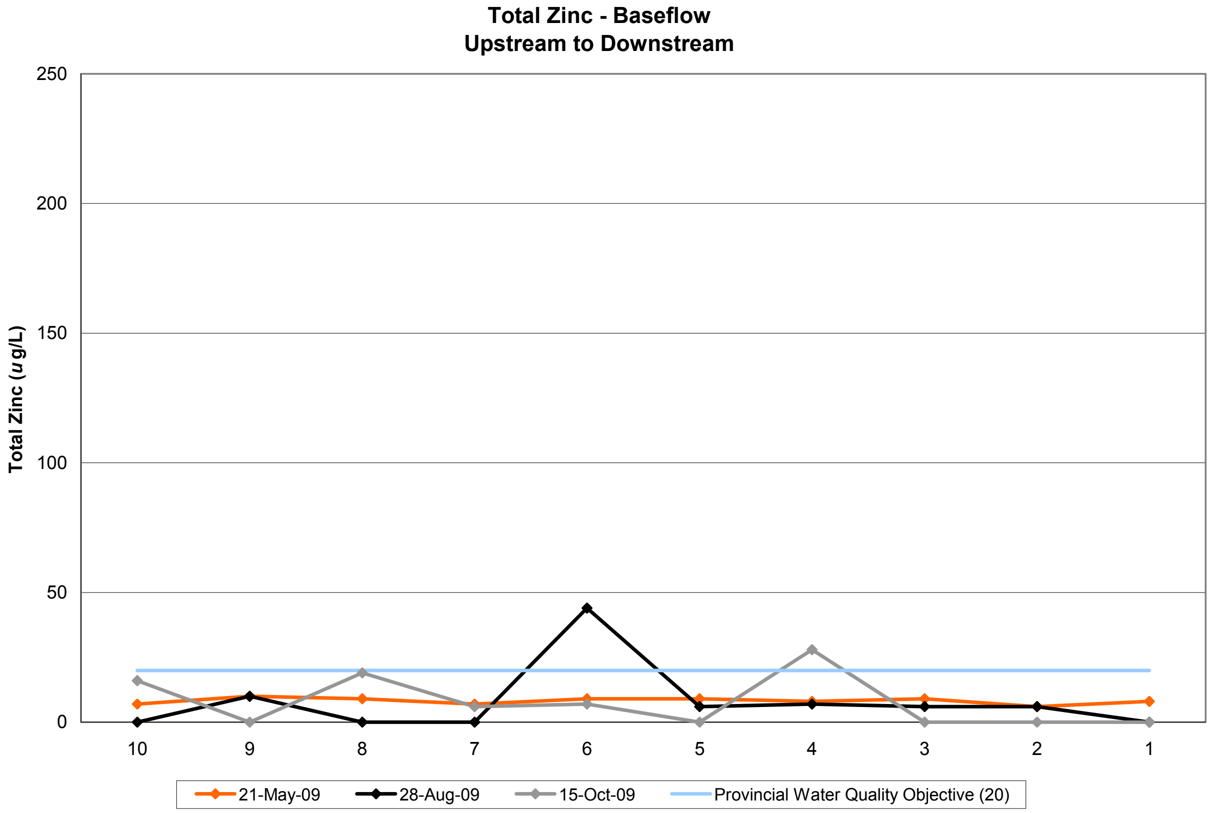
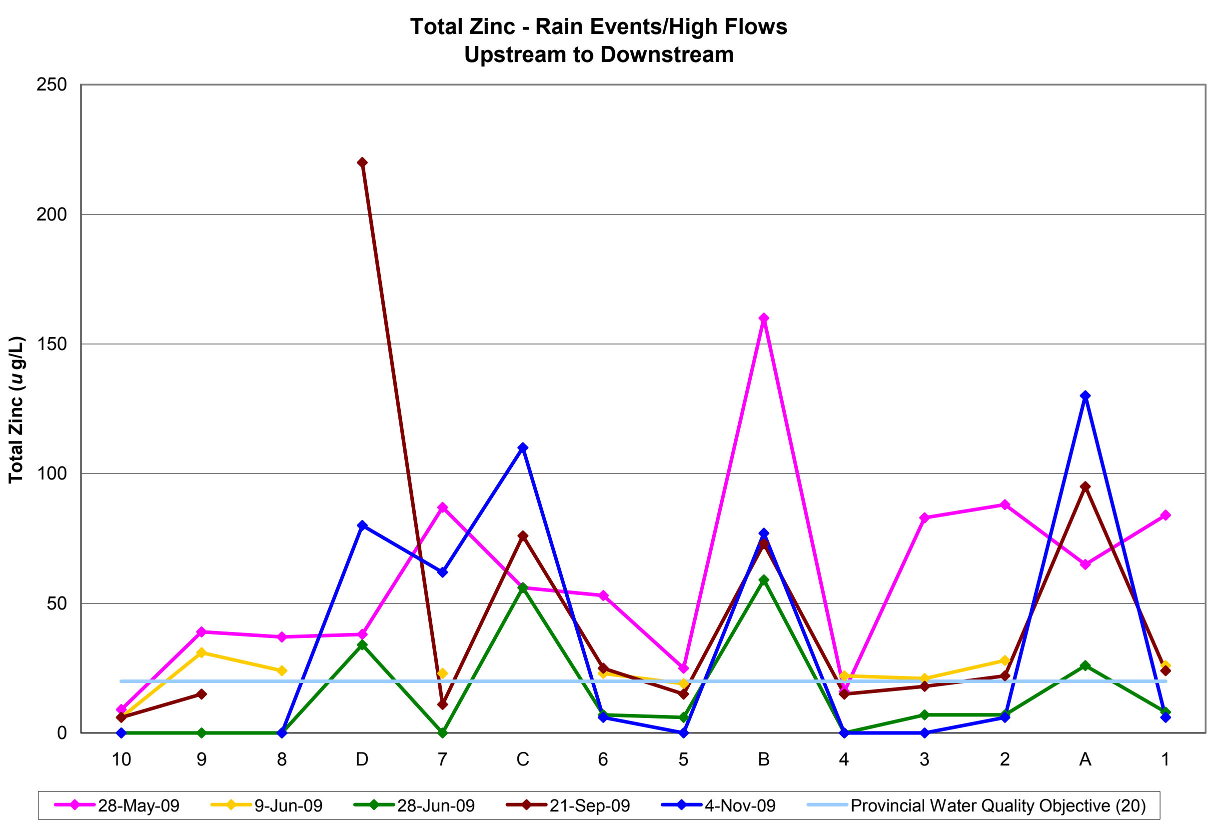


Figure 10b. Zinc Concentrations from Upstream to Downstream for Rain Event Conditions



Cobalt

Sources: The largest use of cobalt metal is to make alloys. Cobalt is also used in pigments for ceramics and glass, in paints and varnishes, semiconductors, enamel coatings on steel, electroplating, batteries, and as a fertilizer and feed additive.

Standards: PWQO of 0.9 ug/L for aquatic life.

Monitoring Results:

- Cobalt concentrations exceeded the Provincial Water Quality Objective for 34% of rain/runoff event samples and only 3% of the base flow samples, indicating some sources delivered by runoff.
- Peak cobalt levels occurred at creek sites 6, 7 and 9 on three rain event dates
- Concentrations of cobalt in the storm drain and creek samples were relatively low compared to other metals monitored.

Figure 11a. Cobalt Concentrations from Upstream to Downstream for Baseflow Conditions

