1.0 INTRODUCTION

1.1 Background

On January 1, 2001 the six municipalities (City of Hamilton, Town of Dundas, City of Stoney Creek, Town of Ancaster, Township of Glanbrook and Town of Flamborough) forming the Regional Municipality of Hamilton Wentworth were amalgamated to form the new City of Hamilton. Prior to amalgamation, the responsibility of the former Region for storm drainage, aside from providing engineering services to the former City of Hamilton, extended only to Regional Roads. Each of the former municipalities managed their own storm drainage system, and set its own storm drainage policies and guidelines. Local differences related to physical setting or past development resulted in differences between the polices and guidelines of the former municipalities.

A majority of the areas within the City have been managed effectively from a stormwater quantity perspective. Historical programs and associated works have included management of urbanization through flood plain management, channelization and the design and construction of flood control storage facilities. However, other aspects of stormwater management (see Figure 1.1) which relate to water quality, erosion, fisheries, groundwater and protection of natural features have, in general, not been dealt with on a comprehensive basis.

In 2003, City Council supported the initiative of coordinating all aspects of development of our community through the Building a Strong Foundation (BASF) program. One of the many integral parts of BASF is to ensure all of the City's stormwater program not only meets the current and future needs of the community and the environment, but is coordinated with the Transportation and Water / Wastewater Master Plans through the Growth Related Infrastructure Development Strategy (GRIDS) program. The GRIDS program is cognizant of VISION 2020 and with the development of the new Official Plan will ensure the objectives of BASF can be achieved. Figure 1.2 illustrates the interrelationships between these initiatives.

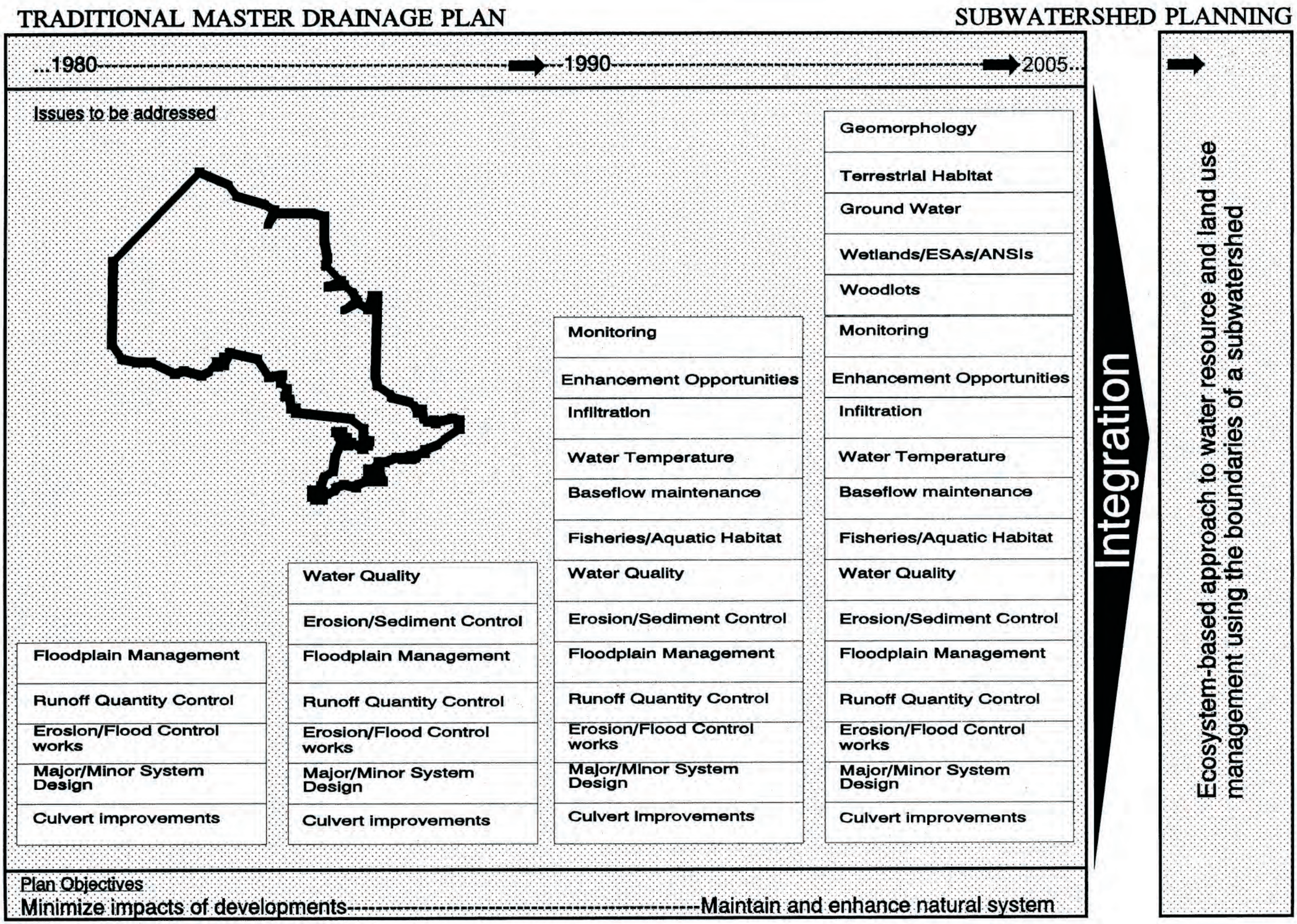


Figure 1.1 - Evolution of Subwatershed Planning

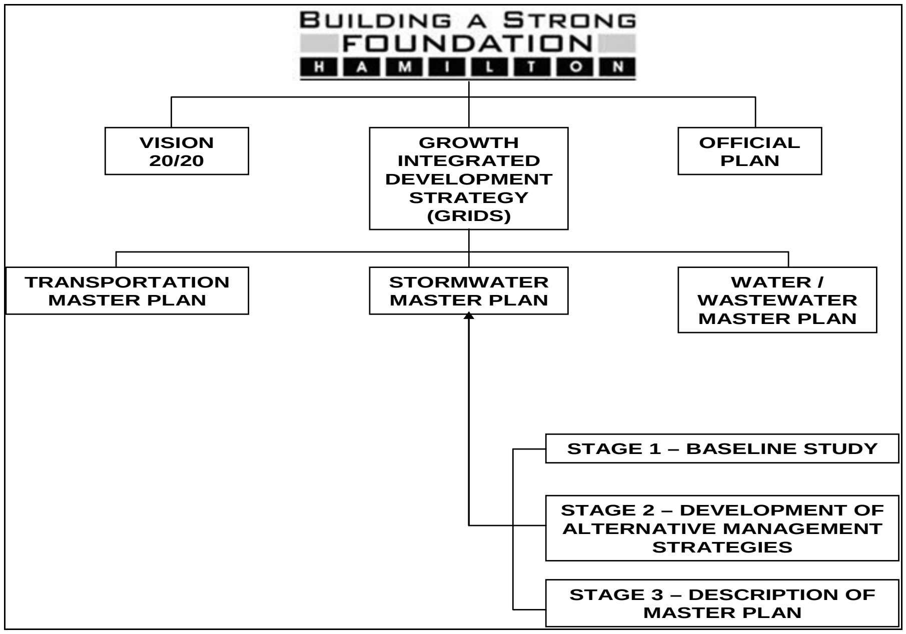


Figure 1.2: Interrelationships between City Initiatives

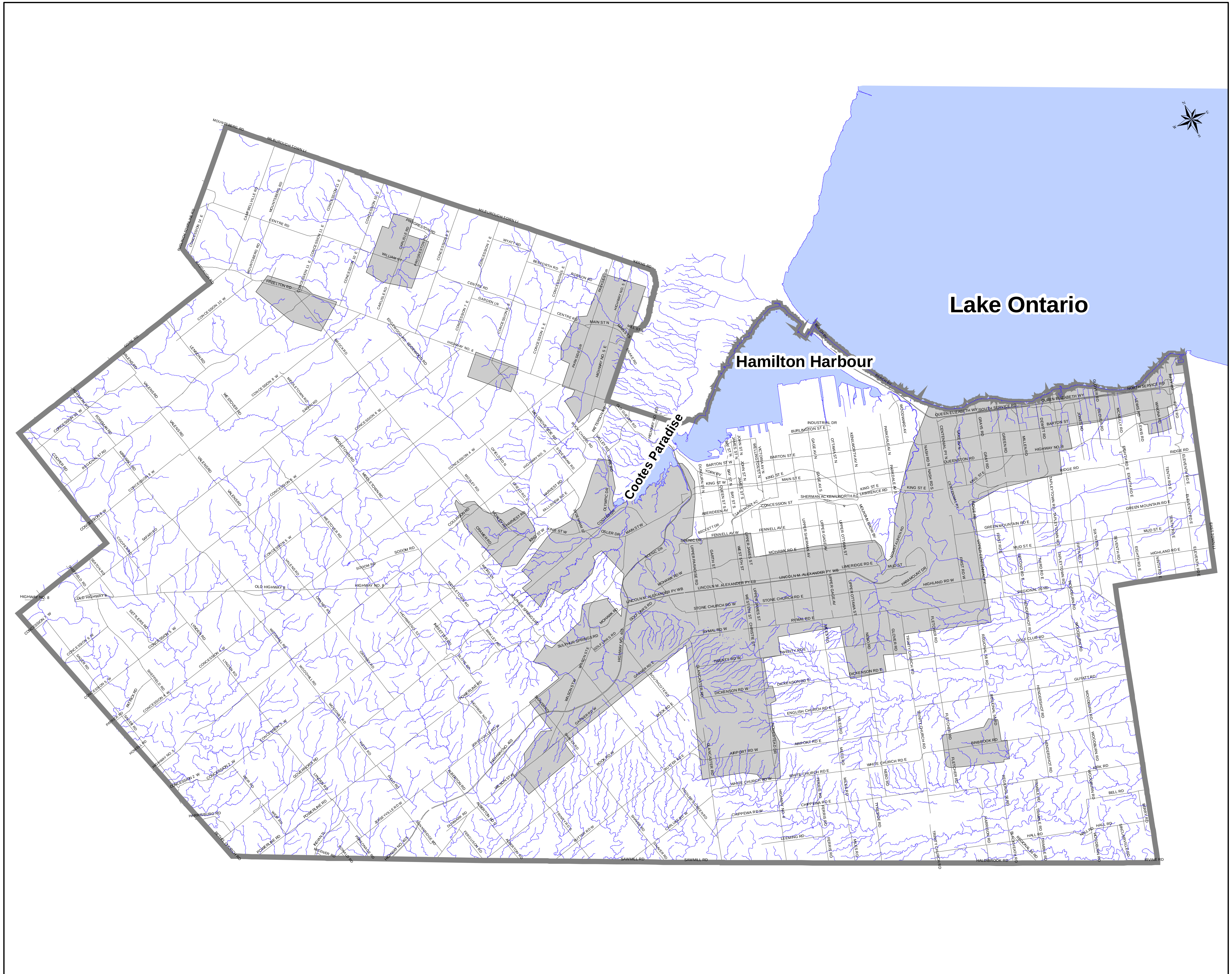
In light of the above the Stormwater Master Plan, together with the Water / Wastewater and Transportation Master Plans were initiated in 2004. The intent of the Stormwater Master Plan was to prepare a practical and implementable framework which balances the requirements of proposed and existing development with infrastructure requirements, economic, social and environmental constraints and opportunities. All three Master Plans will also be used as a basis for evaluating the social, economic and environmental impacts of Alternative Growth Scenarios as developed through the GRIDS process and to assist in the selection of the Preferred Growth Scenario.

There are two general study areas that have been defined for this study. The first area (Figure 1.3) relates to the area of the City that is serviced by separate storm sewers (the Integrated Water and Wastewater Master Plan for the Lake Based Systems will address areas serviced by combined sewer systems). This area will be considered when addressing issues relating to existing storm sewer capacity or the potential impacts of land use change on sewer capacity.

The second area (Figure 1.4) includes the entire City of Hamilton (urban and rural areas). Within the City there are 15 watersheds, and associated tributaries and creeks, as well as several receiving bodies of water including Cootes Paradise, Hamilton Harbour and the Welland River. This area was considered when assessing existing environmental conditions or impacts on the environment associated with existing or proposed land uses.

1.2 Study Overview

The Stormwater Master Plan was completed in three stages. Further description of each of the three stages, together with the relationship of this study to other initiatives within the City, is provided below. Also, as is noted in Section 1.4 all three Master Plans were carried out in conformity with the Municipal Engineers Association Class Environmental Assessment Document (MEA, 2000).



KEY MAP

LEGEND:

City of Hamilton Boundary

Approximate Study Area

NOTES:

0 2.5 5 10

Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

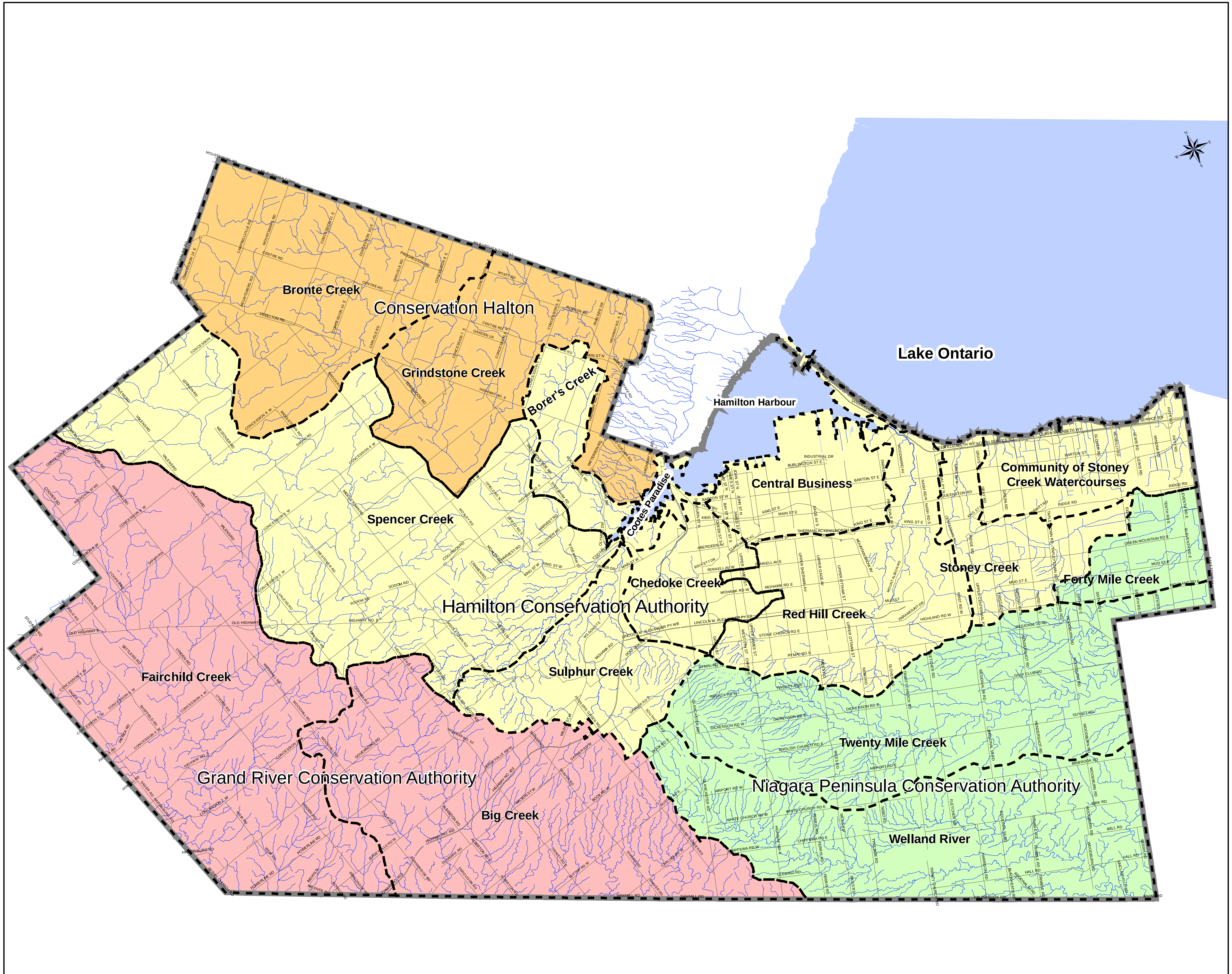
77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

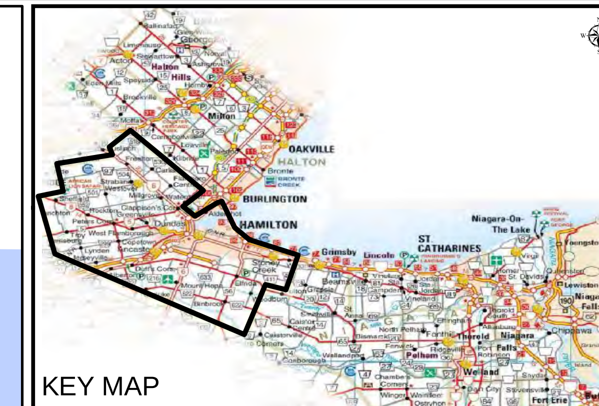
STORMWATER MASTER PLAN

Study Area for Storm Sewer System

FIGURE: 1.3

DATE: 18 April 2007





KEY MAP

LEGEND:

Watershed/Subwatershed Boundary

City of Hamilton Boundary

Jurisdiction

Conservation Halton

Grand River Conservation Authority

Hamilton Conservation Authority

Niagara Peninsula Conservation Authority

NOTES:

0 5 10

Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Study Area for Watersheds

FIGURE: 1.4

DATE: 18 April 2007

Stage 1 – Baseline Study

- Collection and review of background information
- Characterization of existing environmental conditions on a watershed basis
- Storm trunk sewer model setup and determination of existing sewer system capacity using the MOUSE sewer pipe network model
- Model setup and determination of existing flow and water quality conditions within each watershed using a spreadsheet model
- Summary of environmental conditions
- Development of study principle, goals and objectives

Stage 2 – Development of Management Strategies and Policy

- Development of long list of alternatives
- Development of storm sewer systems and flow / water quality models for impact assessment
- First Public Information Centre
- Evaluation of Alternative Growth Scenario for GRIDS
- Development and Assessment of Alternative Management Strategies
- Selection of Preferred Stormwater Management Strategy
- Second Public Information Centre

Stage 3 – Description of Master Plan

- Description of Preferred Stormwater Management Strategy
- Development of an Implementation Plan

1.3 Problem and Opportunity Identification

Urban areas may degrade the environment in many ways. Degradation may occur at the onset as lands are stripped during the construction process. This commonly results in excessive sediment loads being discharged to the receiving bodies of water.

As development of an area progresses, pollutant loadings from the urban area become significant. Common sources of pollutants include heavy metals from automobiles and air emissions, nutrients from fertilizers, bacterial contamination from human (combined sewer overflows) or animal (stormwater runoff) wastes and toxic contaminants from a variety of residential, commercial and industrial sources. Table 1.1 shows concentrations of selected constituents of stormwater runoff (City of Toronto) compared to the Provincial Water Quality Objectives (PWQO) (Aquafor, 1993).

Table 1.1: Comparison of Urban Stormwater Runoff Concentrations with Various Water Quality Criteria

Parameter	Units	PWQO	Observed Concentrations
E. Coli	CNT/100ml	100	100-160,000
Suspended Solids	mg/L	-	87-188
Total Phosphorus	mg/L	0.02	0.3-0.7
Phenolics	mg/L	0.001	0.014-0.019
Lead	mg/L	0.025	0.038-0.055
Copper	mg/L	0.005	0.045-0.46
Zinc	mg/L	0.030	0.14-0.26
Cadmium	mg/L	0.0002	0.001-0.024

The pollutants, when conveyed to the receiving bodies of water, impact the environment in many ways. The particulate (settleable) and dissolved contaminants stress aquatic ecosystems by depleting oxygen, raising ambient water temperature, covering habitat or through the bioaccumulation or bioconcentration of contaminants in the tissues of various aquatic species.

Urban development of the lands draining to the streams also results in a transformation of the hydrologic characteristics within the subwatershed (see Figure 1.5). Large amounts of previously permeable soils, which allowed rainwater to soak into the ground, are covered with impervious materials such as concentrate and asphalt. Rainfall events that previously contributed little or no runoff to the stream now cause flow to occur in the channel. Consequently, the amount of water draining to the stream increases significantly in volume.

