SECTION B – DETAILED STUDIES

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B 1.0 HYDROGEOLOGY

B 1.1 Introduction

One of the important objectives of this subwatershed study is the characterization of the groundwater flow regime within the subwatershed. It sustains the surfacewater and wetland environments and its susceptibility to impact by land change associated with development represents a key constraint when considering future development scenarios.

B 1.1.1 The Water Cycle

A general overview of the hydrologic cycle provides a basic understanding of the physical processes that characterize the streamflow in the Hespeler West subwatersheds. Figure B 1.1.1 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.

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.

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. 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 water flows and reduce peak flows.

Precipitation falling within the subwatershed also contributes to the recharge of the overburden and bedrock aquifers and to baseflow of the creeks and related wetland areas. Continued groundwater recharge is an important component in sustaining the health of the surfacewater environment within the study and possibly also for the important coldwater fishery in the adjacent Chilligo Creek subwatershed. 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. 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 groundwater resources.

B 1.1.2 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 534 Well Records (refer to Figure B 1.1.2) 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 overburden 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.

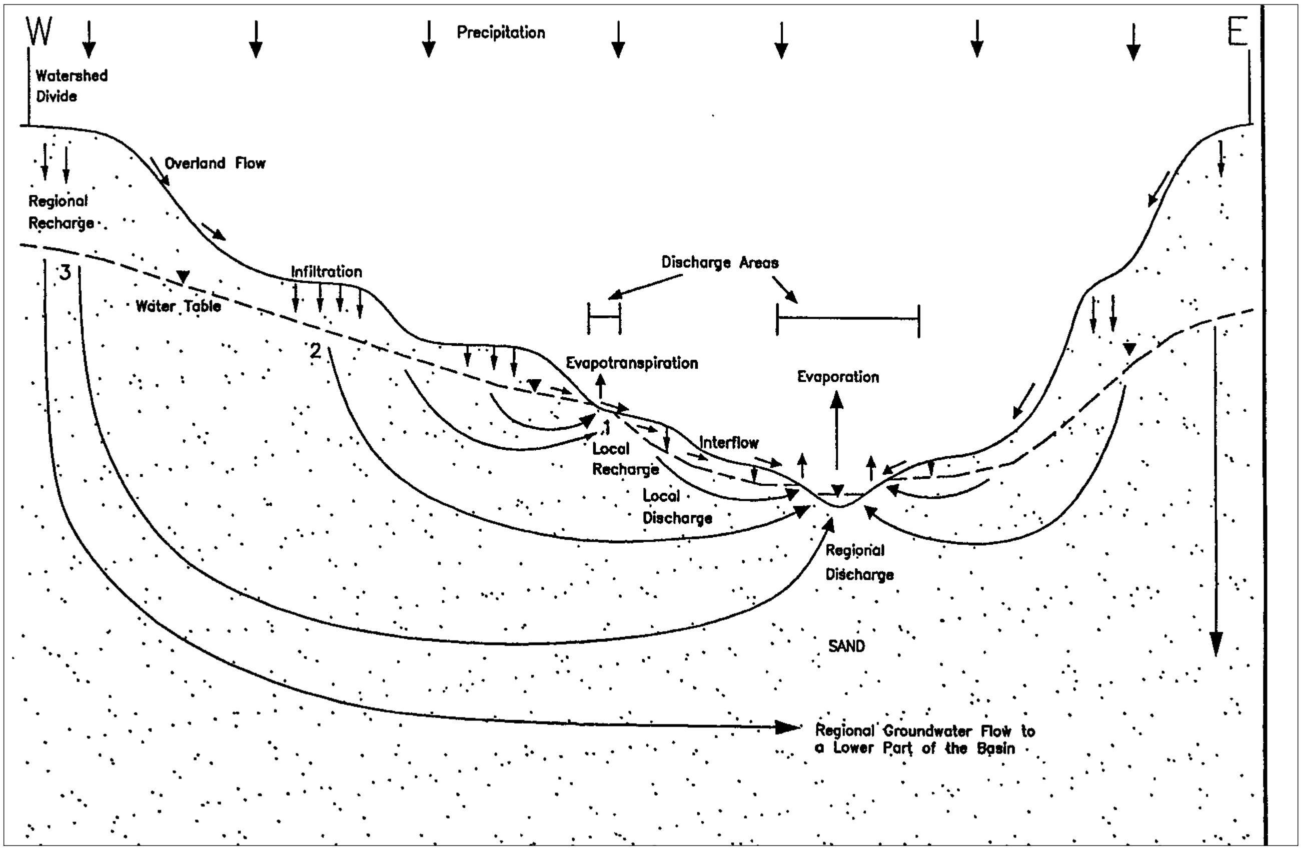


Figure B 1.1.1 Generic Illustration of the Hydrologic Cycle
Source: Canadian Manuscript Report Fisheries and Aquatic Sciences 2284, Department of Fisheries and Oceans 1995

B 1.2 Field Investigation

B 1.2.1 Exploratory Tests 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 in January and February, 2002 and involved installation of eight monitoring wells, fifty shallow boreholes, thirteen mini piezometers, and three drive point 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. Each monitoring well was constructed using pre-cleaned flush-threaded 50 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 metres 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.

Sixteen (16) mini-piezometers or drive point piezometers were installed within the study area in order to identify which areas act as groundwater recharge zones or which gain from the influx of groundwater seepage. Mini-piezometers 1 through 7 and drive point piezometer 2 were installed along Middle Creek; Mini-piezometers 8 through 11 and drive point piezometers 2 and 3 were installed along East Creek; and, Mini-piezometers 12 and13 were installed along West Creek.

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 water level tape accurate to ±0.5 cm equipped with an audible indicator while standpipe measurements were collected with a battery operated co-axial cable unit. The measured groundwater levels are shown on the individual borehole logs in **Appendix C1**.

The manually obtained water level measurements were augmented by the installation of pressure dataloggers in Boreholes (BH) 1, 3, 5, 8, and drive point Piezometers (DP) 1 to 3. The boreholes were instrumented with Solinst M5 Leveloggers while the drive point piezometers were equipped with Solinst Ml.5 Barologgers that also record water temperature. The location of the dataloggers is shown on Figure B 1.2.2.

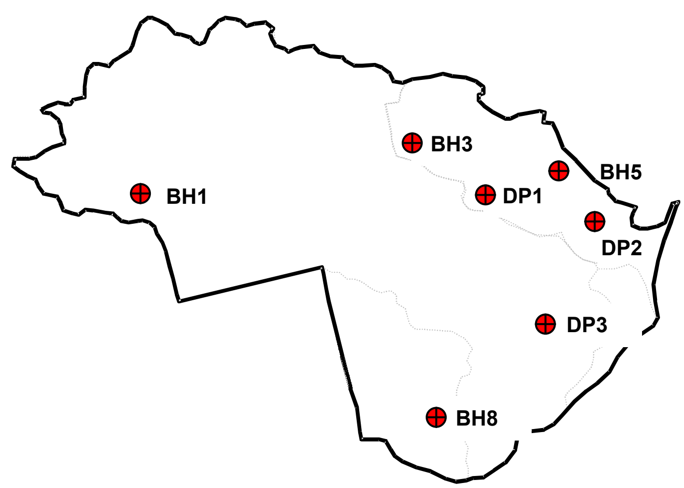


Figure B 1.2.2 Datalogger Locations

B 1.2.3 Hydraulic Conductivity

Hydraulic conductivity (the rate that water moves through a porous medium under a potential energy gradient) was estimated for the shallow overburden soils using Hazen's technique based on grain size gradation curves obtained from soil samples collected during this investigation. Hazen's method is described by the following equation:

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

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 six (6) particle size distribution analyses; and a number of field permeability tests.

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 C2**.

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.

Water samples have been obtained from the monitoring wells installed in Boreholes 1 through 8 and from surfacewater adjacent to the locations of drive point piezometers 1 to 3. The samples were submitted to Enviro-Test Laboratories (Sentinel Division) and 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. The results of this testing are further discussed in this report while the laboratory Certificates of Analysis are provided in **Appendix C3**.

B 1.3 Geological Setting

The geology of the study area profoundly influences the more dynamic processes of hydrology and ecology as well as controlling the topography of the land and the shape, gradient, and flow characteristics of the streams that flow across it. Geology also affects the quantity and chemical character of groundwater and provides the source material for stream sediment and the soils which support the varied woodlands, wetlands and agricultural crops that grow across the area. The physical form and behaviour of natural systems varies from place to place due to differences in geology, topography, climate and other factors. Understanding the geological setting of the study area is therefore a prerequisite to understanding the other natural systems and necessary to adequately predict developmental impacts and to identify appropriate mitigative measures.

B 1.3.1 Physiography and Drainage

The subwatershed area is located within the eastern edge of the physiographic region described by Chapman and Putnam (1984) as the Waterloo Hills. The surficial deposits within the area are primarily ice-contact and outwash deposits of the Grand River and Speed River valley spillways separated by till plain. Outwash alluvial deposits of silt, sand, and gravel were laid down locally by meltwater during deglaciation of the area and organic soils occur within low-lying or poorly drained areas. The Quaternary Geology Map of the Cambridge Area (Ontario Geological Survey Map 2508) shows that the subwatersheds are underlain by glaciolacustrine and outwash sands over a majority of the area with deposits of the sandy silt Port Stanley Till present in the upland areas beneath sand deposits or as the surficial soil.

The topography of the study area is characterized by a relatively level upland area north of Maple Grove Road from which the land falls away toward the floodplain of the Speed River valley. Ground surface elevations range from 325 metres above sea level (masl) in the north portion of the study area to a low of approximately 280 masl along the banks of the Speed River.

B 1.3.2 Overburden Geology

Continental ice sheets have 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.

The most recent episode of glacial activity, known as the Wisconsinan stadial (period of glacial advance), deposited very dense sandy silt till known as the Catfish Creek till. Subsequent advances and retreats of the glacial ice deposited the more recent Maryhill and Port Stanley 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 study area.

The soil conditions in exploratory boreholes drilled as part of this study, MOE Water Well records, and previous geotechnical studies have been used to construct the geological cross sections shown on Figures B 1.3.2 and B 1.3.3. The locations 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. 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 grey to greyish brown colour turning to a yellowish brown where weathered and oxidized. Catfish Creek till is described by Karrow (1987 and 1993) as a stony sandy silt till, with little matrix clay content.

Catfish Creek Till is not exposed on the ground surface within the study area but it is exposed in the Grand River valley to the north and it is likely present beneath a thin mantle of outwash sand and gravel along the southern Portion of the study area where erosion has removed the more recent strata. Figure B 1.3.5 shows the stratigraphic position of the Catfish Creek Till based on an erosional section in the nearby Homer Watson Park in Kitchener.

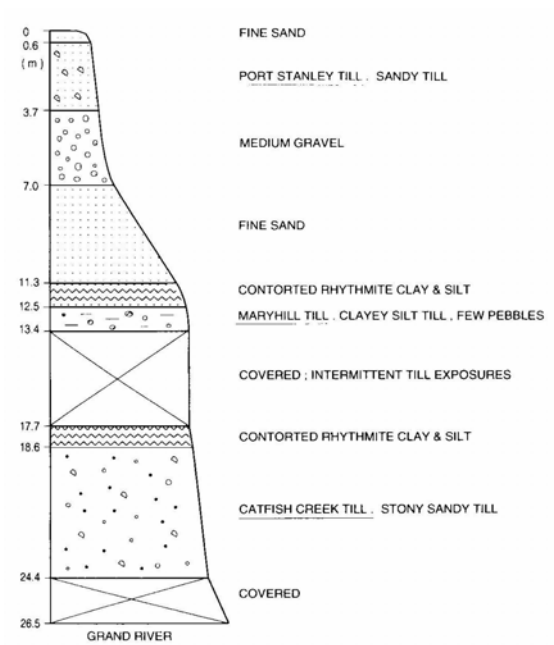


Figure B 1.3.5
Stratigraphic section from the Grand River Valley at Homer Watson Park (White, O. L.; Karrow, P. F. 1999)

Catfish Creek Till is similar in texture and appearance to the younger Port Stanley Till and the two are often mistaken where the geologic context is lacking. It is likely that the dense silt till encountered at depth at the Toyota Plant and along the proposed Fairway Road extension to the north of the study area is Catfish Creek Till.

B 1.3.2.2 Maryhill Till

Maryhill Till is a fine textured silty clay till discontinuously present between the older Catfish Creek Till and the younger Port Stanley Till. Where present, the contrast in texture between the clay-rich Maryhill Till and the coarser textured Port Stanley and Catfish Creek Tills makes the Maryhill Till a valuable stratigraphic marker for geological interpretation.

Maryhill Till does not outcrop within the study area but, like Catfish Creek Till, it is exposed in the Grand River valley and is widely present in the subsurface. **Photograph B1** shows the contact between Maryhill Till and the overlying Port Stanley Till in a soil sample from Borehole 2.

B 1.3.2.3 Port Stanley Till

Port Stanley Till is encountered in the subsurface along the western limit of the study 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 older Catfish Creek Till.

An average hydraulic conductivity (k) of approximately 10^{-6} m/s has been estimated for the Port Stanley Till based on the results of 11 grain size distribution analysis and slug tests as summarized in **Table B 1.3.1**.

Table B 1.3.1 Silt Till – Hydraulic Conductivity Summary

Borehole	K (m/s)	Method	Description
17-206	$1x10^{6}$	Hazen	Sandy silt till
17-211	$1x10^{6}$	Hazen	Sandy silt till
17-216	$1x10^{6}$	Hazen	Sandy silt till
19-4	$9x10^{6}$	Hazen	Silt till
19-5	$6.4x10^{5}$	Hazen	Silt till
14-5	$4.9x10^{5}$	Hazen	Sandy silt till
13-218	$9x10^{6}$	Hazen	Silt till
22-203	$4x10^{6}$	Hazen	Sandy silt till
22-121	$1.69x10^{6}$	Hazen	Sandy silt till
BH3 (86G001)	$4x10^{6}$	Hazen	Sandy silt till
BH8 (86G001)	$2.5x10^{7}$	Hazen	Sandy silt till

B 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 or floodplain 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 the Speed River as gravelly channel deposits and as 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.

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

Table B 1.3.2 Sand – Hydraulic Conductivity Summary

Borehole	K (m/s)	Method	Description
17-204	$9x10^{4}$	Hazen	Sand, some silt
17-217	$1x10^{2}$	Hazen	Sand
17-213	$4.9x10^{3}$	Hazen	Sand, some silt
17-218	$3.6x10^{3}$	Hazen	Sand, some gravel
17-225	$1x10^{4}$	Hazen	Silty sand
19-6	$1.44x10^{2}$	Hazen	Sand
19-7	$9x10^{4}$	Hazen	Sand
19-12	$4x10^{2}$	Hazen	Sand
14-1	$2.25x10^{2}$	Hazen	Sand
14-6	$6.4x10^{3}$	Hazen	Sand
13-214	$1x10^{4}$	Hazen	Sand
13-220	$1x10^{2}$	Hazen	Coarse sand some gravel
6-4	$1x10^{2}$	Hazen	Sand
6-7	$1.6x10^{3}$	Hazen	Sand, trace clay
4-101	$1x10^{4}$	Hazen	Sand
4-107	$1x10^{2}$	Hazen	Sand
8-108	$2.56x10^{2}$	Hazen	Sand
8-109	$1x10^{2}$	Hazen	Sand
22-209	$9x10^{6}$	Hazen	Silty sand
22-119	$1.56x10^{2}$	Hazen	Sand
22-119	$4.9x10^{3}$	Hazen	Sand
BH4	$1.6x10^{3}$	Hazen	Sand
BH8	$4.23x10^{5}$	Hazen	Silty sand
BH2	$8.1x10^{3}$	Hazen	Sand
BH2(3980h1)	$1.0x10^{6}$	Hazen	Silty sand, trace gravel and clay
BH3(3980h1)	$7.2x10^{5}$	Hazen	Sand, trace gravel and silt
BH4(3980h1)	$4.0x10^{6}$	Hazen	Sand, some silt, trace clay
BH5(3980h1)	$2.5x10^{7}$	Hazen	Silty sand, trace clay
BH6(3980h1)	$9.0x10^{8}$	Hazen	Silty sand, some gravel, trace clay
BH8(3980h1)	$2.3x10^{4}$	Hazen	Sand, some gravel, trace silt

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 north part of the study area and in the wetland areas bordering the Speed River. Typical thicknesses are 1 to 2 metres of peat or organic muck occasionally overlying a lower unit of marl. Thicker peat deposits overlying marl have been encountered along the western boundary of the study area (see **Photograph B2**).

B 1.4 Bedrock Geology

The subwatersheds are underlain by a thick sequence of layered sedimentary rocks. The uppermost bedrock formation is the Guelph Formation which underlies the whole of the subwatersheds and outcrops along the Speed River where erosion has removed the overlying soils (see **Photograph B3**). This formation typically consists of brown to beige dolostone, interbedded with grey shales. It is characterized by relatively thick bedding and the fine to medium crystalline structure which dips regionally to the south and west at about 4 metres per km. The Guelph Formation is underlain by similar dolostones of the Lockport Formation. The uppermost unit of the Lockport Formation, known as the Eramosa member, typically consists of thinly bedded dark brown bituminous dolostone.

Overburden thickness within the subwatershed ranges from 0 to slightly more than 40 metres with the thickest overburden being encountered in the northwest portion of the study area and the thinnest overburden occurring along the bank of the Speed River where bedrock is exposed in many locations.

The map showing the overburden thickness is provided on Figure B 1.4.1. The buried bedrock surface is relatively flat-lying across the study area although an area of locally elevated bedrock occurs immediately north of the study area within the Chilligo Creek drainage.

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 which overlie till deposits over the majority of the subwatersheds. 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 present over much of the subwatershed particularly in areas of thick overburden. The middle aquifer, where present, takes the form of lenses or sheet-like layers of sand and gravel overlain by glacial till. The middle aquifer is typically recharged from leakage through the overlying glacial till or through the upwelling of deeper groundwater from the bedrock aquifer.

Bedrock of the Guelph Formation provides much of the potable water supply for the Cambridge area. MOE well records indicate that approximately 75% of wells in the area have been completed into bedrock. Bedrock and deep overburden well pumping rates of approximately 1 to 16.5 L/min and 1.5 to 5.5 L/min, respectively, are reported in the MOE well records. The water well records indicate that glacial clay and silt till units are present at depth and are sometimes underlain by granular sand/sand and gravel deposits of the middle aquifer system. Recharge of the bedrock aquifer occurs in upland areas and in areas where permeable soils 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 (for water supplies), while rural residents have private well systems. Permits to Take Water (PTTW) have been issued by the MOE for thirteen (13) operations within the study area: Arriscraft, the sod farms, the Regional Municipality of Waterloo and others. Unfortunately, data sharing agreements with the Ontario Ministry of the Environment prevent the release of specific information regarding the Permits. MOE well records show that there are 534 water supply wells located within the study site, with approximately 420 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 subwatersheds. 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.

B 1.5.1 Groundwater Flow

The water table elevations and interpreted direction of shallow groundwater flow is illustrated on Figure B 1.5.1 while the piezometric surface in the deeper aquifer is shown on Figure B 1.5.2. Groundwater in both the shallow and deep aquifers generally flows in a southerly direction toward the Speed River valley, which serves as a principal point of groundwater discharge in the area.

Groundwater flow in the deep overburden aquifer is more complex than that of the shallow overburden and bedrock aquifers. While the shallow groundwater flow closely matches the surficial drainage patterns, groundwater in the deep overburden flows toward the nearest significant discharge point which could be along the Speed River, Grand River, and Chilligo Creek depending on the location within the study area. Interpreting groundwater flow in the deep overburden aquifer is further complicated by the fact that the deep overburden aquifer is not a single unit but an aquifer complex where separate layers of sand and gravel may be separated by less permeable strata to form a series of superimposed or "stacked" aquifers each with different flow directions.

Manually measured groundwater levels obtained during this study were augmented by the collection of continuous groundwater level data between early February and late June of this year.

The groundwater levels measured in the instrumented wells and dataloggers. Measured groundwater levels depths are summarized on the following charts.

DP 1 was installed in the upper reaches of East Creek between Mohawk and Maple Grove Roads. Water level data shows little drainage during the monitoring period suggesting that the drive point is located within or near to a point of groundwater drainage. Temperature readings increased dramatically in early April suggesting that the groundwater has infiltrated close to the drive point installation. DP 2 shows a similar pattern of temperature fluctuation but the water level in this location shows a greater response to precipitation events (see Figure B 1.5.3). The monitoring of DP 3 shows a more subdued range of temperature fluctuation and a rapid response to precipitation (see also Figure B 1.5.3). These observations are consistent with high infiltration and a high groundwater flux.

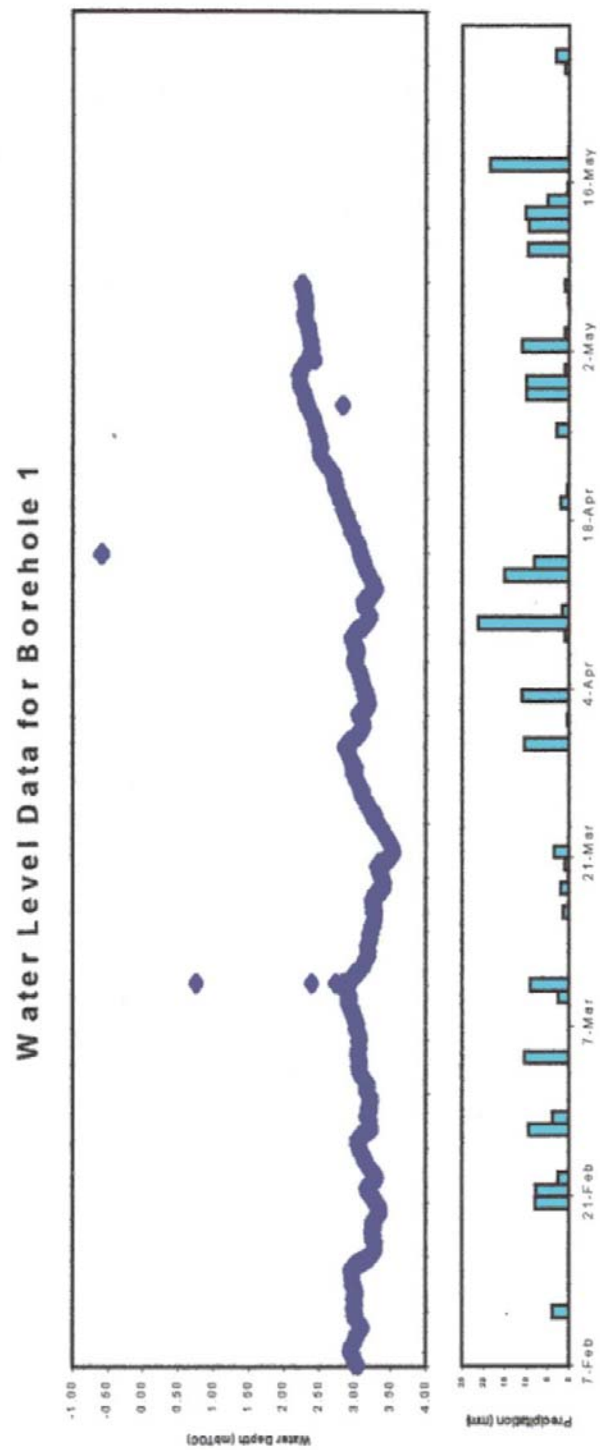
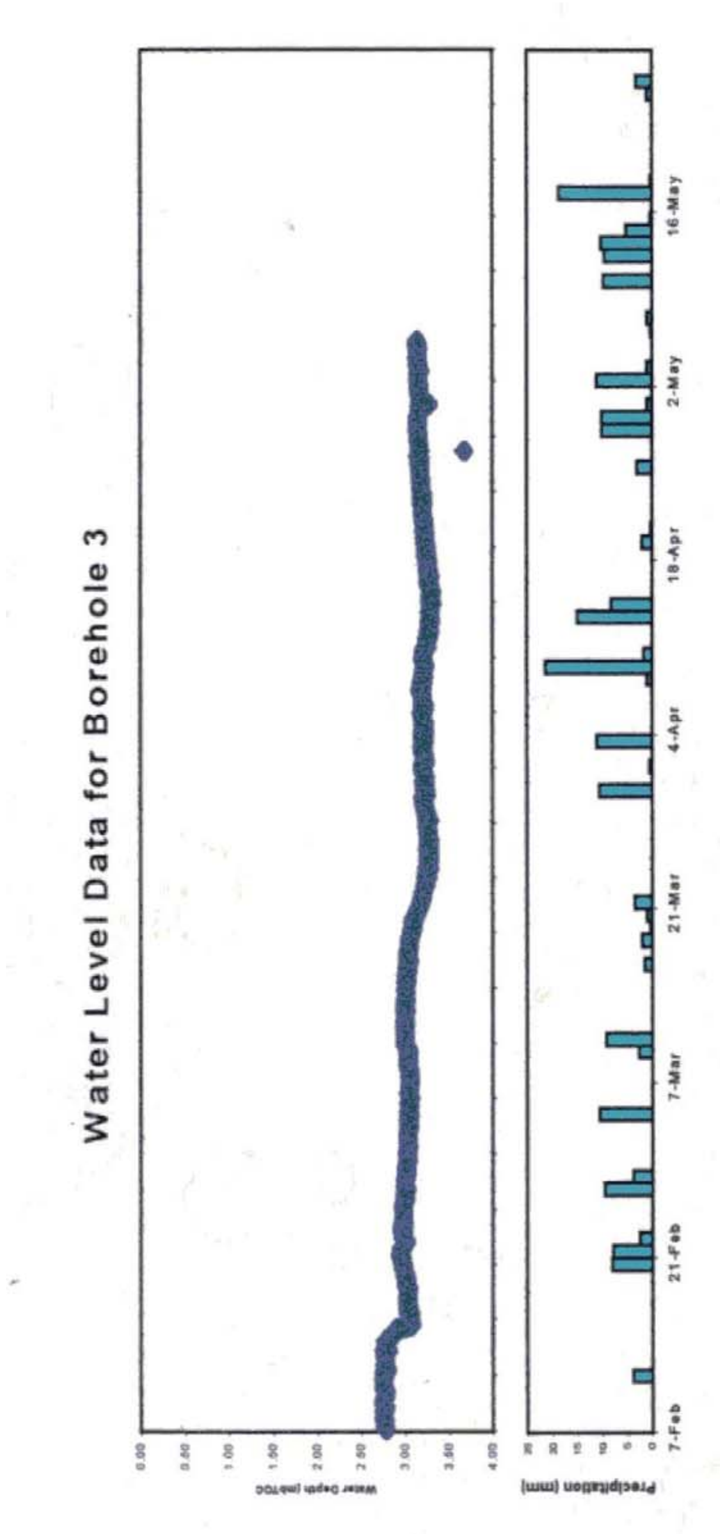


Figure B 1.5.3 a Drive Point and Borehole Graphs



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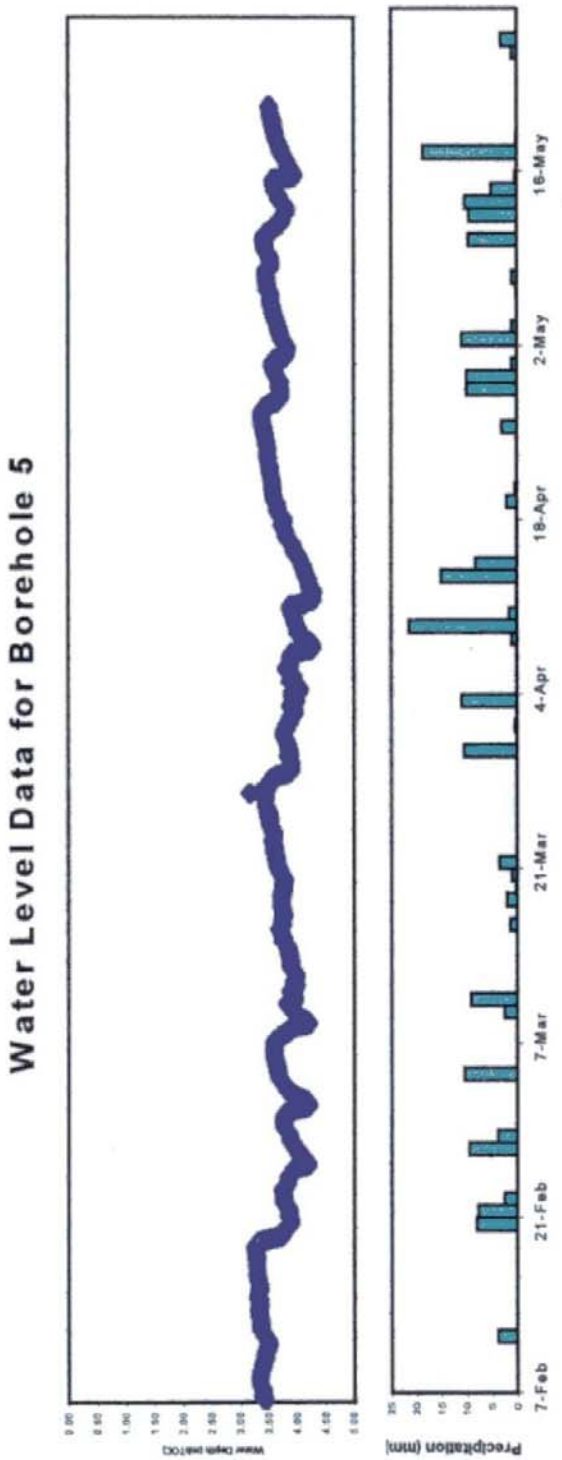

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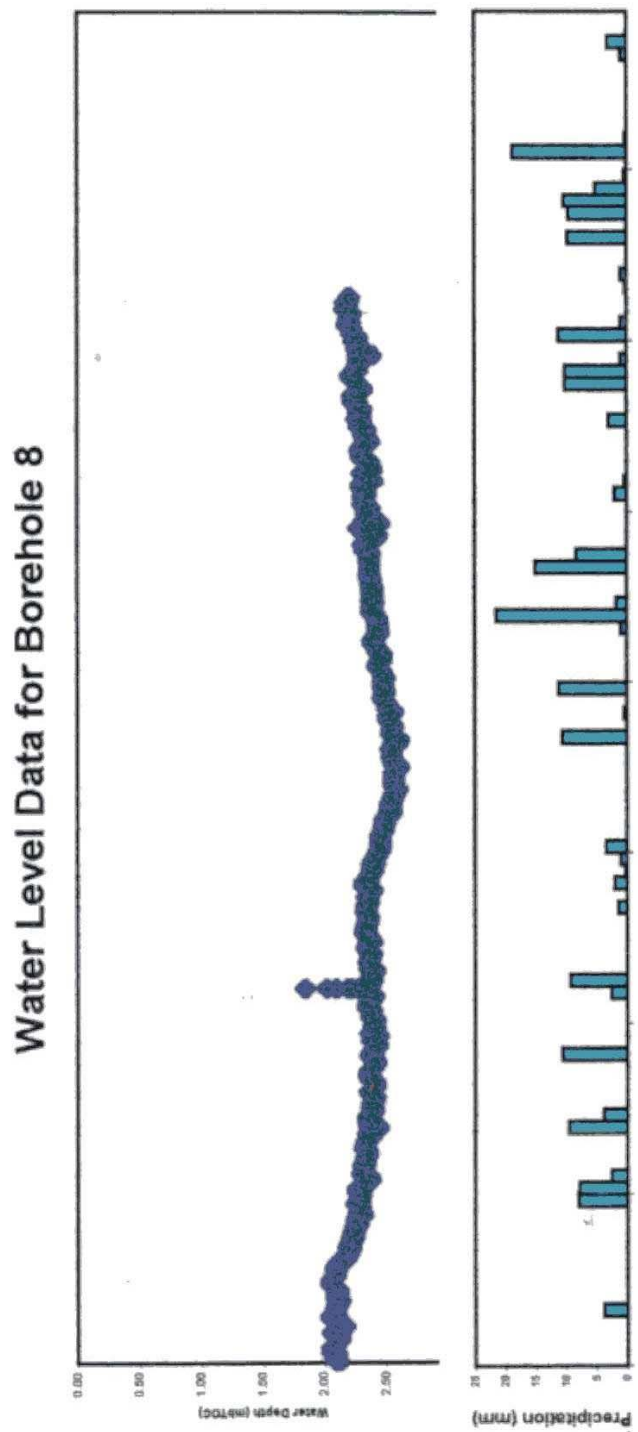

