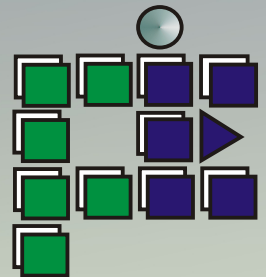




## B - Detailed Studies



PLANNERS

CONSULTING

ENGINEERS &

LANDSCAPE

ARCHITECTS

**SECTION B – DETAILED STUDIES**

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## B 1.0 HYDROGEOLOGY

### B 1.1 Introduction

Precipitation falling within the subwatershed contributes to the recharge of the overburden and bedrock aquifers and to baseflow of Forbes Creek and related wetland areas. Continued groundwater recharge is an important component in sustaining the health of the surfacewater environment within Forbes Creek. Groundwater seepage is the principal contributor to "base flow" in stream and rivers, and this base flow is typically the only reliable source of flow during warm dry periods when small streams are under their greatest ecological stress. The quantity and quality of this base flow is critical to the ecological health of the watercourse, particularly for coolwater and coldwater fish species. Even if existing systems are considered warmwater, the addition of cooler groundwater tends to moderate temperature fluctuations in these systems. Impact on groundwater resources either in terms of quantity or quality can therefore have a significant impact on surfacewater resources, the general ecological environment in the subwatershed and the groundwater resources (in particular the local Region of Waterloo Well H-5).

One of the important objectives of this subwatershed study is the characterization of the groundwater flow regime within the subwatershed, its role sustaining the surfacewater and wetland environments and its susceptibility to impact by land change associated with development.

#### B 1.1.1 Information Sources

The hydrogeological component of the subwatershed study involved the compilation and review of available information regarding the geology, hydrogeology, and general physical characteristics of the study area. Published information was further augmented by the drilling of boreholes, monitoring wells and test pits, and by selected field surveys to locate wells, view natural and artificial soil exposures, view streams under base flow conditions, and to independently verify information obtained from third party sources.

An important information source was the computerized data base of water well records maintained by the Ontario Ministry of the Environment, from records that well drillers are required to submit including drilling locations, soil types, well construction details, and hydraulic test information. A total of 117 Well Records (refer to [Figure B 1.5.1](#)) for wells within the subwatershed and peripheral areas were obtained and reviewed. Analysis of these records forms the basis for much of the geological interpretation prepared for this study, particularly with respect to the buried bedrock topography and deeper overburdened deposits. Other information sources included:

- 1:50,000 scale NTS mapping;
- hydrogeological maps prepared by the Grand River Conservation Authority;
- 1:10,000 scale Ontario base mapping;
- aerial photographs for the subwatershed;
- geological reports and maps from the Ontario Geological Survey;
- engineering reports from local consulting engineers; and,



- borehole and well records from previous Naylor Engineering investigations within or adjacent to the study area.

The Grand River Conservation Authority (GRCA) has carried out a considerable amount of groundwater research and mapping. The GRCA's work involved the compilation and consolidation of the existing geological mapping, updating the MOE's water well record database and the preparation of thematic and summary maps. Much of the information provided in this study was obtained from or modified from prior work by the GRCA, which plays a key role as a custodian of groundwater and surfacewater data within the Grand River basin.

## B 1.2 Field Investigation

### B 1.2.1 Exploratory Test Drilling/Monitoring Well Installation

A program of test drilling was carried out within the subwatershed to better define the geological conditions with particular emphasis on infiltration capability and the extent and characteristics of the principal aquifers and confining aquifers. Fieldwork for this component of the investigation was conducted between November 2000 and January 2001 and involved installation of thirteen monitoring wells, fifty-one boreholes and seventeen mini piezometers at the locations shown on [Figure B 1.2.1](#). Boreholes were carried to depths between 0.9 and 7.9 metres below existing grade using a track mounted CME 55 drill rig owned and operated by Naylor Engineering Associates Ltd. The borehole and test well locations were chosen based on a review of published geological mapping and previous exploratory drilling in the area. Prior to drilling, local utilities were contacted in order to identify any buried services near the boring locations.

Agencies contacted included telephone, electrical utilities, natural gas and cable.

Soil samples were recovered at regular intervals during the drilling operations using the standard penetration test method. Soil samples from each split barrel sampler were subdivided into two sub-samples for moisture content determination and detailed visual classification and laboratory testing respectively.

The information from the field logs is summarized on the appended individual borehole logs included with this report as **Appendix C1**.

Monitoring wells were installed in selected boreholes upon completion of drilling in order to provide geological characterization and groundwater level information over key areas of the subwatershed with particular emphasis given to the eastern portion of the subwatershed where development is greatest. Each monitoring well was constructed using pre-cleaned flush-threaded 15 mm diameter Schedule 40 PVC pipe with rubber O-ring seals to prevent leakage at the riser pipe joints. Monitoring well screens comprised 1.5 to 3.0-metre lengths of Number 10 slot well screen.

The wells were installed by inserting the screen and pipe into the hollow stem of the augers, then pulling back the augers while adding silica sand to pack the screen in place. The sand filter material was added until the level of sand was approximately 0.6 m above the top of the screen. A bentonite seal approximately 0.5 metres thick was then placed on top of the sand pack to prevent infiltration of surfacewater and the remainder of the borehole was backfilled with native drill cuttings to the ground surface. The top of the riser pipe was vented to allow accurate measurement of stabilized groundwater levels.



Seventeen mini piezometers were installed within Forbes Creek and the adjoining floodplain in order to identify which sections of the creek act as groundwater recharge zones or which gain from the influx of groundwater seepage.

### B 1.2.2 Water Level Monitoring

Water levels were measured at monitoring well locations on several occasions in order to determine the stabilized groundwater levels. Water level monitoring was carried out using a Solinst electrical water level meter equipped with both visual and auditory level indicators. The measured groundwater levels are shown on the individual borehole logs in **Appendix C1**.

### B 1.2.3 Hydraulic Testing

Hydraulic conductivity, the rate that water moves through a porous medium under a potential energy gradient was estimated for the shallow overburden soils using the hydrostatic time-lag method of Hvorslev (1951). Hvorslev's method is described by the following equation:

$$K = \frac{r^2 \ln(L/R)}{2LT_0} \quad (1.2.1)$$

where:

- $K$  = hydraulic conductivity of the tested material
- $r$  = radius of the well riser pipe
- $R$  = radius of the sand pack
- $L$  = length of screen and sand pack
- $h$  = water level at each time of measurement
- $H$  = static water level
- $H_0$  = initial water level (start of test)
- $T_0$  = time lag

Hydraulic response curves from the in-situ slug and bail tests are included with this document as **Appendix C2**.

Hydraulic conductivity was also estimated using Hazen's technique using grain size gradation curves obtained from soil samples collected during this investigation. Hazen's method is described by the following equation:

$$K = A(d_{10})^2 \quad (1.2.2)$$

where:

- $K$  = hydraulic conductivity of the tested material (cm/s)
- $d_{10}$  = grain-size diameter (mm) at which 10% by weight of soil particles are finer (percent passing) and 90% are coarser (percent retained)
- $A$  = coefficient equal to 1.0 when  $K$  is in cm/s and  $d_{10}$  is in mm

Though originally developed for use with normally graded sands, Hazen's method can provide a rough but useful approximation for most soils in the fine sand to gravel range. The method is somewhat less accurate for fine-textured soils such as clayey silt and silty clay where fracture permeability dominates over porous flow.

### B 1.2.4 Physical Testing

All soil samples taken during the investigations were returned to Naylor Engineering Associates laboratories for moisture content determination and detailed visual classification. The results of the moisture content information are plotted on the appended monitoring well and borehole logs. Additional geotechnical laboratory tests were carried out on selected samples of the principal subsurface soil types in order to allow estimation of their physical hydrological properties. Physical testing included fifty particle size distribution analyses; and a number of standard Proctor moisture density tests (ASTMC136) for the purpose of completing permeability testing in accordance with ASTM5856.





The results of this physical testing are discussed in the relevant sections of this report while the specific laboratory test results are provided in **Appendix C3**.

### B 1.2.5 Water Sampling And Analysis

Geochemical characteristics of groundwater within the study area were determined through a program of spatially distributed sampling and chemical analysis. Samples of groundwater were collected from the wells following development and purging to ensure that the sample was representative of the groundwater source.

Samples were analyzed for a comprehensive list of general chemistry parameters and metals including calcium, magnesium, chloride, nitrate, sulfate, and alkalinity (expressed as equivalent calcium carbonate). Parameters for analysis were chosen either to serve as indicators of the natural chemical evolution of the groundwater or to identify potential inorganic contaminants and their spatial distribution within the subwatershed.

Groundwater samples were transported to Conestoga Rovers and Associates (CRA) Laboratory Services Division in Waterloo, Ontario for chemical analysis. The results of this testing are further discussed in this report while the laboratory Certificates of Analysis are provided in **Appendix C4**.

## B 1.3 Geological Setting

### B 1.3.1 Physiography And Drainage

The topography of the Forbes Creek subwatershed is gently rolling with an overall slope toward the adjacent Speed River which is the dominant physiographic feature in the area. Ground surface elevations range from 325 MASL in the south/central portions of the subwatershed to a low

of approximately 295 MASL along the banks of Speed River.

The Forbes Creek subwatershed is located near the boundary of two physiographic regions of Southern Ontario known as the Horseshoe Moraines and the Guelph Drumlin Field (Chapman and Putman, 1984). The subwatershed is located along the western limit of the Paris Moraine, the northernmost of the three moraine systems that make up the Horseshoe Moraines. The Paris Moraine is characterized by regular topography with elevated uplands containing numerous kettle depressions of closed drainage. Kame sands and gravels and sandy silt till make up the bulk of the soil profile in the upland areas of the moraine system with outwash granular deposits and organic soils frequently encountered in the low areas.

The Guelph Drumlin Field is characterized as a drumlinized till plain dissected by meltwater spillways. The dominant soils are stony silt and sand tills and gravel terraces along the low-lying spillways.

### B 1.3.2 Overburden Geology

Continental ice sheets have previously scoured the ground surface of southern Ontario eroding or filling in earlier features such as rivers and lakes. The ice sheets left behind a variety of deposits including glacial till, and melt out deposits ranging from sand and gravel to fine silts and clay. The pattern of erosion and deposition was repeated through successive glacial periods. Glacial processes produced the majority of overburden soil deposits within the study area. Our understanding of the geological history is largely restricted to the period after the last glacial activity although earlier sediments may be present in deeply buried soils overlying bedrock. For additional information on this topic, references can be made to Chapman and Putman (1989).





During the beginning of the late Wisconsinian, glacial ice advanced across the Cambridge area depositing very dense sandy silt till known as the Catfish Creek till. Subsequent advances and retreats of the glacial ice deposited the more recent Port Stanley and Wentworth Tills and a variety of glaciolacustrine and glaciofluvial deposits. Since the final retreat of glacial ice from the area, geological activity has been limited to incision of modern stream valleys, the deposition of alluvial sediments, and the deposition of organic materials in wetland and bog areas. [Figure B 1.3.1](#) shows the surficial geology within the Forbes Creek subwatershed area.

As part of the Subwatershed Study, exploratory test holes were drilled at 64 locations across the study area in order to observe soil types and characteristics. The data collected at these sites were used along with information from MOE water well records (see [Figure B 1.5.1](#)) to construct a series of five geological cross sections shown on [Figures B 1.3.2, 1.3.3](#). The locations of the cross sections are shown on [Figure B 1.3.4](#).

Different geological units are described in the following subsections:

#### **B 1.3.2.1 Catfish Creek Till**

Catfish Creek Till was originally described and named by Devries and Dreimanis (1971) from exposures on the north shore of Lake Erie. Catfish Creek Till is a buried deposit that is only exposed locally in deeply eroded areas or encountered in deep boreholes. An older till exposed overlying bedrock along the east bank of the Speed River may be Catfish Creek Till. The till is a stony to bouldery, extremely dense, sandy silt till that typically ranges between 3 to 10 metres in thickness. Where unweathered, it is a light gray to grayish brown colour turning to a yellowish brown where weathered and oxidized. Catfish

Creek till has been dated to the late Wisconsinian stage. Karrow (1987 and 1993) describes the Catfish Creek Till as a stony sandy silt till, with little matrix clay content.

#### **B 1.3.2.2 Port Stanley Till**

Port Stanley Till is encountered in the subsurface along the western limit of the subwatershed area. It is a hard sandy silt-textured till with some trace clay and occasional cobbles and boulders. Grain size distribution testing completed by Karrow (1993) reveals an average clay content of 15% and sand content ranging between 18 and 60%. The coarser facies of this till closely resemble the younger Wentworth Till and the two tills are easily mistaken.

#### **B 1.3.2.3 Wentworth Till**

Wentworth Till is the surface till over much of the study area. Wentworth Till is a coarse stony to bouldery, sandy silt till that is commonly weathered and loosely compacted (Karrow, 1987). It has been mapped by Karrow (1987) as the surficial material in a wide band along the western boundary of the Paris and Galt Moraines in close association with ice contact sand and gravel. The till appears to be absent along part of the west bank of the Speed River where it has likely been removed by glaciofluvial erosion.

An average hydraulic conductivity ( $k$ ) of  $3 \times 10^{-7}$  m/s has been estimated for the Wentworth Till based on the results of 17 grain size distribution analysis and slug tests as summarized in **Table B 1.3.1**.





Table B 1.3.1 Silt Till

Borehole	K (m/s)	Method	Description
MW1	1.0E-08	Hazen	sandy silt, some clay, trace gravel
MW13	2.5E-07	Hazen	sand and silt, trace gravel, trace clay
BH107	1.2E-07	Hazen	silty sand, trace clay, trace gravel
BH112	1.6E-08	Hazen	sand and silt, some gravel, some clay
BH121	2.5E-07	Hazen	silty sand, trace clay, trace gravel
BH123	2.3E-08	Hazen	sand and silt, some gravel, some clay
BH126	2.5E-07	Hazen	silty sand, trace clay, trace gravel
BH127	2.3E-08	Hazen	silt, some sand, some clay
BH131	1.4E-08	Hazen	silt and sand, some gravel, some clay
BH132	1.4E-08	Hazen	silty sand, some gravel, some clay
BH142	9.0E-08	Hazen	silt and sand, some gravel, trace clay
BH146	3.1E-08	Hazen	sand and silt, some gravel, trace clay
BH147	1.2E-07	Hazen	silty sand, some gravel, trace clay
BH148	7.2E-07	Hazen	silty sand, trace clay
MW11	7.6E-08	Slug	compact sand / compact silt till
MW13	2.1E-06	Slug	compact silt
MW13	1.0E-06	Bail	compact silt

An average hydraulic conductivity (K) of  $4.3 \times 10^{-5}$  m/s has been estimated for the outwash granular deposits based on 34 grain size distribution, slug and bail tests. The high level of variability in estimated hydraulic conductivity reflects the heterogeneous nature of the outwash deposits, which range from fine silts to coarse sand and gravels.

Estimated values of hydraulic conductivity from different locations are summarized in **Table B 1.3.2**.

#### 1.3.2.4 Outwash Deposits

Glacial melt-water deposited large quantities of sand or sand and gravel along glacial spillways and channels. Extensive glacial outwash deposits occur within the Cambridge area and the sand and gravel deposits bordering the Speed River in this study are considered to have an outwash origin. Recent alluvium also occurs along Forbes Creek and the Speed River as gravelly channel bars or floodplain deposits of sand and silt.

Glaciolacustrine sediments result from the deposition of finer-grained material in glacial lakes created by the temporary impoundment of glacial melt-waters. These deposits are typically silt to clayey silt-textured although interbedded sands and occasionally sand and gravels may be present locally.





Table B 1.3.2 Sand– Hydraulic Conductivity Summary

Borehole	K (m/s)	Method	Description
MW2	2.3E-03	Hazen	sandy gravel, trace silt, trace clay
MW4	4.0E-04	Hazen	sand, trace silt
MW5	6.4E-05	Hazen	silty, gravelly sand, trace clay
MW6	2.6E-04	Hazen	sand, some gravel, trace silt
MW9	4.0E-06	Hazen	gravelly sand, trace silt, trace clay
MW10	4.0E-06	Hazen	sand and gravel, trace silt, trace clay
BH101	6.3E-06	Hazen	sandy gravel, trace silt, trace clay
BH106	1.6E-03	Hazen	sand and gravel, trace silt
BH108	1.0E-04	Hazen	sandy gravel, trace silt, trace clay
BH110	5.1E-04	Hazen	sand and gravel, trace silt
BH115	4.0E-04	Hazen	sand and gravel, trace silt
BH117	1.6E-05	Hazen	gravelly sand, some silt
BH118	9.0E-04	Hazen	sandy gravel, trace silt
BH120	7.2E-03	Hazen	gravel, some sand, trace silt
BH124	2.3E-04	Hazen	gravelly sand, trace silt
BH130	9.0E-06	Hazen	sand, some silt, some gravel
BH134	4.0E-04	Hazen	sand, trace silt, trace gravel
BH139	9.0E-06	Hazen	sandy gravel, some silt, some clay
BH140	4.0E-04	Hazen	gravel, some sand, trace silt, trace clay
BH141	4.0E-06	Hazen	sand, some silt, trace gravel
BH143	6.3E-04	Hazen	sand, trace gravel, trace silt
BH145	6.3E-04	Hazen	gravelly sand, trace silt
BH153	4.2E-05	Hazen	sandy gravel, trace silt, trace clay
MW3	2.0E-06	Slug	dense sand and gravel
MW5	7.1E-05	Slug	compact silty sand
MW5	7.5E-05	Bail	compact silty sand
MW6	1.3E-04	Slug	compact sand
MW6	2.7E-05	Bail	compact sand
MW7	1.4E-06	Slug	dense sand and gravel (predominant); sandy silt till
MW9	1.1E-06	Slug	compact sand
MW9	1.0E-06	Bail	compact sand
MW10	4.3E-07	Slug	dense sand and gravel
MW12	1.2E-06	Slug	dense sand and gravel
MW12	8.0E-07	Bail	dense sand and gravel

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### B 1.3.2.5 Organic Deposits

Relatively recent, (i.e. post-glacial) organic sediments consisting of muck, marl, and peat occur in low-lying areas within the Forbes Creek subwatershed. Typical thicknesses are 1 to 2 metres of peat or organic muck occasionally overlying a lower unit of marl. Deposits are typically encountered in the existing wetland areas and in shallow depressions that formerly contained ponds.

## B 1.4 Bedrock Geology

The Forbes Creek subwatershed is underlain by a thick sequence of layered sedimentary rocks. The uppermost bedrock formation is the Guelph Formation, which underlies the whole of the subwatershed and outcrops along the eastern boundary of the subwatershed where erosion has removed the overlying soils (see **Photograph B1**). The Guelph Formation is a beige, finely crystalline, sugary-textured dolostone with occasional shale laminae and vugs. **Photograph B1** shows an outcrop of Guelph Formation dolostone exposed along the Speed River.

Overburden thickness within the subwatershed ranges from 0 to slightly more than 30 metres with the thickest overburden being encountered along the western boundary of the subwatershed and the thinnest overburden occurring along the bank of the Speed River where bedrock is exposed in many locations. A contour map showing the overburden thickness is provided on [Figure B 1.4.1](#). Buried bedrock topography is shown on [Figure B 1.4.2](#).

## B 1.5 Hydrostratigraphy

Groundwater is encountered within the subwatershed within the shallow overburden deposits, deeper overburden

and bedrock. Groundwater may therefore be divided into three systems:

- a shallow unconfined or water table aquifer;
- a deep overburden aquifer comprised of buried sand or sand and gravel deposits confined by overlying low permeability glacial till; and,
- a deep aquifer comprising pores and/or fractured bedrock.

The unconfined or water table aquifer is the most widespread occurring within the shallow sands and gravels over approximately two-thirds of the subwatershed. The shallow aquifer is generally recharged from local infiltration and precipitation except in groundwater discharge areas where the shallow aquifer is fed by the upwelling of groundwater from deeper overburden and/or bedrock aquifers.

The middle confined aquifer is only sporadically encountered within the subwatershed usually in areas of thick overburden. The middle aquifer is typically discontinuous and where present, takes the form of lenses or sheet-like layers of sand and gravel overlain by glacial till. Buried deposits of sand and gravel make excellent aquifers elsewhere within the Grand River Basin, however, their limited thickness and lateral extent makes their use as a water supply aquifer impractical within the Forbes Creek Subwatershed. The middle aquifer is typically recharged from leakage through the overlying glacial till or through the upwelling of deeper groundwater from the bedrock aquifer.

The bedrock aquifer is the most important source of potable groundwater supply within the subwatershed, accounting for the majority of groundwater wells examined as part of this study. Recharge of the bedrock aquifer occurs in upland areas and in areas where permeable soils





*Photograph B1 - Guelph Formation Dolostone*



having a high infiltration capability directly overlie the fractured bedrock.

Groundwater constitutes the sole source of potable water supply within the study area and the most significant source of water for non-potable uses. However, most residents live in residential developments and are municipally serviced, while rural residents have private well systems. Most water takings are relatively small and no Permits to Take Water (PTTW) are known to have been issued by the MOE for the study area except for the Municipal Well H-5.

MOE well records show that there are 121 water supply wells located within the study site, with 105 of these wells being completed in bedrock and the remainder being overburden aquifer wells.

[Figure B 1.5.1](#) shows the location of water wells within and adjacent to the Forbes Creek subwatershed. It should be noted that the MOE's water well database tends to be biased towards deeper and more recent wells since wells predating 1945 are not included in the database and many shallow dug wells are not included regardless of their date of construction.

The Water Well records reveal the following information regarding the overburden and bedrock aquifer (see **Table B 1.5.1**).

**Table B 1.5.1 Water Well Records**

Parameter	Overburden Aquifer (n=16)	Bedrock Aquifer (n=105)
Tested Yield – max (L/min)	35	208
Tested Yield – min (L/min)	3.5	2.1
Tested Yield – avg. (L/min)	15	18
Specific Capacity – max (L/min/m)	56	559
Specific Capacity – min (L/min/m)	2	0.5
Specific Capacity – avg. (L/min/m)	29	27

There is a single municipal water supply well within the study area. The Regional Municipality of Waterloo's Production Well H-5 is located south of the west branch of Forbes Creek on the east side of Regional Road #24. Regional records indicate that Well H-5 is a 305 mm diameter well sourcing the bedrock aquifer at a depth of 68.8 metres. The well has a rated capacity of 1990 m<sup>3</sup>/day but is used only for emergencies and has not been used regularly since 1998 at which time it was pumped at an average rate of 17,800 m<sup>3</sup>/month.

Waterloo Hydrogeologic Inc. (1996) carried out preliminary modelling to determine Well Field Capture Zones for municipal wells including H-5. This modelling used the Particle Tracking Module of WHPA to determine capture zones under a variety of simulations using a homogenous semi-confined aquifer under steady-state conditions. This modelling identified a narrow capture zone extending in a northerly direction from Well H-5. More recent studies completed for the Wellhead Protection Strategy incorporate 3-D modelling and the resultant zone of influence is more circular in shape around the wellhead (see [Figure A 2.1.1](#)).





### B 1.5.1 Groundwater Flow

The water table elevations and interpreted direction of shallow groundwater flow is illustrated on [Figure B 1.5.2](#) while the piezometric surface in the deeper aquifer is shown on [Figure B1.5.3](#). Groundwater in both the shallow and deep aquifers generally flows in a southeasterly direction toward the Speed River valley, which serves as a principal point of groundwater discharge in the area.

Measured groundwater depths are summarized on [Figure B 1.5.4](#). As shown, observed levels are relatively consistent throughout the study period although declining levels are observed in the shallow aquifer during the unusually dry summer of 2001.

### B 1.5.2 Water Quality

As groundwater percolates downward through geologic formations, the water acquires a chemical signature. The evolution in chemical quality seen across a geological feature can assist in the definition of the lateral extent and depth of recharge/discharge flow systems. Baseline geochemical characterization of groundwater was carried out as part of this study to identify such trends.

Groundwater samples (1000 ml) volume were collected from the sampled wells following purging. The sampling bottle was thoroughly rinsed and the sample was refrigerated until delivery to the testing laboratory, Conestoga Rovers & Associates Analytical Services Division, in Waterloo, Ontario. Samples were analyzed for a list of inorganic components including: hardness, chloride, nitrate, sulphate, and alkalinity, as well as selected heavy metals, and indicators of general geochemistry. Laboratory Certificates of Analysis are provided in **Appendix C 4**.

Geochemical trends in groundwater were assessed by comparing the major ion composition of groundwater samples for bedrock and overburden aquifers. Chemical testing indicates that groundwater from both the overburden and bedrock aquifers is bicarbonate type with a low to moderately high total dissolved solids content. The bedrock and overburden aquifers differ little in chemistry although the bedrock displays a slightly greater variability in ionic composition. In general both the overburden and bedrock groundwater samples can be characterized as hard with all samples exceeding 300 mg/L hardness.

Elevated concentrations of nitrate were measured in shallow groundwater in several locations, most notably MW3 and MW5 where the concentration of nitrate nitrogen of 24.7 and 33.2 mg/L exceeded the Ontario Drinking Water Standard of 10 mg/L. Re-sampling in September of 2001 revealed similarly elevated nitrates at both locations. MW3 and MW5 are located in areas of coarse outwash sands and gravels where high infiltration and aerobic conditions contribute to the persistence of elevated nitrates.

Moderately elevated levels of dissolved organic carbon were detected in MW9. This sampling location is near the edge of a wetland area and elevated dissolved organic carbon is likely to be a natural phenomenon.

### B 1.5.3 Areas Susceptible To Contamination

An aquifer's susceptibility to contamination is dependent on the presence of contaminants or pathogens within the recharge area of the well and on the presence of one or more geological barriers that prevent contaminants from entering the aquifer. Other factors governing an aquifer's susceptibility to contamination include:

- hydraulic conditions within the aquifer related to pumping, well construction, and aquifer



composition that prevent contaminants from entering the well in sufficient numbers to cause a human health concern; or

- the presence of potential contaminant sources in the recharge area of a well; or
- time of travel in groundwater over which pathogens or degradable contaminants will remain in problematic concentrations.

Flow through confining units can be predicted using Darcy's equation as presented in the EPA document titled *Wellhead Protection Strategies for Confined Aquifer Settings* (1991):

$$q_v = \frac{K_v(h_o - h)}{b'} \quad (1.5.1)$$

where:

- $q_v$  = Vertical leakage (unit of length/unit of time);
- $K_v$  = Vertical hydraulic conductivity (unit of length/unit of time);
- $(h_o-h)$  = Hydraulic head difference across the confining unit (unit of length); and
- $b'$  = Thickness of confining unit (unit of length).

This equation shows that the amount of leakage through a confining unit is proportional to  $K_v$  and  $h_o-h$ . The higher either of these values is, the higher the leakage. In contrast, as the unit thickens (e.g. as  $b'$  increases), the leakage decreases. The primary assumption for evaluating the effectiveness of a confining unit is that the smaller the leakage, the better protected is the underlying aquifer.

This equation can be modified by including the porosity of the confining material to obtain the average linear velocity, which is the rate at which groundwater moves through the material.

$$v = \frac{K_v(h_o - h)}{n_e b'} \quad (1.5.2)$$

where:  $n_e$  = effective porosity and  $v$  = average linear

velocity(unit of length/unit of time).

The effective porosity is the amount of interconnected pore space through which fluids can pass, expressed as a percent of bulk volume. Effective porosity is always less than total porosity (EPA, 1987). The value selected for effective porosity, 0.20, is based on ranges for unconsolidated fine-grained materials. Because this equation is based on the Darcy equation, the average linear velocity varies with changes in  $K_v$ ,  $h_o-h$ , and  $b$  in the same way that  $q_v$  does and it is inversely proportional to the effective porosity,  $n_e$ . Therefore, the average linear velocity increases with decreasing effective porosity although the total vertical leakage may decrease with decreasing effective porosity.

Once this velocity is computed, it is straightforward to determine the amount of time it takes for groundwater to travel through a confining unit. Using equation (2), the approximate travel time through a confining unit of thickness  $b$  is:

$$t = \frac{b'}{v} \quad (1.5.3)$$

where:  $t$  = travel time (units of time)

The hydraulic conductivity of glacial till typically ranges between  $10^{-6}$  and  $10^{-12}$  m/s. Using a maximum vertical hydraulic gradient of 0.1 (based on GRCA mapping) it is possible to use the vertical time-of-travel concept to map zones of aquifer vulnerability over the subwatershed although it should be noted that factors related to well location and construction can render a well susceptible to pathogen contamination regardless of whether a geologic confining unit is present.

The shallow water table aquifer is considered to have a high intrinsic vulnerability to microbiological contamination over the entire study area based on the absence of any



defined protective layer. Vulnerability to other contaminants types such as nitrates (which only persist in aerobic environments), road salts, and organic contaminants is highest in the areas underlain by permeable granular strata of silt, sand, and gravel. The intrinsic vulnerability of the bedrock aquifer is a function of the overburden thickness and the permeability of the overburden materials which vary considerably over the study area. The vulnerability of the bedrock aquifer to microbiological pathogens is similar to its vulnerability to other contaminant types. The middle aquifer is too discontinuous and poorly defined to allow a useful vulnerability map to be prepared for the Forbes Creek subwatershed.

The intrinsic vulnerability of the shallow overburden and bedrock aquifers is summarized on [Figures B 1.5.5](#) and [B 1.5.6](#) respectively. The mapping classifications are based on Vrba and Zaporozex (1994) with the different intrinsic vulnerability classifications summarized on **Table B 1.5.2**. In the Forbes Creek subwatershed there are no “very low” areas of vulnerability. The high and very high vulnerability classifications have been combined since they do not form distinct mapable units at the scale of this study.