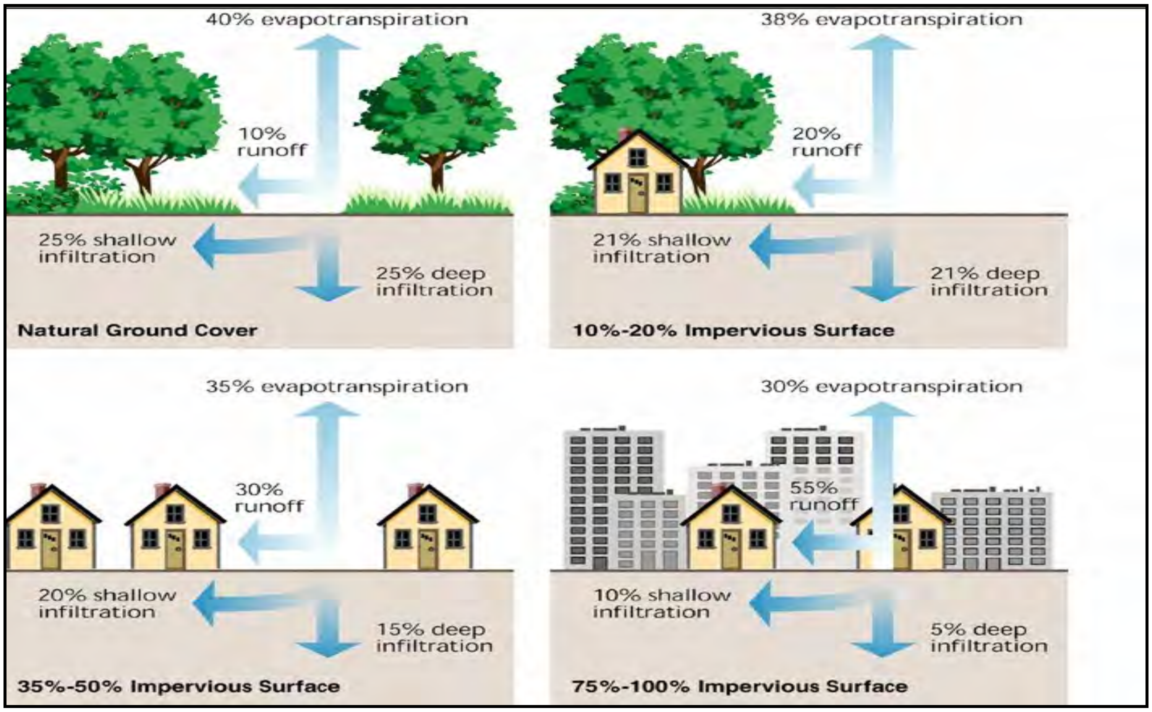


Figure 1.5: The Impact of Conventional Urbanization on the Hydrologic Cycle

Commensurate with the increase in the amount of runoff is a decrease in the time it takes for drainage water to reach the channel. Storm sewers were constructed to rapidly convey the rainwater to the stream resulting in higher flow rates in the channel.

Rural areas may also degrade the environment as a result of increased bacterial, nutrient and suspended solids loadings from farms, golf courses and nurseries.

As a result existing land uses, together with proposed land use changes, a number of potential environmental problems have been identified. These include:

1. Degraded water quality
2. Adverse effects on human and animal health
3. Loss and degradation of fish and wildlife habitat
4. Surface flooding and erosion
5. Reduction in groundwater recharge
6. Basement flooding

1.4 The Class Environmental Assessment Process

The Municipal Class Environmental Assessment (Class EA), Municipal Engineers Association (MEA), June 2000 describes the process that municipalities must follow to meet Ontario's Environmental Assessment requirements for water, wastewater and road projects, including Master Plans. The process is illustrated in Figure 1.6, and may involve up to five phases of assessment. These phases include:

- **Phase 1**: Establish the Problem or Opportunity
- **Phase 2**: Identify and Assess Alternative Solutions to the Problem, and Select a Preferred Alternative

- **Phase 3**: Identify and Assess Alternative Design Concepts for the Preferred Solution, and Select a Preferred Design Concept.
- **Phase 4**: Prepare an Environmental Study Report
- **Phase 5**: Process with Design and Implementation.

Public and agency consultation is also an important and necessary component of the above process.

The level of assessment depends on the type of project or Master Plan that a municipality is undertaking. The MEA's Class EA document classifies projects as Schedules A, B or C depending on their level of environmental impact and public concern.

- **Schedule 'A'** projects are generally routine maintenance and upgrade projects; they do not have big environmental impacts or need public input. Schedule 'A' projects are all so routine that they are generally pre-approved without any further public consultation.

- **Schedule 'B'** projects have more environmental impact and do have public implications. Examples would be stormwater ponds, river crossings, expansion of water or sewage plants beyond up to their rated capacity, new or expanded outfalls and intakes, and the like. Schedule 'B' projects require completion of Phases 1 and 2 of the Class EA process.

- **Schedule 'C'** projects have the most major public and environmental impacts. Examples would be storage tanks and tunnels with disinfection, anything involving chemical treatment or expansion beyond a water or sewage plants rated capacity. Schedule 'C' projects require completion of Phases 1 through 4 of the Class EA process, before proceeding to Phase 5 implementation.

As for particular projects, the MEA's Class EA document has identified different approaches to completing Master Plans. Four approaches have been identified, each representing different levels of assessment. However, despite the approach selected, all Master Plans must follow at least the first two phases of the Class Environmental Assessment process.

- **Approach 1**, the most common approach, is to follow Phases 1 and 2 as defined above, then use the Master Plan as a basis for future investigations of site specific Schedule 'B' and 'C' projects. Any Schedule 'B' and 'C' projects that need specific Phase 2 work and Phases 3 and 4 work, usually have this Phase 2, 3 and 4 deferred until the actual project is implemented.

- **Approach 2**, is to complete all of the work necessary for Schedule 'B' site specific projects at the time they are identified. Using this approach, a municipality would identify everything it needed in the first five years and would complete all the site specific work required, including public consultation to meet Class EA requirements. The Master Plan in such cases has to be completed with enough detail so that the public in site specific locations can be reasonably informed, and so that the approving government Agencies (Conservation Authorities, Natural Resources, Federal Department of Fisheries and Oceans, Transportation Canada etc.) can be satisfied that their concerns will be addressed before construction commences.

- **Approach 3**, is to complete the requirements of Schedule 'B' and Schedule 'C' at the Master Plan stage.

- **Approach 4**, is to integrate approvals under the EA and Planning Acts. For example, the preparation of new or amended Official Plans could be undertaken simultaneously with Master Plans for water, wastewater and transportation, and approval for both sought through the same process.

The City has selected Approach 2 for undertaking this Master Plan. The Master Plan will therefore be completed such that the level of investigation, consultation and documentation is sufficient to fulfill the Municipal Class EA requirements for the Schedule B projects identified in the Master Plan. It will also identify and fulfill any other EA requirements as identified as part of the study design for GRIDS.

Any project identified in this Master Plan must be classified as to their level of complexity which will in turn decide which Schedule process needs to be followed. As a general guideline, Schedule A projects are limited in scale and have minimal adverse environmental effects. Schedule B projects have the potential for some adverse environmental effects, while Schedule C projects have the potential for significant environmental effects.

A Master Planning approach may be followed for studies where it is expected that a series of measures will be distributed geographically throughout the study area and will be implemented over an extended period of time. This approach explicitly recognizes that there are real benefits in terms of better planning when long range holistic studies are undertaken over logical planning units, such as a subwatershed. This long range planning approach enables the municipality to identify opportunities and be proactive in addressing issues before they become a problem. It also allows the municipality to implement individual works, which collectively become part of a larger management system.

The work undertaken in the preparation of the Master Plan must recognize the Planning and Design Process of this Class EA, and should incorporate the five key principles of successful environmental planning as identified above. The documentation of the evaluation of alternatives should clearly state relevant assumptions and methods used in the analysis so that these can be verified by monitoring during the implementation phase. The Master Planning process should satisfy the first two phases in the Planning and Design Process of the Class EA.

Once the report is completed staff will request Council's endorsement prior to issuing the "Notice of Completion" and the 30-day review (Council has directed a minimum 60-day review period).

1.5 Public Consultation

The Master Plan, as presented, is consistent with the requirements of the Municipal Class Environmental Assessment process and the GRIDS process. The Public Consultation process, as summarized below, included meetings, Public Information Centres and Workshops with City staff, Conservation Authorities, Agencies, Remedial Action Plan representatives, Hamilton-Halton Homebuilders Association, stakeholders and the public. The activities that were undertaken as part of this process are described in the following chapters and are considered critical and required under the Class EA Master Planning process.

Sections 6.1, 7.3 and 9.8 summarize the objectives for each of the three Public Open Houses. Full documentation of the consultation and communication program is contained in the appendices to this report. As summarized below, an extensive public consultation program was undertaken and for the most part, was integrated with the GRIDS initiative. The consultation program also included meetings with each of the four Conservation Authorities at key intervals of the study as well as meetings with representatives from the Hamilton Harbour Remedial Action Plan Committee.

The following summarizes the consultation process which took place:

- Public Information Centre for GRIDS: May 30, 2005 at the Hamilton Convention Centre
- Stakeholder Workshop for GRIDS: May 30, 2005 at the Hamilton Convention Centre
- Public Information Centres #1: June 20, 2005 at Redeemer College; June 21, 2005 at Hamilton City Hall; June 23, 2005 at Limeridge Mall
- Stakeholder Workshops for Infrastructure Master Plans (Water/Wastewater/ Stormwater) - June 21 and 22, 2005
- Individual Meetings with the Conservation Authorities: October 15, 2005 (Niagara Peninsula Conservation Authority, Hamilton Conservation Authority), October 16, 2005 (Grand River Conservation Authority), October 21, 2006 (Conservation Halton)
- Public Information Centres #2: November 28, 2005 at the Salvation Army on Winterberry; November 30, 2005 at St. Mary's High School; December 5, 2005 at Dundas Municipal Centre
- Stakeholder Workshop for GRIDS - December 1, 2005
- Public Information Centres for GRIDS growth option: May 16, 2006 at Bishop Ryan High School; May 17, 2006 at Glanbrook Arena; May 18, 2006 at a Committee of the Whole public meeting with delegations at Hamilton City Hall
- Public Information Centres #3: September 25, 2006 at Winterberry Heights Church, September 26, 2006 at Chedoke Presbyterian Church,
- Individual Meetings with each of the Conservation Authorities: November 7, 2006 (Niagara Peninsula Conservation Authority), November 8, 2006 (Hamilton Conservation Authority, Conservation Halton), November 9, 2006 (Grand River Conservation Authority)
- Meeting with Hamilton Remedial Action Plan Representative: November 10, 2006
- Meeting with Hamilton Remedial Action Plan Committee: January 10, 2007
- Meeting with Niagara Escarpment Commission, May 2, 2007.

In addition to the above, at the onset of the project, the City of Hamilton developed a website (www.gridsmasterplans.com), where project publications, presentation materials and other documentation has been made available to the general public. Notices of upcoming Public Information Centres (PIC's) and other project milestones were also posted on this website.

For those without Internet access, the City also maintained a Contact List, and sent relevant project materials to all who had expressed interest in the process.

2.0 STUDY AREA DESCRIPTION AND EXISTING CONDITIONS

2.1 General

As noted in Section 1.1 there are two general study areas that have been defined for this study. The first area (Figure 1.3) relates to the area of the City that is serviced by separate storm sewers (the Water / Wastewater Master Plan addressed areas serviced by combined sewer systems). This area was considered when addressing issues relating to existing storm sewer capacity or the potential impacts of land use change on sewer capacity.

The second area (Figure 1.4) includes the entire City of Hamilton (urban and rural areas). Within the City there are 15 watersheds, and associated tributaries and creeks, as well as several receiving bodies of water including Cootes Paradise, Hamilton Harbour and the Welland River. This area was considered when assessing existing environmental conditions or impacts on the environment associated with existing or proposed land uses.

This chapter will initially summarize existing environmental conditions for the entire City of Hamilton (Section 2.2). It should be noted that for the purpose of this report, existing environmental conditions were based on a review of existing documents.

Section 2.4 summarizes the existing conditions for the storm sewer system.

2.2 Natural Environment

2.2.1 Natural Heritage

The following information was taken primarily from the report "Hamilton Natural Areas Inventory 2003".

The City of Hamilton is located in the transition zone between two major forest regions: the Eastern Deciduous Forest (Carolinian Zone) and the Great Lakes – St. Lawrence Forest. In addition, the area boasts an exceptionally diverse physical landscape dominated by three features: the western Lake Ontario Shoreline and Hamilton Harbour Embayment; the Niagara Escarpment cuesta, running parallel to the shoreline, but some 2 km inland; and, the Dundas Valley, a major partially buried bedrock gorge in the shoreline and Escarpment. The physical landscape also creates some diverse microclimate conditions, particularly between the Escarpment and the Lake shoreline. Consequently, the floral and faunal assemblage is diverse and includes many species that are near the northern or southern limits of their geographic range (Heagy, 1995). Aquatic, wetland and terrestrial ecological systems are represented within the City of Hamilton as follows:

- Aquatic environments, including the Lake Ontario shoreline zone, the Hamilton Harbour – Cootes Paradise embayment, numerous small watercourses draining into the Harbour, Lake Ontario, the Grand River and the Niagara River, four inland reservoirs, and some natural and artificial ponds.
- Wetland environments are generally much more prevalent here than in other parts of Southwestern Ontario, particularly in Flamborough, where extensive areas of relatively undisturbed lowland forest are present on poorly drained, shallow, rocky soils. These forests include broadleaf swamps, mixed swamps, and cedar swamps. Other wetland environments include riparian marshes and swamps, small slough forest remnants, shoreline marshes and a few kettle bogs.

- Throughout most of Hamilton, the terrestrial environment is dominated by agricultural and urban land use. The Dundas Valley and Niagara Escarpment corridors represent the largest remaining natural terrestrial habitats in the Hamilton area. Smaller, more disturbed upland areas with woodlots, plantations and old field habitats are widespread.

The natural areas of Hamilton encompass diverse natural features and serve important ecological and hydrological functions. Natural areas include both undeveloped lands (woodlots, wetlands, wildlife reserves, Escarpment lands and ravines) and previously disturbed lands that are reverting to a more natural state either spontaneously or deliberately. The present distribution of natural areas has been determined largely by geographic factors. Although no part of the area can be considered pristine, several relatively undisturbed greenspace areas remain. The largest natural areas are associated with either the Niagara Escarpment or the extensive bedrock plain found above the Escarpment in Flamborough.

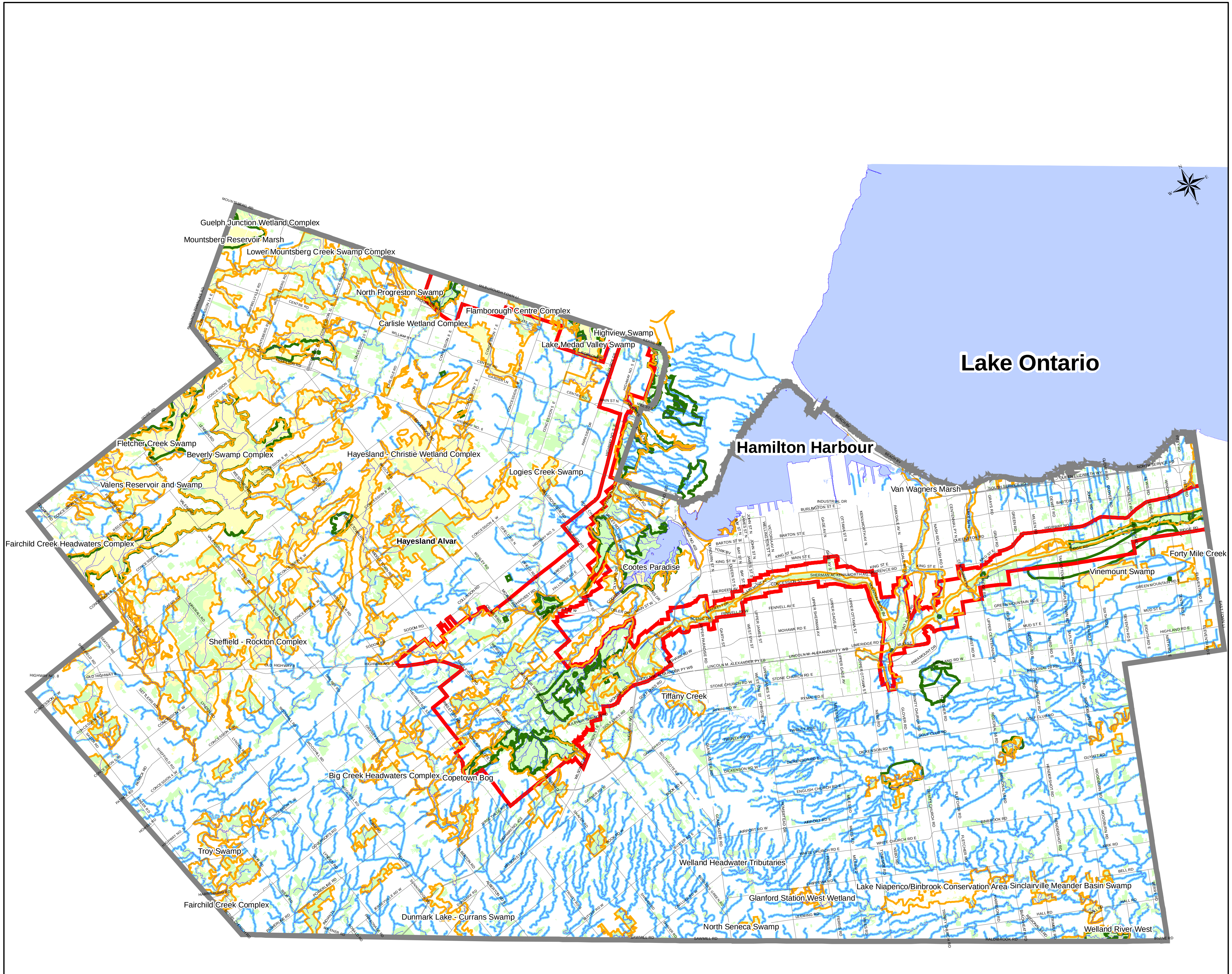
Based on the Natural Areas Inventory study, a total of 107 sites were assessed, leading to the identification of 103 Environmentally Significant Areas (ESA's). Table 2.1 provides a summary of natural heritage features within the City.

Table 2.1: Summary of Natural Areas by Special Status Designation

Area type	Number of Areas	Total Area (ha)
Earth Science ANSI's*	9	
Life Science ANSI's	13	5,438
Candidate Earth Science ANSI's*	17	
International Biological Program Areas*	5	
ESA's (including candidate ESA's)	103	20,924
Provincially Significant Wetlands	25	7,546

* Area not available

The distribution of these features is shown in Figure 2.1. There is considerable overlap among the 3 key special status areas, and as a result, the total natural area within the City with protection status is less than the sum of the individual categories. Table 2.2 provides a summary by watershed, of the area covered by designated natural features within the City.



KEY MAP

LEGEND:

- City of Hamilton Boundary
- Niagara Escarpment Planning Area
- Environmentally Significant Areas
- Provincially Significant Wetlands
- MNR Classified Forests
- Earth Science ANSI's
- Stream Corridors

NOTES:

0 5 10

Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Natural Heritage

FIGURE: 2.1

DATE: 18 April 2007

Table 2.2: Distribution of Natural Areas by Watershed

Watershed	Receiving Waterbody	Natural Areas (ha)	Watershed Area (ha)	Percent Natural Area (%)
Big Creek	Grand River	1165	12473	9.3
Borer's Creek	Hamilton Harbour	350	2092	16.7
Bronte Creek	Lake Ontario	3247	8901	36.5
Central Business	Hamilton Harbour	110	3132	3.5
Chedoke Creek	Hamilton Harbour	224	2658	8.4
Community of Stoney Creek Watercourses	Lake Ontario	442	3491	12.7
Fairchild Creek	Grand River	4172	17421	23.9
Forty Mile Creek	Lake Ontario	140	1986	7.0
Grindstone Creek	Hamilton Harbour	2274	7088	32.1
Red Hill Creek	Hamilton Harbour	905	6912	13.1
Spencer Creek	Hamilton Harbour	5868	36249	16.2
Stoney Creek	Lake Ontario	510	3079	16.6
Sulphur Creek	Hamilton Harbour	1796	4128	43.5
Twenty Mile Creek	Lake Ontario	362	10985	3.3
Welland River	Niagara River	743	10534	7.1
Total		**22308***	**131131**	**17.0***

* Numbers rounded

The largest blocks of designated features occur within the Niagara Escarpment Area and in association with several large Provincially Significant Wetlands (PSWs) occurring in the headwaters of Fairchild, Bronte, Spencer and Grindstone Creeks. A list of Provincially Significant Wetlands is provided in Table 2.3 and is shown on Figure 2.1. The Hayesland Alvar, an ESA with an area of 550 ha located in close proximity to the Hayesland – Christie Wetland complex is also shown.

Table 2.3: List of Provincially Significant Wetlands (1998)

Area Name	Size (ha)
20 Mile Creek- Wetland	30.8
Binbrook Conservation Area - Wetland	90.9
Carlisle Wetland Complex	15.0
Cootes Paradise- Wetland	121.7
Copetown Bog - Wetland	12.0
Dunmark Lake-Currans Swamp	39.2
Fairchild Creek Headwaters Complex	249.0
Flamborough Centre Complex	205.3
Fletcher Creek Swamp - Crieff Bog	525.5
Harrisburg East Swamp	45.4
Hayesland-Christie Wetland Complex	1473.09
Lake Medad Valley Swamp-Wetland	212.9
Logies Creek Wetland Complex	108.51
Lower Mountsberg Creek Complex- Wetland	299.2
North Carlisle Swamp	11.0
North Progreston Swamp	61.3
North Seneca Swamp - Wetland	10.0
Sheffield-Rockton Wetland Complex	735.2
Sinclairville Meander Basin Swamp - Wetland	37.1
Tiffany Creek Headwaters Wetland Complex	30.08
Troy Swamp	55.0
Valen's Reservoir And Swamp - Wetland	259.5
Van Wagner's Marsh	13.3
Vinemount Swamp	95.3
Welland River Area 5- Wetland	49.28

With over 7,500 ha of PSW's (mostly in the northern part of its jurisdiction), the City has a much greater representation of wetlands than the rest of southwestern Ontario. Remaining undesignated natural features are primarily limited to woodlots in the rural parts of the watersheds.

