3.0 SUBWATERSHED DESCRIPTION

3.1 Introduction

This section presents a summary of the existing environmental conditions within the subwatersheds of Shirley's Brook and Watts Creek. This description is based on available background information and field work undertaken as part of this study. Further details on existing conditions are provided in **Appendix C.**

The following environmental components are described:

- Land Use
- Aquatic Biology
- Terrestrial Biology
- Geology
- Hydrogeology (groundwater)
- Surface Water Quality
- Hydrology (surface water flow)
- Stream Morphology (stream form)

3.2 Land Use

The Shirley's Brook and Watts Creek subwatersheds include a mixture of rural and urban land uses as well as areas that are being rapidly developed. Kanata's growth began in the late 1960s changing this part of the former March Township from a rural/agricultural area to an urban community of 50,000 people, with extensive and fast growing commercial/industrial areas.

Although the bulk of the subwatersheds are located within the City Kanata, a portion is contained within the City of Nepean. This includes lands east of Hertzberg/Eagleson Road. All of the lands within Nepean are federally owned under the administration of the NCC and other federal agencies such as DND.

Figure 3.1 (at the end of Chapter 3.0) illustrates existing land uses within the study area.

3.2.1 Watts Creek

The Watts Creek Subwatershed and its major tributary, Kizell Drain, straddle the City of Kanata/City of Nepean municipal boundary. The headwaters are predominantly urbanized at present and will be almost entirely urbanized when the community is fully built out.

Watts Creek Subwatershed (excluding Kizell Drain) has an area of 1500 ha (15 km^2). The 511 ha located in the City of Kanata is primarily low and medium density residential, with smaller areas developed for commercial and office uses. The only vacant areas are located in the Kanata Town Centre (north and south sides of Highway 417). A portion of this area also includes DND lands.

The lower portion of the Watts Creek Subwatershed is contained within the National Capital Commission (NCC) Greenbelt. It contains a mix of agricultural, rural and natural areas, as well as a small (89 ha) enclave of government offices. A portion of this area also includes DND lands.

3.2.2 Kizell Drain

Kizell Drain has an area of 1000 ha (10 km^2) and flows into the main channel of Watts Creek south of Carling Avenue. 515 ha are designated General Urban Area in the Regional Official Plan and are largely developed as low and medium density residential. The Kanata Lakes golf course (18 holes on about 70 ha) occupies part of this land. Two of the four neighbourhoods, located in the northwest part of the Marchwood Community, have not yet been fully developed.

The extreme northwest part of the Subwatershed is an undeveloped Natural Environment Area (72 ha) which will remain undeveloped as part of Kanata's open space network.

Slightly more than half of the Kanata North Business Park (232 ha) is located in the northern part of the Kizell Drain Subwatershed. These lands are approximately 50% developed at present. The balance of the Kizell Drain Subwatershed area (179 ha) is NCC Greenbelt, currently used for and designated rural and agricultural. A few existing single family dwellings are also found in this area.

The balance of the Kizell Drain Subwatershed area (179 ha) is NCC Greenbelt currently used for and designated rural and agricultural. A few existing single family dwellings are also found in this area.

3.2.3 Shirley's Brook

The Shirley's Brook Subwatershed has a total area of 2700 ha (27 km^2). Unlike the Watts Creek/Kizell Drain Subwatershed, the headwaters are not urbanized and are not contained within the future urban area designated in the Regional Official Plan. The urban area is mainly located in the south along the south (main) branch of Shirley's Brook. The area is comprised of Business Park, General Urban Area and Kanata North Expansion Area and is 731 ha in size, or about 27% of the Subwatershed. Approximately 30% of this area is presently developed.

The balance of this subwatershed is comprised of a General Rural Area (970 ha) which is dominated by estate residential and rural residential uses at very low densities. An additional 124 ha is designated Greenbelt Rural, that is contained either within the NCC Greenbelt or DND lands.

Natural Environment Areas and wetlands comprise the balance of the Subwatershed, an additional 844 ha (30%).

3.3 Aquatic Biology

3.3.1 Overview

The aquatic assessment work involved assessing the integrity of the ecosystem through assessment of the fish and benthic invertebrate communities as well as habitat. The Hilsenhoff Index was calculated for the benthic invertebrate collections. This index incorporates relative diversity and numbers of benthic invertebrate species collected and the result is used as a measure of water quality. This information was related to stream habitat which was characterized using the Rapid Assessment Methodology of Version 2.1 of the Stream Assessment Protocol (OMNR 1998). Details regarding the aquatic biology assessment approach are provided in **Appendix C (Annex C-6)**.

3.3.2 Benthic Communities

The benthic invertebrate community in any given area is a reflection of such factors as substrate, oxygen levels and water temperature. Riffle areas generally have higher oxygen levels than pool or glide areas. As well, in riffle areas particle size of the substrate is larger, creating more optimum habitat for benthic species which are adapted for burrowing and adhering to rocks and other large objects. An absence of riffles is often an indicator of low oxygen levels and an overall lack of suitable habitat for a benthic invertebrate community.

3.3.2.1 Shirley's Brook

Results of the benthic sampling program for Shirley's Brook subwatershed (at a site with adjacent land uses not developed) gave a Hilsenhoff Index score of 5.92, which indicates that substantial organic pollution is likely present within the area. This sample consisted of only eight families of benthic invertebrates and approximately 93% of the sample consisted of Platyhelminthes (flatworms) which are indicative of impaired water quality. Sampling was not feasible at sites adjacent to developed lands because of a lack of riffles or a lack of substrate (e.g. bedrock).

3.3.2.2 Watts Creek/Kizell Drain

Benthic invertebrate sampling was conducted for an undeveloped site and an agricultural site in Watts Creek. The Hilsenhoff Index score for the undeveloped site was 4.28 indicating good water quality with some degree of organic pollution likely. The sample was dominated (76%) by the Order Trichoptera (caddisflies). Most taxa within this order are considered pollution sensitive.

The score of the agricultural site was 6.25 which indicates fairly poor water quality with a substantial degree of organic pollution likely. This sample consisted of 10 taxa indicating a degree of biodiversity at this location, however, it was dominated by amphipods, isopods and leeches all of which are considered pollution tolerant.

3.3.3 Fish Communities

3.3.3.1 Shirley's Brook

Shirley's Brook can be considered a warmwater, tolerant stream. No rare, threatened or endangered species were collected from the creek.

Fish sampling was conducted on June 29 and August 27-28, 1998. In addition, a review was undertaken of background information on the upper and lower reaches of Shirley's Brook and the results of electrofishing from sampling conducted by OMNR staff in 1998. A total of 13 fish species were collected during the electrofishing program. Seven additional fish species that had been captured in the lower reaches of the watercourse during previous studies were not collected during this survey.

Table 3.1 provides a listing of species that have been identified in both Shirley's Brook and Watts Creek. Further details on the sampling program are provided in **Appendix C (Annex C-6).**

Two sites (with undeveloped adjacent land uses) were sampled in the upper reaches of Shirley's Brook. These sites supported moderate species diversity with 7 of the 13 species captured during the survey. All species captured are tolerant of degraded conditions with the exception of the bridle shiner (*Notropis bifienatus*) which shows intermediate tolerance. Three of the species captured are carnivorous feeders and the remaining four species are omnivores, which represents an acceptable trophic balance. A stream not impacted by development will support a fish community which consists of a majority of herbivorous species, some omnivores, as well as the presence of several predator species. All sampling conducted in these upper reaches was in undeveloped areas in the south branch of Shirley's Brook. The north branch contained no surface water in the upper reaches at the time of the survey.

TABLE 3.1
FISH SPECIES REPORTED IN THE SHIRLEY'S BROOK AND WATTS CREEK SUBWATERSHED

Common Name	Scientific Name	Shirley's Brook	Watts Creek	Dillon 1998	OMNR 1998	OMNR 1992	OMNR (OFIS) 1975	Robinson Consultants 1994
central mudminnow	*Umbra limi*	✓	✓	✓			✓	
white sucker	*Catostomus commersoni*	✓	✓	✓	✓	✓	✓	✓
northern redbelly dace	*Phoxinus eos*	✓	✓	✓		✓		
finescale dace	*Phoxinus neogaeus*	✓	✓	✓		✓		
bridle shiner	*Notropis bifrenatus*	✓	✓	✓				
common shiner	*Luxilus cornutus*	✓	✓	✓		✓		
blacknose shiner	*Notropsis heterolepis*	✓	✓	✓				
bluntnose minnow	*Pimephales notatus*	✓	✓	✓		✓	✓	
fathead minnow	*Pimephales promelas*	✓	✓	✓		✓		
blacknose dace	*Rhinichthys atromaculatus*		✓	✓				
creek chub	*Semotilus atromaculatus*	✓	✓	✓	✓	✓	✓	
banded killifish	*Fundulus diaphanus*	✓	✓	✓				
brook stickleback	*Culaea inconstans*	✓	✓	✓	✓	✓	✓	
fantail darter	*Etheostoma flabellare*	✓	✓	✓			✓	
smallmouth bass	*Micropterus dolomieu*	✓				✓		
largemouth bass	*Micropterus salmoides*	✓				✓		
American eel	*Anguilla rostrata*	✓				✓		
northern pike	*Esox lucius*	✓	✓		✓	✓		✓
pumpkinseed	*Lepomis gibbosus*	✓				✓		
rock bass	*Ambloplites rupestris*	✓				✓		
logperch	*Percina caprodes*	✓	✓			✓		
yellow perch	*Perca flavescens*		✓		✓			✓
golden shiner	*Notemigonus crysoleucas*		✓		✓			
freshwater drum	*Aplodinotus grunniens*		✓		✓			

Sampling in the middle and lower reaches included two undeveloped sites, two developed sites and one agricultural site. Species diversity in one of the undeveloped sites was low with only two species captured. Ten species were captured at the second undeveloped site which was located closer to the mouth of Shirley's Brook. Diversity in the developed sites was also extremely low with a total of two fish species captured. Both species (common shiner and bluntnose minnow) are omnivorous and tolerant of degraded conditions. No fish were captured at either the second developed site or at the agricultural site. Water temperature at these sites ranged from 25 to 28°C at time of sampling.

3.3.3.2 Watts Creek and Kizell Drain

Watts Creek can be considered a warmwater, tolerant stream. No rare, threatened or endangered species were collected from the creek.

A tolerant warmwater fish community inhabits Watts Creek and Kizell Drain. The fish species captured were tolerant with the exception of the fantail darter (*Etheostoma flabellare*) which was captured at both the developed and undeveloped sites. The fantail darter is considered intermediate in tolerance of degraded stream conditions and is at the northern edge of its range resulting in a somewhat restricted distribution within Canada. It is primarily carnivorous and is found mainly in gravel bottom streams. All other species captured are omnivorous. Water temperature on the day of sampling ranged from 21 to 26°C among the sites. No rare, threatened or endangered species were captured.

The developed and agricultural sections of the watercourse exhibited low species diversity, as expected, with four species (creek chub, brook stickleback, central mudminnow, fantail darter) captured at one of the developed sites, and two species (common shiner and brook stickleback) captured at the other. Background information (MNR 1993) supported the current sampling results.

Results from the two undeveloped sites varied, with six and three species captured. Brook stickleback were common to both sites. All species are characteristic of tolerant, warmwater fish communities with the exception of the fantail darter mentioned above.

3.3.4 Fish Habitat Assessment

Fish habitat in the Shirley's Brook/Watts Creek Subwatershed study area was classified based on the Fish Habitat Conservation and Protection Guidelines for Developing Areas (OMNR 1994) and the Habitat Conservation and Protection Guidelines (DFO 1994). This classification is based on three levels:

Type 1: critical habitat that requires a high level of protection and includes for example spawning areas.

Type 2: requires a moderate level of protection and includes areas utilized by fish for feeding, growth and migration.

Type 3: includes low productive habitat and requires minimal protection. Some type 3 areas may be suitable for restoration efforts and thus could be afforded a higher level of protection.