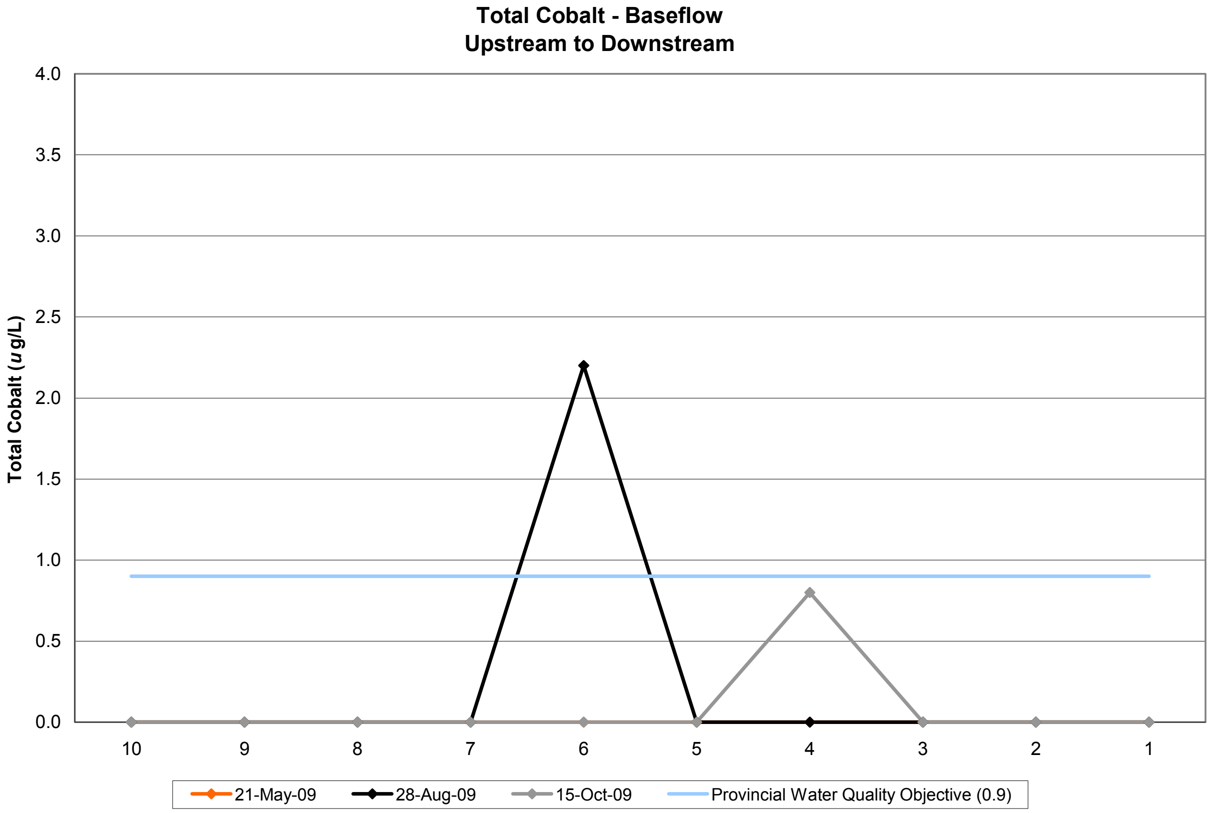
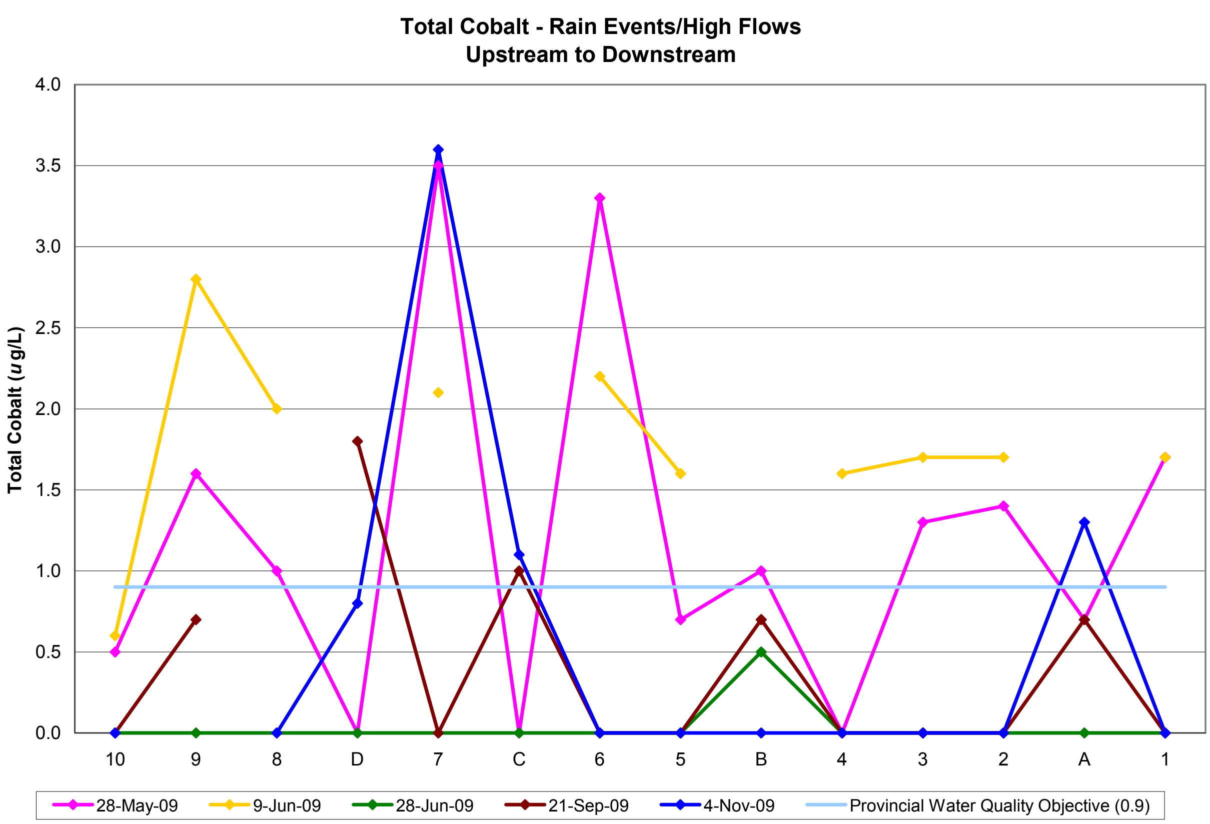


Figure 11b. Cobalt Concentrations from Upstream to Downstream for Rain Event Conditions



3.2 Results: Benthos Monitoring

Methods of analyzing benthos data are diverse, ranging from simple metrics such as Taxa Richness (the total number of different families found in the subsamples) to complex multivariate analyses. For this study, Hilsenhoff's[9] Family Biotic Index (FBI), a relatively simple and fairly consistent and reliable metric, has been utilized. The FBI assigns a biotic index value to each benthos family through a range of 0-10, with 0 being families requiring pristine conditions while those assigned a 10 can survive in severely impacted conditions. A weighted average of the biotic index values of all BMI identified is calculated for each sample. This FBI allows placement of the sample in various water quality/stream health categories from excellent (<4.25) to very poor (>7.5).

Table 1 provides the FBI values for the samples collected in 2009. The detailed information for this table is provided in Appendix B. In addition to the 2009 data, FBI values from 51 samples conducted at 12 sites in the Cedar Creek watershed from previous years are available in a separate document. Figure 12 outlines 2009 benthos FBI results, arranged from headwaters to outflow.

Table 1. Cedar Creek 2009 Benthic Water Quality Sampling Summary

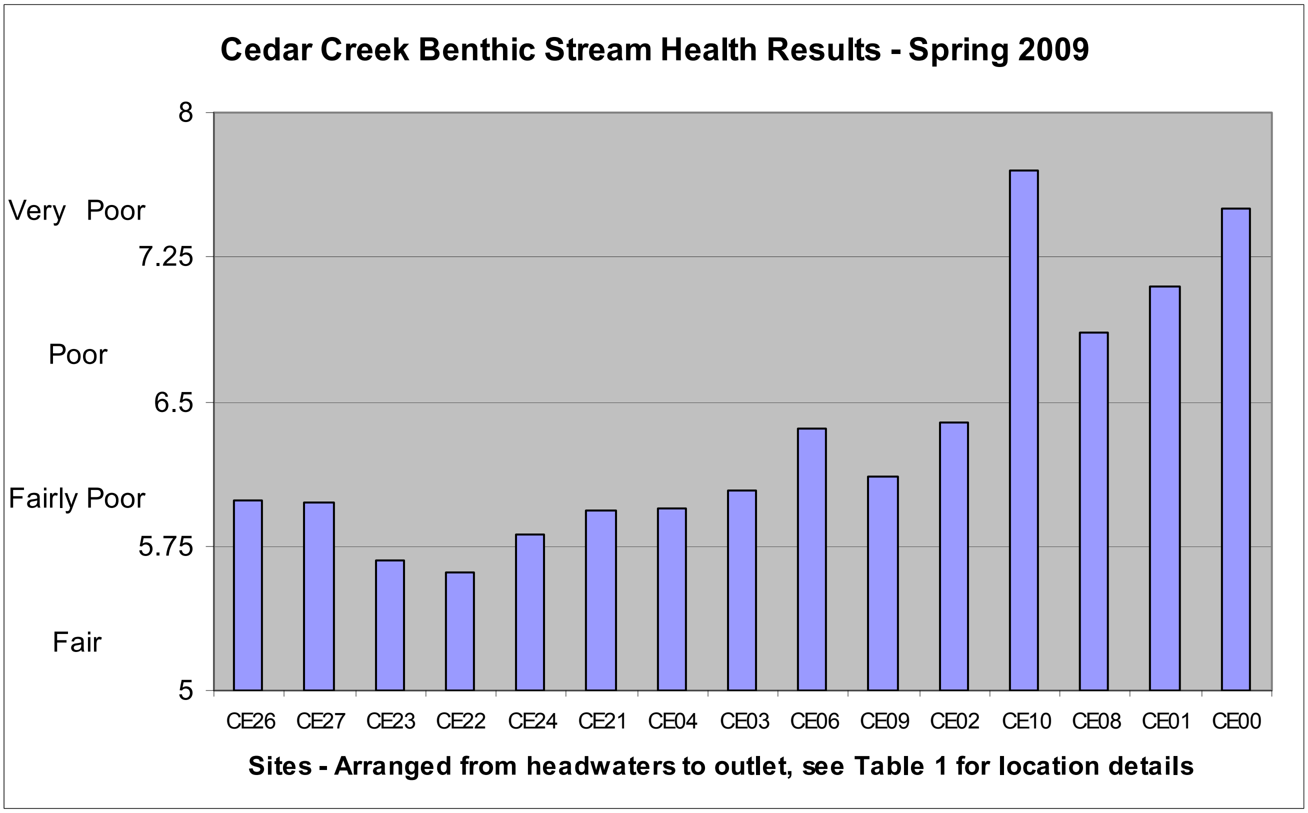
Watercourse Information			Spring Sample Results			Fall Sample Results		
Name	Site Code	Location	Date	Family Biotic Index (FBI) Value		Date	Family Biotic Index (FBI) Value	
Waite Drain	CE26	Dodge Line	May 27	5.99	Fairly Poor			
Rice Drain	CE27	Gunn's Hill Rd.	May 27	5.97	Fairly Poor			
Unnamed Spring Creek	CE23	Northwest of Cedar Line and Rivers Rd.	May 27	5.67	Fair			
Sweaburg Drain	CE22	Cedar line	May 27	5.61	Fair			
Lampman Drain	CE24	At Highway 59	May 27	5.80	Fairly Poor			
Mud Creek	CE21	near outlet to Cedar Cr.	May 27	5.94	Fairly Poor	Sept 30	5.94	Fairly Poor
Cedar Creek	CE04	Curries Road	May 27	5.94	Fairly Poor	Sept 30	5.60	Fair
	CE03	South of Hwy 401	May 27	6.03	Fairly Poor	Sept 30	5.60	Fair
	CE06	Upstream of 401 near Patullo Ave.	May 27	6.36	Fairly Poor			
	CE09	North of 401 at end of Athlone Pl.	May 28	6.11	Fairly Poor	Sept 30	5.77	Fairly Poor
	CE02	Southside Park, artificial riffle site	May 28	6.39	Fairly Poor	Sept 30	6.03	Fairly Poor
	CE10	Southside park near Finkle St.	May 28	7.70	Very Poor	Sept 30	5.57	Fair
	CE07	Butler Street				Sept 30	5.17	Fair
	CE08	Off Park Lane near Mill St.	May 28	6.86	Poor	Sept 30	6.08	Fairly Poor
	CE01	Westend Park behind Chuckwagon	May 27	7.10	Poor	Sept 30	4.74	Good
	CE00	Near outlet to S. Thames off Hwy 2	May 28	7.50	Very Poor	Sept 30	4.83	Good