Despite having a significant number of designated natural features for an area of this size, there are a number of threats to these areas as follows:

- Aggregate extraction, particularly in the northern part of the City: this encroaches on and potentially destroys a number of wetland features and also affects local water tables and even results in localized surface water diversions that impact wetland hydrology
- Agricultural land uses: primarily encroachment on natural features and also installation of tile drainage/diversion of surface flows that change the water balance of these natural features
- Ownership: many of these features remain in private ownership and are at risk from disturbance/destruction by landowners
- Urban land uses: similar to agriculture, impacts relate to encroachment and changes to local water balance, drainage
- Fragmentation: as urban areas gradually replace agriculture, many opportunities to maintain linkages between natural features are lost, in many cases leaving only the watercourses as the primary wildlife corridors. Upland corridors are scarce in the watersheds, primarily limited to the

Niagara Escarpment Planning Area. In particular there are few linkages between features in the headwaters of the watercourses that are outside the drainage of the Hamilton Harbour – Cootes Paradise drainage area. Watercourses for the primary linkages between headwater areas and the natural heritage systems exist downstream in Bronte, Fairchild, Big, Twenty Mile, Forty Mile Creeks and the Welland River

2.2.2 Aquatic Resources

The amount of fisheries information available for watercourses within the City is variable, with most information available on watercourses in the northern part of the City and the central part (draining to Cootes Paradise and Hamilton Harbour). Information is generally sparse for Fairchild and Big Creeks (GRCA); the Welland River, Twenty Mile and Forty Mile Creeks (NPCA); and watercourses within the community of Stoney Creek.

Of equal importance as the streams in supporting fish communities, are the principal receiving waterbodies, including Cootes Paradise, Hamilton Harbour, Lake Ontario, the Grand River and the Niagara River. Both the Niagara River and Hamilton Harbour/Cootes Paradise are Great Lakes Areas of Concern identified by the International Joint Commission. In both cases, Remedial Action Plans have been developed to address aquatic environmental problems associated with these areas, and implementation of the plans is ongoing. Both Fairchild and Big Creek are actively managed as part of the Grand River Fisheries Management Plan (Zones 2 and 3 respectively).

There are several reservoirs within the City including Christie and Valens Reservoirs (Spencer Creek), Mountsberg (Bronte Creek), Lake Medad (Grindstone Creek) and Binbrook/Lake Niapenco (Welland River).

The distribution of aquatic communities is provided in Figure 2.2.

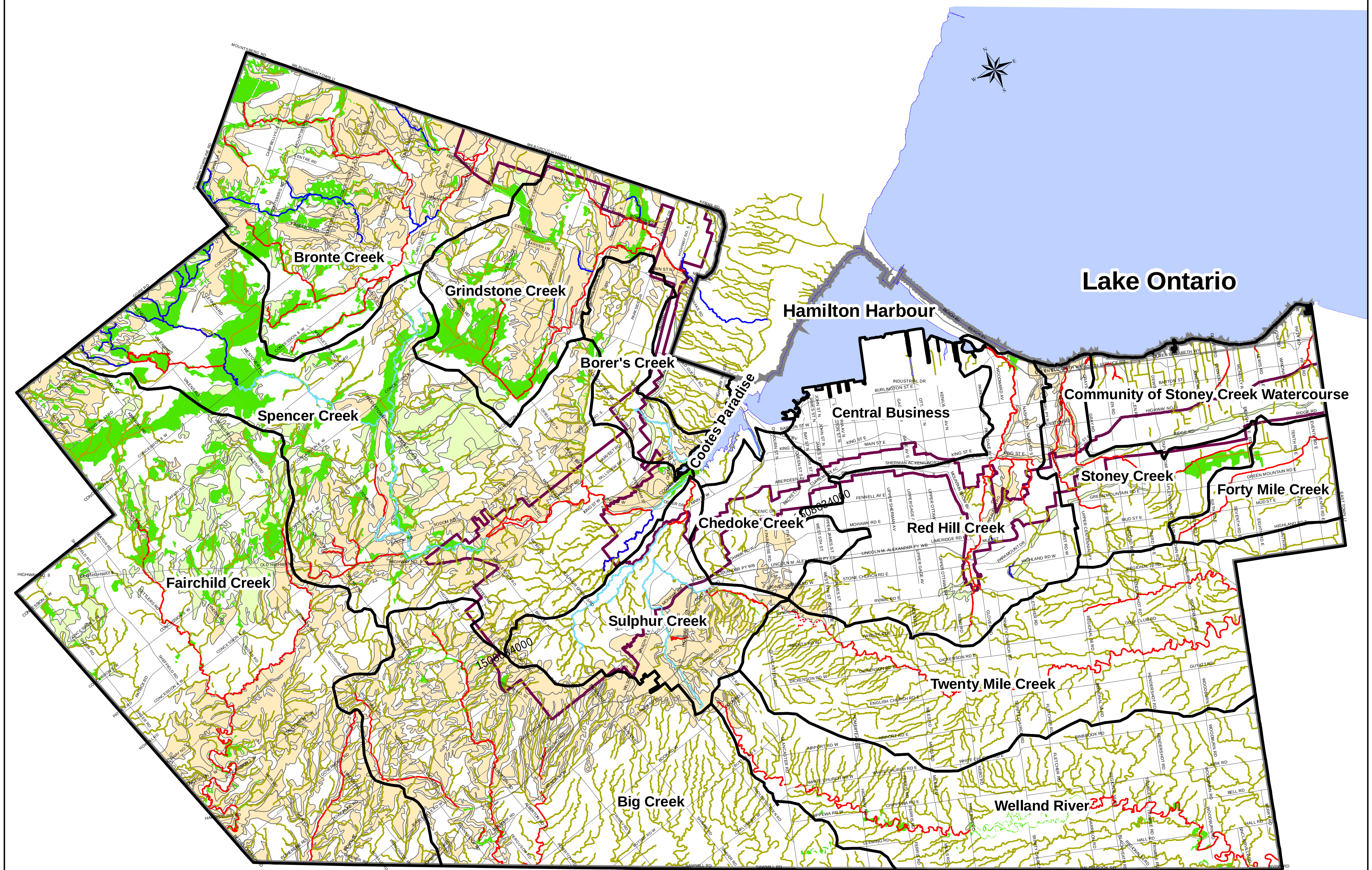
Grand River Drainage: Fairchild Creek, Big Creek

The headwaters of Fairchild Creek contain numerous wetland features, however these appear to function locally to attenuate runoff providing limited local baseflow to Fairchild Creek. The main branch of the creek within the City is considered to be a warmwater stream supporting a tolerant/diverse warmwater fish community. Many of the headwater tributaries are intermittent. Further downstream, Fairchild Creek is part of the Middle Grand Management Zone and is considered to provide an important refuge for coldwater species such as rainbow trout.

The headwaters of Big Creek within the City are characterized by numerous small drainage features that are predominantly intermittent. Big Creek is part of the Lower Grand Management Zone, which is managed for warmwater and coolwater sportfish including large and small mouth bass and walleye.

Agricultural land uses represent the primary stressors on the aquatic communities of Big and Fairchild Creeks. Key limitations include:

- Lack of baseflow
- Erosion and sedimentation of stream channels
- Lack of riparian habitat
- Water quality impacts, primarily nutrient and bacteria enrichment



KEY MAP

LEGEND:

City of Hamilton Boundary

Potential for Groundwater Recharge/Discharge

Permeable Soils

Very Permeable Soils

Niagara Escarpment Planning Area

Provincially Significant Wetlands

Aquatic Community Types

Cold

Cool

Warm

Unclassified

NOTES:

0 5 10

Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Aquatic Resources

FIGURE: 2.2

DATE: 18 April 2007

Lake Ontario South Shore/Niagara River Drainage: Forty Mile Creek, Twenty Mile Creek, Welland River

Forty Mile Creek is represented by several small headwater drainage features near the eastern boundary of the City. These watercourses are intermittent and have been altered to some degree as municipal drains. Further downstream, Forty Mile Creek supports a tolerant/diverse warmwater fish community. Key habitat limitations include:

- Lack of baseflow
- Alteration and sedimentation of stream channels
- Lack of riparian habitat
- Water quality impacts, primarily nutrient and bacteria enrichment

Twenty Mile Creek consists of two major branches and numerous intermittent headwater drainage features. The main branches are low gradient, meandering channels in ill-defined valley features. Based on historic and current fisheries inventories, the fish community of Twenty Mile Creek has changed very little in the past 30 years and is characteristically a tolerant/diverse warmwater fish community. The creek also has some unique species such as grass pickerel, that is currently being evaluated as a potential COSEWIC species. Impacts to the creek are primarily related to agricultural land uses, however there are some urban impacts related to the international airport and associated commercial development. Key habitat limitations that have been identified in the Twenty Mile Creek Watershed Plan (NPCA 2004) include:

- Lack of baseflow
- Alteration and sedimentation of stream channels
- Lack of riparian habitat
- Water quality impacts, primarily nutrient and bacteria enrichment

The Welland River headwaters, including the Binbrook/Lake Niapenco Reservoir are located within the City limits. The physiographic characteristics of the Welland River are similar to the upper Twenty Mile Creek and land use is also similar since the airport and associated commercial lands straddle the watershed boundary between Twenty Mile and Welland River. The Welland River also supports a diverse warmwater fish community, primarily as a result of the reservoir, which creates additional habitat diversity for warmwater species that prefer lacustrine habitats, including the basses, northern pike, grass pickerel, yellow perch and crappie. There is little information on the water quality/fish community of the reservoir, or on its potential effect on the downstream reaches of the river and the Niagara River. In addition, the reservoir is sensitive to sediment generation and transport from the upper watershed. Key habitat limitations include:

- Lack of baseflow
- Alteration and sedimentation of stream channels
- Lack of riparian habitat
- Water quality impacts, primarily nutrient and bacteria enrichment

Hamilton South Shore Drainage: Stoney Creek, Community of Stoney Creek Watercourses

The Community of Stoney Creek Watercourses are a number of small drainage features that drain part of the former municipality of Stoney Creek, north of the Escarpment. These features generally support a tolerant warmwater fish community with stream flows that are dominated by storm runoff.

Stoney Creek itself is a small Lake Ontario tributary that is essentially divided into 2 river segments by the Niagara Escarpment where it flows through the Devil's Punchbowl. The watercourse on the Escarpment is intermittent in nature and supports a very tolerant warmwater fish community. Downstream of the Escarpment, the watercourse is strongly influenced by Lake Ontario fish species as well as the fish community of a large pond in Confederation Park. The fish community is typically a tolerant/diverse warmwater fish community and includes a number of sensitive minnow species such as rosyface shiner and brassy minnow. Salmonids, including rainbow trout migrate into the watercourse on a seasonal basis. Key limitations to fish habitat include:

- Stormwater inputs from industrial/commercial development (water quality and quantity)
- Lack of baseflow (above the Escarpment)
- Lack of riparian vegetation
- Poor instream habitats
- Channelization

Hamilton Harbour – Cootes Paradise Drainage: Chedoke, Red Hill, Sulphur, Spencer, Grindstone and Borer's Creeks

All of these watercourses are characterized by having their headwaters on top of the Escarpment and their lower reaches flowing across glacial Lake Iroquois shore deposits before discharging into Cootes Paradise/Hamilton Harbour.

Chedoke Creek discharges into a long narrow southerly extension of Cootes Paradise adjacent to the Chedoke Parkway, with it headwaters in the vicinity of the Chedoke Golf and Ski Club and the Iroquoia Heights Conservation Area. The majority of the creek flows through parkland, including the Royal Botanical Gardens. The upper Chedoke Creek supports a very tolerant fish community and the lower Chedoke Creek supports a diverse warmwater fish community because of its proximity to Cootes Paradise.

Red Hill Creek flows for a significant portion of its length below the Escarpment and discharges into Hamilton Harbour via Windemere Basin. It flows over the Escarpment at Albion Falls and flows through the Kings Forest Park and Golf Course. Below the Escarpment, Red Hill Creek supports a tolerant warmwater fish community and has been heavily impacted by industrial land use around the harbour. A major restoration project, that includes fish habitat enhancements, is underway as part of the construction of the Red Hill Valley Parkway project. Upstream of the Escarpment (south of Lincoln Alexander Parkway), the creek supports also supports a tolerant warmwater fish community. Key habitat limitations include:

- Stormwater inputs from industrial/commercial development (water quality and quantity)
- Lack of baseflow (above the Escarpment)
- Lack of riparian vegetation (near the Harbour and upstream of the Escarpment)
- Poor instream habitats

- Channelization

Sulphur Creek is actually a tributary of Spencer Creek, joining Spencer Creek just upstream of its point of discharge to Cootes Paradise. Ancaster Creek and Tiffany Creek are major tributaries of Sulphur Creek. Tiffany, Ancaster and Sulphur Creeks have headwaters upstream of the Escarpment. Historically the upper reaches of Sulphur Creek was considered to be coldwater streams, however, currently conditions would be considered marginal to support brook trout. There are some rainbow trout in the headwaters of Sulphur Creek. The lower watercourse is also considered to provide coolwater habitat as a result of groundwater discharges that occur as the creek traverses the Escarpment. A major portion of the lower watershed is located in the Dundas Valley Conservation Area. These watercourse support a tolerant/diverse warmwater fish community downstream of the Escarpment, and in the case of Sulphur Creek in the headwaters as well, including some cool/coldwater species such as American brook lamprey and rainbow trout. The upper Ancaster and Tiffany Creeks support a tolerant warmwater fish community. There are numerous fish barriers on the upper part of Sulphur Creek. Key habitat limitations are primarily related to the portions of the watercourses upstream of the Escarpment and include:

- Lack of baseflow
- Urban construction impacts
- Alteration and sedimentation of stream channels
- Lack of riparian habitat

Spencer Creek is one of the larger watershed within the City and drains into Cootes Paradise via the Desjardins Canal, downstream of the West Pond. The majority of the watershed, particularly upstream of the Spencer Falls (where the creek falls over the Escarpment), is rural. The upper watershed also contains one of the few remaining coldwater streams within the City. A watershed plan was developed for Spencer Creek, including Sulphur and Ancaster Creeks (HCA, 1998). The watercourse is largely urban from the village of Greensville, downstream of the Christie reservoir. Headwater tributaries include Westover, Upper Spencer and Flamborough Creeks, all of which historically or currently support a coldwater fish community, including brook trout and mottled sculpin. These tributaries also historically or current support redside dace. The presence of the Valens and Christie Reservoirs have had a moderating effect on stream temperatures and also have resulted in an increase in abundance of warmwater fish species included yellow perch, northern pike and bass/sunfish species. The impact of the Christie Reservoir has resulted in Spencer Creek being classified as a warmwater stream downstream of this point. The main watercourses upstream of Christie Reservoir are considered to represent a coldwater fish community and a diverse warmwater fish community. Downstream of the reservoir, a diverse warmwater fish community exists. Most of the small tributaries above the Escarpment are either intermittent in nature, supporting a very tolerant warmwater fish community, or are dominated by cedar/tamarack swamp/wetland features and support a limited fish community including species such as redbelly dace, central mudminnow and a variety of minnow species. This wetland dominated headwater areas are limited in their ability to support fish, because they are wetland features rather than well defined watercourses. Key habitat limitations upstream of Christie Reservoir include:

- Lack of riparian habitat
- Runoff from agricultural lands
- Aggregate extraction impacting wetland features
- Nutrient enrichment from rural land uses

Key habitat limitations downstream of Christie Reservoir include:

- Lack of riparian habitat
- Erosion and sedimentation
- Stormwater discharges

Grindstone Creek discharges into Hamilton Harbour near the outlet of Cootes Paradise, after flowing through the Royal Botanical Gardens. There are several headwater tributaries of Grindstone Creek that are considered coldwater streams (the Millgrove Tributary and the Medad Tributary), although they no longer support brook trout. The main Grindstone Creek upstream of the Escarpment supports a tolerant/diverse warmwater fish community and most remaining tributaries upstream of the Escarpment are intermittent. Downstream of the Escarpment, groundwater discharge creates a cool/coldwater environment in the main creek, which is consider to support tolerant coldwater (rainbow trout) and diverse warm water fish communities. The other tributaries to the creek downstream of the Escarpment are considered intermittent. Key habitat limitations occur upstream of the Escarpment and include:

- Lack of baseflow (above the Escarpment)
- Lack of riparian habitat
- Storm drainage impact from urban areas
- Nutrient enrichment from agricultural land uses

Many tributaries of Borer’s Creek are intermittent upstream of the Escarpment, however the main stream supports a tolerant warmwater fish community that also includes northern pike and largemouth bass. Significant portions of the creek have been channelized as a result of urbanization. Downstream of the Escarpment (at Borer’s Falls), to its mouth in Cootes Paradise, the stream is largely in public ownership. It is considered to support a tolerant/diverse warmwater fish community and also has a migratory run of rainbow trout. Key habitat limitations include:

- Channelization in urban areas
- Lack of riparian habitat
- Lack of base flow
- Sedimentation and nutrient enrichment from agricultural land uses

Lake Ontario North Shore Drainage: Bronte Creek

A portion of the headwaters of Bronte Creek occur near the northern limit of the City. This includes part of Mountsberg Creek, including Mountsberg Reservoir and the East/Northeast Tributary of Bronte Creek. Bronte Creek is considered to be a coldwater stream in its lower reaches and discharges to the north shore of Lake Ontario in Oakville. Historically both the East Tributary and Mountsberg Creek were coldwater streams supporting brook trout, however brook trout are now only present in the East tributary. Both of these tributaries are also considered to support redside dace. Mountsberg Creek is considered to support a diverse warmwater fish community, although may still support remnant populations of Brook and Brown Trout. Key habitat limitations include:

- Lack of riparian habitat
- Lack of base flow (East Tributary)
- Thermal effects from Mountsberg Reservoir

2.2.3 Water Quality

Nutrients, bacteria, metals, suspended sediments and other contaminants can enter rivers and streams from a variety of sources, including:

- Excessive application of fertilizers and pesticides on rural and urban lands;
- Road runoff carrying contaminants from road maintenance, vehicle emissions;
- Contaminants in sediments eroded from urban and rural areas;
- Bacteria from domestic pets and livestock wastes;
- Improper storage and handling of chemicals in industrial/commercial/residential areas that enter storm sewers; and
- Sanitary sewage sources incorrectly connected to storm sewers.

Once in rivers and streams, these contaminants can cause degraded water quality leading to algae blooms, fish kills, beach closures, increased stress and even mortality to fish and wildlife, and poor aesthetics. Several water quality parameters that are indicators of water quality and general stream health were selected to compare the current conditions of Hamilton area streams. The following parameters were selected:

- Total Phosphorus: a nutrient that is usually in short supply in streams. High levels of Phosphorus (above Provincial Standards) can cause algae blooms, nuisance aquatic weed growths and reduce oxygen levels necessary to support fish;
- Total Suspended Solids: a measure of the amount of very fine sediment in water. Nutrients, bacteria and metals can be transported by suspended sediment from the land to streams, contributing to water quality degradation. High suspended sediment levels can also smother fish spawning grounds and impair fish respiration leading to mortality;
- E.coli Bacteria: a bacteria known to be associated with human and animal wastes that may indicate the presence of other, more harmful bacteria that can affect human health. The presence of high levels of E.coli result in swimming beach closures; and
- Copper: a metal that can cause stress and mortality to aquatic plants, fish and wildlife. It is one of several trace metals, including zinc and lead, that are often elevated in streams in urban and rural areas.

Table 2.4 summarizes the type of data which is available together with the period for which the data was collected. Water quality data is generally lacking for the other watercourses, although there is anecdotal data available for a number of locations as a result of specific water quality programs such as the Rural Beaches program, various municipal sewer outfall studies and aquatic habitat studies. In addition, there have been a number of benthic invertebrate community studies which were used to provide a relative water quality ranking of watersheds.

Table 2.4 – Summary of Available Water Quantity and Quality Data

Tributary Name	Location	Data Type	
		Flow	Phosphorus, Bacteria, Metals, TSS Concentrations
Spencer Creek	Westover	1989 to 2003	2002 to 2003
Spencer Creek	Main St.	-	1989 to 1995
Spencer Creek	Dundas	1989 to 2003	2002 to 2003
Red Hill Creek	Queenston Rd.	1989 to 1990, 1992 - 2003	2002 to 2003
Red Hill Creek	Barton St.	-	1989 to 1991, 1995, 2002 to 2003
Grindstone Creek	Unsworth	1989 to 2003	-
Grindstone Creek	Hidden Valley Rd.	-	1997 to 2001
Grindstone Creek	Mill St. S.	-	1989 to 1997
Ancaster Creek	Wilson St.	1989 to 1994, 1999 to 2003	2002 to 2003

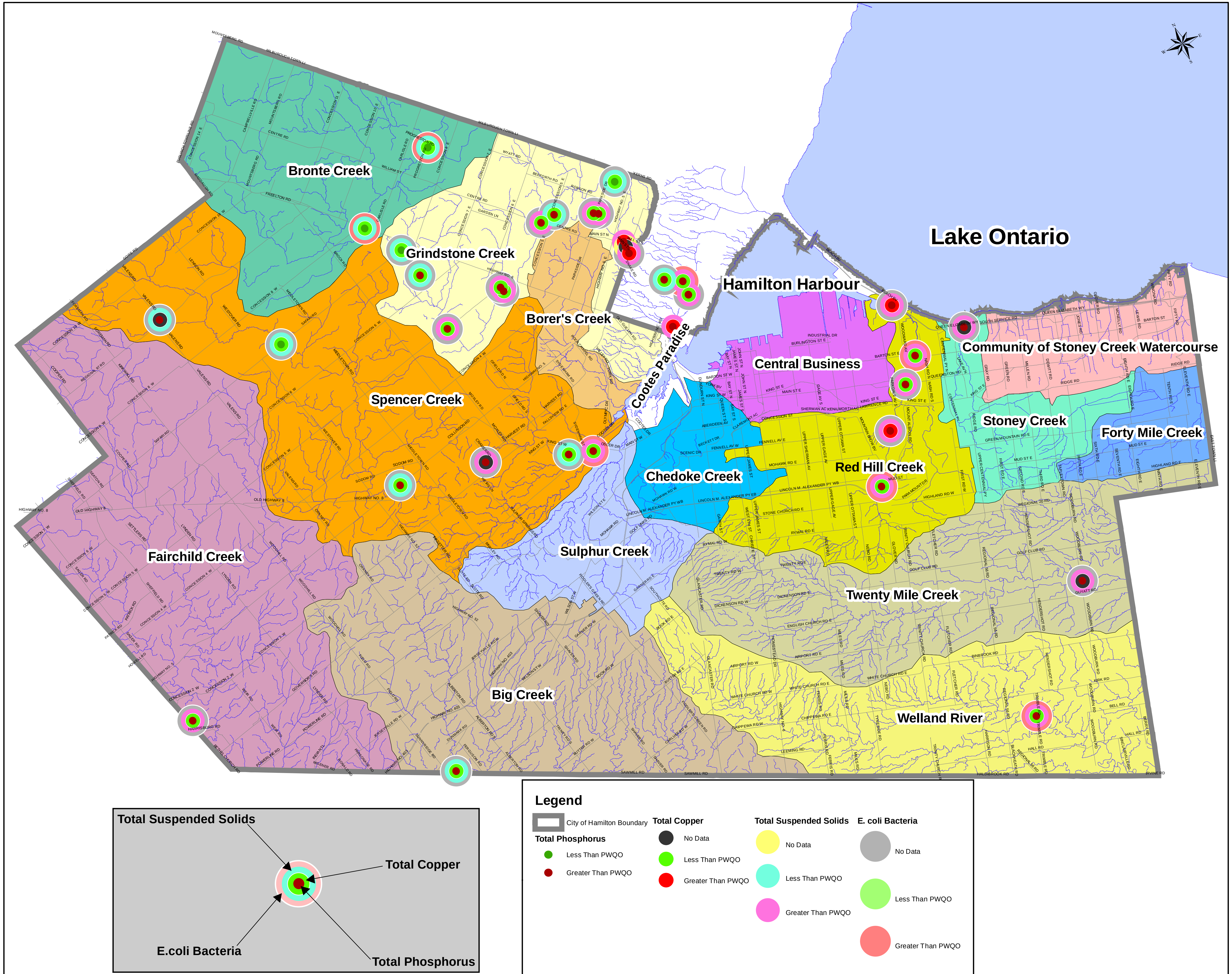
Figure 2.3 and Table 2.5 compare average concentrations of these parameters at monitoring stations in Hamilton area streams to provincial standards. These data generally show that streams exhibit moderately degraded water quality conditions.