**Table B 1.5.2 Intrinsic Bedrock Vulnerability**

Vulnerability	Nature of Unsaturated Zone Strata	Example
Extremely High	Ineffective and/or insignificantly thick or discontinuous overburden	Fractured bedrock on surface
High	Highly permeable with unsaturated zone <2 m thick	Shallow wells in sand and gravel
Medium	Moderate permeability ( $k_v = 10^{-3} - 10^{-5}$ m/s); depth to saturated zone 2 – 20 m	Thin till deposits
Low	Low permeability; depth to saturated zone >20 m	Thick till deposits
Very low	Practically impermeable and of significant thickness	Thick clay-rich overburden

### B 1.5.4 Wellhead Sensitivity Zones

Protection of water resources is part of the Regional Municipality of Waterloo’s responsibility for provision of municipal water supplies. As part of its groundwater protection strategy, the Region has incorporated wellhead sensitivity zones (WPSAs 1 to 4) into its Official Policies Plan (ROPP). This plan is intended to direct new non-residential development to areas of the Region with “limited potential to impact municipal groundwater supplies”.

The potential groundwater contamination hazards associated with various types of non-residential land uses have been classified according to a three level ranking system from 'A' to 'C'. Category 'A' land uses pose the highest concern and include landfills, auto wreckers, and putrescible waste disposal facilities. Category 'B' land uses pose the next highest risk and include such uses as manufacturing or warehousing of industrial chemicals, metal finishing operations, and gasoline stations. Examples of the lower risk Category 'C' uses include manufacturing of electrical appliances, manufacturing of plastic, and repair of motor vehicles. Category 'A' uses are prohibited in any WPSA. Category 'B' and 'C' uses are prohibited in WPSAs 1, 2 and 3.

The Regional Municipality of Waterloo's Production Well H-5 (currently a standby well, and has not been pumped regularly since 1998) is located south of the west branch of Forbes Creek on the east side of Regional Road #24. This well is within an area of sensitivity Zones 2, 3 and 4 (refer to [Figure A 2.1.1](#)).

### B 1.5.5 Recharge Areas

Of the annual amount of precipitation that falls within a watershed (P) it can be assumed that a portion is lost through evapotranspiration (E), runoff from the site (R) or



groundwater recharge via infiltration (I). Therefore a water budget is an estimate of the portion of precipitation that infiltrates to the groundwater, runs off from a site or evapotranspires and is defined by:

$$P = E + R + I \quad (1.5.4)$$

Evapotranspiration is the amount of water that is removed from the land by evaporation and the transpiration process and is dependent on land use and soil moisture contents. The amount of water remaining in a water budget following evapotranspiration is referred to as excess water, which is water that is available for groundwater recharge or which will run off from a site.

The amount of groundwater recharge is dependant on excess water as well as site characteristics such as topography, slope, soil type, climate, and surface cover such as cultivated lands, woodlands and impermeable cover. The portion of excess water not infiltrating to the groundwater table is accounted for as runoff.

Subcatchments are areas of similar drainage characteristics within the Forbes Creek subwatershed. The subcatchments were determined during our hydrological investigations and reference should be made to [Figure B 2.3.1](#). Estimates of groundwater recharge were prepared for each subcatchment area based on soil conditions, depth to the water table, topography, and vegetation. Estimated primary recharge rates are provided on [Figure B 1.5.7](#) while **Table B 1.5.3** shows primary infiltration on a subcatchment-by-subcatchment basis including recharge to the bedrock aquifer and the Speed River.



**Table B 1.5.3 Subcatchment Infiltration Rates**

Subcatchment	Area (ha)	Primary Infiltration (mm/year)	Loss to Bedrock Aquifer (mm/year)	Loss to Speed River (mm/year)	Net Infiltration To Forbes Creek (mm/year)
101	24.08	252	45	...	207
103	45.23	225	45	...	180
105	14.60	234	40.5	...	193.5
107	18.75	225	18	62.1	144.9
109	21.08	198	54	57.6	86.4
111	62.78	216	58.5	...	157.5
113	34.40	261	72	...	189
114	2.91	225	54	...	171
115	4.92	270	54	...	216
116	1.46	252	54	...	198
117	14.25	270	54	...	216
119	12.96	216	81	33.8	101.25
120	15.05	270	45	...	225
121	3.78	252	54	...	198
123	19.87	315	54	78.3	182.7
124	15.05	270	45	...	225
125	46.37	198	45	107.1	45.9
127	7.31	270	18	...	252
901	40.05	288	90	198.0	0
		246.5	52	29.8	164.7

## B 1.6 Hydrogeologic Conditions for Consideration

The geological environment of the Forbes Creek subwatershed influences both the natural environment and the type of development that might occur. Geological issues are as follows:

### B 1.6.1 Geological Issues

- The Forbes Creek subwatershed is underlain by a thick sequence of layered sedimentary rocks, which outcrops along the eastern boundary of the subwatershed where erosion has removed the overlying soils. The shallow bedrock will greatly increase the cost of any excavations in this area and may preclude its use for underground services.



- Most of the overburden soils are of glacial origin and have excellent engineering properties. However, geotechnically problematic soils occur in several areas such as the organic sediments consisting of muck, marl, and peat in low-lying areas. These highly compressible soils are unsuitable to support roads, homes, or other structures.
- High groundwater levels occur in low-lying areas and in much of the land to the west of Regional Road #24. These conditions require drainage around homes and increase the potential for buried utilities to intercept and divert groundwater and thus alter the natural hydrogeological regime.

### B 1.6.2 Hydrogeological Issues

Precipitation falling within the subwatershed contributes to the recharge of the overburden and bedrock aquifers and to base flow of Forbes Creek and related wetland areas. Groundwater therefore plays an important role in sustaining the health of the surfacewater environment within Forbes Creek as well as providing the drinking water supply. Hydrogeological issues are presented below:

- Development in the subwatershed will result in impermeable pavement being placed on areas that were previously permeable. The replacement of permeable surfaces with impermeable ones will increase runoff, decrease infiltration, and decrease evapotranspiration. If stormwater runoff is prevented from infiltrating, development would cause a reduction in groundwater recharge. Provided that the increased runoff can be infiltrated near to its point of generation there need be no loss of groundwater recharge.
- Development in the subwatershed might cause water quality changes such as: degraded

groundwater quality caused by greater use of de-icing salts; degraded groundwater quality caused by vehicle exhaust residue, leaks, and spills; and improved water quality through the reduced use of nitrates and other fertilizers.

- The R.O.P.P. defines groundwater discharge to Provincially Significant Wetlands or ESPAs as “Regional Environmentally Significant Discharge Areas.” As the presence of these features requires special consideration during development (Policy 5.2.3 to 5.2.2.5), such features should be mapped in future studies so that contributing recharge areas may be identified during pre-consultation for individual applications.
- Grading and the construction of buried utilities have the potential to alter the groundwater levels and flow patterns within the subwatershed by intercepting or diverting existing groundwater flow and discharge patterns.
- The soils in the Forbes Creek subwatershed contain areas of highly permeable sand and gravel resulting in high levels of infiltration that provides baseflow to the wetlands, ponds and creek. Existing levels of infiltration should be maintained under future development scenarios.
- At-source infiltration should be maximized wherever feasible as this is the most desirable form of stormwater management from a hydrogeological perspective. Existing coarse-textured soils have maintained their infiltration capacity for millennia – demonstrating the potential for effective maintenance-free at source infiltration structures.
- Infiltration of salt-laden stormwaters should be avoided in areas where wetland vegetation communities are particularly sensitive to salt impacts.





- Development should be carefully evaluated in areas with a high groundwater table where perimeter drains can result in the capture and short-circuiting or diversion of groundwater flow
- Sound dolostone bedrock is encountered at the ground surface or at shallow depth along the east boundary of the subwatershed. This bedrock will greatly increase the cost of servicing if utility corridors require excavation into rock.
- From the temperature data, Forbes Creek is a cool water (potential coldwater) system. Future development should reflect this and water quality should be maintained or improved. This will require additional consideration at the scoped site EIS stage.
- All monitoring wells constructed as part of the hydrogeological study should be decommissioned by a licenced well contractor. Region WRP staff should be consulted prior to the decommissioning in case any should be retained for long term monitoring.

## B 2.0 HYDROLOGY

### B 2.1 Introduction

Watershed conditions and human activities have a significant effect on flows in a stream. These stream flows come from runoff, the ground surface and from the ground (i.e. springs, discharge areas, and other upwelling areas). The surface runoff determines flow conditions during storms or snowmelt, and the groundwater flows largely control stream flow during dry periods. Watershed conditions can influence flows greatly. Woodlot and wetland areas can hold back flows and in many cases can contribute to low flows. Clearing land and paving these areas will increase flows during storm events. Work in a

stream, such as the addition of storm sewers or concrete channels, will speed up flows and increase peak flows. Storage areas such as ponds or reservoirs will hold back flows and reduce peak flows.

The purpose of the hydrologic analysis in this study is to provide the basis for assessment of flow conditions in the subwatershed and the response to rainfall events. This information can then be used for the assessment of flood potential, erosion conditions and flow variations over time. The subwatershed modelling also provides the basis for analyzing other stream characteristics such as low flows (base flow), water quality changes and fish habitat.

This hydrologic assessment was carried out with the use of computer modelling in conjunction with other technical analyses. Initially, an overall subwatershed model was developed to analyze subwatershed hydrology. This model used information on land use, soils, subwatershed topography, and the stream system to enable prediction of the flow rate in the stream during a rainfall or snowmelt event. The flow information generated by the subwatershed model has been used in subsequent sections of this study.

#### B 2.1.1 Description of Subwatershed

The Forbes Creek subwatershed drains 350 hectares in southwestern Ontario. Forbes Creek is part of the Speed River watershed.

Forbes Creek originates within wetlands west of Regional Road #24 (Hespeler Road). At this point there are two branches (East and West). The East Tributary travels through a 1.14 m  $\emptyset$  culvert under Regional Road #24 (Hespeler Road). It then flows south and under Blackbridge Road (300mm  $\emptyset$  culvert). The drainage area to



the Regional Road #24 (Hespeler Road) culvert is 84 ha and 118 ha to Blackbridge Road.

The West Tributary drains 103 ha to Regional Road #24 (Hespeler Road) through a 1.2 m  $\emptyset$  culvert. It then passes under Blackbridge Road through a 1.5m  $\emptyset$  culvert. The drainage area to the Blackbridge Road culvert is 106 ha.

The East and West Tributaries join downstream of Blackbridge Road. Forbes Creek then passes through three online ponds within the former Wood Duck Sanctuary. (Refer to [Figure A 1.1.2](#)).

The major urban section of the Forbes Creek subwatershed, i.e. the Silverheights Community west of Guelph Avenue, drains in two directions. Drainage in the northerly portion of the urban residential development (13 ha) is collected by storm drainage system and is directed to a ditch along Guelph Avenue. This ditch directs flow across a field to Forbes Creek. The remaining 46 ha of urban residential development is also collected in storm drainage system but directly outlets to Forbes Creek through a 1200  $\emptyset$  mm pipe downstream of Pond A. From Pond A, Forbes Creek flows approximately 100 metres before discharging to the Speed River at the Hespeler Mill Pond.

The Forbes Creek subwatershed consists of more than 85% sand and gravel, which is highly permeable. Rainfall on these areas would contribute to groundwater recharge and baseflow within the subwatershed.

### **B 2.1.2 Information Sources**

Background information to identify and characterize the hydrological response component of the study has been derived mainly from field investigations and an extensive investigation of maps, reports, and existing field data

pertaining to Forbes Creek. These sources include the following:

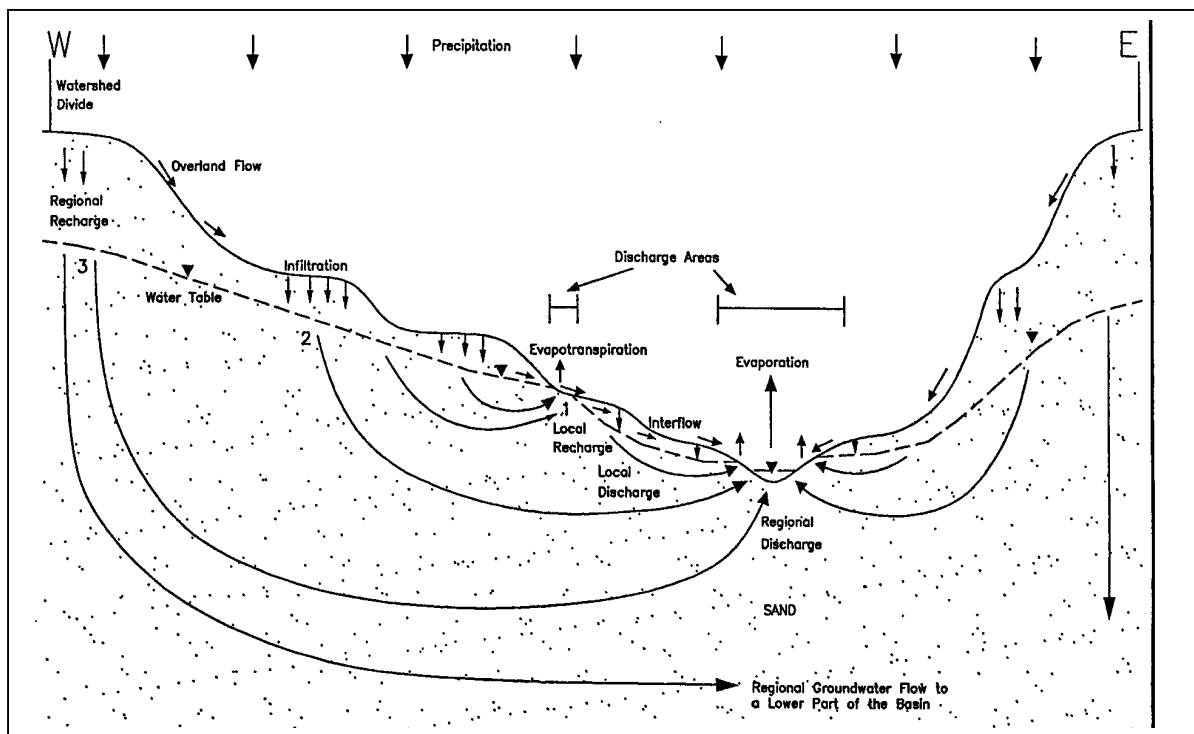
- Grand River Hydrology Study - Phase I (GRCA, 1988);
- Meteorological Services of Canada (MSC) formerly Atmospheric Environment Service (AES) historical meteorological data (e.g. hourly rainfall amounts, daily maximum and minimum air temperature, daily precipitation, wind speed, and direction);
- GRCA real-time meteorological, streamflow, and snow course information (e.g. Erbsville gauge, Laurel Dam rain gauge);
- Water Survey of Canada streamflow data;
- Stream cross-section information (e.g. HEC-2 files);
- The Physiography of Southern Ontario, 3rd Edition, (Chapman & Putnam, 1984);
- The Climate of Southern Ontario, Climatological Studies No. 5 (Brown, McKay and Chapman, 1980);
- Canadian Climate Normals 1951-80, Temperature and Precipitation Ontario (Environment Canada, Meteorological Service of Canada, previously Atmospheric Environment Services, 1982);
- Soils of Waterloo County, Report No. 44 of the Ontario Soil Survey (Research Branch, Canada Department of Agriculture, 1971);
- Surfacewater Data Reference Index, Canada 1991 (Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, 1992);
- Speed and Eramosa Rivers Floodline Mapping Study - Hydrology (Ecologistics Limited, 1988)
- Water Quality Resources of Ontario (Ministry of Natural Resources, 1984).



**B 2.1.3 Overview of the Surfacewater Flow Cycle**

This section gives a general overview of the surfacewater flow component of the hydrologic cycle to provide a basic understanding of the physical processes that characterize the streamflow in the Forbes Creek subwatershed. [Figure B 2.1.1](#) illustrates each part of the hydrologic cycle. The hydrologic cycle is the cycle of water movement through

the earth-atmosphere system, initiated through the collection of water vapour by evaporation and transpiration from water and land surfaces (including vegetation), which is released into the atmosphere (clouds), condenses and is deposited on land by precipitation. When the precipitation reaches the ground it is stored on the surface (e.g. lakes), at depth (groundwater) or is evaporated or transpired to repeat the next cycle.



Source: Canadian Manuscript Report Fisheries and Aquatic Sciences 2284, Department of Fisheries and Oceans 1995

**Figure B 2.1.1 Generic Illustration of the Hydrologic Cycle**





The hydrologic cycle begins with rain or snow (precipitation) falling to the ground. The amount and rate of precipitation that actually arrives at the ground surface is controlled by the prevailing weather system that generated the precipitation on a regional scale. At the more localized scale, topography and land use cover influence the actual precipitation amounts arriving at the ground surface.

This water (as rain, snowmelt or both) either runs off across the ground surface directly to a surfacewater course, infiltrates (percolates) into the ground to recharge groundwater storage or goes back to the atmosphere by evapotranspiration. The amount of water that actually infiltrates is controlled by the rate of precipitation input (rainfall or snowmelt), soil type (e.g. clay, silt, sand or gravel), ground surface conditions (e.g. frozen, cracking) and vegetative cover (e.g. pasture, forests). In some areas, the surface topography (e.g. hummocky ground) has created large depressions, which require several metres of water to pond before overland flow occurs. Consequently, water in these depressions either percolates downward and contributes to groundwater and subsurface storage or evaporates back to the atmosphere.

Runoff water collects in stream channels that lead to larger channels or discharge to ponds, wetlands or lakes. While in these ponds or lakes, part of this water returns to the atmosphere by evaporation, or it may percolate into the ground, or spill to downstream channels. The travel time of flow in these stream channels is governed by the length, slope, roughness and cross-sectional shape of these channels. If the flow is high and fast enough, water may overtop the channel banks, flooding the adjacent land area.

Anywhere along the length of these stream channels, discharge from groundwater storage (either regional,

localized, or interflow) can contribute to the flow in the channel. These groundwater contributions to streamflow are governed by the surrounding topography, surficial geology and bedrock geology.

## B 2.2 Field Investigations

### B 2.2.1 Meteorological Information

Long-term monitoring of meteorological quantities has occurred in the region surrounding Forbes Creek for more than 100 years. Historical data are primarily available from Meteorological Services of Canada (MSC), although within the last 10 years or so, reliable data have been collected at stations maintained by the Grand River Conservation Authority (GRCA). **Table B 2.2.1** gives further details about the observing program for 15 stations whose records have been reviewed in previous studies (e.g. Schroeter and Boyd, 1998; Schroeter & Associates, 1999; Schroeter et al., 2000b). As noted in **Table B 2.2.1**, hourly rainfall depths are available from the GRCA's own operational network, as they have a tipping bucket gauge at Shade's Mill reservoir. For this study, a temporary tipping bucket rain gauge was located within the Forbes Creek subwatershed at the wildlife sanctuary.

For detailed energy balance analysis, a wider array of meteorological variables (e.g. hourly rainfall, air temperature, wind speed and direction, solar radiation, humidity) are available through the Internet from three stations: the Elora Research Station (MSC 6142285), the Guelph Turfgrass Institute, and the University of Waterloo. Weather monitoring at the Elora Research Station has been maintained by the University of Guelph since 1969, and digital information (via dataloggers) has been available since 1985. The Guelph Turfgrass Institute weather station



is also maintained by the University of Guelph, and has been in operation since 1993. The University of Waterloo weather station has been in operation since the mid 1980's. Detailed energy balance information is available from the Guelph OAC (MSC 6143083) station for the period 1950 to 1973.

A continuous meteorological dataset was prepared using available information from long-term weather stations noted in **Table B 2.2.1** that are still in operation in the vicinity of the study area. Utilizing the Preston (MSC 6146711)

records as the basis for data assembly, a 39-year dataset has been established consisting of hourly rainfall depths, daily maximum and minimum air temperature, and daily rainfall and snowfall depths for the period 1960 to 1999. The Preston station was closed at the end of June 1996, so the data set has been extended in recent years using observations from the GRCA's Shade's Mill station, and the MSC Cambridge-Stewart (6141100) station. The methodology for preparing these data for input to the hydrologic model has been fully outlined by Schroeter et al. (2000b).

**Table B 2.2.1 Observing Climate Stations Available for Study**

Station Name	Station Code	Owner	Available Period Of Record*	Data Collected
Cambridge Galt MOE	6141095	MSC	1950-1994	P,T,RG
Cambridge Stewart	6141100	MSC	1973-1999	P,T
Elora Research Station	6142285	MSC	1969-2001	P,T,RG,E
Guelph Arboretum	6143069	MSC	1975-1995	P,T,RG
Guelph OAC	6143083	MSC	1960-1973	P,T,RG,E
Guelph Lake Dam	GRCA003	GRCA	1988-2001	P,T,RG
Guelph Turgrass Inst.		U of G	1993-2001	P,T,RG
Kitchener	6144232	MSC	1950-1977	P,T
Kitchener OWRC	6144245	MSC	1962-1975	P,T
Preston	6146711	MSC	1953-1996	P,T
Preston WPCP	6146714	MSC	1970-1996	P,T,RG
Roseville	6147188	MSC	1972-1999	P,T
Shades Mill	GRCA007	MSC	1988-2001	P,T,RG
University of Waterloo		U of W	1986-2001	P,T,RG
Waterloo-Wellington A	6143987	MSC	1970-1999	P,T,RG

Notes: P – daily precipitation (rain and snow)  
 T - daily maximum and minimum air temperature  
 RG - Recording rain gauge (tipping bucket)  
 E - Pan evaporation estimates



### B 2.2.2 Snow Cover Patterns

Snow course data have been collected bimonthly for more than 25 years at 12 locations within the Grand River watershed. The closest available snow course site to Forbes Creek is located in the Shade’s Mill Conservation Area, east of the Grand River Conservation Authority (GRCA) head office on the north side of Clyde Road in a relatively young forest plantation. Each year the mean of the 10 points (both snow depth and equivalent water content) are collected for the period December 1<sup>st</sup> to April 15<sup>th</sup>, and are reported to the Ontario Ministry of Natural Resources as part of a province wide network. Additional snow course information is collected on other dates when deemed necessary in anticipation of any spring flooding conditions.

Detailed information about snow accumulation characteristics, according to different landscape units in southwestern Ontario, has been reported by Schroeter and Whiteley (1986), Schroeter (1988) and Burkart et al. (1991). Typical snow cover distributions for the Forbes Creek subwatershed were confirmed with actual field measurements on February 5, 2001, and are summarized in **Table B 2.2.2** Typical snow cover distribution curves

taken from the February 2001 survey are illustrated in [Figure B 2.2.1](#). They are very similar to patterns observed in other parts of the Grand River basin for the same land cover types. Information about snow cover pattern is used directly in the step-up of the hydrologic model described in Section B 2.3.

**Table B 2.2.2 Summary of Measurements for February 5, 2001 Snow Survey**

Land Cover Type	Number Of Depth Readings	Mean Depth (cm)	Std. Dev. (cm)	Maximum Depth (cm)	Minimum Depth (cm)
Pasture field	30	29.9	3.43	36	24
Coniferous Forest (No.1)	30	19.6	4.48	28	8
Soy bean field	30	22.5	5.72	37	16
Unimproved pasture	30	35.8	6.23	48	23
Coniferous Forest (No.2)	30	18.4	3.21	25	12
Deciduous Forest	30	26.4	6.57	44	16



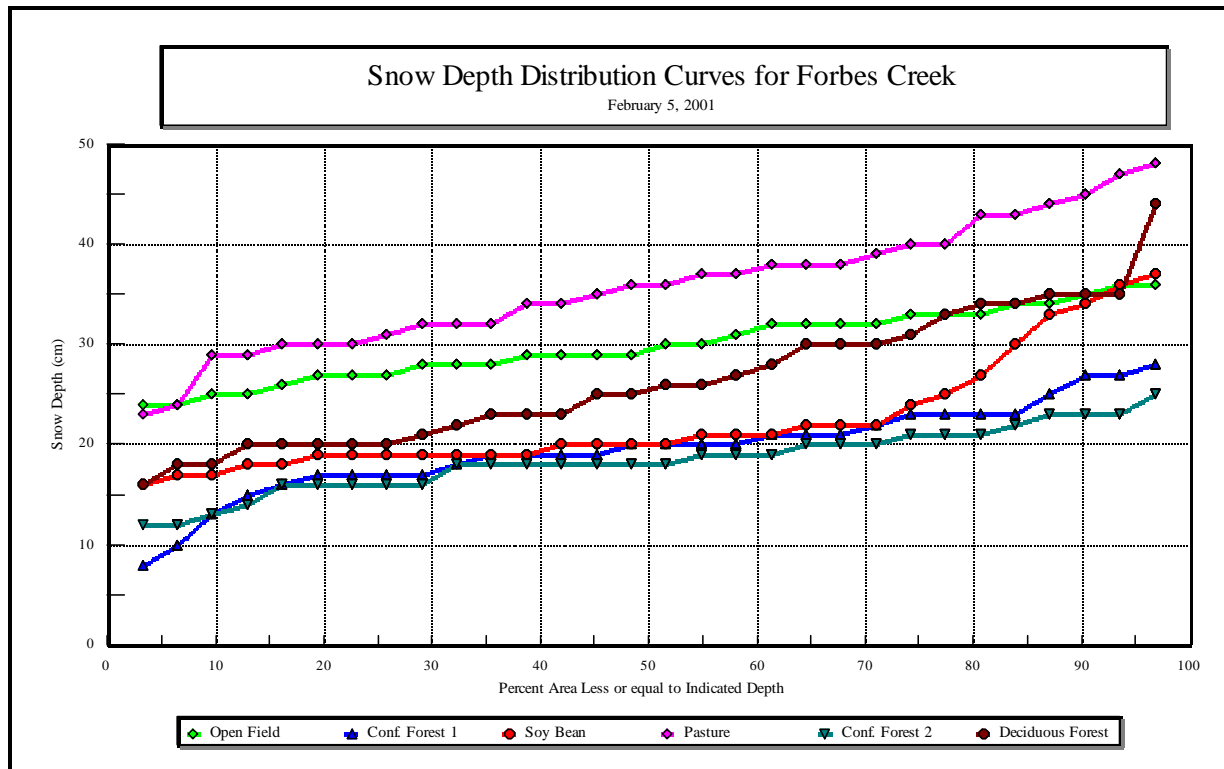


Figure B 2.2.1 Snow Depth Distribution

### B 2.2.3 Streamflow Data

No long-term streamflow data exists for any of the tributaries within the Forbes Creek subwatershed. However, for the purpose of this study, temporary water level recorders connected to digital dataloggers were installed at three locations. Initially, these three gauges were installed in late November 2000, and operated for about three weeks until freeze-up, when they were removed. Then, late in March 2001, these gauges were re-installed, and have continued to operate throughout the study period.

Rating curves, the relationship between water level and discharge, were developed for all three gauges. Due to the severe drought this summer, there have been very few significant rainfall events from which to validate the





hydrologic model in event mode, however, our model has been accurately calibrated to the Grand River watershed and numerous smaller watersheds of similar characteristics and therefore minimal data does not present a problem. The data that was available was used to validate the assumptions and proved to be satisfactory.

### B 2.3 Hydrologic Modelling

The analysis of existing hydrologic conditions in Forbes Creek was handled using the GAWSER (Guelph All-Weather Sequential-Events Runoff) model, a deterministic watershed model based on the HYMO format. It has been applied widely in Ontario for planning, design, real-time flood forecasting, and evaluating the effects of physical changes in the drainage basin (Schroeter & Associates, 1996; Schroeter and Boyd, 1998). GAWSER was originally set-up for the entire Grand River watershed in 1987-1988, and has since formed the heart of the GRCA real-time flood forecasting system. Within the last 6 years, it has been updated for continuous water balance simulations, and climate change impact assessment. The procedures to set-up, calibrate and validate the model for hydrologic analyses developed by Schroeter and Boyd (1998) for the Eramosa River study were applied directly in the present analysis. These procedures are fully documented in **Appendix D**.

#### B 2.3.1 Model Set-up

As shown on [Figure B 2.3.1](#), Forbes Creek has been divided into 18 subcatchment elements for hydrologic modelling purposes. In addition, the expanded study area also consists of 5 subcatchments (911, 912, 913, 914 and 915, or also known as 901 in a lumped fashion). These subcatchments were chosen to have stream crossings at all flow monitoring stations, to provide sufficient distributed flow inputs to the floodplain mapping (backwater curve)

calculations, and to reflect the spatial variations in soil type, as well as present and future land use. Other subcatchments were delineated to improve modelling results based upon: i) large changes in longitudinal slope of major tributary streams within the subwatershed, ii) the need to have subcatchment shapes such that a single overland flow path length is representative, iii) the degree of imperviousness (e.g. can it be classed rural or urban?), and iv) the drainage area contributing to large wetland or depression storage areas (kettles).

The total drainage area of Forbes Creek was found to be 350 hectares, with a mean subcatchment size of 20 hectares, and 12 channel routing reaches having an average length of 300 metres. Eight reservoir elements with significant storage have been identified and considered in the model, five of which are natural depressions/wetlands with some recharge capability in the headwaters of the East and West Branches. Three constructed ponds (A, D and G Refer to [Figure A 3.3.1](#)) situated in the Waterfowl Sanctuary have also been included in the model.

To account for the wide variation in runoff generation response attributed to the different land cover features and soil types (e.g. source areas), the subcatchment elements were further subdivided into nine 'hydrologic response units' (HRUs); one impervious and eight pervious. These HRUs are defined in **Table B 2.3.1**.