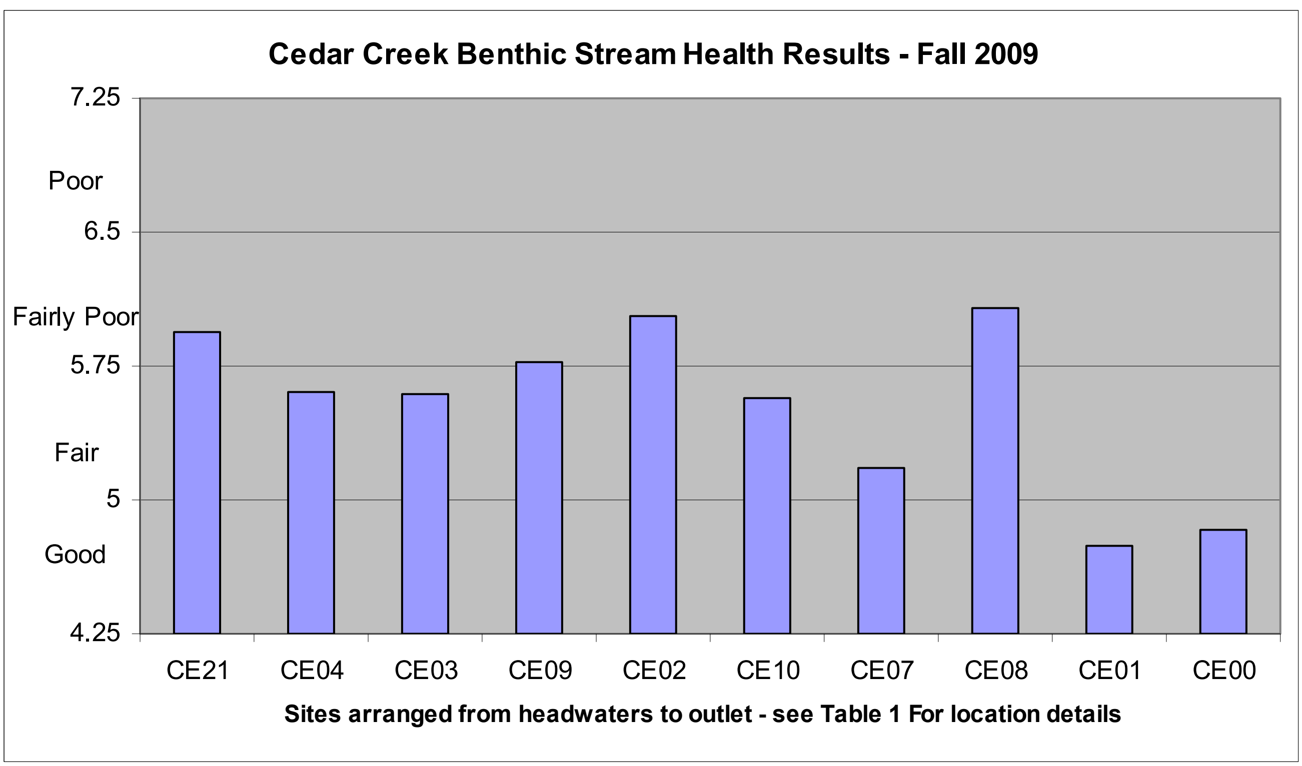
Sites are arranged from headwaters to outlet

Biotic indices are values assigned to benthic invertebrate taxa indicating their pollution sensitivity and tolerance on a scale from 0 to 10. Lower numbers indicate pollution sensitivity; high numbers indicate tolerance. The Family Biotic Index (FBI) is the weighted average of the biotic index and number of bugs in each taxa in the sample. The water quality ranges for the FBI values are as follows:

< 4.25 = Excellent
4.25 - 5.00 = Good
5.00 - 5.75 = Fair
5.75 - 6.50 = Fairly Poor
6.50 - 7.25 = Poor
> 7.25 = Very Poor

Figure 12. **2009 Benthos FBI Results Arranged from Headwaters to Outflow**





3.3 Results: Fish Monitoring

Historically, 36 fish species have been recorded from the Cedar Creek watershed. This number is based on data collected from 36 samples conducted at 19 sites over the last 35 years from UTRCA, the Ontario Ministry of Natural Resources (OMNR), and Royal Ontario Museum (ROM) databases (2009 data appended, complete data records for all years available on request). Of these species, 22 were encountered during 2009 sampling including one previously unrecorded species, Blackside Darter. The fish species are listed in Table 2.

Table 2. Fish Species Summary - Cedar Creek 2009 Sampling

Common Name	Scientific Name	Species at Risk		Native	Coldwater	Sensitive Species	Target	Migrant
		Federal	Provincial					
Black Bullhead	*Ameiurus melas*			✓				
Blacknose Dace	*Rhinichthys atratulus*			✓				
Blackside Darter	*Percina maculata*			✓				
Bluntnose Minnow	*Pimephales notatus*			✓				
Brook Stickleback	*Culaea inconstans*			✓				
Brown Bullhead	*Ameiurus nebulosus*			✓				
Central Mudminnow	*Umbra limi*			✓				
Central Stoneroller	*Campostoma anomalum*			✓				
Common Carp	*Cyprinus carpio*							
Common Shiner	*Luxilus cornutus*			✓				
Creek Chub	*Semotilus atromaculatus*			✓				
Fathead Minnow	*Pimephales promelas*			✓				
Greenside Darter	*Etheostoma blennioides*			✓				
Johnny Darter	*Etheostoma nigrum*			✓				
Largemouth Bass	*Micropterus salmoides*			✓		✓	✓	
Northern Hog Sucker	*Hypentelium nigricans*			✓				
Rock Bass	*Ambloplites rupestris*			✓		✓	✓	
Rosyface Shiner	*Notropis rubellus*			✓				
Smallmouth Bass	*Micropterus dolomieu*			✓		✓	✓	
Stonecat	*Noturus flavus*			✓				
Striped Shiner	*Luxilus chrysocephalus*			✓				
White Sucker	*Catostomus commersoni*			✓				✓

Coldwater: Life history information was reviewed in “Morphological and Ecological Characteristics of Canadian Freshwater Fishes” to identify species habitat, including thermal ‘preferences.’ These species are found in coldwater habitats, defined as having water temperatures of less than 19°C.
Native: A species indigenous to a particular region or area.
Migrant: A species that travels a significant distance in order to carry out one of its life history requirements, such as spawning.
Sensitive: In 2005, Coker and Portt identified sensitive species in the draft "Sensitive Species List for Agricultural Municipal Drain Clean Outs." Sensitive species have specific habitat requirements, and any alterations to their habitat could prove to be detrimental to the species.