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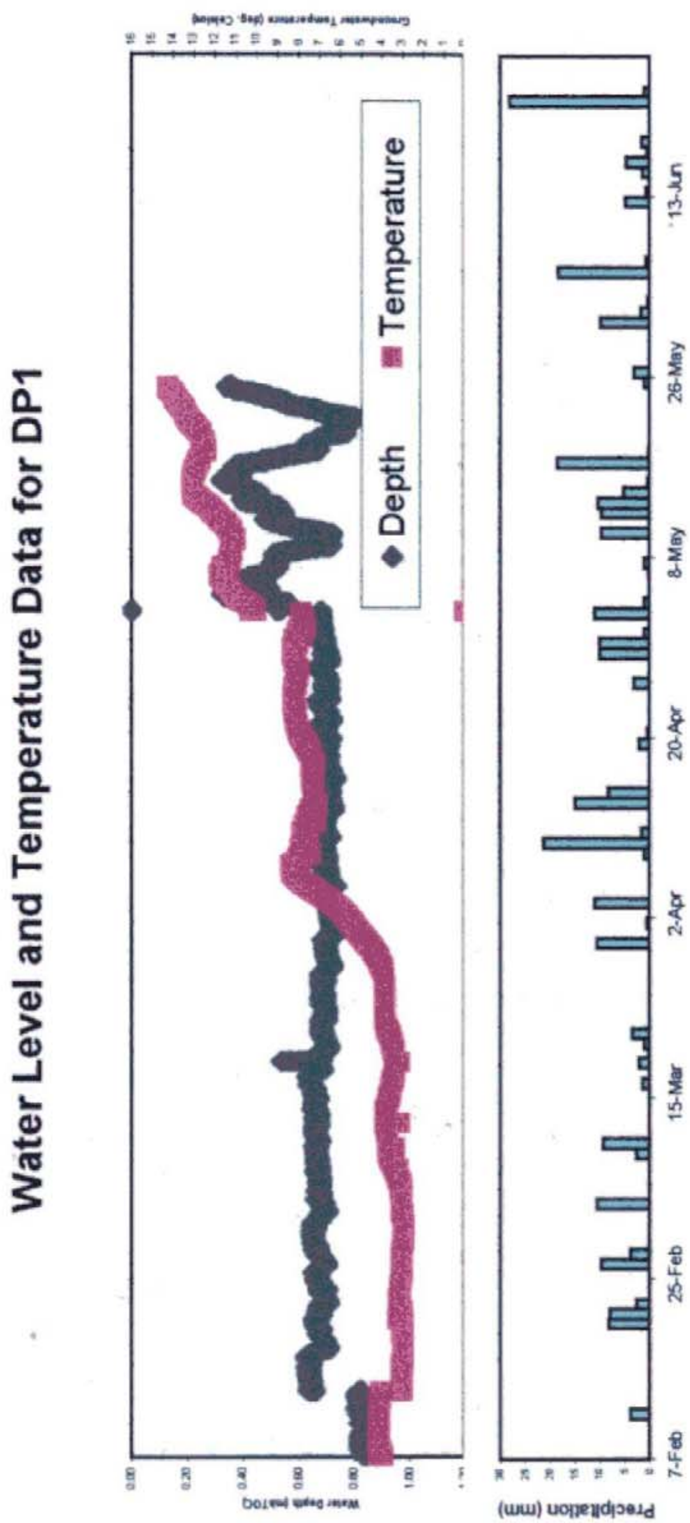

Figure B 1.5.3 b Temperature & Depth Graphs

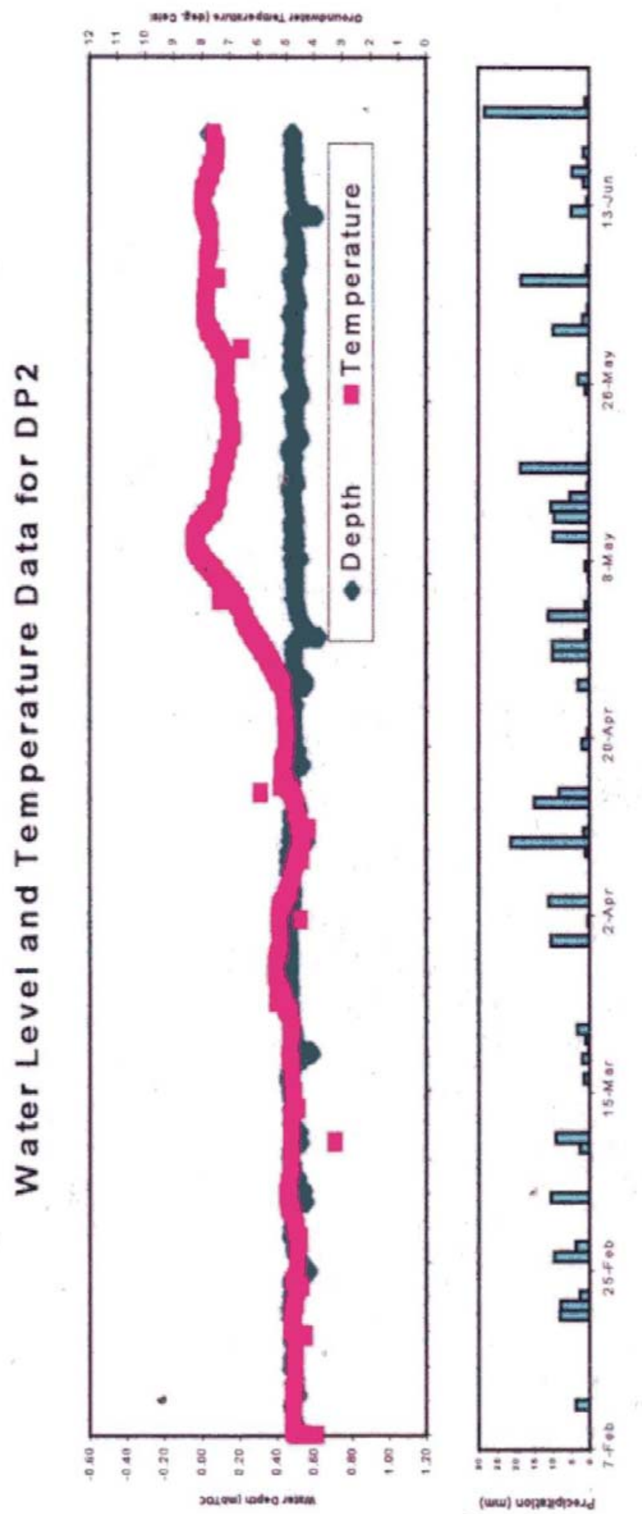

Figure B 1.5.3 b Temperature & Depth Graphs

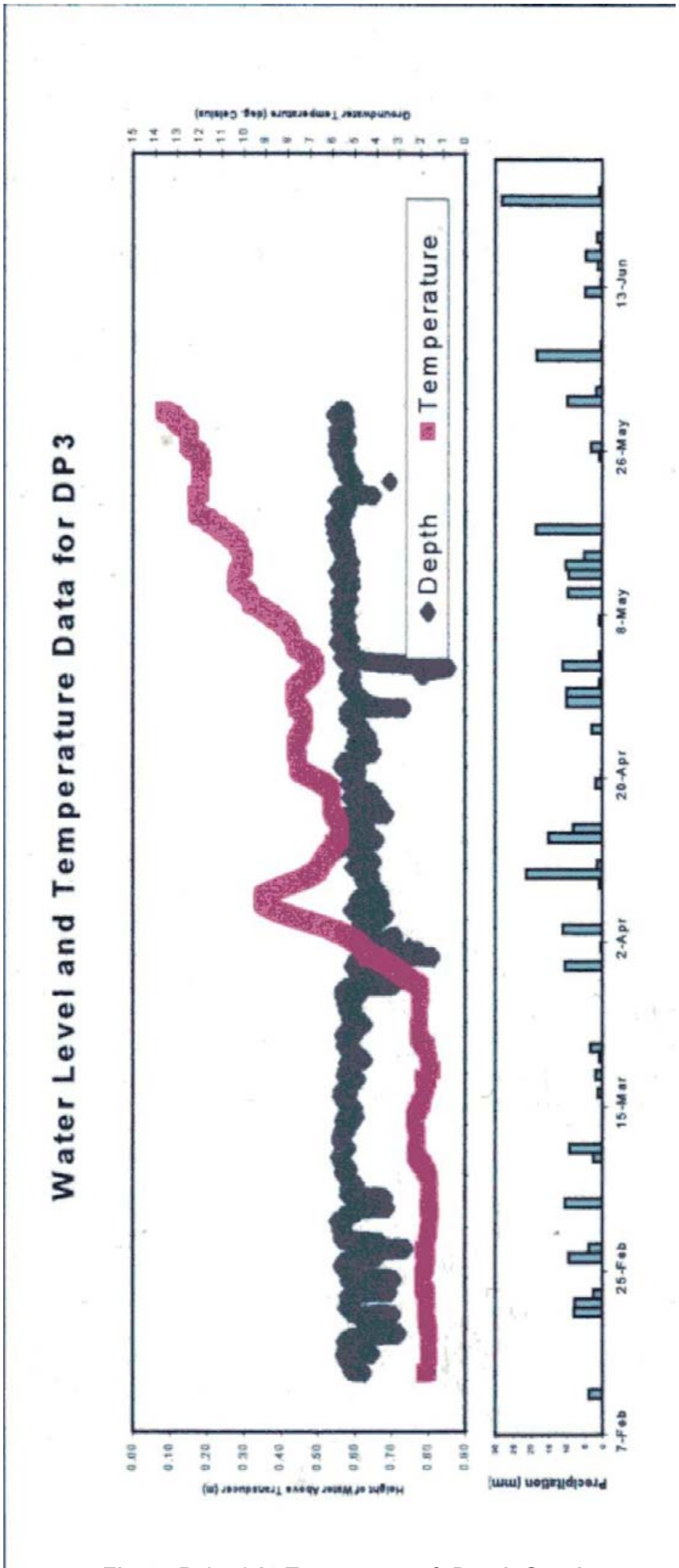

Figure B 1.5.3 b Temperature & Depth Graphs

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 Enviro-Test Laboratories (Sentinel 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. The results of the testing are shown on **Tables B 1.5.1 to B 1.5.3** while Laboratory Certificates of Analysis are provided in **Appendix C-3.**

Table B 1.5.1 Groundwater Geochemistry – General Chemistry

	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	DP1	DP2	DP3
Alkalinity (CaCO3)	325	225	325	195	230	340	290	240	200	175	230
Ammonia as N	0.21	<0.10	<0.10	0.23	<0.10	0.32	0.43	0.26	<0.10	<0.10	<0.10
Bicarbonate (CaCO3)	323	223	324	194	227	339	289	238	199	173	227
Carbonate (CaCO3)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Colour (TCU)	56.0	44.2	17.6	53.7	52.6	33.0	29.0	11.3	24.0	20.0	26.0
Conductivity (umhos/cm)	760	950	900	1200	780	4100	1100	1050	576	565	790
Hardness (CaCO3)	350	450	420	550	380	1300	620	450	270	220	300
Hydroxide (CaCO3)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
pH (pH units)	7.70	7.50	7.30	7.80	7.50	7.1	7.40	7.70	7.91	8.10	8.10
Total Organic Carbon	3	<1	<1	<1	<1	<1	6	<1	4	1	3
Turbidity (NTU)	150	120	17.1	1.20	90	51	32	12.7	0.78	0.65	6.4

Table B 1.5.2 Groundwater Geochemistry – Anions

	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	DP1	DP2	DP3
Bromide	0.10	<0.10	<0.10	<0.10	0.70	<0.10	0.13	0.53	0.13	<0.10	<0.10
Chloride	2.0	25.0	79.0	23.0	590	15.0	1330	64.0	80.0	36.0	58.0
Fluoride	0.10	0.12	<0.10	<0.10	0.13	<0.10	<0.10	0.15	0.10	<0.10	<0.10
Nitrate as N	0.10	2.10	25.0	32.0	<0.10	36.0	<0.10	<0.10	5.00	3.20	1.10
Nitrite as N	0.10	0.11	0.26	<0.10	<1.0	<0.10	<2.0	<0.10	0.74	<0.10	<0.10
Phosphate-P	0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Sulphate	2.0	56.0	54.0	23.0	74.0	22.0	200	280	75.0	44.0	39.0
Bromide	0.10	<0.10	<0.10	<0.10	0.70	<0.10	0.13	0.53	0.13	<0.10	<0.10

Table B 1.5.3 Groundwater Geochemistry - Metals

	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	DP1	DP2	DP3
Aluminum	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.20	<0.02	<0.02	<0.02
Barium	0.01	0.09	0.04	0.02	0.17	0.01	0.14	0.04	0.03	0.02	0.01
Beryllium	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.09	0.05	<0.05	<0.05
Cadmium	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Calcium	0.50	77.1	121	130	115	102	311	120	90.3	85.8	68.6
Chromium	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Iron	0.05	0.06	0.10	0.13	0.10	0.09	0.29	0.12	0.11	0.12	0.11
Lead	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Magnesium	0.50	39.5	36.4	24.1	64.1	30.5	144	77.8	55.4	12.7	12.1
Maganese	0.01	0.05	0.14	0.19	0.05	0.03	0.45	0.23	0.06	0.02	0.02
Molybdenum	0.01	0.01	<0.01	<0.01	0.04	<0.01	0.03	0.08	0.01	<0.01	<0.01
Nickel	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Potassium	0.50	3.53	1.72	3.02	4.78	<0.50	11.9	15.2	4.58	0.57	0.76
Silver	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sodium	0.50	24.5	7.23	16.2	145	5.47	335	18.2	61.3	9.37	20.2
Strontium	0.01	0.57	0.25	0.18	0.47	0.11	0.88	0.53	0.23	0.12	0.10

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 the overburden and aquifer is bicarbonate type with a low to moderately high total dissolved solids content. The groundwater samples can be characterized as hard with all samples exceeding 300 mg/L hardness.

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 Environmental Protection Agency (EPA) document titled *Wellhead Protection Strategies for Confined Aquifer Settings* (1991):

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

where:

q_v = Vertical leakage (unit of length/unit of time);
K_v = Vertical hydraulic conductivity (unit of length/unit of time);
$(h_0\text{-}h)$ = 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_0-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.

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

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_0-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:

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

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 contaminant types such as nitrates (which only persist in aerobic environments), road salts, and organic contaminants are 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 intrinsic vulnerability of the bedrock aquifers is summarized on Figure B 1.5.4. The mapping classifications are based on Vrba and Zaporozex (1994) with the different intrinsic vulnerability classifications summarized on **Table B 1.5.4**. 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 1.5.4 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 metres 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

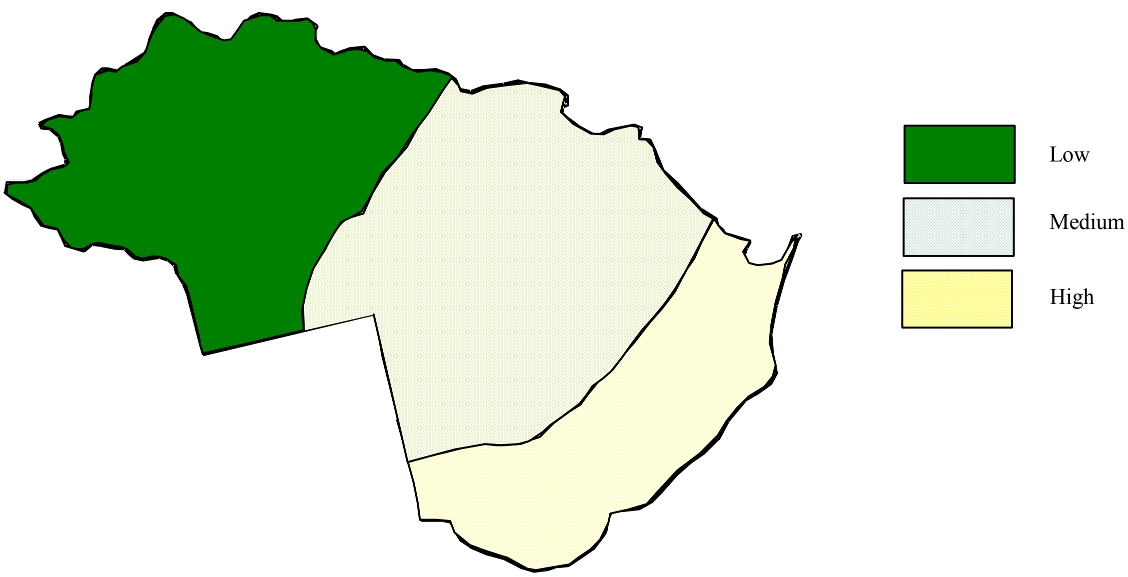

Figure B 1.5.4 Vulnerability to Contamination – Bedrock Aquifer

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 north portion of the Middle Creek subwatershed is classified as Sensitivity 4 while the smaller portion north of Middle Block Road is classified as Sensitivity 3 (see 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 evapotranspirates and is defined by:

$$P = E + R + I$$

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 subwatersheds. Figure B 1.5.5 shows the different subcatchments within the study area. Estimates of groundwater recharge were prepared for each subcatchment area based on soil conditions, depth to the water table, topography, and vegetation. These estimates are shown graphically on Figure B 1.5.6 while **Tables B1.5.5 to B1.5.7** provide a breakdown of the subcatchments for East, Middle and West Creeks respectively.

Hydrology and hydrogeology data are presented using different basis of measurement for infiltration quantities. Infiltration values reported for the hydrological analysis are stream-based, as the transfer of flows between the surface and subsurface is calculated at individual nodes over the length of each watercourse in the GAWSER hydrological model. This calculation is based on a detailed water balance that considers all aspects of the hydrological cycle.

For the hydrogeology results, infiltration values are presented on a catchment basis based on a more straightforward calculation of infiltration given the measured properties of the soil and the average annual rainfall. This difference is noted to ensure confusion does not occur in comparing the two infiltration measurements given the different methods of presentation.

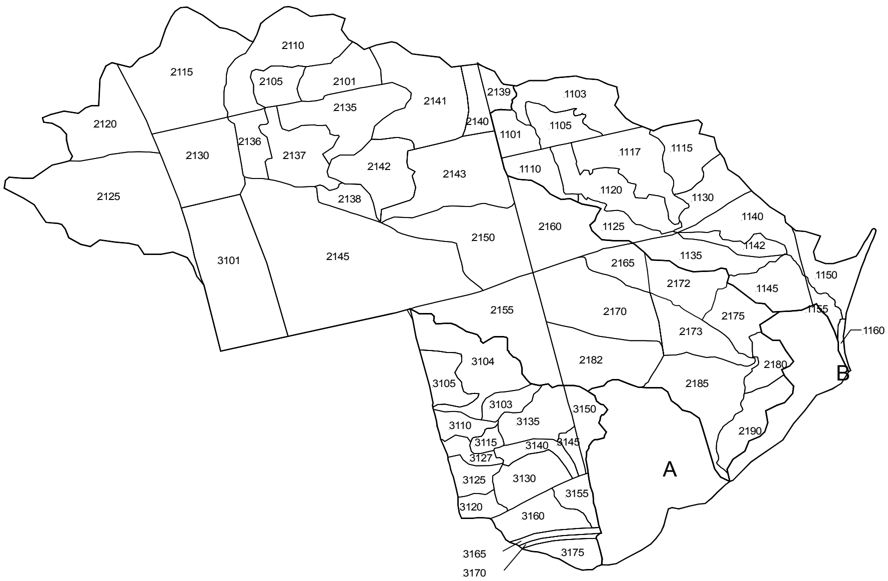

Figure B 1.5.5 Subcatchment Areas

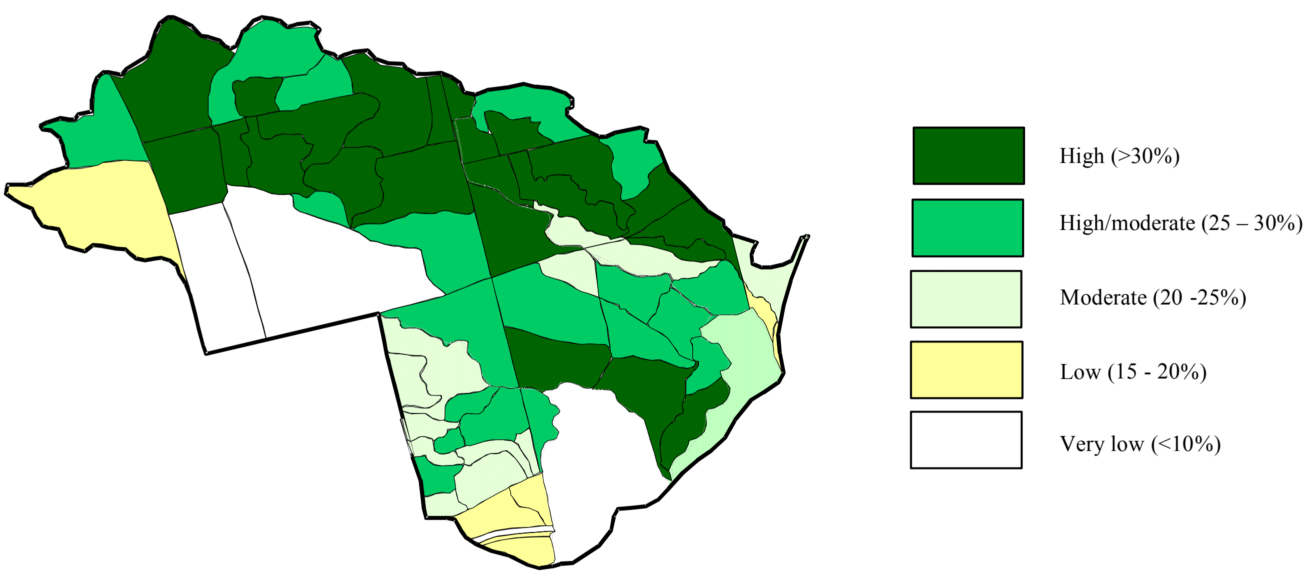

Figure B 1.5.6 Infiltration by Subcatchment

Table B 1.5.5 Subcatchment Infiltration Rates – East Creek

Subcatchment	Area (ha)	Infiltration % of total rainfall	Subcatchment Characteristics
1101	6.4	28	The dominantly agricultural subcatchment is relatively level and underlain by moderate to high permeability sands and silts. A small kettle feature forms an area of closed drainage.
1103	16.6	26	The dominantly agricultural subcatchment slopes to the south and is underlain by moderate to high permeability sands and silts.
1105	8.0	30	The wooded subcatchment is flat and underlain by moderate to high permeability sands and silts. Heavy vegetation and shallow water gives a high ET.
1110	7.5	27	The dominantly agricultural subcatchment slopes gently to the east and is underlain by moderate to high permeability sands and silts.
1115	11.8	26	The dominantly agricultural subcatchment slopes to the south and is underlain by moderate to high permeability sands and silts.
1117	19	26	This large subcatchment includes much of the University Agricultural Research Station. The land slopes to the southwest and is underlain by moderate to high permeability sands and silts.
1120	16.1	28	The wooded subcatchment borders the east side of East Creek and is underlain by moderate to high permeability sands and silts. Heavy vegetation and shallow water gives a high ET.
1125	6.7	24	The subcatchment covers an area of mixed woodland and agricultural land underlain by moderate to low permeability glacial till deposits.
1130	10.3	28	The dominantly agricultural subcatchment slopes to the south and is underlain by moderate to high permeability sands and silts.
1135	12.4	25	The dominantly agricultural subcatchment borders the west side of East Creek and is underlain by glacial till in the north and by sands and silts in the south.
1140	13.3	24	The subcatchment contains a number of privately serviced residences and is underlain by moderate to high permeability sands and silts.
1142	5.2	22	This steeply sloping subcatchment includes both open field and woodland and is underlain by moderate to high permeability sands and silts.
1145	11.8	22	Privately serviced residential area underlain by moderate to high permeability sands and silts overlying bedrock.
1150	11.0	24	The subcatchment extends between Beaverdale Road and Regional Road #24 and slopes steeply to the south. Mainly open fields, it is underlain by sands, till, alluvium, and bedrock.
1155	2.7	22	The subcatchment borders the west side of East Creek south of Beaverdale Road and is underlain by bedrock.
1160	1.1	10	Regional Road #24 and immediately adjacent lands.

Table B 1.5.6 Subcatchment Infiltration Rates – Middle Creek

Subcatchment	Area (ha)	Infiltration % of total rainfall	Subcatchment Characteristics
2101	11.7	27	The dominantly agricultural subcatchment is flat-lying and is underlain by moderate permeability sands and silts.
2105	7.1	28	The dominantly wooded subcatchment is flat-lying and is underlain by moderate permeability sands and silts.
2110	25.2	30	The dominantly agricultural subcatchment is flat-lying and is underlain by moderate permeability sands and silts. A small pond in the south part of the catchment forms an area of closed drainage.
2115	38.5	28	This large flat-lying area contains a mixture of open fields and woodlands as well as several areas of closed drainage. The subcatchment is underlain by moderate permeability sands and silts.
2120	21.9	23	The dominantly agricultural subcatchment is flat-lying and is underlain by moderate to low permeability till deposits.
2125	51.0	25	This subcatchment contains a large woodlot (the largest in the study area apart from the lands bordering the Speed River. The area is underlain by moderate to low permeability till deposits.
2130	23.3	24	The dominantly agricultural subcatchment is flat-lying and is underlain by moderate permeability sands and silts in the north and by low permeability till deposits in the south.
2135	20.3	27	The dominantly agricultural subcatchment is flat-lying and is underlain by moderate permeability sands and silts.
2136	7.8	27	The dominantly agricultural subcatchment is flat-lying and is underlain by moderate permeability sands and silts.
2137	16.2	28	The dominantly wooded subcatchment is flat-lying and is underlain by moderate permeability sands and silts. The heavy vegetation cover and shallow water table combine to give a high ET.
2138	5.5	27	The partially wooded subcatchment is flat-lying and is underlain by moderate permeability sands and silts.
2139	4.0	28	The partially wooded subcatchment is flat-lying and is underlain by moderate permeability sands and silts. A small depression near the south border of the subcatchment forms an area of closed drainage.
2140	5.8	27	The dominantly agricultural subcatchment is flat-lying and is underlain by moderate permeability sands and silts.
2141	27.7	28	The dominantly agricultural subcatchment is flat-lying and is underlain by moderate permeability sands and silts. A small area of closed drainage is located in the central portion of the area.
2142	16.4	27	The dominantly wooded subcatchment is flat-lying and is underlain by moderate permeability sands and silts. The heavy vegetation cover and shallow water table combine to give a high ET.
2143	27.8	29	The partially wooded subcatchment is flat-lying and is underlain by moderate permeability sands and silts. Several areas of closed drainage occur within the area.

Subcatchment	Area (ha)	Infiltration % of total rainfall	Subcatchment Characteristics
2145	65.7	7	The subcatchment is fully developed as an industrial subdivision.
2150	27.0	24	The mainly agricultural subcatchment is flat-lying and is underlain by moderate permeability sands and silts in the north and by low permeability glacial till in the south. A small woodlot is present at the intersection of Maple Grove and Speedsville Roads.
2155	28.4	25	The subcatchment is flat-lying and is a mixture of sod farm and open field. The area is underlain by a mixture of sand and silt and glacial till.
2160	22.1	24	The partially wooded subcatchment is flat-lying and is underlain by moderate permeability sands and silts in the north and by low permeability glacial till in the south.
2165	7.8	22	The mainly agricultural subcatchment is flat-lying and is underlain by low permeability glacial till.
2170	28.2	26	The mainly agricultural subcatchment is flat-lying and is underlain by moderate permeability sands and silts.
2172	11.8	25	The mainly agricultural subcatchment is flat-lying and is underlain by moderate permeability sands and silts in the east and by low permeability glacial till in the west.
2173	12.8	20	The partially wooded subcatchment slopes steeply to the south and is underlain by low permeability glacial till and bedrock.
2175	10.6	20	Privately serviced residential area sloping steeply to the south and underlain by low permeability glacial till and bedrock.
2180	6.8	20	Privately serviced residential area underlain by bedrock beneath a thin mantle of fill and recent alluvium.
2182	20.6	25	The partially wooded subcatchment is flat-lying and is underlain by a mixture of moderate to high permeability sands and silts and low permeability glacial till.
2185	22.5	22	The partially wooded subcatchment slopes steeply to the south and is underlain by low permeability glacial till and bedrock.
2190	11.5	25	Exposed and shallow bedrock along the Speed River.

Table B 1.5.7 Subcatchment Infiltration Rates – Lands Draining Directly to the Speed River

Subcatchment	Area (ha)	Infiltration % of total rainfall	Subcatchment Characteristics
A (West)	65.5	10	Heavily developed. Infiltration is difficult to predict due to on site drainage structures and the areas location within a groundwater discharge zone.
B (East)	28.5	20	Exposed and shallow bedrock along the Speed River. Some development. Predominantly within an area of groundwater discharge.

Table B 1.5.8 Subcatchment Infiltration Rates – West Creek

Subcatchment	Area (ha)	Infiltration % of total rainfall)	Subcatchment Characteristics
3101	39.6	7	The subcatchment is fully developed as an industrial subdivision.
3103	4.8	26	The mainly agricultural subcatchment is flat-lying and is underlain by moderate permeability sands and silts.
3104	21.2	24	The partially wooded subcatchment is flat-lying and is underlain by low permeability glacial till in the north and by moderate permeability sands and silts in the south.
3105	7.9	27	The wooded subcatchment is flat and underlain by moderate to high permeability sands and silts. Heavy vegetation and shallow water gives a high ET.
3110	4.8	25	The agricultural subcatchment slopes to the south and is underlain by moderate to high permeability sands and silts.
3115	2.4	15	The subcatchment includes a steep scarp and a large shallow pond. Soil conditions are variable.
3120	4.0	18	The mainly agricultural subcatchment is flat-lying and is underlain by low permeability glacial till.
3125	5.5	22	The mainly agricultural subcatchment is flat-lying and is underlain by moderate permeability sands and silts.
3127	3.7	22	The mainly agricultural subcatchment is flat-lying and is underlain by moderate permeability sands and silts.
3130	11.4	14	Industrial development.
3135	11.7	24	The agricultural subcatchment slopes to the south and is underlain by moderate to high permeability sands and silts.
3140	5.0	26	The wooded subcatchment borders the north side of West creek and is dominated by organic and alluvial deposits.
3145	2.4	24	The residential subcatchment slopes to the south and is underlain by moderate to high permeability sands and silts.
3150	7.0	34	The subcatchment is flat-lying and underlain by high permeability sands and gravels.
3155	5.2	28	The subcatchment is flat-lying and underlain by bedrock beneath a shallow cover of recent alluvium.
3160	10.8	27	The subcatchment is flat-lying and underlain by a variety of materials.
3165	2.2	5	Highway 401.
3170	1.4	5	Highway 401.
3175	6.1	24	The subcatchment is flat-lying and underlain by bedrock beneath a shallow cover of recent alluvium.