(See **Appendix C (Annex C-6)** for more detailed explanations of each type.)

Figures 3.2a and **3.2b** (at end of chapter) illustrates fish habitat classifications (Type 1, 2 or 3) for Shirley's Brook. All of Watts Creek was classified as Type 2 habitat.

3.3.5 Stream Assessment Result

The use of the Rapid Assessment Methodology of Version 2.1 of the MNR Stream Assessment Protocol provides a systematic and comprehensive understanding of the aquatic resources of the Shirley's Brook and Watts Creek/Kizell Drain subwatersheds. The ability to summarize habitat attributes (bank stability, percent cover, channel structure) for each of the land uses of the watersheds provides an understanding of the status of the aquatic resources. The integration of these attributes with the fish communities and benthic invertebrate populations provides information on the productive capacity of each system and how to manage for that capacity. For example, Shirley's Brook exhibits impaired water quality, low fish species diversity, warm water conditions and channel instability in many areas. Other areas of the system exhibit higher species diversity and more stable conditions. Such a system is capable of sustaining a diverse warm water community but requires an intensive restoration effort. Similarly, Watts Creek/Kizell Drain also exhibits fish species diversity but requires significant restoration efforts in many areas.

A set of baseline conditions has been established through this study that will allow for a comparison against future conditions to assess the effects of development and restoration efforts.

Results of the Stream Assessment Protocol are provided in **Appendix C** (**Annex C-6**).

3.4 Terrestrial Biology

The following characterizes the terrestrial natural features (woodlots, wetlands and old fields) within the study area. This characterization was based on background documentation, previous studies as well as field work. Natural features were characterized through a quantified evaluation process to assist in identifying priority areas for future management initiatives. This evaluation process as well as details on the results, are described in **Appendix C** (**Annex C-7**).

Figures 3.3a and **b** illustrate the location of natural areas (26 in Shirley's Brook, 17 in Watts Creek and 10 in Kizell Drain subwatersheds). It is noted that many of the forest/wetland resources within the subwatersheds act as wildlife corridors. There are two wildlife corridors within the study area. The first extends along the western side of the subwatersheds through the upper and mid reaches of Shirley's Brook. The second extends along the eastern boundary of the Watts Creek Subwatershed connecting into the Ottawa River.

The following is a discussion of these areas.

3.4.1 Kizell Drain Subwatershed

The Kizell Drain subwatershed covers an area of approximately 1,000 ha (10 km^2) of which 31% is covered in either forest, wetland or exposed rock. The remainder has been cleared for agricultural purposes or for residential/commercial purposes. Within the area, ten(10) distinct natural areas were identified ranging in size from 53 ha (K2) to 5 ha (K8). The majority of natural areas are concentrated within the northwestern portion of the subwatershed (K1 to K5). These units are within the Kanata Lakes Study Area which was inventoried by Brunton in 1992. This area includes large expanses of upland (dry) forest, lowland (wet) forests, marsh wetland as well as exposed precambrian shield.

In the upland forest of the Kizell subwatershed (and the other two subwatersheds), typical species within the upper canopy includes sugar maple, beech, white ash, white pine, hemlock and basswood. The shrub layer is composed of saplings of the upper canopy as well as choke cherry, hop hornbeam and hazelnut. The understorey varies according to the degree of sunlight reaching the forest floor, but typical species found here include white snakeroot, cloudberry, white trillium, enchanters nightshade, jack-in-the-pulpit and wild ginger.

In the lowland forest, which also included swamp communities, the upper canopy ranges from pure stands of white cedar or soft maple to a mixed stand of white cedar, alder, balsam fir, poplar, yellow birch, hemlock, willow/dogwood or black ash. It is reported that a stand of Tamarack is also contained here. The shrub layer is usually composed of saplings of the upper canopy as well as willows, alders and dogwood. The understorey is composed of ferns including maidenhair, sensitive, ostrich as well as typical riparian plants including spotted jewelweed, fringed loosestrife, enchanters nightshade, mosses and lichens.

During field work it was noticed that many of the marsh wetlands had become drier with willows, dogwoods, and stands of reed canary grass and Canada bluejoint (both water tolerant species) becoming established.

The investigation of the other natural areas (K6 to K10) found that they were scattered around the perimeter of the subwatershed or isolated within newly built developments.

3.4.2 Watts Creek Subwatershed

The Watts Creek Subwatershed covers an area of approximately 1500 ha (excluding Kizell Drain) of which 18% is covered in either forest, wetland or exposed rock. The remainder has been cleared for agricultural purposes or for residential/commercial purposes. Within the area, seventeen (17) distinct natural areas were identified ranging in size from 55 ha (W10) to 0.9 ha (W12) (see **Figure 3.3b** at end of chapter). While some of the natural areas are scattered throughout the subwatershed, many of the natural areas do form a fairly distinct wildlife corridor along the eastern side of the subwatershed. Units within this area include:

- W17 that is at the mouth of Watts Creek along the Ottawa River;
- W16, W14, W13 and W12 which are located along Range Road along Watts Creek; and
- W11, W10 located along Watts Creek between Carling Avenue and Highway 417 and W5, W4 and W3 which are located between Highway 417 and Robertson Road.

These units provide a wildlife linkage between the Stoney Swamp wetland located south of Robertson Road to the Ottawa River. The largest unit (W10) is the hub of the corridor as it is relatively undisturbed and has a diversity of habitats including upland forests, wetlands, rocky outcrops and regenerating grasslands. This area also has headwater tributaries for Watts Creek, and contributes 21% of the forest to the subwatershed. W11, the next largest totalling 34 ha, is located directly north and has the same conditions as W10. Both units are dominated by sugar maple, bitternut hickory, basswood, white ash and white pine that are approaching 75 years of age. Both these units have wetlands within their interiors which adds to the overall diversity.

The units W12, W13, W14, W16 and W17 are located along Watts Creek and all are dominated by water tolerant species such as red maple, silver maple, trembling and large-toothed aspen as well as white cedar. While some of these natural areas do not appear on Forest Resource Inventory mapping, these scrub communities do offer important habitat to wildlife that live along this watercourse. W17 is especially significant, as it is located at the outlet of Watts Creek at the Ottawa River. This community is dominated by a mature silver/red maple swamp that periodically becomes flooded as the Ottawa River water levels rise.

Units W5, W4 and W3 are located within or near the Energy, Mines and Resources complex, north and south of Timm Road. These areas have been disturbed in the past by light agricultural activity (i.e. pasture) and contain scattered stands of white cedar, white birch, white elm and poplar species. Two isolated wetland swamps which are complexed with the Stoney Swamp provincially significant wetland are located within W5 and W3 and these are dominated by white cedar, poplar and silver maple.

The other units in the subwatershed are scattered throughout the subwatershed and are isolated with residential developments (W1, W2, W6,) or in agricultural fields (W7, W8, W9, W15). With exception of W1 which is 22 ha in size and does have interior bird habitat, the others are less than 10 ha in size and have limited features.

3.4.3 Shirley's Brook Subwatershed

The Shirley's Brook Subwatershed covers an area of approximately 2700 ha with 39% covered in either forest, wetland or exposed rock. The remainder has been cleared for agricultural purposes including pasture land, hay, mixed grain and corn, but many of these areas are now giving way to estate residential or small scale commercial/retail development. Within the area, twenty-six (26) distinct natural areas were identified, ranging in size from 450 ha (S2) to 2.6 ha (S4) (see

Figure 3.3a at end of chapter). The two largest units (S1 and S2) are located on the west side of the subwatershed and extend west of the western subwatershed boundary and east to the large hydro corridor. Unit S2 which extends from Old Carp Road south to the CNR tracks and from the western subwatershed boundary east to the Second Line Road/Goulbourn Road, forms the north half of the South March Highlands area, while S3, S4 and S5 form the southern half. These five units do form the hub of a wildlife corridor that extends along the Carp River north to the Ottawa River.

The eastern portion of S2 and S6 are located on the west and east sides of Goulbourn Road respectively, and forms the natural preserve called Trillium Woods Park. Units S8 and S9 are now urban parks known as Morgan's Grant Woods and Klondike Road Park. A field survey of the latter found an interesting diversity of upland sugar maple, white and basswood mixed with a wetter community of white cedar, poplar and silver maple. While this area has been opened up for park land, much of the upper canopy and understorey layers has been preserved, thus keeping many wildlife habitat features intact. Many of the larger, isolated woodlots including S11, S12, S14 and S19 have undergone some degree of disturbance as estate residential and/or large custom built homes have been built within the forest interior. Similar activity is also occurring on the eastern edge of S1.

3.4.4 Summary

Riley and Mohr (1994) have indicated that in 1981, the Region only had 29.4% of its land area covered in production and non-production forest. This analysis shows that for the Kizell Drain Subwatershed and the Watts Creek and Shirley's Brook Subwatersheds, those forested areas are 31%, 18% and 40% respectively. This shows that Kizell and Shirley's Brook still have considerable forest resources, but Watts Creek is approaching critical levels.

The forest/wetland resources within the subwatersheds act as two corridors located along the western portion of the study area, along the Ottawa River and along the eastern boundary. Despite the expansion of Kanata and Nepean, these two corridors (see **Figure 3.3a** and b)appear to provide a crucial migration corridor for birds and wildlife that travel inland from the Ottawa River. Efforts should be made to maintain these natural areas as much as possible.

While portions of the subwatersheds are being developed, portions of forest are being preserved and being utilized as urban nature reserves. Some of these reserves such as Trillium Woods Park (S6), a proposed 6 acre park south of Kanata Lakes Golf Club (K6), Morgan's Grant Woods (S8) and Klondike Road Park (S9) do contain undisturbed habitat which would be suitable for wildlife such as cottontail, raccoon, skunk, grey and red squirrel and chipmunk. Some of these urban parks (S6), (K6), (W1) and (S9) also contain interior bird habitat.

One trend that seems to be occurring especially in Shirley's Brook Subwatershed, is the establishment of estate residential developments in the interior of mid-sized, mature sugar maple forests. While this lotting technique does preserve more trees than typical urban development, it does tend to eliminate interior forest conditions. Although as much woodlot as possible should be preserved, it is realized that this is not realistic for areas to be developed. **It is recommended that if possible, sizeable portions of woodlots should be preserved in order to provide some amount of bird habitat. These smaller "islands" of habitat are still very important to the overall wildlife corridor system within the subwatershed.**

A more detailed description of the natural areas, as well as long-term protection/ restoration recommendations, are presented in Chapter 7 and in **Appendix C** (Annex C-7).

3.5 Geology

The following provides an overview of geologic conditions in the study area, details are provided in **Appendix C (Annex C-2)**.

3.5.1 <u>Physiography</u>

The study area is made up of three distinct physiographic divisions: gently rolling bedrock uplands of the March Highlands along the southwest; a lowlands area along the northeast; and Paleozoic bedrock plains along the southeast and east. The March Highlands are crested by a Precambrian bedrock ridge referred to as the March or Carp Ridge.

The upland areas of the March Highlands and bedrock plains are characterized by numerous bedrock outcrops, relatively thin overburden cover, and local poorly drained wetlands and marshes which act as headwaters to Shirley's Brook, its various tributaries, Kizell Drain, and the north branch of Watts Creek. The poor draining wetlands flow into narrow stream reaches within deep channels that have been cut into the ridges. The upper reaches of the south branch of Watts Creek are dominated by a Paleozoic bedrock terrain.

The middle and lower reaches of the subwatershed areas consist of erosional terraces characterized by offshore deep water marine deposits of silt and clay. These lowlands comprise the floor of an abandoned channel of the Ottawa River. Bedrock exposures within the lowland area are numerous owing to terrace cutting effects within the former channel.

3.5.2 Surficial Geology and Soils

Overburden thickness throughout the study area, is for the most part, relatively thin. Overburden thicknesses are generally less than 5 metres, and in much of the upper reaches of the subwatershed areas, are less than 1.0 metres. The greatest overburden accumulations (>30 m) lie along the east branch of Watts Creek southwest of the Highway 417/Eagleson Road interchange.