Urban streams: Red Hill and to a lesser extent Stoney Creek have water quality stations the represent urban conditions. Total Phosphorus and E. coli consistently exceed PWQO's, while TSS and total copper generally exceed PWQO's, only during precipitation/runoff events. These conditions would also be expected in Chedoke Creek, the Community of Stoney Creek watercourses, and the urban parts of Spencer and Grindstone Creeks.

Rural streams: Spencer, Grindstone, Bronte and Twenty Mile Creeks and the Welland River exhibit water quality conditions typical of streams dominated by agricultural land uses. Generally Total Copper and E. coli concentrations are within PWQO's, while TSS and Total Phosphorus concentrations exceed PWQO's, particularly during precipitation/runoff events.

While instream water quality conditions are important in terms of impacts on stream fish communities and habitats, the annual loading of these parameters, particularly TSS and Total Phosphorus, from these streams into Cootes Paradise and Hamilton Harbour is also significant, because these contaminants contribute to eutrophication of the wetland and harbour. Likewise, annual loadings from the other watersheds to receiving bodies such as Lake Ontario, the Grand River, and the Niagara River contribute to enrichment/contamination of these waterbodies. Figure 2.4 shows estimated annual loadings for the 4 parameters of concern at the mouths or City limits for each of the watersheds in the study area, under existing conditions, based on the watershed water quality model (see Section 5.3). In general, the results can be summarized as follows:

- Total Phosphorus: the more rural watersheds (Spencer, Fairchild, Big, Welland, Twenty Mile, Bronte and Grindstone) contribute the greatest phosphorus loadings, followed by Red Hill Creek.
- Total Suspended Sediment: results show similar trend to the total phosphorus results.



NOTES:

0 5 10

Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

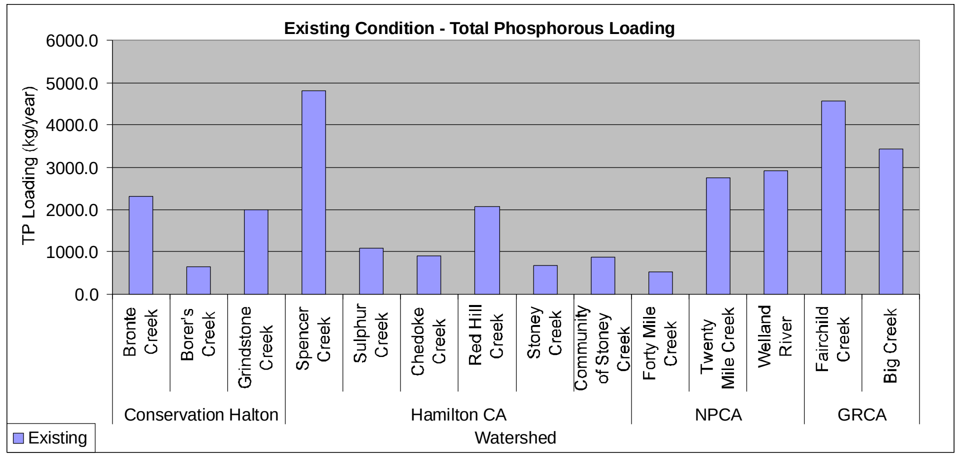
STORMWATER MASTER PLAN

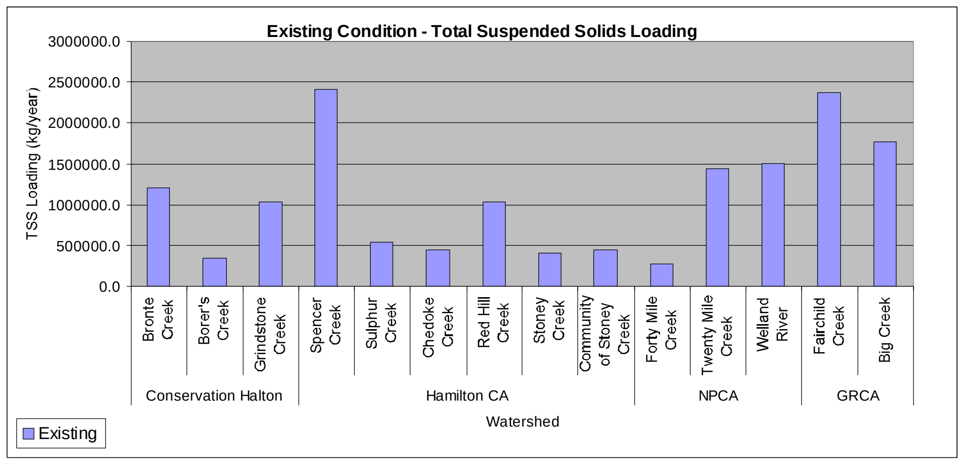
Water Quality

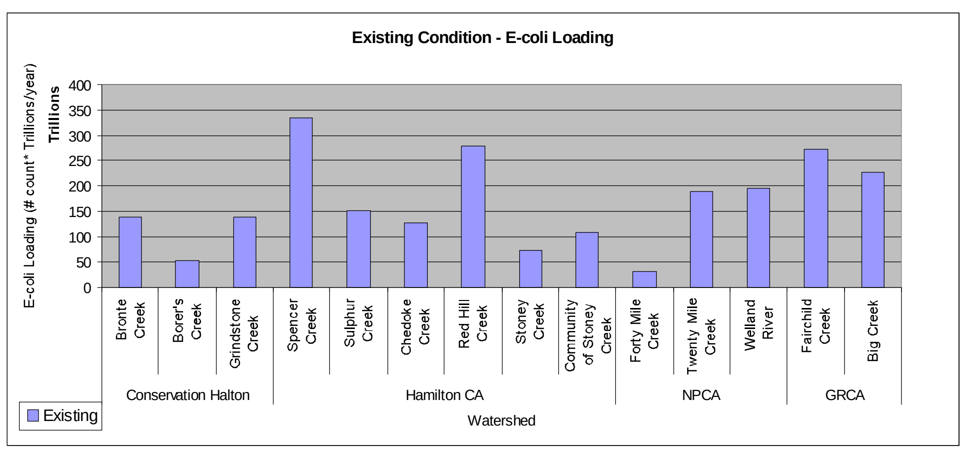
FIGURE: 2.3

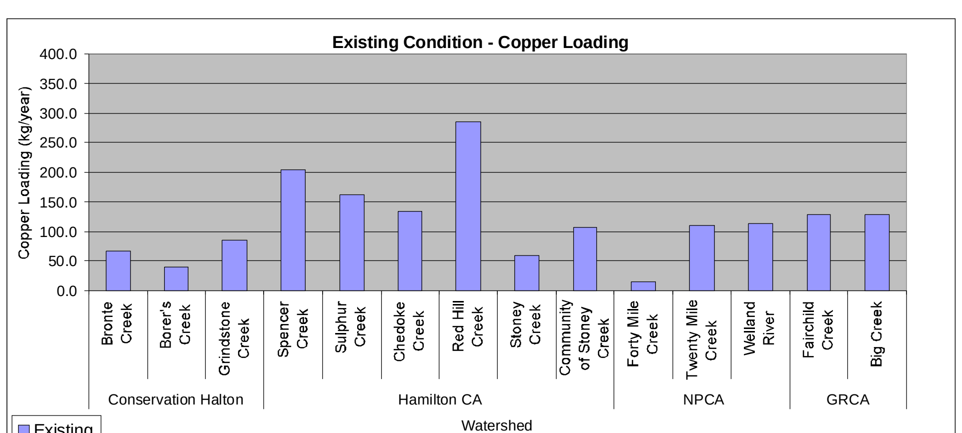
DATE: 18 April 2007

Loading

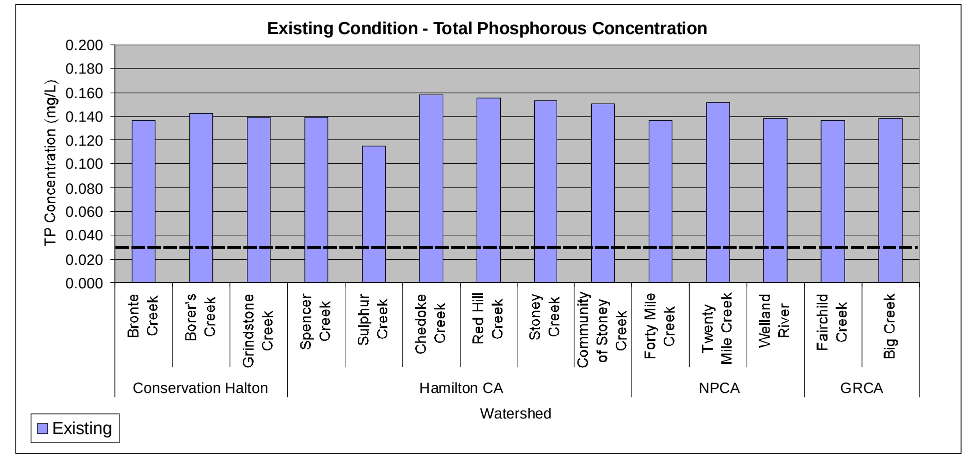


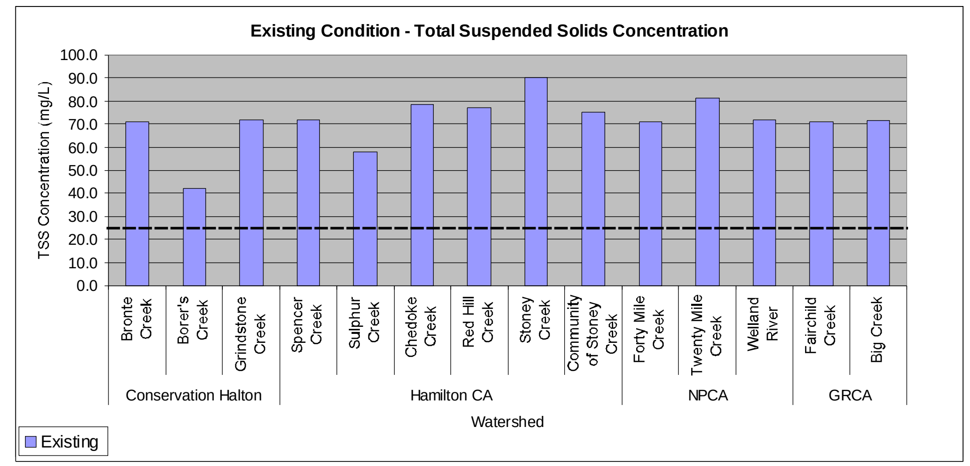


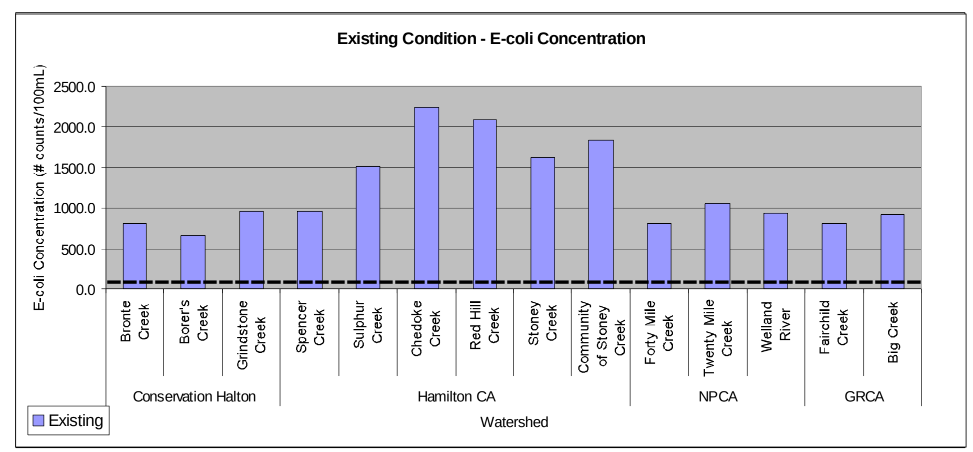


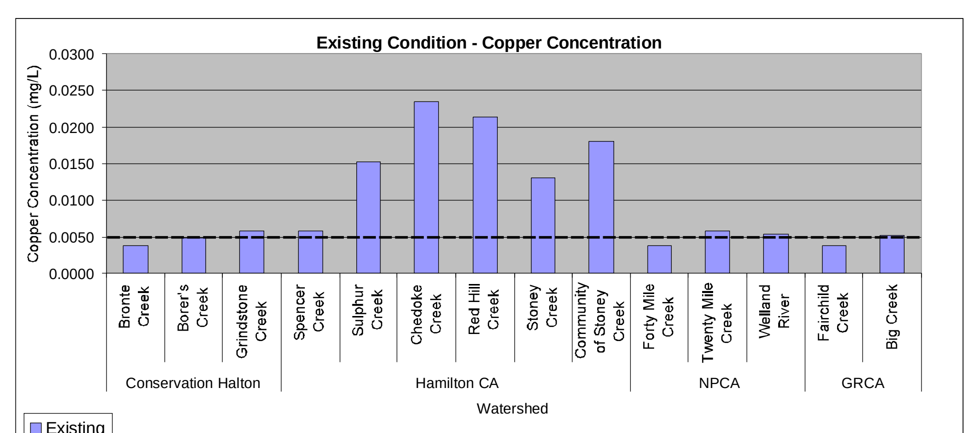


Concentration









LEGEND

------ Provincial Water Quality Objective Limit

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton, ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Water Quality Loading
Existing Conditions

Figure: 2.4

DATE: 18 April 2007

- E.coli: Spencer Creek and Red Hill Creek have the highest loadings, followed by the NPCA and GRCA watersheds, suggesting that both urban and rural sources of bacteria contribute significantly to annual loadings.
- Total Copper: Results generally reflect the urban contribution of each watershed to total copper loadings, with Red Hill, Spencer, Sulphur and Chedoke watershed contributing the greatest loading.

Table 2.5 - Dry and Wet Weather Concentrations for Watersheds within the City of Hamilton Area

Reference Site No.		1	2	3	4	5	6	7	8	Provincial Water Quality Objectives
Creek Location		Spencer Creek @ Dundas	Grindstone Creek at Unsworth Ave.	Red Hill Creek at Queenston Rd.	Sulphur Creek at Wilson St.	Bronte Creek @ Carlisle	Twenty Mile Creek @ Smithville	Fairchild Creek @ Brantford	Welland River @ Trimble Road	
Station ID		9000800502	9000902402	900100502	9000800802	F1,M1,H1302,H1602	6002400602	16018409302	11000100902	
Average Concentration (mg/L) (no. of samples)	TP / dry	0.052 (26)*	0.072 (66)	0.064 (13)	0.046 (2)	0.035 (11)	0.2286 (10)	0.1029 (24)	0.1734 (8)	0.02mg/L
	TP/ wet	0.156 (24)	0.160 (46)	0.113 (3)	0.070 (4)	0.38 (8)	0.3283 (28)	0.1674 (15)	0.1582 (6)	
Average Concentration (mg/L) (no. of samples)	Cu / dry	0.0024 (26)	0.0030 (65)	0.0032 (13)	0.003 (2)	0.002 (9)	0.0044 (27)	0.002 (24)	0.0028 (8)	0.005 mg/L
	Cu / wet	0.0042 (25)	0.0110 (42)	0.0063 (3)	0.0062 (5)	0.0023 (7)	0.0054 (11)	0.0032 (15)	0.0033 (6)	
Average Concentration (mg/L) (no. of samples)	DO / dry	8.4318 (20)	9.9465 (43)	8.4608 (12)	13.37 (1)	10.00 (18)	8.4269 (26)	8.3512 (25)	5.56 (9)	5 mg/L @ 25 deg C for Cold Water Biota
	DO / wet	10.8168 (22)	10.1147 (17)	9.4500 (2)	11.0920 (5)	8.41 (8)	8.5833 (12)	9.3773 (14)	10.6 (3)	4 mg/L @ 25 deg C for Warm Water Biota
Average Concentration (mg/L) (no. of samples)	TSS / dry	20.6925 (26)	7.2278 (27)	5.8615 (13)	6.750 (2)	7.00 (10)	25.8296 (27)	41.276 (14)	88.9 (8)	N/A
	TSS / wet	86.4320 (25)	15.3375 (16)	36.2333 (3)	9.54 (5)	9.61 (7)	72.8 (11)	78.3067 (25)	71.5 (6)	
Average Concentration (counts) (no. of samples)	E.coli / dry	1152 (20)	3007 (10)	4832 (10)	4880 (2)	86 (8)	1196 (14)	N/A	252 (8)	100 E. coil/100mL (base on a geometric mean of at least 5 samples)
	E.coli / wet	3064 (20)	916 (7)	4863 (3)	5402 (5)	425 (4)	1126 (7)	N/A	514 (5)	

(Further details in Appendix D) * Number in brackets represents number of samples

In addition to water chemistry results, that provide an indication of water quality conditions in each watercourse, collections of benthic invertebrates (stream dwelling organisms including aquatic insects, worms, crayfish, clams and snails) can be used to provide an indication of the water quality conditions in a stream. A stream quality index, BIOMAP, can be calculated by tallying up the numbers, diversity and sensitivity of each benthic invertebrate species collected at stream locations, to give a water quality score. This score generally characterizes the degree of nutrient enrichment of the stream but can also indicate the effects of other contaminants such as trace metals, pesticides or organochloride compounds that may be toxic to aquatic life. The resulting scores are grouped into the following categories:

- Unimpaired
- Moderately Impaired
- Impaired
- Severely Impaired

BIOMAP data was sampled and compiled by each conservation authority over the past several years.

Table 2.6 provides a summary by watershed of the BIOMAP results, where data exists:

Table 2.6: Water Quality Conditions Based on BIOMAP Water Quality Index

Watercourse	**Downstream of Escarpment**	**Upstream of Escarpment**
20 Mile Creek		Impaired
Welland River		Impaired
40 Mile Creek*		
Stoney Creek*		
Community of Stoney Creek Watercourses*		
Red Hill Creek	Impaired	Impaired
Chedoke Creek*		
Sulphur Creek	Unimpaired	Impaired
Ancaster Creek	Impaired	Impaired
Tiffany Creek	Unimpaired	Impaired
West Spencer/Westover Creek		Impaired
Flamborough Creek		Unimpaired
Mid Spencer Creek		Impaired
Lower Spencer Creek	Unimpaired	
Borer’s Creek	Unimpaired	Impaired
Grindstone Creek	Moderately impaired	Impaired
Mountsberg Creek		Impaired
East/Northwest Tributary Creek		Unimpaired

* No data available

BIOMAP results generally agree with water quality (chemistry) results, indicating impaired/enriched conditions in both urban areas and agricultural areas. Unimpaired conditions still exist in some watersheds, however these areas are limited to the headwaters of Spencer Creek and a number of locations on creeks immediately downstream of the Escarpment, where significant inputs of groundwater occur, i.e. Sulphur, Tiffany, Lower Spencer and Borer’s Creeks. In addition to the groundwater inputs, these stream locations are well buffered from urban/rural land uses by extensive areas of parkland or open spaces. The BIOMAP sampling locations were selected based on each conservation authorities priorities and are sampled on a routine basis.