B 1.6 Hydrogeologic Constraints and Opportunities

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

- 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.
- The Guelph Formation is a high quality aquifer and the study area has the potential to support additional privately serviced development should planning considerations favour this type of servicing. The mantle of permeable sandy soils that occurs over the majority of the subwatersheds provides a favourable environment for individual or small communal sewage disposal systems (again assuming that planning considerations make this mode of servicing desirable).
- Development in the subwatershed will result in impermeable pavement being placed on areas that were previously permeable. 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.
- 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.
- At-source infiltration should be maximized wherever feasible as this is the most desirable form of stormwater management from a hydrogeological perspective.
- Recharge within the north and northeast portions of the study area may contribute baseflow to the adjacent Chilligo Creek and its Tributaries. Chilligo Creek supports a valuable coldwater fishery and infiltration within the north and northeast portions of the study area should be managed with the assumption that the recharge contributes to Chilligo Creek.
- Infiltration of salt-laden stormwater should be avoided in areas where wetland vegetation communities are particularly sensitive to salt impacts.
- Water quality should be maintained or improved although the temperature of groundwater discharge is less critical in areas bordering the three creeks than would be the case for development bordering coldwater streams.

- 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

B 2.1.1 Purpose

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 model of each of the subwatersheds 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 streams during a rainfall or snowmelt event. The flow information generated by the model of the subwatersheds has been used in subsequent sections of this study.

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 the Hespeler West subwatersheds. These sources include the following:

- Grand River Hydrology Study - Phase I (GRCA, 1988);
- Meteorological Services of Canada (MSC), (previously 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;
- 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, Atmospheric Environment Service, 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);
- Hydrological Summary Report Hespeler West Subwatersheds Study, (Naylor Engineering, July, 2001);

- Speed and Eramosa Rivers Floodline Mapping Study - Hydrology (Ecologistics Limited, 1988);
- Water Quality Resources of Ontario (Ministry of Natural Resources, 1984);
- Ontario Ministry of Natural Resources and City of Cambridge GIS data sets;
- Ontario Geological Survey Quaternary Geology Mapping (Ontario Northern Mines and Development, 1983).

B 2.2 Field Investigations

B 2.2.1 Meteorological Information

Long-term monitoring of meteorological quantities has occurred in the region surrounding Hespeler West for more than 100 years. Historical data are primarily available from 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 Hespeler West study area. Rainfall data was also available from the Schroeter and Associates tipping bucket gauge located in West Guelph.

For detailed energy balance analysis, a wider array of meteorological variables (e.g., hourly rainfall, air temperature, wind speed and direction, solar radiation, humidity) is available through the Internet from three stations: the Elora Research Station (AES 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 1980s. Detailed energy balance information is available from the Guelph OAC (AES 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 (AES 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 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 Turfgrass 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
S&A Guelph		H.S.	1999-2002	P,T,RG

Notes: P – daily precipitation (rain and snow)
T - daily maximum and minimum air temperature
RG - Recording raingauge (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 the Hespeler West study area 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 1st to April 15th, 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). Snow cover distributions have also been confirmed for the north Cambridge area with actual field measurements in the nearby Hespeler West area on February 5, 2001, as part of the Hespeler West Subwatershed Study. Measurements from the survey are summarized in **Table B 2.2.2.** 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 patterns from the above sources 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 Hespeler West Snow Survey (to be used as reference data)

Land Cover Type	Number of Depth Readings	Mean Depth (cm)	Std. Dev. (cm)	Max. Depth (cm)	Min 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

B 2.2.3 Streamflow Data

No long-term streamflow data exists for any of the Hespeler West subwatersheds. However, for the purpose of this study, temporary water level recorders connected to digital data loggers were installed at four locations. Initially, these four gauges were installed in November 2001, and operated for about three weeks until freeze-up, when they were removed. The gauges were re-installed in March 2002, and have continued to operate throughout the study period.

Rating curves, the relationship between water level and discharge, were developed for all three gauges in order to convert measured water level data to discharge values. The water level recorders measured discharge patterns in resulting from several significant rainfall events, which can be used to validate the hydrologic model in event mode. In addition, the GAWSER model has been accurately calibrated to the characteristics of the Grand River and Speed River watersheds, and numerous other smaller watersheds of similar characteristics, which further reinforces confidence in the model results.

B 2.3 Hydrologic Modelling

The analysis of existing hydrologic conditions in the Hespeler West watersheds 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, the study area has been divided into the three constituent subwatersheds for hydrologic modelling purposes. East Creek, Middle Creek and West Creek were divided into 16, 29 and 20 subcatchment areas respectively. 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 subwatersheds, 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 depresson storage areas (kettles).

The drainage areas of the East, Middle and West Creek subwatersheds were found to be 160, 585 and 151 hectares respectively. Respective average subcatchment sizes in the hydrologic model for the subwatersheds are 10, 21 and 8 hectares. Fourteen reservoir elements with significant storage have been identified and considered in the model, 9 of which are natural depressions/wetlands with some recharge capability in the headwaters of the three main creeks. Five constructed ponds, including 4 industrial stormwater management facilities have also been included.

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 surfaces
2	Open water and wetland areas (for direct contribution of precipitation)
3	Clay Till with low vegetative cover
4	Clay Till with high vegetative cover (e.g., Forests)
5	Silt Till with low vegetative cover
6	Silt Till with high vegetative cover
7	Sandy Till with high vegetative cover
8	Sand and Gravel with low vegetative cover
9	Sand and Gravel with high vegetative cover

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 Ministry of Natural Resources data set. 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.

Channel characteristics were based on numerous cross-sections surveyed for the fluvial geomorphology component of the study, with hydraulic roughness values determined based on typical values for natural, excavated, and lined channel channels (Chow, 1959).

Table B 2.3.2 summarizes the subcatchment characteristics for the Hespeler West subwatersheds. On the whole, 22%, 18% and 13% respectively of the East, Middle and West Creek subwatersheds is forested. Correspondingly, 77%, 59% and 45% of the subwatershed soils comprise lacustrine sand and outwash sand and gravel deposits.

Appendix D gives additional information and details regarding the set-up of the existing conditions hydrologic model for Hespeler West. 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, and d) an explanation of initializing the snow accumulation, re-distribution and melt computations.

Table B 2.3.2 Subcatchment Characteristics

Subwater-shed	Sub-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
East Creek	1101	6.4	200	318	4.3	16.6	0	0	0	0	0	77.4	1.6	3
	1103	16.6	350	238	8.8	0.1	0	0	0	0	0	90.3	0.9	2
	1105	8.0	160	249	2.5	71.4	0	0	0	0	0	10.3	15.8	3
	1110	7.5	300	125	3.7	0	0	0	0	0	0	96.3	0	2
	1115	11.8	230	256	1.5	0	0	0	0	0	0	97.8	0.7	2
	1117	19.0	410	231	1.7	0	0	0	0	0	0	97.4	0.9	2
	1120	16.1	190	425	0	62.7	0	0	0	0	0	1.3	36	3
	1125	6.7	211	159	0	0	0	0	33.3	0	0	36.9	29.8	2
	1130	10.3	480	216	0	0.1	0	0	0	0	0	95.7	4.2	2
	1135	12.4	450	50	10.9	0	0	0	83	1.4	0	4.6	0	1.2
	1140	13.3	450	50	21.3	0	0	0	1.2	0	0	66.3	11.2	1.2
	1142	5.2	110	237	0	64.8	0	0	0.5	5.8	0	6.3	22.6	3
	1145	11.8	450	50	28.4	0	0.6	0	59.9	2.6	0	8.5	0	1.2
	1150	12.0	600	100	4.8	1.7	11.6	0	46.7	1.9	0	30.8	3	2
	1155	2.7	450	50	11.5	8.7	43.2	0	33.3	0	0	3.4	0	1.2
	1160	1.1	20	269	6.5	7.6	70.9	1.6	6.2	7.2	0	0	0	2
Middle Creek	2101	11.7	300	391	2.1	0.2	0	0	16.5	0	0	81.1	0	2
	2105	7.1	130	273	4.9	48.1	0	0	0	0	0	30.4	16.6	3
	2110	25.2	950	265	0.5	7.1	0	0	37.8	0	0	52.8	1.8	2
	2115	38.5	900	428	4.6	26.4	0	0	0	0	0	61.2	8.1	3
	2120	21.9	450	50	11.7	0	0	0	61.4	1.1	0	25.9	0	1.2
	2125	51.0	850	600	7.2	22.9	0	0	59.9	9.9	0	0	0	3
	2130	23.3	500	233	5.7	0	0	0	17.4	2.4	0	73.1	1.3	2
	2135	20.3	560	182	6.4	0	0	0	0	0	0	92.6	0.9	2

Table B 2.3.2 Subcatchment Characteristics

Subwater-shed	Sub-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
	2136	7.8	210	185	1	0	0	0	0	0	0	98.9	0.1	2
	2137	16.2	430	188	0.3	65.8	0	0	0	0	0	21.9	12.5	3
	2138	5.5	180	152	3.2	0	0	0	0	0	0	92.7	4.1	2
	2139	4.0	160	125	5.6	14.5	0	0	0	0	0	76.5	3.5	3
	2140	5.8	470	123	0	0	0	0	0	0	0	100	0	2
	2141	27.7	760	364	3.9	0	0	0	0	0	0	94.3	1.7	2
	2142	16.4	390	211	0	51.5	0	0	0	0	0	21.9	27.1	3
	2143	27.8	600	464	4.4	4.9	0	0	0	0	0	85.6	5.2	2
	2145	65.7	450	50	90	0	0	0	7.2	0	0	2.7	0	1.2
	2150	27.0	470	287	2.2	7.4	0	0	11.4	1.6	0	71.5	5.8	2
	2155	28.4	690	206	6.2	0	0	0	56.9	0.5	0	32.8	3.7	2
	2160	22.1	370	298	3.2	21.9	0	0	4.4	0	0	54.9	15.8	3
	2165	7.8	170	230	2.4	0	0	0	71	24.4	0	2.2	0	2
	2170	28.2	380	371	1.2	0	0	0	28.2	12.6	0	48.5	9.5	2
	2172	11.8	330	179	4.6	0	0	0	92.6	2.8	0	0	0	2
	2173	12.8	450	50	12.5	0	1.4	0	40.5	14.9	0	29.1	1.5	1.2
	2175	10.6	450	50	12.7	0	0.1	0	70.9	16.3	0	0	0	1.2
	2180	6.8	180	188	5.2	1.1	78.1	0	13.5	2.1	0	0	0	2
	2182	20.6	240	430	4.7	14.9	0	0	0	0	0	62.6	17.7	3
	2185	22.5	610	184	9.5	10.2	16.3	0.9	21.3	12.6	0	26.2	3	3
	2190	11.5	725	159	0.7	47	46.7	5.9	0	0	0	0	0	3
West Creek	3101	15.1	450	50	90	0	0	0	9.9	0.1	0	0.1	0	1.2
	3102	19.1	450	50	81.5	0	0	0	18.2	0.1	0	0.1	0	1.2
	3103	4.8	390	123	0	0	0	0	0	0	0	100	0	2
	3104	21.2	280	378	0.6	0	0	0	75.1	8.9	0	14.9	0.1	2
	3105	7.9	230	171	2.5	54.4	0	0	1.5	23.4	0	3	15.1	3
	3110	4.8	210	115	2.1	0	0	0	0	0	0	92.1	5.8	2
	3115	2.4	190	64	0	36.8	0	0	0	0	0	58.6	4.6	3
	3120	4.0	190	105	3.1	0	0	0	11.7	0	0	85.2	0	2
	3125	5.5	210	131	2.5	0	0	0	0	0	0	96.7	0.8	2
	3127	3.7	50	365	0	59.8	0	0	0	0	0	1.6	38.6	3
	3130	11.4	450	50	90	0	0	0	0.2	0	0	9.7	0.1	1.2
	3135	11.7	310	189	9.6	0	0	0	0	0	0	82.3	8.1	2
	3140	5.0	90	276	3.3	52.1	0	0	0	0	0	13.3	31.2	3
	3145	2.4	450	50	21.6	0	0	0	0	0	0	67	11.4	1.2
	3150	7.0	230	151	7.2	0	0	0	0	0	0	92.8	0	2
	3155	5.2	140	184	2.4	0	0	0	53.3	22.1	0	18.3	4.1	2

Table B 2.3.2 Subcatchment Characteristics

Subwater-shed	Sub-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
	3160	10.8	500	216	9.6	0	20.4	1.5	59.8	2.4	0	6.3	0	2
	3165	2.2	450	50	99.7	0	0.1	0	0	0	0	0.2	0	1.2
	3170	1.4	450	50	12.2	0	40.6	0	9.1	0	0	38.1	0	1.2
	3175	6.1	450	50	12.8	0.1	35.8	0	38.8	2.2	0	10.3	0	1.2

Note: Definitions for response units (RUs) given earlier in this section.

B 2.3.2 Model Validation

Historic continuous streamflow measurements have not been available for the Hespeler West Creeks. 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 the creeks. 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 are 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 Hespeler West subwatersheds (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 the timing 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. Staff at the City of Cambridge Engineering Department provided the intensity-duration-frequency (IDF) information.

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.

Table B 2.3.3 Event Characteristics				
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 the Hespeler West subwatersheds 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 event, with the greatest discrepancies occurring when comparing the flows from 100-year Chicago Storm event with estimates from the other two techniques. The main reason for any discrepancies 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. 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 those that are currently urbanized. The significant storage volumes in the upper parts of the subwatersheds, particularly in Middle and East Creeks, would tend to dampen out the input intensity effects, particularly for the lower frequency events. In general, agreement between the Index Flood method and the continuous modeling is good. The major reason for any discrepancies in this case lies in the fact that the Index Method formula was developed using frequency flows from watersheds with much larger drainage areas (10 to 20 times) than the Hespeler West subwatersheds. 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 Flood Flows Note: All flows in m^3/s											
Creek	**Hyd No**	**Point of Interest**	**Area (km^2)**	**25mm**	**1:2 yr**	**1:5**	**1:10**	**1:25**	**1:50**	**1:100**	**Regional**
East Creek	1503	Headwater Pond	0.309	0.043	0.084	0.237	0.459	0.699	0.85	1.31	1.84
	1210	Mohawk Road	0.384	0.044	0.090	0.266	0.545	0.851	1.05	1.69	2.44
	1213	Node 1213	0.502	0.044	0.090	0.266	0.545	0.851	1.05	1.69	3.42
	1232	Lower Wetland	1.279	0.721	0.92	1.55	2.39	3.13	3.72	5.04	7.49
	1235	Beaverdale Road	1.332	0.715	0.91	1.55	2.4	3.13	3.75	5.04	7.85
	1255	Speed River Outlet	1.607	1.21	1.52	2.56	3.96	5.22	6.14	8.34	10.3
Middle Creek	2215	Middle Block Road	1.044	0.672	0.862	1.54	2.45	3.30	3.92	5.46	6.45
	2228	Middle Ck. Station 11+25	2.069	0.238	0.348	0.729	1.30	1.92	2.34	3.55	6.43
	2235	Middle Ck. Station 16+25	2.285	0.239	0.364	0.786	1.43	2.13	2.61	4.00	7.81
	2245	Maple Grove Road	4.019	0.527	1.04	2.71	4.97	7.80	9.41	14.2	21.2
	2260	Briardean Road	4.602	0.654	1.24	3.18	5.82	9.11	11.0	16.6	25.0
	2265	Farm Pond Inlet	5.140	0.746	1.40	3.59	6.58	10.4	12.5	19.1	28.6
	2275	Hunt Club Road	5.304	1.04	1.44	3.68	6.79	11.0	13.2	20.1	30.0
	2285	Speed River Outlet	5.850	0.933	1.49	3.64	6.66	10.3	12.7	19.3	31.0
West Creek	3501	Loblaws SWM Pond	0.151	0.064	0.084	0.216	0.441	0.688	0.818	1.21	1.47
	3502	Seaforth SWM Pond	0.191	0.146	0.244	0.684	1.32	1.94	2.34	3.37	2.43
	3204	Start Toyota Diversion	0.680	0.237	0.469	1.32	2.51	3.71	4.43	6.41	6.48
	3210	West Ck u/s of ATS Site	0.848	0.239	0.485	1.44	2.82	4.24	5.11	7.62	8.03
	3505	ATS SWM Pond	0.114	0.044	0.047	0.124	0.458	0.841	1.07	1.70	1.43
	3235	Royal Oak Road	1.222	0.296	0.563	1.63	3.51	5.46	6.63	10.2	11.4
	3245	Highway 401	1.382	0.36	0.592	1.63	3.41	5.33	6.45	10.0	12.5
	3247	Hal Rogers Drive	1.403	0.408	0.593	1.63	3.43	5.38	6.51	10.1	12.7
	3255	Speed R Outlet	1.477	0.663	0.714	1.65	3.37	5.34	6.51	10.2	13.0

Table B 2.3.5 Comparison of Flood Flows at Creek Outlets													
Creek	Area (km^2)	2 Year Event Model (m^3/s)	2 Year Cont. Model (m^3/s)	2 Year Index Flood (m^3/s)	10 Y Event Model (m^3/s)	10 Y Cont. Model (m^3/s)	10 Y Index Flood (m^3/s)	50 Y Event Model (m^3/s)	50 Y Cont. Model (m^3/s)	50 Y Index Flood (m^3/s)	100 Y Event Model (m^3/s)	100 Y Cont. Model (m^3/s)	100 Y Index Flood (m^3/s)
East Creek	1.60	1.52	0.69	1.05	3.96	1.55	1.65	6.14	2.15	2.26	8.34	2.42	2.51
Middle Creek	6.05	1.49	3.30	3.23	6.66	5.46	5.07	12.70	7.07	6.92	19.30	7.71	7.69
West Creek	1.51	0.71	0.99	1.01	3.37	1.56	1.33	6.51	2.97	2.16	10.20	3.43	2.40

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 Hespeler West subwatersheds hydrologic model. **Tables B 2.3.6 to B 2.3.8** gives a sample complete water balance table for the Hespeler West creeks at their outlets at the Speed River. This table shows how the individual water balance quantities change from one month to the next. **Table B 2.3.9** gives the mean annual water balance quantities for five locations within Hespeler West.

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 East Creek at the Speed River						
	Water Balance Quantities (in mm)					
				Infiltration		Total
Month	Precip	ET	Runoff	(Baseflow)	(Losses)	Flow
Jan	50.2	7.8	7.5	18.5	16.5	25.9
Feb	45.5	6.9	12.6	16.8	9.3	29.3
Mar	64.8	10.6	23.4	21.6	9.2	45.0
Apr	78.8	58.7	11.9	33.6	-25.5	45.5
May	76	97.4	3.8	42.6	-67.8	46.4
Jun	83.3	94.3	4	25.3	-40.3	29.3
Jul	87.2	75.9	4.2	17.4	-10.4	21.7
Aug	86.5	69.8	4.8	14	-2.1	18.8
Sep	82.8	47.8	3.8	11.5	19.6	15.3
Oct	73.5	37.4	4.2	10.8	21.1	15
Nov	86.7	18.6	7.9	12.6	47.6	20.5
Dec	67	7.4	9.7	16.4	33.5	26.1
Total	882.1	532.6	97.8	240.9	10.7	338.8

Table B 2.3.7 Water Balance Summary Middle Creek at the Speed River						
	Water Balance Quantities (in mm)					
				Infiltration		Total
Month	Precip	ET	Runoff	(Baseflow)	(Losses)	Flow
Jan	50.2	7.8	10.2	16.7	15.6	26.9
Feb	45.5	6.9	15.4	14.3	8.9	29.7
Mar	64.8	9.9	33.3	17.7	3.9	51
Apr	78.8	54.7	21.9	22	-19.8	43.9
May	76	93.7	10.4	24.3	-52.5	34.7
Jun	83.3	90.5	11.6	14.8	-33.6	26.4
Jul	87.2	73.2	12.3	8.5	-6.8	20.8
Aug	86.5	67.6	13.1	5.5	0.2	18.7
Sep	82.8	46.8	10.9	5	20.1	15.9
Oct	73.5	36.6	11.1	6.4	19.3	17.6
Nov	86.7	17.9	18.8	11.3	38.8	30.1
Dec	67	7.3	16.6	16.7	26.4	33.3
Total	882.1	512.7	185.6	163.3	20.4	348.9

Table B 2.3.8 Water Balance Summary West Creek at the Speed River						
	Water Balance Quantities (in mm)					
				Infiltration		Total
Month	Precip	ET	Runoff	(Baseflow)	(Losses)	Flow
Jan	50.2	7.8	14.4	13	15	27.4
Feb	45.5	6.9	21.5	11.2	5.9	32.7
Mar	64.8	9.6	44.5	13.4	-2.8	58
Apr	78.8	47.4	31.4	16.2	-16.2	47.7
May	76	79.4	19.2	19.5	-42	38.6
Jun	83.3	77.7	21.3	13.3	-29.1	34.6
Jul	87.2	63.3	22.7	7.9	-6.8	30.6
Aug	86.5	58.7	23.6	5.4	-1.3	29
Sep	82.8	41.2	20.9	4.7	16	25.5
Oct	73.5	32.6	19.9	5	16	24.9
Nov	86.7	16.8	29.3	8.4	32.1	37.7
Dec	67	7.2	22.5	12.8	24.5	35.3
Total	882.1	448.7	291.3	130.7	11.3	422

Tables B 2.3.6 to B 2.3.8 illustrate that between 26% and 36% of the 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, evapotranspiration exceeds the mean precipitation depth of 83.3 mm, on East and Middle Creeks. Since 29.3 mm and 26.4 mm of water leave the East Creek and Middle Creek subwatersheds, respectively, as runoff plus baseflow, then the deficit created by having less precipitation than ET means that water must come from soil-water storage.

Table B 2.3.9 Mean Annual Water Balance								
				Water Balance Quantities (in mm)				
						Infiltration		
Hyd No.	Location	Area (km^2)	Precip. (mm)	ET (mm)	Runoff (mm)	Baseflow (mm)	Losses (mm)	Total Flow (mm)
1210	East Creek at Mohawk Road	0.384	882.1	514	88.1	121.8	158.2	209.8
1225	East Creek at Maple Grove Rd	1.023	882.1	537	36.1	74.2	234.8	110.3
1235	East Creek at Node 1235	1.332	882.1	534.5	70.5	268.6	8.5	339.1
1240	East Creek at Beaverdale Road	1.450	882.1	529.5	89.7	253.9	9	343.6
1255	East Creek at Speed R outlet	1.607	882.1	532.6	97.8	240.9	10.7	338.8
2504	Middle Ck at Middle Block Road	1.040	882.1	552.2	116.9	138.6	74.4	255.4
2228	Middle Ck at Node 2228	2.069	882.1	556.6	127.1	148.4	50	275.5
2245	Middle Ck at Maple Grove Road	4.019	882.1	492.2	210	122.9	56.9	332.9
2250	Middle Ck at Speedsville Road	4.303	882.1	497	205.8	125	54.3	330.8
2275	Middle Ck at Hunt Club Road	5.304	882.1	509.8	192	127.4	52.8	319.5
2285	Middle Ck at Speed R outlet	5.850	882.1	512.7	185.6	163.3	20.4	348.9

Table B 2.3.9 Mean Annual Water Balance

				Water Balance Quantities (in mm)				
						Infiltration		
Hyd No.	Location	Area (km^2)	Precip. (mm)	ET (mm)	Runoff (mm)	Baseflow (mm)	Losses (mm)	Total Flow (mm)
3501	West Creek: Loblaws SWM Pond	0.151	882.1	213	659.5	10.1	-0.6	669.6
3502	West Creek: Seaforth SWM Pond	0.191	882.1	248.8	612.5	19	1.8	631.5
3505	Outflow ATS SWM Pond	0.114	882.1	214.2	644.1	26.3	-2.5	670.4
3235	West Creek at Royal Oak Road	1.222	882.1	434	301	108.4	38.6	409.5
3245	West Creek u/s Highway 401	1.381	882.1	448.5	287.9	108.8	36.9	396.7
3250	West Creek at Hal Rogers Drive	1.417	882.1	445.2	293.5	132.7	10.7	426.2
3255	West Creek at Speed R outlet	1.477	882.1	448.7	291.3	130.7	11.3	422

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

The quantities listed in **Table B 2.3.9** represent the areal mean values for the drainage area upstream of the stated location. For the overall study area, notice that the percentage of mean annual precipitation increases from East Creek, to Middle Creek, to West Creek (11%, 21% and 33% respectively). Conversely, evapotranspiration (60%, 58% and 51% respectively) and infiltration (26.5%, 20.6%, and 16.1%) decrease from East Creek to West Creek. This is the result of increasing development in a westerly direction; East Creek is very lightly developed while Middle Creek contains some industrial and residential development and West Creek contains a number of large industrial sites. Surficial geology is also a factor, soils in the study area become less pervious towards the west, with sand and gravel giving way to glacial till.

Generated peak flows at the outlet of East, Middle and West Creeks 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.

Figures B 2.3.2, B 2.3.3 and B 2.3.4 give the flow-duration curves at the outlets for East Creek, Middle Creek and West Creek. In general, these curves represent subwatersheds 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.

The flow duration curves suggest that flow East and Middle Creeks only rarely goes to zero, while West Creek may go to zero about 4% of the time. More than 50% of the time flows at the subwatershed outlets are less than 13 L/s for East Creek, less than 45 L/s for Middle Creek, and 4 L/s for West Creek.

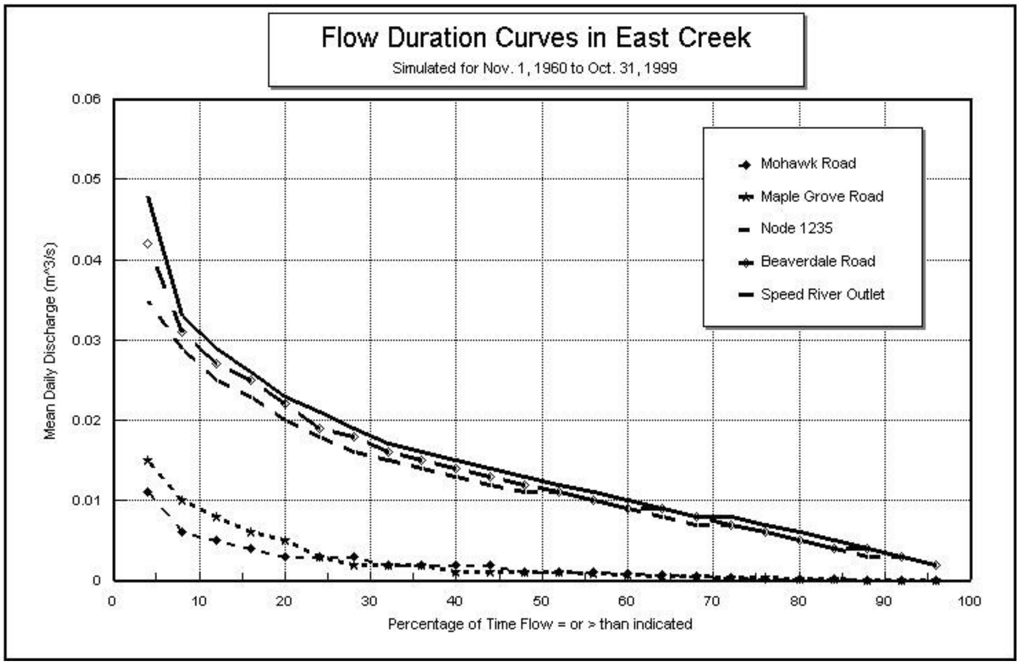

Figure B 2.3.2 Flow Duration Curves – East Creek

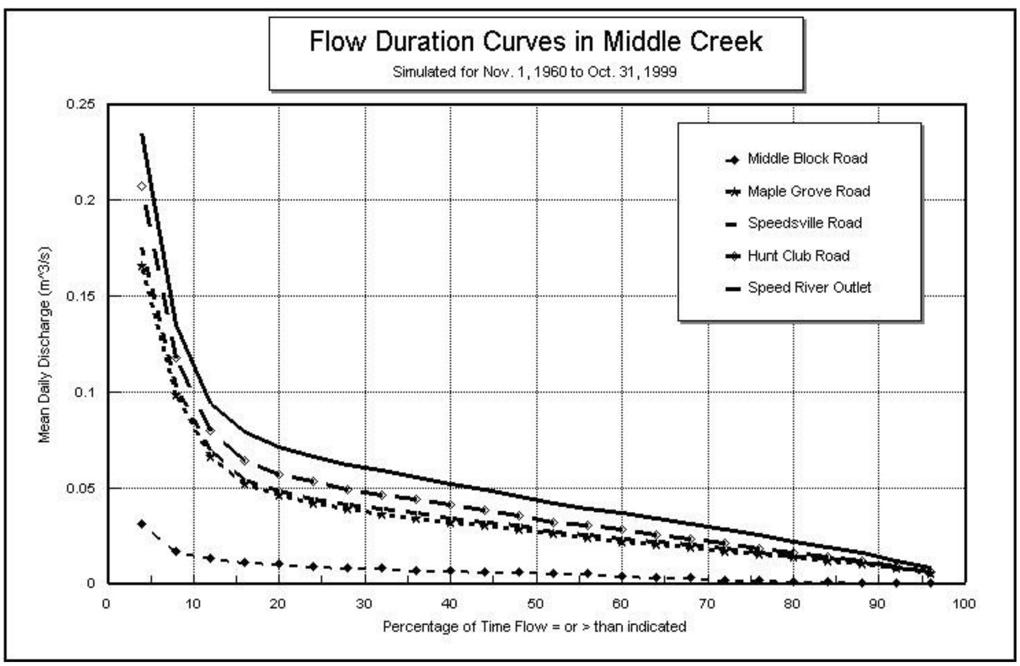

Figure B 2.3.3 Flow Duration Curves – Middle Creek

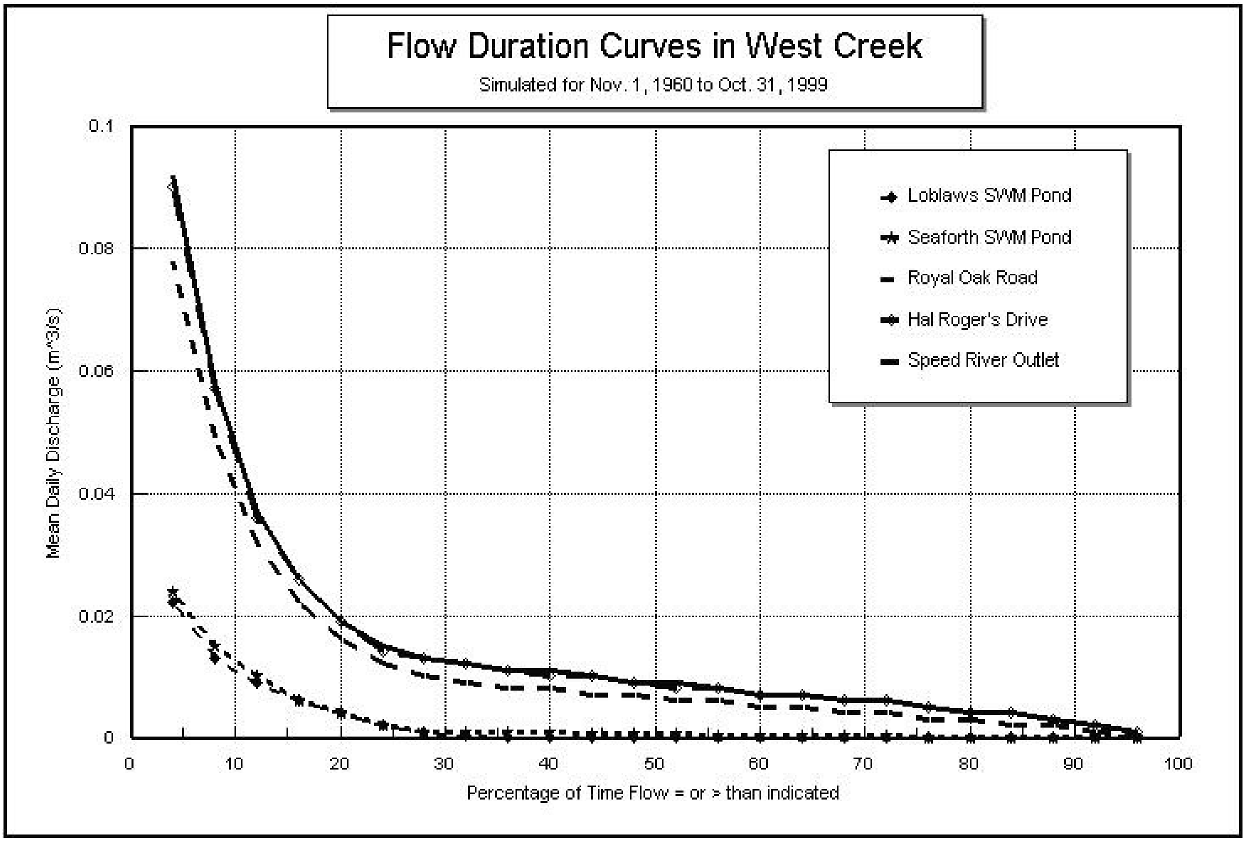

Figure B 2.3.4 Flow Duration Curves – West Creek

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 Hespeler West subwatersheds.
2. Advancing the hydrograph will change the flow duration characteristics of the system. The hydrograph peak should not be advanced and should be maintained to within 75% or greater of the calibrated hydrograph.
3. The soils in the Hespeler West subwatersheds consist of approximately 60% sand and gravel, which are highly permeable resulting in relatively 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 East, Middle and West Creek watersheds. Recharge may also be directed to Chilligo Creek (see Section B 1.0), a coldwater system. Therefore, infiltration rates should be maintained.