Target: Indicates if the species is a sportfish and considered a top level predator or a species requiring the same habitat as a top level predator. Generally speaking, any species that is targeted for angling purposes would be a sportfish.
Species at Risk - Federal: The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses species for their consideration for legal protection and recovery (or management) under the Species at Risk Act (SARA) (current to September 2009).
Species at Risk - Provincial: Species at Risk in Ontario (SARO) are designated by the Ontario Ministry of Natural Resources (OMNR) in accordance with the provincial Endangered Species Act (ESA 2007) through the Committee on the Status of Species at Risk in Ontario (COSSARO) (current to September 2009).

4.0 Discussion and Recommendations

The recommendations for Cedar Creek outlined in the Woodstock Natural Heritage Study (2007) and the Cedar Creek Watershed Report Card (UTRCA 2007) continue to be applicable to the needs of the watershed but have not been reiterated in full in this report. The following are discussions and **recommendations (highlighted)** based on the 2009 study results. It should be noted that there are some limitations to drawing conclusions or making definitive recommendations based on one year of sampling data.

4.1 Water Chemistry and Bacteria – Discussion and Recommendations

Water chemistry and bacteria sampling in 2009 showed there was generally great fluctuation in the data throughout the system, particularly during rain/runoff events. A direct link between the water quality of the four storm drains monitored and the water quality in the closest creek samples was not always clearly apparent. While concentrations were often higher at the storm drain samples, creek samples upstream and downstream of monitored storm drains did not show significant change in pollutant concentrations at the time of sampling. However, benthic invertebrate monitoring, which measures longer term water quality at a site, indicated impaired conditions immediately downstream of storm drains with the largest change at storm drain B. The water quality data indicates a multitude of pollution sources throughout the watershed impacting water quality from upstream to downstream. **This would suggest that broad scale initiatives to reduce pollution throughout Cedar Creek (versus, for example, addressing treatment of one specific storm drain point source) would be key to improving the water quality of Cedar Creek.**

Also observed during monitoring was the low volume of water discharged from some storm drains during rain events, particularly storm drain B. In any given rain event, there was a relatively short period of time during which the storm drains had high flow for capturing a water sample. **Storm drain B with its large drainage area had unexpectedly low flow during rain events and further assessment of this may be warranted.**

Bacteria levels throughout Cedar Creek remain elevated. **Any effort to reduce continuous source (e.g., faulty septic systems) and rain/runoff sources (e.g., pet waste, livestock manure) would be beneficial. Strategies to minimize waste from geese in parkland (e.g., landscaping techniques) would help to reduce bacteria in Cedar Creek.**

Total phosphorus concentrations are elevated throughout the system, particularly during rain/runoff events. **Strategies to minimize fertilizer and waste runoff in the upstream watershed and within Woodstock would be beneficial.**

Most of the pollutants (nutrients, metals) are transported to and through the creek during rain/runoff events. Metals were generally low in base flow samples (below guideline for all but iron, except at site 4 and 6 where peaks occurred in samples for zinc, iron, lead, cobalt, and copper**). Any effort to prevent pollutants from reaching storm drains and efforts to treat stormwater will benefit aquatic life in the creek. One potential project would be a storm drain marking program (e.g., Yellow Fish Road) to raise public awareness about the risk of pollution entering Cedar Creek through storm drains and to remind the public about the proper disposal of household hazardous wastes.** The need for this type of public awareness was made clear during water sampling in November when a fuel spill was observed in the creek. Follow-up revealed fuel had been discarded in storm drain A. Any education and awareness program for the public and industry on spills reporting would also be beneficial.

There has been some recent interest in re-establishing a local action group called the Friends of Cedar Creek. A community action group could be one approach to implementing some of the awareness and implementation activities in the watershed.

4.2 Benthic – Discussion and Recommendations

Spring sampling results, as illustrated in Figure 12, indicated moderately impaired stream health in upper Cedar Creek and its tributaries, with conditions generally declining as Cedar Creek traveled through Woodstock. The single largest change occurred at the two sites (CE02 and CE10 in Figure 12) in Southside Park located up and downstream of the storm drain B outflow. This change indicates that the benthos community structure may be responding to elevated pollution levels, either periodically or from a single event. **Further assessment and, potentially, targeted remedial actions may be warranted.**

The upstream benthos results are fairly typical for rural Southwestern Ontario and reflect the cumulative effects of such things as agricultural runoff, habitat and flow disruptions from loss of riparian vegetation, stream channelization and altered flow (eg. field tiling for drainage). Rural BMPs as set out in the previously referenced documents (1, 2, 3) could mitigate these impacts and result in improved water quality entering Woodstock. **The application of rural BMPs should be encouraged. For example, the Clean Water Program effectively provides technical guidance and financial incentives.**

Although a fairly clear declining trend was evident through Woodstock, benthos sampling results do not reveal causes. Likely contributors are impacts from the Southside Park impoundment (disrupted stream function, excess sediment deposition, nutrient enrichment, etc.) stormwater borne contaminants, spills and, possibly, industrial discharges.

The fall results do not reflect the trend indicated in the spring sites and include some unusual and unexpected results. Generally, fall samples indicate slightly improved stream health, which is more a reflection of the life cycles of some of the sampled benthos than of changes in aquatic ecosystem condition. While most sites demonstrated the expected slight improvement, the two furthest downstream sites showed a remarkable improvement, achieving “Good” scores. The site located in Westend Park improved from an FBI averaged over the previous 13 years of 7.16 to 4.74, a jump of three stream health categories. Two possible explanations are offered for these dramatic improvements. First, the removal of a significant pollution point source (or sources) upstream of Westend Park shortly after the May sampling could have contributed to the change. Second, consistent flows from a wet summer could have diluted inputs that had depressed water quality in previous years. This would allow mid-tolerant BMI taxa, which are usually present in relatively low numbers in impaired waters, to flourish. Particularly in the presence of good quality benthic habitat, taxa such as net-spinning caddisflies and riffle beetles (as illustrated in Appendix B) were able to greatly increase their numbers over the summer. Further sampling would determine if either of these explanations has merit.

The trend towards improved water quality/stream health as Cedar Creek progressed from the headwaters to downstream reaches evident in the fall samples is observed in several Upper Thames watersheds[2]. Streams such as Gregory, Black and Oxbow Creeks have fairly intensive agriculture with altered watercourses and limited riparian vegetation in the upper portions of their watersheds. The downstream portions have relatively undisturbed stream channels protected by extensive riparian vegetation. Well buffered natural channels with meandering channels and alternate riffle and pool habitats host abundant and diverse aquatic micro- and macro-fauna. This enhanced biological activity can metabolize some of the excess nutrients and pollutants introduced from upstream, resulting in some improvements to water quality. The habitat assessments generally indicated higher quality in-stream and riparian cover in Cedar Creek in Woodstock compared to upstream sites. In addition, habitat conditions seemed to improve from the upstream Woodstock sites to the sites nearest the South Thames outflow. **Efforts should be made to protect and enhance the relatively natural sections of Cedar Creek and its riparian zone. Reaches that have seriously degraded habitat should be improved. Examples are Southside Park and Cedar Creek Golf Course (the Downs) where work that has been initiated should continue.**

The presence of two barriers also has serious negative impacts on Cedar Creek’s water quality and aquatic biota. The dams at Hodges’s Pond and in Southside Park, in addition to presenting a barrier to fish movement, tend to elevate water temperatures, lower dissolved oxygen levels, reduce flows during drought conditions due to evaporation, affect sediment transport and trap nutrient rich sediments. **Potential remedies include barrier removal and stream channel restoration, or retention of the ponds and creation of bypass channels. If neither of these solutions should prove plausible, other mitigation measures include installing structures to promote fish passage and naturalizing shorelines and riparian zones.** The latter would alter the present conditions which are ideal for Canada Geese (and their significant nutrient inputs).

4.3 Fish

All fish sampled were fairly common, widespread species typical of warmwater stream communities in Southern Ontario. The presence, on average, of over a dozen species at the three sites downstream of the Southside Park barrier is indicative of relatively high quality, diverse habitat with connectivity with a larger watercourse, the South Thames River. Young of the year Smallmouth and Largemouth Bass in 2009 and Northern Pike in 1997 were sampled at Southside Park. **This likely indicates that Cedar Creek serves as a spawning and nursery area for South Thames gamefish and, with improved habitat and water quality, it might be capable of supporting a sport fishery.** Fewer fish species were found at upstream sites. This likely indicates somewhat more degraded habitat and the impacts of the barriers in Southside Park and at Hodges Pond that prevent fish movement and tend to partition fish habitat (i.e., isolating different habitat types necessary for some species to complete their life cycles). **Previously stated recommendations for mitigating barrier impacts and preserving and enhancing stream and riparian habitat would also greatly benefit Cedar Creek's fish community.**

Large amounts of debris observed in Cedar Creek and its riparian zone also impact fish habitat, to some extent water quality, and the recreational potential and aesthetic quality of the stream corridor. **Regular garbage removal through programs such as "The Thames River Cleanup" is recommended.**

4.4 Summary of Report Recommendations

1. Broad scale initiatives to reduce pollution throughout Cedar Creek (versus, for example, addressing treatment of one specific storm drain) would be key to improving the water quality of Cedar Creek.