**Table B 2.3.1 Hydrologic Response Unit Definitions**

Hydrologic Response Unit (RU)	Description (vegetation/soil type)
1	Impervious (includes some bedrock areas)
2	Open Water
3	Clay Till with low vegetative cover
4	Clay Till with high vegetative cover (Forests)



**Table B 2.3.1 Hydrologic Response Unit Definitions**

Hydrologic Response Unit (RU)	Description (vegetation/soil type)
5	Silt Till with low vegetative cover
6	Sandy Till with low vegetative cover
7	Sandy Till with high vegetative cover (Forests)
8	Sand and Gravel with low vegetative cover
9	Sand and Gravel with high vegetative cover (Forests)

These hydrological response unit definitions are exactly the same as those being applied in the overall Grand River model for the lower part of the Speed River. As such, the response unit drainage parameters are all well established through extensive calibration efforts over the last 14 years.

Soil type areas for each subcatchment were measured from the quaternary geology map of the area, the same information used in the hydrogeologic investigations. Forest cover information was taken from the 1:10,000 scale topographic map for the area. The drainage characteristics (e.g. hydraulic conductivity, soil-water contents, depression

storage depths) for the various response units were taken directly from published information (e.g. Watt et al., 1989) and other studies involving applications of the GAWSER model (e.g. Schroeter & Boyd, 1998; Totten Sims Hubicki, 1998; Schroeter et al., 2000a) within the Grand River basin. The elevation-area relationships for the five natural depressions/wetlands considered in the model were taken directly from available topographic mapping.

Stream channel data are necessary inputs to both the overland flow and channel routing procedures in GAWSER. Numerous cross-sections were surveyed for their distance-elevation relationship in the floodline mapping part of the study. Hydraulic roughness values (Manning's n) were determined during the backwater curve calculations.

**Table B 2.3.2** summarizes the subcatchment characteristics for the Forbes Creek subwatershed. On the whole, 18% of the Forbes Creek subwatershed is forested, with more than 88% of the soils comprising sandy till or sand and gravel outwash gravel deposits.

**Table B 2.3.2 Subcatchment Characteristics**

Catchment	Area (ha)	Length (m)	Width (m)	Imp RU1 %	RU 2 %	RU 3 %	RU 4 %	RU 5 %	RU 6 %	RU 7 %	RU 8 %	RU 9 %	FTB
101	24.1	500	500	0	7.6	0	0	0	15.1	12.9	57.5	7.0	3.0
103	45.2	700	500	0	4.7	0	0	0	39.1	11.4	33.5	11.2	2.0
105	14.6	500	200	0	0	0	0	0	34.0	0.7	65.3	0	2.0
107	18.8	450	420	0	9.6	0	0	0	8.4	0	81.5	0.5	3.0
109	21.1	40	260	0	2.9	0	0	0	35.6	43.4	18.1	0	2.0
111	62.8	70	500	0.9	6.8	0	0	0	40.1	29.5	21.9	0.9	3.0
113	34.4	300	300	4.3	0.2	0	0	0	1.1	0	74.1	20.3	2.0
114	2.9	100	100	19.3	0	0	0	0	66.0	8.3	6.4	0	1.2
115	4.9	250	100	4.3	0	0	0	0	33.5	0	62.2	0	2.0
116	1.5	100	100	5.0	0	0	0	0	0	0	95.0	0	2.0
117	14.2	450	250	2.5	0	0	0	0	0	0	90.9	6.5	2.0
119	13.0	450	50	33.2	0	0	0	0	62.4	4.4	0	0	1.2



**Table B 2.3.2 Subcatchment Characteristics**

Catchment	Area (ha)	Length (m)	Width (m)	Imp RU1 %	RU 2 %	RU 3 %	RU 4 %	RU 5 %	RU 6 %	RU 7 %	RU 8 %	RU 9 %	FTB
120	10.7	250	450	4.0	9.7	0	0	0	10.0	0	76.2	0	3.0
121	3.8	200	300	0	1.2	0	0	0	0	0	98.8	0	2.0
123	19.9	700	200	0.1	4.6	0	0	0	0	0	92.0	3.4	2.0
124	4.4	250	150	0.9	5.3	0	0	0	0	0	93.8	0	3.0
125	46.3	450	50	38.4	0	0	0	0	30.0	19.2	12.2	0.2	1.2
127	7.3	150	200	5.9	1.3	10.1	0	0	0	0	59.2	23.5	2.0
911	3.85	100	100	2.2	0	84.0	0	0	0	1.7	0	12.1	2.0
912	5.87	150	150	0.7	0	70.0	0	0	0	1.6	0	11.9	2.0
913	6.62	230	230	0.6	0	0	0	30.3	22.8	0	0	0	2.0
914	12.7	170	170	2.0	0	0	0	0	8.3	0	89.7	0	2.0
915	11.1	270	270	2.0	0	0	0	0	0	0	98.0	0	2.0

Note: Definitions for response units (RU's) given earlier in this section.

**Appendix D** gives additional information and details regarding the set-up of the existing conditions hydrologic model for Forbes Creek. This additional information includes the following: a) a full model schematic diagram showing the linkage between subcatchment, channel and reservoir elements, b) a detailed discussion of the parameter selection process, c) a sensitivity analysis, d) an explanation of initializing the snow accumulation, re-distribution and melt computations, and e) an evaluation of future and ultimate subwatershed conditions.

### B 2.3.2 Model Validation

Historic continuous streamflow measurements have not been available for the Forbes Creek. The discharge data collected in this study have been collected for an insufficient length of time to fully measure the full range of flow expected along Forbes Creek. Typically, this may take decades to develop and even then may be inadequate to accurately determine the 1:100 year storm flow. In particular, there is no data for the winter months. In these circumstances, it is necessary to make use of more regionally based hydrologic

information, particularly with regard to response unit drainage parameters. In this instance, the GAWSER model of the entire Grand River watershed provides the regionally based hydrologic information. The overall Grand River model has been extensively calibrated/validated over the last 14 years with streamflow data from more than 50 events at 40 gauges or more (see Schroeter et al., 2000a). The monthly parameter adjustment table established from these applications was used directly in the Forbes Creek subwatershed (see **Appendix D**).

The streamflow data collected in the present study was used to confirm the parameter settings developed in the larger model. This form of assessment, although not as rigorous, gives a qualitative check on the model's performance in terms of tracking of flows (routing) through the drainage network.

### B 2.3.3 Event Simulations

The formulated hydrologic model for existing conditions described in the previous section was utilized to generate



flood flow estimates resulting from return period events and the Regional Storm. For the return period flood flow estimates, the 3-hour Chicago Storm (with R=0.40) with 5 minute time step was applied to the model. The intensity-duration-frequency (IDF) information is based on City of Cambridge data.

The intensity-duration-frequency relationship for the City of Cambridge can be expressed as

$$I = A / (B + T)^C$$

where I is the rainfall intensity in mm/h, T is the storm duration in minutes, and A, B, and C are constants determined by regression analysis. **Table B 2.3.3** gives the 3-hour volumes and the fitted IDF curve constants used to develop the Chicago storm patterns for each return period event.

Return Period (Years)	3 Hour Volume (mm)	A	B	C
2	27.6	1778	13	1.000
5	37.7	2463.8	16	1.000
10	51.8	3454.4	20	1.000
25	69.0	2530.0	18.8	0.8883
50	77.7	2290.0	14.2	0.8508
100	105.2	1977.8	10.8	0.7680

For the Regional Storm flood flow estimates, the full 48-hour pattern was taken from the *Floodplain Management Guidelines* (OMNR, 1986), and applied to the existing conditions hydrologic model, operating with a 10-minute computational time step.

No areal reduction factors were applied to the storm volumes, because the computed values were very close to

unity. The initial soil-water conditions were set at field capacity, which is believed to be normal for these events. The soil drainage parameter adjustment factors were set at their mid-October values. **Table B 2.3.4** summarizes the results of applying the 3 hour Chicago Storms and the Regional Storm to the existing conditions hydrologic model.

To help establish the 'reasonableness' of the estimated flood flows, a comparison of the flood flows generated for Forbes Creek using the event modelling outlined in this section are given in **Table B 2.3.5**, together with estimates from the Index Flood Method (Moan and Shaw, 1985), and those generated by continuous simulation (outlined in the next section) for the period November 1, 1960 to October 31, 1999.

Generally, the agreement between the different flood flow estimates is best for the 2 year events in the upper portions of the subwatershed, with greater deviations occurring as one proceeds downstream. The greatest discrepancies occur for the 100-year event, particularly those generated through the application of the Chicago Storm. The main reason for this lies in the computational time applied in the event modelling compared with the continuous simulations. The Chicago Storms are applied using a five-minute time step. Therefore using the IDF information in **Table B 2.3.3**, the 100-year 5-minute rainfall intensity would be 238 mm/h. The continuous simulations are handled using a 60-minute (one hour) time step according to the available rainfall rate data. In these applications, the highest hourly rainfall (or snowmelt) intensity might be 60 to 70 mm/h, occurring maybe two to three times in a 39-year simulation. These differences in meteorological input intensities would be greatest for those subcatchments with little or no storage, such as subcatchment 125, the existing southwestern urban area. The significant storage volumes in the upper parts of the subwatershed would tend to dampen out the input intensity effects, particularly for the lower frequency



events. The major reason for any discrepancies between the Index Flood Method and the event or continuous modelling lies in the fact that the Index Flood Method formula was developed using frequency flows from watersheds with much larger drainage areas (10 to 20

times) than Forbes Creek. In summary then, there is enough agreement between some of the flows in **Table B 2.3.5** to suggest that the estimated flood flows are reasonable, notwithstanding the complexities outlined above.

**Table B 2.3.4 Summary of FloodFlows for Various Return Periods**

Hyd No	Point of Interest	Area (km <sup>2</sup> )	25 mm	1:2	1:5	1:10	1:25	1:50	1:100	Regional
203	East Branch Wetland 203	0.693	0.246	0.326	0.645	1.140	1.780	2.420	4.290	5.900
603	East Branch at Regional Road #24	0.839	0.292	0.409	0.822	1.490	2.150	2.770	4.940	6.280
606	East Branch at Blackbridge Rd	1.183	0.281	0.415	1.230	2.320	3.350	4.060	6.130	9.050
607	Outlet of East Branch	1.340	0.293	0.468	1.510	2.920	4.250	5.220	7.870	10.500
209	West Branch at Regional Road #24	1.027	0.102	0.143	0.280	0.466	0.825	1.070	1.560	4.000
612	West Branch at Blackbridge Rd	1.056	0.238	0.340	0.623	0.937	1.060	1.340	1.830	4.090
615	Outlet of West Branch	1.235	1.180	1.500	2.430	3.570	4.470	5.330	7.190	4.690
617	Confl. East & West Branches	2.575	1.320	1.780	3.380	5.480	7.270	8.750	12.600	15.200
211	Forbes Creek at Pond G	2.720	0.553	0.882	2.140	4.040	5.970	7.300	11.000	16.300
213	Forbes Creek at Gauge#1 (Pond D)	2.963	0.446	0.808	2.210	4.260	6.480	7.970	12.300	18.700
215	Forbes Creek at Pond A	3.036	0.457	0.655	3.220	4.360	7.060	8.570	12.700	19.000
15	Sewer Outlet at Gauge#2	0.463	3.260	3.920	5.790	8.090	10.100	12.600	17.500	6.460
625	625 Forbes Creek outlet at Speed River	3.499	3.330	4.000	5.930	8.310	10.400	13.000	18.000	23.500
911	911 Area East, Part 1	0.038	0.268	0.321	0.468	0.644	0.777	0.923	1.230	0.528
912	Area East, Part 2	0.059	0.322	0.381	0.556	0.776	0.952	1.110	1.510	0.773
913	Area East, Part 3	0.066	0.116	0.168	0.344	0.575	0.770	0.929	1.300	0.838
914	Area East, Part 4	0.127	0.103	0.231	0.639	1.160	1.600	1.990	2.840	1.630
915	Area East, Part 5	0.111	0.047	0.120	0.374	0.719	1.010	1.250	1.820	1.290

*Note: All flows in m<sup>3</sup>/s.*



**Table B 2.3.5 Comparison of Flood Flow**

Hyd. No.	Location	Area (ha)	1:2 Event Model (m <sup>3</sup> /s)	1:2 Cont. Model (m <sup>3</sup> /s)	1:2 Index Flood (m <sup>3</sup> /s)	1:100 Event Model (m <sup>3</sup> /s)	1:100 Cont. Model (m <sup>3</sup> /s)	1:100 Index Flood (m <sup>3</sup> /s)
603	East Branch at Regional Road #24	83.9	0.409	0.290	0.612	4.940	0.700	1.46
605	East Branch at Blackbridge Road	118.3	0.415	0.400	0.818	6.130	1.04	1.95
607	Outlet of East Branch	134	0.468	0.450	0.908	7.870	1.22	2.16
209	West Branch at Regional Road #24	102.7	0.143	0.290	0.726	1.560	0.770	1.73
612	West Branch at Blackbridge Rd.	105.6	0.340	0.300	0.743	1.830	0.790	1.77
615	Outlet of West Branch	123.5	1.500	0.500	0.848	7.190	1.29	2.02
617	Confluence of East & West Br.	257.5	1.780	0.870	1.57	12.600	2.31	3.75
211	Forbes Creek at Gauge No.1	272	0.882	0.890	1.65	11.000	2.40	3.92
15	West Sewer outlet at Gauge No.2	46.3	3.920	1.18	0.371	17.500	3.38	0.884
625	Forbes Creek outlet at Speed River	350	4.000	1.57	2.04	18.000	3.88	4.86

### B 2.3.4 Continuous Simulations

As noted earlier, a 39-year meteorological data set was prepared from climate stations in the surrounding area. The old Preston (MSC 6146711) station provided the longest record available that required very little processing to fill in for missing values.

The 39-year dataset (From November 1, 1960 to October 31, 1999) was applied to the existing conditions Forbes Creek hydrologic model. **Table B 2.3.6** gives a sample complete water balance table for the Forbes Creek at its outlet at the Speed River. This table shows how the individual water balance quantities change from one month to the next. **Table B 2.3.7** gives the mean annual water balance quantities for five locations within Forbes Creek.

Individual quantities in the table are expressed in a water balance  $Precip = (ET/SUB) + Runoff + Baseflow + Losses$  where 'Precip' represents the total precipitation

(rainfall plus snowfall), (ET/SUB) is the combined evapotranspiration and sublimation total, 'Runoff' is the mean annual surface runoff, 'Baseflow' is the portion of the infiltrated water that returns to the stream, and 'Losses' signifies the amount of infiltrated water that does not return to the receiving stream. The 'Losses' total also includes changes in the volume of water stored in the system. 'Total Flow' is the sum of 'Runoff' and 'Baseflow'.



**Table B 2.3.6 Water Balance Summary (Forbes Creek at the Speed River)**

**(All values in millimetres)**

Month	Precip	ET	Runoff	Infiltration (Baseflow)	(Losses)	Total Flow
Jan	50.2	7.8	4.4	22.1	15.9	26.6
Feb	45.5	6.9	7.5	18.6	12.5	26.1
Mar	64.8	9.8	15.2	23.9	15.8	39.1
Apr	78.8	56.9	11.5	31.7	-21.3	43.2
May	76.0	100.2	5.7	29.5	-59.4	35.2
Jun	83.3	103.5	6.1	16.5	-42.8	22.6
Jul	87.2	84.4	6.2	9.0	-12.4	15.1
Aug	86.5	74.3	6.6	6.1	-0.5	12.6
Sep	82.8	50.0	5.4	5.8	21.6	11.2
Oct	73.5	38.1	5.2	8.5	21.8	13.6
Nov	86.7	18.0	7.4	15.8	45.5	23.2
Dec	67.0	7.2	6.8	22.9	30.0	29.7
<b>Total</b>	<b>882.1</b>	<b>557.1</b>	<b>87.8</b>	<b>210.5</b>	<b>26.7</b>	<b>298.3</b>

Upon examination of **Table B 2.3.6**, one can see that on the average 33% of total annual runoff volume occurs in March and April. The negative values for the 'losses' suggest that water is being pulled from soil-water storage in order to satisfy the evapotranspiration potential. Notice that for June, the mean precipitation depth is 83 mm, whereas the actual ET amount is 103.5 mm. Since 22.6 mm of water leaves the subwatershed as runoff plus baseflow, then the deficit created by having less precipitation than ET means that water must come from soil-water storage.

The quantities listed in **Table B 2.3.7** represent the areal mean values for the drainage area upstream of the stated location. For the overall Forbes Creek subwatershed, notice that 9% of the mean annual precipitation appears as runoff, while 65% is lost to the atmosphere (as evapotranspiration),

and 26% infiltrates. In contrast, the amount of runoff generated by the existing southwestern urban area (Subcatchment 125) represents 34% of the mean annual precipitation, with only 51% being lost to the atmosphere, and 15% infiltrates.





Table B 2.3.7 Mean Annual Water Balance

Hyd No.	Location	Area (km <sup>2</sup> )	ET (mm)	Runoff (mm)	Baseflow (mm)	Losses (mm)	Total Flow (mm)
603	East Branch at Regional Road #24	0.839	579.5	44.4	147.9	110.2	192.3
209	West Branch at Regional Road #24	1.027	576.6	55.0	109.2	141.2	164.2
213	Forbes Ck at Gauge No.1 (Pond D)	2.963	574.4	54.6	200.0	53.1	254.5
15	Sewer Outlet at Gauge No.2	0.463	445.0	302.9	183.6	-49.4	486.5
625	Forbes Creek at Speed Outlet	3.499	557.1	87.8	210.5	26.7	298.3

Note: Mean Annual Precipitation is 882 mm for all locations.

Generated peak flows at the outlet of Forbes Creek are given in **Table B 2.3.4**. Low flows are not listed because they go to zero every year, and so the frequency table would contain mostly zero values.

[Figure B 2.3.2](#) gives the flow-duration curves at five locations in Forbes Creek. In general, these curves represent a subwatershed with significant amounts of storage, as suggested by the steady decline between the 20% and 80% exceedance times. This steady decline in the flow duration curve is indicative of water being

evaporated or leaking (recharge) from significant storage areas. It should be noted that five natural wetlands (or depressions) and three constructed ponds have been considered in the model.

Typically flow in Forbes Creek goes to zero about 5 to 10% of the time. More than 60% of the time flows at the subwatershed outlet are less than 20 L/s, and are less than 10 L/s for East Branch, and 5 L/s for the West Branch. For the southwest urban area (Subcatchment 125), flows are less than 10 L/s for 88% of the time.



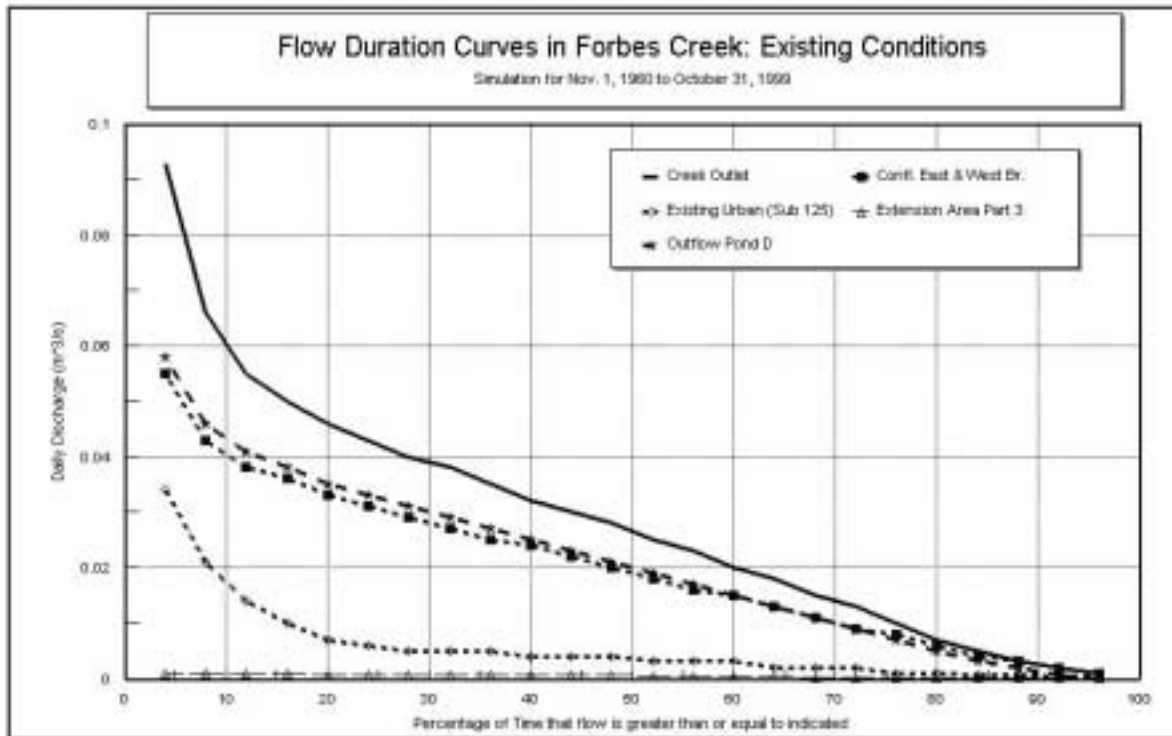


Figure B 2.3.2 Flow Duration Curves

## B 2.4 Hydrologic Considerations

The major considerations in establishing hydrologic management targets are:

1. Increases in peak flows due to uncontrolled development will cause additional flooding in downstream areas. In addition, careful consideration should be given to the discharge of runoff from development to ensure that the fluvial and aquatic characteristics of the creek are not impacted. Typically, peak flows are matched to existing calibrated hydrographs and these have been provided for the Forbes Creek subwatershed.
2. Floodlines should be based on ultimate conditions in the subwatershed.
3. Advancing the hydrograph will change the flow duration characteristics of the system. The hydrograph peak should be maintained to the calibrated hydrograph.
4. The soils in the Forbes Creek subwatershed consist of more than 85% sand and gravel, which are highly permeable resulting in low runoff volumes. Because of low runoff volumes, the infiltration amounts are very high, suggesting significant contributions to groundwater storage (recharge). Infiltration contributes to the local groundwater table, which provides baseflow to the wetlands, ponds and rivers within the Forbes Creek subwatershed. Therefore, infiltration rates should be maintained.
5. The flow attenuation function of the wetlands upstream of Regional Road #24 should be maintained and protected.



6. To ensure that discharge from the stormwater management facilities does not impact riparian systems, extended detention should be used to provide additional volume control for erosion protection. This will also enhance baseflow to the streams.
7. The subwatershed is naturally buffered from extreme runoff events because of significant natural storage areas in the headwater areas. Management decisions need to protect these features for the Forbes Creek subwatershed.

## B 3.0 FLOODPLAIN HYDRAULICS

### B 3.1 Introduction

Floodplain hydraulics are important in order to determine the Regional Storm (and event) flood elevations for the Forbes Creek corridor. As indicated in the revised Terms of Reference, the flood elevations for Forbes Creek will be initiated from the Speed River floodplain (where the elevations are already established by the GRCA) to the wetland areas that mark the origin of the eastern and western tributaries of the creek, north of Regional Road #24. In addition to determining Regional Storm flood elevations, the analysis will also consider the flood frequencies of all structures within the floodplain (including culverts/road crossings, buildings and structures). As per GRCA policy and provincial guidelines, flood flows are assumed to be based on future conditions as discussed further in Section C and **Appendix D and E**. The use of ultimate conditions flood flows and flood lines will allow biologists, geomorphologists, planners and engineers to understand the ultimate effects on the creek system and to make allowances for these flows.

### B 3.2 Hydraulic Modeling

The hydraulic modeling conducted for Forbes Creek used the HEC-RAS v.3.0 (Hydraulic Engineering Centre River Analysis System) model. This is the latest version of the hydraulic analysis program developed by the U.S. Army Corps of Engineers. The HEC family of software is the standard tool used to calculate flood elevations throughout the Province of Ontario (including areas within the Grand River watershed) and it is therefore appropriate to apply the HEC-RAS program in the Forbes Creek subwatershed.

The model requires detailed cross sections of the creek and valley areas (floodplain) in order to accurately determine flood elevations. Cross sections were constructed based on the results of a GPS survey conducted in June 2001, as well as digital topographic data provided by the City of Cambridge. The locations of the cross sections of Forbes Creek used for this analysis are shown on Map 1. Section views for all cross sections are provided in **Appendix E**.

Water surface elevations from the GRCA HEC-2 Speed River model were used as the downstream boundary condition for the analysis. Elevations for the 2- through 100-year events as well as the Regional storm event were taken from cross-section 7670 of the GRCA model, which is located immediately upstream of the Forbes Creek outlet, on the Hespeler Mill Pond. By this method, the starting water level estimates for the Forbes Creek HEC-RAS model have a concrete basis. Also, the results will provide a conservative estimate of the extent of flooding on Forbes Creek, particularly at the downstream end, because it is assumed that the flood events on both watercourses are occurring at the same time.

Using flows from the hydrologic modeling described in Section B 3.2 and **Appendix D**, Regional Storm flows as



well as event flows (2-year through 100-year storms) for ultimate conditions (Scenario 3) were evaluated in the HEC-RAS model to determine flood elevations. The ultimate conditions scenario requires that all future developments provide control of post-development peak flows to pre-development levels (2 year through 100 year

storms). The model summary output is provided in **Appendix E**. Flood elevations at specific locations (for the Regional Storm events) are summarized in **Table B 3.2.1**. The floodplain mapping for Forbes Creek is provided on [Figure B 3.2.1](#) and Map 1 (1:2000 scale).

**Table B 3.2.1 Regional Flood Elevations**

Section No.	Cross-Section Location	Ultimate Conditions Regional Flood Elevation (m)
420 (w)	West branch – 70 m upstream of CSP culvert under Regional Road #24	306.27
325 (w)	West branch – 1350 mm ø CSP culvert under Regional Road #24	306.27
230 (w)	West branch – 150 m upstream of CSP culvert under Blackbridge Rd.	306.37
96 (w)	West branch – 1600 mm ø CSP culvert under Blackbridge Rd.	305.37
2290	East branch – 150 m upstream of CSP culvert under Regional Road #24	305.73
2135	East branch – 1150 mm ø CSP culvert under Regional Road #24	305.69
1819	East branch – 300 m upstream of CSP culvert under Blackbridge Rd.	302.65
1507	East branch – 500 mm CSP culvert under Blackbridge Rd.	302.71
1049	Main channel – downstream of confluence of East and West tributaries	301.75
685	Main channel – Pond G	300.52
569	Main channel – weir structure separating Ponds G and D	300.47
459	Main channel – south major pond upstream of Milton Ave.	300.09
358	Main channel – weir structures at south end of Pond D	299.91
317	Main channel – weir on Pond C, 20 m upstream of Milton Ave bridge	298.25
301	Main channel – Milton Avenue bridge crossing	298.24
223	Main channel – 75 m south of Milton Avenue at upstream end of dry pond	295.81
166	Main channel – weir structure at downstream end of Pond A	295.54
91	Main channel – 75 m upstream of concrete box culvert under pedestrian walkway	293.35
18.5	Main channel – culvert under pedestrian walkway 45 m upstream of outlet to Speed River	292.68

### B 3.3 Flooding Frequency

A summary of structures within the floodplain and their frequency of flooding are provided in **Table B 3.4.1**.

**Table B 3.4.1** demonstrates that flood elevations are sufficient to cause overtopping of Regional Road #24 at the west branch during the regional event, Milton Avenue during the 100 year event, and Blackbridge Road during the 2-year event. The frequency of flooding on Blackbridge Road is excessive for an arterial road and should be



addressed. The discharge capacities of the pond weir structures in the waterfowl area are exceeded during the 2- to 10-year events but this is of little consequence, as the natural topography will continue to direct flows in a downstream direction. The private residence on Milton

Avenue, west of Forbes Creek, is the only existing building in close proximity to the creek. The modelling demonstrates that the residence does not lie within the regulatory floodline and will not be inundated in flows up to and including the regional event.

**Table B 3.4.1 Hydraulic Summary of Forbes Creek Structures**

Structure No.	Description	Location	Frequency Flooded
1	1350 mm ø CSP culvert	West tributary under Regional Road #24	25 years
2	1600 mm ø CSP culvert	West tributary under Blackbridge Road	> REG
3	1150 mm ø CSP culvert	East tributary under Regional Road #24	> REG
4	500 mm ø CSP culvert	East tributary under Blackbridge Road	2 years
5	Weir, 3 m width	Main creek channel between Pond G and Pond D	5 years
6	Weirs, 2 m and 4 m wide openings	Downstream end of Pond D	10 years
7	Private residence	20 m north of Milton Avenue	> REG
8	Weir, 3 m wide opening	10 m upstream of Milton Avenue bridge crossing	5 years
9	Bridge, 5 m wide deck	Milton Avenue crossing	100 years
10	Concrete box culvert – 2 m wide opening	Under private driveway, 45 m upstream of outlet to Speed River	2 years
11	Concrete box culvert – 2.7 m wide opening	Under CN Railway, 30 m upstream of outlet to Speed River	25 years

### B 3.4 Summary of Hydraulic Considerations for Management Targets

Based on the foregoing analysis, the major considerations in establishing hydraulic management targets are:

- To maintain floodlines, stormwater management strategies must ensure that post-development peak flows do not exceed pre-development levels.
- The ultimate conditions Regional storm floodline should be accepted as the Regulatory Floodline by the GRCA for future land use decisions.
- Any channel alterations or structure removals will ultimately require an update of the HEC-RAS model to reflect these changes.

- The existing CSP culvert on the east branch of Forbes Creek at Blackbridge Road is hydraulically deficient and should be upgraded to reduce the frequency of road overtopping.