4. The flow attenuation function of the wetlands and natural depressions in the headwaters of the East, Middle and West Creeks should be maintained.
5. 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.
6. 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 Hespeler West subwatersheds.

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 Hespeler West watercourse corridors. As indicated in the revised Terms of Reference, the flood elevations for Hespeler West will be determined from the Speed River floodplain (where the elevations are already established by the GRCA) to the wetland areas that mark the origins of the three creeks in the study area. 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 flood flows and floodlines will allow biologists, geomorphologists, planners, and engineers to understand the ultimate effects on the creek system and make allowances for these flows.

B 3.2 Hydraulic Modeling

The hydraulic modeling conducted for East Creek, Middle Creek and West Creek used the HEC-RAS v.2.2 (Hydraulic Engineering Centre River Analysis System) model 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 to the Hespeler West subwatersheds.

The model requires fairly 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 total station survey conducted in June 2002, as well as digital topographic data and cross-section surveys from the fluvial geomorphology component of the study. The locations of HEC-RAS cross sections on East, Middle and West Creeks used for the analysis are shown on **Maps 1A – 1E**. Section views for all cross sections are provided with the model output in **Appendix E**. The digital topographic data and contour information were provided to PEIL by the City of Cambridge for use during the project. In the course of the field investigations and subsequent analysis, there were no apparent discrepancies in elevations or related data from the contour layer when compared with field surveys. Therefore, we have confidence that the quality of mapping produced by PEIL meets all appropriate FDRP standards.

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 the HEC-2 cross-sections closest to the outlets of East, Middle and West Creeks, or interpolated if necessary. By this method, the starting water level estimates for the Hespeler West HEC-RAS models have a concrete basis. Also, the results will provide conservative estimates of the extent of flooding on East Creek, Middle Creek and West Creek, particularly at the downstream ends; because it is assumed that the flood events on the creeks and the Speed River are occurring at the same time.

Using flows from the hydrologic modeling described in Section B 2.0 and **Appendix D**, Regional Storm flows as well as event flows (2-year through 100-year storms) for ultimate conditions for SWM controls were evaluated in the HEC-RAS model to determine flood elevations. 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**. Floodlines for East, Middle and West Creeks are shown on Figure B 3.2.1 as well as in the detailed floodplain mapping on **Maps 1A – 1E**.

Initial floodline mapping using the HEC-RAS analysis results indicated a very large extent of flooding upstream of the Middle Block Road embankment during the Regional Storm Event. However, it was not certain whether there was sufficient volume of runoff generated upstream of Middle Block Road to back up to the level suggested by the HEC-RAS model. This was investigated using the GAWSER model to report the volume of runoff stored in the area upstream of the embankment, which had already been modeled as a reservoir storage element in the model. The results showed that approximately 192,000 m^3 of storage is utilized in this areas during the Regional Event, which corresponds with an elevation of approximately 310.28 m on the stage-storage-discharge curve for this element. Although this is slightly lower than the flood elevation of 310.34 m calculated by the HEC-RAS model immediately upstream of Middle Block Road, the effect of the 0.06 m difference on the extent of flooding is negligible and the values are considered equal by the GRCA due to rounding off to one significant digit. Consequently, the original HEC-RAS results were used for plotting the final floodlines on Middle Creek.

Table B 3.2.1 Regional Flood Elevations

Creek	Section No.	Cross-Section Location	Ultimate Conditions Regional Flood Elevation (m)
East	2699	Headwater wetland	310.26
	2618.5	0.610 metre ∅ CSP culvert under Mohawk Road	310.26
	2056	350 metres upstream of Maple Grove Road	307.81
	1615.5	1.140 metre ∅ CSP culvert under Maple Grove Road	307.79
	1083	450 metres upstream of Beaverdale Road	300.99
	717.5	0.910 metre ∅ CSP culvert under Beaverdale Road	296.03
	598	0.760 metre ∅ concrete culvert under farm lane	292.12
	260	250 metre upstream of outlet to Speed River	285.77
Middle	5364	Headwater wetland	310.36
	5194.5	0.610 metre ∅ CSP culvert under Middle Block Road	310.34
	4509	600 metre downstream of Middle Block Road	307.97
	3383	300 metre upstream of Maple Grove Road	306.51
	3037	Twin 1.400 metre ∅ CSP culverts under Maple Grove Road	306.49
	2655	Twin 1.400 metre ∅ CSP culverts under Speedsville Road	305.90
	1705.5	1.525 metre x 0.830 metre CSP arch culvert and 1.070 metre x 0.635 metre CSP arch culvert under Briardean Road	303.53
	1483	250 metre downstream of Briardean Road	300.03
	1324	0.800 metre ∅ CSP culvert under farm lane	300.04

Table B 3.2.1 Regional Flood Elevations

Creek	Section No.	Cross-Section Location	Ultimate Conditions Regional Flood Elevation (m)
	945	Farm Pond	290.41
	627	Twin 1.220 metre x 2.450 metre box culvert under Hunt Club Road	284.56
West	1728	Outlet of Toyota diversion pipe	299.50
	1322	ATS property boundary	297.31
	1067	250 metre upstream of Royal Oak Road	297.21
	713	1.830 metre ∅ CSP culvert under Royal Oak Road	297.15
	463	250 metres downstream of Royal Oak Road	286.07
	235.5	3.670 metre x 1.500 metre box culvert under Highway 401	278.82
	186	4.000 metre x 1.100 metre box culvert under Hal Rogers Drive	278.38

Table B 3.3.1 Hydraulic Summary of Hespeler West Structures

Creek	Structure No.	Description	Location	Frequency Flooded
East	1	0.610 metre ∅ CSP culvert	Mohawk Road crossing	10 years
	2	1.140 metre ∅ CSP culvert	Maple Grove Road crossing	25 years
	3	0.910 metre ∅ CSP culvert	Beaverdale Road crossing	10 years
	4	0.760 metre ∅ CSP culvert	Farm lane crossing	5 years
Middle	5	0.610 metre ∅ CSP culvert	Middle Block Road crossing	5 years
	6	2 x 1.400 metre ∅ CSP culvert	Maple Grove Road crossing	100 years
	7	2 x 1.400 metre ∅ CSP culvert	Speedsville Road crossing	25 years
	8	1.525 metre x 0.830 metre and 1.070 metre x 0.635 metre CSP arch culverts	Briardean Road crossing	5 years
	9	0.800 metre ∅ CSP culvert	Farm lane crossing	5 years
	10	2 x 1.220 metre x 2.450 metre box culvert	Hunt Club Road crossing	25 years
West	11	1.830 metre ∅ CSP culvert	Royal Oak Road crossing	REG
	12	3.670 metre x 1.500 metre box culvert	Highway 401 crossing	>REG
	13	4.000 metre x 1.100 metre box culvert	Hal Rogers Drive crossing	REG

B 3.3 Flooding Frequency

A summary of structures within the floodplain and their frequency of flooding are provided in **Table B 3.3.1**.

Table B 3.3.1 demonstrates that flood elevations are sufficient to cause overtopping of all roadways within the study area under conditions varying from the 2-year rainfall event to the regional storm. The frequency of flooding at the farm lane crossings on East and Middle Creeks, as well as at Middle Block Road and Briardean Road on Middle Creek and Mohawk Road on East Creek, is relatively high but not excessive given existing traffic volumes on these roadways. Maple Grove Road, Speedsville Road and Royal Oak Road have acceptable overtopping frequencies for arterial roads (25+ years).

However, the 10-year frequency of flooding at the Beaverdale Road crossing is not acceptable for a major arterial road. The hydraulics of the culvert structure at this location were investigated to determine if opportunities exist to eliminate or reduce flooding through upstream flow control. The HEC-RAS model results indicated that the existing capacity of the culvert is approximately 1.6 m^3/s, which is slightly greater than the 1:5 year event discharge. The existing Regulatory Flood discharge at the culvert is much larger at 9.5 m^3/s, which would require an impractically large flow control facility to control to the capacity of the culvert. It is therefore recommended that the frequency of flooding at the Beaverdale Road crossing be reduced by upgrading the culvert structure to pass the 25-year event discharge as a minimum. This should be investigated during any reconstruction of Beaverdale Road.

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 existing floodlines for all events up to the 100 yr. event, stormwater management strategies must ensure that post-development peak flows do not exceed pre-development levels.
- The Regional Storm floodline should be accepted as the Regulatory floodline by the GRCA.

Any channel alterations or structure removals will ultimately require an update of the HEC-RAS model to reflect these changes.

B 4.0 FLUVIAL GEOMORPHOLOGY

B 4.1 Introduction

Each watercourse is a separate entity, responding to inputs and stresses imposed upon it, inputs and stresses which are not transferable from watershed to watershed. Each stream is assessed independently of all others, to properly assess the unique stresses and responses of each watershed. This allows us to provide management strategies and options which are specific to the watershed under study. Additional background information is provided in **Appendix F1**.

B 4.2 Specific Concerns Relating to Hespeler West Streams

In order to properly assess the stream courses, it is essential that each creek be dealt with individually, rather than collectively. This arises from the fact that stresses operating on either East, Middle or West Creeks may not be operating on the others, and also from the fact that resilience to stresses will be different for each different watercourse. Clearly, Middle Creek is undergoing the majority of stresses at present with extensive development in the upper areas of the watershed. East and West Creeks, being smaller and less developed, are in a different phase of stability and should not be considered with Middle Creek.

Assessment of the Hespeler West creek systems began in the late Fall 2001 and was completed in August 2002.

B 4.3 Detailed Studies

The following assessments within the context of the Hespeler West Subwatersheds Study are undertaken individually on East, Middle and West Creeks: We have conducted stream walks on all reaches of each creek to characterize the entire system using a rapid geomorphic assessment approach. During this component we have identified reaches that characterize each of the streams in the study, and are subjecting these to detailed geomorphic analysis.

A geomorphological assessment includes the examination of channel and valley morphological characteristics; physical habitat attributes; and fluvial processes. The result is a detailed total flow analysis for the system, which is instrumental in assessing alternative strategies for the area.

B 4.3.1 Summary of Work Performed

The Hespeler West Creeks have been assessed on a reach perspective, with each reach representing process boundaries that are appropriate to the functioning of each creek. In particular, attempts were made to choose reaches in the upper plateau, transitional high gradient, and lower depositional zones of each creek system.

Each Creek has been divided into representative reaches and each reach further subdivided into 10 cross-sections (5 pools and 5 riffles in sequence) that were surveyed and subjected to detailed analysis. Reach characteristics are summarized below. In total there were 8 reaches (2 on East Creek, 3 each on Middle and West Creeks) for a total of 80 cross-sections (40 pools and 40 riffles). This level of detail was felt to provide ample information to properly characterize the creeks. Reach segment locations and individual cross-sections are found in Figure B 4.3.1.

East Creek, Reach One (see **Photograph B4**) is located downstream of Beaverdale Road in a low-density residential area, upstream of the confluence with the Speed River. In this area, the channel flows through a relatively flat area, which consists primarily of manicured lawn. No riparian buffer exists as the grass is mown right up to the channel banks. In-channel vegetation consists primarily of grass-species that have colonized the channel bed and banks. The reach is somewhat sinuous with a number of well-formed bends. The channel is well connected with the floodplain at the top end of the reach but becomes increasingly entrenched in the downstream direction, and as a result cross-section dimensions are highly variable. A number of areas contain vegetated mid-channel bars, which are submerged at the bankfull stage. During early site visits, significant bank erosion and bank failure were observed in a number of locations in the reach. However, later observations suggested that a resident is maintaining the creek channel by replacing earth and re-vegetating eroded banks. Bed sediment in the reach is generally composed of cobble- to gravel-size particles, except at the extreme downstream end of the reach where much finer material was observed.

East Creek, Reach Two (see **Photograph B5**) is located upstream of Beaverdale Road and is set in a corridor bordered by the Idylwild subdivision to the west and a private residence to the east, downstream of a large wetland. A riparian buffer approximately 5-10 metres in width borders the stream on either side, which consists primarily of herbaceous species with a few willows, dogwoods and larger trees. In-channel vegetation is sparse to non-existent. The channel is well defined and relatively straight, and is well connected with the floodline for the entire length of the reach. Channel banks are near vertical but low and well-vegetated in most areas, with no evidence of significant bank erosion or failure. Bed sediment consists of a mix of cobble- to sand-sized particles with small accumulations of fine sediment found periodically.

Middle Creek, Reach One (see **Photograph B6**) is located approximately 100 metres upstream of the confluence with the Speed River, in a large wetland area that extends upstream to Hunt Club Road. The channel through the reach is bordered by grassy wetland areas although its meandering course periodically extends to the wooded areas on either side. There is little vegetation within the channel although watercress was observed in a few locations. The channel is well defined through the study reach but tends to disappear into the wetland in areas upstream. Connectivity with the floodplain is good with low, well-vegetated banks throughout. The channel bed is generally composed of material ranging from bedrock to boulder-sized material.

Middle Creek, Reach Two (see **Photograph B7**) is situated in a wooded area upstream of the farm pond north of Hunt Club Road. The channel flows through an area of mature woods with some smaller species and herbaceous plants found near the channel banks. The channel is mildly sinuous and is significantly wider than in Reach One. The channel is well connected to the floodplain throughout most of the reach although bank height varies with a number of higher banks particularly where the channel impinges on the valley walls. Bank vegetation is generally sparse, likely because of shade cover, and the banks appear to be eroding more actively than in other areas. Some banks are near vertical while others are undercut. There are also significant amounts of large woody debris (LWD) in the channel throughout the entire reach. The channel bed consists primarily of cobble-size material with accumulations of smaller material found, particularly in pools.

Middle Creek, Reach Three (see **Photograph B8**) is located immediately upstream of Briardean Road, in a large wooded area. The channel is mildly sinuous but flows around a very large valley bend, and is somewhat narrower than in Reach 2. Riparian vegetation consists primarily of a dense growth of herbaceous species at the downstream end, giving way to sparser, larger woody species upstream. In the downstream area, the channel cross-section is relatively narrow and deep, with well-vegetated, vertical banks. Upstream, vegetation coverage of the banks is poor and the channel is wider with sloping banks that appear to erode readily. There are a number of areas with high banks at the upstream end where the channel impinges on the outside of the bend in the valley wall that appear to be actively eroding and contributing sediment to the channel. Large quantities of large woody debris are also found in this reach. Bed sediment is highly variable, ranging from sand and silt to gravel and cobbles. In general, the bed material tends to become coarser towards the upstream end of the reach.

West Creek, Reach One (see **Photograph B9**) is found immediately upstream of the confluence with the Speed River, in Riverside Park, through a wetland area east of the park's playing fields. The channel is relatively straight which may be the result of past channelization activities. In cross-section, the channel is narrow and of medium depth, with near-vertical, well-vegetated banks in most areas. There is no evidence of significant bank erosion or failure. Riparian vegetation consists of dense herbaceous growth with some willows, dogwoods and larger species. The riparian corridor is extensive on the west bank of the creek but is only about 5 metres wide on the east side where it is limited by Hal Rogers Drive. The channel bed consists primarily of sand-sized sediment with occasional cobbles. In some locations the bed is supported by dense root structures from riparian vegetation with no loose sediment apparent.

West Creek, Reach Two (see **Photograph B10**) is situated approximately 100 metres downstream of Royal Oak Road in a mature woodlot. The channel is relatively straight but tends to meander from one side to the other of the narrow, steep channel valley. The channel is wider and shallower than in Reach 1, with a wide corridor of sparse riparian vegetation that consists primarily of woody species. The channel is well connected with the floodplain, and the channel banks are low with a relatively mild slope throughout. However, there is evidence of erosion on exposed bank material at some locations. The channel bed consists largely of cobble-sized material with gravel and sand found in the interstices of the larger particles. Significant LWD is found throughout.

West Creek, Reach Three (see **Photograph B11**) is located north of the ATS industrial site on Royal Oak Road, in a large wooded/wetland area. The wide riparian corridor consists primarily of herbaceous species near the channel banks, giving way to large woody species further away from, the stream. The channel is narrow and of medium depth with well-vegetated banks throughout, with occasional LWD. The channel is mildly sinuous with a medium gradient, and is well connected to the floodplain within the wide channel valley. The channel bed is composed of fine sand- and silt-sized material with occasional gravel and cobbles. There is no significant evidence in the reach of recent bed or bank erosion.

In addition to the reaches described above, a number of highly modified, channelized sections were noted, and though they did not comprise part of the geomorphic assessment that follows, they do require inclusion as they affect the natural functioning of these creek systems.

Table B 4.3.1 Channelized Sections of the Study Creeks

Creek	Channelized Areas
East Creek	• Artificial channel cut through wetland south of Mohawk Road, no reinforcing materials. • Drainage ditch along Beaverdale Road – lined with riprap/riverstone. • Last 200 metres or so before Speed River confluence – relocated and straightened for Highway 24, lined with riprap.
Middle Creek	• Entire length of channel between origin and where it heads south of Maple Grove Road was artificially constructed (originally called Hunsperger Drain) through what was historically a wetland, no reinforcement in channel upstream of Maple Grove, riprap along Maple Grove. • Channel lined with riprap from farm pond down to Hunt Club Road.
West Creek	• Entire upper length of creek to Boxwood Drive has been either removed or piped underground. • Section through Riverside Park looks like it has been relocated and straightened to accommodate Speedsville Road/Hal Rogers Drive, no reinforcement in channel.

B 4.3.2 Morphological Assessment

Morphological characteristics for the study creeks were assessed using standard desktop methods to determine characteristics such as meander amplitude, wavelength, and arc length, as well as sinuosity. In order to properly understand the results the creeks were divided into similar reaches according to morphological characteristics; these reaches do not necessarily correspond with process reaches as discussed in Section B 4.3.1, due to the high degree of alteration of some reaches of the creeks (see **Table B 4.3.1**).

Each of the creeks in the Hespeler West subwatersheds were subjected to a desktop analysis of stream morphological characteristics, in order to summarize general trends in the creeks and to give supplemental information to the analysis of detailed field data (**Table B4.3.2**). Morphological characteristics considered for this exercise included: Sinuosity (channel length vs. valley length); Meander arc length (length of meanders along the channel bottom); Meander wavelength; and Meander amplitude (also referred to as belt width). For each creek and sub-reach these characteristics were gleaned from recent air photos which were amplified in scale in order to properly identify individual features.

Table B 4.3.2 Morphological Analysis of Creek Segments					
Creek, Reach *Segment*	Channel Length (m)	Sinuosity Index	Meander Arc Length (m)	Meander Wavelength (m)	Meander Amplitude (m)
East Creek (entire Creek)	**2845**	**1.06**			
Headwaters to Maple Grove Road	1181	1.03	Min 34.93 Max 127.0 Avg 63.82	Min 22.23 Max 120.65 Avg 55.04	Min 15.87 Max 31.11 Avg 21.08
Maple Grove Road to Beaverdale Road	889	1.07	Min 19.05 Max 33.02 Avg 26.8	Min 12.7 Max 47.63 Avg 22.23	Min 12.7 Max 15.9 Avg 13.97
Beaverdale Road to Speed River	774	1.08	Min 69.85 Max 79.37 Avg 73.03	Min 50.8 Max 79.38 Avg 68.79	Min 6.35 Max 19.05 Avg 15.87
Middle Creek (Entire Creek)	**5399**	**1.30**			
Headwaters to Maple Grove Road	2461	1.34 **Not true SI***	No Real Meanders	No Real Meanders	No Real Meanders
Maple Grove Road to Briardean Road	1174	1.09	Min 28.58 Max 114.3 Avg 66.67	Min 33.02 Max 82.55 Avg 51.94	Min 12.7 Max 34.93 Avg 19.81
Briardean Road to Hunt Club Road	1111	1.73	Min 31.8 Max 269.9 Avg 93.18	Min 30.48 Max 206.4 Avg 76.83	Min 11.43 Max 79.38 Avg 29.85
Hunt Club Road to Speed River	652	1.14	Min 41.91 Max 91.66 Avg 62.48	Min 38.1 Max 57.15 Avg 47.05	Min 15.24 Max 22.87 Avg 20.00
West Creek (Entire Creek)	**1678**	**1.16**			
Toyota Plant to Royal Oak Drive	1020	1.17	Min 42.9 Max 76.0 Avg 61.7	Min 62.01 Max 73.91 Avg 66.4	Min 12.46 Max 29.61 Avg 18.49
Royal Oak Drive to Riverside Park	467	1.24	Min 33.7 Max 61.2 Avg 47.5	Min 51.21 Max 72.01 Avg 61.97	Min 6.09 Max 21.46 Avg 11.84
Riverside Park	191	1.00	No Real Meanders	No Real Meanders	No Real Meanders

Not True SI*: Middle Creek from the headwaters to Maple Grove Road is highly diverted and altered to accommodate drainage of former agricultural lands. While the SI indicates a departure from a straight line of a factor of 1.34, in fact this reach is virtually straight with the 'valley' in which it flows, so technically the sinuosity would be on the order of 1.0 under bankfull stage.

Note that there are sections of Middle and West Creeks where no real meanders are evident. While there may be thalweg meandering in these reaches under base flow conditions, it is difficult to assess the significance of this flow meandering in the context of channel morphological change until there is a corresponding change in channel planform. It should be noted that there are localized sections in these straight reaches where lateral movement is beginning to occur, however the scale of meandering is not large enough to make conclusive statements about morphological change.

Results indicate there are some rather large and actively migrating meanders on these creek systems (for example on Middle Creek downstream of Briardean Road and on East Creek upstream of Maple Grove Road). Meander wavelengths vary considerably within the same creek (example Middle Creek: min = 12.7m; max = 120.65m), this indicates that the creeks are in a state of disequilibrium and are attempting to stabilize. While it is expected that there would be a range of values for this parameter, the wide range found on such small systems is out of the expected pattern and an indicator of potential instability.

There appear to be no drastic meanders that are at risk of becoming cutoffs at the present time.

B 4.3.3 Flow Assessment and Channel Dimensions

B 4.3.3.1 Individual Reach Assessments

Tables B 4.3.3 through **B 4.3.10** summarize channel dimensions at bankfull stage for each of the cross-sections at each reach on East, Middle and West Creeks. These dimensions relate to the maximum capacity of the channel form before flow spills onto the floodplain adjacent to the cross-section. Bankfull discharge was determined by analysis of the stage/ discharge relationship for the cross-section based on field survey and hydraulic parameters. An example summary of stage/discharge and channel dimensions are found in **Appendix F2**. As there are 80 cross sections that have been analyzed, the summary sheets have been provided to the GRCA in digital format.

Table B 4.3.3 Channel Dimensions, East Creek Reach 1

Site	Local Slope	Bankfull Discharge (m^3 sec^{-1})	Bankfull Width (m)	Bankfull Flow Area (m^2)	Bankfull Wetted Perimeter (m)	Bankfull Depth (m)	Bankfull Velocity (m sec^{-1})
Riffle1	0.025	0.67	3.72	0.55	3.91	0.32	1.22
Riffle2	0.025	2.81	4.64	1.43	5.01	0.55	1.96
Riffle3	0.025	5.03	4.75	2.06	5.17	0.66	2.44
Riffle4	0.025	8.09	4.95	2.79	5.41	0.92	2.90
Riffle5	0.025	12.80	5.31	3.95	6.48	0.98	3.24
Pool 1	0.025	1.54	3.05	0.84	3.25	0.48	1.83
Pool 2	0.025	2.27	4.18	1.23	4.75	0.56	1.84
Pool 3	0.025	5.62	4.32	2.13	4.76	0.78	2.64
Pool 4	0.025	2.92	4.19	1.40	4.49	0.65	2.08
Pool 5	0.025	5.97	4.37	2.21	4.47	0.75	2.70

Bankfull capacity ranges from 0.55 to 3.95m^2 in East Creek Reach 1, giving a difference in bankfull discharge of between 0.67 and 12.80 m^3 sec^{-1}. This is a significant range differential for any creek, and can be explained by the fact that this reach has been significantly altered by both human and natural process activities in tandem. The lack of riparian vegetation in this section has allowed the creek to adjust to higher flows at selected locations, as there is no buffer from stream energy that might decrease erosion potential in this section. The pools tend to be somewhat more consistent than the riffles in cross-section; this is an expected result, as riffles tend to be more dynamic and undergo change more readily.

Table B 4.3.4 Channel Dimensions, East Creek Reach 2

Site	Local Slope	Bankfull Discharge ($m^3\ sec^{-1}$)	Bankfull Width (m)	Bankfull Flow Area (m^2)	Bankfull Wetted Perimeter (m)	Bankfull Depth (m)	Bankfull Velocity ($m\ sec^{-1}$)
Riffle1	0.020	0.64	1.92	0.48	2.45	0.54	1.36
Riffle2	0.020	0.69	3.14	0.57	3.42	0.46	1.22
Riffle3	0.020	1.41	3.01	0.87	3.42	0.48	1.62
Riffle4	0.020	0.55	2.26	0.44	2.54	0.33	1.26
Riffle5	0.020	0.44	2.88	0.42	3.28	0.33	1.03
Pool 1	0.020	1.01	2.28	0.63	2.56	0.50	1.59
Pool 2	0.020	1.75	2.08	0.90	2.73	0.55	1.93
Pool 3	0.020	1.30	2.18	0.75	2.67	0.54	1.73
Pool 4	0.020	0.38	1.27	0.28	1.51	0.30	1.33
Pool 5	0.020	0.44	2.88	0.42	3.28	0.33	1.03

Bankfull capacity ranges less in East Creek Reach 2, which is in the transitional area between the upper and lower plateaus. The presence of a buffer in this area is helping to control the variability in area for both the pools and riffles and is a clear indication of the importance of establishing a vegetated riparian buffer in East Creek Reach 1.

Table B 4.3.5 Channel Dimensions, Middle Creek Reach 1

Site	Local Slope	Bankfull Discharge ($m^3\ sec^{-1}$)	Bankfull Width (m)	Bankfull Flow Area (m^2)	Bankfull Wetted Perimeter (m)	Bankfull Depth (m)	Bankfull Velocity ($m\ sec^{-1}$)
Riffle1	0.007	0.49	4.19	0.70	4.45	0.37	0.70
Riffle2	0.007	0.21	1.55	0.29	1.77	0.33	0.72
Riffle3	0.007	0.58	3.82	0.74	3.95	0.38	0.78
Riffle4	0.007	1.20	7.83	1.53	8.13	0.36	0.79
Riffle5	0.007	0.40	3.93	0.60	4.00	0.28	0.67
Pool 1	0.007	0.81	3.61	0.89	3.85	0.44	0.90
Pool 2	0.007	0.33	2.12	0.43	2.38	0.35	0.77
Pool 3	0.007	0.21	1.48	0.29	1.70	0.28	0.74
Pool 4	0.007	0.71	3.87	0.85	4.13	0.35	0.83
Pool 5	0.007	0.70	6.47	1.03	6.76	0.31	0.68

Channel dimensions in Middle Creek Reach 1 indicate the stability of the upstream reaches and the impact of the presence of the wetland area downstream of Hunt Club Road on channel process. The relative consistency of bankfull dimensions, and the lower overall bankfull velocities reflect buffering in both the upstream channel area (through increased vegetation in the channel itself) and in the riparian area alongside the channel. Bankfull discharges are lower than in the upstream reach (Reach 2 below); this indicates that there may be some groundwater recharge in the area as well as indicating the presence of low banks and a flatter floodplain area. In addition to this, the presence of the on-line pond downstream of Reach 2 may act to capture some stream energy, which could decrease channel dimensions to a degree.

Table B 4.3.6 Channel Dimensions, Middle Creek Reach 2

Site	Local Slope	Bankfull Discharge (m^3 sec^{-1})	Bankfull Width (m)	Bankfull Flow Area (m^2)	Bankfull Wetted Perimeter (m)	Bankfull Depth (m)	Bankfull Velocity (m sec^{-1})
Riffle1	0.015	2.37	4.90	1.51	5.04	0.44	1.57
Riffle2	0.015	1.76	4.90	1.27	5.08	0.34	1.39
Riffle3	0.015	1.98	7.68	1.63	7.93	0.34	1.22
Riffle4	0.015	2.44	6.28	1.70	6.47	0.41	1.43
Riffle5	0.015	1.84	4.93	1.30	5.07	0.40	1.41
Pool 1	0.015	2.13	5.83	1.51	5.95	0.36	1.41
Pool 2	0.015	3.30	5.64	1.96	5.86	0.54	1.68
Pool 3	0.015	3.73	9.36	2.55	9.45	0.46	1.46
Pool 4	0.015	2.71	7.19	1.91	7.40	0.55	1.42
Pool 5	0.015	2.79	4.91	1.68	5.16	0.45	1.66

Middle Creek Reach 2 is in the transitional area upstream of the main on-line pond on Middle Creek. Because of this, there tends to be a healthier riparian area and this reflects again on the rather consistent channel dimensions in terms of bankfull area and discharge. Depths are slightly higher at bankfull stage in this reach, indicating some tendency toward incision, however there is no direct evidence of an entrenched channel in the more naturalized areas.

Table B 4.3.7 Channel Dimensions, Middle Creek Reach 3

Site	Local Slope	Bankfull Discharge (m^3 sec^{-1})	Bankfull Width (m)	Bankfull Flow Area (m^2)	Bankfull Wetted Perimeter (m)	Bankfull Depth (m)	Bankfull Velocity (m sec^{-1})
Riffle1	0.006	1.08	2.66	1.02	3.12	0.61	1.05
Riffle2	0.006	0.85	2.72	0.89	3.12	0.40	0.96
Riffle3	0.006	0.87	3.86	1.00	4.05	0.47	0.87
Riffle4	0.006	0.78	3.96	0.94	4.11	0.42	0.83
Riffle5	0.006	0.54	2.81	0.66	2.98	0.38	0.81
Pool 1	0.006	1.31	3.79	1.27	4.03	0.56	1.03
Pool 2	0.006	1.02	2.33	0.96	2.86	0.52	1.07
Pool 3	0.006	1.22	4.38	1.29	4.62	0.57	0.95
Pool 4	0.006	0.95	2.77	0.95	3.14	0.50	1.00
Pool 5	0.006	0.75	3.14	0.86	3.49	0.46	0.87

Middle Creek Reach 3 is located upstream of Briardean Road and is immediately upstream of the transitional area for Middle Creek. Bankfull flow areas appear rather low considering upstream contributing area; however this may be related to the presence of sod farm operations in the upstream area. The low-lying areas around sod farms disperse higher flows over a wide range of area and can contribute to greater infiltration and/or evaporation during hotter periods, limiting the amount of flow that makes its way back to the channel and contributes to channel formation.