2.2.4 Surface Drainage and Hydrology

There are numerous watersheds within the City of Hamilton that flow as far away as the Niagara River and Lake Erie. Major watersheds include:

- Lake Ontario: Bronte Creek, Forty Mile Creek, Stoney Creek, Twenty Mile Creek, Community of Stoney Creek Watercourses
- Hamilton Harbour: Borer's Creek, Chedoke Creek, Grindstone Creek, Red Hill Creek, Sulphur Creek, Spencer Creek
- Niagara River: Welland River
- Lake Erie: Fairchild Creek, Big Creek

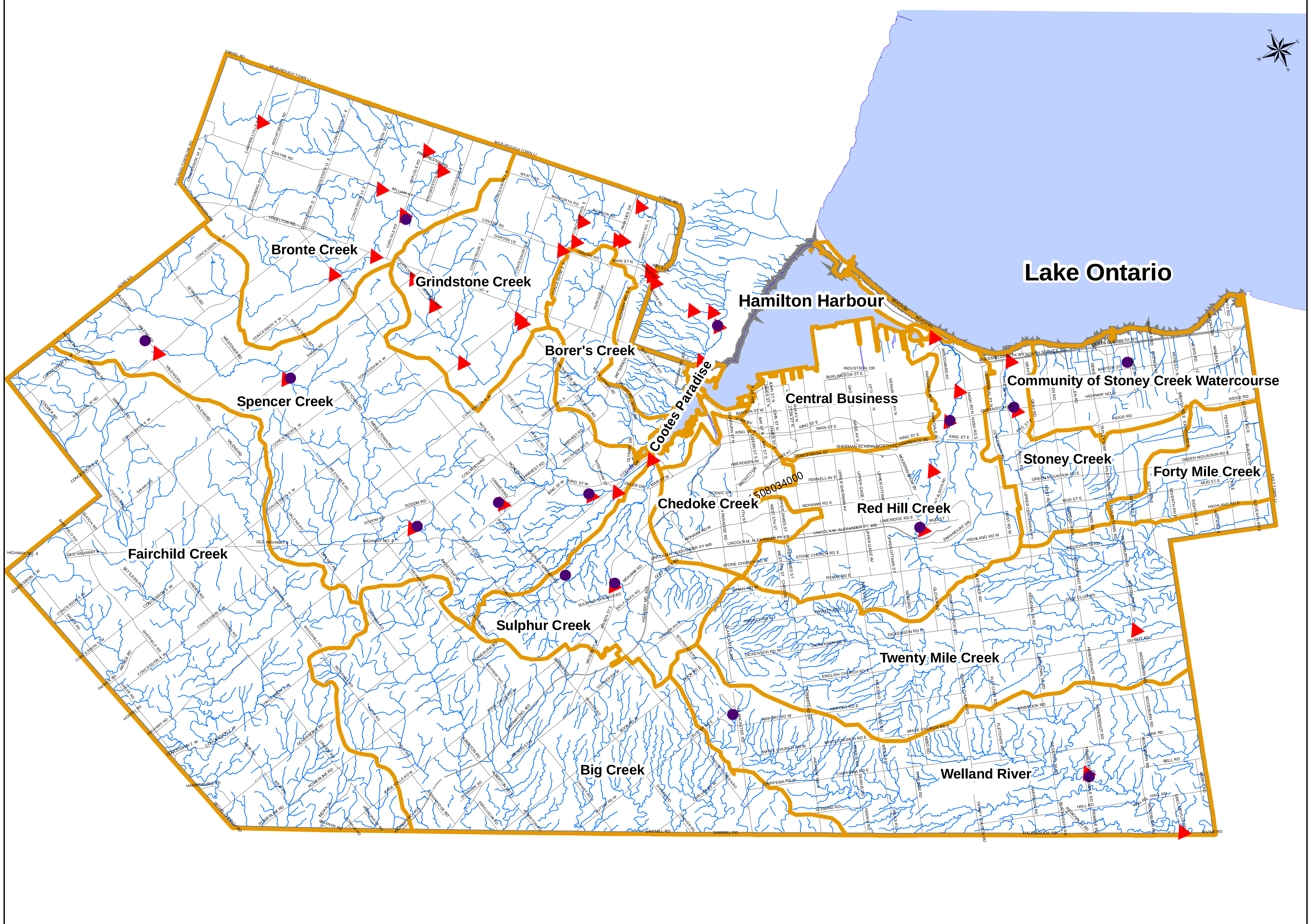
In addition, there are many smaller watercourses that drain into Hamilton Harbour, Cootes Paradise and Lake Ontario (Community of Stoney Creek). Streams are nature's infrastructure, just as roads move vehicles and sewer systems move wastewater from one place to another, streams move water and their associated sediment, nutrient and contaminant load from their headwaters (on the Escarpment) to their mouths at the harbour or lake.

The hydrologic cycle describes how water moves. Precipation reaching the ground is either taken up by plants (evapotranspiration), soaks into the ground (infiltration) entering the groundwater system or runs over the land surface to enter a creek (runoff). Stream flow is a combination of runoff and baseflow. Baseflow is groundwater that discharges into the stream. Land use change changes the proportions of runoff and baseflow entering streams. Urbanization often increases runoff and reduces baseflow in streams resulting in increased flooding and erosion and reduced baseflow. Streams with baseflows representing a large proportion of total flow often support coldwater fish communities, while streams with lower baseflows often support warmwater fish communities.

Floodline mapping has been completed by the Conservation Authorities for many of the City's streams. Floodplain mapping identifies areas subject to flooding where development is prohibited. In some areas, historic development within the floodplain has occurred.

Stream flow gauges within the City are illustrated in Figure 2.5. Information from these gauges provides an overview of stream flows which can be linked to land use. For example, Figure 2.6 shows an annual hydrograph for Spencer Creek, a mostly rural watershed and Red Hill Creek, a mostly urban watershed. Comparison of the graphs show that runoff from rural areas is generally less flashy (precipitation events enter the stream more gradually showing an inverted "V" shape) than urban areas (precipitation events enter the stream quickly showing a "pulse" or "spike" of flow). Base flow in rural streams is also generally more consistent than in urban streams, as more water is able to infiltrate into the ground in a rural stream, since paved surfaces prevent infiltration and promote rapid runoff. On an annual basis, the amount of base flow in rural streams often is greater than 20% of the total annual streamflow, while in urban streams it is often less than 20%. The relative amount of base flow and runoff or event flow in a watercourse is significant for a number of reasons:

- Surface runoff generally transports more contaminants from land surfaces to streams than base flow, meaning a greater loading of pollutants to the stream



KEY MAP

LEGEND:

- City of Hamilton Boundary
- Watersheds
- Stream Monitoring Location
- Provincial Water Quality Monitoring Location

NOTES:

0 5 10

Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Flow & Provincial Water Quality Monitoring Locations

FIGURE: 2.5

DATE: 18 April 2007

- Base flow is generally cooler than surface runoff, meaning that coldwater fish have a better chance to survive in streams with greater baseflows
- A larger proportion of surface runoff typically results in greater potential for stream flows to cause erosion, meaning that the stream may become wider and shallower and create erosion hazards to nearby properties and structures.

As one of the larger urban centres in southern Ontario, the surface drainage within the City of Hamilton is unique in that its jurisdiction straddles two significant landforms: the Niagara Escarpment, that defines an earlier lake shoreline; and the drainage divide between two Great Lakes – Lake Ontario and Lake Erie. Thus, not only are there 15 watersheds, with a total drainage area of over 131,000 ha, located within the City, but each has a significant portion of its headwaters within the City. As a result, Hamilton has a preponderance of headwater streams, which are often the watercourses that are most sensitive to land use impacts. Under current land use conditions, the majority of these headwater streams are located in the rural portions of the City. While the City is predominately rural – 61% of total land use, land use within each watershed varies considerably:

Table 2.7: Existing Land Use Characteristics by Watershed

Watershed	Urban (%)	Rural (%)
Big Creek	3.5%	96.5%
Borer's Creek	13.4%	86.6%
Bronte Creek	0.0%	100.0%
Central Business	99.8%	0.2%
Chedoke Creek	99.4%	0.6%
Community of Stoney Creek Watercourses	56.8%	43.2%
Fairchild Creek	0.0%	100.0%
Forty Mile Creek	0.0%	100.0%
Grindstone Creek	5.3%	94.7%
Red Hill Creek	80.6%	19.4%
Spencer Creek	5.1%	94.9%
Stoney Creek	27.4%	72.6%
Sulphur Creek	46.2%	53.8%
Twenty Mile Creek	4.6%	95.4%
Welland River	4.1%	95.9%

Floodplain mapping has been completed for most of the watersheds. Most flooding upstream of the Escarpment does not create hazardous conditions and is primarily associated with the large wetland features in the northern part of the City, as well as the well defined valley systems along Fairchild, Big and Twenty Mile Creeks and the Welland River. On the other hand, where watercourses cross the Escarpment and the historic lake deposits below the Escarpment, flooding and erosion hazards exist. This area also includes the majority of the urban lands in the City. There are ongoing erosion and flooding concerns (including some areas with basement flooding issues) in the following watercourses, downstream of the Escarpment: Borer's, Sulphur, Ancaster, Red Hill and Chedoke Creeks. There are also localized flooding problems in Stoney Creek and the Community of Stoney Creek Watercourses. Localized flooding and erosion problems also occur in some of the rural settlement areas, and both the Welland River and Twenty Mile Creek have flood damage centres located downstream of the City of Hamilton.

There are several reservoirs that serve a flood control function within the City including Christie and Valens Reservoirs (Spencer Creek), Mountsberg (Bronte Creek), Lake Medad (Grindstone Creek) and Binbrook/Lake Niapenco (Welland River).

The City updated their Development Charges in 2006 that included estimated costs for stormwater management facilities and erosion control works, updated from the 2004 study. Approximately $43 million was identified for erosion control works associated with new development, however only a portion of this total was considered recoverable through Development Charges. In total, 53 sites were identified for erosion control works in the following areas:

- Waterdown
- Ancaster
- Hamilton Mountain
- Mount Hope
- Upper Stoney Creek
- Binbrook
- Lower Stoney Creek

This work did not address existing erosion problems within the urban area.

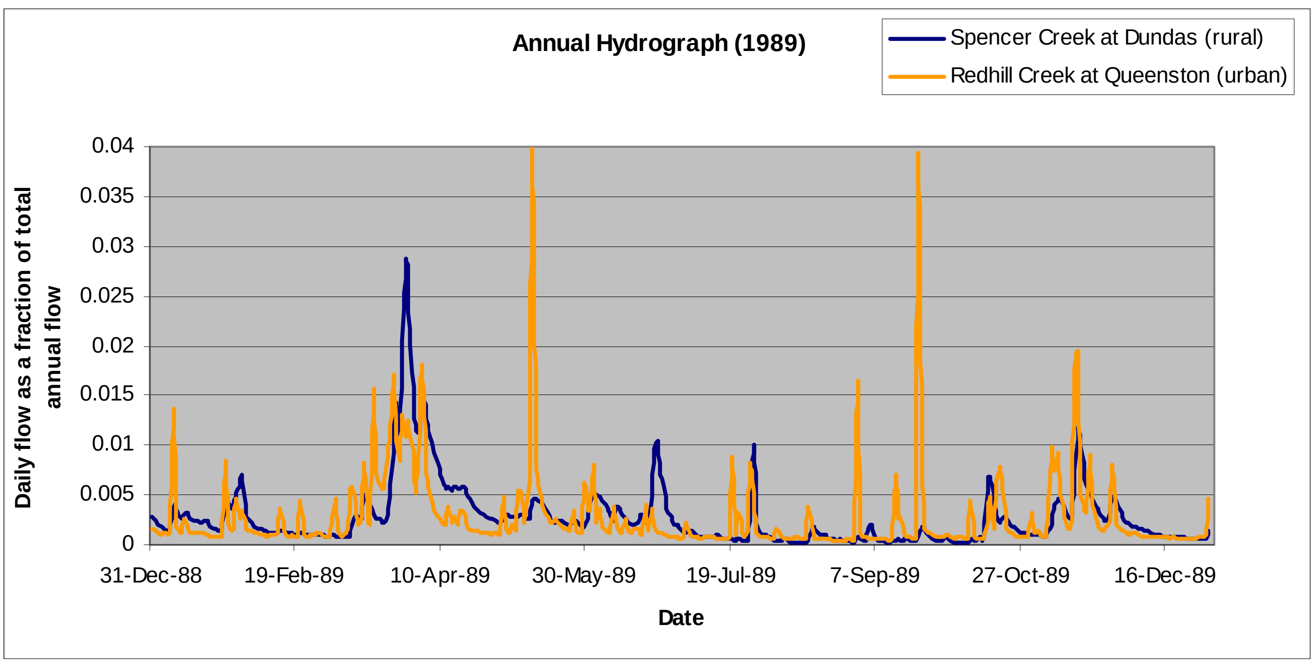


Figure 2.6: Annual hydrographs from a rural (Spencer Creek) versus an urban (Red Hill Creek) stream

2.2.5 Geology, Physiography and Soils

Material for this section was taken primarily from the report "Hamilton Groundwater Resource Characterization and Wellhead Protection Partnership Study" (SNC Lavalin, 2004).

Physiography

Portions of the following physiographic regions, as described by Chapman and Putnam (1984), occur within the study area:

- Niagara Escarpment,
- Iroquois Plain,
- Flamborough Plain,
- Horseshoe Moraines, and
- Norfolk Sand Plain.

The Niagara Escarpment extends through the study area in a westerly direction from Stoney Creek in the southeast end of Hamilton to a point west of Dundas from where it then runs east-northeast to Waterdown. It is a bedrock Escarpment characterized by steep cliffs on the eastern side and gently sloping terrain to the west. Extending back from the Escarpment, the surficial deposits overlying the dolostone bedrock are generally thin to non-existent. The configuration of the Escarpment is greatly influenced by the Dundas Valley, within which the old City of Hamilton is located. It is of pre-glacial origin and extends inland for about 13 kilometers from the western edge of Lake Ontario. It contains a major buried valley and creates a re-entrant feature within the Escarpment. There are no large streams within the valley, however, there are a number of smaller streams that have dissected the drift and nearby Red Hill Creek occupies another pre-glacier valley. From the Dundas valley northward, the crest of the Escarpment increases in elevation, and is cut by numerous creeks, including Bronte Creek. A broad band of red shale is exposed beneath the dolostone and the long lower slopes for the Escarpment are highly eroded.

Between the foot of the Escarpment and Lake Ontario is the Iroquois Plain that resulted from the inundation of the area by glacial Lake Iroquois. The Iroquois Plain consists of lacustrune deposits and lake-bottom sediments that have been smoothed by wave action and which extend around the western end of Lake Ontario through the study area. The width of the plain is about 3 kilometres in the study area, and it is cut by a number of creeks, with lagoons or marshes near their outlet to the lake.

The Flamborough Plain is a small area of shallow drift overlying the dolostone rocks that outcrop at the top of the Niagara Escarpment, and is bounded to the northwest by the Galt Moraine. A few drumlins are scattered over this plain and swamps are plentiful. The underlying dolostone is exposed in places, particularly near the edge of the Escarpment on its eastern border. The little overburden that is present is either bouldery glacial till or sand and gravel. The Beverley Swamp and other small swamp features provide flow to Spencer and Bronte Creeks. The dolostone bedrock of the Flamborough Plain is a major aquifer supplying the Carlisle and Freelton municipal wellfields.

The Haldimand Clay Plain occupies the area from the Niagara Escarpment to Lake Erie in the south portion of the study area. A glacial lake covered this area and, as a result, at some locations stratified clay overlies clay till and there are also intermixed layers of till and stratified clay. The overburden thickness increases southward from the Niagara Escarpment. The Horseshoe Moraines constitute a long system of moraines that skirts the west edge of the study area. The deposits are mixed till, kame, and sand and gravel terrace deposits. Some of the moraine is very hilly with significant local relief.

Between the Horseshoe Moraines and the Haldimand Clay Plain there are glaciolacutstrine sand deposits which make up the Norfolk Sand Plain and overly the upper reaches of the Dundas Valley. The bedrock within the centre of the Dundas Valley is believed to be about 105 m below sea level and the valley has been traced southwestward into the Branford area (Karrow and Sprague, 1975) where it connects to the Grand River valley. Karrow (1987) suggests the valley was cut by an earlier form of the Grand River and then deepened by glacial action.

Geology

The Quarternary Geology of the study area closely parallels the Physiography. The lacustrine deposits of the Iroquois Plain are found along the Lake Ontario shoreline, and extend from Hamilton towards Burlington. Sand and gravel bars also occur and there are alluvial fan gravels at the outlet of the Dundas Valley. Halton till mantles the Escarpment north of Burlington and through Dundas, over the Dundas Valley, and extending along the south shore of Lake Ontario through Stoney Creek and Grimsby. Areas of Queenston Shale are exposed along the slopes of the Escarpment where gullies have cut through the Halton Till, and fairly extensively along the south shore of the Lake. Above the Escarpment, from the City's eastern boundary to west of Lynden, there are deposits of lacustrine sand. Through Flamborough, the bedrock surface is covered by a thin veneer of sand or is exposed at the surface. Further north, dposits from the Wentworth Till, a stoney sandy silt till, occur along with northwest to southeast trending drumlins and deposits of the Galt Moraine along the northwest boundary of the study area. Glacio lacustrine gin grained sediments (silt and clay) occur in much of the southern portion of the study area, encompassing most of Glanbrook, the southern portion of Ancaster, and extending along the western City boundary.

Paleaozoic Geology

The oldest bedrock in the study area includes the Georgian Bay formation (which does not outcrop in the study area but lies beneath the Queenston Formation) and the Queenston formation that outcrops extensively between the base of the Escarpment and the Lake Ontario shoreline. It is also exposed as reddish brown mudstones and shales at the Escarpment base with a thickness of about 140 m. The remaining bedrock units are of Silurian age and are exposed along the face of the Niagara Escarpment and outcrop or subcrop up to 70 km west of the Escarpment.

The Silurian bedrock shows considerable variation throughout the study area, thus making it difficult to represent the study area in one cross section. The deepest Silurian group is the Cataract Group (about 15 m thick in the study area) that includes sandstones, dolostones, as well as shales. Reddish-brown sandstones and shales of the Grimsby formation represent the most recent Silurian deposits, near the base of the Escarpment. The Clinton Group overlies the Cataract Group in the central part of the study area and have a combined thickness of about 30 m, consisting of a succession of sandstones, shales, dolostones and limestones most of which pinch out to the west and north (for example they are only about 9 m thick where they underlie former Flamborough Township). The Clinton Group is overlain by the Lockport and Amabel Formations, the shallowest of the bedrock features that form the cliffs of the Escarpment. The Lockport Formation is about 30 m thick gives way laterally to the Amabel Formation around Waterdown. The Eramosa formation (Lockport Formation unit) overlays much of the Lockport and Amabel bedrock in the study area. The Amabel Formation is a reef-rich formation exceeding 30 m in thickness. The Guelph Formation outcrops extensively in the Flamborough Township area and reaches a thickness of 10 – 15 m. In the southern portion of the study area, and in Haldimand County, petroleum gas reserves are found in some of the bedrock formations. These reserves occur in the lower Silurian layers including the Thorold, Grimsby and Whirlpool Formations (Cataract layers).

There is one location that has been officially recognized as a provincially significant area of natural and scientific interest (ANSI) because of the existence of clearly defined karst landforms and features. It is the Eramosa Karst and is located in the former City of Stoney Creek, roughly bounded by Highland, Rymal and Upper Mount Albion Roads and Second Road West. It has examples of 16 different karst features and is owned by HCA. In the Waterdown area, karst features have also been identified and it can be expected that karst features may exist wherever carbonate deposits are found, however these are often obscured by overlying quaternary deposits and not easily observed. Karst topography likely plays a role in the movement of groundwater in the aquifers supplying Carlisle, Freelton and Greensville municipal wells.

The soils in the City to a large extent reflect the surficial geology. The most striking features are the extensive areas in the former township of Flamborough, with very shallow soils or exposed bedrock. The soils in this area which includes much of Fairchild, Bronte, Spencer have limited capability for agriculture and are sandy and nutrient poor. Overburden thickness is much greater in much of the remainder of the rural parts of the City with much heavier loamy – clayey till soils. This is the case for parts of Big Creek as well as the watersheds draining the southern part of the City.

2.2.6 Hydrogeology

The overburden aquifers in the study area consist of granular deposits within the shallow overburden and those present in the thicker deposits found within or on the flanks of bedrock valleys, such as the Dundas Valley.

The Bedrock aquifers are found primarily in the dolostones of the Guelph and Amabel/Lockport Formations, occurring above the Niagara Escarpment and supply municipal wells at Freelton, Carlisle and Greensville. This aquifer, referred to as the Guelph-Lockport Aquifer or in the area north of Hamilton, as the Guelph-Amabel Aquifer, is considered to be one of the major aquifers in Ontario. In the Niagara Peninsula, this aquifer has a maximum thickness of over 60 m, but in the vicinity of Carlisle and Freelton municipal wellfields, where the Guelph formation is absent, the aquifer thickness is significantly less, about 13 – 27 m. The Salina formation, which overlies the Guelph Formation in western parts of the study area, is not exploited as a source of municipal water supply within the City of Hamilton, however it does serve as the source of water for many private wells and can be considered as a regional aquifer, however water quality problems occasionally arise.

The shales of the Cataract Group that underlie the Dolostones form a regional aquitard beneath the area, as is apparent from the springs which occur along the face of the Niagara Escarpment at the contact beween the water-bearing dolostones and the underlying shales. While the Guelph-Amabel/Guelph-Lockport Aquifer extends beneath much of the City and is used as a source of water throughout the area, it is only in the Dundas Valley, where it has been developed as a source of municipal water supply. Limestones and dolostones, while typically having low permeability, frequently have a high secondary permeability due to the presence of solution channels the develop along faults, fractures and bedding planes. The aquifers in Freelton, Carlisle and Greensville are developed on these characteristics.

The complex nature of the surficial and bedrock geology as well as the complexity of the aquifer systems results in some variable effects on groundwater discharge streams. In areas where there is Karst topography, there are “losing” streams, streams that recharge the groundwater through the stream bed. Such areas occur in the middle and upper reaches of Spencer Creek, in Twenty Mile Creek and possibly in parts of Bronte Creek. In many areas above (upstream) of the Escarpment, it appears that there is limited local groundwater supplies to support stream base flows and as a result, many headwater drainage features in all of the watersheds are intermittent. Instead, recharge occurring on and above the Escarpment tends to supply deeper aquifer systems and often discharges to watercourses as they descend over the Escarpment. This phenomenon is sufficiently pronounced, that in the case of some streams, such as Grindstone, Borer's, Ancaster and Sulphur Creeks, there is a marked reduction in stream temperature, in some cases sufficient to result in cool/cold water stream status.