## B 4.0 FLUVIAL GEOMORPHOLOGY

### B 4.1 Introduction

As part of the Forbes Creek Subwatershed Study, we have provided a fluvial geomorphological assessment of the Forbes Creek system. The objective was to study Forbes Creek in the context of a larger Subwatershed Study and to provide recommendations for management strategies as they relate to the Creek System with respect to potential



development in the area. These recommendations are considered separately from a fluvial process perspective, and again considering the stream system as aquatic habitat for species entering from the Speed River System.

As indicated above, the Forbes Creek system has been divided into a series of Reach Segments according to controls placed on the System. The locations of these reaches are highlighted in [Figure B 4.1.1](#). Summary information is found in **Table B 4.1.1**.

**Table B 4.1.1 Reach Segments**

Reach Segment	Sites Within Reach Segment	Distance (m)	Approx. Elevation Change (m)	Local Slope	Sinuosity Index
Overall main channel	1-17	3005.3	16.0	0.0053	1.05
Mouth to Pond A	1-5	203.4	4.0	0.019	1.08
Pond A to Pond D	6-7	210.0	5.0	0.024	1.07
Pond D to Tributary Split	8-11	761.2	3.0	0.004	1.01
Tributary Split to Blackbridge Road	12-13	485.6	2.0	0.001	1.06
Blackbridge Road to Regional Road #24	14-16	721.8	1.0	0.001	1.05
Upstream of Regional Road #24	17-18	557.7	1.0	0.002	1.06
Overall Tributary Channel	19-20	1981.6	14.0	0.007	1.04
Tributary Split to Blackbridge Road	19-20	406.8	1.0	0.002	1.05
Blackbridge Road to Regional Road #24	0	170.6	0.5	0.003	1.02
Upstream of Regional Road #24	0	131.2	0.5	0.004	1.05

## B 4.2 Summary of Work Performed

Assessment of the Forbes Creek System began in the late Fall, 2000, and continued to early Fall, 2001. In all, 20 geomorphic monitoring stations were established ([Figure B 4.2.1](#)) on the Main Branch (18) and the Tributary Branch (2). Station locations were determined during a creek walk in order to choose representative stations that, when considered together, would characterize the Forbes Creek System accurately. At each station the following data were collected:

- Cross-sectional profile measurements
- Bed material samples
- Total Suspended Solids (TSS) samples

- Sediment transport assessment
- Discharge measurements
- Bank erosion monitoring
- Erosion sensitivity analysis (using our Reach Assessment Form)
- Bank strength
- Bankfull dimensions
- Tractive force analysis as well as overall planform characteristics (slope, sinuosity).

Each site was visited a minimum of 6 times over the study period, under varying flow conditions.

The Forbes Creek System was then assessed according to a Reach Perspective, the reach boundaries being delineated by existing creek structures, either natural or



human-made. The purpose of this assessment was to conceptualize the Forbes Creek System according to potential management strategies, each having boundaries that are somewhat determined by existing structures (i.e. roads, ponds, tributaries).

### B 4.3 Background

The fundamental goal of fluvial ecosystem assessment, maintenance, restoration and monitoring is to maintain a condition that resembles a balance between form and process as closely as possible. Achievement of this goal entails maintenance of the target system's structure and function both locally and within its broader landscape or subwatershed context. To measure the degree of success in achieving such goals, physical, chemical, and biological evaluation data are necessary to verify that an ecosystem is performing as it should. To achieve long-term success, fluvial ecosystem maintenance should, where possible, address the causes and not just the symptoms of potential ecosystem disturbance. Sometimes these causes are obvious, and sometimes they are far removed in time and space from the ecological damage.

The changes that stress fluvial systems impair their value for both human use and environmental services. Stresses can arise from (1) water quantity or flow mistiming, (2) morphological modifications of the channel or riparian zone, (3) excessive erosion and sedimentation, (4) deterioration of substrate quality, (5) deterioration of water quality, (6) decline of native species, and (7) introduction of alien species. In most systems, these conditions arise from rapid or poorly planned development where no predictive studies of channel adjustment have been undertaken.

This study consists of a geomorphological assessment of the Forbes Creek subwatershed and its tributary stream. In order to complete this assignment, it was necessary to

assess the existing conditions of the entire system, using existing digital and ortho-rectified mapping as well as stream-side assessments. We conducted field investigations into the existing geomorphological conditions in the study area as validation of the morphological assessment, which was a desktop exercise.

#### B 4.3.1 The Concept of Channel Maintenance and Alluvial Channel Behaviour

The concept of channel maintenance derives from an understanding of the behavior and characteristics of self-formed alluvial channels. Alluvial refers to material moved by running water. Alluvial channels, composed of sediments deposited by the river itself, are free to adjust their form and substrate, and to a lesser extent, their gradient. Because of this, an alluvial river develops over time a cross-section and substrate reflecting the quantities of water and sediment and the sizes of sediment brought to it, and reflecting the channel boundaries. Channel maintenance flows are intended to maintain the physical characteristics of the stream channel such that the transport capacity of the channel is preserved. The methodology for determining the minimum amount of water to maintain these channels is based on an understanding of the hydrology, sediment transport processes and channel characteristics at water claim sites, fluvial process study sites and gravel bed channels in general. This applies to Forbes Creek which displays a  $D_{50}$  from the high end sand to the low end gravel range. Assessment relies upon available historical records and measurements initiated to develop these claims including streamflow, sediment transport, channel geometry, and channel substrate measurements.

The claimed streamflow is the minimum amount necessary to transport all of the bedload sediment through the claim reaches, thereby preventing long-term accumulation of





sediment and associated reduction in channel size, and maintaining the ability of the channels to transport the mass and size classes of available sediment. The claimed streamflow is generally less than all of the streamflow in any channel because the finer size classes of sediment are supply-limited. While sediment historically moved by unclaimed low flows will temporarily accumulate in the channels, the claimed high flows have the ability to remove the temporarily accumulated finer sediment such that the ability of the channels to pass flows and convey water downstream is maintained over the long-term.

Alluvial channels, composed of sediments deposited by the river itself, are free to adjust their form and substrate, and to a lesser extent, their gradient. Because of this, an alluvial river develops a cross section and substrate that over time reflects the quantities of water and sediment and the sizes of sediment brought to it. While this form, in any given period, responds to the variability of flow and sediment, observations of natural alluvial channels demonstrate that the channel, over time, develops a cross-sectional form reflecting an integration of these temporal variations. Thus, despite considerable variability, natural alluvial channels subject to larger flows characteristically have greater widths and depths than those carrying smaller flows. Many studies have generalized this observation that stream channels are larger where larger volumes of flow occur (Leopold, 1994). In general, channels have a cross-sectional area, width, and depth at bankfull discharge that is related to the range of flows capable of eroding and transporting the alluvial deposits constituting the channel boundaries.

A variety of observations support the generalization that alluvial channels are both adjustable and, over time, establish channel sizes and forms consonant with the flow and sediments available to them. In a given river reach, or length of stream, repeated measurements of cross sections

of a channel reveal maintenance of the channel form as the river migrates across the valley floor (Leopold and Wolman, 1960). Similarly, observations of channel width following a period of high flood flows, show an increase in width and subsequent narrowing following a period of average or more normal annual flows (Wolman and Gerson, 1978).

In an open channel in which both the bed and banks are fixed boundaries, and no sediment is being transported, the depth and velocity of the flow and the profile of the water surface for a given discharge are controlled by the gradient or slope of the channel, the resistance to flow imparted by the boundary materials and the channel size and shape. In contrast, in a channel with mobile boundaries where the flow may alter both the form of the bed as well as the position of the bed and banks through erosion and deposition, channel size and shape reflect a dynamic interaction of erosion, transport and deposition. At low flow little or no sediment may be in motion. As flow increases, smaller particles may be entrained with progressively larger particles in motion at successively higher flows. With increasing flow, the energy available to transport sediment generally increases. Depending on the particle sizes available, the sediment may be transported as suspended or bedload. In general, smaller particles (suspended sediment) are moved by all flows, while larger flows are needed to move the larger particles making up the channel bed. Consequently, as bed-material size increases, the discharge required to cause changes in channel morphology increases.

While there is much variability across the entire spectrum of alluvial channels, distinctive broad regional similarities characterize different kinds of rivers. Among alluvial rivers, gravel-bed and sand-bed rivers have been differentiated (Simons and Simons, 1987). Gravel-bed alluvial rivers are those whose beds are primarily composed of unconsolidated material with median sizes larger than





sand, that is, greater than 2mm. Gravel-bed channels are characteristic of many of the channels of the Grand River basin, and although Forbes Creek for the most part is not categorized as such (especially in the upper reaches), in the lower reaches the creek system operates more as a gravel-bed system than a sand-bed system. In many such channels, both bed and banks are dominated by gravels. Gravel-bed rivers typically have a pavement or armor layer of coarser materials covering the bed channel. Although suspended sediment usually constitutes more of the total sediment load than bedload, it plays a less important role in determining channel morphology (Leopold, 1992).

Much of the bedload in gravel-bed channels is composed of sand and fine gravel particles. This sediment is mobile over a large range of flows and is often supply limited, that is, the stream has more energy than is needed to move the available material. The coarse sediment, which makes up much of the bed, and which is mobile only during higher flows, may be transport limited; that is, the supply is not limited but movement is controlled by the energy of the streamflow. Emmett (1976) suggested the existence of two distinct phases of bedload transport in armored channels: a first phase in which finer sediment moves over the coarser substrate, and a second phase in which the coarser channel-forming materials become mobile (Jackson and Beschta, 1982; Beschta, 1987; Ashworth and Ferguson, 1989; Warburton, 1992).

It is commonly observed that most, if not all, alluvial rivers are subject to episodic floods. That is, the flow overtops the riverbanks and spills over the adjacent lands. Floodplains are formed by lateral movement of the channel and deposition of bars and by vertical accretion resulting from deposition of sediment by floods. To the extent that the adjacent land is the product of deposition by the existing river it is, by definition, a floodplain. The floodplain therefore is a flat area adjacent to the channel constructed

by the river in the present hydrologic regimen. Deposits and surfaces other than the floodplain may exist on the valley floor. If they are alluvial, that is riverine in origin, they may constitute terraces (topographic surfaces) or terrace deposits laid down by the river under a different and/or earlier hydrologic regimen. Although there is some evidence to suggest that the bankfull stage, i.e., height of the floodplain, in many rivers corresponds to a discharge of a relatively constant frequency, for example every 1 to 2 years (Wolman and Leopold, 1957; Emmett, 1975), variability is encountered among river sites in a given region and in different regions (Williams, 1978). Similarly, in some rivers there is a close correspondence between flows during which much of the sediment load is transported over the long-term (effective discharge) and bankfull flow.

## B 4.4 Detailed Studies

The following Data Summaries which characterize the existing conditions of the Forbes Creek System, and represent the input data for determining management strategies.

### B 4.4.1 Flow Assessment

**Table B 4.4.1** shows the results of existing flow conditions for a sampling period in May, 2001, which was chosen as representative of the collection of site visits over the study period. Of importance to note is the fact that discharges are very low (maximum  $0.08 \text{ m}^3/\text{s}$ ), while velocities appear high in the lower reaches. This is due to the rather strong changes in gradient along some sections of the creek system, particularly south of the existing farm lane. Note that in the upper reaches the discharge and average velocity are both quite low, representing the low gradient and impact of grassy beds in the existing channel (which in most instances is nothing more than a swale).





**Table B 4.4.2** shows the bankfull dimensions of the existing channel. This information indicates the maximum capacity of the channel form before flow spills into the floodplain area. As is expected in any creek system, bankfull capacity decreases as the stream moves from its mouth at the Speed River to the headwater areas above Blackbridge Road and Regional Road #24. The data indicates that below the lower ponds (Sites 1-6) the channel is in good shape and can accommodate a suitable volume of flow, however above the lower ponds the capacity of the channel is somewhat reduced.

Hydrological results from Section B 2.0 indicate the 2-year return storm at the mouth of Forbes Creek is on the order of  $2.0 \text{ m}^3/\text{s}$ . This indicates that the channel is incapable of handling this volume of flow as the channel evidence of the 1:2 to 1:5 year return period (as indicated by the bankfull discharge) of 0.27 cubic metres per second indicates. The expected reason for this is the modifications the channel has undergone since the on-line ponds were constructed (collapsing in on itself as part of a channel evolution model situation).

In the lower reaches of the Forbes system there is stormwater contribution from a system arriving from the Guelph Avenue area. Investigation of the flow contribution shows that under baseflow conditions this input equals 50% of the flow volume in the lower creek, and during periods when the creek was dry upstream contributed 100% of the flow volume (there may be some groundwater recharge in this area (Sites 3 & 4) as indicated by the presence of watercross in the creek bed). Separating out this flow from volumes found in the study indicates the channel capacity based on current form may be remnant from a period prior to construction of the online ponds.



**Table B 4.4.1 Existing Flow Conditions (Spring 2001)**

Site	Top Width (m)	Wetted Perimeter (m)	Flow Area (m <sup>2</sup> )	Flow Depth (m)	Mean Velocity (m sec <sup>-1</sup> )	Discharge (m <sup>3</sup> sec <sup>-1</sup> )
1	1.00	1.05	0.06	0.13	0.34	0.02
2	1.12	1.14	0.06	0.07	0.33	0.02
3	1.07	1.12	0.07	0.13	0.37	0.02
4	1.44	1.48	0.11	0.13	0.43	0.05
5	1.20	1.23	0.05	0.06	0.29	0.01
6	2.18	2.19	0.11	0.08	0.33	0.04
7	0.94	0.95	0.03	0.04	0.22	0.01
8	0.71	0.82	0.05	0.16	0.39	0.02
9	1.20	1.31	0.08	0.16	0.38	0.03
10	0.88	0.95	0.06	0.14	0.39	0.02
11	2.00	2.06	0.15	0.14	0.42	0.06
12	1.69	1.73	0.16	0.18	0.49	0.08
13	1.84	1.88	0.17	0.17	0.49	0.08
14	1.60	1.63	0.11	0.12	0.40	0.04
15	1.59	1.62	0.15	0.14	0.21	0.03
16	1.99	2.01	0.13	0.11	0.17	0.02
17	2.21	2.26	0.11	0.13	0.05	0.01
18	1.27	1.28	0.02	0.04	0.07	0.002
19	0.99	1.09	0.05	0.17	0.32	0.02
20	1.40	1.43	0.07	0.10	0.13	0.01





Table B 4.4.2 Modelled BF Flow Conditions

Site	Bankfull Discharge (m <sup>3</sup> sec <sup>-1</sup> )	Bankfull Width	Bankfull Flow Area (m <sup>2</sup> )	Bankfull Wetted Perimeter (m)	Bankfull Depth (m)	Bankfull Velocity (m sec <sup>-1</sup> )
1	0.27	1.64	0.55	1.88	0.33	0.79
2	0.27	2.12	0.38	2.33	0.25	0.73
3	0.35	2.38	0.46	2.58	0.38	0.77
4	0.27	1.60	0.34	1.85	0.28	0.81
5	0.22	1.40	0.29	1.68	0.25	0.75
6	0.31	2.40	0.42	2.59	0.22	0.74
7	0.12	1.10	0.18	1.32	0.19	0.66
8	0.04	0.80	0.08	0.95	0.20	0.47
9	0.10	1.30	0.17	1.50	0.23	0.59
10	0.11	1.10	0.17	1.29	0.24	0.64
11	0.09	2.13	0.18	2.19	0.16	0.47
12	0.19	1.86	0.28	1.99	0.25	0.67
13	0.18	2.36	0.30	2.41	0.23	0.60
14	0.18	1.73	0.27	1.89	0.22	0.68
15	0.07	2.02	0.27	2.10	0.21	0.27
16	0.10	2.27	0.35	2.41	0.21	0.30
17	0.03	3.29	0.34	3.38	0.22	0.09
18	0.01	1.98	0.08	2.01	0.08	0.13
19	0.01	1.17	0.06	1.28	0.18	0.15
20	0.04	2.47	0.20	2.52	0.18	0.22

August 16, 2002





### B 4.4.2 Sediment Analysis

In order to determine possible management strategies it was necessary to undertake sediment analyses of the bed and transportable materials. This information assists in determining potential loss of sediment to erosion, and is coupled with the flow data to make statements on channel stability and to assess alternatives.

**Table B 4.4.3** shows the results of the sediment analysis. For the most part the channel bottom of Forbes Creek contains materials in the silt/sand/gravel range (indicated

by the  $D_{50}$  size value (column 3 in **Table B 4.4.3**)), with tendencies toward the finer classes of sediment. The lack of coarse sediment is interesting in that the creek flows through some glacial till, however the low flows and introduction of fine material over the years as overland transport may have covered the original bed of the stream with fine sediments after the ponds were developed. Note that there were no bed samples from Sites 17-20, as these were characterized by a grassy bed and could be regarded as swales.

Suspended sediment concentrations (TSS in **Table B 4.4.3**) indicate how much sediment is transported as wash load during storms and during low flows. Concentrations of greater than 30 mg/L are considered areas of concern for fish health, concentrations higher than 200 mg/L would be of concern relating to sedimentation of the on-line ponds. Data indicates that average concentrations, over more than 20 site visits to collect samples, are very low indicative of existing land use in the area. The presence of buffers and wetlands in the Forbes Creek system help to keep sediment concentrations low, however this does have the potential to lead to other erosion problems in the downstream direction. Maximum concentrations exceed the

30 mg/L threshold in only one instance, indicating this stream system is not producing excess sediment for transport. This also indicates that the on-line ponds, while being a sink for sediment transported in this manner, do not appear to be in danger of filling in with sediment at this time. This of course could change if land use changes occur, principally in the construction phase where sediment supply is increased by orders of magnitude; these situations can be controlled by maintaining proper buffers around the creek and ponds and by utilizing proper sediment control strategies.





Table B 4.4.3 Results of Bed and TSS Sampling

Site	D <sub>16</sub> mm	D <sub>50</sub> mm	D <sub>84</sub> mm	Mean TSS Mg/L	Min TSS Mg/L	Max TSS Mg/L
1	15.45	8.00	3.48	4.7	0.8	12.3
2	6.73	2.46	0.758	5.1	1.6	13.8
3	13.45	1.43	0.717	4.1	0.3	26.3
4	0.716	0.149	0.053	1.9	1.0	41.0
5	N/A	13.00	6.06	1.6	0.9	18.7
6	3.25	0.210	0.092	2.5	1.6	14.2
7	0.518	0.28	0.082	3.4	2.1	12
8	1.189	0.32	0.053	3.6	0.4	13.1
9	2.00	0.30	0.065	4.4	1.3	8.7
10	1.189	1.00	0.077	5.3	1.6	3.7
11	4.595	0.33	0.117	2.7	0.9	5.2
12	1.149	0.28	0.067	2.9	1.4	6.1
13	5.65	2.64	1.00	4.1	1.2	4.7
14	6.06	2.46	0.812	5.4	0.6	16.9
15	11.71	2.79	0.379	6.1	0.2	23.6
16	3.48	0.435	0.134	4.9	0.1	15.4
17				0.1	0.0	0.4
18				0.1	0.0	0.2
19				0.1	0.0	0.3
20				0.2	0.0	0.3

Note the Mean TSS sample is based on a minimum of 6 samples, the Min and Max represent the minimum and maximum TSS concentrations collected under the sampling conditions. Note there are no bed samples for Sites 17-20, they are grass-bottomed channels with no apparent sediment substrate.





### B 4.4.3 Shear Stress Analysis

Further to the flow and sediment analysis is an investigation of the potential for bed movement according to shear stress relationships. Shear stress is the effect of water flowing over the bed material, and is a function of the slope of the stream channel, in a particular segment, and the pressure exerted by the water, usually indicated by the depth of flow. Also included in the equation is the specific weight of water itself at certain temperatures. **Table B 4.4.4** shows the results of this investigation.

This data indicates one of the principal flaws in using shear stress analysis. The results show that under bankfull stage, in most instances, both the median diameter particle and the finer diameter particle (in this case the  $D_{16}$  particle) would be set in motion. Sediment traps set under a series of flows show nil results, indicating only the finest material carried as wash load was in transport under most conditions.

The explanation for these results lies in the presence of the on-line ponds, and their impact on overall slope. The channel dimensions and the overall slopes indicate sediment would be in motion, however the presence of flat-gradient impediments at semi-regular intervals (wetland complexes, on-line ponds) have the effect of negating the slope influence. If we were able to reduce slope in the shear stress equation we would see that little or no material would be set in motion at bankfull stage.

This has the potential to present erosion problems elsewhere, for if no material is moving along the bed the turbulent energy of the stream must be expended elsewhere, and in most cases on streams of this size and larger the place this is expended is in bank erosion. Fortunately, Forbes Creek is not experiencing bank erosion

at locations along the channel at scales that would indicate the “starving water syndrome”<sup>1</sup> is present in the system. In fact, while the on-line ponds are the cause of potential misinterpretations of the shear stress data, they also in fact are the buffer against further erosion.

This highlights the need for proper fluvial geomorphological assessment of creek systems. Simple data collection and interpretation of numbers from standard equations results in errors in assessment.

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<sup>1</sup> **Starving Water Syndrome:** One mechanism by which a stream dissipates energy is through the transport of sediment. If the stream has the ability, it will pick up and move sediment in the downstream direction. By doing so, there is less energy available to erode the bed and banks. For example, if a stream has a potential for erosion by flow of 100%, and 25% of that potential energy is used up in transporting sediment, that flow can only use 75% of the total flow energy for erosion. This means that a particular flow is incapable of eroding to its maximum extent.

If, for some reason, sediment in transport is taken out of transport (as in this case as the creek enters an online pond), that 25% expended energy is not spent on transporting sediment any longer. Therefore as flow leaves the online pond, it is not carrying any sediment and therefore has 100% erosion potential once again. In essence the water is “starved” of a mechanism to expend energy, and therefore it starts to do work on the nearest erodible boundary (in most cases the banks). The flow will erode the boundary until it reaches that threshold (in this example the 25% value), which is in effect a state of equilibrium with the flow energy condition. This process is very evident downstream of dams and other flow regulation structures, but is not evident downstream of pools in a stream as the pool structure allows for some sediment to be transported through the reach. Starving water syndrome is the terminology used to describe the situation where flow which has excess sediment competence erodes a bed or bank to achieve that equilibrium state.



**Table B 4.4.4 Shear Stress**

Site	D <sub>16</sub> mm	D <sub>50</sub> mm	D <sub>84</sub> mm	$\tau_{cr}$ D <sub>50</sub>	Stream Power	$\tau_o$	$\tau_o/\tau_{cr}$ D <sub>50</sub>	U <sub>c</sub> D <sub>50</sub>	Erosion Potential (N M sec <sup>-1</sup> )
1	15.45	8.00	3.48	5.83	14.01	12.21	2.10	0.514	1.05
2	6.73	2.46	0.758	1.79	14.01	10.50	5.86	0.299	2.98
3	13.45	1.43	0.717	1.04	18.16	11.76	11.29	0.233	5.93
4	0.716	0.149	0.053	0.11	14.01	10.76	99.15	0.083	59.75
5	N/A	13.00	6.06	9.47	11.41	9.56	1.01	0.643	0.63
6	3.25	0.210	0.092	0.15	12.14	7.28	47.59	0.096	27.49
7	0.518	0.28	0.082	0.20	4.70	5.53	27.11	0.110	15.57
8	1.189	0.32	0.053	0.23	1.57	5.22	22.40	0.117	5.60
9	2.00	0.30	0.065	0.22	3.92	6.65	30.44	0.114	10.18
10	1.189	1.00	0.077	0.73	4.31	6.54	8.98	0.198	3.74
11	4.595	0.33	0.117	0.24	3.52	5.45	22.66	0.119	5.98
12	1.149	0.28	0.067	0.20	7.44	7.72	37.83	0.110	15.45
13	5.65	2.64	1.00	1.92	1.76	1.88	0.98	0.309	0.32
14	6.06	2.46	0.812	1.79	1.76	1.72	0.96	0.299	0.45
15	11.71	2.79	0.379	2.03	0.68	1.70	0.84	0.317	0.14
16	3.48	0.435	0.134	0.32	0.98	1.73	5.47	0.135	1.14
17					0.59	3.80			
18					0.52	3.84			
19					0.49	6.74			
20					1.96	7.69			

**Table 4.4.4: Shear Stress assessment and erosion potential of existing bed materials based on flow geometries at bankfull stage. D16, D50 and D84 are representative grain sizes of the 16<sup>th</sup>, 50<sup>th</sup> and 84<sup>th</sup> percentile;  $\tau_{cr}$  D<sub>50</sub> represent the critical shear stress required for initiation of movement for the 50<sup>th</sup> percentile size particle;  $\tau_o$  represents the boundary shear stress acting on the particles under bankfull stage;  $\tau_o/\tau_{cr}$  represent the relationship between critical and boundary shear stress (a value >1.0 indicates the particles in that size range should be in motion) for the 50<sup>th</sup> percentile; and U<sub>c</sub> D<sub>50</sub> represents the critical velocity in metres per second required to initiate transport for the 50<sup>th</sup> percentile fraction (to be compared to Column 7 in Table 2; erosion potential is based on the relationship between critical shear and average shear for each section with respect to bankfull velocities, as per the Shear1 module in Qualhymo and other hydrological models:**

**Note: Samples at sites 17-21 are not available since there is no exposed bed and bank, and channels are entirely grassed.**





These results indicate that erosion is a potential issue at site 4, and to a lesser degree sites 6, 7, 9 and 12. Viewing these results in the context of stream power at these sites, which reaches a maximum value at site 3, it is clear to conclude that erosion potential with respect to channel processes is negligible at bankfull discharges with the exception of site 4. What this indicates is there are sections of the lower reaches of Forbes Creek which are subject to erosion and which may require stabilization if there are any structures at risk by lateral migration in this area.

#### B 4.4.4 Erosion Assessment

The results from the flow and sediment analysis give only a partial picture to the processes of erosion in any watershed. Therefore it is necessary to provide detailed data on erosion of bank materials through direct measurement. In order to do this, erosion monitoring pins were placed at each cross-section and at control points along the Forbes Creek system to monitor bank retreat over the course of the study. [Figure B 4.2.1](#) details the location of the erosion monitoring stations at where the erosion pins are located. **Table B 4.4.5** shows the results of erosion pin monitoring.

Usually results of long term monitoring programs are presented in a step-wise manner to determine the rate of erosion at different times of the year, in most cases to separate winter from summer effects on bank retreat. However in this case, given the low values of retreat and the short monitoring period, data is presented as total retreat between November 2000 and September 2001.

Note that there is little if any bank retreat at any of the study sites. Control points had no bank retreat over the study period. Given the low values of sediment transport in the system we would expect more bank erosion to occur,

however again the presence of on-line impediments to flow (wetlands, ponds) is protecting the banks to a certain degree.

While there has been some retreat of the banks (maximum detected 4 cm), this is well within the lower limits of expected retreat for banks based in this type of material and in basins of this size (minimum thresholds in the scientific literature being on the order of 2-9 cm per year).





Table B 4.4.5 Erosion Pin Monitoring

Site	Left Bank (cm)	Right Bank (cm)	Avg. Torvane (kg/cm <sup>2</sup> )
1	4	1	0.16
2	3	2	0.14
3	0	1	0.70
4	1	3	0.25
5	2	0	0.22
6	0	0	0.30
7	0	0	0.21
8	1	2	0.13
9	3	1	0.11
10	1	0	0.31
11	4	1	0.16
12	1	0	0.25
13	0	0	0.22
14	2	1	0.46
15	3	6	0.39
16	1	0	0.41
17	0	0	0.61
18	0	0	0.39
19	0	0	0.56
20	0	0	0.42

*Left Bank and Right Bank refer to upstream-facing left and right banks of the channel. The Torvane measurements refer to a rotational shear stress test, applied in the field, and are used to represent bank strength (for example at Site 1 the banks average a strength of 0.16 kg of pressure per cm<sup>2</sup> of bank area). The higher the value in this column, the more resistant the bank is to erosion.*

Further to erosion pin monitoring, an additional assessment of the creek was completed using a Rapid Reach Assessment Form (RRAF), initially developed in the US and modified by Dr. Beebe for use in Southern Ontario.

**Table B 4.4.6** shows the results of the RRAF (see **Appendix F**). Results indicate that few reaches are at risk of instability under current conditions (Sites 6 and 7 being the only ones at potential risk). Clearly the stream system is

in a state of quasi-equilibrium with existing conditions and while this may change if land use changes, there are management strategies which can be utilized to assist with maintaining stability.

Sites 6 and 7 get a low rating for stability because of the lack of riparian width and the lack of flow diversity across the reaches. It is important that management alternatives relating to the fluvial functioning of the Forbes system take this into consideration and provide for remediation of these conditions. Specific recommendations will be presented in a later section of this report.

Overall, the data indicates the system is somewhat stable and functioning in equilibrium with existing pressures and stresses on the Creek. Alteration of these conditions can impact the functioning of the stream and should be carefully assessed. The Forbes Creek System operates unlike other creek systems of similar contributing area in that it has been highly altered and is currently regulated by a series of on-line ponds which hinder flow and sediment transport. Having said this, however, the System appears to be in dynamic equilibrium with its surrounding conditions and, if there were to be no development in these lands, we would be recommending leaving the system as it currently exists. Potential issues stem from the impending development of the adjacent lands, which will have the potential to create changes in the Creek System over time. It is best that the system be enhanced in order to protect it from the development impacts, and in doing so create and/or maintain habitat for other fish and wildlife that may utilize the area. The Forbes Creek System is highly altered and is in need of rehabilitation downstream of the two main ponds to the Speed River. This work is required to create a naturally functioning fluvial system which has the resilience to accommodate potential development in the upstream reaches, and which has the ability to increase fish habitat potential.