While not a detailed study reach, the channelized sections of Middle Creek upstream of Maple Grove Road are actually oversized for the capacity of the drainage area and are suffering from channel evolution processes, which include bank slumping and channel constriction as the cross-section adjusts to actual flow rates.

Table B 4.3.8 Channel Dimensions, West Creek Reach 1							
Site	**Local Slope**	**Bankfull Discharge (m^3 sec^{-1})**	**Bankfull Width (m)**	**Bankfull Flow Area (m^2)**	**Bankfull Wetted Perimeter (m)**	**Bankfull Depth (m)**	**Bankfull Velocity (m sec^{-1})**
Riffle1	0.010	0.35	2.02	0.38	2.16	0.33	0.90
Riffle2	0.010	0.89	1.68	0.68	2.19	0.56	1.31
Riffle3	0.010	0.38	2.42	0.44	2.55	0.29	0.88
Riffle4	0.010	1.11	2.54	0.88	3.00	0.61	1.26
Riffle5	0.010	1.15	3.87	1.03	4.21	0.66	1.12
Pool 1	0.010	1.75	2.49	1.17	3.07	0.79	1.50
Pool 2	0.010	0.92	2.49	0.76	2.79	0.58	1.20
Pool 3	0.010	1.95	2.88	1.30	3.38	0.81	1.51
Pool 4	0.010	0.95	2.44	0.77	2.73	0.50	1.23
Pool 5	0.010	0.97	1.94	0.75	2.46	0.58	1.29

West Creek Reach 1 is within Riverside Park and has been channelized in the past, therefore one would expect to find rather consistent dimensions and bankfull discharges throughout the reach. For the most part this is found in the results, however Riffle 1 and 3 are decreasing in area with respect to the other cross-sections, indicating these riffles are adjusting to the low flow volumes found relative to the constructed channel dimensions.

Table B 4.3.9 Channel Dimensions, West Creek Reach 2							
Site	**Local Slope**	**Bankfull Discharge (m^3 sec^{-1})**	**Bankfull Width (m)**	**Bankfull Flow Area (m^2)**	**Bankfull Wetted Perimeter (m)**	**Bankfull Depth (m)**	**Bankfull Velocity (m sec^{-1})**
Riffle1	0.030	1.26	4.63	0.82	4.78	0.27	1.53
Riffle2	0.030	1.17	3.95	0.74	4.10	0.27	1.58
Riffle3	0.030	0.74	3.88	0.55	3.93	0.21	1.34
Riffle4	0.030	1.02	4.21	0.69	4.28	0.27	1.47
Riffle5	0.030	0.79	4.55	0.62	4.67	0.23	1.28
Pool 1	0.030	1.70	5.12	1.03	5.30	0.30	1.66
Pool 2	0.030	0.54	4.29	0.48	4.42	0.20	1.13
Pool 3	0.030	1.10	3.35	0.67	3.55	0.27	1.63
Pool 4	0.030	1.94	4.29	1.03	4.39	0.37	1.88
Pool 5	0.030	1.77	4.73	1.01	4.82	0.33	1.75

West Creek Reach 2, downstream of the online pond at Royal Oak Drive, is a more transitional area which has a better riparian buffer than the downstream reach (Reach 1). Therefore, we see less consistency in channel dimensions between pools and riffles, though there is rather clear consistency within pools and within riffles in this reach. Bankfull discharges tend to be higher than in the downstream reach, which is indicative of an overriding or controlling factor to channel process in this area.

Table B 4.3.10 Channel Dimensions, West Creek Reach 3							
Site	Local Slope	Bankfull Discharge (m^3 sec^{-1})	Bankfull Width (m)	Bankfull Flow Area (m^2)	Bankfull Wetted Perimeter (m)	Bankfull Depth (m)	Bankfull Velocity (m sec^{-1})
Riffle1	0.120	0.28	2.92	0.37	3.16	0.26	0.75
Riffle2	0.120	0.31	1.26	0.30	1.54	0.33	1.05
Riffle3	0.120	1.30	4.15	1.07	4.44	0.60	1.21
Riffle4	0.120	1.08	3.49	0.90	3.81	0.59	1.20
Riffle5	0.120	1.47	4.95	1.23	5.19	0.53	1.20
Pool 1	0.120	0.62	1.66	0.50	2.00	0.41	1.24
Pool 2	0.120	0.75	1.87	0.58	2.17	0.46	1.29
Pool 3	0.120	0.46	1.79	0.42	2.05	0.41	1.09
Pool 4	0.120	0.62	3.04	0.61	3.22	0.36	1.03
Pool 5	0.120	0.58	1.96	0.50	2.25	0.44	1.15

West Creek Reach 3 is in the upper area behind ATS, in a rather well vegetated and relatively undisturbed section of creek. Again there is natural variability in channel dimensions, though the pools are very consistent in area. The somewhat greater variability in dimensions in the riffle areas indicates the channel may be adjusting to a loss of upstream drainage area (caused by the creation of the Toyota Plant, which overlies some of the historical drainage area of West Creek). This adjustment would take the place of channel dimensions decreasing in a natural channel evolution model scenario; there is some indication of this occurring upstream of the reach and this will likely continue in the downstream direction.

B 4.3.3.2 Assessment Summary

The range of discharges found throughout this system are consistent with similar systems of equal size, drainage area and physiography. The period of highest discharge recorded during site visits occurred in May, the period of lowest discharge occurred in the summer and early fall.

The manner in which creeks respond to inputs from precipitation will have a direct impact on the stability of the channel. If a high-energy, short-duration rainstorm were to pass through a basin, the creeks may respond with a rapid rate of change of discharge (usually associated with urban areas or under extremely wet or dry conditions) or may respond with a lower rate of change of discharge (usually under conditions of high infiltration capacity of the soil). A rapid rate of change will more likely result in greater instability by nature of the forces involved on the bed, banks and in the water itself. As much as the amount of change in discharge caused by precipitation is important, from both a geomorphological and biological perspective it is the rate of change (which is indicated by basin conditions) that is of greater importance. Geomorphologically, slow rates of increase in fluid speed (as associated with increases in discharge) have a lesser effect on bed instability than faster rates of change. In fact, a slow rate of change may selectively remove some of the finer particles on the bed, allowing the larger particles to flip or rotate in such a manner as to armour the bed, enhancing stability for a period of time. Faster rates of change could have the effect of removing the entire contents of the bed, replacing it with material from upstream.

B 4.3.4 Sediment Analysis

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

Representative bank material, bed pavement and subpavement samples were collected at numerous locations for each reach. Each sample was analyzed using standard grain size methodologies (either sieving or pebble-count) according to size of the materials. Results are shown in **Table B 4.3.11** while grain size sheets are found in **Appendix F2.** Total suspended solids samples were collected at two intervals, a low flow stage in December 2001 and a higher flow stage in March 2002.

Table B 4.3.11 Sediment Analysis Results

Site	Bed Pavement D_{50} (mm)	Bed Subpavement D_{50} (mm)	Bank Material D_{50} (mm)	TSS Low Flow (mg L^{-1})	TSS High Flow (mg L^{-1})
ECR1	27.5	2.35	0.29	0.02	17.95
ECR2	59.7	4.98	1.00	0.08	15.23
MCR1	37.0	Bedrock	0.20	1.02	37.22
MCR2	64.0	2.95	0.29	0.92	26.01
MCR3	21.0	2.59	0.27	0.47	18.88
WCR1	23.3	0.26	0.17	2.35	23.34
WCR2	23.3	8.65	0.36	1.62	16.92
WCR3	30.0	0.35	0.22	0.96	28.45

Note: TSS Low Flow samples collected December 2001, High Flow samples collected March, 2002

Results indicate that these creeks have gravels and cobbles overlying finer sands and silt/clays in the sub-pavement area. The fact that there is a combination of larger and smaller particles is indicative of proper stream function, in that the larger particles, which are not imbricated in an armouring manner, and the smaller particles are in transport over a range of flows (see results of shear stress analysis in Section B 4.3.5).

In general, the results indicate a diversity of substrate materials, which is a positive situation overall for aquatic habitat. An overly large substrate would be indicative of excessive flow energy, which would selectively transport out the smaller gravels/sands/silts, leaving an armoured bed and putting the banks at risk. This condition was not observed to any great extent on East, Middle or West Creeks. Conversely, too fine a bed indicates flow interruption and sedimentation, which is not an optimal situation either. Localized reaches of fine, homogenous bed material were observed on Reach 3 of Middle Creek and Reaches 1 and 3 of West Creek, suggesting that flow in these reaches is not sufficiently competent to transport the sediment load delivered from upstream. This may indicate either an increase in sediment supply associated with construction and agricultural practices, or a decrease in baseflow from reduced infiltration in highly impervious, developed areas. In the case of West Creek, another probable cause is the diversion of a significant portion of the upstream drainage area during the development of the Toyota facility, which has decreased the magnitude of stream flows under all conditions. No significant evidence of fine sediment accumulation was observed at the other study reaches. In these areas, higher channel gradient is maintaining sufficient flow competence to prevent excessive deposition.

B 4.3.5 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, the weight of the water and the slope of the channel. Also included in the equation is the specific weight of water itself at certain temperatures. **Table B 4.3.12** shows the results of this investigation.

Table B 4.3.12 Shear Stress Assessment

Site	D_{50} mm	τ_{cr} D_{50}	Stream Power	τ_o	τ_o/τ_{cr} D_{50}	U_c D_{50}	Erosion Potential (N M sec^{-1})	Critical Discharge (m^3 sec^{-1})
ECR1P1	37.0	26.95	376.88	117.47	**4.36**	1.04	7.98	0.03
ECR1P5	18.0	13.11	1461.01	183.54	**13.99**	0.75	37.80	0.08
ECR2R2	56.0	40.79	135.09	90.06	**2.21**	1.26	2.69	0.11
ECR3R5	18.0	13.11	86.14	64.61	**4.93**	0.75	5.08	0.02
ECR2P5	105.0	76.48	86.14	64.61	0.85	1.68	0.87	0.72
MCR1R5	37.0	26.95	27.41	19.19	0.71	1.04	0.48	1.03
MCR2R3	49.0	36.59	290.73	49.92	**1.39**	1.18	1.71	0.99
MCR2R5	23.0	16.75	270.18	58.73	**3.51**	0.84	0.84	0.18
MCR2P5	120.0	87.41	409.67	66.06	0.76	1.79	1.25	4.42
MCR3R3	21.0	15.30	51.10	27.60	**1.81**	0.80	1.57	0.29
WCR2R2	33.0	24.04	343.59	79.29	**3.30**	0.99	5.21	0.07
WCR2R5	45.0	32.78	231.99	67.54	**2.06**	1.14	2.64	0.09
WCR2P3	30.0	21.85	323.04	79.29	**3.63**	0.94	5.91	0.03
WCR2P5	21.0	15.30	519.79	96.91	**6.34**	0.80	11.09	0.02
WCR3R1	30.0	21.85	32.89	30.54	**1.35**	0.94	1.05	0.14

Note: Assessment of existing bed materials based on flow geometries at bankfull stage. **D_{50}** represents median grain size of the pavement material; **τ_{cr} D_{50}** represents the critical shear stress required for initiation of movement for the 50th percentile size particle; **τ_o** represents the boundary shear stress acting on the particles under bankfull stage; **τ_o/τ_{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 50th percentile; and **U_c D_{50}** represents the critical velocity in metres per second required to initiate transport for the 50th percentile fraction; erosion potential is an indicator of the relationship between critical/boundary shear stress and bankfull velocity; and critical discharge is the discharge under which the D_{50} fraction is set in motion with respect to boundary shear stress under that flow condition. Critical discharge comprises part of the flow exceedence exercise in the Hydrology section of this report.

Results indicate that under bankfull flow conditions, the median particle size of the pavement material (and subsequently the entirety of the subpavement materials) should be in motion for all reaches except ECR2P5, MCR1R5, and MCR2P5.

For the most part, erosion potential is quite low, with the exception of ECR1P5, which has a high stream power (indicative of high discharge) and a low D_{50} value. Note that in two instances the median grain size is so large that greater than bankfull discharges are required to set the particles in motion (ECR2P5, MCR2P5).

The results indicate that erosion is a potential issue on all three creeks, although not at all locations. While natural processes of erosion are expected, care should be taken to limit changes in land use that would increase instability in these creeks without mitigating that instability. Additional information on shear stress is provided in **Appendix F3**.

B 4.3.6 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 selected cross-sections and at control points along the three creek systems to monitor bank retreat over the course of the study. **Table B 4.3.13** shows the results of erosion pin monitoring

There are two areas of potential concern regarding erosion potential. First, as flow rises to accompany flood passage through a reach, there is an increase in flow velocity and a corresponding increase in shear stress on the bed. The result is a scouring of the bed as the flood wave passes through the reach. Once flows start to recede, decreased flow competence allows for the settling out of transported material from upstream onto that recently scoured bed, filling in the scoured area. The decreasing volume of flow passing through as a flood wave recedes decreases the shear stress on the bed, and less scour results. However, finer material that is in transport from upstream continues to move through the reach until flow competence decreases, and sedimentation of the finer material occurs over the coarser material that should have been moved by the wave. This causes sedimentation of the bed. While this sequence of events occurs naturally in streams, there is a requirement of bankfull flows which have the ability to remove both the accumulated fine sediment and the coarser material below, starting the sequence all over again. Removal of bankfull flows then results in decreased erosion potential of the beds and may result in sedimentation.

Secondly, decreased flow volumes can enhance erosion of banks. In areas where undercut banks exist, continual cutting by a new flow surface level has been shown to increase the potential of that bank to be cut, delivering relatively large amounts of sediment to the channel at highly localized regions. Additionally, lack of overbank flows contributes to bank dewatering and the reversal of hydropotential gradients, effectively drying out the bank and making it more susceptible to erosion by weaker than expected flows.

The movement of sediment, as suspended load, solution load, or bedload, through a drainage system is of fundamental importance in environmental management. Firstly, sediment movement influences the character of the channel network and changes can alter the nature and the loci of erosion and deposition, and channel geometry. Such changes may affect channel navigability, flooding, property boundaries, and the stability of bridges, embankments, and other engineering structures. Secondly, the turbidity of flows influences water quality and any increase in sediment concentration may damage fish and other biota in the system and the quality of water used for domestic and industrial purposes.

Removal of large portions of overbank flow decreases the deposition of sediment on the floodplain, thereby increasing the concentration of sediment in transport within the channel. Since the transport of sediment is a random and discrete process, sediment in transport will be deposited at some location in the channel, and this sedimentation can result in some of the difficulties noted above. Therefore, it is important that overbank flows are allowed to exist, and that increased flows over the course of a year are allowed to move sediment that has accumulated.

Bank erosion is important to the natural functioning of streams. Eroding banks deliver sediment to the channel, which is then transported downstream, a process that assists the stream in lessening the impact of flowing water. If there is no bank delivery of sediment, the energy of the flowing water then is directed at the bed, and downward scour is the result. This is not a favorable situation from a fluvial geomorphological or aquatic habitat perspective. Therefore, it is beneficial to have some bank erosion along a stream corridor.

At each site, erosion pins were located in each bank to determine rates of bank retreat due to natural bank collapse. Each pin was introduced and measured as to its protruding length, at each subsequent visit the pins were again measured and the amount of retreat recorded. Attempts were also made to use sedimentation chains at various locations, with little success. The results that follow indicate how much retreat has occurred; however it should be noted that there were few rain events over the study period, and the creeks have been noted as dropping in volume over the study period. It is recommended that further erosion monitoring be conducted as part of a follow-up study.

Table B 4.3.13 Erosion Pin Monitoring Results

Site	Left Bank (cm)	Right Bank (cm)	Avg. Torvane (kg/cm^2)
EC 1			
Ri 1	+2.5	NC	0.90
P 3		-0.7	0.85
Ri 5		-2.7	0.35
EC 2			
Ri 2	-2.0	-4.2	0.55
P 3	-3.8		0.18
Ri 4	-1.2		0.33
MC 1			
P1	-3.0	-0.9	0.25
P2	-1.9	-4.8	0.16
Ri2	-1.0	-1.5	0.22
MC 2			
P 1	-0.1	-0.5	0.22
Ri 5	-0.7	-1.0	0.10
P 4	-1.6	-1.8	0.18
MC 3			
Ri 1	-1.3	-0.4	0.15
Ri 4	-1.5	-1.2	0.15
P 4	-1.3	-0.1	0.35
EC 1			
Ri 2	-1.3	-3.0	0.46
P 3	-0.5	-0.4	0.58
Ri 5	-2.1	-1.1	0.38
EC 2			
Ri 2	-0.8		0.13
P 3	-4.5		0.98
P 5		Disturbed	0.82
EC 3			
Ri 2	-3.3	-0.8	0.35
P 2	-0.5	-4.3	0.22
P 3	-0.7	-2.9	0.29

In addition to erosion pin monitoring, the creek systems were assessed using a Rapid Reach Assessment Form (RRAF), which was initially developed in the US and modified for use in Southern Ontario (see **Appendix F2** for a sample form and reference).

The rapid reach assessment for erosion sensitivity was undertaken to identify reaches of each subwatershed which may be at risk for erosion if changes in land use patterns or flow characteristics were to occur in the candidate watershed. The assessment form is a visual assessment which characterizes instream substrate, morphological diversity and flow conditions, channel stability at base flow, bank stability and riparian vegetation zone width; and scores them as either poor, marginal, suboptimal or optimal according to guidelines on the form. A total score out of 20 is determined for each category, and a sum out of 100 determines the overall sensitivity to erosion. The following table summarizes the data collected during this assessment and highlights sites that are at risk.

Table B 4.3.14 shows the results of the RRAF. Results indicate that the majority of reaches are at risk of instability under current conditions. Clearly the three stream systems are in a state of flux with existing conditions and while this may be exacerbated if land use practices change, there are management strategies that can be utilized to assist with maintaining stability.

Table B 4.3.14 Rapid Reach Assessment Results for Each Station, Used as an Indicator of Potential Instability

Site	Instream Substrate Characterization	Morphological Diversity of Flows	Channel Stability (Base Level)	Bank Stability	Riparian Vegetative Zone Width	Total Score (100)	Erosion Risk Sensitivity Category
East Creek							
Headwaters to Maple Grove Road	5	5	20	18	16	64	**Mod Med**
Maple Grove Road to Beaverdale Road	11	9	5	8	17	50	**Mod High**
Beaverdale Road to Speed River	11	14	10	6	0	41	**High**
Middle Ck							
Headwaters to Maple Grove Road	5	5	20	12	7	49	High
Maple Grove Road to Briardean Road	14	12	7	10	10	53	**Mod High**
Briardean Road to Hunt Club Road	16	14	12	10	15	68	**Mod Med**
Hunt Club Road to Speed River	12	9	12	14	18	65	**Mod Med**
West Creek							
Toyota Plant to Royal Oak Drive	12	9	6	9	17	53	**Mod High**
Royal Oak Drive to Riverside Park	10	10	8	10	10	48	**High**
Riverside Park	14	12	16	18	5	65	**Mod Med**

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 4.3.7 Impact Assessment

Combining all information gathered on the East, Middle and West Creek systems, it is possible to determine an overall Impact Sensitivity to changes in land use practices for these systems. Figure B 4.3.2 is a depiction of the reaches which are sensitive to any change in land use (high sensitivity), to a moderate change in land use (medium sensitivity), and reaches which are relatively stable for one reason or another (low sensitivity).

Impact sensitivity is a combination of a number of factors, including flow assessments, sediment assessments, erosion pin and rapid reach assessments, and existing land use conditions. While the degree of sensitivity is simplified to low, medium and high, there are reaches that are more sensitive to change than others in each category. It is proposed that any changes to land use for any of the Hespeler West subwatersheds be precluded by a detailed geomorphological assessment of the impacts of the proposed land use change in any of the high or medium sensitivity areas, and a cursory assessment of the impacts of proposed changes be conducted in areas of low sensitivity.

While this assessment may be negative of the systems as a whole, there are some reaches that are excellent examples of proper fluvial process at work and deserve preservation. From the perspective of river channel adjustment to human activities, the Hespeler West subwatersheds as a whole are a classic example of what happens to streams when individual projects create cumulative impacts.

The study reaches chosen for the fluvial analysis were required to be located in areas where the creeks were functioning at a good to marginal level. The rationale for this stems from the need to assess the entire systems as a whole: if one can gain understanding of the properly functioning components of the system it becomes a comparative analysis to determine the overall health of each creek system. That becomes the rational method for fluvial analysis when time and financial constraints prevent full-scale channel assessment.

Based on this approach, then, it is clear that overall, these creeks are on the edge. The segments of the creeks which are properly functioning comprise only a small percentage of the overall stream length for each creek. The degree of existing alteration coupled with the increased development in the area is at risk of putting these three creeks into a rapid state of decline if no management strategies are put in place in the near future. Once these creeks start to degrade further they will be at the point of no return, and they would require significant capital expenditure to return to even the existing condition found at this time. It is recommended that these creeks receive immediate attention if they are at all going to retain, and possible regain, some of their past, functioning condition.

B 4.4 Summary of Fluvial Geomorphology Issues

The data presented above indicate that the Hespeler West subwatersheds, (East, Middle and West Creeks) are in a state of flux with respect to fluvial functioning and are in no means stable and resilient to long-term changes in land use activities.

East Creek displays classic symptoms of being a flashy system, with areas of high to moderate instability downstream of Maple Grove Road, with the exception of channelized ditches along Beaverdale Road. A lack of riparian buffer in the lower reaches coupled with the impacts of transportation infrastructure leave a creek with little fluvial stability, this is an area for attention. Upstream, the creek appears to be relatively stable and should be protected from future development in the basin.

Middle Creek is in a high state of flux. With the exception of channelized reaches at Maple Grove Road and below the pond upstream of Hunt Club Road, and the stable section near the junction with the Speed River, Middle Creek is in poor shape. Unless mitigation measures are undertaken to rehabilitate the creek, it will continue to degrade to the point where the existing stable, properly functioning reaches will be virtually useless. It may de difficult to rehabilitate the entire creek, but clearly measures must be taken to prevent further damage. This will be no easy task and is not to be taken lightly.

West Creek will continue to adjust to having its contributing area decreased significantly. The reaches below the Toyota plant will continue in a channel evolution mode to decrease capacity over time, effectively maintaining a period of high instability for many years to come. While the creek has achieved a state of quasi-equilibrium downstream of the pond at Royal Oak road, being in the transitional area instability remains the norm. Even the reach downstream of Highway 401 in Riverside Park will adjust over time to become in equilibrium with contributing area.

While this assessment may paint a negative picture of the systems as a whole, there are some reaches that are spectacular examples of proper fluvial process at work and deserve preservation. From the perspective of river channel adjustment to human activities, the Hespeler West subwatersheds as a whole are a classic example of what happens to streams when individual projects create cumulative impacts.

Overall, these creeks are on the edge. The degree of existing alteration coupled with the increased development in the area is at risk of putting these three creeks into a rapid state of decline if no management strategies are put in place in the near future. Once these creeks start to degrade further they will be at the point of no return, and they would require significant capital outlay to return to even the existing condition found at this time. It is recommended that these creeks receive immediate attention if they are at all going to retain, and possibly regain, some of their natural form and functions.

B 5.0 SURFACEWATER QUALITY

B 5.1 Background

This section of the report will provide an overview of the existing surfacewater quality of Hespeler West subwatersheds. The following information is included:

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

Currently, this study represents the only source of information on surfacewater quality for Hespeler West subwatersheds. 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 Hespeler West; (b) perform several spot measurements of temperature and dissolved oxygen and (c) define a set of water quality parameters to be monitored in the future. As such, several samples were collected at various watercourses. The samples were collected in November 2001 and May 2002.

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 in the watershed. Water pollution is the unfavourable alteration of water caused by human actions which renders the water unpotable and unhealthy for other organisms. Water pollution is 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 people and one or 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 has been implemented since November 2001. The program consisted of the following components:

- Spot measurements of dissolved oxygen and temperature;
- Continuous measurement of temperature;
- Water quality sampling for general chemistry;
- Water quality sampling for baseline information;
- Additional information on the conditions in the study area collected during site visits.

The locations of the monitoring stations with are presented in **Appendix G**. Monitoring protocol for each component of the monitoring program is given as follows:

- ***Spot measurement of dissolved oxygen and temperature:*** Four monitoring stations have been established for this purpose, Hunt Club Road (SW1), Maple Grove Road (SW2), Beaverdale Road (SW3) and culvert under the Highway 401 (SW4). The selected monitoring locations were situated at downstream end of the culverts crossing major roads within the watershed. Several spot measurements of dissolved oxygen and temperature were taken using a portable analytical instrument. The purpose of this measurement was to gather direct information on temperature and dissolved oxygen, as these parameters can be only measured in the field. We note that all DO measurements are spot measurements taken during the day;
- ***Continuous Temperature Monitoring:*** Continuous monitoring of water temperature was also completed at various sites. This included long term monitoring at the flow monitoring

stations and the placement of temperature probes at 4 locations in the study area. The results of this are provided in **Appendix G**;

- ***Water quality sampling for general chemistry***: Two monitoring stations (SW1 and SW2) were used for surfacewater quality sampling. The samples collected on November 30, 2001 were submitted for analysis for total suspended solids. 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 for the purpose of this study. The samples were submitted for a large number of parameters, to allow for baseline characterization of water quality under dry weather conditions. The complete list of chemical parameters sampled in accordance with all applicable analytical standards is provided in **Appendix G**; and
- ***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 information collected on surfacewater quality has been summarized in **Table B 5.4.1**. The purpose of the water quality monitoring program was to acquire baseline information under various conditions and to use that experience to design future monitoring programs. This information will be used to design and implement future monitoring programs. The amount of data collected does not allow for more in-depth conclusions, and only general comments on surfacewater quality have been offered.

With respect to spot stream temperature, readings taken on November 2001 and May 2002 indicate typical values that do not differ significantly from other observations in the Grand River watershed. The only exception is temperature reading at Maple Grove Culvert (SW2), where lower temperature was observed than for the rest of the stations. This could be possibly caused by groundwater discharge, but the number of observations is too low to be conclusive.

With respect to dissolved oxygen, again typical values were observed that would indicate fairly undisturbed natural watercourse, except for the reading on November 30, 2001 at Hwy 401 culvert. There is also a potential that this reading might have been erroneous.

With respect to total suspended solids content, two samples collected at SW1 and SW2 are another indicator of undisturbed watercourses.

With respect to the baseline sampling, samples were collected on June 17, 2002 at Maple Grove Road. There was a constant flow at the collection time, indicating that this sampling was representative.

We note that a single sample can be only used as a reference point for future considerations, and no statistical/trend analysis/conclusions are possible at this time. However, based on our review and a comparison to Ontario Drinking Water Standards (January 2001), we offer the following comments:

a) Recorded (or assumed) values for a number of parameters listed as volatile organics and various pesticides were below detection limits;
b) Very low TSS content, as expected in a relatively undisturbed natural stream;
c) Zero bacteria count;
d) Values for various anions well below recommended values; and

e) Values for metals SLIGHTLY exceeded recommended values for aluminum (0.17 mg/L vs. 0.10 mg/L), iron (0.4 mg/L vs. 0.3 mg/L) and manganese (0.07 mg/L vs. 0.05 mg/L), but this may be simply reflecting the characteristics of mineral deposits through which groundwater is passing - mostly clay for aluminum and other minerals for iron and manganese.

Table B 5.4.1 Surfacewater Quality

Sampling Date	Watercourse	Monitoring Location	Observed Temperature [°C]	Observed Dissolved Oxygen [ppm]	Total Suspended Solids Content [mg/l]
November 30, 2001	Middle Creek	Hunt Club Culvert	6.0	10.1	14.2
November 30, 2001	Middle Creek	Maple Grove Culvert	6.7	2.1	11.8
November 30, 2001	West Creek	Hwy 401 Culvert	6.0	0.9	Not sampled
November 30, 2001	East Creek	Beaverdale Culvert	6.6	9.8	Not sampled
May 02, 2002	Middle Creek	Hunt Club Culvert	10.5	9.6	Not sampled
May 02, 2002	Middle Creek	Maple Grove Culvert	6.2	9.0	Not sampled
May 02, 2002	West Creek	Hwy 401 Culvert	10.5	7.7	Not sampled
May 02, 2002	East Creek	Beaverdale Culvert	10.7	8.8	Not sampled

B 6.0 FISH HABITAT AND COMMUNITY

B 6.1 Introduction

The fisheries resources of the three creeks were investigated by C. Portt and Associates. Fish survey records from an Ontario Department of Planning and Development survey conducted in 1952 were reviewed. Background information was sought from the Guelph office of the Ontario Ministry of Natural Resources and the Grand River Conservation Authority. Existing physical habitat conditions were observed by walking the streams during the spring of 2002 and representative sites for fish collections were made on the basis of those observations. Reaches with similar habitat have been identified on each of the three watercourses. Fish were sampled at representative locations on each stream in June 2002.

B 6.2 Background Review

The results of fish sampling in 1952 by the Department of Planning and Development are presented in **Table B 6.2.1 and** Figure B 6.2.1. Four species, three minnows and brook stickleback were captured from Middle Creek. Two species were captured from East Creek, one at each site. All three locations examined on West Creek were dry.

The Ministry of Natural Resources sampled fish at four locations on Middle Creek and three locations on East Creek in 1994 (**Table B 6.2.2** and Figure B 6.2.1). Five fish species were captured from Site 1 on East Creek, which was near the confluence with the Speed River. Unidentified cyprinids were present at Site 2. No fish were captured at Site 3and Site 4 was dry. Two or three species were present at each of the four sites sampled on Middle Creek, and a total of four species were captured. There is a single MNR record of a fish collection, capturing creek chub and blacknose dace, in West Creek during 1989. The

Table B 6.2.1 Fish Species Captured by Seining by Ontario Department of Planning and Development Staff in 1952

Creek	East Creek		Middle Creek		West Creek		
Station	N1Q1	N1Q2	N1R1	N1R2	N1S1	N1S2	N1S3
Date	Jun. 20, 1952	Aug. 1, 1952	Aug. 1, 1952	Jun. 20, 1952	Jun. 20, 1952	Jun. 20, 1952	Jun. 20, 1952
blacknose dace *Rhinichthys atratulus*		X	X	X			
creek chub *Semotilus atromaculatus*			X	X			
brook stickleback *Culaea inconstans*	X		X	X			
northern redbelly dace *Phoxinus eos*				X			
Comments	will probably go dry		dry to pools		dry	dry	dry

Note: X = species recorded but no quantity.

Grand River Conservation Authority has no additional records of fish sampling on these creeks, nor are they specifically mentioned in the Grand River Fisheries Management Plan (S. Geddes, G.R.C.A., personal communication).

In summary, the background data indicate that East, Middle and West Creeks contain non-game fish species that are common in small streams in the area. Two of the species, northern redbelly dace and central mudminnow, are considered to prefer cool water temperatures, but no coldwater species, such as brook trout (*Salvelinus fontinalis*) or mottled sculpin (*Cottus bairdi*), were captured. The data also indicate that the headwaters of East and West Creeks go dry during the summer.