2. Storm drain B with its large drainage area had unexpectedly low flow during rain events and further assessment of this may be warranted.

3. Any effort to reduce continuous source bacteria (e.g., faulty septic systems) and rain/runoff sources (e.g., pet waste, livestock manure) would be beneficial. Strategies to minimize waste from geese in parkland (e.g., landscaping techniques) would help to reduce bacteria in Cedar Creek.

4. Strategies to minimize fertilizer and waste runoff in the upstream watershed and within Woodstock would be beneficial to reduce phosphorus levels.

5. Any effort to prevent pollutants from reaching storm drains and efforts to treat stormwater will benefit aquatic life in the creek. One potential project would be a storm drain marking program (e.g., Yellow Fish Road) to raise public awareness about the risk of pollution entering Cedar Creek through storm drains and to remind the public about the proper disposal of household hazardous wastes.

6. The application of rural BMPs should be encouraged. For example, the Clean Water Program effectively provides technical guidance and financial incentives.

7. Efforts should be made to protect and enhance the relatively natural sections of Cedar Creek and its riparian zone. Reaches that have seriously degraded habitat should be improved. Examples are Southside Park and Cedar Creek Golf Course (the Downs) where work that has been initiated should continue.

8. Potential remedies to the effects of barriers/dams currently in Cedar Creek include barrier removal and stream channel restoration, or retention of the ponds and creation of bypass channels. If neither of these solutions should prove plausible, other mitigation measures could include installing structures to promote fish passage and naturalizing shorelines and riparian zones.

9. Cedar Creek serves as a spawning and nursery area for South Thames gamefish and, with improved habitat and water quality, it might be capable of supporting a sport fishery. Mitigating barrier impacts and preserving and enhancing stream and riparian habitat would greatly benefit Cedar Creek's fish community.

10. Regular garbage removal through programs such as "The Thames River Cleanup" is recommended.

11. There has been some recent interest in re-establishing a local action group called the Friends of Cedar Creek. A community action group could be one approach to implementing some of the awareness and implementation activities in the watershed.

References

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Appendix A. Site Conditions for Water Quality Monitoring Dates

May 21
The first sample collection happened on May 21 with 10 creek sites sampled. The water at the sites was turbid, and still in high flows from the spring melt.

May 28
The second sample collection occurred on May 28 which was a storm event that captured peak runoff. Ten creek sites and four storm drains were sampled and they were turbid and in flood conditions.

June 9
Ten creek site samples were collected. Although no storm drain samples were collected, this was a runoff event where everything was turbid and in flood conditions.

June 28
Ten creek sites and four storm drains were sampled as a large storm event was beginning.

August 28
Ten creek sites were sampled. All sites were turbid and low, even though flow data indicated a storm event.

September 21
A small storm event was sampled, and 10 creek sites and four storm drains were collected. All sites were turbid with most of them having elevated flows from runoff. Some sites had runoff but no elevated flows.

October 15
Ten creek sites were sampled. They were all clear and low with little flow.

November 4
Ten creek sites and four storm drains were collected during a small storm event. A few sites were in flood conditions and a visual assessment on some sites was not possible because they were sampled after dark.

Appendix B. Cedar Creek Benthos Community – 2009 Study

Watercourse And Site Code	Location	Sample Date	Taxonomic Name	Common Name	Life Stage	# Individuals	Biotic Index	Family Biotic Index	Stream Health
Cedar Creek	Butler Street	30-Sep-09	*Acariformes*	Water Mite	A	10	4		
CE07			*Baetidae*	Small Mayfly	N	11	4		
			Caenidae	Crawling Mayfly	N	2	7		
			Chironomidae	Midge	L	73	6		
			Chironomidae	Midge	P	4	6		
			Elmidae	Riffle Beetle	A	1	4		
			Elmidae	Riffle Beetle	L	28	4		
			Empididae	Dance Fly	L	11	6		
			Heptageniidae	Stream Mayfly	N	5	4		
			Hydropsychidae	Net-spinning Caddisfly	L	99	4		
			Nematoda	Thread Worm	A	1	-1		
			Oligochaeta	Aquatic Worm	A	16	8		
			Philopotamidae	Finger-net Caddisfly	L	1	3		
			Simuliidae	Black Fly	L	12	6		
			Sphaeriidae	Fingernail Clam	A	32	8		
			Turbellaria	Flatworm	A	33	4	5.174556213	Fair
CE04	Curries Road	27-May-09	*Acariformes*	Water Mite	A	2	4		
			Asellidae	Sow Bug	A	1	8		
			Baetidae	Small Mayfly	N	10	4		
			Caenidae	Crawling Mayfly	N	2	7		
			Capniidae	Stonefly	N	1	1		
			Ceratopogonidae	Biting Midge	L	1	6		
			Chironomidae	Midge	L	259	6		
			Chironomidae	Midge	P	17	6		
			Elmidae	Riffle Beetle	A	7	4		

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Watercourse And Site Code	Location	Sample Date	Taxonomic Name	Common Name	Life Stage	# Individuals	Biotic Index	Family Biotic Index	Stream Health
			Elmidae	Riffle Beetle	L	13	4		
			Empididae	Dance Fly	L	2	6		
			Empididae	Dance Fly	P	2	6		
			Erpobdellidae	Leech	A	1	10		
			Haliplidae	Crawling Water Beetle	A	1	5		
			Hydropsychidae	Net-spinning Caddisfly	L	2	4		
			Oligochaeta	Aquatic Worm	A	22	8		
			Simuliidae	Black Fly	L	1	6		
			Sphaeriidae	Fingernail Clam	A	1	8	5.942028986	Fairly Poor
		30-Sep-09	*Acariformes*	Water Mite	A	55	4		
			Caenidae	Crawling Mayfly	N	15	7		
			Capniidae	Stonefly	N	2	1		
			Ceratopogonidae	Biting Midge	L	2	6		
			Chironomidae	Midge	L	178	6		
			Corixidae	Water Boatmen	A	3	5		
			Elmidae	Riffle Beetle	L	22	4		
			Glossiphoniidae	Leech	A	1	8		
			Heptageniidae	Stream Mayfly	N	2	4		
			Nematoda	Thread Worm	A	2	-1		
			Oligochaeta	Aquatic Worm	A	10	8		
			Phryganeidae	Large Caddisfly	L	1	4		
			Simuliidae	Black Fly	L	2	6		
			Sphaeriidae	Fingernail Clam	A	8	8		
			Tabanidae	Horse Fly	L	2	6	5.603960396	Fair
CE00	Near outlet to S. Thames off Hwy 2	28-May-09	*Acariformes*	Water Mite	A	2	4		
			Asellidae	Sow Bug	A	1	8		
			Caenidae	Crawling Mayfly	N	2	7		

2009 Cedar Creek Water Quality Study

Watercourse And Site Code	Location	Sample Date	Taxonomic Name	Common Name	Life Stage	# Individuals	Biotic Index	Family Biotic Index	Stream Health
			Chironomidae	Midge	L	53	6		
			Chironomidae	Midge	P	5	6		
			Elmidae	Riffle Beetle	L	10	4		
			Hydropsychidae	Net-spinning Caddisfly	L	1	4		
			Oligochaeta	Aquatic Worm	A	276	8		
			Simuliidae	Black Fly	L	3	6		
			Simuliidae	Black Fly	P	1	6	7.497175141	Very Poor
		30-Sep-09	*Acariformes*	Water Mite	A	29	4		
			Ancylidae	Limpet	A	3	6		
			Asellidae	Sow Bug	A	5	8		
			Baetidae	Small Mayfly	N	15	4		
			Caenidae	Crawling Mayfly	N	22	7		
			Chironomidae	Midge	L	56	6		
			Chironomidae	Midge	P	10	6		
			Elmidae	Riffle Beetle	A	3	4		
			Elmidae	Riffle Beetle	L	54	4		
			Empididae	Dance Fly	L	11	6		
			Heptageniidae	Stream Mayfly	N	1	4		
			Hydropsychidae	Net-spinning Caddisfly	L	162	4		
			Leptoceridae	Long-horned Caddisfly	L	2	4		
			Nematoda	Thread Worm	A	2	-1		
			Oligochaeta	Aquatic Worm	A	7	8		
			Simuliidae	Black Fly	L	6	6		
			Sphaeriidae	Fingernail Clam	A	12	8		
			Tipulidae	Crane Fly	L	2	3		
			Turbellaria	Flatworm	A	1	4	4.827930175	Good
CE09	North of 401 at end of	28-May-09	*Acariformes*	Water Mite	A	9	4		