Table B 4.4.6 Rapid Reach Assessment

Site	Instream Substrate Characterization	Morphological Diversity of Flows	Channel Stability (Base Level)	Bank Stability	Riparian Vegetative Zone Width	Total Score (100)	Erosion Sensitivity Category
1	18	15	14	17	20	84	Low
2	18	15	14	17	20	84	Low
3	14	14	15	18	20	81	Low
4	14	15	13	16	20	78	Low
5	7	13	15	15	20	70	Mod Low
6	6	5	18	13	9	51	Mod High
7	7	5	18	13	9	52	Mod High
8	12	14	15	17	15	73	Mod Low
9	11	14	14	18	13	70	Mod Low
10	13	13	15	16	13	70	Mod Low
11	12	14	15	17	12	70	Mod Low
12	11	12	18	18	16	75	Low
13	12	12	16	18	18	74	Mod Low
14	15	17	15	16	20	83	Low
15	15	16	15	15	20	81	Low
16	14	15	15	15	20	79	Low
17	0	5	20	20	20	65	N/A
18	0	5	20	20	20	65	N/A
19	0	5	20	20	20	65	N/A
20	0	5	20	20	20	65	N/A

Note: Low Sensitivity 75-100  
 Moderate Sensitivity 50-74  
 Moderate High Risk Mod H 50-59  
 Moderate Medium Risk Mod M 60-69  
 Moderate Low Risk Mod L 70-74  
 High Sensitivity 0-49

Values in Columns 2-7 represent field scores from the Rapid Reach Assessment Form. Each category has a maximum value of 20, indicating the most optimal situation. A value of 0 indicates extremely poor conditions. High sensitivity to erosion indicates the reach is exhibiting at least two areas of concern, one of which being bank stability. Note a Moderate sensitivity category may be at high risk for bank erosion problems yet may be masked by high values in the riparian vegetation category, therefore this category is split into high, medium and low risk to erosion.

## B 4.5 Summary

The data presented above indicates that the Forbes Creek system is in relatively good shape from the perspectives of fluvial geomorphology. There are however areas of concern which need to be addressed.

Generally, there are areas of the creek system which are hindered from proper functioning as a result of human interventions: the large number of concrete impediments to flow are a serious concern and there is a need to consider that, at the very least, they be removed completely as part of the management strategy.

Additionally, there is stormwater outflow that enters the lower reaches of the Forbes system (below the fenced-off property at the lower end of the first pond). This contribution to flow was found to be almost 50% of the early summer base flow, and in fact as of early September 2001, when the entire creek system was dry, contributed 100% of the flow in the lower reaches. This indicates that there may be water quality concerns in the lower reaches. So while the storm sewer discharges coolwater at low flow conditions, first flush flows will have adverse temperature spikes and excessive sediment delivery at certain times of the year that may need attention. One simple solution is to create a settling area for this flow, which diverts it from the creek system altogether until the flow moderates its temperature and sediment characteristics. Water quality issues are discussed further in Section B 5.0.

There are a number of potential issues relating to the fluvial functioning of the Forbes Creek system. These include:

- The presence of wetland complexes on-line with the creek system, in particular upstream of Ponds





D and G and upstream of Reach 3. These wetlands slow flow considerably through the reaches and result in decreased competence and dropping of sediment. This also alters the energy budget of the stream system which in turn alters derived relationships such as shear stress and other 'critical' thresholds.

- On-line ponds (Ponds A, D and G primarily) create potential issues along the same lines as the wetland complexes listed above. There is always a concern with on-line ponds that they will suffer sedimentation, if there is enough sediment delivery from the upstream area. While this is not a primary concern due to the lack of channel form upstream (and therefore little opportunity for stream bank and streambed erosion), it should not be dismissed entirely as there is evidence of some sediment accumulation at the inlet of the top pond.
- Downstream of Ponds D and G and the bridge crossing, the channel through Reach 2 has an opportunity to acquire a proper form and function, but is limited from doing so by the presence of Pond A farther downstream.
- Within this channel reach, however, there are other issues of concern:
  1. There is no real form to the channel – it acts more like a spillway than a creek, there are no real well-defined banks and the presence of thick, instream vegetation prevents flow from being able to carve a channel.
  2. There is a great deal of concrete in the channel at the lower end of Reach 2 which needs to be removed. This concrete, while possibly protecting the bed from erosion, is not natural and is preventing sediment transport at the upstream end due to a change in grade.

Additionally, the change in grade at the downstream end is problematic as it creates a small waterfall situation, which can cause undue erosion.

- The presence of concrete in a system such as the Forbes Creek presents difficulties in that it restricts natural stream processes from operating at the channel scale. In some larger river systems lateral bank erosion and vertical bed erosion is an issue due to land use constraints, thereby requiring the use of concrete or other "hard" engineering structures. In Forbes Creek this is not an issue as the concrete in the channel at numerous locations inhibits the creek from forming a natural pathway as well as acting as a barrier to sediment transport. At this scale the existing concrete barriers are preventing the Forbes Creek system from attaining a natural equilibrium with existing conditions, and therefore they need to be removed and the creek sections where concrete currently exists need to be rehabilitated.
- The creek essentially disappears below Pond A and goes underground, only to reappear downstream of a large concrete wall through a narrow pipe. The creek needs to be brought back to the surface and the concrete barrier, which hinders sediment transport, needs to be removed.
- Downstream from this wall, the creek is attempting to form a natural channel. There is some recognizable creek form in this area, which has the potential for rehabilitation. This area is the only area of the creek which has sustained flow for the entire study period, indicating it is an area of groundwater discharge.
- Downstream of this location, and immediately upstream of the footpath crossing, the creek is joined by another creek which has been formed by





stormwater outfall arriving from Guelph Ave. This outfall contributes to the flow volumes of the lower portion of Forbes Creek, to the point of up to 50% of the flow volume of the lower reaches during summer base flow studies. This additional flow contributes to channel widening at the lower reaches, and is the prime component causing erosion of the left bank at the footpath structure (though the footpath is not at great risk because of the erosion).

- At the location between the footpath bridge and the railroad crossing there is another drop in the stream, this also becomes a barrier to sediment transporting from upstream, and also causes erosion at the drop through the waterfall action.

## B 5.0 SURFACEWATER QUALITY

### B 5.1 Background

This section of the report will provide an overview of the existing surfacewater quality of Forbes Creek. The following information is included:

- Monitoring goals
- Description and significance of surfacewater quality parameters;
- Information on the implemented monitoring program, monitoring protocol, sampling locations and observed local conditions;
- A summary and interpretation of the monitoring result;
- Identification of potential contaminant sources
- Conclusions and recommendations for future surfacewater monitoring.

Currently, this study represents the only source of information on surfacewater quality for Forbes Creek watercourse.

Complex and interactive processes occurring in the environment determine surfacewater quality. Field monitoring programs required to fully understand these processes are very demanding in terms of labour and time and typically include some continuous monitoring operations.

In this particular case, however, the goals of monitoring program were to:

- a) acquire baseline information on surfacewater quality at Forbes Creek; and
- b) define a set of water quality parameters to be monitored in the future. As such, several samples were collected at various points along the watercourse.

The samples were collected in the summer, when most of the interactions affecting water quality are most intense.

### B 5.2 Surfacewater Quality Parameters

Water is important for human existence and support of natural habitat. As a result, changes in water quality can have serious consequences. The chemical composition of water is a measure of its sustainability for human and animal consumption, and for industrial and other purposes. Water quality also affects ecosystem health and function. The chemistry of surfacewater reflects input from atmosphere and soil, as well as from various urban and rural pollutant sources. Surfacewater is typically more susceptible to contamination than groundwater.



Surfacewater quality is characterized through a multitude of chemical, physical and biological parameters. Chemical parameters include:

- a) inorganics (acidity, alkalinity, pH, metals, hardness);
- b) organics (BOD, COD, THM, PCB, hydrocarbons, etc.);
- c) major ions (cations and anions); and
- d) nutrients (nitrogen and phosphorus group)

Physical parameters include odour, taste, solids content, turbidity, pH, DO and temperature. Biological parameters are bacteria, protozoa, viruses, plankton, invertebrates, algae and aquatic plants.

Water quality parameters are used to assess the general conditions of watercourses and larger water bodies and to identify potential source of pollution. Water pollution is the unfavourable alteration of water caused by human actions which renders the water unfit for use by man or other organisms. Water pollution is a rather complex issue, as it is difficult to establish definite criteria to determine when water becomes polluted. Given time, water interacts with the natural elements on the surface and acquires chemical composition, thus giving the water a natural background water quality. These natural elements include geographic location, geology, climate, topography and flora and fauna. This natural water quality consists of chemical parameters that are normally stable and consistent throughout the year. When the natural levels are affected by humans and one or a number of parameters become “out-of-balance”, then the entire ecosystem can change and cause the water to be “polluted”.

### B 5.3 Water Quality Monitoring Program

Water quality monitoring program was implemented from April to November 2001. The program consisted of the following components:

- Continuous monitoring of water temperature;
- Spot measurement of dissolved oxygen and temperature;
- Water quality sampling for general chemistry;
- Water quality sampling for baseline information (dry weather);
- Water quality sampling for baseline information (wet weather);
- Additional information on the conditions in the study area collected during site visits.

Monitoring protocols for each of the components of the monitoring program are given as follows:

- Temperature measurement: Three monitoring stations (indicated as T1, T2 and T3 in [Figure B 5.3.1](#)) have been established for this purpose. Information on water temperature was collected using the same instrumentation that was used for water level measurement, which simplified maintenance and download of the equipment. The purpose of this measurement was to assess the impact surface runoff has on various segments of the watercourse. Station T1 was established just downstream from the weir between Ponds D and G. Location T2 was established at the discharge point of the storm sewer, and location T3 was upstream of the culvert under the railroad tracks. All the probes were deployed to record temperature data at 15-minute intervals, which is considered to be appropriate to observe



temperature changes in an open watercourse. The probes were maintained and downloaded at regular intervals and no problems were observed during the monitoring program;

- Spot measurements of dissolved oxygen and temperature: Several spot measurement of dissolved oxygen and temperature were taken at monitoring stations T1, T2 and T3 using a portable analytical instrument. The purpose of this measurement was to (a) allow for quality control for data collected using automatic dataloggers; and (b) gather some information on dissolved oxygen, as this parameter can be only measured in the field;
- Water quality sampling for general chemistry: In general, three monitoring stations (indicated as W1, W2 and W3 in [Figure B 5.3.2](#)) have been used for sampling. Station W1 was located just downstream from Pond C, Station W2 at the discharge point of storm sewer and Station W3 was upstream of the culvert under the railroad tracks. One set of samples was collected at stations W1 and W3 on May 16, 2001 and submitted for general chemistry. All the applicable laboratory standards related to collection and preservation of the samples in terms of number and type of containers have been strictly followed during the submission.
- Water quality sampling for baseline information (dry weather): One set of samples was collected at Station W3 under dry weather conditions on October 4, 2001. The samples were submitted for a larger number of parameters, to allow for baseline characterization of water quality under dry weather conditions. As previously indicated, sampling was performed in accordance with all applicable analytical standards.

- Water quality sampling for baseline information (wet weather): Two sets of samples were collected at stations W1 and W3 under wet weather conditions on October 16, 2001. The samples were submitted for a larger number of parameters, to allow for baseline characterization of water quality under wet weather conditions;
- Additional information on the study area: Information on debris, floatables, oil sheen on the surface, erosion and vegetation was also recorded during field trips, to be complemented with the results of laboratory analysis.

## **B 5.4 Summary and Interpretation of Monitoring Results**

The purpose of water quality monitoring program was to acquire baseline information under various conditions and to use that experience to design future monitoring programs. The information was collected over relatively short period of time, but also during the period when different processes in the environment are most intense. As the purpose of the monitoring program was not to identify trends in the environment, or to accurately model response of the river system to rainfall and pollutants, the collected information is considered to be of good quality and sufficient to accomplish the set goal.

### **B.5.4.1 Temperature Measurement**

Temperature data for T1, T2 and T3 have been summarized and presented in [Figures B 5.4.2, B 5.4.3](#) and [B 5.4.4](#) respectively.

In general, seasonal variations can be recognized for all the three Stations T1, T2 and T3. Average daily temperatures increased from the beginning of April to mid-August, and then dropped again towards the end of



October. The values recorded at Station T1 were higher than for the other two stations when seasonal variations are considered in absolute terms. As baseflow temperature at Station T2 (storm sewer discharge) never exceeded

14°C, it has been concluded that groundwater recharge contributes to this component, having a cooling effect on the downstream reach of the watercourse.

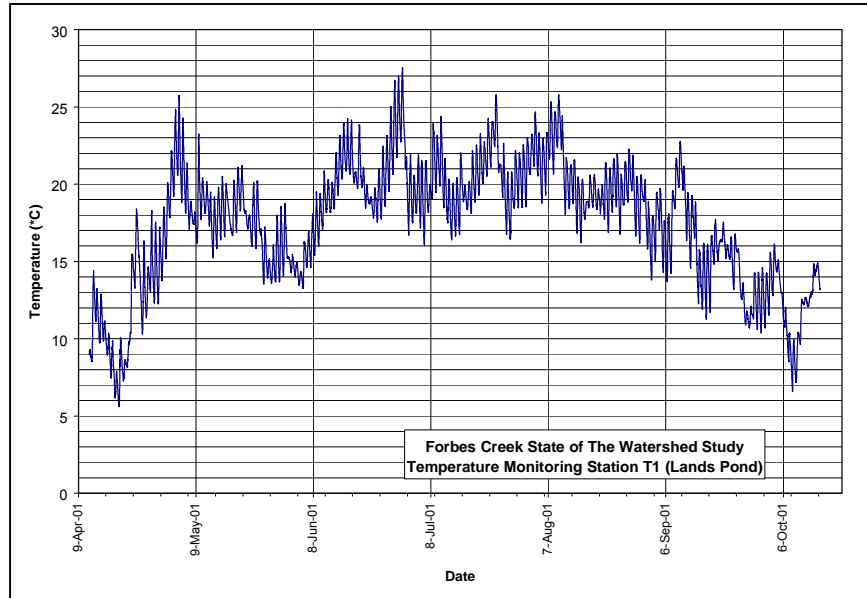


Figure B 5.4.2 Temperature Monitoring – Ponds D and G

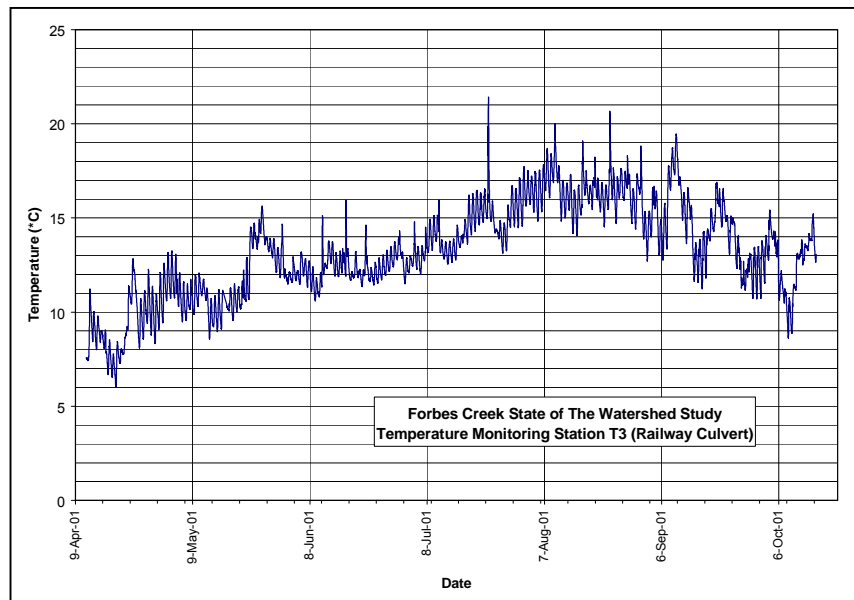


Figure B 5.4.3 Temperature Monitoring Storm Sewer



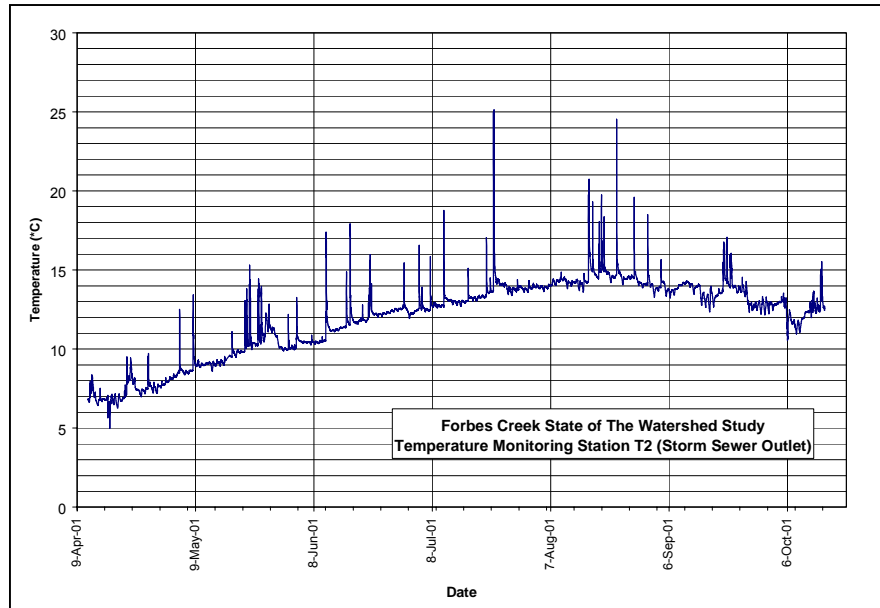


Figure B 5.4.4 Temperature Monitoring Railway Culvert



Another remark is related to diurnal variations. These variations have been easily identified for the Stations T1 and T3, with very weak response to changes in air temperature for T2. Daily temperature fluctuations for T1 and T3 were up to 5°C, with corresponding value of less than one degree for T2. Flows in the sewer are not exposed to direct thermal exchange, which significantly reduces diurnal variations. It is pointed out that temperature loggers deployed at T1 and T3 were placed close to the bottom, thus readings do not reflect the temperature of the upper layer.

Finally, the stations showed different response to storm events. Storm events caused “peaky” response at T2, where runoff caused water temperature to temporarily increase by almost 10°C in July. These effects have been short-lived and temperatures would return to their normal seasonal values. Whereas there was some weak response to storm events at T3 in July, there were practically no changes in water temperature induced by rainfall at T1.

In conclusion, temperature measurements at various locations along the watercourse indicate that there is visible cooling effect of the storm sewer discharge on the downstream reach. This effect is in particular emphasized regarding seasonal variations, where lower baseflow temperature at T2 contributes to generally lower maximum average temperatures at T3. For a given season, this resulted in average daily temperature at T3 lower than 20°C, which could, theoretically, create potential for coldwater fishery.

Additional measurements of temperature and dissolved oxygen have been summarized in **Table B 5.4.1**. These observations support the finding that discharges from the storm sewer have generally cooling effect on the downstream reach. For warmer months, monitoring station

T3 recorded lower temperatures and higher dissolved oxygen levels.

**Table B 5.4.1 Forbes Creek Water Quality Testing**

Date	Parameter	Location	
		Pond C Outlet W1	Rail Culvert W3
May 16, 2001	Water Temperature	20 <sup>o</sup> C	12.5 <sup>o</sup> C
	Dissolved Oxygen	9.9 ppm	9.4 ppm
May 23, 2001	Water Temperature	20 <sup>o</sup> C	16.7 <sup>o</sup> C
	Dissolved Oxygen	10.4 ppm	6.63 ppm
June 22, 2001	Water Temperature	21.1 <sup>o</sup> C	13.2 <sup>o</sup> C
	Dissolved Oxygen	3.04 ppm	5.76 ppm
August 20, 2001	Water Temperature	22 <sup>o</sup> C	18.4 <sup>o</sup> C
	Dissolved Oxygen	2.83 ppm	7.86 ppm
October 3, 2001	Water Temperature	17 <sup>o</sup> C	14.3 <sup>o</sup> C
	Dissolved Oxygen	3.04	7.01 ppm

*Note: DO readings based on daytime sampling*

## B 5.5 Water Chemistry

A summary of laboratory results for the samples collected on May 16, 2001 (general chemistry) is given in **Table B 5.5.1**, and for samples collected on October 5 and October 16, 2001 in **Appendix G**.

As for the results presented in **Table B 5.5.1**, values for a number of metals (aluminum, copper, iron, nickel, zinc) have not exceeded maximum values set in Provincial Water Quality Objectives, with rather low suspended solids content (22.5 mg/L and 1.6 mg/L for W1 and W3 respectively) and low Total Coliform count (300 and 160 for W1 and W3 respectively). As these samples were collected under dry weather conditions, they reflect mostly baseflow quality, and the fact that the two on-line ponds (Ponds D



and G) perform, at least to some extent as sedimentation basins.

Phosphate-P (mg/L)	<0.30	<0.30
Sulphate (mg/L)	9.5	27

**Table B 5.5.1 General Chemistry Samples**

Sample	Detection Limits (mg/L)	Sample No.1 (mg/L)	Sample No.2 (mg/L)
Alkalinity (CaCO <sub>3</sub> ) (mg/L)		140	269
Ammonia as N (mg/L)		<0.10	<0.10
Conductivity (umhos/cm)		740	1010
pH (ph units)		8.6	8
Phosphorus	0.01	<0.05	<0.05
Total Dissolved Solids (mg/L)		456	636
Total Suspended Solids (mg/L)		22.5	1.6
Fecal Coliforms (cfu/100ml)		45	58
Total Coliforms (cfu/100ml)		300	160
Aluminum (mg/L)	0.075	<0.02	<0.02
Barium (mg/L)		0.02	0.05
Beryllium (mg/L)	0.011	<0.001	<0.001
Boron (mg/L)	0.2	<0.05	<0.05
Cadmium (mg/L)	0.0002	<0.002	<0.002
Calcium (mg/L)		63	112
Chromium (mg/L)		<0.01	<0.01
Cobalt (mg/L)	0.0009	<0.01	<0.01
Copper (mg/L)	0.005	<0.005	<0.005
Hardness (CaCO <sub>3</sub> ) (mg/L)		260	400
Iron (mg/L)	0.3	0.17	0.13
Lead (mg/L)	0.005	<0.01	<0.01
Magnesium (mg/L)		25.1	28.7
Manganese (mg/L)		0.07	0.05
Molybdenum (mg/L)	0.04	<0.01	<0.01
Nickel (mg/L)	0.025	<0.01	<0.01
Potassium (mg/L)		1.1	2.3
Silicon (mg/L)		0.8	3.9
Silver (mg/L)	0.0001	<0.001	<0.001
Sodium (mg/L)		66.6	78.4
Strontium (mg/L)		0.014	0.2
Thallium (mg/L)	0.003	<0.002	<0.002
Titanium (mg/L)		<0.01	<0.01
Vanadium (mg/L)	0.006	<0.01	<0.01
Zinc (mg/L)	0.02	<0.01	<0.01
Zirconium (mg/L)	0.004	<0.01	<0.01
Bromide (mg/L)		<0.10	<0.10
Chloride (mg/L)		120	140
Fluoride (mg/L)		<0.10	<0.10
Nitrate as N (mg/L)		<0.10	4.1
Nitrate as N (mg/L)		<0.10	<0.10

With regards to a larger number of parameters presented in **Appendix G**, concentrations for a number of them were below detection limits. For the samples collected under wet weather conditions on October 16, 2001, there was not much difference in comparison with the previously discussed set in terms of suspended solids (13.2 mg/L and 5.6 mg/L for W2 and W3, respectively). Major difference has been observed in bacteria count. For the sample collected under dry weather conditions on October 4, 2001, Total Coliform count at W3 was 1,360, as compared to 16,000 and 8,900 on October 16, 2001 at W3 and W2, respectively.

Previous studies indicated that there is a strong correlation between TSS and other pollutants for a number of parameters (metals, nutrients, phosphorus). By applying the same principle on a limited set of samples, it has been concluded that upstream on-line ponds (Ponds D and G) effectively reduce total suspended solids in the watercourse both under dry and wet weather conditions. High bacteria count could be probably contributed either to farming practices or wildlife, waterfowl in particular in the area, but additional monitoring is definitely required to support these findings.

### B 5.6 Identification of Potential Contaminant Sources

The contaminant sources (point source and non- point source) within the Forbes Creek subwatershed have been established by review of land use mapping, observations within the subwatershed boundaries, and review of MOE records. No actual testing was conducted to confirm what



(if any) impacts these sources currently have on Forbes Creek.

The following list summarizes possible contaminant sources for Forbes Creek:

- **Historical Land Use:** Due to past activities related to a shooting range, there is the potential for lead contamination at the lower portion of the subwatershed (see Section A 1.7.1).
- **Agricultural land use:** A large portion of the subwatershed is currently used for agricultural purposes and therefore there is a risk of contamination associated with agricultural practices. The majority of farming consists of crop farming (e.g. corn, etc.). Non-point source contaminant sources would indicate herbicide and pesticide use on agriculture lands and point source contaminants could originate from animal waste found along the watercourse.
- **Urban residential land uses:** The western area of the subwatershed contains an urban area of the City of Cambridge. Possible non-point contaminant sources include fertilizer and herbicide use on residential lawns. Potential point sources from urban uses include sedimentation of the watercourse (e.g. from stream crossings, etc.), debris/garbage in the stream and stormwater management inputs.

### **B 5.7 Conclusions and Recommendations for Future Monitoring**

The primary problem regarding the water quality concerns for Forbes Creek is the lack of consolidated information. Through the completion of this Subwatershed Study, a considerable amount of monitoring has taken place and the results of those tests have been consolidated in the final Subwatershed Management Plan. More specifically, the completion of the sampling program will provide an

accurate picture of the health of the watercourse and a benchmark to measure watercourse health under future conditions and to confirm that (future) subwatershed targets and being met.

Using the information compiled in this Background Review, preliminary objectives for the water quality are based on the Ministry of Natural Resources' criteria for coldwater and warmwater streams in Southern Ontario, as both are present in the subwatershed. The following water quality parameters represent preliminary objectives for surfacewater quality for Forbes Creek:

**Coldwater:**

Water Temperature:	Will not exceed 20° C between Apr 1 and Oct 1 Will not exceed 14° C and not less than 4° C between November 1 and March 31
Dissolved Oxygen:	no less than 8 mg/L.
Phosphorus:	less than 0.03 mg/L.
Sediment:	less than 25 mg/L suspended solids.
Bacteria:	less than 100 counts/ 100 mL.

**Warmwater:**

Water Temperature:	Will not exceed 26° C between June 1 and August 1 Will not exceed 29° C between August 1 and October 31
Dissolved Oxygen:	No less than 5 mg/L.
Phosphorus:	Less than 0.08 mg/L.
Sediment:	Less than 25 mg/L suspended solids.
Bacteria:	Less than 200 counts/ 100 mL.

Additionally, the use of Stormwater Management Practices (SWMP's) from the MOEE's Stormwater Management Practices Planning and Design Manual (June 1994) or any relevant updates will require to be implemented for any proposed new development to address water quality concerns and attempt to maintain or improve existing conditions.





## B 6.0 FISH HABITAT AND COMMUNITY

### B 6.1 Fisheries Management Context

Forbes Creek is a first order tributary to the Speed River and flows into the mill pond upstream from the Hespeler dam. The Grand River Fisheries Management Plan (GRCA and MNR, 1998) describes the Speed River between the City of Guelph and the confluence of the Speed and Grand Rivers as having “a diverse warmwater fish community dominated by top predators (e.g. smallmouth bass [*Micropterus dolomieu*], pike [*Esox lucius*]). Forbes Creek is not specifically mentioned in the discussion of tributaries contained in the Grand River Fisheries Management Plan.

### B 6.2 Habitat Characteristics

Permanent flow in Forbes Creek appears to begin with groundwater seepage immediately upstream from the chain link fence separating the approximately 50 metres downstream from Pond A (see [Figure A 3.3.1](#)). There was no flow upstream from that point on July 19, 2001, and the stream channel was dry except for various ponds. On July 19, 2001, although there had been no recent rain, there was more flow coming from the storm sewer that enters the creek than from the natural channel upstream from that point.

The furthest upstream reach with permanent flow is located in an area that had been previously occupied by a pond that was created by a dam. The dam remains however it no longer holds back water. Through this section the canopy is open and there is a dense bed of watercress growing in fine substrate in a poorly defined channel. Downstream from the old dam the gradient increases, the channel is well-defined, and the substrate is dominated by

cobble, with patches of gravel, sand and silt. This section flows through forest and is well shaded. The stream flows through a culvert beneath a private lane, and then over a manmade barrier to upstream fish movement at the fence line. It then passes through a culvert beneath the railway and to the Speed River.

In addition to the barriers to upstream fish migration noted above, there are two more dams upstream at the outlet of dug ponds. These ponds vary in size and permanence, and are discussed in a more detail in the Fish Community section.

Art Timmerman of the Ministry of Natural Resources also took spot water temperatures at four locations in the subwatershed in September 2000. The results indicated cool water conditions at Blackbridge Road and coldwater conditions at the CNR right-of-way.

Benthic invertebrate samples were collected at three locations on July 19, 2001. These were located immediately upstream and downstream from the confluence of Forbes Creek and the storm sewer outfall as well as within the storm sewer outfall channel itself.