Table B 6.2.2 Fish Species Captured by Seining by MNR Staff at Various Site in East, Middle and West Creeks

Watercourse Date	East Creek July 22, 1994				Middle Creek July 7, 1994				West Creek Nov. 11, 1989
Site	1	2	3	4	1	2	3	4	1
Central mudminnow *Umbra limi*								1	
White sucker *Catostomus commersoni*	20								
Unidentified minnows *Cyprinidae*		2			1				
Northern redbelly dace	10								
Blacknose dace	5					4	3		X*
Creek chub	5				2	1	10		X*
Brook stickleback	20				1	1		1	
Comments			No catch	dry					

B 6.3 Field Investigations

B 6.3.1 Field Methodology

The watercourses were examined by C. Portt on April 16 and May 15, 16 and 17, 2002. Reaches with similar habitat characteristics were identified and the habitat conditions within these reaches were characterized. Barriers to fish migration were also noted. Photographs were taken of typical locations within the various reaches and of migration barriers. The reach information was used to select representative locations for fish sampling.

Electrofishing was conducted at 13 locations on June 13 and 14, 2002, using a Smith-Root Model XII backpack electrofisher. A 50 metre long reach was sampled at each location. All fish captured were identified in the field (by C. Portt) and released except for a few representative cyprinids which were preserved in 10% formalin and identified in the laboratory according to keys in Scott and Crossman (1973).

The location where flow began on each of the three creeks was determined on September 10, 2002, by C. Portt. As this was following a prolonged drought, the conditions at that time were thought to represent worst case, or nearly so, with respect to base flow.

B 6.3.2 Findings

B 6.3.2.1 Aquatic Habitat

The reaches with similar habitat within each of the streams are identified on Figure B 6.3.1 and the habitat conditions are summarized in **Table B 6.3.1**. Barriers to fish migration and online ponds are identified in Figure B 6.3.2 The reaches which appear to experience perennial flow, based on flow being present on September 10, 2002, are identified in Figure B 6.3.3. The habitat conditions in each stream are discussed briefly below.

Table B 6.3.1 Habitat Characteristics of Reaches Along East, Middle and West Creeks

Reach	Gradient	Channel Form	Substrate	Riparian Vegetation	Barriers
East Creek					
1	low	ditched	sand/detritus	swamp	none
2	low	diffuse through swamp	sand/detritus	swamp	none
3	low	run/riffle	sand/silt	cultivated/meadow	culvert at downstream end
4	moderate	pool/riffle/run	gravel/cobble/sand/silt	woodlot/yards	none
5	moderate	pool/riffle/run	gravel/sand/silt	road allowance	road culvert
6	moderate	pool/riffle/run	gravel/sand/silt	yard	waterfall at downstream end
7	moderate	pool/riffle/run	silt/sand/gravel/rip rap	yard/road allowance	none
Middle Creek					
1	low	ditched	sand/silt	swamp/agricultural/hedge row	none
2	moderate	ditched	sand/silt/rubble	road allowance	none
3	low	ditched	sand/silt	agriculture/wood lot	none
4	moderate	pool/riffle/run	gravel/sand/silt/cobble	wood lot/lawn	small dam
5	moderate	pool/riffle/run/pond	sand/silt	meadow	old control structure at downstream end

Table B 6.3.1 Habitat Characteristics of Reaches Along East, Middle and West Creeks					
Reach	**Gradient**	**Channel Form**	**Substrate**	**Riparian Vegetation**	**Barriers**
6	moderate	pool/riffle/run	gravel/sand/silt/cobble/rip rap	wood lot/wetland	none
7	pond	pond	silt/muck	lawn/berm	dam at outlet
8	high	rip rap channel	rip rap	lawn/meadow/hedge row	none
9	low	run/diffuse	silt/sand	wet meadow	none
10	moderate	pool/riffle/run	gravel/sand/silt	cedar bush	none
West Creek					
1	moderate	pool/riffle/run	silt/sand	cedar bush/wetland	begins at storm sewer outlet
2	moderate	pool/riffle/run	silt/sand	lawn	weir at downstream end
3	high	step pool	gravel/cobble/sand/silt	wooded valley	possible barrier at old berm/roadway
4	moderate	pool/riffle/run	silt/sand/gravel	park/road allowance	none

East Creek

East Creek arises in a swamp north of Mohawk Road. The upper portion (Reach 1) has been ditched. At the downstream end of the ditched portion the watercourse enters a swamp where there was a lot of standing water in mid-May of 2002. The channel is poorly defined, and at times undefined, through the swamp (Reach 2), which ends at Maple Grove Road. Based on the September 10, 2002 observations, permanent flow begins at Maple Grove Road.

Reach 3 extends from Maple Grove Road to an old road or laneway that crosses the stream and valley. The stream is conveyed beneath this road in a corrugated steel pipe and there is a vertical drop at the end that would prevent upstream fish migration. Reaches 1, 2 and 3 all have low gradient and fine-textured substrate.

The stream changes character at Reach 4. Gradient increases and the substrate becomes coarser, with gravel and cobble present in significant amounts for the first time. It was also in Reach 4 that fish were first observed. The channel within Reach 4 has a pool/riffle/run configuration. A portion of Reach 4 borders or passes through rear lawns and some clearing and encroachment has occurred. Reach 5 has been straightened and runs parallel to Beaverdale Road, but has developed a relatively natural form. There is a vertical drop at the downstream end of the Beaverdale Road culvert that is a barrier to fish migration. Reach 6 flows through a lawn east of Beaverdale Road. The upper portion of this reach in particular is quite steep and there is a naturally occurring waterfall approximately 1 metre high at the downstream end of this reach that is the limit of upstream limit of potential migration for fish from the Speed River. Reach 7 flows through an abandoned pond downstream of the waterfall and then along a channel within the Regional Road #24 allowance that was created to eliminate the need for a culvert beneath that road when it was constructed in the early 1990s.

Water temperature data were shown in **Appendix G**. Water temperature reached a maximum of 23.4°C in East Creek at Beaverdale Road during the summer of 2002. and rarely exceeded 20°C. Summer daily maxima were higher where East Creek enters the Speed River, generally by 3 to 5 centigrade degrees. This increase is probably due to solar heating between the two locations. Summer daily minima were similar at the two locations in the early summer and during the latter part of the summer, were lower at the confluence with the Speed than at Beaverdale Road. This is consistent with there being proportionately more groundwater discharge to the lower reaches as the drought progressed.

Middle Creek

Middle Creek arises in a swamp north of Middle Block Road. The headwaters (Reach 1) are ditched through agricultural fields with hedge rows developed along the banks in many areas. The substrate is consistently fine sand and silt and there is very little riffle or pool development. Reach 2 flows in a man-made channel along the south side of Maple Grove Road. The banks have been armoured with rounded field-stone but the substrate in the channel proper is primarily fine-textured silt and sand, except where rip rap has been placed at fire hydrants. Although this reach is man-made, the lower portion (downstream from Speedsville Road) has a deep thalweg bordered by dense beds of watercress.

Reach 3 is another ditched section that runs through agricultural land, with hedgerow development in some places, and then enters a wood lot. The gradient is low and the substrate is fine sand and silt. Reach 4 begins shortly after the stream enters the woodlot. The channel is natural, gradient is higher and the substrate is coarser. At the downstream end of Reach 4, east of Briardean Road, the stream flows through yards and there is an on-line pond maintained by a small weir that is a barrier to upstream fish migration. Reach 5, which may have been ditched at some time, flows through meadow/old field to an old control structure that may have created a pond at one time. There is a vertical drop at this structure, creating a barrier to upstream fish migration. The gradient is quite low through most of Reach 5, but at the upstream end, at its border with Reach 4, there is some bank erosion occurring.

Reach 6 begins at the old control structure mentioned above and flows through a well-defined wooded valley. The stream gradient is higher again here, with gravel and small cobble present in the well-developed natural channel in addition to the finer sand and silt substrates. This reach ends with a short gabion lined section at the entrance to an online pond (Reach 7). The pond emptied over a small dam/weir into a steep gabion-lined section (Reach 8) that ends at Hunt Club Road.

On September 10 there was a steady flow into this pond, but very little visible flow leaving it. It is possible that water exits the pond and flows through the rip rap, so it is not observable, however there was no discernable flow at Hunt Club Road and the stream was completely dry closer to the mouth. It appears that the water in the stream is lost to the ground through this reach. This is consistent with observations in the wetland to the west, where springs were observed to emerge, creating “streams” that flowed through the wetland and then disappeared, apparently recharging into the ground.

Downstream from Hunt Club Road the watercourse enters a large, wet meadow (Reach 9). On May 16, 2002, this meadow also was receiving water from a small channel originating from a pipe just west of the driveway at the end of the road. The channel becomes better defined at the downstream end of Reach 9, and Reach 10 begins where the creek enters a cedar bush. The channel through Reach 10 has a pool/riffle/run configuration and there is a considerable amount of gravel present. One other small tributary was observed entering this channel from the west within Reach 10.

Water temperature was monitored at Maple Grove Road and Hunt Club Road beginning in the fall of 2001, and commenced upstream and downstream of the pond above Hunt Club Road and at the outlet to the Speed River in early July. The data are presented in **Appendix G**. High daily temperature fluctuations at the mouth of Middle Creek heralded the fact that this section of the stream was going dry. Summer maxima and minima were higher downstream from the pond than upstream. The maximum recorded water temperature was 30.9°C degrees at Maple Grove Road, 25.4°C immediately upstream from the pond, and 30.8°C immediately downstream from the pond. The high temperatures at Maple Grove and downstream from the pond are thought to be due to solar heating, as both areas are exposed to the sun. The decrease between Maple Grove Road and the pond is believed to be due to improved shading and the influence of groundwater discharge.

West Creek

The headwaters of West Creek have been extensively modified, and the creek proper now appears to begin at a storm sewer outlet along the east embankment of Boxwood Drive. Reach 1 flows through a wetland (primarily cedar swamp), and is characterized by low gradient and fine substrate. Reach 2 flows through a series of back yards and ends at a small weir/dam immediately upstream from Royal Oak Road. There is some leakage through this structure, but it is probably a complete barrier to upstream fish migration. Reach 3 extends from this structure downstream nearly to Highway 401. It is quite steep, with coarser substrate than is present in most of the rest of the stream, and flows in a wooded valley over most of its length. There is a laneway that crosses the creek and its valley near the upper end of this section and the culvert that passes beneath is may be a barrier to fish migration. Reach 4 is the lower reach of this creek, most of which is a ditched channel running through Riverside Park downstream from Highway 401.

The summer water temperature in West Creek rarely exceeded 20°C and reached a maximum during the summer of 23.1°C.

B 6.3.2.2 Fish Community

The electrofishing results are presented in **Table 6.3.2.2** and the sampling locations are shown in Figure B 6.3.1. A total of 12 fish species were captured at one or more locations. None of the species captured are considered to be at-risk in Ontario. No trout or other coldwater species were captured, although three of the species, northern redbelly dace, brassy minnow and central mudminnow are often considered 'coolwater' species, as they are usually found in stream reaches that are receiving some groundwater discharge. The maximum water temperatures (to July 26) recorded in Middle Creek were 28.2ºC at Hunt Club Road and 30.9ºC at Maple Grove Road, which are well in excess of the thermal tolerance of trout.

In all three streams there are more fish species in the lower reaches than in the upper reaches. This is probably because the lower reaches are readily accessible from the Speed River and the upper reaches of all three tributaries are either intermittent or experience very low flows during most summers. The absence of fish at location E-4 is consistent with intermittent flow, as is the presence of only small brook stickleback, which probably originated from upstream ponds, at M5.

Table B 6.3.2 Fish Captured at Various Locations by Electrofishing on June 13 and 14, 2002.

East Creek					
Station	E-1	E-2	E-3	E-4	
central mudminnow	1			no	
northern redbelly dace		1		catch	
common shiner	2				
bluntnose minnow	3				
fathead minnow		1			
blacknose dace	8	15	11		
creek chub	1	7			
brook stickleback	1	2	1		
Middle Creek					
Station	M-1	M-2	M-3	M-4	M-5
central mudminnow	23	78		2	
white sucker	1			1	
northern redbelly dace				3	
bluntnose minnow	4	17	18		
blacknose dace	9				
creek chub	4			1	
pumpkinseed	5	54	61		
brook stickleback				6	20+
West Creek					
Station	W-1	W-2	W-3		
white sucker	31				
northern redbelly dace	1				
common shiner	9				
bluntnose minnow	1				
blacknose dace	27	7			
creek chub	53		3		
brassy minnow	1				
hornyhead or river chub	1				
brook stickleback	12		1		

B 6.4 Summary of Aquatic Management Considerations

All three creeks begin as low gradient watercourses in their headwaters, which have fine-textured substrates, have been ditched (the uppermost reaches of West Creek have been eliminated) and quite likely experience only intermittent flow. Each creek also has a steeper middle section that probably reflects underlying bedrock topography. East and West Creek have only short low- to moderate-gradient reaches between their steeper section and the Speed River, but Middle Creek flows a considerable distance downstream of the topographic break before entering the Speed. This section of Middle Creek, however, goes dry as the water from the stream apparently is recharged.

There are two culverts that are barriers to upstream fish migration on East Creek, although both are upstream of the natural falls that also prevents upstream migration. Middle Creek has three man-made barriers to fish migration, two weirs and an old control structure. There is one confirmed barrier to fish migration on West Creek, immediately upstream from Royal Oak Drive, and another potential barrier a short distance downstream.

The fish communities consist of warmwater and coolwater non-game species, with more species present in the reaches that are close to, and accessible from, the Speed River. The absence of fish in some of the headwaters and the low numbers in others reflect the fact that these areas are periodically dry.

The absence of coldwater fish species in the study area, and especially in West and East Creeks which have consistently coldwater temperatures in some reaches is somewhat surprising. It may be due to severe conditions, such as high temperatures imposed by weather or other factors during the past.

Aquatic resources are affected by the physical, chemical and biological characteristics of their habitat. In the absence of human influences, climate and geology/physiography would be the key determinants of watershed processes and watercourse characteristics, and, combined with the 'natural' distribution of plants and animals, would determine the biological communities. Of course, human activity has altered many of the watershed processes to a greater or lesser extent. Activities which have led to these modifications include changes to the land surface (land clearing and agricultural or urban development), pumping from wells or discharges of effluents or stormwater and direct alteration of stream channels. Thus today's existing conditions reflect not only the natural characteristics of the watersheds but also by the cumulative impacts of past and present human influences.

The key processes/functions/characteristics of watercourses which influence their biota are base flow, hydrology, channel form, water temperature, water chemistry and riparian vegetation. Base flow is derived from groundwater that discharges to a stream and it is necessary to prevent streams from going dry between precipitation events. Changes in base flow are cumulative in a downstream direction, so that increases or decreases in base flow in one stream or section of stream influences base flow in sections downstream. Thus, base flow in the Hespeler West tributaries contributes to base flow in the Speed River, which contributes to base flow in the Grand River.

Groundwater also plays a role in temperature moderation. In southern Ontario, groundwater is necessary to maintain low enough summer stream temperatures to permit streams to support brook trout and other coldwater species. Furthermore, brook trout spawn exclusively in areas where groundwater discharge occurs. This is presumed to be an adaptation to prevent the developing embryos, which are spawned in the fall, from freezing during their winter incubation. Thus, for several reasons, the maintenance or enhancement of both groundwater recharge and groundwater discharge is very important to streams.

Hydrology is linked to channel form and stability. Generally, natural streams with (dynamically) stable banks and channels support more fish and more fish species than unstable streams. Furthermore, some life stages or activities of many fish and invertebrate species are seasonal, and are linked to hydrologic events, such as the spring freshet. Therefore maintenance of a natural hydrologic regime is generally beneficial.

Natural channels vary in nature with the geology, topography, hydrology and riparian vegetation, but generally consist of repeating series of pools, riffles and runs that each have differing depth, velocity and substrate characteristics. Different habitats support different fish and invertebrate species or, in some cases, different life stages of a single species. Thus maintaining or recreating natural channel form is desirable.

Water chemistry deals primarily with dissolved substances, including dissolved oxygen which is essential for fish life. Decomposing organic matter can reduce dissolved oxygen concentrations in streams and ponds to levels where some fish species cannot survive. Excessive plant growth can also contribute to low night-time dissolved oxygen concentrations when plants are consuming oxygen through respiration but not producing it through photosynthesis, as they do during the day, the solubility of oxygen increases as temperature decreases. Consequently, lower water temperatures are of benefit where dissolved oxygen levels are of concern.

Riparian vegetation serves several functions for stream ecosystems. It provides shade, thereby reducing solar heating. It increases bank stability. It provides cover for fish and other animals and provides food, both in the form of insects that may fall from it into the water and, more importantly, as leaves and debris that falls into the streams and then are consumed by a variety of invertebrate organisms.

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 and rural 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 investigation are to:

- provide a general description of agriculture within the subwatershed study area;
- characterize the urban-agricultural interface;
- identify any existing agricultural issues;
- evaluate how agricultural impacts on subwatershed ecology can be minimized;
- identify possible agricultural Best Management Practices; and
- Identify location of aggregate resources.

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 on the east side is predominantly a cream to buff colored dolomite of the Guelph formation. On the west side, the underlying bedrock has been mapped as Salina Formation and consists of interbedded brown dolomite and gray shale (Karrow, 1971). The bedrock is overlain by overburden that resulted from the action of glaciers. The depth of the overburden varies but in some areas is relatively close to the surface, that is, within one metre of the soil surface. Where bedrock is close to the surface within the subwatershed, soil series such as Brooke and Farmington have been mapped (Presant and Wicklund, 1971).

Part of 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 which have relatively little topographic variation. More specific mapping and descriptions of the bedrock and Pleistocene geology are summarized by Karrow in the report *Soils of Waterloo County* by Presant 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 Presant and Wicklund (1971), approximately 24 different soil series, soil phases or land types have been identified. The characteristics of these soils are summarized in **Table B 7.2.1**. Within the study area, the predominant soils to the north are Lisbon and Brady series. These soil series are well and imperfectly drained respectively, and have sandy loam surface textures. Texture below the soil surface horizon ranges from loamy sand to sandy loam. In the south, an additional soil called Burford is also relatively predominant. This series is well-drained and is coarse with surface textures mapped as a gravelly loam or cobbly sandy loam. The underlying layer, called parent materials, has a gravelly sandy loam texture

B 7.2.2 Soil Capability for Agricultural Production

Most of the land within the subwatershed remaining in agricultural production has been rated for soil capability between Classes 1 and 3 (following the soil map and capability class interpretation published by Presant and Wicklund, 1971). There are some areas that are not prime and are classified in capability classes 4, 5 and 6. Field observations for individual farm fields indicate that soil capability classes tend to follow the published capability ratings.

Table B 7.2.1 Summary of Agricultural Soil Characteristics

Soil Name	Drainage	Surface Texture	Parent Materials/underlying soil or rock	Slope Classes	Capability Class
Brady	Imperfect	Sandy loam	Sandy loam	A,B	2
Brisbane	Imperfect	Sandy loam	Gravelly loamy sand	A	2
Brooke	Poor	Loam or silt loam	Dolomitic limestone	A	6
Burford	Well	Gravelly loam	Gravelly sandy loam	A, B, C, c, D	2, 3, 4
Burford	Well	Cobbly sandy loam	Gravelly sandy loam	b, D	3, 5
Caledon	Well	Sandy loam	Gravelly loamy sand	A, B	2
Camilla	Imperfect	Sandy loam	Gravelly sandy loam	A	2
Conestogo	Imperfect	Silt loam	Loam till	A	1
Farmington	Well	Sandy loam	Dolomitic limestone	A	6
Floradale	Imperfect	silt loam	Loam -- gravelly layers	A, B	1
Fox	Well	Sandy loam	Sand	C	3
Gravel pit	Variable	Not present	Sand and gravel suitable for aggregate	Variable	Not rated
Guelph	Well	Loam	Loam till	A, B, C, D	1, 2, 3, 4
Guelph	Well	Sandy loam	Loam till	A, B	2, 3
Hespeler	Poor	Sandy loam	Gravelly sand	A	4
Hawkesville	Poor	Silt loam	Sandy loam and loam over gravelly sandy loam	A	4
Lisbon	Well	Sandy loam	Loamy sand	A, B, b, C, c, D	2, 3, 4
London	Imperfect	Loam	Loam and sandy loam till	A, B	1, 2
Organic	Very poor	Decomposed organics	Decomposed organics 12 to 36 inches deep	A	0
Organic	Very poor	Decomposed organics	Decomposed organics > 36 inches deep	A	0
Maryhill	Poor	Loam	Loam till	A	2
Preston	Imperfect	Sandy loam	Loamy sand over dolomitic limestone	A	4
St. Jacobs	Well	Silt loam	Very gravelly loamy sand	A, B	1
Woolwich	Well	Silt loam	Loam till	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 7.3 Socio-economic Description

Less than half of the land area within the Hespeler West subwatersheds is in agricultural production with common field crops such as corn, wheat and soybeans predominating. Some fields are used as hay/pasture. Because of the aforementioned variability in the soils and topography, ownership patterns as well as the broad mix of land uses within the study area, farm fields are relatively small and are subdivided by existing woodlots, wetlands and hedgerows (see Section B 8.0).

Two other agricultural land uses are significant within the subwatershed. The first is a crop research area of 270 ha that is called the Cambridge Research Station part of which is located within the subwatershed. The station is operated jointly by the University of Guelph and the Ontario Ministry of Agriculture and Food. The second is a relatively large sod production business located within and around the subwatershed.

B 7.3.1 Planning Designation and Land Use Trends

Currently, the agricultural designation in the City Official Plan extends north of Maple Grove Road and north of Middle Creek. This area has cash crop and mixed farming in addition to a number of sod farm operations and includes the agricultural research station. This is shown as the border between the Agricultural Resource Area and City Urban Area (see Figure A 2.2.1).

The Regional Municipality of Waterloo has taken a proactive approach to growth management and has identified a number of potential growth areas within the Region. One such area is the land between the City's industrial subdivision on the north side of Maple Grove Road, to the City's northern boundary. The City has responded to that initiative by stating the desire to maintain a "Countryside Line" that runs along Middle Block Road and Mohawk Road. The "Countryside Line" is shown on Figure C 2.1.1 and was derived from the report titled, "Response to Planning our Future: A Smart Growth Initiative by the Region of Waterloo" (Report # P-58-02). Discussions between the Region and the City are continuing on future growth boundaries, but the current Official Plan with a planning horizon of 2016 remains in effect.

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, farm investment in infrastructure within the subwatershed is generally low. Farm buildings within the subwatershed vary in size and condition. However, many of the farm buildings do not currently appear to be in agricultural uses related to their original design. There is an exception to the general observations on infrastructure as some significant infrastructure is associated with the research station operated by the University of Guelph and OMAF.

Drainage improvements such as tile drainage are not required in many locations because soils are well-drained. Erosion control structures were observed in fields where sod is being produced. The relatively low investment in non-institutional farm related infrastructure within the study area is predictable given that:

- The subwatershed area is urbanizing.
- The lack of available funding due to the low economic returns associated with common field crop production like that which is present in 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 and Food (from:http://www.gov.on.ca/OMAFRA/english/stats/finance/index.html, 2001) clearly indicate that, on average, more of total 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 these crops are sold directly to the public. This relationship is illustrated in Figure B 7.3.2 (from:http://www.gov.on.ca/OMAFRA/english/stats/hort/index.html 2001) where the dollars received per unit area are significantly higher for the specialty crops sod, potatoes 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 to retail buyers 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 OMAF (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. With respect to the subwatershed, sod is produced and sold directly to the public. As well, the soils in the subwatershed area have the potential to be used (and have been used) for potato production and these crops can also be sold directly to the public - thereby maximizing gross returns. Generally speaking, it should be noted that net returns are higher when gross returns are higher.

In addition, part of the subwatershed is used for agricultural research. These research lands are subject to economic and political influences not found in other parts of the subwatershed.

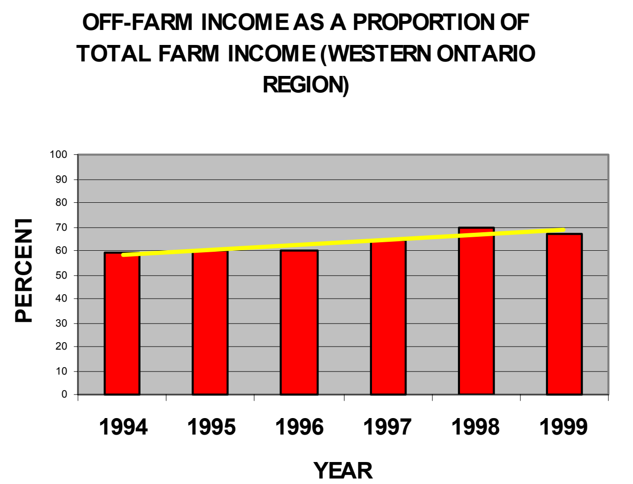

Figure B 7.3.1
Off Farm Income

Figure B 7.3.2
Dollar Value

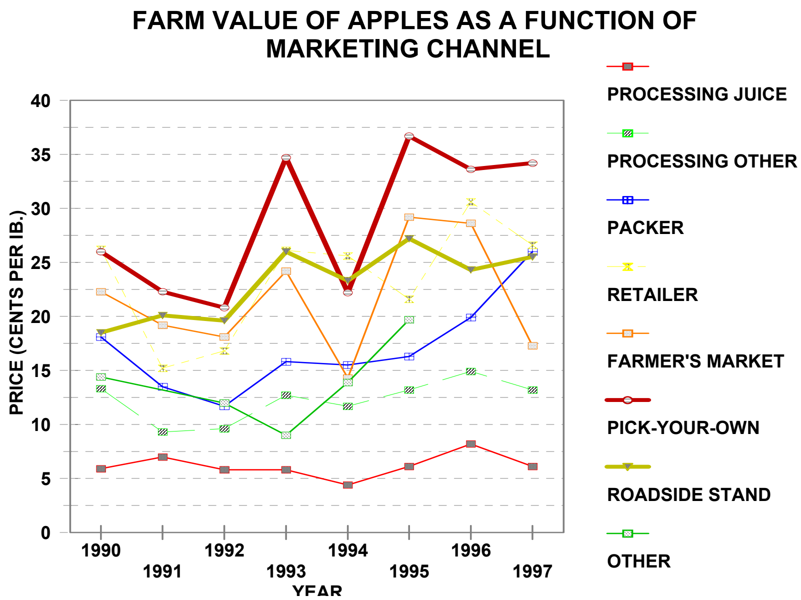

Figure B 7.3.3
Farm Value

B 7.3.3 Soil Erosion in Agricultural Fields

On the basis of field observations, cultivated lands within the subwatershed are currently eroding. This erosion ranges from shallow loss or deposition areas related to wind erosion in addition to small rills or relatively large gullies caused by water erosion. However, no detailed assessment of the subwatershed has been completed to quantify the relative amount/severity and location of erosion by water or wind within farm fields. The same field observations also indicate that sediment delivery to creeks, ponds or wetlands located within the subwatershed is relatively low. In other words, most of the sediment appears to be re-deposited 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 detailed assessment of soil erosion potential has been completed for individual fields. 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. The level of detail required is beyond the scope of this study.

B 7.4 Aggregate Resources

The Ontario Geological Survey is responsible for the identification of general locations of aggregate deposits within the Province. Aggregate Resource Inventory Paper 161 for Waterloo Region (1998) identifies two types of deposits within the study area.

First, a ‘primary significant sand and gravel deposit’ (Number 26) generally underlies an area north of Highway 401 and south of Maple Grove Road. On the easterly portion of this deposit, east of Speedsville Road, abutting the Speed River Wetland Complex, is a Category 3 Class A aggregate operation licensed under the Aggregate Resources Act (License #5537). This area was first licensed under the old Pits and Quarries Act in 1971-72, and revised in 1996. North of Briardean Road, just east of Speedsville Road, is another Category 3 Class A licensed aggregate operation (License #46162), approved and licensed in 2000. These licenses are both issued in the name of Arriscraft International Inc. Under the Aggregate Resources Act, all activities within these licensed areas are governed by the terms of the licenses, the site plans and the operating standards prescribed by the regulations under the Act. The licensed pit areas have been shown on Figure B 7.4.1

Secondly, a large 'tertiary significant sand and gravel deposit' underlies the northeast quadrant of the study area. Neither the Region nor the City have identified these deposits in their Official Plans, since these aggregates have marginal commercial viability. There are no licensed pit areas in this deposit in the study area.

B 7.5 Summary of Agricultural and Rural Resource 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 portion of the subwatershed and have the potential to significantly affect water quality and quantity.

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 lands with higher common field crop capability. In addition, additional characteristics may need to be considered when assigning priorities for the preservation of agricultural land. For example, public opinion may indicate that the Cambridge Research Station should be given a higher priority when rating agricultural lands.
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 and/or 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.

3. The Cambridge Official Plan discourages a high concentration of sod farms in agricultural areas. However, within this subwatershed such discouragement is not necessary for the following reasons. Sod farms are more economically viable

than other farms (particularly those producing common field crops). As well, sod farms need to be close to the market that they serve (urban areas) because of transportation costs in addition to problems of heating associated with rolled sod product. The heat destroys the sod. While there is some criticism of sod farming because it results in soil removal, more recent management techniques minimize or eliminate topsoil loss. In addition, sod has been shown to improve soil tilth, water infiltration and provide protection from wind and water erosion. In an urbanizing area, sod farms provide an open green area similar to the adjacent landscaped urban lands and are generally perceived to be better neighbours then some other kinds of agricultural operations - particularly those involved in livestock production. Some of this information and additional discussion on sod production is available at http://www.gov.on.ca:80/OMAFRA/english/crops/facts/info_sodprod.htm. Locations of local sod farms within Hespeler has been shown in Figure B 7.4.1.

4. Two aggregate deposits, a primary and a tertiary, are located within the study area. In addition, two approved aggregate licenses are present within the study area. Future studies (i.e., the Community Plan) and development should incorporate the reality of existing approved licenses made under the Aggregate Resources Act and maximize the use of the existing resource during development.

B 8.0 TERRESTRIAL RESOURCES

B 8.1 Introduction

Background documents relating to terrestrial resources (vegetation and wildlife) within the Hespeler West subwatersheds documents were reviewed in the fall and winter of 2001-02. Existing terrestrial resources were inventoried in the winter, spring and summer of 2002. Based on the data gathered, lists of flora and fauna were produced and their conservation status evaluated. The summary map is Figure B 8.3.1 - “Existing Natural Heritage Features”, which depicts discrete vegetation communities according to the Ecological Land Classification system (Ecosite Level).

B 8.2 Background Review

B 8 2.1 Special Features

Figure A 2.2.3 shows existing Provincially and Locally Significant Wetlands in the study area, based on Map 8 in the City of Cambridge Official Plan. Figure A 2.2.4 shows existing Environmentally Sensitive Policy areas and Locally Significant Natural Areas, based on Map 9 in the Official Plan.

The study area contains two existing evaluated wetland complexes: the ‘Locally Significant’ Maple Grove Road Complex (Skinner *et al*., 1995) and the ‘Provincially Significant’ Speed River Wetland (Coulson *et al*., 1986). The Maple Grove Road Complex extends across on the upper reaches of Middle Creek and the lower reaches of East Creek (Figure A 2.2.3). The Speed River Wetland is mainly found in areas adjacent to the Speed River. Several unevaluated wetland features are also found within the subwatershed; some of these are being added to the evaluated wetlands (see below).

Two other 'Provincially Significant' wetland complexes are found within 500 metres of the subwatershed boundaries. They are the Ellis Creek Wetland Complex (Coulson *et al*., 1987) and the Kossuth Wetland Complex (Timmerman *et al*., 1995).