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Watercourse And Site Code	Location	Sample Date	Taxonomic Name	Common Name	Life Stage	# Individuals	Biotic Index	Family Biotic Index	Stream Health
	Athlone Pl.		*Asellidae*	Sow Bug	A	23	8		
			Caenidae	Crawling Mayfly	N	1	7		
			Chironomidae	Midge	L	216	6		
			Chironomidae	Midge	P	31	6		
			Corixidae	Water Boatmen	A	7	5		
			Cyclopoida	Fish Lice	A	4	8		
			Dytiscidae	Predacious Diving Beetle	L	1	5		
			Elmidae	Riffle Beetle	A	1	4		
			Elmidae	Riffle Beetle	L	12	4		
			Empididae	Dance Fly	L	3	6		
			Empididae	Dance Fly	P	1	6		
			Glossiphoniidae	Leech	A	2	8		
			Hydrophilidae	Water Scavenger Beetle	L	1	5		
			Leptoceridae	Long-horned Caddisfly	L	1	4		
			Oligochaeta	Aquatic Worm	A	17	8		
			Simuliidae	Black Fly	L	2	6	6.114457831	Fairly Poor
		30-Sep-09	*Acariformes*	Water Mite	A	5	4		
			Ancylidae	Limpet	A	1	6		
			Asellidae	Sow Bug	A	6	8		
			Baetidae	Small Mayfly	N	1	4		
			Caenidae	Crawling Mayfly	N	2	7		
			Ceratopogonidae	Biting Midge	L	1	6		
			Chironomidae	Midge	L	221	6		
			Corixidae	Water Boatmen	A	65	5		
			Cyclopoida	Fish Lice	A	1	8		
			Daphniidae	Water Flea	A	1	8		
			Elmidae	Riffle Beetle	L	19	4		

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Watercourse And Site Code	Location	Sample Date	Taxonomic Name	Common Name	Life Stage	# Individuals	Biotic Index	Family Biotic Index	Stream Health
			Heptageniidae	Stream Mayfly	N	4	4		
			Oligochaeta	Aquatic Worm	A	10	8		
			Simuliidae	Black Fly	L	1	6		
			Sphaeriidae	Fingernail Clam	A	4	8	5.774853801	Fairly Poor
	Off Park Lane near Mill St.	28-May-09	*Acariformes*	Water Mite	A	3	4		
CE08			*Asellidae*	Sow Bug	A	7	8		
			Caenidae	Crawling Mayfly	N	11	7		
			Chironomidae	Midge	L	142	6		
			Chironomidae	Midge	P	14	6		
			Cyclopoida	Fish Lice	A	8	8		
			Dytiscidae	Predacious Diving Beetle	L	1	5		
			Elmidae	Riffle Beetle	L	6	4		
			Empididae	Dance Fly	P	1	6		
			Oligochaeta	Aquatic Worm	A	126	8	6.858934169	Poor
		30-Sep-09	*Acariformes*	Water Mite	A	21	4		
			Ancylidae	Limpet	A	1	6		
			Asellidae	Sow Bug	A	3	8		
			Caenidae	Crawling Mayfly	N	93	7		
			Chironomidae	Midge	L	114	6		
			Chironomidae	Midge	P	1	6		
			Cyclopoida	Fish Lice	A	1	8		
			Elmidae	Riffle Beetle	A	5	4		
			Elmidae	Riffle Beetle	L	16	4		
			Empididae	Dance Fly	L	10	6		
			Heptageniidae	Stream Mayfly	N	12	4		
			Hydropsychidae	Net-spinning Caddisfly	L	40	4		
			Oligochaeta	Aquatic Worm	A	55	8		

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Watercourse And Site Code	Location	Sample Date	Taxonomic Name	Common Name	Life Stage	# Individuals	Biotic Index	Family Biotic Index	Stream Health
			Simuliidae	Black Fly	L	2	6		
			Sphaeriidae	Fingernail Clam	A	7	8		
			Tipulidae	Crane Fly	L	2	3		
			Turbellaria	Flatworm	A	1	4	6.075520833	Fairly Poor
CE03	South of Highway 401	27-May-09	*Acariformes*	Water Mite	A	10	4		
			Asellidae	Sow Bug	A	21	8		
			Baetidae	Small Mayfly	N	1	4		
			Capniidae	Stonefly	N	1	1		
			Chironomidae	Midge	L	230	6		
			Chironomidae	Midge	P	20	6		
			Elmidae	Riffle Beetle	A	3	4		
			Elmidae	Riffle Beetle	L	11	4		
			Empididae	Dance Fly	L	2	6		
			Empididae	Dance Fly	P	5	6		
			Hydropsychidae	Net-spinning Caddisfly	L	2	4		
			Hydroptilidae	Micro-caddisfly	L	1	4		
			Nematoda	Thread Worm	A	1	-1		
			Oligochaeta	Aquatic Worm	A	14	8		
			Simuliidae	Black Fly	L	4	6		
			Sphaeriidae	Fingernail Clam	A	1	8	6.033742331	Fairly Poor
		30-Sep-09	*Acariformes*	Water Mite	A	56	4		
			Asellidae	Sow Bug	A	1	8		
			Baetidae	Small Mayfly	N	1	4		
			Caenidae	Crawling Mayfly	N	4	7		
			Capniidae	Stonefly	N	1	1		
			Chironomidae	Midge	L	138	6		
			Chironomidae	Midge	P	3	6		

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Watercourse And Site Code	Location	Sample Date	Taxonomic Name	Common Name	Life Stage	# Individuals	Biotic Index	Family Biotic Index	Stream Health
			Elmidae	Riffle Beetle	A	3	4		
			Elmidae	Riffle Beetle	L	31	4		
			Empididae	Dance Fly	L	22	6		
			Glossiphoniidae	Leech	A	1	8		
			Hydropsychidae	Net-spinning Caddisfly	L	6	4		
			Hydroptilidae	Micro-caddisfly	L	3	4		
			Nematoda	Thread Worm	A	2	-1		
			Oligochaeta	Aquatic Worm	A	31	8		
			Simuliidae	Black Fly	L	15	6		
			Sphaeriidae	Fingernail Clam	A	14	8		
			Turbellaria	Flatworm	A	16	4	5.598265896	Fair
CE10	Southside park near Finkle St.	28-May-09	*Acariformes*	Water Mite	A	2	4		
			Asellidae	Sow Bug	A	8	8		
			Caenidae	Crawling Mayfly	N	3	7		
			Chironomidae	Midge	L	29	6		
			Chironomidae	Midge	P	9	6		
			Cyclopoida	Fish Lice	A	55	8		
			Daphniidae	Water Flea	A	3	8		
			Dytiscidae	Predacious Diving Beetle	L	1	5		
			Elmidae	Riffle Beetle	A	1	4		
			Oligochaeta	Aquatic Worm	A	202	8		
			Ostracoda	Seed Shrimp	A	1	8		
			Simuliidae	Black Fly	L	1	6		
			Trichoptera	Caddisfly	P	1	-1	7.695238095	Very Poor
		30-Sep-09	*Acariformes*	Water Mite	A	11	4		
			Asellidae	Sow Bug	A	9	8		
			Baetidae	Small Mayfly	N	11	4		

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Watercourse And Site Code	Location	Sample Date	Taxonomic Name	Common Name	Life Stage	# Individuals	Biotic Index	Family Biotic Index	Stream Health
			Caenidae	Crawling Mayfly	N	52	7		
			Ceratopogonidae	Biting Midge	L	1	6		
			Chironomidae	Midge	L	78	6		
			Chironomidae	Midge	P	8	6		
			Elmidae	Riffle Beetle	A	3	4		
			Elmidae	Riffle Beetle	L	20	4		
			Empididae	Dance Fly	L	4	6		
			Heptageniidae	Stream Mayfly	N	4	4		
			Hydropsychidae	Net-spinning Caddisfly	L	90	4		
			Nematoda	Thread Worm	A	2	-1		
			Oligochaeta	Aquatic Worm	A	33	8		
			Simuliidae	Black Fly	L	2	6		
			Simuliidae	Black Fly	P	1	6		
			Sphaeriidae	Fingernail Clam	A	7	8		
			Turbellaria	Flatworm	A	10	4	5.569767442	Fair
CE02	Southside Park, artificial riffle site	28-May-09	*Asellidae*	Sow Bug	A	8	8		
			Baetidae	Small Mayfly	N	4	4		
			Caenidae	Crawling Mayfly	N	2	7		
			Chironomidae	Midge	L	117	6		
			Chironomidae	Midge	P	23	6		
			Elmidae	Riffle Beetle	L	14	4		
			Empididae	Dance Fly	P	1	6		
			Hydropsychidae	Net-spinning Caddisfly	L	12	4		
			Hydroptilidae	Micro-caddisfly	L	6	4		
			Oligochaeta	Aquatic Worm	A	102	8		
			Simuliidae	Black Fly	L	25	6		
			Sphaeriidae	Fingernail Clam	A	3	8		