Figure 3.4 (located at the end of the chapter) displays the various surficial soils within the Shirley's Creek/Watts Creek Subwatershed, the characteristics of which are described below. The surficial soils within the Shirley's Brook/Watts Creek Subwatershed vary considerably as series of bands more or less aligned in a north-south direction across the Subwatershed.

The **upper reaches of the subwatershed areas** are dominated by exposed or shallow Precambrian and Paleozoic bedrock that comprises roughly 50% of the Shirley's Brook and Kizell Drain subwatersheds and 35% of the Watts Creek Subwatershed. Where unexposed, the shallow bedrock cover is typically less than 1 metre in thickness and is generally comprised of silt/clay till.

The **middle and lower reaches of the study area** are overlain by offshore marine deposits of clay, silty clay, and silt and are commonly locally overlain by thin sands. The offshore marine deposits comprise approximately 25%, 20%, and 15% of the Shirley's Brook, Kizell Drain, and Watts Creek Subwatersheds, respectively.

East of March Road along the centre line of the lowland area the surficial deposits consist of alluvial sand. The sand deposit is roughly linear in shape measuring approximately 7 km in length by 800 metres in width. The sand consists of a medium grained stratified sand with some silt. Information in the MOE water well database indicates these deposits to be less than 2 metres in thickness. This alluvial sand deposits comprise approximately 10 - 15% of each of the subwatershed areas. **This area provides the best opportunity for ground infiltration based storm water management measures within the study area.**

3.6 Hydrogeology

3.6.1 Groundwater Usage

Owing to the relatively thin and/or low yield nature of much of the overburden deposits, the vast majority (>98%) of the wells within the study are reportedly completed within bedrock. In fact, only 4 of the 276 water wells identified in the study area reportedly obtain water from an overburden aquifer. In all four wells, groundwater is obtained from a basal gravel layer overlain by varying thicknesses of marine clay. These basal aquifers consist of small, discontinuous accumulations with local bedrock depressions.

The vast majority of the water wells were completed prior to urbanization of the study area and are located along the major and minor arteries such as Carling Avenue, Hazeldean Road, Eagleson Road, and March Road. It is likely that many of the wells within the urbanized areas no longer serve a primary use owing to the servicing of these area with municipal water. The rural areas of the Shirley's Brook Subwatershed will more than likely remain dependent upon groundwater resources, depending upon future municipal servicing initiatives.

Several significant moderate to high yield Paleozoic bedrock aquifer units have been identified in the study area including the Nepean, March, and Oxford Formations (Geo-Analysis, 1976). Well yields for the Nepean and March Formations range from 13 litres per minute to greater than 50 litres per minute.

The water quality within the Nepean, March, and Oxford Formations is generally potable, however, iron and manganese generally exceed the MOEE Drinking Water Aesthetic Objectives.

3.6.2 Groundwater Flow

The groundwater flow paths mimic the topography suggesting that groundwater flow in the area is topographically driven. Groundwater flow for the most part is to the northeast towards the local discharge areas, namely Shirley's Bay and the Ottawa River. Variations in the regional groundwater flow regime occur locally. In the upper reaches of the Kizell Drain subwatershed, groundwater flows radially in response to the local topography.

A major linear bedrock groundwater recharge area lies within the March Highlands parallel to and immediately east of the March Ridge within the upper reaches of the Shirley's Brook Subwatershed.

Figure 3.5 (located at end of chapter) illustrates the location of the recharge areas. Several smaller bedrock recharge areas lie within the upper reaches and along the east flank of the Watts Creek Subwatershed where the overburden cover is relatively thin. However, much of the recharge potential within the shallow bedrock regions of the upper reaches of the Watts Creek Subwatershed has been lost due to urban development. Minor groundwater recharge also occurs along sand units, particularly in the lowland area, however their extent is limited. To preserve this recharge area, Chapter 7.0 of this report provides some recommendations.

3.6.3 Groundwater Discharge

While various geotechnical studies completed throughout the study area report a relatively high water table throughout these deposits (approximately 1 to 2 metres below grade), the hydraulic conductivities of such deposits are characteristically low and as such lead to relatively low groundwater flow and discharge rates.

Given the physiography and the nature and thickness of the overburden materials, the groundwater discharge contributions to streamflow are anticipated to be relatively minor in terms of quantity throughout the study area. While the volume of groundwater discharge may be low, the contribution to the overall streamflow is significant owing to the relatively low flows. Section 3.8.6 describes watercourse baseflows further.

No areas of significant active groundwater seepage such as upwelling were observed during the course of a field reconnaissance

Groundwater seepage meters were installed at five stream channel locations throughout the study area to establish the watercourse recharge/discharge characteristics and to quantify the groundwater seepage flux. Results are discussed in **Appendix C (Annex C-2).**

3.7 Surface Water Quality

3.7.1 Scope of Data Review

To assist in the characterization of water quality conditions, the Region, MOE and MVCA were contacted for water quality monitoring data pertaining to the Shirley's Brook and Watts Creek watercourses. Neither the MOE nor the MVCA had recent (i.e. within the last 20 years) surface water quality monitoring data. However, data previously collected and published by the RMOC was obtained and reviewed. This data has been collected between a period of 1993 to 1997.

A summary of the surface water quality objectives, data and conditions of the streams are presented below.

3.7.2 Surface Water Quality Objectives

Provincial and federal guidelines for the protection of aquatic communities were used as a basis for assessing surface water quality. The source for the Provincial Water Quality Objectives (PWQO) was:

- *Water Management, Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of Environment and Energy (MOEE, 1994);*
- *Canadian Water Quality Guidelines, Canada Council for the Minister of the Environment (CCME, 1990).*

In some cases, where no values were provided by neither the PWQO or the CWQG, the Ontario Drinking Water Objectives (ODWO) were applied for comparison purposes only (*Ontario Drinking Water Objectives* (MOEE, 1994)).

Additional guidelines for the protection of aquatic ecosystems were provided by the following document:

- *A Quick Reference Guide for Developers, (MNR - Kemptville District Office).*

3.7.3 Surface Water Quality Data Review

The Region data collected covers a standard set of parameters. The list of parameters is divided into the following categories:

general chemistry - This group of parameters (temperature, pH, alkalinity and TSS) describe the principle chemical character of the water and can be used to account for the majority of the dissolved and suspended matter in water.

major ions - Along with carbonate and bicarbonate which make up alkalinity, these comprise the bulk of the dissolved material in the water and some of the specific parameters are of regulatory concern. With the exceptions of nitrate and phosphate, the major ions are conservative, *i.e.* their concentrations do not change significantly in physical, chemical or biological processes in water. As such, they can be used to detect gross inputs from human activity

nutrients - Nitrogen is an essential nutrient for plants and animals, and can be found naturally in various forms in the atmosphere, hydrosphere, lithosphere and biosphere. The chemical and physical transformations that nitrogen undergoes within and between these "spheres" is known as the nitrogen cycle. The common forms by which nitrogen may be found in natural waters are nitrate; nitrite; ammonia; and total phosphorous.

bacteriological indicators - The bacteriological indicators of water quality reviewed in this study provide another measure of surface water quality. Data for the two indicators (*Escherichia coli* and fecal coliform) are of regulatory interest as they reflect waste discharge from human and/or animal sources.

trace constituents - Trace constituents are either toxic to a variety of life forms or are aesthetically displeasing. These are found in surface waters as a result of human activity and from natural sources.

A discussion of the parameters and collected data is presented in **Table 3.2**. **Appendix C** (**Annex C-3**) presents the location of the sampling sites as well as the collected data.

TABLE 3.2
SURFACE WATER QUALITY ANALYSIS SUMMARY

Parameter	Description	Data
pH	The pH of the water indicates the acidic or basic (alkaline) character of water and varies with the partial pressure of carbon dioxide and concentration of algae in the sample.	The pH levels for the Shirley's Brook and Watts Creek watercourses were found to vary between 7.3 and 8.7 for the most part, indicative of slightly alkaline waters within the subwatershed. The PWQO pH range for the protection of aquatic life is set at 6.5 - 8.5. Similarly, the CWQG for aquatic communities is set at 6.5 - 9.0. Excesses beyond this range by increasing acidity or alkalinity may lead to the enhanced toxic effect by various pollutants.
Conductivity	Conductivity is used as a surrogate for Total Dissolved Solids (TDS) and is a measure of a water's ability to carry electrical current. This ability is directly dependent on the amount of ionic species present and water temperature. TDS is related to hardness and alkalinity.	Data collected for Shirley's Brook and Watts Creek were generally below 1,200 umhos/cm, acceptable for natural waters in this region.
Alkalinity	Alkalinity is a measure of the capacity of a water to neutralize acids	No set PWQO or CWQG value is provided. Nevertheless, for comparison purposes, alkalinity values for the subject watercourses were well within the drinking water criteria of 30 - 500 mg/L set by the ODWO, indicative of waters with "normal" alkalinities.
Total Suspended Solids	Total suspended solids (TSS) measures the amount of particulate matter found in a water sample. High levels of suspended solids may be undesirable for aquatic life, industrial supply and as a source for potable water. As well, high solids concentrations may provide nutrients to microorganisms, causing algae or other aquatic organisms to flourish and deplete dissolved oxygen levels.	Total suspended solids levels were generally high and exceeded the MNR guideline of 80 mg/L for warm water fisheries in addition to the CWQO criteria of 10 mg/L. Most of these exceedances were noted at monitoring stations located within the more urbanized areas of the subwatersheds along Shirley's Brook and Watts Creek.
Major ions	These comprise the bulk of the dissolved material in the water and some of the specific parameters are of regulatory concern.	The major ions for which data was available include: chloride, sulphate, sodium, magnesium, calcium, and potassium. All of these parameters were, for the most part, below criteria levels where criteria levels were available.
Nitrates and Nitrite	Nitrates are found in almost all natural waters at concentrations that do not exceed 5 mg/L (as N), that have not been contaminated. However, concentrations above 2 mg/L (as N) may be indicative of external sources of contamination that may include fertilizers, municipal wastewater, drainage from barnyards, feedlots, septic systems and cesspools.	The data reviewed did not differentiate between nitrate and nitrite compounds as results were presented for all NOx forms. Consequently, no comparative analysis with any of the guidelines is feasible.

TABLE 3.2
SURFACE WATER QUALITY ANALYSIS SUMMARY
(Cont'd)

Parameter	Description	Data
Ammonia	Ammonia/ammonium ion is naturally present in surface waters, and is formed through the microbiological decay of nitrogenous organic matter (plant and animal waste) by a process known as ammonification. It may also be produced by the hydrolysis of urea (a waste product of animal metabolism) and through the reduction of nitrate by certain types of nitrifying bacteria, under anaerobic conditions. The use of inorganic fertilizers high in ammonia, nitrate or both, also greatly contribute to increased ammonia/ammonium ion levels in watercourses intercepting surface runoff and drainage from agricultural lands. Excessive levels of ammonia gas can be detrimental to aquatic life forms, and result in fish kills.	The data reviewed for the un-ionized portion of total ammonia (calculated using total ammonia, temperature and pH) indicate that the PWQO of 0.020 mg/L for un-ionized ammonia was not exceeded at any of the monitoring stations.
Total Kjeldahl Nitrogen	Total Kjeldahl nitrogen (TKN) is commonly used analytically to reflect the degree of nitrogenous matter present in the form of ammonia and all organically bound nitrogen. The normal range for TKN in waters not influenced by organic inputs is between 0.1 - 0.5 mg/L.	The data review indicated TKN levels for both watercourses below this criterion.
Phosphorus	Phosphorus compounds are released into natural waters through the erosion and solution of phosphorus containing rocks. It is a constituent of many important biological molecules such as DNA and also found in the membrane structure of cells and in the bones and teeth of animals. Through the decomposition of organic matter (detritus and animal waste), phosphorus is recycled back into a dissolved form available for uptake again by plants and animals. Other significant sources of phosphorus and phosphates in surface waters include fertilizers, domestic and industrial effluents, domestic detergents, agricultural and urban drainage. Although there is no firm objective for phosphorus, a guideline of 30 ug/L has been set by the Ministry of Environment to avoid excessive plant growth in rivers and streams. Excessive algae or aquatic plant growth is a direct consequence of elevated levels of phosphorous or phosphates in runoff.	Total phosphorus levels generally exceeded the MOE's PWQG of 30 μg/L at all monitoring stations for both watercourses. High total phosphorus levels are typically associated in with nearby agricultural activities that discharge surface runoff and field tile drainage to the watercourses.