According to Map 9 in the City of Cambridge Official Plan (Corporation of the City of Cambridge, 1999), most of the natural heritage features associated with the upper reaches of Middle Creek are officially recognized as a "Locally Significant Natural Area" (LSNA). Pages 40 and 41 of the Official Plan list the LSNA designation criteria. More specifically, it appears that the natural heritage features recognized correspond with Units 9A and 10A of the Cambridge Natural Areas Inventory, as shown on Map 3 of the NAI Study (Environmental Advisory Services, 1996). These two units almost entirely contain within their boundaries the upper half of the Locally Significant Maple Grove Road Wetland Complex. The natural heritage features associated with the lower half of the Maple Grove Road Complex have not received equal recognition as an LSNA, however Locally Significant Wetlands normally merit such designation and are designated Class One (Significant Natural Features) Open Space District. As part of this subwatersheds study all natural heritage features will be reviewed to determine their wetland and LSNA status for potential inclusion into the City's Natural Environment System.

No "Environmentally Sensitive Policy Areas" (ESPAs) are recognized as occurring within the Hespeler West subwatersheds study area (Regional Municipality of Waterloo, 1998; Corporation of the City of Cambridge, 1999). However, similar to the treatment of LSNAs, this subwatersheds study will review all new and background information to determine whether any natural heritage features merit such designation. ESPAs are defined by their designation criteria listed on pages 33–34 of the Regional Official Policies Plan (Regional Municipality of Waterloo, 1998). The closest ESPA to the Hespeler West Subwatersheds Study is the "Kossuth Swamp" (ESPA #22). It is located approximately 675 metres north of the subwatersheds boundary (Regional Municipality of Waterloo, 1998).

B 8 2.2 Vegetation Resources

The Hespeler West subwatersheds (comprised of East Creek, Middle Creek and West Creek) are located in a transitional area between the Great Lakes - St Lawrence Forest and the Deciduous Forest Regions (Hosie, 1975); the former forest region is also known as the Carolinian floristic zone [Soper (1956)]. As such, vegetation resources in the subwatershed are represented by species with northern and southern affinities.

Vegetation resources in the subwatersheds 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).
- Ontario Natural Heritage Information Centre – Rare species element occurrence database (ONHIC, 2001h).
- Distribution and Status of the Vascular Plants of Central Region (Riley, 1989).
- Wetland Data Record – Maple Grove Road Complex. Third Edition (March, 1995). Aug 16, 22–25, 1995. (Skinner, A., B. Tilt, and R. Jollette, 1995).
- Wetland Data Record – Speed River Wetland. Second Edition (1984). June 23–25, 1986. (Coulson, D.P., E. O'Neill, B. Neeb-Brechin, M. Ross, M. Belanger, and B. Ahrens, 1986).

- Wetland Data Record and Evaluation – Ellis Creek Wetland Complex. Second Edition (1984). Second Edition. June 19, 1987; July 28 and Aug 2, 1988. Ontario Ministry of Natural Resources (1987) and Ecologistics Ltd. (1988). Manuscript. 22pp. (Bergmann, B., M. Ross, N. Sullivan, D. Coulson and D. Stephenson. 1988).

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

Scientific Name	Common Name	Status	Significant species
Quercus bicolor	Swamp White Oak	b	S
Lycopus uniflorus	Northern Bugleweed	b	NPL
Bidens frondosa	Devil's Beggar's Ticks	b	NPL
Leersia oryzoides	Rice Cutgrass	a	NPL
Salix humilis	Tall Prairie Willow	a	S
Populus deltoides	Eastern Cottonwood	a	n
Zanthoxylum americanum	Northern Prickly Ash	a	T
Bidens vulgata	Tall beggar's Ticks	b	NPL
Carex cristatella	Crested Sedge	b	NPL
Carex flava	Yellow Sedge	a	NPL
Carex woodii	Pretty Sedge	b	T
Salix eriocephala	Heart-leaved Willow	a	NPL
Polygonatum biflorum	Giant Solomon's Seal	b	NPL
Sorbus americana	American Mountain-ash	b	S
Solidago gigantea	Smooth Goldenrod	a	NPL
Pilea fontana	Springs Clearweed	b	S
Salix bebbiana	Bebb's Sedge	a	NPL
Alnus rugosa	Speckled Alder	a	T
Menispermum canadense	Canada Moonseed	a	S
Gentiana andrewsii	Closed Gentian	a	S
Epilobium strictum	Downy Willow-herb	b	S
Equisetum sylvaticum	Woodland Horsetail	a	NPL
Dryopteris filix-mas	Male Fern	b	S

a = Regionally Rare-Waterloo (1985)
b = Regionally Rare, Riley (1989)
S = Is regionally significant
T = Is regionally significant but is expected to be delisted
n = Native colonies only
NPL = Not on present list

- Wetland Data Record – Kossuth Wetland Complex. Third Edition (March 1995). July 21, Aug 1,2,9 and 18, 1995. (Timmerman. A., A. Skinner, and B. Tilt, 1995).

Environmental Advisory Services Ltd. (1996) examined most of the natural heritage features in the Hespeler West subwatersheds in 1995 as part of a natural area study undertaken for the City of Cambridge. During the course of their work they noted several species considered significant in the Regional Municipality of Waterloo. Status designations were based on *A Preliminary Annotated List of the Plants of the Regional Municipality of Waterloo, Ontario* (Campbell and Lamb, 1984) and MNR's *Distribution and Status of the Vascular Plants of Central Region* (Riley, 1989). These species and their approximate locations are listed in **Appendix J1**. Some of these species were also incorporated into the Ministry of Natural Resource's wetland evaluation scoring for the Maple Grove Road Complex (Skinner *et al*., 1995).

The most current expression of botanical status in Waterloo Region is the revised Regional Municipality of Waterloo Significant Plant List (R. M. Waterloo, 1999). This document was released after the Cambridge Natural Areas Inventory was completed. **Table B 8.2.1** provides a comparison between those species considered significant at the time the Cambridge Natural Areas Inventory was conducted and those species considered significant today.

Based on this most recent status list, at least eleven, and possibly twelve regionally rare species are reported in background documents to occur in the Hespeler West subwatersheds (R. M. of Waterloo, 1999). They include:

Alnus rugosa Speckled Alder
Carex woodii Pretty Sedge
Dryopteris filix-mas Male Fern
Epilobium strictum Downy Willow-herb
Gentiana andrewsii Closed Gentian
Pilea fontana Springs Clearweed
Populus deltoides Eastern Cottonwood
Quercus bicolor Swamp White Oak
Salix humilis Tall Prairie Willow
Sorbus americana American Mountain-ash
Zanthoxylum americanum Northern Prickly Ash
Menispermum canadense Canada Moonseed

Additional plant records were obtained from the data sheets for the Speed River Provincially Significant Wetland (Coulson *et al*., 1986). Two of the species listed are considered regionally significant. They are: Interrupted Fern (*Osmunda claytoniana*) and Walking Fern (*Campytosorus rhizophyllus*). However, since the wetland extends beyond the boundaries of the subwatersheds, the two species may not occur in the Hespeler West subwatersheds. For this reason, they have been excluded from the list above until their location can be ascertained.

B 8.2.3 Wildlife Resources

The following sources were consulted for wildlife information:

- Cambridge Natural Areas Inventory – Table 5 and original field notes (Environmental Advisory Services Ltd., 1996).
- Ontario Natural Heritage Information Centre – Rare species element occurrences database (ONHIC, 2001h).
- Ontario Herpetofaunal Atlas – data records for UTM squares 17NU40 & 17NU50 (NAD27) – aside from individual local contributors, includes data gathered as part of the atlas project of the herpetofauna of Waterloo Region (1976–1981) and Hamilton Herpetofaunal Atlas (1984–1992).
- "The Herpetofauna of Waterloo Region, Ontario" – Journal article documenting the results of the 1976–1981 atlas project (Francis, G.R. and C.A. Campbell, 1983).
- "The Reptiles and Amphibians of the Hamilton Area: A Historical Summary and Results of The Hamilton Herpetofaunal Atlas" (Lamond, 1994).
- Wetland Data Record – Maple Grove Road Complex. Third Edition (March, 1995). Aug 16, 22–25, 1995. (Skinner, A., B. Tilt, and R. Jollette, 1995).
- Wetland Data Record – Speed River Wetland. Second Edition (1984). June 23–25, 1986. (Coulson, D.P., E. O'Neill, B. Neeb-Brechin, M. Ross, M. Belanger, and B. Ahrens, 1986).
- A Checklist of Waterloo Lepidoptera, Papilionoidea – The Butterflies (Larry Lamb, April 11, 1967).
- Woodward, Susan (The Centre for Biodiversity and Conservation Biology at the Royal Ontario Museum) – personal (e-mail) communication, November 8, 2001.
- Ontario Mammal Atlas (Dobbyn, 1994) – data records for UTM square.
- Thompson, Melinda (Species at Risk Biologist – OMNR Guelph) – personal communication, December 19, 2001.
- Ontario Breeding Bird Atlas 2001 – field data records for UTM square 17NJ50 (NAD83) "Cambridge North". (Bill Wilson [Regional Coordinator for Waterloo Region], December 21, 2001).
- Kitchener-Waterloo Field Naturalists – letter read out at January 2002 meeting and February 2002 outing requesting natural history information.

Based on the list of sources reviewed above, 55 species of wildlife have been recorded from the three component Hespeler West subwatersheds (**Appendix J2**). Most refer to resident breeding species, but some are also observations of species passing through during migration. They include 11 species of amphibians and reptiles, 35 species of birds and 9 species of mammals. Of the breeding residents, 6 species are recognized to be 'significant' in the Regional Municipality of Waterloo (R. M. of W., 1985a; R. M. of W., 1985b; R. M. of W., 1996). This includes 2 species of herpetofauna, 2 birds and 2 mammals.

A check of the Ontario Natural Heritage Information Centre rare species element occurrence database yielded no 'significant' species for the Hespeler West subwatersheds area (M. Thompson pers. comm. 2001). Typically, this includes species officially recognized to be provincially 'vulnerable', 'threatened' or 'endangered', as well those with a provincial rarity rank of S3 (rare to uncommon in Ontario; usually between 20 and 100 occurrences in the province) or lower.

Most of the background information on wildlife was obtained from the City of Cambridge Natural Areas Inventory (Environmental Advisory Services, 1996). A list of species observed from within the Hespeler West subwatersheds was compiled based on this source (see **Appendix J3**). In total, 34 wildlife species are on record, including 6 species of herpetofauna (amphibians and reptiles), 25 species of birds, and 3 species of mammal. Four of these species are considered to be "significant" in the Regional Municipality of Waterloo: Bullfrog (*Rana catesbeiana*), Great Blue Heron (*Ardea herodias*) Ruby-throated Hummingbird (*Archilochus colubris*), and Hairy Woodpecker (*Picoides villosus*). No details were provided in the field notes to distinguish whether the Great Blue Heron was actually breeding on site or simply an individual foraging in the area.

A review of the Ontario Herpetofaunal Atlas database (administered by the Ontario Natural Heritage Information Centre) yielded 23 individual records for the subwatersheds, representing ten species (**Table B 8.2.2**). An eleventh species, the Northern Redback Salamander (*Plethodon cinereus*) may also have been documented from the subwatershed. Unfortunately, detailed location information was absent. One of the species noted, the Northern Water Snake (*Nerodia sipedon sipedon*) is considered to be significant in the Regional Municipality of Waterloo (Regional Municipality of Waterloo, 1985a.) It was observed along the Speed River in 1987. In addition to various local contributors, the Ontario Herpetofaunal Atlas records included data gathered as part of the atlas project of the herpetofauna of Waterloo Region (1976–1981) and Hamilton Herpetofaunal Atlas (1984–1992). In fact, 15 of the 23 records date back to between 1978 and 1981. The remainders are for the mid to late 80s.

Table B 8.2.2 Ontario Herpetofaunal Atlas (Summary) records for the Hespeler West subwatersheds (as of 2002).

Common Name	Scientific Name	Obs.	Year(s) recorded
American Toad	*Bufo a. americanus*	4	1981-87
Gray Treefrog	*Hyla versicolor*	2	1978
Western Chorus Frog	*Pseudacris triseriata*	3	1987-88
Spring Peeper	*Pseudacris c. crucifer*	5	1981
Northern Leopard Frog	*Rana pipiens*	1	1987
Wood Frog	*Rana sylvatica*	2	1980
Snapping Turtle	*Chelydra serpentine*	2	1996-97
Midland Painted Turtle	*Chrysemys picta marginata*	2	1987-88
Northern Water Snake†	*Nerodia s. sipedon*	1	1987
Eastern Garter Snake	*Thamnophis s. sirtalis*	1	1987

† = Regionally Significant (Regional Municipality of Waterloo, 1985a)

The Ontario Mammal Atlas database yielded only five records clearly known to have occurred within the boundaries of the three Hespeler West subwatersheds (**Table B 8.2.3**). All of the species are considered common or very common in Ontario (ONHIC, 2001g). One of the species, the Virginia Opossum (*Didelphis virginiana*), is recognized as 'significant' in the Regional Municipality of Waterloo (R.M. of Waterloo, 1985b). Most of the observations (except for those of the White-tailed deer (*Odocoileus virginianus*) were made from along roadways.

No additional mammal records for the Hespeler West subwatersheds area are on record with The Centre for Biodiversity and Conservation Biology at the Royal Ontario Museum database (S. Woodward, pers. comm.).

Most wetland features found within the subwatersheds have also been inventoried as part of the Ministry of Natural Resources wetland evaluation program. The wetland data records for the Maple Grove Road Complex (Skinner *et al*., 1995) and Speed River Wetland (Coulson *et al*., 1986) were reviewed for wildlife observations. **Table B 8.2.4** lists species documented from these reports. It should be noted that while the Maple Grove Road Complex is completely contained within the study area boundaries, the observations listed for the Speed River Wetland may not be present within the Hespeler West subwatersheds since the wetland extends beyond the boundaries of the subwatersheds. Two species of birds and eight species of mammals were noted in the documentation. Of these, several are considered to be significant in the Regional Municipality of Waterloo (see **Table B 8.2.4**). The Region's designations for 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. Furthermore, the information gathered from the Speed River Wetland Data and Scoring Records is quite dated. For example, if the American Black Duck (*Anas rubripes*) and Osprey (*Pandion haliaetus*) did breed in the subwatersheds during the time of the evaluation, conditions may have changed since then. These records should be interpreted with caution.

Contact to secure 2001 Ontario Breeding Bird Atlas data for the "Cambridge North" atlas square (17NJ51) was initiated in December 2001. Unfortunately, based on conversations with the regional coordinator, little time was spent in the Hespeler West subwatersheds in 2001, more or less in the form of a reconnaissance. The few observations that took place were incorporated into the overall species list in January 2002. Database information from the first Ontario Breeding Bird Atlas (Cadman, *et al*., 1987) was not utilized due to the dated nature of the records (1980-1985) and their lack of site specificity.

Local residents have come forward with limited additional wildlife information to date (as of the June 26, 2002 Public Meeting). There have been general references to deer, coyote, and Great Blue Heron.

Table B 8.2.3 Mammals documented in the Hespeler West Subwatersheds by the Ontario Mammal Atlas[1]

	Common Name	Scientific Name	Conservation Status	
			Ontario[2]	R.M. Waterloo[3]
1	Virginia Opossum	*Didelphis virginiana*	S4	RS
2	Eastern Cottontail	*Sylvilagus floridanus*	S5	---
3	Norway Rat	*Rattus norvegicus*	SE	---
4	Raccoon	*Procyon lotor*	S5	---
5	White-tailed Deer	*Odocoileus virginianus*	S5	---

Legend
S4 = Breeding resident. Common and apparently secure in Ontario; usually with more than 100 occurrences in the province.
S5 = Breeding resident. Very common and demonstrably secure in Ontario.
SE = Exotic; not believed to be a native component of Ontario's fauna.

RS = Regionally Significant in Regional Municipality of Waterloo (R.M. Waterloo, 1985b).

References

1. **Dobbyn, J.A.S. 1994.** Atlas of the Mammals of Ontario. Federation of Ontario Naturalists, Don Mills, Ontario. 120p.
2. **Ontario Natural Heritage Information Centre (ONHIC). 2002.** NHIC List of Ontario Mammals. Ontario Natural Heritage Information Centre Home Page. http://www.mnr.gov.on.ca/MNR/nhic/queries/listout.cfm?el=am.
3. **Regional Municipality of Waterloo, 1985.** Appendix 4: Mammals in Environmentally Sensitive Policy Areas. Technical Appendix. Approved by Council: 1986.

Table B 8.2.4 Wildlife observations documented in the Maple Grove Road and Speed River Wetland Data and Scoring Records

	Common Name	Scientific Name	Conservation Status	Maple Grove Wetland Complex	Speed River Wetland
Birds					
1	American Black Duck	*Anas rubripes*	RS		X
2	Osprey	*Pandion haliaetus*	RS		X
Mammals					
1	Red Squirrel	*Tamiasciurus hudsonicus*		X	
2	Beaver	*Castor canadensis*	RS		X
3	Muskrat	*Ondatra zibethicus*			X
4	Coyote	*Canis latrans*	RS	X	X
5	Red Fox	*Vulpes vulpes*		X	X
6	Raccoon	*Procyon lotor*		X	X
7	Mink	*Mustela vison*	RS		X
8	Striped Skunk	*Mephitis mephitis*			X

Legend
RS = Regionally significant in Waterloo (R.M. of Waterloo, 1985b; R.M. of Waterloo, 1996).

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 new field 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 an ortho-rectified base. Individual polygons were assigned a unique identifier and prefixed with a number corresponding to the habitat block they are located in.

Preliminary roadside reconnaissance of vegetation features was undertaken in October 2001. Detailed fieldwork of vegetation resources, and verification of vegetation community boundaries was carried out between early June and mid July 2002. 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 constraint methodology utilized for the current study is presented in **Appendix J5**. Individual vegetation polygons were 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 database. A checklist of all the vascular plants observed in the subwatersheds is included in **Appendix J4a**. Nomenclature for vascular plant species follows the Ontario Plant List (Newmaster *et al.,* 1998).

Fieldwork included verification of existing MNR wetland boundaries, and identification of unevaluated wetlands. In order to permit the updating of the wetland evaluations, dominant vegetation forms were noted in accordance with the protocols of the Ontario Wetland Evaluation System (1993).

B 8.3.2 Summary of Findings

B 8.3.2.1 Vegetation Communities

The Hespeler West subwatersheds support a diverse assemblage of vegetation community types, which can be attributed to its geographic and physiographic setting. Nine ELC community series categories have been identified. A list of vegetation communities and associated attributes is presented in **Appendix J6**. The locations of individual vegetation community units or polygons are presented in Figure B 8.3.1 and Map 02. Terrestrial and aquatic community classes 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. Please note that the terminology used to describe the vegetation communities present (i.e., forest, woodland) is based on the system adopted under the MNR Ecological Land Classification system (Lee *et al*., 1998) and should not be confused with the terminology used in the Regional Municipality of Waterloo 'Tree By-law' (By-law No. 99-045) (see Section D 2.9). The definitions under the By-law will apply to its application without regard to any other designations applied in this report. A summary of community series categories in the subwatersheds is provided below; areas and percentages are summarized in **Table B 8.3.1**.

A general characterization of the vegetative systems in the subwatershed is as follows:

The upper watershed areas, principally north of Maple Grove Road, are in a relatively flat landscape with sandy surficial soils over variable parent materials. Areas underlain by fine-textured soils exhibit seasonal ponding that has led to the establishment of soft maple swamps as well as local mixed swamp stands. Occasional hummocks and rises have upland cover; the forests on East Creek in this area exhibit high botanical diversity due to the complexity of local hydrology and topography. There are also some soft maple swamp stands south of Maple Grove Road, where they tend to be quite localized, in some cases created by shallow bedrock.

The creek valleys between Maple Grove Road and the heights above the Speed River exhibit fairly extensive groundwater discharge zones along the creek floodplains which are quite diverse and include mixed and deciduous swamp cover as well as marsh and thicket pockets. These are also areas of high botanical diversity. A remnant woodlot on the Arriscraft lands (Unit 6.30 series) is an example of a highly diverse discharge system that has been otherwise eliminated within the entire study area. In this feature, an extensive array of springs and small creeks feed into mixed and coniferous swamp and marsh on deep organic soils. Examples of Carolinian species such as shagbark hickory and Canada moonseed occur in this area.

The forests along the Speed River are dominated by white cedar forest and swamps, located on shallow mineral or organic soils that are locally fed by springs and also sustained by periodic flooding. Local pockets with high species diversity occur in this extensive forest block.

Table B 8.3.1 ELC Community Series' Present in the Hespeler West Subwatersheds

ELC Community Series	Area (Hectares)	Percentage of subwatersheds
Agriculture	379.04	38.29
Anthropogenic	222.34	22.46
Cultural Meadow	87.69	8.86
Cultural Plantation	14.36	1.45
Cultural Savannah	1.39	0.14
Cultural Thicket	23.87	2.41
Cultural Woodland	7.41	0.75
Coniferous Forest	7.51	0.76
Deciduous Forest	23.14	2.34
Mixed Forest	4.09	0.41
Hedgerow	10.12	1.02
Meadow Marsh	32.16	3.25
Shallow Marsh	0.27	0.03
Open Aquatic	8.80	0.89
Coniferous Swamp	10.18	1.03
Deciduous Swamp	87.36	8.82
Mixed Swamp	26.16	2.64
Thicket Swamp	14.78	1.49
TOTAL	**960.67**	**97.04***

*Roadways and other built features comprise the remaining 2.96% (29.30 ha).

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. No significant plant 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, Orchard Grass and Queen Anne's Lace.

Cultural Thicket

The majority of these 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, and Staghorn Sumac.

Cultural Plantation

Cultural plantations are present in several areas of the subwatershed, particularly on lands in the lower to mid reaches of the East and Middle Creeks. Most are immature coniferous plantings that are in poor condition due to lack of management. Larger stands are gradually converting to mixed deciduous cover. One mature stand (pine-hemlock) was noted in the Middle

Creek subwatershed, north of Maple Grove Road. When associated with existing wetland cover and upland forest cover, these stands provide substantive benefits to overall natural functions. Conifer plantations have important benefits for wildlife in terms of winter shelter, and also attract bird species which are reliant on coniferous cover.

Cultural Woodland

Cultural woodlands were observed in only a few locations. They consist of areas with canopy coverage between 35-60%, comprised of native and non-native species. Composition typically includes species such as Manitoba Maple, Cottonwood, Norway Spruce, and Scots Pine.

Forest

Upland forest communities consist of immature to mature deciduous, mixed and coniferous forest. Individual vegetation units in this category are generally small, often forming fringe areas around, or pockets within the more extensive wetlands. This shortage of upland cover reflects the intensity of past agricultural activity in the subwatersheds. Regionally and provincially significant plant species were identified in several of these communities.

Representative forest types include *Fresh-Moist Ash Lowland Deciduous Forest* adjacent to some of the deciduous swamp units north of Maple Grove Road. The canopy is dominated by Green Ash with Trembling Aspen and White Elm. Plants in the groundcover layer include Jack in the Pulpit, Downy Yellow Violet, Spinulose Woodfern and Sedges. Other vegetation types documented included *Dry-Fresh Sugar Maple Deciduous Forest, Fresh-Moist Sugar Maple Deciduous Forest,* and *Fresh-Moist Hemlock Mixed Forest*. A single unit of this latter community type was observed in the Middle Creek Subwatershed, north of Maple Grove Road. The tree cover is mature, and there is an associated groundcover of Trilliums, Woodferns and Sedges. *Fresh-Moist White Cedar Coniferous Forest* is prevalent in lands along the Speed River, and is closely affiliated with wetland units. Typically the canopy is dominated by White Cedar, which tends to suppress the growth of groundcovers.

Marsh

These wetland community types consist of mineral and organic meadow marshes. Most of the marsh communities in the subwatershed are associated with the Speed River PSW and Maple Grove Wetland Complex. Significant species are present in several of these communities.

Mineral Meadow Marsh

Communities associated with this ecosite occur sporadically throughout the watersheds, associated with flat topography. Some units are associated with abandoned agricultural fields that are not productive due to poor drainage. Cover is generally dominated by Rushes, Sedges and Reed Canary Grass, as well as broad-leaved plants including Asters, Joe Pye Weed and Boneset.

Organic Meadow Marsh

Communities associated with this ecosite occur occasionally throughout the subwatersheds, forming extensive marsh in the flat topography of the upper watersheds, pockets in areas with confined surface hydrology, and open pockets in swamp-dominated floodplains along the creek channels. Dominant vegetation includes Common as well as Narrow-leaved Cattail, often with localized Willow, Red Osier Dogwood and Glossy

Buckthorn shrubs. Other examples are dominated by narrow-leaved Sedges, with forbs such as Panicled Aster, Boneset and Joe Pye Weed. Rare species such as Sweet Flag occur in some units (see **Photograph B12**).

Mineral Shallow Marsh

Communities of this ecosite type are generally confined to margins of constructed ponds. Dominant vegetation includes Cattails and Tall Reed Grass.

Swamp

This wetland community consists of treed and thicket swamp community. This community class is the most prevalent in the subwatersheds, associated with both evaluated and unevaluated wetlands.

Thicket Swamp

Thicket Swamps may occur on organic or mineral soil with a canopy closure of trees less than 25% and hydrophytic shrubs greater than 25%. They are relatively uncommon in the study area.

Coniferous 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 primarily associated with the Speed River PSW.

Mixed Swamp

This ecosite type occurs sporadically in the subwatersheds, sometimes affiliated with deeper (i.e., greater than 60 cm) deposits of organic soils. Substantive blocks of mixed swamp occur in close association with the East, Middle and West Creeks.

Deciduous Swamp

This is the most prevalent ecosite observed in the upper subwatersheds. It may occur on organic or mineral soils. *Maple Mineral Deciduous Swamp* is very common throughout the subwatersheds, dominated by Soft Maple (Silver and Freeman Maple), with frequent to abundant Ash (Black and Green), Elm, Willows and Poplars. Most of the significant plant species were observed in areas of deciduous or mixed swamp cover.

Open Water

This aquatic community type consists primarily of relatively small dug ponds, several of which occur within the subwatersheds. The largest ponds are associated with the headwaters of Middle Creek, and adjacent to West Creek. No significant plant species were observed in these features. A large pond in a former gravel pit, located along the West Creek, is the largest such feature (see **Photograph B13**).

Agricultural Fields

Agricultural communities include cultivated fields. Corn, oats, soybeans, sod and hay are the most dominant types of cover crops. 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.

Hedgerows can provide for important connections between the other communities within the subwatersheds and also to natural areas outside of the subwatersheds.

Hedgerows within the subwatershed were ranked in three classes based on their size, composition and structure (**Table B 8.3.2**). Class 1 hedgerows are comprised of mature cover with relatively high continuity.

Table B 8.3.2 Hedgerow Linkage Analysis

Vegetation Unit (Polygon)	Hedgerow Class
1.05j, 2.02, 2.22, 2.28a, 2.28b, 3.05, 4.18, 6.14a & 6.14b	1
0.01, 1.18, 2.06, 2.07, 2.08, 2.14, 2.16, 2.32, 4.03, 4.05a, 4.10, 4.20, 5.04, 5.06, 5.07, 5.08, 5.20b, 5.22c, 6.16a, 6.20a, 6.21, 6.25b, 6.26c, 6.31c & 7.01	2
1.02, 2.19, 2.40, 3.03, 4.15, 5.10 & 6.28c	3

Hedgerow Classes:

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

B 8.3.2.2 Wetland Re-evaluation

The most significant natural features of the three subwatersheds are the wetlands, which are primarily associated with floodlands on the East, Middle and West Creeks, and the Speed River. They are comprised of swamp, marsh and limited areas of open water. These are divided into more specific wetland communities (see ELC categories above). The Ontario Wetland Evaluation system recognizes five classes of wetlands: bog, fen, swamp, marsh, and open water (less than 2 metres deep). Only swamp, marsh and open water were observed in the subwatersheds.

Marshes form in flat, seasonally flooded depressions, fed by surface runoff and groundwater discharge. As storage and groundwater recharge areas they help to maintain the water balance in the subwatersheds.

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

Evaluated wetlands that are determined to be Provincially Significant (PSW) based on scoring under the Ontario Wetland Evaluation System – Southern Manual (Ontario Ministry of Natural Resources, 1993), are subject to the Provincial Policy Statement as well as Official Plans, and require special consideration and designation as part of the subwatershed study. Locally significant wetlands (LSW) are also recognized in the City Official Plan (Corporation of the City of Cambridge, 1999), as Locally Significant Natural Areas.

As background to this study the existing MNR wetland mapping (1995) was consulted. This mapping shows that most of the previously known wetlands in the subwatersheds are included in the Provincially Significant Speed River Wetland Complex, and the locally significant Maple Grove Wetland Complex (see Figure A 2.2.3).

As required in the Terms of Reference for the present study, the two existing wetland evaluations were reviewed and updated based on the information gleaned from field surveys conducted for this subwatershed study. Staff of the Guelph Office of the Ministry of Natural Resources were consulted to determine their preferred approach for the re-evaluation. Based on the documentation of additional wetland units that fulfill the wetland complexing requirements, and the discovery of rare and significant plant and animal species in the wetlands, the evaluations have been updated and re-organized into three complexes, as follows:

Speed River Wetland Complex (existing PSW)

The boundaries of the Provincially Significant Speed River Wetland Complex are basically unchanged; however, new records for regionally rare plants and wildlife were added to the data record for this complex. These records will be provided to MNR upon completion of the Subwatershed Study.

Maple Grove Road Wetland Complex (new PSW)

This complex, formerly locally significant, encompasses wetland habitats in the East and Middle Creek Subwatersheds. Updated scoring based on the inclusion of several additional wetland units, and several new records for regionally significant plants and wildlife, indicates that this complex should be recognized as Provincially Significant. A finalized data record will be provided to the Ministry of Natural Resources upon completion of the Subwatershed Study.

West Creek Wetland Complex (new LSW)

MNR staff recommended that the wetland habitats located within the West Creek Subwatershed be placed in a separate complex. Preliminary scoring indicates that this is a Locally Significant complex. This will be confirmed when the finalized data record is provided to MNR upon completion of the Subwatershed Study.

Figure B 8.3.2 summarizes the boundaries of the three complexes as determined by the present study. Wetland boundaries are based on polygon units recognized as 'wetlands' under the Ecological Land Classification system (Lee et al., 1998).

B 8.3.2.3 Subwatershed Flora

A total of 437 species of vascular plants were observed in the Hespeler West subwatersheds in 2001-2002. The list of observed species can be found in **Appendix J4a** and includes associated status information (i.e., native or introduced, conservation status in Waterloo Region, in the Province, and in Canada). **Appendix J4b** describes the status codes used in **Appendix J4a**. Of the species observed, 78% are considered native to Ontario, 24 species are considered Regionally Significant for Waterloo (Regional Municipality of Waterloo, 1999); based on final identification confirmations, one species is currently considered Provincially Rare (Oldham, 1999; ONHIC, 2002a). Significant plant species observed in the subwatersheds in 2002 fieldwork and the habitat attributes where they were located in the subwatersheds are summarized in **Table B 8.3.3** below (see also **Photograph B14**).

Table B 8.3.3 Significant Vascular Plants Documented in the Hespeler West Subwatersheds in 2002.