While there are numerous wetlands, particularly in the northern part of the City, the function of these wetlands in recharging groundwater supplies appears limited to recharging the deep aquifer system. These wetlands do also serve a significant water storage function and as such contributed to stream base flow in Spencer, Bronte and Fairchild Creeks.

The groundwater system behaves similarly within the headwaters of Big Creek, Welland River, Twenty and Forty Mile Creeks, in that the majority of headwater streams are intermittent and bedrock outcrops in these systems occur much further downstream outside of the City limits.

2.3 Socio-Economic Environment

2.3.1 Social Environment

Hamilton has a long history of human settlement and development. Due to the combination of favorable climate conditions and productive soils, Hamilton includes some of the best agricultural lands in Canada, including specialty croplands used for growing tender fruits. The area continues to support an important agricultural industry.

Due to its strategic geographic location at the apex of the Ontario's Golden Horseshoe, much of the area's landscape has been strongly influenced by human settlements and land use activity. Non-agricultural development in the area was initially concentrated in small clusters wherever streams could provide a source of hydraulic power. Following the construction of shipping canals in the 1800's, urban centers began to develop around the Harbour facilities at Hamilton and Dundas. Industrial, commercial and residential developments subsequently spread out along the system of railways that radiated out from the head of the lake.

The City of Hamilton spans 110,000 hectares along the Niagara Escarpment and south western shores of Lake Ontario. It is home to approximately 510,000 people and millions of annual visitors. Hamilton's geography is distinctive, with the Escarpment (the Mountain) acting as a dividing line between the waterfront / core area and other parts of the City.

Hamilton has a diversity of neighbourhoods. The core area along with parts of Dundas, Flamborough, Ancaster and Stoney Creek has well established, mature neighbourhoods defined by older homes, mature trees and heritage properties. The core area is also where much of Hamilton's higher density neighbourhoods are located. Suburban parts of former Hamilton, Flamborough, Ancaster and Stoney Creek have modern residential and commercial development. Glanbrook typifies the more rural parts of the City that blend old with new homes.

The south and east shores of the Harbour have been filled over time and developed for industrial and commercial activities (primarily the iron and steel industries), marine terminals, railway and highway construction, institutional uses and recreational uses. Twenty-five percent of the area of the original bay has been filled, eliminating 65 percent of the wetlands, protected inlets and shallow areas.

The eastern shore is comprised of the highway, the Desjardins canal, institutional lands, as well as commercial activities that prevent significant general public access. However, increasing public access in the south eastern end is one of the tasks of the Hamilton Harbour RAP.

The north shore of the Harbour in the Aldershot district of the City of Burlington consists largely of private homes, a private golf course, two cemeteries and public park.

The western shore is shared between railway land and the Hamilton Waterfront Trail, a public walking trail.

The western end of the south shore includes Bayfront Park and Pier 4 Park, both with public beaches.

Urban land uses within the City of Hamilton comprise approximately 15 percent of the total land area. Of the remaining 85 percent, approximately 61 percent of the lands are classified as rural. Proposed development, which includes the development of vacant lands within the existing Official Plan and lands outside the existing urban boundary, will increase the percentage of urban lands from 15 percent to 21 percent.

2.4 Municipal Infrastructure

2.4.1 Stormwater Infrastructure

Prior to amalgamation, each of the former municipalities managed their own storm drainage system, and set its own storm drainage policies and guidelines. Local differences related to physical setting or past development resulted in differences between the policies and guidelines of the former municipalities. The City of Hamilton Storm Drainage Policy (2004) provides a historical perspective as to how each former municipality designed and managed their storm drainage system. Further information with respect to storm drainage system criteria and policy is provided in section 5.2.3 of this report.

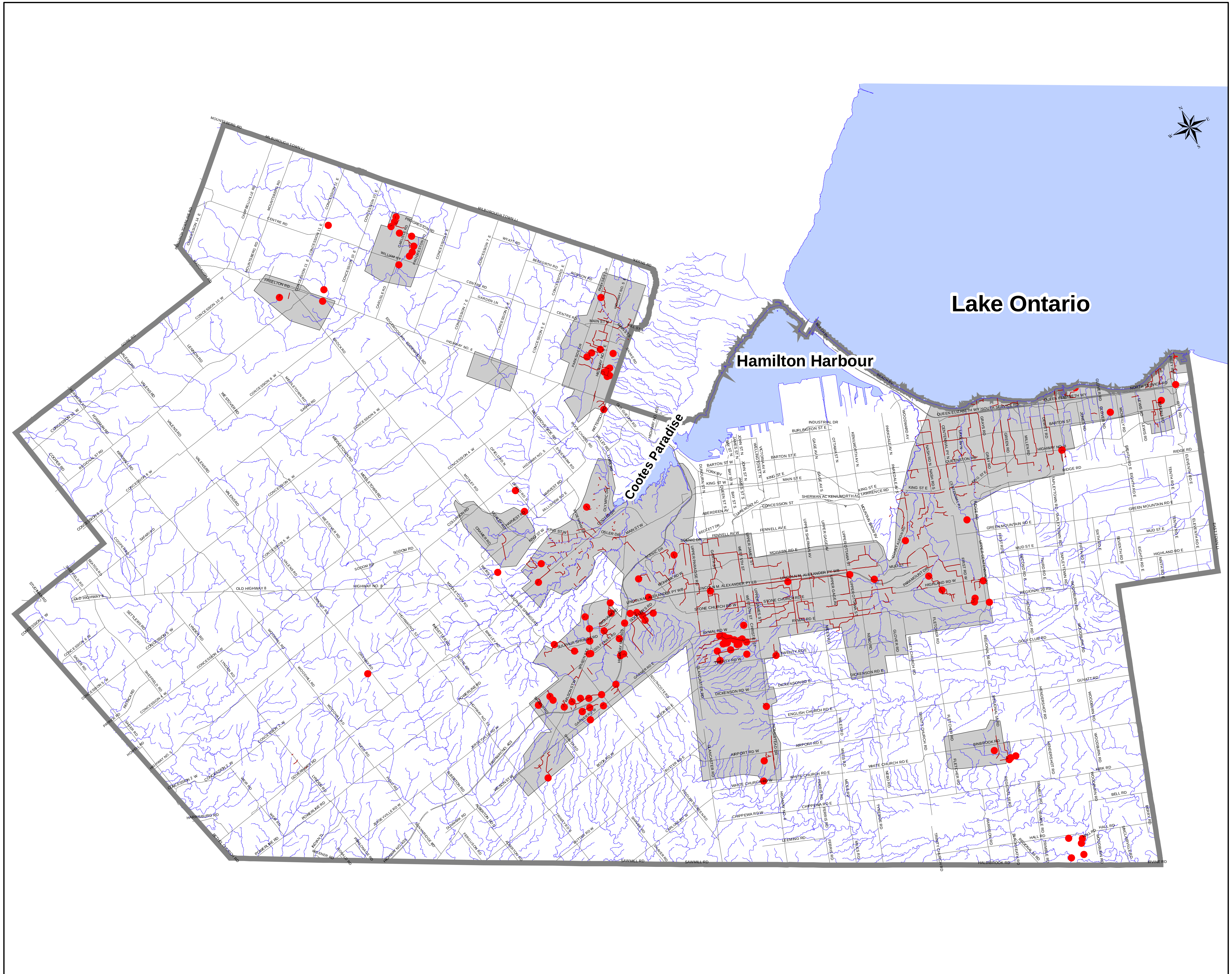
The stormwater infrastructure that was considered in this study includes the storm trunk sewers for areas serviced by separate storm sewer system together with the existing (as of 2004) stormwater management facilities. Figure 2.7 illustrates the study area, approximate location of the stormwater management facilities and general extent of the storm sewer infrastructure that was included as part of this study. Chapter 5 provides further details.

2.5 Summary of Environmental Conditions

Physiography and Groundwater

Portions of the following physiographic regions, as described by Chapman and Putnam (1984), occur within the study area:

- Niagara Escarpment,
- Iroquois Plain,
- Flamborough Plain,
- Horseshoe Moraines, and
- Norfolk Sand Plain.



KEY MAP

LEGEND:

- City of Hamilton Boundary
- Approximate Study Area
- Existing Storm Sewer
- Existing Stormwater Management Pond

NOTES:

0 2.5 5 10
Kilometers

Aquafor Beech Limited

Capital Planning & Implementation Division

Hamilton

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN STRATEGY

Existing Storm Sewer and
Stormwater Management Pond Locations

FIGURE: 2.7

DATE: 18 April 2007

Together with their proximity to Lake Ontario, Hamilton Harbour and Cootes Paradise, these features create a complex mosaic of geology and topography, unique in southern Ontario. Overburden is thin to non-existent in the northern part of the City, however richer loamy and silty clay soils persist to south and east. Below the Escarpment, which is mostly urban, are the glacial lake deposits and prehistoric shore features of Lake Iroquois. The Niagara Escarpment, which runs through the centre of the City's jurisdiction around the harbour, is the most prominent topographic feature and creates radically different environmental conditions between the landscapes at its base versus those above it. There are also numerous karst features scattered along the Escarpment, most notably in Twenty Mile and Spencer Creeks. Significant recharge areas exist in the northern part of the City above the Escarpment and also in scattered areas along the landward side of the Escarpment to the south and east. The headwaters of Big and Fairchild Creeks also have some extensive recharge areas.

The Bedrock aquifers are found primarily in the dolostones of the Guelph and Amabel/Lockport Formations, occurring above the Niagara Escarpment and supply municipal wells at Freelton, Carlisle and Greensville. This aquifer, referred to as the Guelph-Lockport Aquifer or in the area north of Hamilton, as the Guelph-Amabel Aquifer, is considered to be one of the major aquifers in Ontario. Shallow groundwater supplies are generally poor, and the majority of the watercourses above the Escarpment are intermittent in nature, except where wetlands provide a source of stream flow by storing surface runoff. This is the case with Fairchild, Grindstone, Spencer and Bronte Creeks. As the creeks fall over the Escarpment there is significant groundwater discharge, to the extent that some streams that are warmwater streams above the Escarpment become coldwater streams below it, for example, Ancaster, Sulphur, Borer's and Grindstone Creeks.

While there are numerous wetlands, particularly in the northern part of the City, the function of these wetlands in recharging groundwater supplies appears limited to recharging the deep aquifer system. These wetlands do also serve a significant water storage function and as such contributed to stream base flow in Spencer, Bronte and Fairchild Creeks.

The groundwater system behaves similarly within the headwaters of Big Creek, Welland River, Twenty and Forty Mile Creeks, in that the majority of headwater streams are intermittent and bedrock outcrops in these systems occur much further downstream outside of the City limits.

Surface Drainage and Hydrology

As one of the larger urban centres in southern Ontario, the surface drainage within the City of Hamilton is unique in that its jurisdiction straddles two significant landforms: the Niagara Escarpment, that defines an earlier lake shoreline; and the drainage divide between two Great Lakes – Lake Ontario and Lake Erie. Thus not only are there 15 watersheds, with a total drainage area of over 131,000 ha, located within the City, but each has a significant portion of its headwaters within the City. As a result, Hamilton has a preponderance of headwater streams, which are often the watercourses that are most sensitive to land use impacts. Under current land use conditions, the majority of these headwater streams are located in the rural portions of the City. While the City is predominately rural – 61% of total land use, land use within each watershed varies considerably:

Existing Land Use Characteristics by Watershed

Watershed	Urban (%)	Rural (%)
Big Creek	3.5%	96.5%
Borer's Creek	13.4%	86.6%
Bronte Creek	0.0%	100.0%
Central Business	99.8%	0.2%
Chedoke Creek	99.4%	0.6%
Community of Stoney Creek Watercourses	56.8%	43.2%
Fairchild Creek	0.0%	100.0%
Forty Mile Creek	0.0%	100.0%
Grindstone Creek	5.3%	94.7%
Red Hill Creek	80.6%	19.4%
Spencer Creek	5.1%	94.9%
Stoney Creek	27.4%	72.6%
Sulphur Creek	46.2%	53.8%
Twenty Mile Creek	4.6%	95.4%
Welland River	4.1%	95.9%

Floodplain mapping has been completed for most of the watersheds. Most flooding upstream of the Escarpment does not create hazardous conditions and is primarily associated with the large wetland features in the northern part of the City, as well as the well defined valley systems along Fairchild, Big, Twenty Mile Creeks and the Welland River. On the other hand, where watercourses cross the Escarpment and the historic lake deposits below the Escarpment, flooding and erosion hazards exist. This area also includes the majority of the urban lands in the City. There are ongoing erosion and flooding concerns (including some areas with basement flooding issues) in the following watercourses, downstream of the Escarpment: Borer's, Sulphur, Ancaster, Red Hill and Chedoke Creeks. There are also localized flooding problems in Stoney Creek and the Community of Stoney Creek Watercourses. Localized flooding and erosion problems also occur in some of the rural settlement areas, and both the Welland River and Twenty Mile Creek have flood damage centres located downstream of the City of Hamilton.

The City updated their Development Charges in 2006 that included estimated costs for stormwater management facilities and erosion control works, updated from the 2004 study. Approximately $43 million was identified for erosion control works associated with new development, however only a portion of this total was considered recoverable through Development Charges.

There are several reservoirs that serve a flood control function within the City including Christie and Valens Reservoirs (Spencer Creek), Mountsberg (Bronte Creek), Lake Medad (Grindstone Creek) and Binbrook/Lake Niapenco (Welland River).

Water Quality

Contaminants from urban and rural land uses are delivered to watercourses through surface runoff and in suspended sediments. Once in rivers and streams, these contaminants can cause degraded water quality leading to algae blooms, fish kills, beach closures, increased stress and even mortality to fish and wildlife and poor aesthetics. Several water quality parameters that are indicators of water quality and general stream health were selected to compare the current conditions of Hamilton area streams. The following parameters were selected:

- Total Phosphorus: a nutrient that is usually in short supply in streams. High levels of Phosphorus (above Provincial Standards) can cause algae blooms, nuisance aquatic weed growths and reduce oxygen levels necessary to support fish;
- Total Suspended Solids: a measure of the amount of very fine sediment in water. Nutrients, bacteria and metals can be transported by suspended sediment from the land to streams, contributing to water quality degradation. High suspended sediment levels can also smother fish spawning grounds and impair fish respiration leading to mortality;
- E.coli Bacteria: a bacteria known to be associated with human and animal wastes that may indicate the presence of other, more harmful bacteria that can affect human health. The presence of high levels of E.coli result in swimming beach closures; and
- Copper: a metal that can cause stress and mortality to aquatic plants, fish and wildlife. It is one of several trace metals, including zinc and lead, that are often elevated in streams in urban and rural areas

A comparison of average concentrations of these parameters at monitoring stations in Hamilton area streams was made to provincial standards. These data generally show that streams exhibit moderately degraded water quality conditions.

Urban streams: Red Hill and to a lesser extent Stoney Creek have water quality stations the represent urban conditions. Total Phosphorus and E. coli consistently exceed PWQO’s, while TSS and Total Copper generally exceed PWQO’s, only during precipitation/runoff events. These conditions would also be expected in Chedoke Creek, the Community of Stoney Creek watercourses, and the urban parts of Spencer and Grindstone Creeks.

Rural streams: Spencer, Grindstone, Bronte and Twenty Mile Creeks and the Welland River exhibit water quality conditions typical of streams dominated by agricultural land uses. Generally Total Copper and E. coli concentrations are within PWQO’s, while TSS and Total Phosphorus concentrations exceed PWQO’s, particularly during precipitation/runoff events.

While instream water quality conditions are important in terms of impacts on stream fish communities and habitats, the annual loading of these parameters, particularly TSS and Total Phosphorus, from these streams into Cootes Paradise and Hamilton Harbour is also significant, because these contaminants contribute to eutrophication of the wetland and harbour. Likewise, annual loadings from the other watersheds to receiving bodies such as Lake Ontario, the Grand River, and the Niagara River contribute to enrichment/contamination of these waterbodies.

Sources of these poor water quality conditions can be linked to the following:

- Excessive application of fertilizers and pesticides on rural and urban lands;
- Road runoff carrying contaminants from road maintenance, vehicle emissions;
- Contaminants in sediments eroded from urban and rural areas
- Bacteria from domestic pets and livestock wastes;
- Improper storage and handling of chemicals in industrial/commercial/residential areas that enter storm sewers
- Sanitary seweage sources incorrectly connected to storm sewers

Aquatic Resources

The general character of the aquatic communities in the 15 watersheds within the City is strongly influenced by physiography and land use. Many of the watercourses upstream of the Escarpment are intermittent streams, except in the northern part of the City where numerous wetland features serve and important water storage function and provide a source of baseflow. As the watercourses flow over the Escarpment, they receive groundwater discharge and a number of streams shift in thermal regime from warmwater to coldwater as a result. Agriculture is the dominant land use in the headwaters of the streams with urban uses dominating below the Escarpment. While some watercourses are predominantly urban (e.g. Chedoke and Red Hill) and others rural (e.g. Spencer, Big, Fairchild, Welland), others are mixed use and are impacted by both land uses.

The Welland River headwaters, including the Binbrook/Lake Niapenco Reservoir are located within the City limits. The characteristics of the Welland River are similar to the upper Twenty Mile Creek and land use is also similar since the airport and associated commercial lands straddle the watershed boundary between Twenty Mile and Welland River. The Welland River also supports a diverse warmwater fish community, primarily as a result of the reservoir, which creates additional habitat diversity for warmwater species that prefer lacustrine habitats, including the basses, northern pike, grass pickerel, yellow perch and crappie. The headwaters of Fairchild Creek contain numerous wetland features; however these appear to function locally to attenuate runoff providing limited local baseflow to Fairchild Creek. The main branch of the creek within the City is considered to be a warmwater stream supporting a tolerant/diverse warmwater fish community. Many of the headwater tributaries are intermittent. The headwaters of Big Creek within the City are characterized by numerous small drainage features that are predominantly intermittent. Big Creek is part of the Lower Grand Management Zone, which is managed for warmwater and coolwater sportfish including large/small mouth bass and walleye. The upper Spencer and Bronte watersheds contain one of the few remaining coldwater streams within the City. The presence of the Valens and Christie Reservoirs have had a moderating effect on stream temperatures and also have resulted in an increase in abundance of warmwater fish species included yellow perch, northern pike and bass/sunfish species. Grindstone and Borer’s Creeks are also considered warmwater streams although there are some historic coldwater streams in upper Grindstone Creek.

Agricultural land uses represent the primary stressors on the aquatic communities these watercourses. Key limitations include:

- Lack of baseflow
- Erosion and sedimentation of stream channels
- Lack of riparian habitat
- Water quality impacts, primarily nutrient and bacteria enrichment

The upper Chedoke Creek supports a very tolerant fish community and the lower Chedoke Creek supports a diverse warmwater fish community because of its proximity to Cootes Paradise. Below the Escarpment, Red Hill Creek supports a tolerant warmwater fish community and has been heavily impacted by industrial land use around the harbour. Upstream of the Escarpment, the creek supports also supports a tolerant warmwater fish community. These watercourses support a tolerant/diverse warmwater fish community downstream of the Escarpment, and in the case of Sulphur Creek in the headwaters as well, including some cool/coldwater species such as American brook lamprey and rainbow trout. The upper Ancaster and Tiffany Creeks support a tolerant warmwater fish community.

The fish community is typically a tolerant/diverse warmwater fish community and includes a number of sensitive minnow species such as rosyface shiner and brassy minnow. Salmonids, including rainbow trout migrate into the watercourse on a seasonal basis. Key limitations to fish habitat in these watercourses include:

- Stormwater inputs from industrial/commercial development (water quality and quantity)
- Lack of baseflow (above the Escarpment)
- Lack of riparian vegetation
- Poor instream habitats
- channelization

Terrestrial Resources

The City of Hamilton is located in the transition zone between two major forest regions: the Eastern Deciduous Forest (Carolinian Zone) and the Great Lakes – St. Lawrence Forest. In addition, the area boasts an exceptionally diverse physical landscape dominated by three features: the western Lake Ontario Shoreline and Hamilton Harbour Embayment; the Niagara Escarpment cuesta, running parallel to the shoreline, but some 2 km inland; and, the Dundas Valley, a major partially buried bedrock gorge in the shoreline and Escarpment.

The present distribution of natural areas has been determined largely by geographic factors. Although no pare of the area can be considered pristine, several relatively undisturbed greenspace areas remain. The largest natural areas are associated with either the Niagara Escarpment or the extensive bedrock plain, found above the Escarpment in Flamborough. Based on the Natural Areas Inventory study, a total of 107 sites were assessed, leading to the identification of 103 Environmentally Significant Areas (ESA's) and 25 Provincially Significant Wetlands. Together these areas represent over 17% of the City's area. The largest blocks of designated features occur within the Niagara Escarpment Area and in association with several large Provincially significant wetlands occurring in the headwaters of Fairchild, Bronte, Spencer and Grindstone Creeks.

Despite having a significant number of designated natural features for an area of this size, there are a number of threats to these areas as follows:

- Aggregate extraction, particularly in the northern part of the City: this encroaches on and potentially destroys a number of wetland features and also affects local water tables and even results in localized surface water diversions that impact wetland hydrology
- Agricultural land uses: primarily encroachment on features and also installation of tile drainage/diversion of surface flows that change the water balance of these features
- Ownership: many of these features remain in private ownership and are at risk from disturbance/destruction by landowners
- Urban land uses: similar to agriculture, impacts relate to encroachment and changes to local water balance, drainage
- Fragmentation: as urban areas gradually replace agriculture, many opportunities to maintain linkages between natural features are lost, in many cases leaving only the watercourses as the primary wildlife corridors. Upland corridors are scarce in the watersheds, primarily limited to the Niagara Escarpment Planning Area. In particular there are few linkages between features in the headwaters of the watercourses outside the drainage of Hamilton Harbour – Cootes Paradise to natural heritage systems that existing downstream in Bronte, Fairchild, Big, Twenty Mile, Forty Mile Creeks and the Welland River

3.0 STUDY GOAL AND OBJECTIVES

3.1 General

The development of the Master Plan Guiding Principle, Goals and Objectives was completed through a series of meetings of the Steering Committee as well as feedback from the public and stakeholders at Public Information Centres and Workshops held on June 20, 21 and 23, 2005.