### B 6.3 Fish Community

As indicated above, Forbes Creek is isolated from the Speed River by a barrier to fish migration located at the property line upstream from the CNR right-of-way. The Ministry of Natural Resources received a credible report of a (1) brook trout (*Salvelinus fontinalis*) being captured downstream from this barrier by angling in recent years (Art Timmerman, personal communication). Downstream from this barrier, Ministry of Natural Resources staff captured three common fish species, creek chub (*Semotilus atromaculatus*), brook stickleback (*Culaea inconstans*) and pumpkinseed (*Lepomis gibbosus*) in July of 2000. C. Portt





and Associates staff (C. Portt and G. Coker) electrofished this reach of the stream and captured only brook stickleback (14) on July 19, 2001. They also captured approximately 25 brook stickleback and one fathead minnow (*Pimephales promelas*) by electrofishing from the laneway culvert, just upstream from the railway, to the next barrier (dam) upstream. On July 19, 2001, there was more flow coming from the storm sewer than from the natural channel upstream and there was no flow in the creek upstream from the seepage area just upstream from the chain-link fence.

The ponds were also electrofished on July 19, 2001. No fish were captured in the pond that was furthest downstream (Pond A). This pond was a shallow, shrinking pool surrounded by exposed mud on that date and was completely dry later in the summer. Pumpkinseed were observed guarding nests in this pond by A. Timmerman of OMNR in 1995 (MNR files). Pond B was dry on July 19, 2001. Pond C was shrinking in size on July 19, 2001, and was not sampled. It was dry later in the summer. Pond D was seined several times on May 25, 2001, by G. Coker assisted by students from Jacob Hespeler Secondary School. A total of five fish species were captured. They were in order of abundance pumpkin seed, brook stickleback, fathead minnow, northern redbelly dace (*Phoxinus eos*) and brown bullhead (*Ameiurus nebulosus*). Pumpkin seed were the only species captured in Pond D, where they were abundant. Submergent vegetation completely covered the bottom of this pond.

Young-of-the-year fathead minnows were extremely abundant in Pond E on July 19, 2001. Dozens were captured with every scoop of the dipnet, but no other species were captured. This pond was also choked with submergent vegetation. No fish were captured or observed in Pond F. In Pond G, Brook stickleback were abundant and the only species captured by electrofishing on July 19,

2001. This pond was choked with dense submergent vegetation, which made fish sampling difficult. Both pumpkinseed and brook stickleback were observed in this pond by A. Timmerman in 1995.

No fish were captured in Pond J, which was electrofished on August 24, 2001.

### B 6.3.1 Benthic Invertebrate Methodology

Three benthic invertebrate samples were collected from Forbes Creek on July 19, 2001, using a modified kick and sweep method. The sampling locations were in the main creek immediately upstream from the channel leading from the storm sewer outfall, in the main creek immediately downstream from that channel, and in the channel itself. At each location the substrate was disturbed by hand and by foot and larger rocks were rinsed by hand along a transect across the wetted channel. The disturbed material was collected in a 500 µm D-net and then preserved in 5% buffered formalin.

In the laboratory each sample was first placed into a geological sieve with a 0.250 mm mesh and rinsed with tap water to remove excess field preservative. Successive subsamples were then removed to sorting trays and all the invertebrates removed from each until 200 organisms were found. These were sorted into like groups and identified to the lowest practical taxonomic level. A reference collection containing representatives of each taxon was compiled for future referral.

## B 6.4 Results

The number of each taxon identified from each site is presented in **Table H1** as found in **Appendix H**. The total number of taxon was highest (24) in the main creek downstream from the confluence with the stormwater





outfall and similar in the main creek upstream from the confluence (12) and in the stormwater outfall channel (15). Isopods (aquatic sow bugs) were the dominant taxa at all locations. We have observed this before in headwater streams where few fish were present and suspect that it may be due to the low level of predation. In general the numbers of taxa were low and groups that are considered indicators of good water quality, such as stoneflies and mayflies, were not found at any of the sites. Although the absence of these taxa is often considered indicative of poor water quality, these sampling locations are all within a short distance of where permanent flow begins, and thus the sample composition must be interpreted with caution. The greater number of Chironomids and lower numbers of Trichoptera (damselflies) and Sphaeriid clams downstream from the stormwater outfall suggest that the stormwater has a negative effect on water quality.

## B 6.5 Summary of Management Considerations

Flow in Forbes Creek is intermittent except in the reaches closest to the Speed River where groundwater discharge maintains permanent flow. Fish use of the creek proper upstream from the initial seepage point is seasonal at most. There is a credible report of an angler catching a brook trout near the mouth of the creek (downstream from the railway), but recent sampling has resulted in the capture of only common non-game species, and in this study only two species were captured in these lower reaches. The larger, permanent ponds upstream also contain common non-game species, including minnow species, pumpkin seed and sticklebacks.

The benthic invertebrate community in the permanently flowing reach of Forbes Creek did not contain sensitive mayflies or stoneflies, and there was some indication that

the stormwater discharge was negatively affecting water quality.

There are several barriers along the creek that prevent fish migration upstream from the Speed River and between various reaches of the creek. These include a grate arrangement that has become a barrier immediately downstream from the railway and the dams that maintain several of the ponds on the system. The on-line ponds, in addition to providing fish habitat, will warm the water in the stream, when the stream is flowing.

Constraints and opportunities for fisheries within the study area are associated with:

- Baseflow (permanence of flow has major impacts upon fish community).
- Channel form/size
- Barriers to fish migration and ponds
- Water quality/temperature

Specific rehabilitation recommendations are presented in Section C 3.1.4.

## B 7.0 AGRICULTURE AND RURAL RESOURCES

### B 7.1 Introduction

It is recognized that the land within the subwatershed study area is in a state of transition from agricultural uses to urban uses. However, a portion of the study area is presently designated agricultural. Agriculture, because of its presence in the subwatershed, has the potential to affect water quality and quantity either in the short-term or in the long-term. As agricultural uses are present in the upstream area of the subwatershed, what occurs in agricultural areas has the potential to affect water that is currently flowing





through and will continue to flow through an urban area downstream from the agricultural areas. Therefore, the objectives of this agricultural investigation are to:

1. provide a general description of agriculture within the subwatershed study area;
2. assess the urban-agricultural interface;
3. Identify any existing agricultural issues;
4. evaluate how agricultural impacts on subwatershed ecology can be minimized; and
5. identify possible Agricultural Best Management Practices.

The information presented is not intended to be as detailed and/or specific as that which would be included in an agricultural impact assessment associated with an official plan amendment.

## B 7.2 Biophysical Description

The bedrock underlying the subwatershed is a cream to buff colored dolomite of the Guelph formation. The bedrock is overlain by overburden that resulted from the action of glaciers. Thus, the study area is characterized by rolling topography typical of glacial moraine. The moraine has subsequently been reworked by melt waters resulting in glaciofluvial deposits of outwash sand and gravel as well as glaciolacustrine sand and silt soil materials. More specific mapping and description of the bedrock and Pleistocene geology is summarized by Karrow in the report *Soils of Waterloo County* by Present and Wicklund (1971). As well, soil materials are described in Section B 1.0 of this report.

### B 7.2.1 Agricultural Soils

As a result of the past soil formation processes, the land has a broad cross-section of different agricultural soil types,

drainage classes and topography. Organic soils as well as mineral soils are found within the subwatershed. Based on the maps produced by Present and Wicklund (1971), approximately 20 different soil series have been identified. The characteristics of these soils are summarized in **Table B 7.2.1**.



**Table B 7.2.1 Summary of Agricultural Soil Characteristics**

Soil Name	Drainage	Surface Texture	Parent Materials	Slope Classes	Capability Class
Bookton	Imperfect	Sandy loam	Clay loam	B	3
Brady	Imperfect	Sandy loam	Sandy loam	A,B	2
Brant	Well	Loam	Loam	B,b,C	1,2,3
Brisbane	Imperfect	Sandy loam	Gravelly loamy sand	A	2
Burford	Well	Silt loam to loam	Very gravelly sand	A,B,b,C,c,D	2,3,4
Caledon	Well	Sandy loam	Gravelly loamy sand	A,B	2,3
Camilla	Imperfect	Sandy loam	Gravelly sandy loam	A	2
Colwood	Poor	Loam	Loam to fine sandy loam	A	3
Conestogo	Imperfect	Silt loam	Loam till	A	1
Dumfries	Well	Loam	Gravelly sandy loam	B,b,C	3,4
Floradale	Imperfect	silt loam	Loam -- gravelly layers	A,B	1
Freeport	Well	Fine sandy loam	Gravelly loam till	A	2
Guelph	Well	Silt loam	Loam till	B,C,D	2,3,4
Heidelberg	Imperfect	Very fine sandy loam	Fine sandy loam	A	1
Lisbon	Well	Sandy loam	Loamy sand	A,B,b,C,D,d	2,3,4,5
Organic	Very poor	Decomposed organics	Decomposed organics	A	0
St. Jacobs	Well	Silt loam	Very gravelly loamy sand	A,B	1
Tuscola	Imperfect	Loam	Silt loam	A,B	1
Waterloo	Well	Fine sandy loam	Fine sand	A,B,C,D	1,2,4
Woolwich	Well	Silt loam	Loam	A,B	1

**NOTES:**

**1 SLOPE CLASS CONVENTION**

Slope classes mapped within the Region of Waterloo follow an alphabetic convention. Slopes are recorded in the field as a percent which is calculated by dividing rise by run and subsequently multiplying the result of the division by 100 percent. Slope class represents a range of percent as follows:

**Slope Classes**

Simple	Complex	Range (%)
A	a	0.0 - 3.0
B	b	3.1 - 6.0
C	c	6.1 - 12.0
D	d	12 +

Uppercase letters denote simple regular slopes whereas lowercase letters indicate complex irregular slopes.

**2 COMMON FIELD CROP CAPABILITY CLASS**

The class, the broadest category in this classification, is a grouping of subclasses that have the same relative degree of limitation or hazard. The limitation or hazard becomes progressively greater from Class 1 to Class 7. The class indicates the general suitability of the soils for agricultural use.

- Class 1 - Soils in this class have no significant limitations in use for crops.
- Class 2 - Soils in this class have moderate limitations that restrict the range of crops or require moderate conservation practices.
- Class 3 - Soils in this class have moderately severe limitations that restrict the range of crops or require special conservation practices or both.
- Class 4 - Soils in this class have severe limitations that restrict the range of crops or require special conservation practices or both.
- Class 5 - Soils in this class have very severe limitations that restrict their capability of producing perennial forage crops, and improvement practices are feasible.
- Class 6 - Soils in this class are capable only of producing perennial forage crops and improvement practices are not feasible.
- Class 7 - Soils in this class have no capability for arable culture or permanent pasture.

The original soil capability rating report (Environment Canada, 1972) has a number of assumptions which have been applied to the interpretation of soils in the Subwatershed. Two of these assumptions (Environment Canada, 1972) are germane to a discussion on the capability of the Subwatershed and are as follows:

- Good soil management practices that are feasible and practical under a largely mechanized system of agriculture are assumed.
- Soils considered feasible for improvement by draining, by irrigating, by removing stones, by altering soil structure, or by protecting from overflow, are classified according to their continuing limitations or hazards in use after the improvements have been made. The term "feasible" implies that it is within present day economic possibility for the farmer to make such improvements and it does not require a major reclamation project to do so. Where such major projects have been installed, the soils are grouped according to the soil and climatic limitations that continue to exist. A general guide as to what is considered a major reclamation project is that such projects require co-operative action among farmers or between farmers and governments. (Minor dams, small dykes, or field conservation measures are not included).





### B 7.2.2 Soil Capability for Agricultural Production

Most of the land within the subwatershed has been rated for soil capability between Classes 1 and 3 (following the map published by Presant and Wicklund, 1971). There are some areas that are not prime and are classified in capability classes 4 and 5. Field observations indicate that soil capability classes tend to vary significantly within individual farm fields.

### B 7.2.3 Soil Erosion in Agricultural Fields

On the basis of limited field observations, cultivated lands within the subwatershed are currently eroding. This erosion ranges from small rills to relatively large and extensive gullies. However, no systematic study of the subwatershed has been completed to identify the relative amount/severity and location of erosion by water within farm fields. Similarly, studies have not been completed which identify the relative amount and location of wind erosion. The same field observations also indicate that sediment delivery to Forbes Creek, the ponds or wetlands located within the subwatershed is relatively low. In other words, most of the sediment appears to be redeposited in swales within farm fields or within grassed and/or forested lands located adjacent to the fields within which erosion is occurring.

In addition, no estimate of soil erosion potential has been completed for the subwatershed. A detailed study of soil erosion potential as well as the severity and extent of existing erosion would need to be completed to identify those areas either currently or potentially at risk.

### B 7.3 Socio-economic Description

The majority of the land area within the Forbes Creek subwatershed is in agricultural production with common field crops such as corn and soybeans predominating. Some fields are used as hay/pasture and a relatively small acreage is in specialty crops. Specialty crops, grown in the north end of the study area, include apples, strawberries and pumpkins. Hay/pasture areas appear to be used for cattle production as cattle were observed in the fields in part of the subwatershed. Because of the aforementioned variability in the soils and topography within the study area, farm fields are relatively small and are subdivided by existing woodlots, wetlands and hedgerows (see Section B 8.0).

#### B 7.3.1 Planning Designation and Land Use Trends

The predominance of agricultural land uses within the subwatershed is a function of historical use as well as the area's current planning designation. The Official Plan of the City of Cambridge has much of the subwatershed designated as a Class 1 (Prime) Agricultural Resource District for the lands north of Blackbridge Road and north and west of Regional Road #24. The same area has extensive amounts of land designated as an Open Space District. Similarly, the Official Policies Plan of the Regional Municipality of Waterloo has all of the lands north of Blackbridge Road and north and west of Regional Road #24 designated as a prime agricultural area.

Because of its location adjacent to existing built-up area in Cambridge, the subwatershed is in a state of transition between urban and rural uses. This transition is reflected in the presence of non-farm development as well as in the relatively poor condition of some of the buildings



associated with former agricultural operations. As well, a limited review of information on ownership and tenancy on lands currently used for agricultural production, indicates that parts of the subwatershed are owned by individuals or businesses interested in developing the land to meet the housing needs of the people of Cambridge. This urban/rural mix of ownership of agricultural lands is typical of areas located adjacent to cities.

### B 7.3.2 Farm Infrastructure and Economics

Farm infrastructure includes buildings as well as improvements to land such as tile drainage, irrigation systems (or parts thereof) and erosion control structures. Relative to other areas in the Province, investment in infrastructure is low. Farm buildings within the subwatershed vary in size and condition. However, many of the buildings do not currently appear to be in uses related to their original design. Drainage improvements such as tile drainage are not required in many locations because soils are well-drained.

The relatively low investment in infrastructure is appropriate given the low economic returns associated with common field crop production like that which predominates the subwatershed. The problem of low economic returns within agriculture has been relatively consistent over time. An older planning report, evaluating agriculture in Ontario, suggested that profitable agriculture on soil capability Class 2 or poorer lands was difficult if common field crops were grown (Center for Resources Development, 1972). Relatively low returns associated with common field crop production have resulted in the need to supplement farm income from sources other than the farm. Relatively recent data available from Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) (from <http://www.gov.on.ca/OMAFRA/english/stats/finance/index.html>, 2001) clearly indicate that, on average, more of total

OFF-FARM INCOME AS A PROPORTION OF TOTAL FARM INCOME (WESTERN ONTARIO REGION)

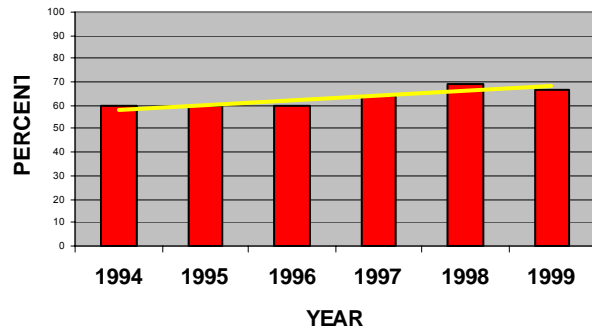


Figure B 7.2.1 Off Farm Income

farm income comes from non-farm sources than from farm sources (See [Figure B 7.3.1](#)). Better economic returns are associated with specialty crop production especially when fruits and vegetables are sold directly to the public in the way that they are at two locations adjacent to Regional Road #24 within the subwatershed. This relationship is illustrated in the following [Figure B 7.3.2](#) (from <http://www.gov.on.ca/OMAFRA/english/stats/hort/index.html>, <http://www.gov.on.ca/OMAFRA/english/stats/crops/index.html> 2001) where dollars received per unit area are significantly higher for the specialty crops garlic, strawberries and tomatoes when compared to common field crops such as soybeans and hay. The dollars received are also a function of what is called marketing channel. Therefore, dollars received are significantly higher when produce is sold directly through a marketing channel such as a roadside stand or farmers' market. Finding data that provide a breakdown for price related to marketing channel is difficult. However, past studies by OMAFRA (from <http://www.gov.on.ca/OMAFRA/english/stats/hort/index.html>, 2001) are available for apples and demonstrate clearly the differences in price received within different marketing channels. The data are summarized in [Figure B 7.3.3](#).



\$ GROSS RETURNS PER UNIT AREA - SELECTED CROPS

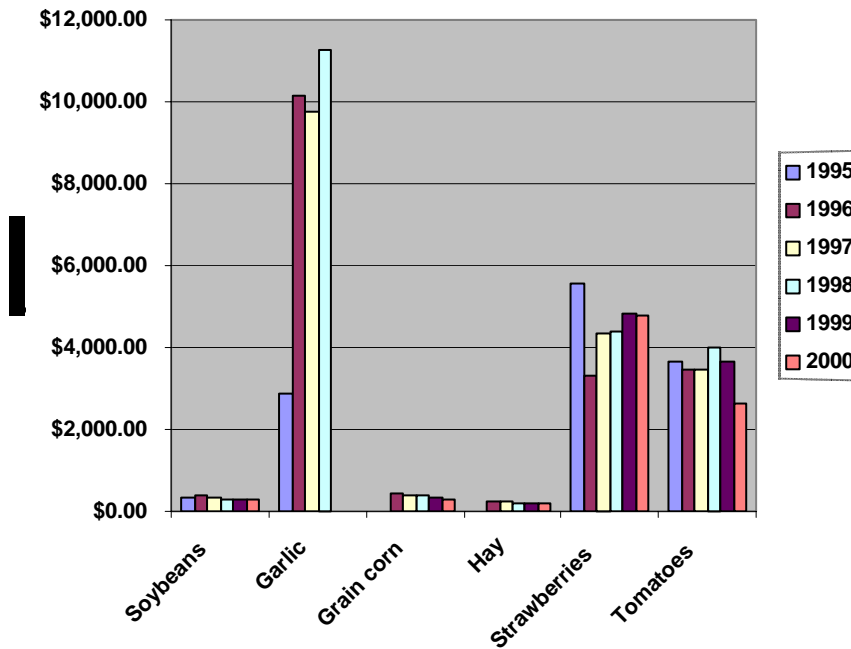


Figure B 7.3.2 Dollar Value

FARM VALUE OF APPLES AS A FUNCTION OF MARKETING CHANNEL

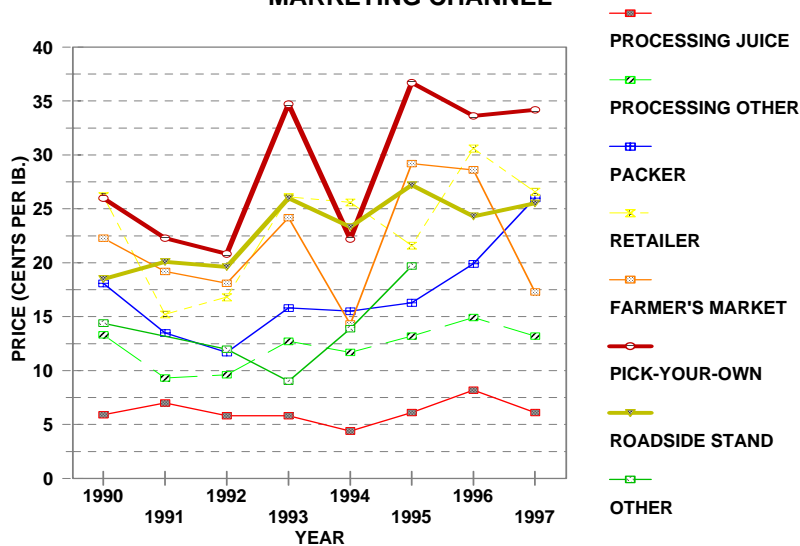


Figure B 7.3.3 Farm Value



## B 7.4 Summary of Agricultural Issues

The management of the subwatershed will be influenced by the relative weight given to agriculture within the planning process in the short run as well as in the long-term. Agricultural uses are predominant in the north and west portions of the subwatershed and have the potential to significantly affect water quality and quantity (see the reference in Section B 1.5.2 concerning elevated levels of nitrates at locations MW3 and MW5. For an additional reference to effects related to agriculture, see Section B 5.6.).

This effect is a function of the kinds of agricultural use and their relative proportion within the subwatershed but most importantly is a function of the management practices chosen and applied by each agricultural operation. Planning policies directly related to agriculture are, for the most part, related to the preservation of the soil resource supporting agriculture but do not address issues related to best management practices. Therefore, agricultural issues related to the management plan can be divided into two distinct categories where the first category relates to agricultural provincial planning policy and the second category relates to best management practices as summarized in the following:

1. Planning within the subwatershed should maximize the preservation of agricultural land as long as possible with priority given to specialty crop areas and lands with higher common field crop capability.
2. Encouragement of, or recommendations related to, best management practices will need to consider:
  - a. farm economics (that is, how much money is available to the farmer for the

application/implementation of a particular practice),

- b. the sometimes contradictory characteristics of best management practices (that is, the fact that some practices may be best for one particular environmental component but may represent a negative condition when associated with a different environmental component) and
- c. finally and most importantly, the individual skill sets and interests of farmers applying those best management practices.

## B 8.0 TERRESTRIAL RESOURCES

### B 8.1 Introduction

Terrestrial resources (vegetation and wildlife) within the Forbes Creek subwatershed were studied by Dougan and Associates, Ecological Consulting Services. Background documents were reviewed in the Fall of 2000. Additional information was obtained from members of the public on a regular basis throughout the remainder of the study. Existing terrestrial resources were inventoried in the autumn of 2000 and winter, spring and summer of 2001. Based on the data gathered, complete lists of flora and fauna were produced and their conservation status evaluated. The principal map resource produced was [Figure B 8.3.1](#) - "Existing Natural Heritage Features", which depicts discrete vegetation communities according to the Ecological Land Classification system (Ecosite Level). A constraint ranking was assigned to each vegetation community based on the identified ecological attributes.



## B 8.2 Background Review

### B 8.2.1 Vegetation Resources

The Forbes Creek subwatershed is located in a transitional area between the Great Lakes - St Lawrence Forest and the Deciduous Forest Regions (Hosie, 1975); the latter region is also known as the Carolinian floristic zone (Soper and Heimburger, 1982). As such, vegetation resources in the subwatershed are represented by species with northern and southern affinities.

Vegetation resources in the subwatershed have been previously documented through a number of studies including the following:

- Cambridge Natural Areas Inventory – **Table 4** and original field notes (Environmental Advisory Services Ltd., 1996)
- Memorandum from A. Goodban dated October 7, 1998, regarding Forbes Creek Wetland Evaluation – Recommended Revisions (Ecoplans Ltd., 1998)
- Memorandum from Thomas J. Wheaton dated July 21, 1998 (Environmental Advisory Services Ltd., 1998)
- Forbes Creek Wetland – reclassification letter (A. Timmerman of the O.M.N.R., August 28, 2000)
- Ontario Natural Heritage Information Centre – Rare species element occurrence database (2001).
- Regional Road #24 - Cambridge to Guelph - Environmental Study Report (M.M. Dillon, Ltd., 1996)
- Distribution and Status of the Vascular Plants of Central Region (Riley, 1989)
- Wetland Data Record-Forbes's Creek Wetland Complex. Third Edition (March 1993). June

9,12,15,19, 1995. (Timmerman, A., A. Skinner and R. Jolette, 1995a)

- Wetland Evaluation Data Record- Glenchristie Wetland Complex. Third Edition (March 1993). June 27, July 13,14,19,28 and 31, 1995. (Timmerman, A., A. Skinner, and R. Jolette, 1995b).
- Wetland Data Record – Ellis Creek Complex. Second Edition. June 19, 1987; July 28 and Aug 2, 1988. (Bergmann, B., M. Ross, N. Sullivan, D. Coulson and D. Stephenson, 1988)

The subwatershed contains an evaluated wetland known as the Forbes Creek Wetland. (Timmerman *et al.*, 1995a). At the onset of the subwatershed study process, the wetland complex was considered to be Locally Significant (Timmerman, 2000). Three other Provincially Significant wetland complexes are located less than 2 km away: Glenchristie Wetland Complex (Timmerman *et al.*, 1995b) to the north, the Ellis Creek Wetland (Bermann *et al.*, 1988) to the west, and the Speed River Wetland to the south.

Environmental Advisory Services Ltd. examined the Forbes Creek subwatershed in 1995 as part of a natural area study undertaken for the City of Cambridge. During the course of their work they noted several significant species; these species and their approximate locations are listed in **Table B 8.2.1**.

Also in 1995, the Forbes Creek Wetland Complex was officially evaluated through a partnership between the City of Cambridge and the Ministry of Natural Resources (Timmerman, A., A. Skinner and R. Jolette, 1995a). Part of information used to score the wetland complex, in particular information for provincially, regionally and locally significant species of flora and fauna, was based on the Environmental Advisory Services Ltd. fieldwork. Based on the acceptance of this information, the Forbes Creek



Wetland Complex was recognized as Provincially Significant. However, several significant plant species were subsequently questioned by A. Goodban (July 21, 1998). The species noted were:

- |                          |                              |
|--------------------------|------------------------------|
| <i>Alisma gramineum</i>  | <i>Lobelia spicata</i>       |
| <i>Bidens connata</i>    | <i>Hieracium paniculatum</i> |
| <i>Carex emoryi</i>      | <i>Pilea fontana</i>         |
| <i>Carex folliculata</i> | <i>Prenanthes trifoliata</i> |
| <i>Carex retroflexa</i>  | <i>Pycnanthemum incanum</i>  |
|                          | <i>Epilobium strictum</i>    |

Many of these species are not known from this region, and are typically found in habitats further south. The locations that they were listed from also do not coincide with the habitats that the species typically grow in. In response to the concerns raised over the identification of certain species, Environmental Advisory Services Ltd responded with the following comments and changes to the identifications (correspondence dated September 22, 1998):

- Alisma gramineum* should be *Alisma plantago-aquatica*
- Carex emoryi* should be *Carex stricta*
- Carex folliculata* was misidentified
- Carex retroflexa* should be *Carex rosea*
- Epilobium strictum* - difficult to distinguish between hybrids
- Lobelia spicata* is correct
- Hieracium paniculatum* should be *Hieracium pratense*
- Pilea fontana* should be listed as *Pilea pumila*
- Prenanthes trifoliata* should be *Prenanthes alba*
- Pycnanthemum incanum* should be *Pycnanthemum virginianum*

Based on this new information, the wetland complex was reclassified from Provincially Significant to Locally Significant. The wetland complex had a total score of 595, five points shy of the Provincially Significant Wetland designation.

Based on our own present review, the identification and/or status of several other species listed in the City of Cambridge Natural Areas Inventory (1995) is questionable, as follows:

*Asclepias quadrifolia* – This species has been extirpated from Canada. It was last known from the Niagara Gorge and is unlikely to be present at the location and habitat noted.

*Eurybia divaricata* (formally known as *Aster divaricatus*) – This species is currently listed by the Committee for the Status of Endangered Wildlife in Canada (COSEWIC) as Threatened. It is found in the Regional Municipality of Niagara in upland deciduous woods and it is unlikely to occur in deciduous treed swamps.

*Picea glauca* is considered to be regionally significant only if it is native.

*Carex scoparia* is considered regionally significant, but may prove to be too common to be so regarded in the future.