	Scientific Name	Common Names	Provincial Status*	Regional Status**	Habitat (this study)
1	*Acorus americanus*	Sweetflag	S4	S	Lowland
2	*Carex atherodes*	Awned Sedge	S4S5	S	Lowland
3	*Carex brunnescens*	Brownish Sedge	S5	T	Lowland
4	*Carex formosa*	Handsome Sedge	S3S4	S	Lowland
5	*Carex laevivaginata*	Smooth-sheath Sedge	S4	S	Lowland
6	*Carex laxiculmis*	Spreading Sedge	S4	S	Upland
7	*Carex normalis*	Larger Straw Sedge	S4	T	Lowland
8	*Carex scabrata*	Rough Sedge	S5	S	Lowland
9	*Carex tuckermanii*	Tuckerman's Sedge	S4	S	Lowland
10	*Carex woodii*	Pretty Sedge	S4	T	Upland
11	*Celtis occidentalis*	Common Hackberry	S4	T	Upland & Lowland
12	*Cypripedium calceolus*	Small Yellow Lady's Slipper	S5	S	Lowland
13	*Eleocharis pauciflora*	Fewflower Spikerush	S5	S	Lowland
14	*Galium obtusum*	Wild Madder	S4S5	T	Lowland
15	*Glyceria canadensis*	Canada Manna Grass	S4S5	T	Lowland
16	*Juncus canadensis*	Canada Rush	S5	S	Lowland
17	*Menispermum canadense*	Canada Moonseed	S4	S	Upland
18	*Platanthera psycodes*	Small Purple-fringe Orchid	S5	S	Lowland
19	*Rubus odoratus*	Purple-flowering Raspberry	S5	S	Lowland
20	*Stellaria longifolia*	Longleaf Stitchwort	S5	S	Lowland
21	*Vaccinium angustifolium*	Late Lowbush Blueberry	S5	T	Lowland (acidic)
22	*Wolffia columbiana*	Columbia Watermeal	S4S5	S	Lowland
23	*Zannichellia palustris*	Horned Pondweed	S4	Not previously reported	Lowland
24	*Zanthoxylum americanum*	Northern Prickly Ash	S5	T	Lowland (near bedrock)

Legend

† Provincially Rare (Oldham, 1999).
* 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.
S Is regionally significant.
T Is regionally significant but is expected to be delisted.

B 8.3.2.4 Existing Impacts to Natural Heritage System

Past and existing land uses have had substantial impacts on the natural heritage system in the three subwatersheds. These include:

Roads and traffic – The study area is located between busy metropolitan areas, and the road infrastructure has been upgraded over the past 1-2 decades. Traffic levels along Maple Grove Road, Fountain Street, Speedsville Road, and Beaverdale Road are likely having a variety of effects on wildlife as documented in other jurisdictions, including road kills, impacts from road noise, changes to wildlife behaviours, and impacts of road salt usage on habitat composition and quality. Highway 401 severs the connection between Middle Creek and its outlet on the Speed River. However there is a substantial forested corridor along the north side of the Speed River, extending eastward into less urbanized areas where deer yards and major staging of waterfowl are known to occur. The Regional Road #24 bridge is adequate to permit active wildlife migration between the lower study area and adjoining Speed River corridor.

Changes to Drainage Regimes – There is widespread evidence throughout the watersheds that the existing drainage network, which includes the main creek channels as well as man-made ditches, has been substantially modified over many decades. Based on conditions observed in the late spring and summer of 2002, the basic functionality of remaining wetlands is relatively intact despite these changes, as evidenced by prevalent stable canopy cover. This is due in part to the flat topography of the upper subwatershed areas, and to the contribution of groundwater to streams and wetlands downstream of Maple Grove Road.

Existing industrial and residential developments – There are long-standing residential and agricultural uses in the study area. In the past two decades, estate residential and industrial uses have intensified, displacing agricultural uses. However, the existing landscape matrix is still largely agricultural, which provides a ‘low resistance’ landscape facilitating the movement of wildlife, and to some extent, plant communities.

Removal and fragmentation of upland and wetland cover – Agricultural uses, aggregate extraction, and more recent residential and industrial developments, have eliminated most upland features, and have also encroached significantly into former wetland areas. Despite this loss of habitat, the drainage characteristics of the upper watershed have generally promoted the retention of fairly substantial blocks of forested wetlands. The good canopy health of these wetland units indicates that their hydrology is relatively stable.

Logging – Although all of the subwatershed areas have been intensively logged since settlement, the most extensive evidence of relatively recent logging was observed in the East Creek subwatershed forest complex between Maple Grove Road and Mohawk Road. Here logging was relatively intensive in the upland areas 10-20 years ago. Now these areas are dominated by dense sapling growth. Elsewhere in the study area, periodic firewood cutting appears to be the most common practice, in uplands and swamps.

Filling of wetlands – There has been past filling of wetlands, and some filling operations were observed in the upper subwatershed of Middle Creek during field studies in 2002. These activities gradually reduce the extensive water storage capacity of the landscape, and contribute to downstream flooding due to increased runoff. The changes also reduce the species diversity and structure in remaining habitats.

Aggregate extraction activities – The major aggregate extraction operation in the lower end of the subwatersheds has eliminated significant areas of forest and wetland habitat associated with a major groundwater discharge zone. Several remnant habitats were examined that exhibit a high degree of species richness and habitat resiliency due to their groundwater-sustained hydrology. The restoration of habitats in this groundwater-rich area could have profound benefits to the Speed River as well as natural heritage features associated with the lower reaches of all three creeks.

Existing Industrial Developments – The development of industrial and warehousing facilities north of Maple Grove Road is currently underway, and will likely be expanded once planning studies are completed. These facilities present constraints as well as potential opportunities. Noise and traffic associated with trucking will have a variety of impacts on wildlife species utilization in the vicinity. Large stormwater management facilities servicing these sites may present opportunities to buffer and enhance connectivity.

Exotic Species – The most extensively encountered invasive introduced or exotic plant species observed was glossy buckthorn (*Rhamnus frangula*). This species invades lowlands and wetlands, and formed the dominant understorey or canopy in certain units. It has displaced a diverse group of native shrubs. Common buckthorn (*Rhamnus catharticus*) was also prevalent in lowland and upland units. It has been identified as a co-factor in the decline of breeding success of some forest breeding songbirds, likely due to its effect on canopy structure.

The long-term control of these and other exotic species poses a significant problem in the future management of natural areas. Strategies to manage these species today tend to require very intensive actions using herbicides and manual removal. Hopefully other measures such as biological control will be developed to facilitate their broad-scale management.

B 8.3.2.5 Vegetation Constraint Ratings

Each vegetation community was assigned a vegetation constraint rating based on average canopy tree diameter, canopy structure and closure, drainage, slopes and topography, and botanical quality. The vegetation constraint identification methodology is described in **Appendix J5**. **Appendix J6** summarizes vegetation community data, including constraint ratings, for all community polygons. As discussed below in Section B 8.4.4, a wildlife constraint rating was also applied to each unit. The highest constraint score for each natural vegetation polygon is the priority constraint rating. Figure B 8.3.3 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, and/or containing rare or significant 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 between March 2002 and July 2002 so that critical seasonal information such as late winter mammal use, the occurrence of breeding amphibians, and habitat use by breeding birds could be established (**Table B 8.4.1**). Personnel documenting vegetation resources also recorded incidental wildlife sightings. In total 12 visits (representing 29 hours) were made to document wildlife.

Constraints related to wildlife were identified according to the methodology described in **Appendix J7**. This system assigns wildlife constraint ratings of low, medium or high to individual polygons based on a set of habitat and species attributes. These include: 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 is presented in **Appendix J6**. Final constraint ratings appearing on Figure B 8.3.3 will 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 as general indicators of overall biological diversity and habitat quality.

Herpetofauna (Amphibians & Reptiles)

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 to night surveys in April 2002, coinciding with the greatest number of frogs that call in early spring. Daytime observations of frogs and toads were duly noted in subsequent wildlife and vegetation studies. Surveys for calling frogs and toads utilized the 'Call Level Codes' and 'Abundance Count' terminology used in the Marsh Monitoring Program 'Amphibian Surveys' (LPBO, 1997).

Pond-breeding salamanders were searched for at night in April 2002 while documenting calling frogs and toads. Suitable logs, stumps and rocks were also be turned during daytime breeding bird surveys. All incidental snake and turtle observations were also documented.

Birds

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

Special attention was paid to any wooded areas that may support 'forest interior species'. Forest interior species represent migratory songbirds 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 metres to more than 300 metres in various studies, most authors recognize forest interior as the area at least 100 metres inside of the forest edge (Freemark and Merriam, 1986).

Surveys during the winter 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 survey work. Records were based on evidence such as visual observations, calls, scats, bones, smells, tracks, browsing evidence, road kills 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 Hespeler West Subwatersheds

	Date	Observer	Time in field	Total Hours	Purpose
1	21-Mar-02	Karl Konze	09:30 - 11:45	2.25	Late-winter survey to detect mammals and birds
2	28-Mar-02	Karl Konze	10:00 - 12:30	2.50	Late-winter survey to detect mammals and birds
3	7-Apr-02	Karl Konze	20:00 - 20:30	0.50	Salamander and spring frog survey
4	9-Apr-02	Karl Konze	20:00 - 21:30	1.50	Salamander and spring frog survey
5	24-Apr-02	Karl Konze	20:45 - 23:00	2.25	Salamander and spring frog survey
6	4-Jun-02	Karl Konze	07:15 - 09:15	2.00	Breeding Bird Survey
7	6-Jun-02	Karl Konze	06:40 - 09:30	2.83	Breeding Bird Survey
8	8-Jun-02	Karl Konze	06:40 - 09:55	3.25	Breeding Bird Survey
9	9-Jun-02	Karl Konze	06:45 - 09:00	2.25	Breeding Bird Survey
10	10-Jun-02	Karl Konze	06:10 - 10:40	4.50	Breeding Bird Survey
11	20-Jun-02	Karl Konze	09:15 - 10:55	1.67	Breeding Bird Survey
12	17-Jul-02	Karl Konze	06:30 - 10:00	3.50	Breeding Bird Survey
			TOTAL HOURS	29.00	

B 8.4.2 Summary of Findings

As of 17 July 2002, 144 species of wildlife have been documented from the Hespeler West subwatersheds, 133 of which were observed during field surveys conducted in 2002 by Dougan & Associates. Communications with the Kitchener-Waterloo Field Naturalists, local residents, and a review of available literature yielded 11 additional species. The complete list of species observed by Dougan & Associates in 2002 can be found in **Appendix J8**. A breakdown according to wildlife group is provided below in **Table B 8.4.2**.

Of the 144 wildlife species known to occur within the subwatersheds, 35 are considered to be significant in the Regional Municipality of Waterloo (R. M. of W., 1985a; R. M. of W., 1985b; R. M. of W., 1996). All 35 species are summarized below in **Table B 8.4.3**. All observations in the table refer to 2002 sightings unless described otherwise.

Table B 8.4.2 Number and Type of Wildlife Groups Known to Have Occurred in the Hespeler West Subwatersheds Study Area

Number	Wildlife Group
11	Damselflies and Dragonflies
12	Butterflies
13	Amphibians and Reptiles
91	Birds
17	Mammals
144	**TOTAL**

Table B 8.4.3 'Regionally Significant' Wildlife Species Recorded from the Hespeler West Subwatersheds 2002

	Common Name	Scientific Name	Comments
1	Bullfrog	*Rana catesbeiana*	Apparently recorded during the Cambridge Natural Areas Inventory (N.A.I.) in 1995 but no details provided. Not detected in 2002 but habitat remains suitable. May still be present.
2	Northern Water Snake	*Nerodia sipedon*	Recorded from along the Speed River in 1987. Likely still a resident. Habitat conditions have not changed much in the meantime. Not observed in 2002.
3	Great Blue Heron	*Ardea herodias*	Observed several times foraging in suitable habitat in 2002 but no heronry discovered. It is possible individual nests may be present. Also recorded during the Cambridge N.A.I.
4	Green Heron	*Butorides virescens*	Recorded foraging and from suitable breeding habitat. Also noted flying over Middle Creek 'corridor' north of Maple Grove Road on two occasions.
5	Turkey Vulture	*Cathartes aura*	Nest with two young found in large, open-sided stump. See **Photograph B16**.
6	Cooper's Hawk	*Accipiter cooperii*	Observed in April 2002. May be a local resident or migrant. Not detected again.
7	Sora	*Porzana carolina*	A single bird called several times from suitable habitat on June 20, 2002.
8	Yellow-billed Cuckoo	*Coccyzus americanus*	Single individual heard calling.
9	Ruby-throated Hummingbird	*Archilochus colubris*	Recorded from 2 separate vegetation units in 2002. Possible breeder. Also recorded in 1995 during the Cambridge N.A.I.
10	Belted Kingfisher	*Ceryle alcyon*	Pair observed entering nest hole. Also observed foraging along the nearby Speed River.
11	Red-bellied Woodpecker	*Melanerpes carolinus*	One male observed calling in suitable breeding habitat.
12	Hairy Woodpecker	*Picoides villosus*	Observed from 4 separate vegetation units in 2002. Breeding confirmed from one. Also recorded in 1995 during the Cambridge N.A.I.
13	Pileated Woodpecker	*Dryocopus pileatus*	No birds observed, yet both old and fresh feeding holes detected.
14	Alder Flycatcher	*Empidonax alnorum*	Recorded from two wetland locations.
15	Willow Flycatcher	*Empidonax traillii*	Recorded from three locations.
16	Least Flycatcher	*Empidonax minimus*	Recorded from three locations. This 'edge' species appeared to associate with Poplar.
17	Warbling Vireo	*Vireo gilvus*	Recorded from six different locations. Breeding confirmed with discovery of nest.
18	Red-breasted Nuthatch	*Sitta canadensis*	Heard calling from one location.
19	Brown Creeper	*Certhia americana*	Reported from seven different locations with the study area. Found mostly in mature deciduous swamps, but also near hemlocks.
20	Golden-crowned Kinglet	*Regulus satrapa*	Two separate observations; one of fledged young. This 'forest interior' species associated with spruces and cedars.
21	Eastern Bluebird	*Sialia sialis*	At least 2 pairs observed along NE edge of subwatershed by local resident in 2001, 2002.
22	Veery	*Catharus fuscescens*	One record; singing from suitable habitat during breeding season.
23	Black-throated Green Warbler	*Dendroica virens*	Single bird heard singing from suitable habitat in June 10, 2002.
24	Pine Warbler	*Dendroica pinus*	Two different birds heard singing in suitable breeding habitat. Closely associated with pines in both cases.
25	American Redstart	*Setophaga ruticilla*	Recorded five times from within study area; probable breeder.
26	Ovenbird	*Seiurus aurocapillus*	Single birds heard singing at two locations.
27	Mourning Warbler	*Oporornis philadelphia*	Single birds heard singing at two locations.
28	Clay-colored Sparrow	*Spizella pallida*	Bird observed on territory through most of June at rural residence.
29	Vesper Sparrow	*Pooecetes gramineus*	Only reported from one location; single bird heard singing from along hedgerow between agricultural fields.
30	Grasshopper Sparrow	*Ammodramus savannarum*	Unusual song thought to belong to this species discovered at one location. Identity not confirmed.
31	Swamp Sparrow	*Melospiza georgiana*	Reported from a half dozen separate locations. Territory established at least one location.
32	Virginia Opossum	*Didelphis virginiana*	Roadkill observed in April 2002 along Maple Grove Road.
33	Beaver	*Castor canadensis*	Cut trees and shrubs observed adjacent to pond in April 2002.
34	Porcupine	*Erethizon dorsatum*	Characteristic 'debarking' observed in April 2002. See **Photograph B17**
35	Coyote	*Canis latrans*	Possible den observed in April 2002. Scat & tracks detected elsewhere.

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

Twenty-three species of damselfly, dragonfly and butterfly were recorded from within the study area in 2002 (**Appendix J8**). Some of the species could not be identified to species in the field. All sightings were based on incidental observations; i.e., no special surveys were made to specifically identify these groups. It is likely the list may represent less than a third of all of the species actually present. In addition, it should also be noted that 2002 is acknowledged to be a poor year for butterflies. The cold and wet spring, followed by a hot and dry summer may explain why butterfly numbers were down across the province.

All but two of the species documented are considered 'very common' in Ontario (ONHIC, 2002b; ONHIC, 2002c). The Delta-spotted Spiketail (*Cordulegaster diastatops*), a dragonfly, is recognized to be 'common' in Ontario (ONHIC, 2002b), but prior to this sighting, had not been recorded from the Regional Municipality of Waterloo (Catling and Brownell, 2000). It is possible the species may have been overlooked in the Region since it is known to occur in the Regional Municipalities of Peel, to the east, as well as Haldimand-Norkolk, to the south. It was found sunning itself on June 9, 2002, adjacent to vegetation unit 6.30 which contains small woodland streams and springs, its preferred habitat.

The second noteworthy invertebrate species discovered was the Baltimore Checkerspot (*Euphydryas phaeton*), a butterfly (see **Photograph B15**). Even though it is considered common from a provincial perspective, its distribution is very localized, corresponding closely with the presence of its preferred foodplant, turtlehead (*Chelone glabra*), a wet meadow species (Powers, 2001). It was observed at two different thicket swamps, not far from the Speed River on July 9, 2002.

B 8.4.2.2 *Herpetofauna (Amphibians & Reptiles)*

Eight species of amphibians and reptiles were discovered during the 2002 field surveys (**Appendix J8**). Egg shells from an unidentified turtle species representing a ninth species were also noted. None of the species are considered to be 'vulnerable', 'threatened' or 'endangered' provincially or federally (ONHIC 2002d; ONHIC 2002e). As well, none are considered to be significant in the Regional Municipality of Waterloo (R.M. of W., 1985a). Five of the 13 species known to have occurred in the study area were not recorded during the 2002 inventories. They were Bullfrog (*Rana catesbeiana*), Western Chorus Frog (*Pseudacris triseriata),* Snapping Turtle (*Chelydra serpentina*), Midland Painted Turtle (*Chrysemys picta marginata*), and Northern Water Snake (*Nerodia sipedon sipedon*). With the exception of Western Chorus Frog, it is quite possible that all of these species may have been overlooked. Suitable habitat appears to exist for all four. And, as mentioned above, the unidentified remains of a turtle nest were discovered, but were not identified to species. With regard to the Western Chorus Frog, early spring nocturnal calling frog surveys did not reveal any evidence of this species, and both locations where this species was reported in April 1980 were surveyed. It is not clear if any disturbance has taken place at these locations since the original reports.

Most of the 2002 observations corresponded closely with existing deciduous and mixed swamp features. Others were associated with a variety of permanent or temporary dug ponds or depressions. Nevertheless, they too were typically located close to other natural heritage features, including woodlands.

B 8.4.2.3 Birds

Eighty-four species of birds were observed in the Hespeler West study area by Dougan and Associates staff in 2002 (**Appendix J8**). One other species was observed by a local resident. Eighty-one of the 85 species were recorded during the breeding season; four were considered migrants or winter residents. Of the 81 species observed during the summer, 76 showed some evidence of breeding. Seventeen of the 76 species were confirmed to be breeding within the study area (e.g., young were seen being fed etc.), 28 species were considered probable breeders (i.e., pairs or birds on territory were observed), and 31 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.

None of the bird species detected during the 2002 surveys are recognized to be 'vulnerable', 'threatened' or 'endangered', in Ontario or Canada (ONHIC, 2002f). However, 28 of the 76 breeding species (37%) are considered 'significant' in the Regional Municipality of Waterloo (R.M. of W., 1996) (**Table B 8.4.4** and **Photograph B16**). One other regionally significant species, the Pileated Woodpecker (*Dryocopus pileatus*) used the study area to forage (i.e., fresh feeding holes were discovered) but no direct evidence of breeding could be established.

Table B 8.4.4 Breeding Birds* Present in the Hespeler West Subwatersheds (2002) that are Recognized to be Significant in the Regional Municipality of Waterloo or Considered to be 'Conservation Priorities'.

	Common Name	Scientific Name	Highest Breeding Status	Conservation Status		Habitat Association		
				Significant in Waterloo	'Conservation Priority'	Forest/ Swamp	Marsh	Open Country
1	Great Blue Heron	*Ardea herodias*	Possible	X			X	
2	Green Heron	*Butorides virescens*	Possible	X	X		X	
3	Turkey Vulture	*Cathartes aura*	Confirmed	X	X	X		
4	Wood Duck	*Aix sponsa*	Probable		X	X		
5	Cooper's Hawk	*Accipiter cooperii*	Possible	X	X	X		
6	Ruffed Grouse	*Bonasa umbellus*	Confirmed		X	X		
7	Sora	*Porzana carolina*	Possible	X	X		X	
8	Spotted Sandpiper	*Actitis macularia*	Possible		X			X
9	American Woodcock	*Scolopax minor*	Possible		X	X		
10	Yellow-billed Cuckoo	*Coccyzus americanus*	Possible	X	X	X		
11	Ruby-throated Hummingbird	*Archilochus colubris*	Possible	X	X	X		
12	Belted Kingfisher	*Ceryle alcyon*	Confirmed	X			X	
13	Red-bellied Woodpecker	*Melanerpes carolinus*	Possible	X	X	X		
14	Hairy Woodpecker	*Picoides villosus*	Confirmed	X		X		
15	Alder Flycatcher	*Empidonax alnorum*	Possible	X	X	X		
16	Willow Flycatcher	*Empidonax traillii*	Probable	X				X
17	Least Flycatcher	*Empidonax minimus*	Possible	X	X	X		
18	Eastern Phoebe	*Sayornis phoebe*	Probable		X	X		
19	Eastern Kingbird	*Tyrannus tyrannus*	Probable		X			X
20	Warbling Vireo	*Vireo gilvus*	Confirmed	X		X		
21	Horned Lark	*Eremophila alpestris*	Possible		X			X
22	Bank Swallow	*Riparia riparia*	Confirmed		X			X
23	Black-capped Chickadee	*Poecile atricapillus*	Probable		X	X		

Table B 8.4.4 Breeding Birds* Present in the Hespeler West Subwatersheds (2002) that are Recognized to be Significant in the Regional Municipality of Waterloo or Considered to be 'Conservation Priorities'.

	Common Name	Scientific Name	Highest Breeding Status	Conservation Status		Habitat Association		
				Significant in Waterloo	'Conservation Priority'	Forest/ Swamp	Marsh	Open Country
24	Red-breasted Nuthatch	*Sitta canadensis*	Possible	X	X	X		
25	Brown Creeper	*Certhia americana*	Probable	X	X	X		
26	Golden-crowned Kinglet	*Regulus satrapa*	Confirmed	X	X	X		
27	Eastern Bluebird	*Sialia sialis*	Probable	X	X			X
28	Veery	*Cathartes fuscescens*	Possible	X	X	X		
29	Wood Thrush	*Hylocichla mustelina*	Possible		X	X		
30	Gray Catbird	*Dumetella carolinensis*	Possible		X	X		
31	Black-throated Green Warbler	*Dendroica virens*	Possible	X	X	X		
32	Pine Warbler	*Dendroica pinus*	Possible	X	X	X		
33	American Redstart	*Setophaga ruticilla*	Probable	X	X	X		
34	Ovenbird	*Seiurus aurocapillus*	Possible	X	X	X		
35	Mourning Warbler	*Oporornis philadelphia*	Possible	X	X	X		
36	Clay-colored Sparrow	*Spizella pallida*	Probable	X	X			X
37	Field Sparrow	*Spizella pusilla*	Probable		X			X
38	Vesper Sparrow	*Pooecetes gramineus*	Possible	X	X			X
39	Savannah Sparrow	*Passerculus sandwichensis*	Probable		X			X
40	Grasshopper Sparrow	*Ammodramus savannarum*	Possible	X	X			X
41	Swamp Sparrow	*Melospiza georgiana*	Probable	X	X	X		
42	American Goldfinch	*Carduelis tristis*	Probable		X			X

*Breeding evidence for Pileated Woodpecker, a Regionally Significant and Conservation Priority species, could not be obtained

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 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 Region of Waterloo does not currently recognize the species listed as being regionally significant (V. Martin, *pers. comm.*).

According to Couturier (1999), 38 of the 76 (50.0%) breeding bird species documented are considered to be of 'conservation priority' in the Regional Municipality of Waterloo (**Table B 8.4.4**). However, one species, the Pileated Woodpecker (*Dryocopus pileatus*) did not show any breeding evidence and was excluded from the list. In addition to the 38 species mentioned above, 3 other bird species observed are also regarded as conservation priorities for the Regional Municipality of Waterloo, but were simply passing through or foraging within the subject lands and did not show breeding evidence. These species were the American Kestrel (*Falco sparverius*), Pileated Woodpecker (*Dryocopus pileatus*), and Bobolink (*Dolichonyx oryzivorus*).

Twelve 'forest interior' species were documented in the breeding bird surveys, suggesting the study area contains forested blocks adequate to support these 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 metres 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 deforestation, forest fragmentation, and nest predation/parasitism. The 12 forest interior species are listed in **Table B 8.4.5**.

Table B 8.4.5 'Forest Interior' and 'Area Sensitive' Bird Species Found in the Hespeler West Subwatershed (2002)

	Common Name	Scientific Name	Forest interior species*	Area sensitive species**
1	Cooper's Hawk	*Accipiter cooperii*	X	X
2	Hairy Woodpecker	*Picoides villosus*	X	X
3	Pileated Woodpecker	*Dryocopus pileatus*	X	X
4	Red-breasted Nuthatch	*Sitta canadensis*	X	X
5	White-breasted Nuthatch	*Sitta carolinensis*	X	X
6	Brown Creeper	*Certhia americana*	X	X
7	Golden-crowned Kinglet	*Regulus satrapa*	X	
8	Veery	*Catharus fuscescens*	X	X
9	Black-throated Green Warbler	*Dendroica virens*	X	X
10	Pine Warbler	*Dendroica pinus*	X	X
11	American Redstart	*Setophaga ruticilla*	X	X
12	Ovenbird	*Seiurus aurocapillus*	X	X
13	Savannah Sparrow	*Passerculus sandwichensis*		X
14	Grasshopper Sparrow	*Ammodramus savannarum*		X

Legend
* Designations based on Freemark and Merriam (1986); and Hounsell (1989).
** Designations based on Ontario Ministry of Natural Resources (2000).

Nine habitat blocks present in the Hespeler West subwatersheds study area contain forest interior habitat as defined by the 100 metre threshold (**Table B 8.4.6**). With the exception of two observations, all of the forest interior bird species noted during the surveys were found in these habitat blocks. The two observations of forest interior species not found within forest interior blocks were from vegetation communities in the Speed River corridor lying adjacent to the forest interior units.

Table B 8.4.6 Habitat Blocks that Support 'Forest Interior' Bird Habitat

	Habitat Block	Component Vegetation Units
1	A	1.05a,c,d,e,f,h
2	B	2.00 and 2.01
3	C	2.17a
4	D	2.29a,b,c, and 2.31
5	E	3.06; 3.07; 3.08; and 3.09
6	F	4.01a,b,c,e; and 4.16a,b,c
7	G	5.02 and 5.03
8	H	6.17a and 6.18a,b
9	I	6.30a,b,c,d,e and 6.54

*See Map 2 for location of units.

The significance of these 'forest interior' species needs to be viewed with some caution since there is not scientific 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. **Table B 8.4.5** lists all of the area sensitive bird species found in the study area in 2002. In this case, most of the recognized area sensitive species correspond closely with the forest interior species. However, in addition to the area sensitive forest interior species, two area sensitive grassland species also made the list. They were Savannah Sparrow (*Passerculus sandwichensis*), and Grasshopper Sparrow (*Ammodramus savannarum*). Both species were associated with agricultural habitats.

It should also be noted that while none of the identified habitat blocks support large amounts of forest interior habitat, the fact that almost a dozen such blocks exist in relatively close proximity to one another may help explain the relatively high diversity of forest interior species present. It is generally accepted that small wooded habitats found near other wooded habitats tend to support a higher number and diversity of bird species, compared with other identical wooded habitats located in more isolated or open landscapes, such as those dominated by agriculture.

B 8.4.2.4 Mammals

Evidence of 14 of the 17 species previously reported in the study area were observed in 2002 (**Appendix J8**). All are considered 'very common' in Ontario (ONHIC, 2002g). However, four are recognized to be significant in the Regional Municipality of Waterloo (R.M. of W., 1985b). They are: Virginia Opossum (*Didelphis virginiana*), Beaver (*Castor canadensis*), Porcupine (*Erethizon dorsatum*), and Coyote (*Canis latrans*). A 15th species observed was an unidentified small rodent.

The single observation of the Virginia Opossum was an individual found dead along Maple Grove Road, just east of Briardean Road. Although this species' numbers are known to fluctuate regularly in response to the severity of winters, it is likely common in the Cambridge area. Its nocturnal habits make it more difficult to get a sense of abundance.

Beaver was detected in one location in the study area, at the south end, but away from the Speed River corridor. No individuals were actually observed but their tell-tale signs were evident along the shores of a local pond. Both felled trees and damming activity were noted.

Porcupine was discovered near the northern boundary of the study area. It too was not actually observed, but its characteristic 'debarking' was obvious (see **Photograph B17**). Porcupines feed on the living, inner bark (cambium) in winter, which contains the most food value.

Evidence of the presence of Coyotes was supported by observing tracks and scat, as well as from comments by residents. A possible den first observed in April 2002 was checked in June 2002 but it appeared to be inactive. It should be noted that the Region's designations for mammals has not been reviewed since 1985 and some rankings may no longer represent actual status. The Coyote may represent one such species.

White-tailed Deer are very common in the study area. Along with numerous observations of tracks, scat and beds throughout natural features in all the subwatersheds, several sightings (including fawns) were documented.

B 8.4.3 Master List of Wildlife Observations

A master digital file containing all wildlife observations made during the course of the study will be provided to the City of Cambridge and Ministry of Natural Resources (MNR) upon completion of this study. 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 J7**. The scores applied to each natural feature polygon received based on these attributes are listed in **Appendix J6**. Also listed in **Appendix J6** are the vegetation community data (scores) for all community polygons. Constraints identified related to vegetation are discussed in Section B 8.3.2.5. Figure B 8.3.3 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 medium and high wildlife constraint features are associated with areas of forest interior or wetland habitat.

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:

- Three wetland complexes are found in the watersheds: a) part of the Speed River Wetland Complex (Provincially Significant); b) the Maple Grove Wetland Complex, determined to be a Provincially Significant Wetland (PSW) based on the presence of additional significant species, as well as other attributes; and c) the newly evaluated West Creek Wetland Complex (Locally Significant). The Provincial Policy Statement (1997) prohibits development within and may restrict development adjacent to PSWs.
- Twenty-four 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 17.75% of the land base in the subwatershed, and wetlands comprise 18.15%. The overall forest cover in the subwatershed is deficient, but wetland cover is adequate, based on 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 significant numbers of White-tailed Deer, which are known to overwinter along the Speed River. Habitats supporting significant wildlife include upland forest, wetlands, and successional meadows.
- Nine habitat blocks were identified that provide potential 'forest interior' habitat for breeding migratory birds. Forest interior species were detected in all of these areas.
- The natural cover tends to be localized along the creek channels, with some blocks of habitat relatively fragmented by past agricultural encroachment. Smaller units of isolated habitat also occur away from the creek corridors. The agricultural cover provides opportunities for wildlife movement between core areas, but inhibits the movement of forest interior plants.
- Roads including Highway 401, Maple Grove Road, Beaverdale Road, and Fountain Street have a significant fragmenting effect on habitat connectivity.
- Existing human encroachment into natural habitats (e.g., logging, clearing for aggregate extraction & agriculture, wetland filling, trampling, tree cutting, understorey removal, informal trails, garbage and debris dumping, vandalism) has occurred in some locations in the subwatersheds.
- The quality, quantity, and seasonal flow of runoff in the subwatersheds is directly related to the habitat quality and species diversity of wetlands. There is clear evidence that many wetland communities located downstream of Maple Grove Road are reliant on groundwater discharge zones.
- Although somewhat constrained by existing residential, agricultural, aggregate extraction and

highway land uses, the subwatersheds contain 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

Section B has discussed the existing conditions within the Hespeler West subwatersheds. Each discipline provided a detailed assessment and a summary of management considerations. Each section has summarized their respective results and Section C will look at Management Alternatives to address these issues.