The Guiding Principle, Goals and Objectives were used to assist in the development of a Long List of Alternatives and Management Strategies. The objectives were also used to assist in the evaluation of strategies.

3.2 Guiding Principle, Goals and Objectives

Provided in Table 3.1 are the Guiding Principle, Goals and Objectives that were established for this study.

Consistent with the study focus, separate Goals have been established for storm sewer infrastructure and for the natural resources of the watersheds located within the City. The objectives also reflect distinct categories for natural resources and the separated storm sewer system.

Table 3.1: Master Plan Guiding Principle, Goals and Objectives

Guiding Principle

- Treat rainwater as a resource to be protected and managed, rather than a waste product to be quickly moved from where it falls.

Goals

1. To develop management guidelines for the maintenance / replacement of the City's existing separated storm sewer systems and for design of proposed systems.
2. To develop and implement appropriate strategies in order to protect, enhance and restore the natural resources of the watersheds located within the City under present conditions and as land use changes occur in the future.

Objectives

Water Quality

1. Maintain or enhance water and sediment quality to achieve ecological integrity.
2. Improve water quality in watercourses and major receiving waters including the Grand, Niagara and Welland Rivers as well as Hamilton Harbour and Lake Ontario.
3. Improve water aesthetics including odour, turbidity and clarity.
4. Protect groundwater quality to support watershed functions.

Water Quantity

5. Preserve and re-establish the natural hydrologic cycle.
6. Reduce erosion impacts on habitats and property.
7. Minimize risk to human life and property due to flooding.
8. Maintain groundwater levels and baseflows to sustain watershed functions.

Aquatic Communities and Habitats

9. Protect, enhance or restore native aquatic species and communities.
10. Protect, enhance or restore the stability, diversity and connectivity of habitats in watercourses, riparian habitats and other waterbodies to support native aquatic plants, invertebrates, animals and fish.

Terrestrial Communities and Habitats

11. Protect, enhance or restore habitat diversity, health and distribution in the watershed to support plant and animal communities.
12. Minimize the impact of surrounding land uses on natural system integrity.

Sewer System

13. Manage storm runoff to reduce basement flooding.
14. Incorporate into the design of sewer systems an allowance to accommodate future growth, including intensification.

4.0 DEVELOPMENT OF LONG LIST OF ALTERNATIVES

4.1 General

The approach for developing and evaluating alternatives is consistent with the requirements of the planning and design process for Master Planning projects described in the Municipal Class Environmental Assessment (Class EA) (Municipal Engineers Association, June 2000). It involves reviewing Phase 1 work (i.e. Identification of the Problem) and undertaking Phase 2 (i.e. Establishing Existing Conditions, Identification of a Long List of Alternatives, Development and Assessment of Alternative Management Strategies and Selection of a Preferred Strategy). Consultation with stakeholders is also a necessary and important component of this process.

Section 1.4 describes the steps of each phase of the Class EA process in detail. Figure 4.1 illustrates the study process.

The first step undertaken in the development and evaluation of Alternative Management Strategies and the ultimate selection of a Preferred Stormwater Strategy was the development of a long list of alternatives. The long list of alternatives had to be all encompassing, and consistent with the study principle, goals and objectives. Furthermore, the development of the long list of alternatives considered both existing and proposed land uses within the study area. For the City of Hamilton these land uses include urban and rural uses (existing conditions) together with intensification and proposed development (future conditions).

The long list also considered recent City initiatives such as the development of the Draft City of Hamilton Criteria and Guidelines for Stormwater Infrastructure and Design (Philips, 2006) and the City of Hamilton Storm Drainage Policy (Philips, 2004).

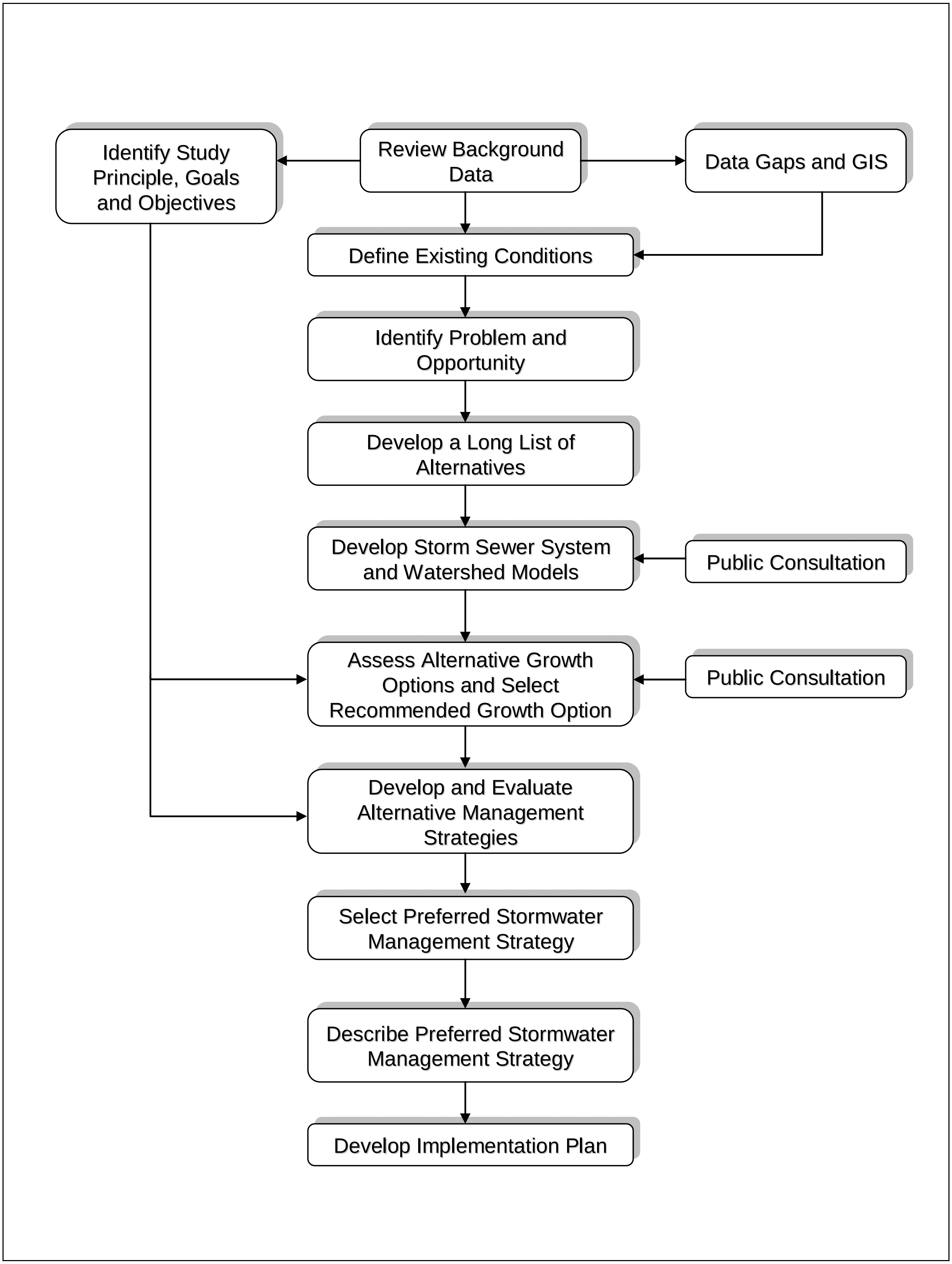


Figure 4.1: City of Hamilton Stormwater Master Plan Study Process

4.2 Overview and Characterization of Alternatives for Urban Areas

4.2.1 General

The long list of alternatives, as discussed in Section 4.1, had to be all encompassing, and consistent with the study principle, goals and objectives. Furthermore, the development of the long list of alternatives considered both existing and proposed land uses within the study area.

Subsequent chapters of this report will present details of a variety of proposed measures. Provided below is a brief overview as to the type of measures that were initially considered in the development of the Alternative Management Strategies. Other documents, including the Ministry of the Environment Stormwater Management Planning and Design Manual (MOE, 2003), Draft City of Hamilton Criteria and Guidelines for Stormwater Infrastructure and Design (Philips, 2006) and the City of Toronto Wet Weather Flow Management Master Plan Blue Book (WWFMMP, 2002) provide details with respect to technical and physical requirements and limitations, costs and operation and maintenance considerations of the individual measures which are summarized below. Table 4.1 summarizes the Preliminary Long List of Alternatives that are discussed below. Figures 4.2 and 4.3 illustrate representative measures.

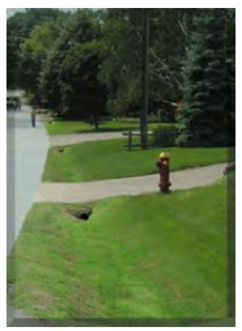
Conveyance Control Measures

Conveyance Control Measures are stormwater transport systems that are generally located within the road right-of-way. These facilities promote infiltration, reduce pollutant loadings and cool stormwater runoff prior to discharging to the stream.


Perforated Pipe (during construction) used to promote infiltration


Perforated Pipe (underground)


Schematic of proposed Infiltration System


Swale/Ditch

Historically, development occurred without regards to the impacts associated with urbanization. The associated impacts include increased surface runoff, pollutant loadings, and decreased infiltration. The resultant effects are increased flooding and erosion, reduced baseflows, and nuisance algae/plant growth in streams.

Urban BMP's have evolved in recent years to recognize that rainwater needs to be treated as a resource that must be protected and managed; instead of a waste to be moved quickly offsite.

Urban BMP's can be grouped into 4 functional categories, based on the point at which they intercept rainwater and stormwater runoff. These categories include:

Source controls
Conveyance controls
End-of-pipe controls
Restoration measures

[1]Best Management Practices: Conservation measures intended to minimize or mitigate effects from a variety of land-use impacts.

Source Control Measures

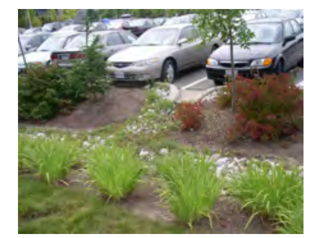
Source Control Measures are physical measures that promote ground infiltration and mitigate stormwater overflow. Generally these control measures are located at the beginning of a drainage system on private property.

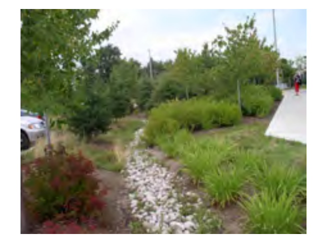

Rain Barrel


Rain Garden


Pervious Driveway

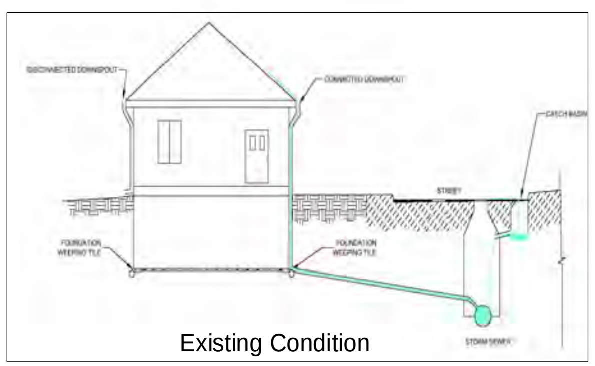

Soakway Pit


Biofilter


Biofilter

Traditional Approach

Traditional approach for dealing with intensification, involves installing a larger storm sewer to accommodate increased flows.


Existing Condition


Future Condition

TRADITIONAL APPROACH

End-of-Pipe Control Measures

End-of Pipe control measures occur at the end of a flow conveyance system. These facilities are utilized for erosion, quantity and quality control applications.


Wet Pond


Wetland


Photographs illustrating implementation of stormwater pond and infiltration facility within Terraview Park

Restoration Measures

Restoration Measures are implemented to restore degraded habitat. These measures may be used to restore streams, wetlands or other aquatic habitat


Before Restoration


After Restoration

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton, ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

URBAN BEST MANAGEMENT PRACTICES[1] (BMP's)

Figure: 4.2

DATE: 18 April 2007

NON-STRUCTURAL MEASURES

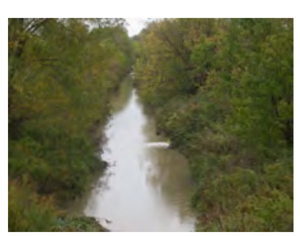
1) Livestock Access Control – watercourse fencing, stream crossings, off stream watering facilities

2) Nutrient/Manure Management:

- On-Field Measures – timing/rate of application, crop rotation/strip cropping, conservation tillage, cover crops, drainage management,
- Streamside Measures – grassed waterways, streamside buffer plantings, drain outlet controls

3) Fragile Land Management:

- Management Actions – woodlot management, windbreaks/shelterbelts, stabilization with cover crop, reforestation with harvestable crop
- Retirement of Lands – wetland protection, natural regeneration, reforestation with native trees



Approximately 65% of the lands within the City are agriculture: pasturelands or croplands. Management of agricultural practices to reduce nutrient, suspended solids and bacteria loads in streams is an important way to improve the health of streams and other water features such as Cootes Paradise and Hamilton Harbour.

Agricultural Best Management Practices include various structural and non-structural management actions/measures to aid in the reduction of sediment, nutrient, pesticide, and bacterial loads to watercourses. Measures can be generally classified into the following groups: **Non-Structural Measures and Structural Measures.**

The decision regarding the appropriate environmental BMP's to use should be made as part of an overall assessment of farming operations and combined with measures/actions to improve overall farm productivity, livestock health, crop yield and economic benefit, for example through the Environmental Farm Plan.

Sources of agricultural impacts to watercourses can be classified as point sources and non-point sources. A point source impact occurs when sediment, nutrients, bacteria and/or pesticides enter streams via a channel or pipe or overland within a short reach of stream. Examples include runoff from a manure pile, roadside ditches, milkhouse wastes discharging through a tile drain or an unrestricted livestock watering site. A non-point source impact occurs when these materials are carried overland and enter an un-buffered watercourse along its entire length. Examples include runoff from croplands, pasture lands and other actively tilled lands. Other examples include streambank erosion, wind erosion and erosion of steep slopes and erosion-prone soils.

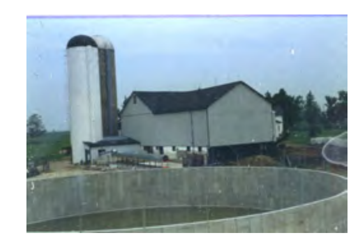
STRUCTURAL MEASURES

1) Manure/Feedlot Storage and Handling:

- Clean runoff diversion, regular storage facility cleanouts, storage facility drainage control,
- covered facilities, solid storage facilities, liquid storage facilities

2) Other Practices: These include specific problems and farmland management.

- Milkhouse Waste Management – separate storage facilities, combined facilities (with manure storage)
- Faulty Septic System Replacement



Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division
77 James Street North
Hamilton, ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

RURAL BEST MANAGEMENT PRACTICES (BMP's)

Figure: 4.3

DATE: 18 April 2007

Table 4.1: Preliminary Long List of Alternatives

<table>
<tr><th colspan="2">Source Control</th></tr>
<tr><td><u>Residential</u>
• Soakaway pits
• Rain barrels / roof downspout disconnection
• Pesticide and fertilizer reduction
• Porous pavement
• Enhanced yard vegetation and rain / storm gardens
• Reduced lot grading
• Water conservation
• Green roofs</td><td><u>Commercial/Industrial/Institutional</u>
• Reduced lot grading
• Rooftop storage
• Parking lot storage
• Biofilters
• Infiltration trenches
• Water conservation</td></tr>
<tr><th colspan="2">Conveyance</th></tr>
<tr><td colspan="2">• Pervious pipe systems
• Stream / valley buffer strips
• Vegetated filter strips
• Storage tanks
• Sewer rehabilitation
• Sewer replacement
• Roadside ditches</td></tr>
<tr><th colspan="2">End of Pipe</th></tr>
<tr><td colspan="2">• Wet ponds
• Constructed wetlands / hybrid wet ponds / wetlands
• Dry ponds
• Infiltration basins
• Filters</td></tr>
<tr><th colspan="2">Restoration</th></tr>
<tr><td colspan="2">• Stream restoration
• Wetland restoration
• Woodland restoration
• Fish movement / barrier alteration</td></tr>
<tr><th colspan="2">Rural Measures</th></tr>
<tr><td colspan="2">• Live stock fencing
• Buffer strips
• Conservation tillage
• Manure storage and handling facilities</td></tr>
<tr><th colspan="2">Management/Operation Measures</th></tr>
<tr><td colspan="2">• Catch basin cleaning
• Street cleaning
• Yellow fish road program</td></tr>
</table>

4.2.2 Source Controls

Source Control Measures are physical measures that are located at the beginning of a drainage system; generally on private property. Source controls can be installed within a variety of land uses including residential, commercial, industrial and institutional properties. Source control measures can be retrofit into existing areas and implemented in urbanizing areas.

Several representative source control measures include:

Rooftop Storage: Water is stored on flat roofs, thereby attenuating flows, by installing restrictors on the roof within the plumbing system.

Parking Lot Storage: Water is stored on parking lots by restricting the flows getting into the catch basins, or by providing a control device at the property line.

Super Pipe Storage: Large underground pipes are constructed in order to temporarily store flows.

Reduced Lot Grading: Typical grading around buildings (≥ 2%) is reduced to encourage infiltration.

Rooftop Leader to Ponding Area: Water from the roof downspouts is directed to a depressed area where infiltration and temporary storage is encouraged.

Soakaway Pits: Underground units, typically filled with clear stone, are constructed and infiltrate water discharged from the downspouts.

Infiltration Trenches: Underground trenches, constructed of clear stone, sand, or peat moss, capture runoff from grassed or paved areas and promote infiltration, store, cool and clean runoff.

Rooftop Grading: Units which are constructed on top of buildings to reduce runoff (via increased evapotranspiration), improve water quality and reduce energy usage.

4.2.3 Conveyance Controls

Conveyance Control Measures are physical measures that are located within the road right-of-way where flows are concentrated and are being conveyed along the right-of-way. Conveyance measures include swales, ditches, culverts, catch basins, manholes and storm sewers.

Several representative conveyance control measures include:

Grass Swales: Linear grassed channels which attenuate runoff and promote infiltration.

Pervious Pipe Systems: Sewers, which promote storage and infiltration through perforations constructed in the pipes.

Pervious Catch Basins: Catch Basins with pervious walls or bottoms.

Vegetated Filter Strip: Linear swales, with vegetation and possibly permeable soils to promote cleaning of water as well as attenuation of runoff.

Stream / Valley Buffer Strips: Vegetated strips adjacent to streams / valleys which clean and attenuate runoff.

4.2.4 End of Pipe Measures

End of pipe measures include Best Management Practices that are installed at the end of the storm sewer system prior to discharging to the stream or river. Typical end of pipe measures which are used to treat stormwater include stormwater ponds (dry or wet), wetlands or infiltration basins.

Several representative end of pipe measures include:

Wet Ponds: Stormwater Ponds which, by storing water, address issues related to water quality, erosion and flooding.

Constructed Wetlands: Wetlands which are designed to treat stormwater runoff.

Hybrid Wet Ponds / Wetlands: A combination of Wet Ponds and Constructed Wetlands.

Dry Ponds: Stormwater Ponds, which are dry except during rainfall events, which are designed for erosion and flood control.

Infiltration Basins: Above ground or below ground facilities which are designed primarily to infiltrate runoff.

Filters: Systems, using sand, peat moss or clear stone which filter out pollutants in stormwater runoff.

Oil / Grit Separators: Mechanical devices used for capture of spills and treatment of stormwater.

4.2.5 Restoration Measures

Restoration of degraded habitats may be done in a number of ways. Representative restoration / enhancement programs are summarized below.

Stream Restoration Programs: These include measures designed to address erosion and flooding problems and restore stream functions and stability. They are generally applied on a stream reach basis and include stream rehabilitation using Natural Channel Design principles, and naturalization of stream riparian zones using native materials. They may also include individual structures, such as streambank regrading, gradient controls and floodplain contouring to address specific erosion and flooding problems.

Aquatic Habitat / Fish Community Enhancement: These are generally instream measures designed to enhance aquatic/fish habitat. Typically, they are integrated with Stream Restoration Measures, however they may be implemented on their own in stable stream environments. They include spawning habitat creation, refuge pool construction, undercut bank structures, boulder placements, half log cover structures and flow deflectors. They may also include stream bank planting to provide overhanging shade.

Terrestrial Habitat Enhancement: These are measures designed to protect and enhance terrestrial habitats for native flora and fauna. They include establishing buffers adjacent to sensitive features, wetland restoration, reforestation, native plantings, setting aside lands to naturally revegetate, controlling access to sensitive areas and creating natural linkages between existing features. They also may include increasing the size and distribution of natural areas.

4.2.6 Rural Measures

Rural Measures are generally characterized as structural or non-structural. A description of each is provided below.

Structural Best Management Practices for Rural Areas: These are measures that are applied to reduce runoff and pollution from agricultural operations. They include manure storage and handling facilities, feedlot runoff controls, and wetland systems to treat feedlot runoff and milkhouse wastes, and outlet controls on tile drainage systems.