TABLE 3.2
SURFACE WATER QUALITY ANALYSIS SUMMARY
(Cont'd)

Parameter	Description	Data
Escherichia coli (E. coli)	A wide variety of microorganisms are commonly found in water, most being of no health significance. However, since *E. coli* occurs in great numbers in the intestinal tracts of warm blooded animals and is prevalent in faecal matter and sewage, it serves as a good indicator of recent faecal contamination. Though *E. coli* itself is harmless to humans, its presence may be indicative of other pathogens. For this reason, the Ontario Ministry of the Environment has adopted *Escherichia coli* as the indicator of faecal contamination for recreational use of surface water, and has set an objective of 100 *E. coli* per 100 ml.	For the most part, the data reviewed indicates an exceedance of this level at all of the monitoring stations.
Fecal Coliforms	Although new compliance monitoring and enforcement activities of the Ministry are to be based on *E. coli*, Fecal Coliforms can be used to monitor trends where long-term records exist. The former guideline for Fecal Coliforms was 100 counts per 100 mL.	Results for Fecal Coliforms show exceedances at all monitoring stations, especially at those within agricultural areas of the subwatershed.
Trace Constituents	Trace constituents are either toxic to a variety of life forms or are aesthetically displeasing. These are found in surface waters as a result of human activity and from natural sources. Modern analytical methods can detect small changes in these constituents from background levels, and along with some trace organics provide a good indication of problematic discharges.	The concentrations of the trace constituents reviewed were generally below the available PWQO. The exceptions were for aluminum, iron, copper, zinc, lead, manganese, vanadium and cobalt. Based on the data collected, aluminum and iron levels exceeded the PWQO on a number of occasions at just about all the monitoring stations. PWQO exceedances of copper levels were found at very few of the monitoring stations along Shirley's Brook and Watts Creek. Zinc levels generally exceeded the PWQO level for zinc on a few occasions throughout the two subwatershed areas. Although no PWQO criterion exists for manganese, the ODWO criterion of 0.05 mg/L and the CWQO criterion of 0.2 mg/L for irrigation water were generally exceeded at both the Shirley's Brook and Watts Creek monitoring stations. At trace levels, cobalt is an essential element in plant and animal nutrition. Cobalt levels were found to marginally exceed the interim guideline PWQO of 0.0006 mg/L in a few instances at the Shirley's Brook and Watts Creek watercourses.

3.7.4 Summary of Surface Water Quality Conditions

In summary, the accumulated data indicates that the Shirley's Brook, Watts Creek and Kizell Drain subwatersheds all share similar water quality characteristics and have all been impacted by human activities.

On a rather consistent basis , total phosphorous, *E. coli* bacteria and fecal coliforms were found at levels above PWQO or the typical ranges described above. These are indicative of agricultural activities which may include fertilizers, manure runoff, livestock wastes, leaching of septic systems and soil erosion which can release these nutrients and bacteria into streams. Continued high levels of organic compounds and nutrients may lead to excessive growths of aquatic plants (*e.g.* algae and macropytes) and ultimately to the depletion of dissolved oxygen in the watercourse. Low DO levels can be detrimental to most native aquatic species.

The elevated levels of sodium, iron, aluminum, cobalt, manganese, zinc and chloride are indicative of inputs from natural weathering of rocks and urban activities such as road salting. These constituents pose no threat to humans for recreational purposes, however excessively high levels may be detrimental to aquatic life.

3.8 Surface Water Hydrology

3.8.1 Methodology

The surface water hydrology within the Shirley's Brook/Watts Creek Subwatershed area was characterized and assessed from a variety of background information sources, field reconnaissance and inventories of hydraulic structures. In addition, both continuous and discrete measurements of streamflows, water and air temperatures were collected. Analytical calculations including hydrologic computer modelling were used to quantify hydrologic conditions in terms of surface water drainage.

The principal watercourse systems identified and assessed in the study area are discussed according to the following groups:

- Shirley's Brook, including two principal (unnamed) tributaries;
- Watts Creek; and,
- Kizell Drain; the main tributary to Watts Creek.

Figures 3.6a and **3.6b** (located at end of the chapter) illustrates the subwatershed and catchment area boundaries.

3.8.2 Surface Water Drainage

Surface water drainage in the study area is accomplished through numerous gullies, streams and creeks of varying size and with different characteristics. For each of the principle watercourse tributaries, selected physical and hydraulic characteristics were recorded. A description of the drainage system is included in **Appendix C (Annex C-4)**.

3.8.3 Municipal and Tile Drainage Systems

Agricultural drainage through the construction/installation of tile drainage systems is quite prevalent in the mid-reaches of the Watts Creek Subwatershed. Only a very small parcel of land situated along Fourth Line Road in the Shirley's Brook Subwatershed has been tile drained. Tile drainage information was abstracted from 1:25,000 scale *"Artificial Drainage System"* maps for the Region prepared by the Ontario Ministry of Agriculture and Food (OMAF, Revised 1996).

The majority of tile drained areas within Watts Creek Subwatershed are located east of Hertzberg Road between Carling Drive/CNR and Corkstown Road. The systems are typically installed to improve drainage in isolated wet areas of agricultural fields, improve the soil structure and increase crop productivity.

3.8.4 Hydraulic Structures

A complete inventory was compiled of all culverts and bridges situated within the Shirley's Brook/ Watts Creek Subwatershed. For each structure, selected physical and hydraulic characteristics were recorded and have been summarized in **Appendix D** along with a field inventory sheet including site photographs.

3.8.5 Streamflow

Streamflows reflect the time variation in discharges and are characterized by their frequency (how often they occur), their duration (how long they last) and their magnitude (how large they are). Streamflows include peak flows generated from surface runoff caused by rainfall and snowmelt events, as well as groundwater discharges that appear as baseflow. An average year may include approximately 40 runoff producing storms (Gehrels and Mulamoottil, 1990).

The entire range (or regime) of streamflows (i.e., their frequency, magnitude and duration) controls many of the natural and ecological functions that occur in the creeks and streams present in the Subwatersheds. Low streamflows (or baseflow) sustain aquatic and terrestrial ecosystems in periods of no rain or runoff. Moderate streamflows (recurrence interval between 1:0.5 and 1:1.5 years) control the natural evolution of channel shape and form through erosion (MacRae and Rowney, 1992). Seasonal flooding, caused by spring freshets or rainfall storms, serves to infuse floodplains and wetlands with nutrients and sediments, and provides spawning opportunities for some fish species. High streamflows caused by snowmelt events and/or extreme rainfalls events, such as the 100-year event may result in flooding hazards and a risk to human life and property.

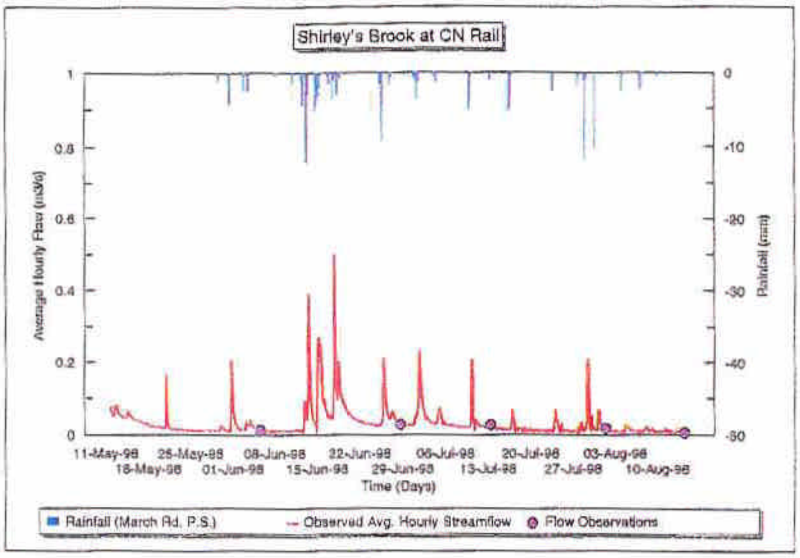
Shirley's Brook

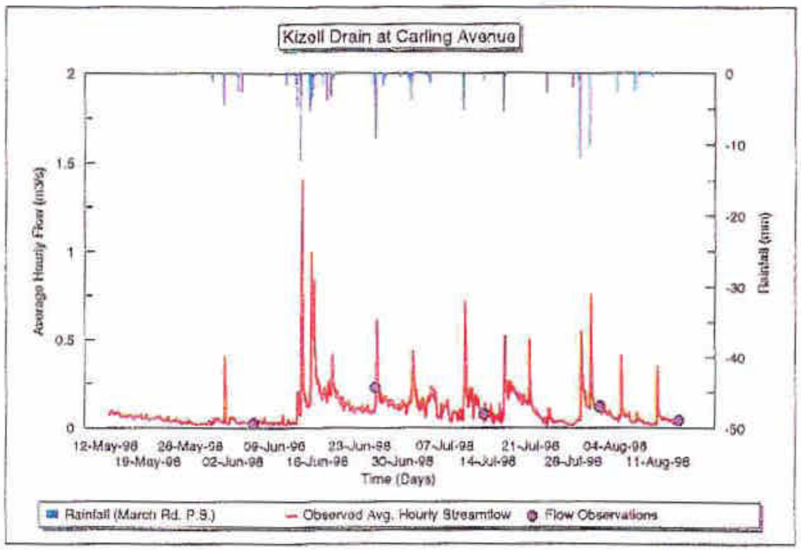
As shown in **Figure C2a (Appendix C)**, continuous measurements of streamflow were recorded at one location in Shirley's Brook upstream of Fourth Line Road at CN Rail. Data was collected and compiled over the 3 month monitoring period. In addition, spot measurements of flow were collected at the following locations:

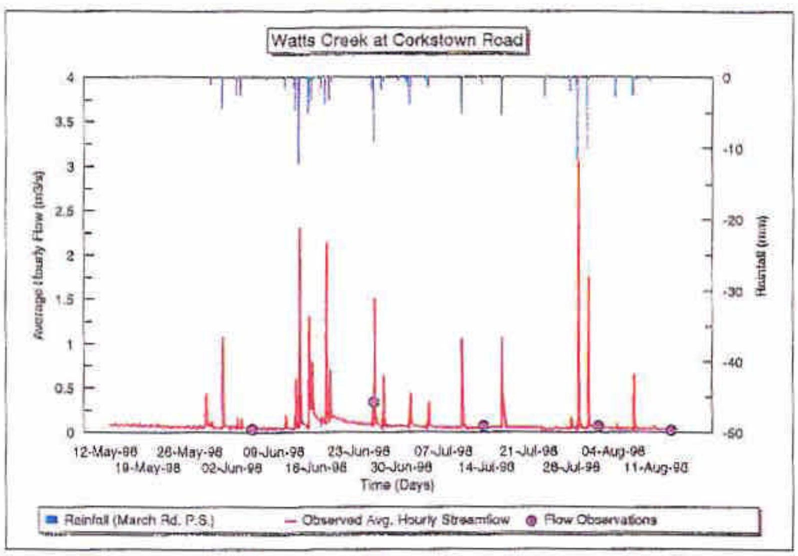
- Tributary 1: at March Road;
- Tributary 2: at March Road;
- Main Branch: Klondike Road; and
- Main Branch: at Hines Road.