**Table B 8.2.1 Significant Species Reported in the Cambridge Natural Areas Inventory (1995)**

Cambridge Natural Area Unit	Cambridge N.A.I. Subunit	Significant species
25	25A-a	<i>Picea glauca-a</i>
	25A-c	<i>Carex cristatella-b</i>
	25A-d	<i>Verbena stricta-a</i>
		<i>Hieracium paniculatum-2</i>
32	25A-f	<i>Pilea fontana-b</i>
	25A-h	<i>Pilea fontana-b</i>
	32-a	<i>Lycopus uniflorus-b</i>
		<i>Solidago gigantea-a</i>
	32-b	<i>Lycopus uniflorus-b</i>
		<i>Bidens frondosa-b</i>
33	32-e	<i>Lycopus uniflorus-b</i>
		<i>Bidens frondosa-b</i>
		<i>Salix eriocephala-a</i>
	32-f	<i>Leersia oryzoides-a</i>
		<i>Leersia oryzoides</i>
		<i>Carex scoparia</i>
35	32-g	<i>Leersia oryzoides-a</i>
	32-h	<i>Bidens frondosa-b</i>
	33-a	<i>Salix eriocephala</i>
	33-b	<i>Lycopus uniflorus-b</i>
35		<i>Leersia oryzoides-a</i>
	33-c	<i>Asclepias tuberosa-a</i>
	35-a	<i>Lobelia spicata -a,b</i>



**Table B 8.2.1 Significant Species Reported in the Cambridge Natural Areas Inventory (1995)**

Cambridge Natural Area Unit	Cambridge N.A.I. Subunit	Significant species
36A	35-b	<i>Lindera benzoin-a</i> <i>Solidago patula-a</i> <i>Sorbus americana-b</i> <i>Lycopus uniflorus-b</i> <i>Aster divaricatus- 1</i> <i>Carex comosa-b</i> <i>Leersia oryzoides- a</i> <i>Salix bebbiana-a</i>
	35-d	<i>Lindera benzoin-a</i> <i>Lycopus uniflorus -b</i> <i>Carex folliculata-2</i>
	35-e	<i>Leersia oryzoides-a</i> <i>Solidago gigantea-a</i>
	35-f	<i>Lycopus uniflorus-b</i>
	36A-a	<i>Triosteum aurantiacum-a</i> <i>Carex rosea-b</i>
	36A-c	<i>Alnus rugosa</i>
	36A-d	<i>Liparis loeselii- a</i> <i>Lindera benzoin-a</i> <i>Geum laciniatum-a</i> <i>Vaccinium corymbosum- a</i> <i>Lysimachia thrysiflora-a</i> <i>Alisma gramineum-2</i> <i>Carex folliculata-2</i> <i>Salix bebbiana-a</i>

Significance: 1~National; 2~Provincial; a~Regional (Reg. Municipality of Waterloo Significant Plant list (1985 version); b~Regional Significant (Riley, 1989)

In 1999, a number of the species present in the subwatershed were removed from the Regional Municipality of Waterloo Significant Plant List (R. M. Waterloo, 1999). Species no longer regarded as regionally significant include:

- Lycopus uniflorus*
- Carex comosa*
- Lindera benzoin*
- Solidago patula*
- Solidago gigantea*
- Salix bebbiana*

Based on our current review of the available documents, eight regionally rare species are reported to occur in the Forbes Creek subwatershed (Regional Municipality of Waterloo, 1999):

- Verbena stricta*
- Pycnanthemum virginianum*
- Carex flava*
- Carex scoparia*
- Vaccinium corymbosum*
- Equisetum palustre*
- Cypripedium calceolus var parviflorum*
- Lobelia spicata*

According to MNR's *Distribution and Status of the Vascular Plants of Central Region* (Riley, 1989) three species known to occur in the Forbes Creek Subwatershed are considered to be significant:

- Sorbus americana*
- Carex comosa*
- Carex rosea*

In general, the Regional Municipality of Waterloo Significant Plant List (Regional Municipality of Waterloo, 1999) is the most current expression of botanical status in Waterloo Region.

### B 8.2.2 Wildlife Resources

The following sources were consulted for wildlife information:

- Cambridge Natural Areas Inventory – **Table B 8.2.1** and original field notes (Environmental Advisory Services Ltd., 1996)
- Ontario Natural Heritage Information Centre – Rare species element occurrences database
- Ontario Mammal Atlas (Dobbyn, 1994) – data records for UTM squares 17NU50 & 17NU51 (NAD27)
- Regional Road #24 - Cambridge to Guelph - Environmental Study Report (M.M. Dillon Ltd., 1996)
- Hespeler East Trunk Community Storm Sewer Outlet ESR (Paragon Engineering Limited – January 26, 1995) File 3 – 5410/50





- Southern Ontario Wetland Evaluation, Data and Scoring Record-Forbes's Creek Wetland Complex. Third Edition (March). June 9,12,15,19, 1995. (Timmerman, A., A. Skinner and R. Jollette, 1995a)
- Forbes Creek Wetland – reclassification letter (Art Timmerman of the O.M.N.R., August 28, 2000)
- A Checklist of Waterloo Lepidoptera, Papilionoidea – The Butterflies (Larry Lamb, April 11, 1967)
- Tschanz, Tina (local resident) – personal communication, December 8, 2000 & February 13, 2001
- Wilson, Dayle (local resident) – personal (e-mail) communication, February 22, 2001
- Anonymous (local resident) – personal communication, February 28, 2001
- Reid, Alec (local resident) – personal communication, August 15, 2001
- Powers, John (local butterfly expert) – personal communication, August 31, 2001

Information from the Hamilton Herpetofaunal Summary could not be accessed; the Ontario Breeding Bird Atlas database (Cadman *et al.*, 1987) was not utilized due to the dated nature of the records (1980-1985) and their lack of site specificity. Several field surveys were planned for the summer to document avifauna.

Most of the background information on wildlife was obtained from the City of Cambridge Natural Areas Inventory. A list of species observed from within the Forbes Creek subwatershed boundary was compiled based on this source (see **Appendix J1**). In total, 44 wildlife species are on record, including 5 species of herpetofauna (reptiles and amphibians), 32 species of birds, and 7 species of mammal. Nine of these species are considered by the

Regional Municipality of Waterloo to be “significant” within its jurisdiction: Bullfrog (*Rana catesbeiana*), Green Heron (*Butorides virescens*), Turkey Vulture (*Cathartes aura*), Northern Harrier (*Circus cyaneus*), Common Snipe (*Gallinago gallinago*), Ruby-throated Hummingbird (*Archilochus colubris*), Brown Creeper (*Certhia Americana*), Mourning Warbler (*Oporornis philadelphia*), and Coyote (*Canis latrans*). However, the Region's designations for herpetofauna and mammals have not been reviewed since 1985 and some rankings may no longer “unofficially” apply. For example, Coyote may no longer merit regionally significant status.

The Ontario Mammal Atlas database yielded only one mammal record clearly within the boundaries of the revised Forbes Creek subwatershed, the common Eastern Chipmunk (*Tamias striatus*). Several other common species were reported from just outside the subwatershed boundary in the Atlas data: Virginia Opossum, Red Squirrel, Red Fox, Striped Skunk and White-tailed Deer. All of these reports are from the early 1990's.

The Hespeler East Community Trunk Sewer Outlet ESR (1995) was also reviewed as part of the background review. Of special interest was the 1994 observation of a Caspian Tern (*Sterna caspia*) from the Mill Pond on the Speed River. This species is presently recognized to be “rare to uncommon” (S3 status) in Ontario (ONHIC, 2001e). Based on the lack of suitable habitat available, it is not considered to be a breeding species here, however the record does highlight the fact that the Mill Pond, being a relatively large body of water, can attract a wide variety of species. The ESR also mentions that Osprey (*Pandion haliaetus*) have been observed feeding along this stretch of river. There are no recent reports of breeding evidence for this species from the local area. The Osprey is currently considered “common” (S4) in Ontario (ONHIC, 2001e). Lastly, reference was made to the occurrence of Pileated





Woodpecker (*Dryocopus pileatus*) from the wetland areas along the Speed River. It was thought that these areas form part of a pair's territory. The wetland areas likely serve as places to forage. Pileated Woodpeckers are "common to very common" (S4-S5) in Ontario (ONHIC, 2001e).

Conversations with local residents conducted between December 2000 and August 2001 yielded supplementary incidental wildlife observations. Although specific dates and locations of observations could not be verified, **Table B 8.2.2** summarizes the incidental reports.

The American Bittern observations are the most significant as both were from the breeding season. Nevertheless, based on our assessment, suitable breeding habitat for this species is probably not present within the subject lands. Therefore these observations may pertain to early migrants. Virginia Opossum is presently recognized as significant in the Regional Municipality of Waterloo (Regional Municipality of Waterloo, 1985b).

Migrating waterfowl use the Mill Pond, immediately south of the study area as a stopover location. However, the wetland features that are contained in the subwatershed to the north appear to be used far less frequently. This no doubt has to do with the lack of suitable habitat and the fact that the Mill Pond is a much larger body of water and becomes free of ice earlier. The habitat quality and species diversity of wetlands in the Forbes Creek Wetland Complex are directly related to the quality, quantity, and seasonal flow of runoff in the subwatershed. One local resident remarked that some waterfowl, including Tundra Swans, congregate in the fields in spring. Based on discussions with the observer, the Tundra Swan observations appear to be regular most springs, typically lasting only a few days. The Ruffed Grouse is considered a species of "conservation priority" in the Regional Municipality of Waterloo (Couturier, 1999). Belted

Kingfisher, Virginia Opossum, Coyote and Mink are listed as significant in the Regional Municipality of Waterloo (Regional Municipality of Waterloo, 1985b; Regional Municipality of Waterloo, 1996).

Another local resident, T. Tschanz, provided a relatively long list of wildlife she has observed from her property on Blackbridge Road (**Appendix J2**). Several of the species mentioned are considered to be significant in the Regional Municipality of Waterloo.





Table B 8.2.2 Wildlife Species Reported by Local Residents in Forbes Creek “Wetland” &amp; Vicinity

Common Name	Scientific Name	Comments
Snapping Turtle	<i>Chelydra serpentina</i>	Observed in Pond D
American Bittern	<i>Botaurus lentiginosus</i>	Observed 1 individual sitting on cedars in wetland in 2000 (unit 6.05). Observed another individual flying NE in August 2001.
Great Horned Owl	<i>Bubo virginianus</i>	Resident observed in woods next to railway tracks
Snowy Owl	<i>Nyctea scandiaca</i>	Observed east of Guelph Avenue, date unknown.
Great Blue Heron	<i>Ardea herodias</i>	Common foraging species in the area.
Tundra Swan	<i>Cygnus columbianus</i>	Resident stated that they stop over for a few days in spring. They are not apparently observed during the fall migration.
Mallard	<i>Anas platyrhynchos</i>	Common year-round resident; congregate in spring and fall.
Teal (spp?)		Resident stated that they congregate in spring and fall.
Ruffed Grouse	<i>Bonasa umbellus</i>	Observed by two residents; Observed in vegetation units 7.12 (February 7, 2001) & 7.30 (February 21, 2001)
Belted Kingfisher	<i>Ceryle alcyon</i>	Observed. No additional information available.
Pileated Woodpecker	<i>Dryocopus pileatus</i>	Likely a local resident foraging in area
Black-throated Blue Warbler	<i>Dendroica caerulescens</i>	Likely a migrant passing through
Common Yellowthroat	<i>Geothlypis trichas</i>	Observed at wetland along Blackbridge Road in 2001.
White-throated Sparrow	<i>Zonotrichia albicollis</i>	Migratory species only in Waterloo Region
White-crowned Sparrow	<i>Zonotrichia leucophrys</i>	Migratory species only in Waterloo Region
Indigo Bunting	<i>Passerina cyanea</i>	Relatively common breeding species in area
Muskrat	<i>Ondatra zibethicus</i>	Observed lodges in the kettle immediately northwest of Regional Road #24
Virginia Opossum	<i>Didelphis virginiana</i>	Seen regularly on Guelph Ave. and Blackbridge Road, including 2001.
Coyote	<i>Canis latrans</i>	Observed by more than one resident; den reported in vegetation unit 7.26, active in 2001.
Red Fox	<i>Vulpes vulpes</i>	Seen by two residents, on Blackbridge Road and elsewhere
Raccoon	<i>Procyon lotor</i>	Seen on Blackbridge Road
Mink	<i>Mustela vison</i>	Observed in vegetation unit 7.12 February 7, 2001.
White-tailed Deer	<i>Odocoileus virginianus</i>	Seen on Blackbridge Road and railway tracks; up to 27 individuals reported moving from west end of wetland complex; fawns observed on lot along Blackbridge Rd.





## B 8.3 Vegetation Resources

### B 8.3.1 Field Methodology

Vegetation resources (communities and plant species) within the subwatershed were characterized using available background information sources and supplemented with data collected for the current study. Individual vegetation communities were selected to represent the base terrestrial resource-mapping unit (polygons). Vegetation communities were interpreted from 1:8,000 scale black and white aerial photographs dated April 2000, and mapped as polygons onto ortho rectified base. Individual polygons were assigned a unique identifier and prefixed with a number corresponding to the habitat block they are located in.

Field reconnaissance of vegetation resources and verification of vegetation community boundaries was carried out on October 24<sup>th</sup> & November 13<sup>th</sup>, 2000 and on July 6, 2001. Individual polygons were characterized according to a set of biophysical attributes including species composition, structural diversity, average canopy tree diameter, canopy closure, topography, slope, drainage and linkage value. These ratings were used to identify constraints related to individual features. A detailed description of the vegetation assessment and preliminary constraint methodology utilized for the current study is presented in **Appendix J3**. Individual vegetation polygons were also classified according to the Ontario Ministry of Natural Resources - Southern Ontario Ecological Land Classification (ELC) (Lee *et al.*, 1998). Vegetation data for individual polygons was entered into a GIS database. A checklist of all vascular plants observed in the subwatershed and their status was compiled. Nomenclature for vascular plant species follows the Ontario Plant List (Newmaster *et al.*, 1998).

Additional fieldwork was conducted on August 14<sup>th</sup> and 22<sup>nd</sup>, 2001 for the purposes of delineating wetland boundaries in the vicinity of Blackbridge Road east of Guelph Avenue.

### B 8.3.2 Summary of Findings

#### B 8.3.2.1 Vegetation Communities

The Forbes Creek subwatershed supports a diverse assemblage of vegetation community types, which can be attributed to its geographic and physiographic setting. A total of 177 individual vegetation polygons representing at least 5 ELC community series categories were identified as part of the current study. A complete listing of vegetation communities and associated attributes is presented in **Appendix J4**. The locations of individual vegetation community units or polygons are presented in [Figure B 8.3.1](#) and Map J1. Terrestrial and aquatic community series represented in the subwatershed include: Cultural, Forest, Marsh, Swamp and Open Water. Although not included in the current ELC system, Agricultural Fields and Hedgerows represent two additional community series that are present in the subwatershed. A summary of each community series category and its representation in the subwatershed is provided below. **Table B 8.3.1** summarizes the relative proportion of vegetation community series types in the subwatershed. None of the communities observed in the subwatershed are considered provincially rare.





Table B 8.3.1 ELC Community Classes Present in the Forbes Creek Subwatershed

ELC Community Class Category	Area (Hectares)	Percentage of subwatershed
Cultural	59.68	17.06
Forest	32.58	9.31
Marsh	12.27	3.51
Open Water	2.08	0.59
Swamp	31.54	9.02
Agricultural	145.90	41.71
Hedgerows	5.75	1.64
<b>TOTAL</b>	<b>289.80</b>	<b>82.84% vegetation cover</b>

The following sections provide a brief description of each vegetation community.

### Cultural

Cultural communities consist of old agricultural fields, plantations, woodlands, meadows, overgrown lawns and old pastures, the development of which is clearly dominated by human influence. These communities comprise 59.68 ha or (17.06 %) of the total subwatershed area. Individual vegetation units in this category range in size from 0.08 ha to 12.14 ha. No significant species were found in these habitats.

#### Cultural Meadow

Cultural meadow communities are areas of recently abandoned agricultural lands that have developed into old field/meadow associations. These vary from pasture grasses and agricultural weeds (generally non-native species) to aster/goldenrod communities. Plants that are commonly found in these communities include Canada Goldenrod, Tall Goldenrod, Knapweed, Orchard Grass and Queen Anne's Lace.

#### Cultural Thicket

This community occurs in relatively few places in the subwatershed. The majority of the areas consist of non-native vegetation in the ground layer with shrubs in the overstorey. The tree cover is less than 25% with the shrub cover greater than 25%. Common species for this community include Orchard Grass, Kentucky Blue Grass, Tall and Canada Goldenrod, Red Osier Dogwood, Grey Dogwood. No significant species were noted for this community.

#### Cultural Woodland

Cultural woodlands exist in only a few places in the subwatershed. They consist of areas that have a canopy closure of trees of 35-60%, consisting of native and non-native species. Composition includes Sugar Maple, Manitoba Maple, Staghorn Sumac, Queen Anne's Lace and Bittersweet Nightshade.

#### Forest

Forested communities consist of immature to mature deciduous and coniferous forest. These forested communities comprise 32.58 ha or (9.31%) of the total subwatershed area. Individual vegetation units in this category range in size from small (0.09 ha) forest fragments to large (13.95 ha) continuous bands of forest surrounding the wetlands or along Forbes Creek. Regionally and Provincially significant species are present in several of these communities.

#### Fresh- Moist Poplar Deciduous Forest



This community is prevalent adjacent to wet areas throughout the subwatershed. The canopy is dominated by White Birch, Trembling Aspen, Balsam Poplar and Cottonwood. Plants in the ground layer include Red Osier Dogwood, Wild Grape, False Nettle and Jack in the Pulpit.

#### ***Dry- Fresh Sugar Maple Deciduous Forest***

This community is dominated for the most part by mature Sugar Maple with associates of Beech and White Ash. This community occurs on the highest points in the subwatershed with Unit 1.01 being the best example. The dominant understorey in that Unit was Sugar Maple and White Ash with Chokecherry as well as non-native Common Buckthorn. Wildflowers that are common in the ground layer include Trillium, non-native Garlic Mustard, Leeks, and Baneberry. One provincially rare species was present in this particular community.

#### ***Dry – Fresh Deciduous Forest***

This community is similar in composition to the preceding one except that White Ash, Beech and Green Ash dominate this community, which is relatively uncommon in the subwatershed.

#### ***Fresh-Moist Sugar Maple Deciduous Forest***

This community is scattered across the subwatershed. It is dominated by Sugar Maple with Green Ash and Poplar, located on sites that are lower in topography than the Dry – Fresh Sugar Maple Forest. Understorey species include False Nettle, Jack in the Pulpit, Calico Aster, and Rough Goldenrod.

#### ***Fresh- Moist Coniferous Forest***

This community occurs at one area within the subwatershed. The canopy is dominated by mature White Cedar in a relatively dense stand. Cedar, Foamflower, Trillium and Hemlock are just a few of the species prevalent in this community.

#### **Marsh**

These wetland community types consist of mineral and organic meadow marshes. Marsh communities represent approximately 12.27 ha or (3.51%) of the total subwatershed area. Individual vegetation units in this category range in size from 0.07 ha to 2.77 ha. Most of the marsh communities in the subwatershed are associated with the Forbes Creek Wetland. Significant species are present in several of these communities.

#### ***Organic Meadow Marsh***

This community is very common throughout the subwatershed. It is located in low topography areas, in kettles and next to creek channels. The dominant vegetation is Cattail (narrow and wide leaved). Other plants found include sedges, rushes and grasses as well as forbs such as Boneset and Joe Pye Weed.

#### **Swamp**

This wetland community consists of treed and thicket swamp community types. Swamp communities comprise 31.54 ha or (9.02 %) of the total subwatershed area. Units range in size from 0.13 ha to 6.03 ha. All swamp communities in the subwatershed are associated with the Forbes Creek Wetland. This community type supports most



of the significant vegetative resources that occur in the subwatershed.

### ***Organic Thicket Swamp***

Organic Thicket Swamps consist of organic soil that is greater than 40 cm deep with a canopy closure of trees less than 25% and hydrophytic shrubs greater than 25%. The dominant shrub is Red Osier Dogwood, with various willow species in the canopy and understorey.

### ***Mineral Thicket Swamp***

Mineral Thicket Swamps are found at two locations in the subwatershed. Many of the same species that are present in Organic Thicket Swamps are found in Mineral Thicket Swamps, but mineral soils dominate the substrate.

### ***Organic White Cedar Swamp***

This community is dominated by White Cedar to the exclusion of most other species. Sedges and grasses are found in the understorey. This community is uncommon (Units 2.05 and 2.09) in the subwatershed.

### ***Maple Mineral Deciduous Swamp***

This community is the most prevalent swamp community in the subwatershed. It is dominated by Red, Silver and the hybrid Freeman's Maple. It is wet for the majority of the season so forbs are less prevalent compared to other communities. Jewelweed, fern species and sedges are prevalent. Mounds created by tree fall also harbour vegetative cover.

### ***Mineral Deciduous Swamp***

This community is dominated by Willows and Poplars. Canopy closure is lower than in the Maple Mineral Deciduous Swamp, supporting more sun loving wetland plants. Joe Pye weed, Boneset, Tall Nettle and American Elm are common in this community

### ***Open Water***

This aquatic community type consists primarily of dug ponds, several of which are located south of Blackbridge Road. Major ponds are online with Forbes Creek. Many of these aquatic communities form part of the Forbes Creek Provincially Significant Wetland, based on the presence of water less than 2 m deep. Approximately 2.08 ha of this community type is present in the subwatershed, accounting for 0.59% of its total area. None of the areas of open water were greater than 1 ha in size. No significant species were located within this community.

### ***Agricultural Fields***

Agricultural communities include cultivated fields. This community comprises 145.90 ha or (41.71 %) of the total subwatershed area. Corn, oats, soybeans and pastureland are the most dominant types of cover crop. This community represents the most abundant vegetative cover type in the subwatershed. Fields ranged in size from 0.97 ha to 44.53 ha. No significant terrestrial resources are associated with this community type.

### ***Hedgerows***

Hedgerows or fencerows are narrow strips of vegetation that typically occur between cultivated or open fields. This community type represents approximately 5.75 ha or 1.64





% of total subwatershed area. Hedgerows can provide for important connections between the other communities within the subwatershed and also to natural areas outside of the subwatershed (i.e., Speed River Wetland Complex to the southeast, Glenchristie Wetland Complex to the east, and Ellis Creek Wetland Complex to the west).

Hedgerows within the subwatershed were ranked in three classes based on their size, composition and structure (Table B 8.3.2). The results of the analysis indicate that over 82 % of the hedgerows in the subwatershed are considered class 2 or higher. This indicates that the majority of the hedgerows are comprised of mature cover with relatively high continuity.

Table B 8.3.2 Hedgerow Linkage Analysis

Vegetation Unit (Polygon)	Hedgerow Class
3.04, 4.10, 4.20, 4.21, 4.22, 7.09	1
1.16, 1.17, 2.07, 2.16, 2.18, 4.13, 4.24, 4.32, 5.10, 5.17, 5.20, 5.21, 5.23, 5.27, 6.16, 6.18, 6.27, 7.00, 7.04, 7.05, 7.11	2
1.06, 1.10, 4.16, 4.18, 4.30, 6.20, 7.07	3

Hedgerow Classes:

- 1: Dominated by mature trees or continuous cover with minimal breaks
- 2: Mature, with occasional breaks less than 50 m wide or immature and continuous, with minimal breaks
- 3: Composed of widely scattered trees or shrubs, breaks regularly more than 50 m wide

B 8.3.2.2 Wetlands

The most significant natural features of the Forbes Creek subwatershed are the wetlands, which are scattered throughout the landscape and are comprised of swamp and marsh. These were divided into more specific wetland communities (see ELC categories above). Some of the wetlands are associated with Forbes Creek, but a significant number occur in kettle depressions.

Kettles are depressions that were created by the melting of glacial ice. The water balance in kettles is controlled by three main factors: precipitation, evapo-transpiration and infiltration. Water enters the kettles through three routes: direct precipitation, surface runoff from surrounding lands, and occasionally from seasonal groundwater inputs. Water leaves the kettles through evapo-transpiration (evaporation and respiration by plants) and by percolation through the soils into the deeper water table.

Marshes are flat, damp depressions, fed by surface runoff and groundwater discharge. As storage areas they help to maintain the water balance in the subwatershed.

Swamps are wetlands dominated by woody vegetation. They are reliant on surface runoff and a limited amount of groundwater discharge. Swamps are important in maintaining the water balance, in maintaining water quality and temperatures in watercourses, and in providing wildlife habitat.

Evaluated wetlands are subject to the Provincial Policy Statement as well as Official Plans, and require special consideration and designation as part of the subwatershed study. As background to this study the existing MNR wetland mapping (1995) was consulted. This mapping shows that most of the wetlands in the subwatershed are included in the provincially significant Forbes Creek Wetland.

B 8.3.2.3 Subwatershed Flora

A total of 278 species of vascular plants were observed in the subwatershed natural areas (refer to Appendix J5a for a complete checklist). Appendix J5b describes the status codes used in Appendix J5a. Of this total, over 203 or 73% are considered native to Ontario, 10 species are considered Regionally Significant for Waterloo (Regional



Municipality of Waterloo, 1999), and one species is considered Provincially Significant (Riley, 1989). The significant species and their habitat attributes are summarized in **Table B 8.3.3** below.

**Table B 8.3.3 Significant Vascular Plants Documented in the Forbes Creek Subwatershed in 2001**

Species	Provincial Status*	Regional Status**	Habitat
<i>Vaccinium angustifolium</i>	S5	t	Lowland
<i>Vaccinium corymbosum</i>	S4	t	Lowland
<i>Carex canescens</i>	S5	t	Lowland
<i>Carex scoparia</i>	S5	t	Lowland
<i>Equisetum palustre</i>	S5	S	Lowland
<i>Cypripedium calceolus var parviflorum</i>	S5	S	Lowland
<i>Lobelia spicata</i>	S4	S	Lowland
<i>Carex jamesii</i>	S3	S	Upland
<i>Verbena stricta</i>	S5	S	Upland
<i>Pycnathemum virginianum</i>	S4	S	Upland

**Legend**

- \* Provincial designations based on Newmaster et. al. (1998).
- \*\* Regional Status based on Regional Municipality of Waterloo (1999)
- S3 Rare to uncommon in Ontario; usually between 20 and 100 occurrences in the province; may have fewer occurrences, but with a large number of individuals in some populations; may be susceptible to large-scale disturbances
- S4 Common and apparently secure in Ontario; usually with more than 100 occurrences in the province
- S5 Very common and demonstrably secure in Ontario
- t** **Is regionally significant but is expected to be delisted**
- S Is regionally significant

**B 8.3.2.4 Vegetation Constraint Ratings**

Each vegetation community was assigned a constraint rating based on average canopy diameter of trees, canopy structure and degree of closure, drainage, slopes and topography, and botanical quality. The constraint identification methodology is described in **Appendix J3**. **Appendix J4** summarizes vegetation community data, including constraint ratings, for all community polygons. Whichever constraint score is highest for each community polygon (vegetation based or wildlife based) is the applicable constraint rating. Constraints were also identified related to wildlife resources as discussed in Section B 8.4.

[Figure B 8.3.2](#) summarizes overall natural heritage constraints identified in the study area.

The majority of the identified high to medium constraint features related to vegetation are associated with wetlands and closed-canopy forest features, often containing regionally or provincially rare plant species. Low constraint areas are those that have normal planning controls (Planning Act approvals, permits, Agency approvals, etc), however, there are minimal terrestrial environmental constraints associated with those lands.





## B 8.4 Wildlife resources

### B 8.4.1 Field Methodology

Field investigations of wildlife were carried out throughout four seasons between autumn 2000 and summer 2001. Field visits by the team biologist were specifically timed to provide critical seasonal information on habitat use by breeding birds, winter mammal use (especially White-tailed Deer) and the occurrence of amphibians. Personnel documenting vegetation resources also recorded incidental wildlife sighting. Detailed information related to the focus of visits is presented in **Table B 8.4.1**.

Constraints related to wildlife were identified according to a methodology described in **Appendix J6**. This system assigned wildlife constraint ratings of low, medium or high to individual polygons based on a set of habitat and species attributes. These included: the presence of significant species, diversity of amphibians and reptiles, forest interior and grassland habitats. The actual scores that each vegetation community received based on these attributes are presented in **Appendix J4**. Final constraint ratings appearing on [Figure B 8.3.2](#) apply the higher of the two ranking systems scores (vegetation based vs. wildlife based).

#### Insects (Damselflies, Dragonflies & Butterflies)

Although terrestrial invertebrates were not comprehensively sampled as part of this study, observations of damselflies, dragonflies and butterflies were recorded to complement general impressions of overall biological diversity and habitat quality.

#### Herpetofauna (Amphibians & Reptiles)

Surveys for calling frogs and toads were modeled after the Marsh Monitoring Program 'Amphibian Surveys' (LPBO, 1997). Areas of suitable habitat, such as wetlands, dug ponds, reservoirs and creek valleys were identified from 1:8000 scale spring 2000, black-and-white aerial photography. These areas were subjected night surveys to document the level of amphibian calling. Surveys were conducted in April, coinciding with the greatest number of frogs that call in early spring. Daytime observations of frogs and toads were duly noted.

Pond-breeding salamanders were searched for at night in April 2001 while documenting calling frogs and toads. Logs, stumps and rocks were also turned during daytime breeding bird surveys. All incidental snake and turtle observations were documented.

#### Birds

Breeding birds were surveyed by walking transects, primarily through suitable wooded and semi-wooded environments. All field observations were categorized according to the new (2001) Ontario Breeding Bird Atlas protocols (Ontario Breeding Bird Atlas, 2001).

Special attention was paid to wooded areas that may support forest interior species. These represent migratory songbird species that are reliant on relatively large forest tracts that contain sufficient 'interior' to buffer them from predatory and parasitic birds and mammals that inhabit the forest 'edge'. Many of these songbird species are undergoing long term declines in population in eastern North America due to forest fragmentation and habitat loss. Although forest 'edge' has been determined to range from 50 m to more than 300 m in various studies, most authors





recognize forest interior as the area at least 100 m inside of the forest edge (Freemark and Collins, 1992).

Surveys during the late fall and winter seasons were initiated to help provide an overall sense of the landscape as well as to document important wintering areas if any.

### **Mammals**

No specific surveys or live trapping of mammals were conducted. This includes the detection of nocturnal species such as bats. All observations were incidental with other surveys. Records were based on evidence codes such as visual observations, calls, scats, bones, smells, tracks, browsing evidence, roadkills etc. after Dobbyn (1994). Mammal observations were also noted during night surveys for calling frogs and toads.