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Watercourse And Site Code	Location	Sample Date	Taxonomic Name	Common Name	Life Stage	# Individuals	Biotic Index	Family Biotic Index	Stream Health
			Turbellaria	Flatworm	A	13	4	6.393939394	Fairly Poor
		30-Sep-09	*Acariformes*	Water Mite	A	13	4		
			Asellidae	Sow Bug	A	4	8		
			Baetidae	Small Mayfly	N	3	4		
			Caenidae	Crawling Mayfly	N	1	7		
			Chironomidae	Midge	L	119	6		
			Chironomidae	Midge	P	9	6		
			Cyclopoida	Fish Lice	A	1	8		
			Elmidae	Riffle Beetle	A	1	4		
			Elmidae	Riffle Beetle	L	2	4		
			Empididae	Dance Fly	L	11	6		
			Heptageniidae	Stream Mayfly	N	3	4		
			Hydropsychidae	Net-spinning Caddisfly	L	37	4		
			Hydroptilidae	Micro-caddisfly	L	1	4		
			Oligochaeta	Aquatic Worm	A	75	8		
			Simuliidae	Black Fly	L	36	6		
			Sphaeriidae	Fingernail Clam	A	35	8		
			Turbellaria	Flatworm	A	50	4	6.027431421	Fairly Poor
CE06	Upstream of 401 near Patullo Ave.	27-May-09	*Acariformes*	Water Mite	A	8	4		
			Asellidae	Sow Bug	A	17	8		
			Baetidae	Small Mayfly	N	1	4		
			Caenidae	Crawling Mayfly	N	2	7		
			Chironomidae	Midge	L	200	6		
			Chironomidae	Midge	P	13	6		
			Cyclopoida	Fish Lice	A	1	8		
			Elmidae	Riffle Beetle	L	13	4		
			Empididae	Dance Fly	L	3	6		

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Watercourse And Site Code	Location	Sample Date	Taxonomic Name	Common Name	Life Stage	# Individuals	Biotic Index	Family Biotic Index	Stream Health
			Empididae	Dance Fly	P	5	6		
			Hydroptilidae	Micro-caddisfly	L	1	4		
			Nematoda	Thread Worm	A	1	-1		
			Oligochaeta	Aquatic Worm	A	65	8		
			Simuliidae	Black Fly	L	12	6		
			Simuliidae	Black Fly	P	1	6		
			Sphaeriidae	Fingernail Clam	A	2	8		
			Tipulidae	Crane Fly	L	1	3	6.356521739	Fairly Poor
CE01	Westend Park behind Chuckwagon	27-May-09	*Acariformes*	Water Mite	A	2	4		
			Asellidae	Sow Bug	A	12	8		
			Baetidae	Small Mayfly	N	9	4		
			Caenidae	Crawling Mayfly	N	1	7		
			Chironomidae	Midge	L	84	6		
			Chironomidae	Midge	P	10	6		
			Elmidae	Riffle Beetle	A	2	4		
			Elmidae	Riffle Beetle	L	17	4		
			Empididae	Dance Fly	L	6	6		
			Hydropsychidae	Net-spinning Caddisfly	L	6	4		
			Hydroptilidae	Micro-caddisfly	L	2	4		
			Nematoda	Thread Worm	A	6	-1		
			Oligochaeta	Aquatic Worm	A	260	8		
			Simuliidae	Black Fly	L	14	6		
			Simuliidae	Black Fly	P	3	6		
			Trichoptera	Caddisfly	P	1	-1	7.095794393	Poor
		30-Sep-09	*Acariformes*	Water Mite	A	12	4		
			Baetidae	Small Mayfly	N	14	4		
			Caenidae	Crawling Mayfly	N	11	7		

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Watercourse And Site Code	Location	Sample Date	Taxonomic Name	Common Name	Life Stage	# Individuals	Biotic Index	Family Biotic Index	Stream Health
			Chironomidae	Midge	L	34	6		
			Elmidae	Riffle Beetle	A	9	4		
			Elmidae	Riffle Beetle	L	58	4		
			Empididae	Dance Fly	L	8	6		
			Heptageniidae	Stream Mayfly	N	3	4		
			Hydropsychidae	Net-spinning Caddisfly	L	215	4		
			Nematoda	Thread Worm	A	2	-1		
			Oligochaeta	Aquatic Worm	A	24	8		
			Simuliidae	Black Fly	L	3	6		
			Sphaeriidae	Fingernail Clam	A	24	8		
			Turbellaria	Flatworm	A	8	4	4.744680851	Good
Lampman Drain	At Highway 59	27-May-09	*Acariformes*	Water Mite	A	3	4		
			Baetidae	Small Mayfly	N	9	4		
CE24			*Chironomidae*	Midge	L	282	6		
			Chironomidae	Midge	P	2	6		
			Cyclopoida	Fish Lice	A	1	8		
			Dytiscidae	Predacious Diving Beetle	L	1	5		
			Elmidae	Riffle Beetle	A	1	4		
			Elmidae	Riffle Beetle	L	25	4		
			Gammaridae	Sideswimmer	A	1	4		
			Hydroptilidae	Micro-caddisfly	L	5	4		
			Nematoda	Thread Worm	A	3	-1		
			Oligochaeta	Aquatic Worm	A	12	8		
			Perlodidae	Stonefly	N	1	2	5.804664723	Fairly Poor
Mud Creek	Butler Property near outlet to Cedar Cr.	27-May-09	*Acariformes*	Water Mite	A	6	4		
CE21			*Asellidae*	Sow Bug	A	6	8		
			Baetidae	Small Mayfly	N	1	4		

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Watercourse And Site Code	Location	Sample Date	Taxonomic Name	Common Name	Life Stage	# Individuals	Biotic Index	Family Biotic Index	Stream Health
			Ceratopogonidae	Biting Midge	L	2	6		
			Chironomidae	Midge	L	242	6		
			Chironomidae	Midge	P	8	6		
			Corixidae	Water Boatmen	A	11	5		
			Elmidae	Riffle Beetle	A	4	4		
			Elmidae	Riffle Beetle	L	11	4		
			Empididae	Dance Fly	L	1	6		
			Hydropsychidae	Net-spinning Caddisfly	L	1	4		
			Leptoceridae	Long-horned Caddisfly	L	1	4		
			Oligochaeta	Aquatic Worm	A	8	8		
			Ostracoda	Seed Shrimp	A	1	8		
			Sphaeriidae	Fingernail Clam	A	5	8	5.938311688	Fairly Poor
		30-Sep-09	*Acariformes*	Water Mite	A	6	4		
			Asellidae	Sow Bug	A	6	8		
			Caenidae	Crawling Mayfly	N	2	7		
			Chironomidae	Midge	L	118	6		
			Chironomidae	Midge	P	1	6		
			Coenagrionidae	Narrow-winged Damselfly	N	1	9		
			Corixidae	Water Boatmen	A	98	5		
			Cyclopoida	Fish Lice	A	6	8		
			Elmidae	Riffle Beetle	L	18	4		
			Empididae	Dance Fly	L	1	6		
			Glossiphoniidae	Leech	A	1	8		
			Hydropsychidae	Net-spinning Caddisfly	L	1	4		
			Oligochaeta	Aquatic Worm	A	45	8		
			Ostracoda	Seed Shrimp	A	1	8		

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Watercourse And Site Code	Location	Sample Date	Taxonomic Name	Common Name	Life Stage	# Individuals	Biotic Index	Family Biotic Index	Stream Health
			Sphaeriidae	Fingernail Clam	A	4	8		
			Turbellaria	Flatworm	A	1	4	5.938709677	Fairly Poor
Rice Drain	Gunn's Hill Rd.	27-May-09	*Baetidae*	Small Mayfly	N	7	4		
CE27			*Chironomidae*	Midge	L	333	6		
			Chironomidae	Midge	P	9	6		
			Elmidae	Riffle Beetle	L	1	4		
			Hydroptilidae	Micro-caddisfly	L	1	4		
			Nematoda	Thread Worm	A	5	-1		
			Oligochaeta	Aquatic Worm	A	7	8		
			Perlodidae	Stonefly	N	2	2		
			Simuliidae	Black Fly	L	5	6		
			Sphaeriidae	Fingernail Clam	A	1	8	5.972677596	Fairly Poor
Sweaburg Drain	Cedar Line	27-May-09	*Acariformes*	Water Mite	A	1	4		
			Baetidae	Small Mayfly	N	127	4		
CE22			*Capniidae*	Stonefly	N	1	1		
			Ceratopogonidae	Biting Midge	L	3	6		
			Chironomidae	Midge	L	121	6		
			Chironomidae	Midge	P	15	6		
			Diptera	Two-winged Fly	P	1	-1		
			Dytiscidae	Predacious Diving Beetle	L	4	5		
			Hydroptilidae	Micro-caddisfly	L	1	4		
			Oligochaeta	Aquatic Worm	A	66	8		
			Simuliidae	Black Fly	L	4	6		
			Simuliidae	Black Fly	P	1	6		
			Sphaeriidae	Fingernail Clam	A	1	8	5.614492754	Fair
Unnamed Spring Creek	Northwest of Cedar Line and Rivers Rd.	27-May-09	*Acariformes*	Water Mite	A	1	4		
			Baetidae	Small Mayfly	N	35	4		