The streamflow observation locations and the collected data is summarized in **Appendix C (Annex C-4)**.

Figure 3.7 displays the recorded streamflows for Shirley's Brook at the CN Rail location. At this location, average daily flows in Shirley's Brook ranged from 0.007 to 0.180 m^3/s. For the monitoring period, the maximum average hourly recorded peak flow was 0.500 m^3/s and the minimum was 0.003 m^3/s. The streamflow response to rainfall events is moderately slow; from the beginning of runoff, peak flows typically occurs within four hours for the CN Rail location. This location drains a predominately forested and agricultural area, 17.2 km^2 in size. As a result, little runoff occurs for rainfall amounts less than 9 mm, due to initial abstractions from plant interception, surface







DILLON CONSULTING

Shirley's Brook/Watts Creek
Subwatershed Study

Streamflow Monitoring Data

Figure 3.7

depressions and soil infiltration. When runoff does occur, the hydrograph response tends to be flatter (*i.e.*, less peaky) and longer in duration (refer to **Figure 3.7**).

Watts Creek

Continuous measurements of streamflow were recorded at one location in Watts Creek upstream of Corkstown Road **(see Figure C2b - Appendix C)**. In addition, spot measurements of flow were collected downstream, at Carling Avenue.

Figure 3.7 displays the recorded streamflows for Watts Creek at the Corkstown Road location. At this location, average daily flows in Watts Creek ranged from 0.029 to 0.368 m^3/s. For the monitoring period, the maximum average hourly recorded daily peak flow was 3.045 m^3/s and the minimum was 0.016 m^3/s. The streamflow response of Watts Creek to rainfall events is quite rapid; from the beginning of runoff, peak flows generally occur within one hour for the Corkstown Road location. This location drains a total area of approximately 8 km^2 of which 45% is completely urbanized with residential, business and commercial land uses. Consequently, the runoff hydrographs respond faster (*i.e.*, peaky), more frequently, with less rainfall and with higher peak flows because of the large amount of impervious surfaces (*e.g.* rooftops, driveways, roads, and parking lots) and the presence of storm sewers that convey the runoff directly to Watts Creek.

Kizell Drain

Continuous measurements of streamflow were recorded at one location in the Kizell Drain downstream of Carling Avenue **(see Figure C2b - Appendix C)**. In addition, spot measurements of flow were collected at the outlet of the Beaver Pond.

Figure 3.7 displays the recorded streamflows for the Kizell Drain at Carling Avenue. At this location, average daily flows in the Kizell Drain ranged from 0.018 to 0.463 m^3/s. For the monitoring period, the maximum hourly average recorded daily peak flow was 1.411 m^3/s and the minimum was 0.015 m^3/s. The streamflow response to rainfall events is moderately rapid; from the beginning of runoff, peak flows typically occur within 2 to 3 hours for the Carling Avenue location. This location drains a total area of approximately 6.4 km^2, 33% of which is completely urbanized with residential, business and commercial land uses. Consequently, the runoff hydrographs respond faster (*i.e.*, peaky), more frequently, with less rainfall and with higher peak flows because of the large amount of impervious surfaces and the presence of storm sewers that convey the runoff directly to the Kizell Drain.

3.8.6 Baseflow

Baseflow is recognized as an important contributor to the biological habitat quality and to the structure of aquatic ecosystems identified in Shirley's Brook, Watts Creek and the Kizell Drain. Groundwater discharge is crucial to the maintenance of baseflow and to buffering thermal changes that could otherwise impact aquatic habitat (MOEE, 1991b). In addition, high baseflow conditions can help assimilate pollutants found in urban stormwater, treatment plant effluent and agricultural runoff.

During the three months of monitoring and field reconnaissance, baseflow was identified in the three main watercourses listed above. Many of the numerous other small feeder streams and creeks are expected to convey baseflow during the spring and fall months, but for the most part, were found to be dry during the summer months between rainfall events.

Baseflows in Shirley's Brook, Watts Creek and the Kizell Drain were estimated from the continuous streamflow monitoring results in addition to spot measurements taken during the three month monitoring period. Groundwater discharge contributes to baseflow have been previously discussed.

Shirley's Brook

For the CN Rail location, average daily baseflow is approximately 10 L/s. The predominant sources of baseflow appears to be groundwater discharge, the slow release of surface water temporarily detained in the numerous wetland areas upstream and, to a very small extent, from field tiles discharging infiltrated surface water from the surrounding agricultural lands.

During the June 1998 field reconnaissance, a well flowing under artesian conditions was observed discharging into the Shirley's Brook approximately 250 m upstream of Klondike Road. In terms of baseflow, the well discharge was significant enough to augment the flow in Shirley's Brook by approximately 50%.

Watts Creek

Continuous baseflow was observed in Watts Creek extending from south of Highway 417 to its Ottawa River outlet. Based on the collected data, average daily baseflow at the Corkstown Road location is approximately 22 L/s. At this location, sources of baseflow are attributed to groundwater seepage and dry weather flow observed discharging from storm sewers (anticipated to be from groundwater infiltration into the storm sewers). For the downstream location at Carling Road, average daily baseflow is estimated at approximately 50 L/s and includes contributions from Kizell Drain.

Kizell Drain

Continuous baseflow was observed in the entire length of the Kizell Drain extending from the outlet of the Beaver Pond to its confluence with Watts Creek. Based on the collected data, average daily baseflow at the Carling Avenue location is approximately 20 L/s. At this location, sources of baseflow is from groundwater seepage and the slow release of surface water temporarily detained in the Beaver Pond, which in turn discharges into the upstream end of the Kizell Drain.

Miscellaneous Stream and Creek Tributaries

Random observations of baseflow were witnessed in some of the miscellaneous tributaries draining to Shirley's Brook and Watts Creek. Sources of baseflow in these tributaries were attributed to groundwater seepage, slowly draining surface wetlands and ponds, and to a lesser extent, agricultural field tiles. No direct measurements of baseflow were taken in the small tributaries, however these flows were estimated at less than 1 L/s. These tributaries do not contribute significantly to the baseflow in Shirley's Brook or Watts Creek and most likely dry up in the summer months.

3.8.7 Stream Temperature

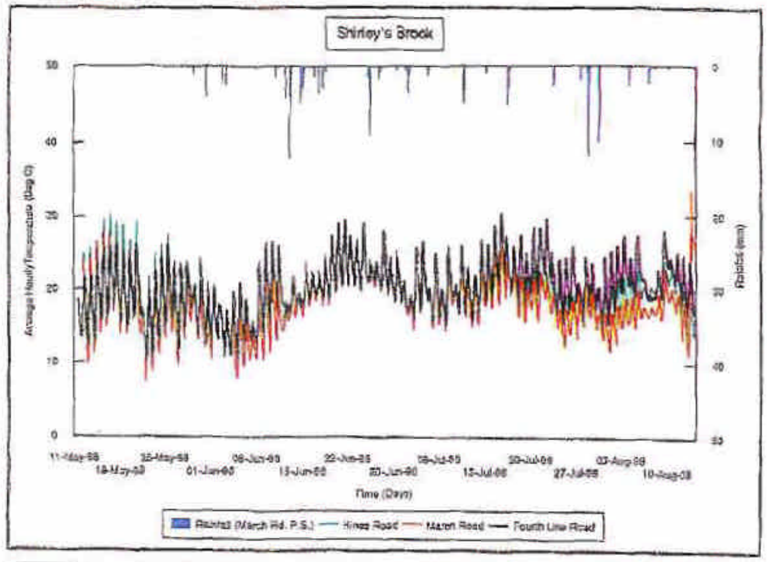
Continuous measurements of stream temperature was recorded at 7 locations within the Shirley's Brook/Watts Creek Subwatershed study area during the monitoring period (refer to **Figure C2a** and **C2b - Appendix C, Annex C-4**). The locations included the following:

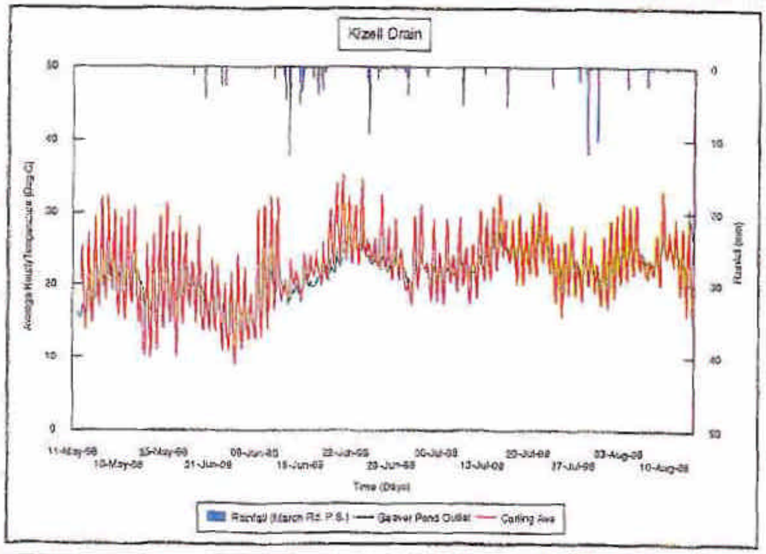
- Shirley's Brook
  - Main branch @ CNR (upstream of 4th Line) (FM-S)
  - Main branch @ Hines Road (WT-S1)
  - Tributary 2 @ March Road (WT-S2)
- Watts Creek
  - @ Corkstown Road (FM-W7)
  - @ Carling Avenue (WT-W7)
- Kizell Drain
  - @ Outlet of Beaver Pond (WT-K1)
  - @ Carling Avenue. (FM-K1).

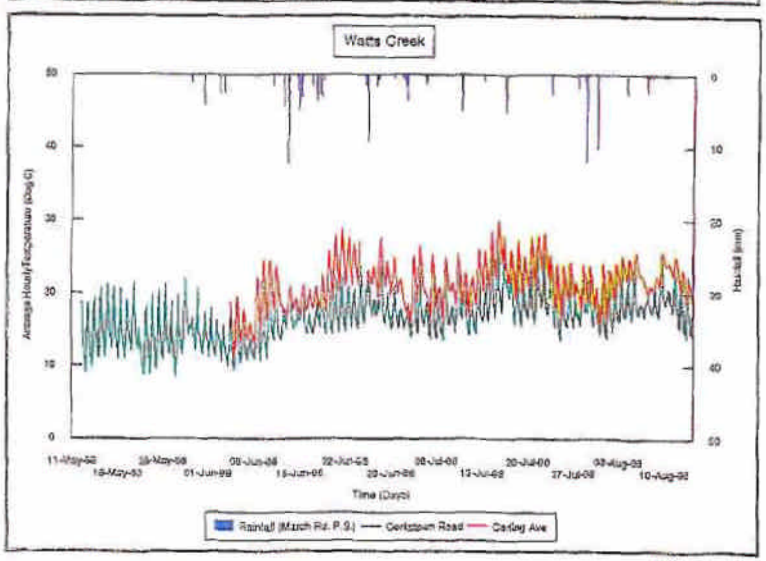
Figure 3.8 displays the recorded stream temperatures for the various locations. Minimum, maximum and average daily stream temperatures for each location are summarized in **Table C.8** in **Appendix C (Annex C-4)**.

3.8.7.1 Shirley's Brook

Based on the monitoring results, the average daily stream temperature in the upper reaches of Shirley's Brook (*i.e.*, at Hines Road) is approximately 19°C for the summer months. This cooler water temperature is attributed to the absence of upstream development which reduces thermal impacts from runoff and the presence of streamside vegetation which provides shade and cooling effects.







DILLON CONSULTING

Shirley's Brook/Watts Creek Subwatershed Study

Stream Temperature Monitoring Data

Figure 3.8

Average daily water temperature in Tributary 2 of Shirley's Brook (i.e. at March Road) exhibited similar temperature responses, but was found to be influenced by ambient air temperatures to a greater degree than those recorded for the main branch.