**Table B 8.4.1 Summary of Wildlife Surveys Conducted in the Forbes Creek Subwatershed**

Date	Participants	Time in field	Hours in Field	Purpose	Area s South of Blackbridge Road	Upland woods South of RRNo.24	Upland woods North of RRNo.24	Swamp north of Guelph Avenue	Swamp north of Blackbridge Road	Kettle wetlands and woods in NE part of SW	Speed River PSW (adjacent to tracks)	Speed River at Blackbridge Road	Mill Pond (from Ellacott Lookout)
1 30-Oct-00	K.K. & T. Fa.	09:45 - 12:15	2.50	Late fall survey – Introduction to subwatershed	X							X	X
2 01-Nov-00	Karl Konze	11:00 - 12:15	1.25					X					
3 03-Nov-00	Karl Konze	08:45 – 12:15	3.50				X		X			X	X
4 02-Feb-01	K.K. & M.S.	09:30 – 12:15	2.75	Mid-winter survey to detect animal tracks/ usage by deer			X						
5 13-Feb-01	Karl Konze	14:30 - 16:30	2.00						X			X	X
6 28-Feb-01	Karl Konze	13:30 - 15:45	2.25		X						X		
7 26-Mar-01	Karl Konze	10:00 - 12:30	2.50							X		X	X
8 03-Apr-01	Karl Konze	15:00 - 16:00	1.00	Waterfowl survey								X	X
9 09-Apr-01	Karl Konze	20:15 - 21:45	1.50	Salamander and spring frog survey						X			
10 10-Apr-01	K.K. & T. Fa.	20:00 - 23:15	3.25				X	X	X	X			
11 17-Apr-01	Karl Konze	09:15 - 10:15	1.00	Waterfowl survey								X	X
12 21-Apr-01	Karl Konze	20:30 - 21:30	1.00	Spring frog survey	X				X				
13 06-Jun-01	K.K. & M.S.	06:30 - 10:15	3.75	Breeding bird survey			X	X					X
14 07-Jun-01	Karl Konze	05:45 - 09:15	3.50							X			
15 08-Jun-01	Karl Konze	06:00 - 10:45	4.75		X				X				
16 18-Jun-01	Karl Konze	08:00 - 10:00	2.00		X	X							
17 19-Jun-01	Karl Konze	09:05 - 10:20	1.25	Butterfly survey	X								
18 05-Jul-01	Karl Konze	11:00 - 11:15	0.25	Breeding bird survey	X								
19 13-Jul-01	Karl Konze	08:50 - 10:05	1.25	Breeding bird survey						X			
20 15-Aug-01	T. Farrell	Incidental obs.	0.00	Wetland mapping	X								
21 23-Aug-01	K.K. & T. Fa.	09:30 - 10:45	1.25	Miscellaneous survey	X								
22 28-Sep-01	Karl Konze	13:00 – 16:00	3.00	General site visit – ESPA consideration	X				X				
23 12-Oct-01	Karl Konze	09:00 – 13:45	4.75				X	X		X			
		<b>TOTAL HOURS</b>	<b>50.25</b>										



## B 8.4.2 Summary of Findings

At least 179 species of wildlife have been known to occur in the Forbes Creek subwatershed and adjacent Mill Pond and Speed River of which 164 species were observed during field surveys conducted in 2000 and 2001 by Dougan & Associates. Communications with local residents and a review of available literature yielded 15 additional species (see Section B 8.2.2 for sources). The complete list of species observed by Dougan & Associates can be found in **Appendix J7**. See Section B 8.4.3 for information on how to access the more detailed “Master List of Wildlife Observations” database. It provides additional information such as the date of each observation as well as from what vegetation unit the observation was made. [Figure B 8.3.1](#) – “Existing Natural Heritage Features” depicts with a triangle all of the vegetation units that have wildlife data associated with them.

Each group of wildlife is represented by the following number of species:

13	Damselflies & Dragonflies
26	Butterflies
11	Amphibians and Reptiles
114	Birds
15	Mammals

### B 8.4.2.1 Insects (Damselflies, Dragonflies & Butterflies)

All 39 species of insects were observed during fieldwork conducted in 2001 (**Appendix J7**). Thirteen of these species were Odonates (Damselflies & Dragonflies) and 26 were Butterflies. However, not all of the odonates could be identified to species.

Only one species of insect recorded, the Monarch butterfly (*Danaus plexippus*), is considered nationally significant (*i.e.* “Vulnerable”) by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (ONHIC, 2001a,b). No evidence of egg-laying was detected on site at the time. The individual observed may or may not have originated inside the study area. The Ministry of Natural Resources currently considers this species as “Not In Any Category”, meaning that it is not considered at risk in Ontario (ONHIC, 2001b).

From a provincial perspective, the rarest species insect discovered was the Baltimore Checkerspot (*Euphydryas phaeton*). It has a provincial rarity rank of S4, defined as “common and apparently secure in Ontario; usually with more than 100 occurrences in the province” (ONHIC, 2001b). S5 species are “very common and demonstrably secure in Ontario”. The Baltimore Checkerspot was found in the wet meadow north of the two large online ponds (Units 6.03, 6.04 & 6.06). They are a very local species, usually only found where its preferred foodplant, Turtlehead (*Chelone glabra*) occurs. John Power, a local butterfly expert working with the “Wings of Paradise” agreed with this status interpretation.

The wet meadow located north of the two online ponds (Units 6.03–6.06) was also the area with the greatest diversity of insect species. Many species, while not rare, are not encountered commonly and their presence reflects the type and quality of habitats that are currently present in the area (J. Power, *pers. comm.*, 2001). In addition to the Baltimore Checkerspot, some of the butterflies documented there were: Bronze Copper (*Lycaena hyllus*), Meadow Fritillary (*Boloria bellona*), Milbert’s Tortoiseshell (*Nymphalis milberti*) and Red-spotted Purple (*Limenitis arthemis astyanax*).





#### B 8.4.2.2 Herpetofauna (Amphibians & Reptiles)

Eight amphibian species, and three reptile species were detected during 2000 and 2001 fieldwork (**Appendix J7**). None are recognized to be provincially or nationally “vulnerable”, “threatened”, or “endangered” (ONHIC 2001c,d). Similarly, none are considered to be significant in the Ministry of Natural Resources former “Central Region” (Plourde *et al.*, 1989). Only one species, Bullfrog (*Rana catesbeina*), is recognized to be significant in the Regional Municipality of Waterloo (Regional Municipality of Waterloo, 1985a). However, based on a conversation with a local resident, the population established in the larger online ponds may have been transplanted in the middle of the last century from near Georgian Bay after the construction of the local ponds. Nevertheless, the geographic range of Bullfrog in Ontario encompasses the Waterloo area, and the population has apparently been successfully reproducing for many years. Therefore, we consider this population as naturally occurring.

To gain a better understanding of the population ecology of amphibians found within the subwatershed, several night surveys were conducted in April 2001. Night surveys focused on calling toads and frogs and pond-breeding salamanders. Almost every wetland area found within the study area was searched.

Although apparently suitable habitat was present, no pond-breeding salamanders (*i.e.* *Notophthalmus* or *Ambystoma*) were found. Given the fact that other pond-breeding species were active at the time, the lack of salamanders discovered was not a result of us overlooking them. Later in the summer one terrestrial species, the Northern Redback Salamander (*Plethodon cinereus*), was discovered from two upland locations from within the subwatershed.

In contrast, most wetland areas were found to contain calling frogs. Calling levels varied from location to location, from single individuals to a full chorus. Areas most significant to calling frogs were the larger kettle wetlands. However, a few relatively isolated and small ponds (*e.g.* unit 1.12) also contained calling frogs. Ponds A (unit 7.23), D (unit 7.19) and G (unit 7.18) did not contain any calling frogs during the April visits. The paucity of vegetation found in and along the pond edges may explain this observation since other frogs were actively calling that same night from the two smaller ponds located to the east of the larger ones.

Species heard calling during the April 2001 visits included, Spring Peeper (*Pseudacris crucifer*), Wood Frog (*Rana sylvatica*), and Northern Leopard Frog (*Rana pipiens*). Later in the summer, Green Frog (*Rana clamitans*) and Bullfrog (*Rana catesbeina*) were heard calling from Ponds D (unit 7.19) and G (unit 7.18). Another late-calling species, the Tetraploid Gray Treefrog (*Hyla versicolor*), was discovered from several locations across the subwatershed later in the summer.

#### B 8.4.2.3 Birds

A total of 101 species of birds were observed during the 2000 and 2001 field inventories (**Appendix J7**). Of these 76 were observed during the breeding season. The remaining 23 species were either migrants passing through the area, or winter residents. Of the 76 species recorded during the breeding season, 71 showed evidence of breeding. Thirteen of the 71 species were confirmed to be breeding within the study area (*e.g.* young were seen being fed etc.), 24 species were considered probable breeders (*i.e.* pairs or birds on territory were observed), and 34 showed possible breeding evidence (*i.e.* birds were detected in suitable habitat during the breeding season). The remaining five species observed during the breeding



season were either flying through the area or only using the available habitats to feed or rest during migration.

Of the 71 species of birds that demonstrated breeding evidence, 20 species (28.2%) are considered to be regionally significant in the Regional Municipality of Waterloo (Regional Municipality of Waterloo, 1996) (**Table B 8.4.2**).

In addition to the significant bird species recognized by the Regional Municipality of Waterloo, the Ontario Ministry of Natural Resources, Bird Studies Canada, and Environment Canada recently collaborated to produce a document entitled *Conservation Priorities for the Birds of Southern Ontario* (Couturier, 1999). The document lists “conservation priority” species for all southern Ontario municipalities, including the Regional Municipality of Waterloo. Conservation priorities were assigned to individual species based on attributes such as *Jurisdictional Responsibility* (i.e. how much of a species’ range occurs within a given jurisdiction), *Preservation Responsibility* (e.g. abundance, breadth of breeding range, reproductive output, population trends) and *Area Sensitivity* (i.e. a species’ tolerance to human disturbance and habitat fragmentation). The Regional Municipality does not currently recognize the species listed as being regionally significant (V. Martin, *pers. comm.*).

According to Couturier (1999), 32 of the 71 (45.1%) breeding bird species documented are considered to be of ‘conservation priority’ in the Regional Municipality of Waterloo (**Table B 8.4.1**). In addition to the 32 species mentioned above, 4 other bird species observed are also regarded as conservation priorities for the Regional Municipality of Waterloo, but were foraging within the subject lands and did not show breeding evidence, or were not found nesting in natural habits. These species were Great Blue Heron (*Ardea herodias*), Northern Rough-

winged Swallow (*Stelgidopteryx serripennis*), Barn Swallow (*Hirundo rustica*), and Bobolink (*Dolichonyx oryzivorus*).

Although significant breeding bird species, or those recognized as ‘conservation priorities’, were found throughout the entire subwatershed, the vast majority were observed either in forested habitats (including swamps) or in open country habitats (**Table B 8.4.2**). This highlights the fact that wooded habitats, though often protected via natural heritage planning, are not the only areas that support uncommon species. Often the combination and intermingling of habitat types enables areas to support diverse species assemblages, including significant species; this is true for the Forbes Creek subwatershed.

Five confirmed, and possibly a sixth ‘forest interior’ species were found during the breeding bird surveys: Cooper’s Hawk (*Accipiter cooperii*), Hairy Woodpecker (*Picoides villosus*), Red-breasted Nuthatch (*Sitta canadensis*), Brown Creeper (*Certhia americana*), and Pine Warbler (*Dendroica pinus*). Other authors (e.g. Hounsell, 1989) also recognize Pileated Woodpecker (*Dryocopus pileatus*) as a forest interior species. Forest interior species are generally considered to be those that nest only within the forest interior and rarely occur near the edge. Most authors recognize the forest interior as the area greater than 100 m away from the forest edge. This group of species has received special concern over the past decade, since it has been shown that many are undergoing significant population declines due to increased deforestation, forest fragmentation, and nest predation/parasitism.



**Table B 8.4.2 Significant Breeding Birds and Conservation Priorities in Forbes Creek Subwatershed (2000-2001)**

Common Name	Scientific Name	Highest Breeding Status	Conservation Status		Habitat Association		
			Significant in Waterloo	"Conservation Priority"	Forest/Swamp	Marsh	Open Country
1 Turkey Vulture	<i>Cathartes aura</i>	Possible	X	X	X		
2 Wood Duck	<i>Aix sponsa</i>	Probable	X	X	X		
3 Hooded Merganser	<i>Lophodytes cucullatus</i>	Possible	X	X	X		
4 Northern Harrier	<i>Circus cyaneus</i>	Possible	X	X			X
5 Sharp-shinned Hawk	<i>Accipiter striatus</i>	Possible	X	X	X		
6 Cooper's Hawk	<i>Accipiter cooperii</i>	Possible	X	X	X		
7 Ruffed Grouse	<i>Bonasa umbellus</i>	Possible		X	X		
8 Spotted Sandpiper	<i>Actitis macularia</i>	Possible		X			X
9 American Woodcock	<i>Scolopax minor</i>	Possible		X	X		
10 Ruby-throated Hummingbird	<i>Archilochus colubris</i>	Probable	X	X	X		
11 Belted Kingfisher	<i>Ceryle alcyon</i>	Possible	X			X	
12 Red-bellied Woodpecker	<i>Melanerpes carolinus</i>	Probable	X	X	X		
13 Pileated Woodpecker	<i>Dryocopus pileatus</i>	Possible	X	X	X		
14 Alder Flycatcher	<i>Empidonax alnorum</i>	Possible	X	X	X		
15 Willow Flycatcher	<i>Empidonax traillii</i>	Possible	X				X
16 Least Flycatcher	<i>Empidonax minimus</i>	Probable	X	X	X		
17 Eastern Phoebe	<i>Sayornis phoebe</i>	Probable		X	X		
18 Eastern Kingbird	<i>Tyrannus tyrannus</i>	Confirmed		X			X
19 Warbling Vireo	<i>Vireo gilvus</i>	Probable	X		X		
20 Horned Lark	<i>Eremophila alpestris</i>	Probable		X			X
21 Black-capped Chickadee	<i>Poecile atricapillus</i>	Confirmed		X	X		
22 Red-breasted Nuthatch	<i>Sitta canadensis</i>	Possible		X	X		
23 Brown Creeper	<i>Certhia americana</i>	Probable	X	X	X		
24 Eastern Bluebird	<i>Sialia sialis</i>	Confirmed	X	X			X
25 Wood Thrush	<i>Hylocichla mustelina</i>	Probable		X	X		
26 Gray Catbird	<i>Dumetella carolinensis</i>	Confirmed		X	X		
27 Brown Thrasher	<i>Toxostoma rufum</i>	Confirmed	X	X			X
28 Chestnut-sided Warbler	<i>Dendroica pensylvanica</i>	Possible	X	X	X		
29 Pine Warbler	<i>Dendroica pinus</i>	Probable	X	X	X		
30 Vesper Sparrow	<i>Poocetes gramineus</i>	Probable	X	X			X
31 Savannah Sparrow	<i>Passerculus</i>	Possible		X			X
32 Grasshopper Sparrow	<i>Ammodramus</i>	Possible	X	X			X
33 Swamp Sparrow	<i>Melospiza georgiana</i>	Probable		X		X	
34 Eastern Meadowlark	<i>Sturnella magna</i>	Probable		X			X
35 American Goldfinch	<i>Carduelis tristis</i>	Probable		X			X





Areas with known forest interior habitat are vegetation communities units 1.00 and 1.01. Another block of habitat, comprised of vegetation units 2.00, 2.01, 2.05, 2.09, 2.11 and 2.12, also contains interior forest habitat. Hairy Woodpecker, Pileated Woodpecker and Brown Creeper were associated with at least one of the two forest interior habitat blocks. The remaining species were found in a single forested unit that, based on the accepted definition, did not contain forest interior. They all utilize coniferous forests, and in this case pines are a dominant species present in this particular vegetation unit.

The presence of these 'forest interior' species needs to be viewed with some caution since there is not universal agreement as to what species should be so recognized. Greater attention is now being placed on 'area sensitivity', essentially an evaluation of a species' tolerance to disturbance and habitat fragmentation. This also may help to explain the presence of 'forest interior' species from areas not considered to be forest interior.

As part of the subwatershed study, several visits were made to the Mill Pond, immediately adjacent and south of the subwatershed area, to document waterfowl use in spring. This is one of the largest bodies of water in the immediate vicinity and its significance to migrating waterfowl was of particular interest. Observations of wildlife from the Mill Pond could help put in perspective any such similar usage of lands by wildlife from within the subwatershed, especially the online ponds and small kettle wetlands. Almost all of the species of waterfowl that are expected to occur on small water bodies were found on the Mill Pond during the spring surveys (**Table B 8.4.3**). With the exception of Greater Scaup (*Aythya marila*), Bufflehead (*Bucephala albeola*), Common Goldeneye (*Bucephala clangula*), and Common Merganser (*Mergus merganser*),

all of the species could be considered "puddle ducks", that is, species that do not regularly dive deep underwater in search of food. These "diving ducks" were uncommon in comparison to the other species.

Quick checks of the online ponds and adjacent fields near the old Land residence did not reveal similar usage by migrating waterfowl in spring. In fact, the small size and relatively shallow depths of the ponds meant that they became ice free later than the Mill Pond, which is influenced by the currents of the Speed River. The spring passage of Tundra Swans (*Cygnus columbianus*), first brought to our attention by a local resident, was confirmed on March 9, 2002, when approximately 50 were observed at the Mill Pond. Another unidentified local resident reported seeing larger numbers, approximately 150, earlier on the same day. However, based on their normal migratory route, it is not likely this species regularly utilizes the Mill Pond or surrounding agricultural fields during their fall passage through southern Ontario.

In summary, with the exception of the Tundra Swan, it does not appear that the local significance of the Mill Pond to migrating waterfowl extends to habitats found within the subwatershed.

#### B 8.4.2.4 Mammals

Thirteen species of mammals were recorded during the 2000 and 2001 field surveys (**Appendix J7**). None of them are currently recognized to be "vulnerable", "threatened", or "endangered" in Ontario or Canada (ONHIC, 2001f). Three additional species were reported by local residents (see Section B 2.2), bringing the total number of mammal species known to occur in the Forbes Creek subwatershed to sixteen. Of these, 3 are considered significant in the Regional Municipality of Waterloo (1985b): Virginia





Opossum (*Didelphis virginiana*), Coyote (*Canis latrans*), and Mink (*Mustella vison*). Of these, only Coyote was confirmed during the 2000 and 2001 surveys. All three were reported in habitats south of Blackbridge Road, but they are probably more widespread within the subwatershed.

Numerous signs of White-tailed Deer (*Odocoileus virginianus*) activity were noted during the various field inventories. In particular, there were several trails used regularly by deer in winter to move north and south between wooded areas to the north of Blackbridge Road / Regional Road #24, and the Speed River floodplain (recognized by the Ministry of Natural Resources to be a deer wintering yard). Several local residents commented on seeing deer movements through the valley on a regular basis, sometimes in groups of more than ten individuals. Additional suitable wintering habitat exists in the swamp immediately north of Regional Road #24. The Forbes Creek valley therefore supports deer movement between these areas, but the relative significance of this particular route compared with others in the local vicinity is not clear. The possible effects of loss of the valley connection are uncertain.

### B 8.4.3 Master List of Wildlife Observations

A Master digital file containing all wildlife observations made by Dougan & Associates staff between November 2000 and March 2002 has been provided to the City of Cambridge and Ministry of Natural Resources (MNR). Given the sensitive and site-specific information with respect to certain wildlife records, it is recommended that formal requests for this information be directed to the MNR (Guelph Office).

### B 8.4.4 Wildlife Constraint Ratings

Each vegetation community was assigned a wildlife constraint rating based on a set of habitat and species attributes. These included: the presence of significant species, diversity of amphibians and reptiles, and forest interior and grassland habitats. The wildlife constraint identification methodology is described in **Appendix J6**. The actual scores that each vegetation community received based on these attributes are listed in **Appendix J4**. Also present in **Appendix J5** is the vegetation community data (scores) for all community polygons. Constraints identified related to vegetation are discussed in Section B 9.3. [Figure B 8.3.2](#) summarizes the overall natural heritage constraints identified in the study area. Whichever constraint score is highest for each community polygon (i.e. vegetation based or wildlife based) is the constraint rating that is depicted on the figure.

The majority of the constraint features related to wildlife that were identified as high or medium are associated with areas of forest interior or wetland habitat. All areas that contained forest interior habitat were found north of Regional Road #24.



**Table B 8.4.3 Birds Observed at the “Mill Pond” and Speed River**

Common Name	Mill Pond from Ellacott Lookout						Speed River @ Blackbridge Rd.					
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001		
	30-Oct	3-Nov	13-Feb	28-Feb	26-Mar	3-Apr	17-Apr	6-Jun	30-Oct	13-Feb	26-Mar	17-Apr
1 Pied-billed Grebe		2				1	2					
2 Canada Goose	Lots	lots	a few			2	12	1			3	3
3 Wood Duck						2						
4 Gadwall	12	1										
5 American Wigeon	1 ♂	2 ♂										
6 American Black Duck	9	5	2			6					2	
7 Mallard	168	43	12+			26	8	8		4	4	
8 Northern Shoveler		2 ♀										
9 Northern Pintail						2 ♂						
10 Green-winged Teal							3					
11 Ring-necked Duck					4 ♂, 2 ♀	65	4					
12 Greater Scaup						3	2					
13 Bufflehead					1 ♀	9	2				8 ♂	
14 Common Goldeneye											1 ♂	
15 Hooded Merganser					2	4			8		4	
16 Common Merganser	1 ♀		10		2	17				3 ♂, 1 ♀		
17 Bald Eagle				1-2 yr old								
18 American Coot						1						
19 Killdeer						1						
20 Ring-billed Gull	≈ 480	lots			≈ 35	34	7	2				
21 Herring Gull	1				≈ 20							
22 Mourning Dove							2 S	1				
23 Downy Woodpecker								1 nest				
24 Blue Jay								1				
25 Tree Swallow							4				2	
26 Cliff Swallow								1				
27 Cedar Waxwing								1				
28 Song Sparrow							2					
29 Dark-eyed Junco							1					
30 Northern Cardinal							1					
31 Red-winged Blackbird							1					
32 Common Grackle							2					
33 American Goldfinch							2					

August 16, 2002



## B 8.5 Summary of Natural Heritage Concerns

The following key issues were identified related to the natural heritage resources, particularly vegetation and wildlife, in the subwatershed:

- Wetlands in the subwatershed (the Forbes Creek Wetland Complex) were determined to be Provincially Significant Wetland (PSW) based on significant species present. The Provincial Policy Statement (1997) prohibits development within and may restrict development adjacent to PSWs.
- Several regionally-significant plant species, and one provincially rare species, are associated with upland forest and wetland habitats in the subwatershed.
- Forest cover (*i.e.* forests, treed-swamps & plantation) currently represents 14.7% of the land base in the subwatershed, and wetlands comprise 13.12%. Although relatively well linked, the overall forest cover in the subwatershed is deficient in comparison to targets recommended by Environment Canada (1998): 30% forest cover, 6% wetland cover.
- Significant wildlife issues include the presence of numerous bird, several mammal, and one amphibian species that are considered rare in the Region. The subwatershed supports the movement of significant numbers of White-tailed Deer between the Speed River corridor and adjoining subwatersheds. Habitats supporting significant wildlife include upland forest, wetlands, and successional meadows.
- The natural cover downstream of Regional Road #24 tends to be localized along the disturbed

creek channel, but due to the diverse habitat, proximity to the Speed River corridor, and predominantly rural character, the existing Natural Heritage System is well-linked and contributes significantly to the ecological functions of adjoining subwatersheds. Regional Road #24 currently interferes with these linkage functions, but there are still many opportunities for movement of a wide range of species across Regional Road #24 due to diverse topography and cover.

- Existing human encroachment into natural habitats (*e.g.* trampling, tree cutting, understorey removal, informal trails, garbage and debris dumping, vandalism) is currently limited in the subwatershed.

The habitat quality and species diversity of wetlands in the Forbes Creek Wetland Complex are directly related to the quality, quantity, and seasonal flow of runoff in the subwatershed. There is clear evidence that some wetland communities located downstream of Regional Road #24 are reliant on shallow groundwater flows and discharge zones.

Although somewhat constrained by existing residential, agricultural and highway land uses, the Forbes Creek corridor contains a range of upland forest, wetland and successional communities that sustain quality species and active wildlife movements. The quality, attributes and functions of these habitats are supported in part by the linked cover of the wetland and upland habitats, their relationship to local groundwater and surfacewater regimes, but also by the agricultural matrix which greatly facilitates species movements.





### B 9.0 SUMMARY OF NATURAL HERITAGE CONCERNS

Section B has discussed the existing conditions within the Forbes Creek subwatershed. Each discipline provided a detailed assessment and a summary of management considerations. The Forbes Creek subwatershed can be redefined as four separate subwatershed areas. Each of

these areas was divided on the basis of topographic watershed divides related to the surface drainage systems. To summarize the results of the previous section and to facilitate discussion in this section, the following tables summarize the resources, activities and issues with each subwatershed area.

Table B 9.1.1a Existing Residential Community

Description: The major land uses in this area are: Residential, Commercial and Institutional. The area is known as Silverheights and also has small version of commercial activities as well as the Silver Heights Public School.		
Discipline	Resources	Summary of Findings
Aquatic	None	No ponds or creeks present.
Hydrogeology	None	Groundwater contributions to lower Forbes
Surfacewater	Stormsewer collection system also acts as groundwater collection system.	Stormwater discharge to upper and lower Forbes system  Lack of Stormwater Management controls impacting lower Forbes Creek
Agricultural	None	Potential to inform local residents about importance of agricultural land uses and activities
Natural Heritage	Impacted woodland fragment and open space corridor situated on south side of Regional Road #24.	Limited Natural Heritage features are fragmented from other core natural areas and Linkage opportunities along Regional Road #24 corridor.  Intensive residential area



**Table B 9.1.1b South of Blackbridge Road and East of Guelph Avenue**

**Description:** The major land uses in this area are: Residential, Agricultural and Open Space. The portion of Forbes Creek South of Blackbridge Road is primarily agricultural (tenant farmers) with local residential South of Milton Avenue and along Guelph Avenue. This portion of the study area also includes the Forbes Sanctuary lands and a private estate.

<b>Discipline</b>	<b>Resources</b>	<b>Summary of Findings</b>
	Main branch of Forbes Creek.	Impacted system
Aquatic	Two large on-line ponds with permanent water and several smaller ponds that go dry during the year.	Several unsafe artificial structures and ponds Improving fish passage potential will improve habitat as well
Hydrogeology	Discharge area to pond systems. Infiltration area west of pond system.	Baseflow and wetland flow contributions
Surfacewater	High infiltration area.	Stormwater management issues
Agricultural	Reducing runoff volumes. Largely corn/row crops. Forbes Creek PSW forms a significant north-south corridor, linking features to the north with the Hespeler Mill Pond and Speed River PSW.	Water quality and quantity controls Loss of agricultural land but area is already designated for urban land uses
Natural Heritage	PSW reliant on surface runoff and shallow groundwater. Regionally significant plant and wildlife species are associated with this corridor. Forbes Creek Corridor connects a deer overwintering area (Speed River PSW) to headwater habitats; agricultural fields support wildlife movements.	Future sustainability of natural habitats, significant species, and broad-scale corridor functions if land use is altered Partial barrier effects of Blackbridge Road and Regional Road #24 to wildlife passage



Table B 9.1.1c North of Blackbridge Road/Regional Road #24

Description: The portion of Forbes Creek North of Blackbridge and RR No.24 is primarily agricultural with some rural residential related to the agricultural land use.

Discipline	Resources	Summary of Findings
Aquatic	Two branches of Forbes Creek have previously been impacted through straightening and channelization.	Potential to rehabilitate impacted stream areas.
Hydrogeology	Tighter soils and undulating topographical features.	Maintain surface depressions and recharge functions of wetlands.
Surfacewater	High infiltration area reducing runoff volumes.	Depressional areas minimize runoff.
Agricultural	Predominantly agricultural uses with common field crops such as corn, hay/pasture, some fruit and vegetable as well as livestock production.	Agricultural loadings on system Some local erosion problems (gullies and rills) Potential to implement agricultural BMPs
Natural Heritage	Contains northern half of Forbes Creek PSW. Natural features and agricultural lands supplement movements of wildlife from Speed River corridor to headwaters. Non-PSW features contain varying amounts of wooded cover are City LSNAs and candidate Regional ESPA. Regionally and Provincially significant flora and fauna have been recorded in these natural areas.	Largest natural features are within Forbes Creek PSW. Other adjacent wooded habitats may be designated as an ESPA. Larger core natural heritage areas are not well linked. Habitat enhancement efforts (plantations building on hedgerows) could strengthen connections Regional Road #24 is a significant barrier for north-south wildlife movements. Blackbridge Road is a less significant barrier to wildlife movement.





Table B 9.1.1d Expanded Study Area

Description: The expanded study area east of the subwatershed boundary to the railroad track is primarily agriculture with several rural residential houses along Blackbridge Road.

Discipline	Resources	Summary of Findings
Aquatic	Existing dug farm pond. No stream channels.	Preservation of pond form and function.
Hydrogeology	Area of high infiltration. Exposed bedrock at Railroad.	Maintain groundwater flow paths to pond and wetlands.
Surfacewater	Single water body with no direct outlet. Source is primarily surface runoff.	Ultimate outlet to Speed River PSW through railroad culverts.
Agricultural	Land is managed by tenant farmers.	North of Blackbridge Road is outside of urban boundary while south of Blackbridge Road is designated for urban land uses.
Natural Heritage	Existing natural features are primarily situated adjacent to existing railway tracks.  Wetland features (6.24 & 6.25) drain toward and are part of the Speed River PSW complex.  Southern finger of land provides an important habitat connection to Subwatershed via corridor along Forbes Creek Regularly used by White-tailed Deer to move to and from the Speed River floodplain.  Regionally significant plants and wildlife have been documented from the natural areas.	Contains important habitat connection between Forbes Creek system and Speed River floodplain.