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Watercourse And Site Code	Location	Sample Date	Taxonomic Name	Common Name	Life Stage	# Individuals	Biotic Index	Family Biotic Index	Stream Health
CE23			*Ceratopogonidae*	Biting Midge	L	2	6		
			Chironomidae	Midge	L	111	6		
			Chironomidae	Midge	P	1	6		
			Dytiscidae	Predacious Diving Beetle	L	4	5		
			Elmidae	Riffle Beetle	A	1	4		
			Gammaridae	Sideswimmer	A	5	4		
			Isotomidae	Springtail	A	1	5		
			Lepidostomatidae	Lepistomatid Caddisfly	L	1	1		
			Leptoceridae	Long-horned Caddisfly	L	1	4		
			Limnephilidae	Northern Caddisfly	L	2	4		
			Perlodidae	Stonefly	N	1	2		
			Simuliidae	Black Fly	L	147	6		
			Stratiomyidae	Soldier Fly	L	1	7	5.671974522	Fair
Waite Drain	Dodge Line	27-May-09	*Acariformes*	Water Mite	A	6	4		
CE26			*Ceratopogonidae*	Biting Midge	L	1	6		
			Chironomidae	Midge	L	274	6		
			Chironomidae	Midge	P	12	6		
			Dytiscidae	Predacious Diving Beetle	L	4	5		
			Nematoda	Thread Worm	A	5	-1		
			Oligochaeta	Aquatic Worm	A	6	8	5.98679868	Fairly Poor

Benthic Samples were obtained using a Rapid Bioassessment Protocol developed by the United States Environmental Protection Agency, and modified by Dr. Robert Bailey of the University of Western Ontario Zoology Department.
A representative section of stream is selected, incorporating a riffle (if present), and sampled by moving upstream along a diagonal transect, dislodging and capturing invertebrates with a .5 mm mesh "D"- frame net. Samples are preserved in the field and analyzed in the lab to randomly select a 100 bug subsample which is identified to the Family taxonomic level.

The biotic index is a value assigned to benthic invertebrate taxa indicating their pollution sensitivity and tolerance on a scale from 0 to 10. Lower numbers indicate pollution sensitivity; high numbers indicate tolerance. A value of -1 indicates that no biotic index value has been assigned to these taxa.

The Family Biotic Index (FBI) is the weighted average of the biotic index and number of bugs in each taxon in the sample. The water quality ranges for the FBI values are as follows: < 4.25 = Excellent; 4.25 - 5.00 = Good; 5.00 - 5.75 = Fair; 5.75 - 6.50 = Fairly Poor; 6.50 - 7.25 = Poor; and > 7.25 = Very Poor.

Appendix C. Cedar Creek Fish Sampling Records – 2009 Study

Watercourse Name And Site code	Location	Sample Date	Common Name	Scientific Name	Thames
Cedar Creek	Gunn's Hill Road	17-Nov-09	Blacknose Dace	*Rhinichthys atratulus*	Abundant
CE903			Bluntnose Minnow	*Pimephales notatus*	Abundant
			Brook Stickleback	*Culaea inconstans*	Abundant
			Creek Chub	*Semotilus atromaculatus*	Abundant
			Greenside Darter	*Etheostoma blennioides*	Abundant
			Johnny Darter	*Etheostoma nigrum*	Abundant
			White Sucker	*Catostomus commersoni*	Abundant
CE00	Near outlet off Hwy 2	04-Nov-09	Blackside Darter	*Percina maculata*	Abundant
			Bluntnose Minnow	*Pimephales notatus*	Abundant
			Common Shiner	*Luxilus cornutus*	Abundant
			Creek Chub	*Semotilus atromaculatus*	Abundant
			Greenside Darter	*Etheostoma blennioides*	Abundant
			Johnny Darter	*Etheostoma nigrum*	Abundant
			Rock Bass	*Ambloplites rupestris*	Abundant
			Stonecat	*Noturus flavus*	Abundant
			White Sucker	*Catostomus commersoni*	Abundant
CE02	Southside Park	04-Nov-09	Black Bullhead	*Ameiurus melas*	Common
			Blackside Darter	*Percina maculata*	Abundant
			Bluntnose Minnow	*Pimephales notatus*	Abundant
			Brook Stickleback	*Culaea inconstans*	Abundant
			Central Stoneroller	*Campostoma anomalum*	Abundant
			Common Shiner	*Luxilus cornutus*	Abundant
			Creek Chub	*Semotilus atromaculatus*	Abundant
			Greenside Darter	*Etheostoma blennioides*	Abundant
			Johnny Darter	*Etheostoma nigrum*	Abundant

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Watercourse Name And Site code	Location	Sample Date	Common Name	Scientific Name	Thames
			Largemouth Bass	*Micropterus salmoides*	Abundant
			Northern Hog Sucker	*Hypentelium nigricans*	Abundant
			Rock Bass	*Ambloplites rupestris*	Abundant
			Smallmouth Bass	*Micropterus dolomieu*	Abundant
			Stonecat	*Noturus flavus*	Abundant
			Striped Shiner	*Luxilus chrysocephalus*	Abundant
			White Sucker	*Catostomus commersoni*	Abundant
CE03	South of Hwy 401	17-Nov-09	Blacknose Dace	*Rhinichthys atratulus*	Abundant
			Bluntnose Minnow	*Pimephales notatus*	Abundant
			Common Carp	*Cyprinus carpio*	Abundant
			Creek Chub	*Semotilus atromaculatus*	Abundant
			Greenside Darter	*Etheostoma blennioides*	Abundant
			Johnny Darter	*Etheostoma nigrum*	Abundant
			White Sucker	*Catostomus commersoni*	Abundant
CE08	Off Park Row near Mill Street	17-Nov-09	Blackside Darter	*Percina maculata*	Abundant
			Bluntnose Minnow	*Pimephales notatus*	Abundant
			Brown Bullhead	*Ameiurus nebulosus*	Uncommon
			Central Stoneroller	*Campostoma anomalum*	Abundant
			Common Carp	*Cyprinus carpio*	Abundant
			Creek Chub	*Semotilus atromaculatus*	Abundant
			Greenside Darter	*Etheostoma blennioides*	Abundant
			Johnny Darter	*Etheostoma nigrum*	Abundant
			Northern Hog Sucker	*Hypentelium nigricans*	Abundant
			Rock Bass	*Ambloplites rupestris*	Abundant
			Rosyface Shiner	*Notropis rubellus*	Abundant
			Striped Shiner	*Luxilus chrysocephalus*	Abundant
			White Sucker	*Catostomus commersoni*	Abundant

Watercourse Name And Site code	Location	Sample Date	Common Name	Scientific Name	Thames
CE09	Downstream of 401 at end of Athlone Pl.	04-Nov-09	Bluntnose Minnow	*Pimephales notatus*	Abundant
			Creek Chub	*Semotilus atromaculatus*	Abundant
			Greenside Darter	*Etheostoma blennioides*	Abundant
			Johnny Darter	*Etheostoma nigrum*	Abundant
			Rock Bass	*Ambloplites rupestris*	Abundant
			White Sucker	*Catostomus commersoni*	Abundant
Cedar Creek Tributary 1	Cedar Line	17-Nov-09	Brook Stickleback	*Culaea inconstans*	Abundant
			Central Mudminnow	*Umbra limi*	Abundant
CE23			Creek Chub	*Semotilus atromaculatus*	Abundant
Mud Creek	Just upstream of outlet to Cedar Cr.	17-Nov-09	Bluntnose Minnow	*Pimephales notatus*	Abundant
CE21			Brook Stickleback	*Culaea inconstans*	Abundant
			Creek Chub	*Semotilus atromaculatus*	Abundant
			Fathead Minnow	*Pimephales promelas*	Abundant
			Johnny Darter	*Etheostoma nigrum*	Abundant
			White Sucker	*Catostomus commersoni*	Abundant

With respect to the preceding table, the terms are:

Abundance: Refers to the relative abundance or common occurrence of the species found within the waters of the Thames River watershed based on sampling results. Consideration was given to accurately reflect the species presence within the watershed due to the sampling capture method, effort and biases, difficulty in capturing certain species, and anecdotal reporting.

Abundant: More than 50 sample records in the database
Common: Between 15 and 50 sample records in the database
Historical: Species that have been previously recorded in the Thames
Rare: Fewer than 5 sample records in database
Uncommon: Between 5 and 15 sample records in database