Further downstream at Fourth Line Road, stream temperatures rise slightly owing to the absence of streamside vegetation along the main branch extending from March Road to Klondike Road as well as thermal warming due to stormwater from impervious surfaces associated with the Kanata North Business Park and residential development. In addition, increases in stream temperature along the main branch are attributed to thermal warming of ponded water discharging from the stormwater management facilities located at Terry Fox Drive and Shirley's Brook Drive.

It is important to note that the presence of the artesian well located upstream of Klondike Road may help to mitigate the extent of the Shirley's Brook warming due to augmentation of colder groundwater discharges directly into the watercourse.

3.8.7.2 Watts Creek

Based on the monitoring results, the average daily stream temperature in the upper-mid reaches of Watts Creek (*i.e.*, at Corkstown Road) is approximately 17°C for the summer months. This cool water temperature is somewhat surprising recognizing the amount of existing urban development situated upstream. However, based on observations of continuous flow in several of the storm sewer outfalls discharging into the Watts Creek, these sources, likely are a result of human activities such as lawn watering and groundwater seepage into the storm sewer are believed to provide a source of cool water inflow.

As Watts Creek flows through its mid-reaches between Hertzberg Road to its confluence with the Kizell Drain, it is anticipated that water temperatures will remain near 17°C since the stream is generally well shaded and there is no major inputs of urban stormwater runoff. However, once Watts Creek is joined by the warmer Kizell Drain flows (see below), Watts Creek displays elevated stream temperatures averaging 21°C, as recorded at the Carling Avenue monitoring location.

3.8.7.3 Kizell Drain

Based on the monitoring results, the average daily stream temperature in the upper reaches of the Kizell Drain (*i.e.*, Beaver Pond outlet) is approximately 22°C for the summer months. This warm stream temperature is attributed in part to the warming effect of Beaver Pond, which temporarily detains runoff from upstream (including residential development areas), prior to discharging it downstream. The plotted water temperature data at the Beaver Pond outlet displayed distinct increases following rain fall events.

As the Kizell Drain flows through its mid-reaches between March Road and Hertzberg Road, stream temperatures increase, as evident by the measurements recorded at Carling Avenue. This can be attributed to the inflow of stormwater runoff from the large urban areas present between the two locations as well as the absence of watercourse shading downstream of March Road. As such, Kizell Drain at Carling Avenue displays elevated stream temperatures that on average, are maintained at 22°C.

3.8.8 Floodplain Mapping

Floodplain mapping delineating the 100 year regulatory floodplain along portions of Shirley's Brook and Kizell Drain have been prepared in 1985 by the MVCA (A.J. Robinson & Associates, 1985) as well as Watts Creek (Chrysler & Lathem Ltd.). The mapping extends along Shirley's Brook from upstream of Goulbourn Forced Road to it's outlet into the Ottawa River; Kizell Drain from upstream of the Beaver Pond to it's confluence with Watts Creek; and, Watts Creek from upstream of Highway 417 to the Ottawa River. In 1989, the previous hydrologic and hydraulic computer models were updated and the flood levels were recomputed to reflect the anticipated urbanization and the planned stormwater management facilities within the Subwatershed. **Figures 3.9a** and **3.9b** (located at end of chapter) illustrates the flood line location based on the above work. It is highlighted that the floodlines shown on **Figures 3.9a** and **3.9b** are approximate and that MVCA floodplain maps should be referred to for the exact boundary.

New floodplain mapping along Shirley's Brook and portions of Watts Creek is anticipated to be conducted in 1999 (Personal Communications; J. Price, 1998). For the purposes of this Study, the MVCA 1989 mapping was obtained and reviewed to provide insight into the identification of natural hazard areas associated with flooding. In addition, several previous studies were reviewed to assist in the identification of existing flood prone areas resulting from hydraulic deficiencies, such as inadequate channel and/or culvert capacity.

Based on the background review, several flood susceptible areas (shown on **Figure 3.9a** and b) were identified along Shirley's Brook, Watts Creek and the Kizell Drain. These areas are listed as follows:

3.8.8.1 Shirley's Brook Flood Susceptible Areas

S1 - Main branch, downstream of Fourth Line Road: out of bank flow due to insufficient channel capacity, proximity of flood plain to Fourth Line Road, and inadequate hydraulic capacity of the DND entrance culvert.

S2 - Main branch, upstream of CNR: backwater due to inadequate hydraulic capacity of CNR culvert.

S3 - Main branch, upstream of Terry Fox Drive crossing: out of bank flow and southeast spill zone to Kizell Drain due to insufficient channel capacity.

S4 - Tributary 1, upstream of March Road crossing: backwater and overtopping of adjacent farm access road due to inadequate hydraulic capacity of the March Road culvert.

3.8.8.2 Watts Creek Flood Susceptible Areas

W1 - Main branch, upstream of Sandhill Road crossing: backwater and flooding of agricultural lands due to inadequate hydraulic capacity of the Sandhill Road culvert.

W2 - Main branch, upstream of Carling Avenue: out of bank flow and east spill zone due to insufficient channel capacity and inadequate hydraulic capacity of Carling Avenue culvert.

W3 - Main branch, upstream of CNR crossing: backwater and flooding of agricultural lands extending upstream to bike path and second CNR culvert due to inadequate hydraulic capacity of the CNR culvert.

W4 - Main branch, upstream of sewer-laneway crossing: overtopping of sewer-laneway and backwater extending upstream to bike path due to inadequate hydraulic capacity of the sewer-laneway culvert.

W5 - Main Branch, upstream of Chimo Drive: backwater and north spill zone across Chimo Drive and Katimavik Road due to inadequate hydraulic capacity of Chimo Drive culvert.

3.8.8.3 Kizell Drain Flood Susceptible Areas

K1 - Main Branch, upstream of Carling Avenue crossing: backwater and flooding of upstream agricultural lands due to insufficient hydraulic capacity of the Carling Avenue culvert.

K2 - Main Branch, upstream of Legget Drive crossing: backwater and flooding of upstream agricultural lands due to influence of spill zone from Shirley's Brook.

K3 - Kizell Drain tributary, upstream of CNR: out of bank flow and overtopping of CNR due to inadequate hydraulic capacity of CNR culvert.

K4 - Kizell Drain tributary, upstream of Hertzberg Road: flooding of Digital parking lot due to out of bank flow and inadequate hydraulic capacity of Hertzberg Road culvert.

K5 - Kizell Drain tributary adjacent to W4.

3.8.9 Hydrologic Modelling

Hydrologic computer modelling of the Shirley's Brook/Watts Creek Subwatershed was conducted to characterize the existing hydrologic regime. In addition, existing land use condition peak flows were determined to provide the basis of comparison for the future land use development scenarios. In this way, potentially adverse surface water impacts could be identified and assessed as part of the technical assessment of hydrologic process and natural systems.

The modelling included specific emphasis on the main watercourses associated with Shirley's Brook, Watts Creek and Kizell Drain and included both continuous and single event modelling, which are discussed below. A more detailed description of hydrologic modelling is included in **Appendix C, Annex C-4**.

3.8.9.1 Continuous Hydrologic Modelling

Continuous hydrologic computer modelling was conducted for the Shirley's Brook/Watts Creek Subwatershed. By simulating the response of the receiving watercourse continuously, year-round, the dominant hydrologic processes such as rainfall, snowpack accumulation, snowmelt, infiltration and runoff could be represented in the time series of predicted streamflows. Continuous simulation allows for the detailed accounting of antecedent soil moisture conditions, important for the prediction of runoff peak flows and volumes. Since continuous simulation uses actual long-term historic meteorologic data, the unique temporal variations inherent in the precipitation and temperature sequences are preserved. In this way, predictions of the various hydrologic responses unique to the Shirley's Brook/Watts Creek Subwatershed can be reproduced more accurately and more characteristically, resulting in a better basis for quantifying and evaluating potential surface water impacts arising from development or other changes in land use.

Based on the results of the continuous simulations (see **Tables 3.3** and **3.4**), the following observations were noted for Shirley's Brook/Watts Creek Subwatershed:

- On average, approximately 923 mm of precipitation or, 45 million m^3/yr, falls annually on the Subwatershed. Approximately 79% falls as rain and 21% as snow. Of this volume,

TABLE 3.3
SUMMARY OF QUALHYMO MODELLING WATER BALANCE CALCULATIONS
SHIRLEY'S BROOK, EXISTING LAND USE CONDITIONS

Year	Meterological				Hydrologic											
					[1]Components					Snowpack			Streamflows			
	[2]Precip. (mm)	[3]Rain (mm)	[3]Snow (mm)	[4]Evap. (mm)	[5]Water Surplus (mm)	[6]Stream flow (mm)	[7]Surface Runoff (mm)	[8]Base flow (mm)	[9]Gndwtr Recharge (mm)	[10]Max. Depth (mm)	Date of Max. Depth	Date of Final Melt	[11]Max. Peak Flow (m^3/s)	Date of Max. Peak Flow	[12]Avg. Stream Flow (m^3/s)	[12]Avg. Base flow (m^3/s)
1986	1,088	927	167	611	477	100	73	27	404	86	Mar. 15	Apr. 1	3.6	Sept. 12	0.076	0.021
1987	908	697	207	611	297	95	60	35	237	137	Mar. 1	Apr. 8	3.5	Mar. 22	0.073	0.027
1988	869	672	195	611	258	110	72	38	186	103	Jan. 15	Apr. 1	4.2	Mar. 26	0.084	0.029
1989	829	598	257	611	218	86	58	28	160	72	Mar. 8	Apr. 1	3.7	Mar. 28	0.066	0.021
1990	1,008	815	191	611	397	127	89	38	308	86	Jan. 23	Mar. 15	4.1	Mar. 13	0.097	0.029
1991	772	610	196	611	161	76	43	33	118	84	Feb. 1	Mr. 23	1.6	Apr. 22	0.058	0.025
1992	988	775	254	611	377	107	82	25	295	122	Mar. 1	Apr. 8	5.4	Mar. 27	0.082	0.019
Average Annual	923	728	210	611	312	100	68	32	244	99	-	-	3.7	-	0.077	0.024

Note:
1. Hydrologic components expressed as depth over subwatershed area of 2412 ha (outlet of main branch).
2. Precipitation as input into the QUALHYMO model using data obtained from AES Ottawa International A Station.
3. Rain and snowfall as recorded at AES Ottawa International Airport Station. Total computed by the QUALHYMO model may differ slightly.
4. Potential evapotranspiration as input QUALHYMO model using data obtained from AES Ottawa CDA Station.
5. Water surplus is water available for runoff and infiltration, which either recharges groundwater systems and/or contributes to baseflow. Calculated as Precipitation minus Evapotranspiration.
6. Streamflow as computed by QUALHYMO model and includes runoff, interflow and baseflow.
7. Surface runoff as computed by QUALHYMO model
8. Baseflow as computed by QUALHYMO model using inputs of minimum constant flow based on streamflow measurements May to August 1998. Includes interflow.
9. Groundwater recharge calculated as difference between Water Surplus and Surface Runoff.
10. Snowfall and pack depth is expressed in terms of water equivalent for the winter/spring season.
11. Maximum annual peak flow as computed from QUALHYMO model, at subwatershed outlet.
12. Average streamflow and baseflow determined from annual depth expressed as flows.

TABLE 3.4
SUMMARY OF QUALHYMO MODELLING WATER BALANCE CALCULATIONS WATTS CREEK, EXISTING LAND USE CONDITIONS

Year[1]	Meterological				Hydrologic											
					[1]Components					Snowpack			Streamflows			
	[2]Precip. (mm)	[3]Rain (mm)	[3]Snow (mm)	[4]Evap. (mm)	[5]Water Surplus (mm)	[6]Stream flow (mm)	[7]Surface Runoff (mm)	[8]Base flow (mm)	[9]Gndwtr Recharge (mm)	[10]Max. Depth (mm)	Date of Max. Depth	Date of Final Melt	[11]Max. Peak Flow (m³/s)	Date of Max. Peak Flow	[12]Avg. Stream Flow (m³/s)	[12]Avg. Base flow (m³/s)
1986	1,088	927	167	611	477	323	194	129	283	86	Mar. 15	Apr. 1	14.0	Jul. 24	0.253	0.101
1987	908	697	207	611	297	327	154	173	143	137	Mar. 1	Apr. 8	11.6	Jul. 24	0.256	0.121
1988	869	672	195	611	258	320	177	143	81	103	Jan. 15	Apr. 1	12.9	Jun. 25	0.251	0.112
1989	829	815	191	611	218	282	141	141	77	72	Mar. 8	Apr. 1	8.6	Mar. 27	0.221	0.110
1990	1,008	598	257	611	397	395	205	190	192	86	Jan. 23	Mar. 15	16.8	Feb. 22	0.310	0.149
1991	772	610	196	611	161	303	127	176	24	84	Feb. 1	Mr. 23	5.2	Apr. 22	0.237	0.138
1992	988	775	254	611	377	320	192	128	185	122	Mar. 1	Apr. 8	16.9	Jul. 17	0.251	0.100
Average Annual	923	728	210	611	312	324	170	154	142	99	-	-	12.3	-	0.254	0.119

Note:
1 Hydrologic components expressed as depth over subwatershed area of 2471 ha (includes Kizell Drain).
2 Precipitation as input into the QUALHYMO model using data obtained from AES Ottawa International Airport Station.
3 Rain and snowfall as recorded at AES Ottawa International A Station. Total computed by the QUALHYMO model may differ slightly.
4 Potential evapotranspiration as input QUALHYMO model using data obtained from AES Ottawa CDA Station.
5 Water surplus is water available for runoff and infiltration, which either recharges groundwater systems and/or contributes to baseflow. Calculated as Precipitation minus Evapotranspiration.
6 Streamflow as computed by QUALHYMO model and includes runoff, interflow and baseflow.
7 Surface runoff as computed by QUALHYMO model
8 Baseflow as computed by QUALHYMO model using inputs of minimum constant flow based on streamflow measurements May to August 1998. Includes interflow.
9 Groundwater recharge calculated as difference between Water Surplus and Surface Runoff.
10 Snowfall and pack depth is expressed in terms of water equivalent for the winter/spring season.
11 Maximum annual peak flow as computed from QUALHYMO model, at subwatershed outlet.
12 Average streamflow and baseflow determined from annual depths expressed as flows.

approximately 611 mm/yr, or 30 million m^3/yr, is lost to evapotranspiration, leaving 312 mm/yr, or 15 million m^3/yr, for water surplus;

- Of the water surplus volume, approximately 52% is estimated to appear as direct surface runoff in Watts Creek, whereas only 22% is estimated to appear as surface runoff in Shirley's Brook. Although both subwatersheds are similar in size, the more urbanized Watts Creek Subwatershed generates 2.5 times more surface runoff than the Shirley's Brook Subwatershed. The larger runoff quantities directly influences the annual streamflow totals which, for Watts Creek, are 3.2 times higher than Shirley's Brook;

- Streamflows (which includes direct runoff and baseflow) in Watts Creek average 0.254 m^3/s per day, corresponding to 8.0 million m^3/yr (or 324 mm expressed over the Subwatershed). Of this volume, almost 48% is attributed to baseflow sources, while direct surface runoff comprises the remaining 52%. In contrast, streamflows in Shirley's Brook average only 0.077 m^3/s, corresponding to 2.4 million m^3/yr (or 100 mm expressed over the subwatersheds). Of this volume, 68% is attributed to direct surface runoff. Baseflow sources are estimated at comprising the remaining 32%;

- The maximum snowpack accumulation generally occurs between late January to early March;

- The date by which the snowpack is completely melted occurs between mid-March to early April;

- The maximum annual peak flows for the Shirley's Brook Subwatershed tend to occur, between the late winter/early spring months of March, most likely a result of snowmelt and/or snowmelt plus rainfall on saturated or frozen ground conditions. Maximum annual peak flows for Watts Creek Subwatershed generally occur in late spring and summer resulting from higher proportion of urban areas; and

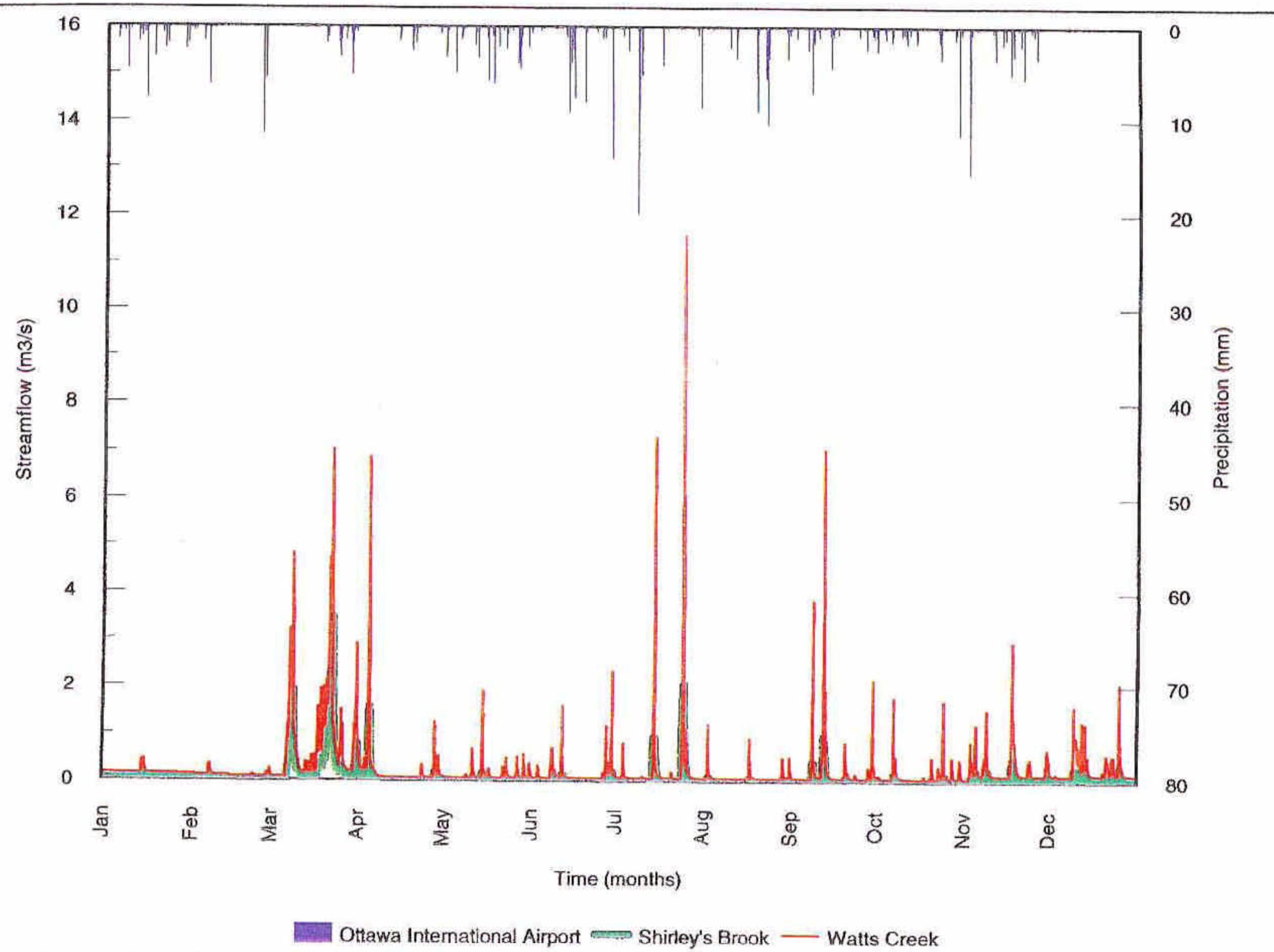
- The maximum annual hourly peak flow of 16.9 m^3/s occurring on March 27, 1992,was the highest streamflow predicted by the QUALHYMO model for the 7-year simulation period. This simulated peak flow occurred in Watts Creek, the result of rainfall, combined with snowmelt. In addition, the high peak was possibly influenced by the greater percentage of urban area present in the Watts Creek Subwatershed.

In addition, **Figure 3.10** displays hourly streamflows at the respective Shirley's Brook and Watt's Creek Subwatershed outlets for the year 1987. This year experienced an average amount of precipitation. Based on **Figure 3.10**, the following observations are noted for the respective streamflow responses:

- On average, approximately 40 runoff events occur over the period of one year. The frequency of runoff events tends to be distributed evenly through the year (although this is dependant on the distribution of rainfall events). The largest runoff event simulated occurred on July 24 resulting from a summer rainfall event;

- Streamflows in Watts Creek are very sensitive to rainfall events situated over the Subwatershed and the response is generally quite rapid. This is primarily due to the considerable imperviousness associated with the existing urban area. Streamflows in Shirley's Brook are less sensitive to rainfall events and exhibit a slower, more dampened response owing to the lack of development and the preponderance of wetlands situated in the headwater areas;

- For Shirley's Brook, rainfall events of less than 9 mm generally do not result in measurable runoff due to initial abstractions related to interception, depression storage and infiltration (prior to runoff). In contrast, the downstream locations on the Kizell Drain and Watts Creek draining the larger urban areas, tend to respond to smaller rainfall events, typically greater than 5 to 7 mm; and



Shirley's Brook/Watts Creek
Subwatershed Study

Shirley's Brook/Watts Creek 1987 Streamflows
Existing Land Use Conditons

Figure 3.10

- For Watts Creek, runoff from precipitated water (rain and/or snow melt) tends to respond quickly and in relatively large volumes, reflective of the underlying clay soils and the land use changes that have taken place. These changes include: the addition of impervious areas associated with urban development, removal of tableland forest vegetation, the installation of subsurface tile drainage systems; the construction of municipal surface drains and storm sewers; and, improved lot grading.

3.8.9.2 Single Event Hydrologic Modelling

Single event hydrologic computer modelling of the Shirley's Brook/Watts Creek Subwatershed was conducted to characterize the existing hydrologic regime so that potential off-site surface water impacts could be identified and assessed. Single event modelling uses discrete design storm events derived from rainfall statistics obtained from local climatic station data to simulate the runoff response of the subwatershed. Generally, each storm event represents a specific return period frequency (*i.e.*, probability of occurrence) based on the individual characteristics of the rainfall such as maximum average intensity, rainfall volume and storm duration. In this way, event modelling is advantageous for the assessment of potential impacts and for engineering design of drainage facilities as it represents the accepted and commonly applied engineering method for design and performance assessment.

Methodology

The calibrated QUALHYMO computer model used in the continuous simulations was also run in "event mode" using 12 hour duration SCS Type II synthetic design storm (rainfall) events derived from intensity-duration-frequency curves obtained from the AES Ottawa International Airport climatic station.

Results

Peak flows and runoff values generated from the single event hydrologic modelling for the 2-year, 10-year, and 100-year return period events are summarized for each flow location in **Table 3.5**. In addition, **Figure 3.11** displays design storm hydrographs at the watercourse outlets of Shirley's Brook, Watts Creek and Kizell Drain.

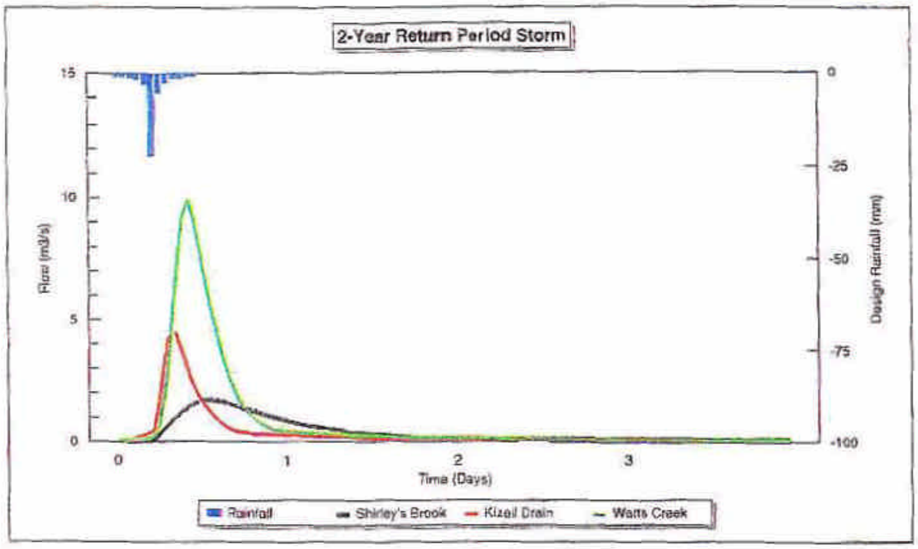
Based on these results, the following observations were noted:

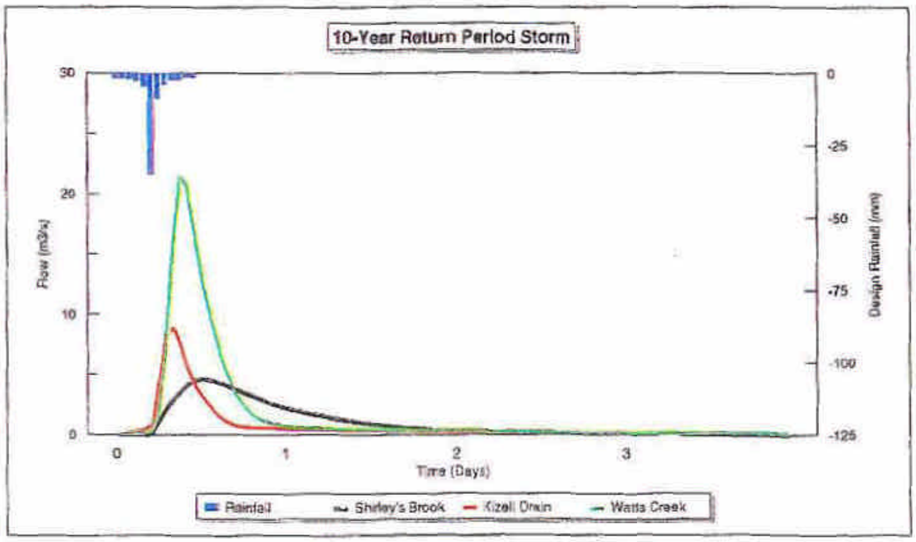
- The 100-year return period storm generates the highest peak flows analysed for Shirley's Brook, Watts Creek and Kizell Drain;
- Design storm rainfall produces lower runoff, longer duration flow hydrographs within the Shirley's Brook Subwatershed which is reflective of the rural land uses and natural attenuation associated with the upper portion of the subwatershed;
- The Beaver Pond, located at the upper reach of Kizell Drain, provides significant attenuation of peak flows generated by the upstream area up to the 100-year event. Outflows from the on-line pond are significantly lower and are maintained over an extended duration;
- Runoff generated from downstream areas of Kizell Drain is higher and responds more quickly due to the existing urban land uses;
- Runoff hydrographs for Watts Creek respond faster and peak more quickly than the hydrographs associated with the Shirley's Brook due to the higher degree of urbanization in the upper portion of the subwatershed.

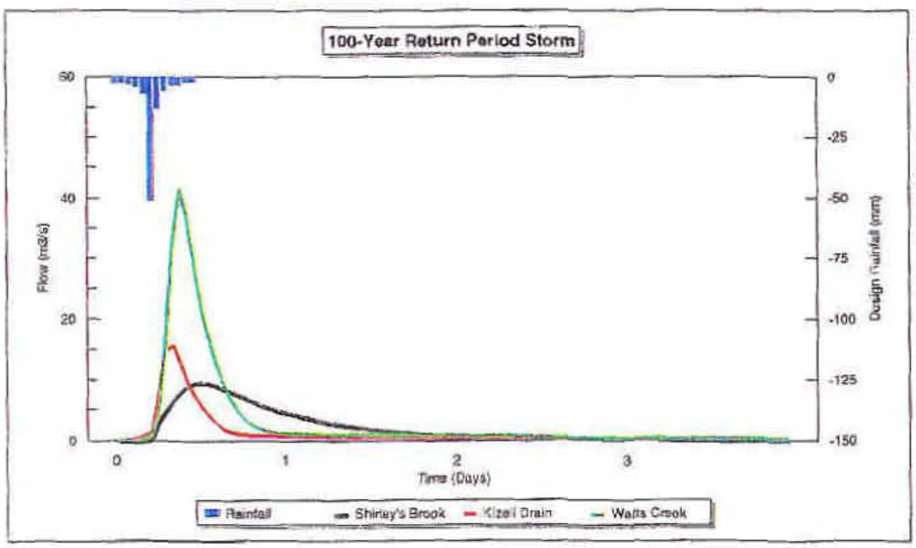
TABLE 3.5
SUMMARY OF QUALHYMO PEAK FLOWS AND RUNOFF VOLUMES FOR EXISTING LAND USE CONDITIONS

Flow Point (Refer to Fig. 3.6a and 3.6b)	2-Year		10-Year		100-Year	
	[1]PF (m^3/s)	[2]RV (mm)	PF (m^3/s)	RV (mm)	PF (m^3/s)	RV (mm)
Shirley's Brook Subwatershed						
A Shirley's Brook, Tributary 1 at March Road	0.25	4	0.72	13	1.5	27
B: Shirley's Brook, Tributary 2 at March Road	0.22	3	0.60	9	1.3	20
C: Shirley's Brook, Tributary 1 and 2 at March Road	0.47	4	1.3	11	2.8	24
D: Shirley's Brook, Main Branch at Hines Road	0.32	4	0.82	13	1.7	27
E: Shirley's Brook, Main Branch at Klondike Road	0.87	6	1.9	15	3.6	30
F: Shirley's Brook confluence downstream of Klondike Road	1.3	5	3.2	13	6.4	27
G: Shirley's Brook at Ottawa River Outlet	1.8	5	4.6	14	9.5	28
H: Shirley's Brook Tributary at Fourth Line Road	0.43	26	0.88	45	1.3	70
I: Shirley's Brook Tributary at Ottawa River Outlet	0.58	15	1.4	29	2.4	50
Kizell Drain Subwatershed						
J: Kizell Drain downstream of Beaver Pond	0.31	22	0.56	47	0.81	70
K: Kizell Drain at Carling Avenue	2.2	18	4.2	42	7.2	69
L: Kizell Drain at confluence with Watts Creek	4.4	16	8.8	35	15.7	63
Watts Creek Subwatershed						
M: Watts Creek north of Highway 417	6.1	14	11.6	27	20.5	50
N: Watts Creek at Corkstown Road	6.7	13	12.8	25	22.9	48
O: Watts Creek at confluence with Kizell Drain	6.2	11	13.7	23	24.5	44
P: Watts Creek at CNR	10.6	13	22.6	29	40.2	53
Q: Watts Creek at Ottawa River Outlet	9.9	12	21.5	27	41.6	51

Note: [1] Peak flows added internally in the model to preserve timing of peaks.
[2] Runoff volume expressed over contributing drainage area and does not include minimum baseflow constants.







DILLON CONSULTING

Shirley's Brook/Watts Creek
Subwatershed Study

Design Event Hydrographs - Existing Conditions
Shirley's Brook, Kizell Drain & Watts Creek

Figure 3.11

3.9 Stream Morphology

The science of fluvial geomorphology studies the form of watercourses and the processes responsible for creating that form. The most important processes are the movement of sediment and the movement of water through the drainage system.

The main source of sediment for the channel originates from regions of the subwatershed that are overlain by glacial till and lacustrine sediments. Low relief and proximity to Shirley's Bay contribute to the poor drainage in the lowest region of Shirley's Brook and is indicated by large areas of wetlands within this area. The Precambrian bedrock (granite, gneiss and marble) that is exposed in various parts of Kizell Drain and the middle to upper regions of Shirley's Brook is resistant to erosion and therefore does not constitute a major source of sediment. The shallow overburden, coupled with the exposed bedrock, depressional topography, contributes to the poor drainage of these regions and is expressed through the presence of bogs and marshes.

Elements within the subwatershed can modify the characteristics of the drainage basin that are controlled by geology and climate. These elements include beaver activity, riparian vegetation and surrounding land use. Modifying effects of riparian vegetation include the ability to protect the channel banks, resulting in narrower, but deeper channels than would normal be expected given flows produced from the upstream area. This is especially true in meadows, where the root density from grasses and sedges is greater than roots from mature trees.

Land use in the basin primarily effects the hydrologic cycle, by influencing the amount of runoff, infiltration and evapotranspiration. Ponds situated upstream of beaver dams are areas of deposition while the increased carrying capacity of a watercourse downstream of the beaver pond increases erosion. Beaver activity modifies the drainage process and may cause shifts in channel pattern. Changes in land use and riparian vegetation within the basin and especially along the stream corridor can affect the intricate functions between the channel and its floodplain, as well as the primary functions regarding the movement of water and sediment.

To examine the function of watercourses in a subwatershed, the main channel of a drainage network is divided into reaches. Reaches are identified on topographic maps and air photos as lengths of the channel, which display similar and physical characteristics, such as sinuosity, valley gradient, land use, and relation between channel and valley form. Once identified, historical analyses of reaches are conducted to examine both land use and channel changes. The results of these analyses, in conjunction with a rapid stream assessment of the reaches in the field, guide the detailed field work that assesses the function of a watercourse throughout its drainage basin.

Channel bank erosion is a process that occurs in most natural watercourses. When changes in the flow or sediment regimes occur, or when the platform of the watercourse has changed through natural or human influences, then excessive stream bank or bed erosion can occur. To identify sites along the drainage network where erosion is occurring, several methods are used. Air photos are examined, a rapid stream assessment is completed and detailed field work is undertaken. Through map work and air photo analyses, reaches were identified for all three subwatersheds. Given the limitations of scale on both the map and the aerial photographs, specific areas of erosion and subtle changes in stream characteristics cannot be readily identified. For this reason, a rapid stream assessment technique (RSAT) was applied to the main drainage channel within each subwatershed. The visual assessment of the main channels that are part of the drainage network allows identification of areas of erosion and instability. Further, this technique permits an evaluation of the appropriateness of map defined reach-boundaries. Results of the RSAT are used to guide the location of detailed field work, and also applied in the interpretation of the geomorphic relations based on the detailed field measures.

Based on results of all the analyses completed, five reaches were selected for detailed field investigations and long-term monitoring, and five additional reaches were selected for monitoring purposes only. In total, 2 field sites and 2 monitoring sites are situated in each of Shirley's Brook and Watts Creek and 1 field and 1 monitoring site are situated in Kizell Drain. Each of the reaches included in the field investigation or monitoring program represent areas in which erosion is occurring, natural channel adjustments are being made or the channel appeared to be relatively stable. The purpose of selecting the reaches in different settings is to gain a broad, general understanding of the different functions that the channel serves within each of the subwatersheds and the processes that are occurring in the drainage network.

As part of the field investigation, information is collected pertaining to the cross-sectional shape, the sediment characteristics, and the longitudinal profile of the channel. This information is summarized and is used in quantitative analyses of channel stability, hydraulic geometry, and erosion potential.

In total, ten monitoring cross-sections were established within the subwatersheds. Five of these cross-sections are positioned in reaches wherein detailed field work was conducted and the remainder were positioned at other locations within the subwatersheds. The purpose of these monitoring sites is to measure changes to the cross-sectional shape of the channel and to quantify erosion rates of bank materials after the passage of bankfull discharge events.

Further details on the Morphology existing conditions is contained in **Appendix C (Annex C-5).**