Non-Structural Best Management Practices for Rural Areas: These are measures that are applied to address non-point pollution sources from agricultural operations. They include livestock fencing, buffer strips, conservation tillage and nutrient management.

4.2.7 Management / Operation Measures

Management/operation measures are typically undertaken by the municipality and include stream drain flushing, catch basin cleaning, street cleaning, leaf clearing and removal, cross connection control programs, and public education programs such as the Yellow Fish Road Program.

5.0 DEVELOPMENT OF STORM SEWER SYSTEM AND WATERSHED MODELS

5.1 General

Urban areas may degrade the environment in many ways. Degradation may occur at the onset as lands are stripped during the construction process. This can result in excessive sediment loads being discharged to the receiving bodies of water.

As development of an area progresses, pollutant loadings from the urban area become more significant. Common sources of pollutants include heavy metals from automobiles and air emissions, nutrients from fertilizers, bacterial contamination from human (combined sewer overflows) or animal (stormwater runoff) wastes, and toxic contaminants from a variety of residential, commercial and industrial sources. Table 1.1 shows concentrations of selected constituents of stormwater runoff compared to the Provincial Water Quality Objectives (Aquafor, 1993).

The pollutants, when conveyed to the receiving bodies of water, impact the environment in many ways. The particulate (settleable) and dissolved contaminants stress aquatic ecosystems by depleting oxygen, raising ambient water temperature, covering habitat, or through the bioaccumulation or bioconcentration of contaminants in the tissues of various aquatic species.

Urban development of lands draining to streams also results in a transformation of the hydrologic characteristics within the subwatershed (see Figure 1.5). Large amounts of previously permeable soils, which allowed rainwater to soak into the ground, are covered with impervious materials such as concentrate and asphalt. Rainfall events that previously contributed little or no runoff to the stream now cause flow to occur in the channel. Consequently, the amount of water draining to the stream increases significantly in volume.

Commensurate with the increase in the amount of runoff is a decrease in the time it takes for drainage water to reach the channel. Storm sewers convey the rainwater to the stream, resulting in higher flow rates in the channel.

Rural areas may also degrade the environment as a result of increased bacterial, nutrient and suspended solids loadings from farms, golf courses and nurseries.

As a result of existing land uses, together with proposed land use changes, a number of environmental problems have been identified. These have been summarized in Section 1.3.

In order to address these environmental concerns, a long list of alternatives has been developed (Chapter 4). The long list of alternatives was then be refined and a number of Alternative Stormwater Management Strategies were developed. Computer models were used as a tool to assist in the evaluation of the long list of alternatives and the Alternative Management Strategies.

Two computer models were used to assist in the evaluation process. A City-wide storm trunk sewer model (for areas serviced by separate storm and sanitary sewers) was used to:

- Characterize the existing storm trunk sewer system;
- Determine the relative level of service of the system; and
- Evaluate the potential impact on the level of service as a result of proposed intensification.

As was noted previously, the Stormwater Master Plan is one of three Master Plans undertaken concurrently. The Water/Wastewater Master Plan addressed the above objectives for areas of the City that are serviced by combined sewer systems. This study addresses the above noted objectives for areas serviced by separate storm and sanitary sewer systems.

Figure 5.1 illustrates the concept of combined and separate sewer systems.

Figure 5.2 illustrates the approximate area within the City of Hamilton that is serviced by a separate storm and sanitary sewer system.

A City-wide spreadsheet water balance/water quality model was also developed for this study. This model summaries flow and water quality conditions on a daily basis for each of the 15 subwatersheds located within the City. The objectives of the spreadsheet model are to:

- Characterize existing flow and water quality conditions for each watershed;
- Assess the changes in flow and water quality conditions as a result of land use change; and
- Assess the effectiveness of various Alternatives Management Strategies with respect to protecting, enhancing and restoring the natural resources of the subwatersheds located within the City under present conditions and as the land use changes in the Recommended Growth Option occur in the future.

A further description of the computer models that were used, together with the results, is provided below.

5.2 Storm Sewer Model

5.2.1 Model Selection

The City of Hamilton required a software program that is universally supported and continually updated. The required capabilities of the new sewer system model were determined more by the complexities of the combined sewer system and the requirements of the computerized Real Time Control (RTC) System than the simpler operational requirements of the separate sanitary and storm sewer systems. Analysis of the combined sewer system requires a fully dynamic model capable of continuous simulation of sewer hydraulic including sewer surcharging and backwater effects, complex control structures and RTC. Analysis of the trunk sanitary and storm sewer systems requires accurate and reliable algorithms for the continuous simulation of dry weather sewage flow and rainfall dependent infiltration and inflow (RDII).

The MOUSE simulation package from DHI software was selected by the City as the most appropriate tool for the modeling of Hamilton’s trunk sanitary, combined and separate storm sewer systems. MOUSE is a powerful and comprehensive computer package for simulating surface runoff, open channel flow, pipe flow, water quality and sediment in urban drainage systems including sanitary, storm and combined sewers. MOUSE combines complex hydrology, hydraulics, water quality and sediment transport in a completely graphical, easy-to-use interface.

Typical applications of MOUSE include studies of combined sewer overflows (CSO), sanitary sewer overflows (SSO), complex Real Time Control (RTC) scheme development and analysis, design of new site developments, regulatory consenting procedures and analysis and diagnosis of existing storm water and sanitary sewer systems.

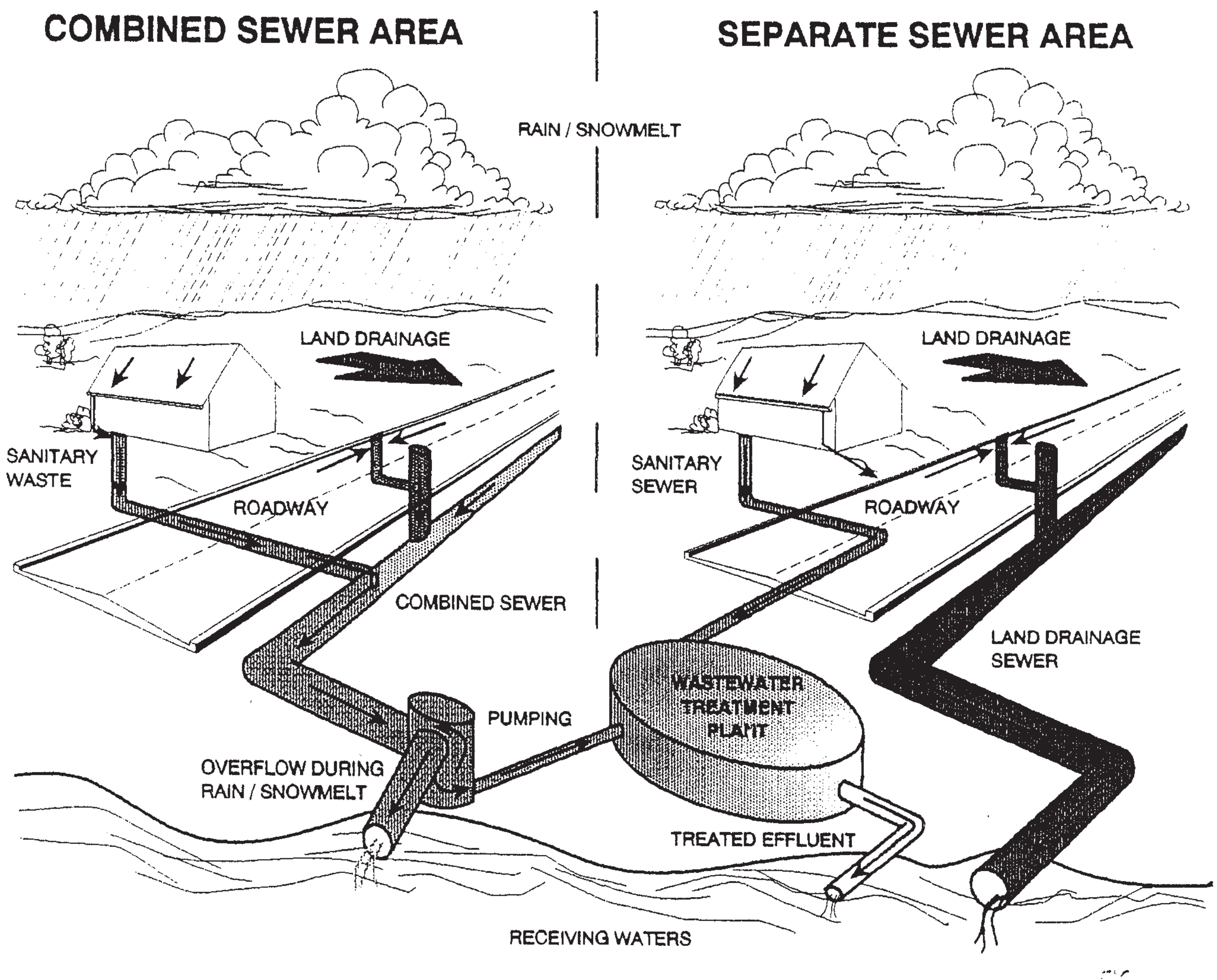
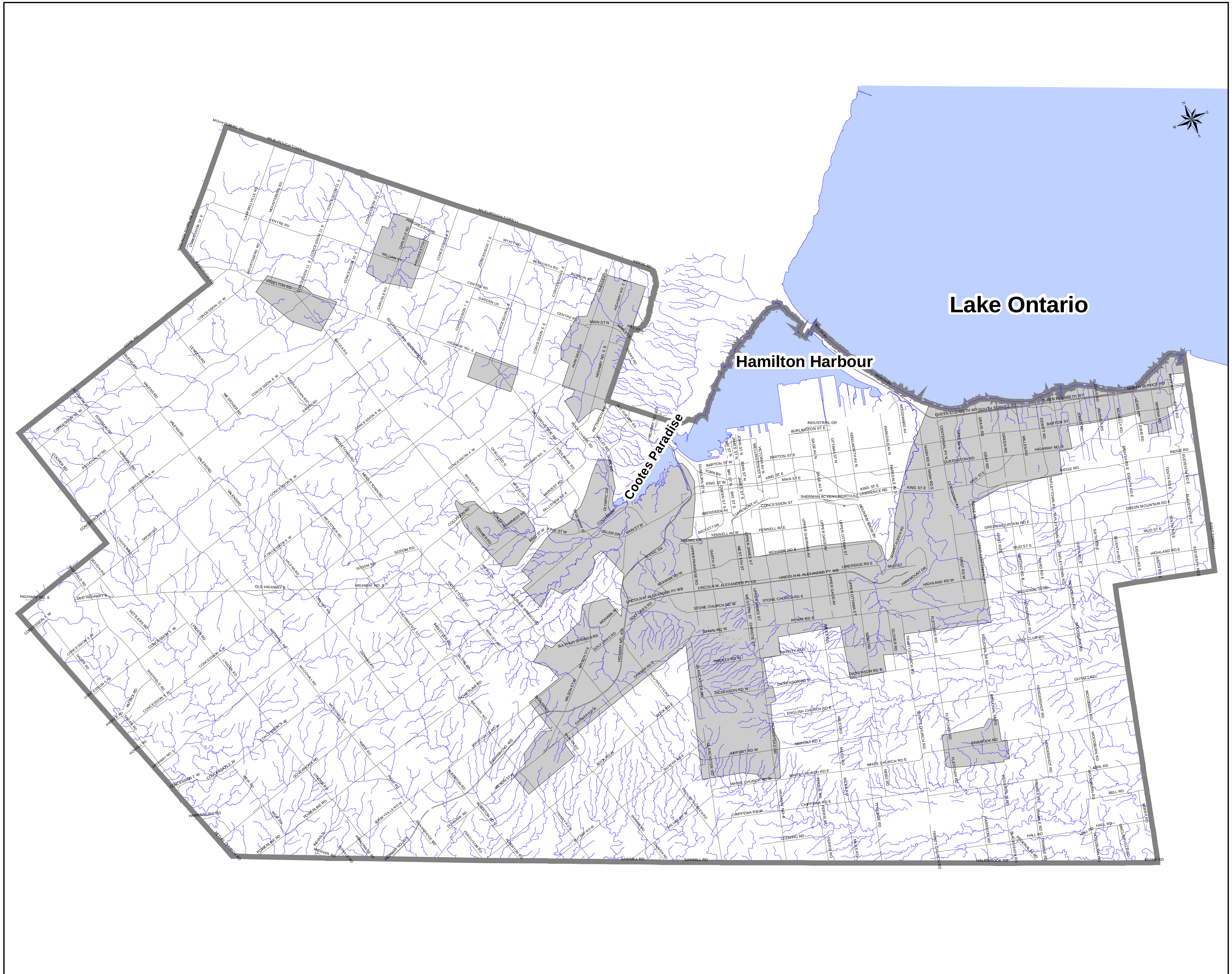


Figure 5.1 - Conceptual Drawing Illustrating Combined and Separate Sewer Systems



KEY MAP

LEGEND:

City of Hamilton Boundary

Approximate Study Area

NOTES:

0 2.5 5 10

Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Study Area for Storm Sewer System

FIGURE: 5.2

DATE: 18 April 2007

The MOUSE simulation package consists of several modules, which can be used alone or in combination, to simulate a multitude of urban drainage processes:

- MOUSE Runoff is the surface runoff model used for urban catchment application.
- MOUSE HD is a detailed hydrodynamic network model with some limited options of flow regulation.
- MOUSE RDII is an advanced hydrological model for continuous simulation of all processes affecting the RDII process.
- MOUSE RTC provides advanced reactive RTC capabilities for MOUSE pipe models.
- MOUSE LTS provides long-term hydraulic simulations with statistical analyses of the results.
- MOUSE TRAP provides several sub-programs for the simulation of water quality processes, including MOUSE SRQ, which simulates pollutant build-up and transport on catchment surfaces; MOUSE AD, which simulates pollutant advection and dispersion in drainage networks; MOUSE WQ, which simulates water quality processes in drainage networks; and MOUSE St, which simulates sediment transport in drainage networks.

MOUSE Surface Runoff and Pipe Flow (HD) are the two main modules which were used in this study.

The MOUSE Surface Runoff Module includes five types of surface runoff computation and three hydrological levels for the description of the urban catchments surfaces. This implies that the surface runoff computations can be adjusted according to the amount of available information. The models run with well proven default hydrological parameters, which can be adjusted for better accuracy. The computed hydrographs are used as input to the MOUSE Pipe Flow model.

MOUSE Hydrodynamic Pipe Flow Model (HD) solves the complete St. Venant (dynamic flow) equations throughout the drainage network (looped and dendritic), which allows for modeling of backwater effects, flow reversal, surcharging in manholes, free-surface and pressure flow, tidal outfalls and storage basins.

MOUSE has been updated and now entitled MIKE URBAN. MIKE URBAN Collection Systems-Pipeflow includes DHI’s MOUSE engine. With MIKE URBAN CS-Pipeflow, the user is able to get access to hydrodynamic simulation of networks with MOUSE, pipe design (MOUSE engine) and long term statistics (MOUSE engine).

The modular structure of MIKE URBAN is illustrated on the following page:

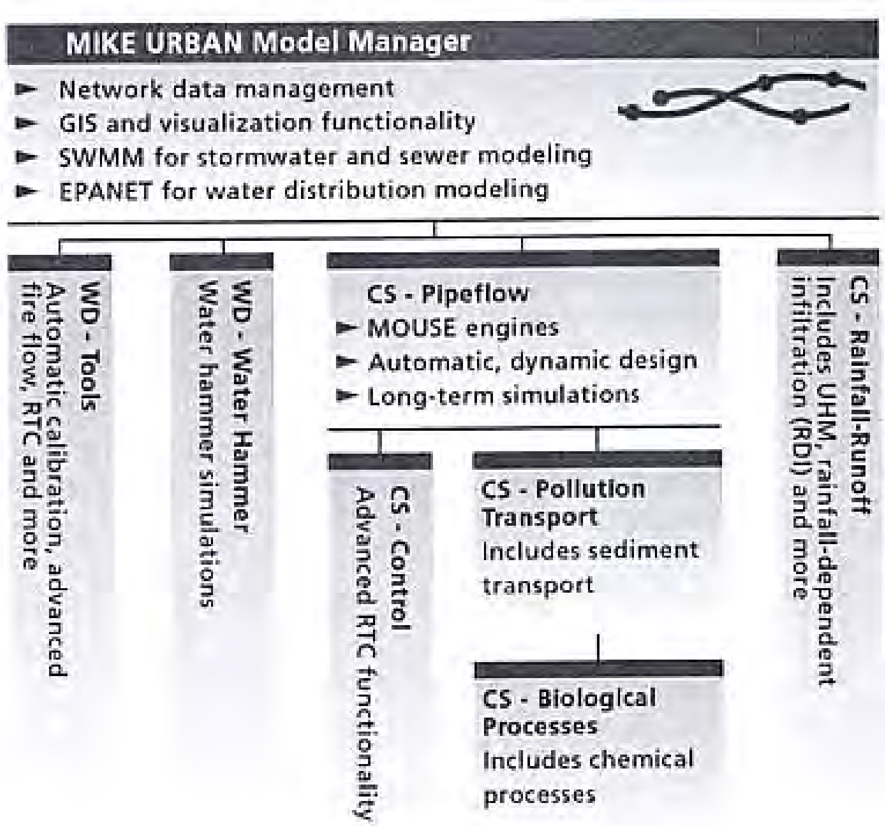


Figure 5.3: The modular structure of MIKE URBAN

5.2.2 Model Setup

The City of Hamilton provided drainage areas of the six communities that now make up the City of Hamilton (former City of Hamilton, Town of Dundas, City of Stoney Creek, Town of Ancaster, Township of Glanbrook and Town of Flamborough) for the separate storm sewer system.

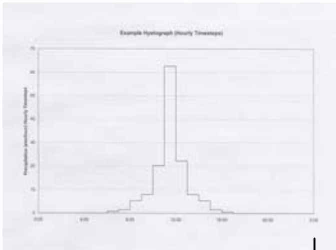
The City developed a skeletal model of the trunk storm sewer system (generally includes pipes with 525 mm diameter and greater) in MOUSE. For the purpose of this study, the trunk sewer system implies a pipe system with a diameter, height or width greater than or equal to 600 mm within the Community of Stoney Creek and former City of Hamilton (in the area not serviced by combined sewer system) and a diameter greater than or equal to 525 mm in the rest of the City.

Aquafor Beech constructed the remainder of the model which included determination of flows to the sewer system and water levels within the system for different storm events. The existing stormwater management ponds were also incorporated into the model.

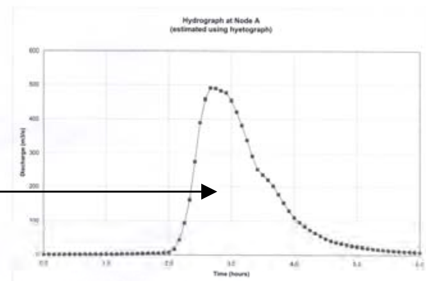
The following sections illustrate the approach used to determine flow rates and associated water levels.

5.2.3 Determination of Flow Rates

In order to determine the flow rate (hydrograph) for a sub-catchment area, several key pieces of information need to be defined. This information includes a hyetograph, the sub-catchment area and a variety of parameters which determine the timing and volume of flows that are generated for the sub-catchment area. An illustration of pieces is shown on the following page:



Hyetograph (Rainfall)



Catchment Area Hydrograph (Surface Runoff)

A **hyetograph** (storm event) is a graphical representation of the amount of precipitation that falls through time.

Surface runoff is generated as a result of the precipitation that occurs. The precipitation (rainfall) is specified in the form of a time series, i.e. as a sequence of measured or synthetic values for rainfall with time and data labels.

The selection of the design storm was based as a number of factors including the size of the drainage system. A 6-hour Chicago distribution design storm hyetograph was selected to ensure that the design storm duration exceeded the travel time in the larger sewer systems (located on the mountain in the former City of Hamilton) and to approximate how existing stormwater management ponds would function.

The City of Hamilton Storm Drainage Policy (March 2004) provides a historical perspective as to how each former municipality designed and managed their storm drainage system. Table 5.1, taken from the Storm Drainage Policy document, describes some of the key differences between the former municipalities. As noted in the policy document, the table is offered only for context and is not intended to be exhaustive.

Table 5.1: Comparison of Former Area Municipalities Storm Drainage System Criteria and Policy

Former Municipality	Minor System Criteria	Foundation Drainage Requirements (2)	Combined Sewers	Roof Leader Policy	Major System Criteria
Hamilton	18 - 50 yr (1)	Gravity	Yes	Direct to Sewer	100 yr
Ancaster	2 yr	Sump Pumps	No	Surface	100 yr
Dundas	2 - 5 yr	N/A	No (3)	Surface	100 yr
Flamborough	2 - 5 yr	Gravity/Sump Pumps	No	Surface	100 yr/Regional (4)
Glanbrook	5 yr	Sump Pumps	No	Surface	100 yr
Stoney Creek	5 yr	Gravity	No	Surface	100 yr

(1) 1942 – 1992 (inclusive) used an 18 year storm event; post 1992 used 50 year. Both design storm uses in Modified Rational Area Method
(2) Foundation drainage requirement exceptions are currently permitted upon receipt of a SWM report
(3) The Pleasant Valley neighbourhood (Dundas) only has a combined sewer system permitted by By-Law
(4) Regional event is Hurricane Hazel

The Draft City of Hamilton Criteria and Guidelines for Stormwater Infrastructure Design (December, 2005) also provide direction with respect to which rain gauge should be used as a basis for determining the rainfall volume for a given return period storm. Mount Hope Airport and Royal Botanical Gardens rainfall gauge areas are separated by Niagara Escapement. Figure 5.4 illustrates which areas of the City should use the Mount Hope and Royal Botanical Gardens gauging information (Philips Engineering Limited, 2005). It should be noted that the most recent version of the Guidelines (December 2006) recommends the use of one (Mount Hope) gauge.

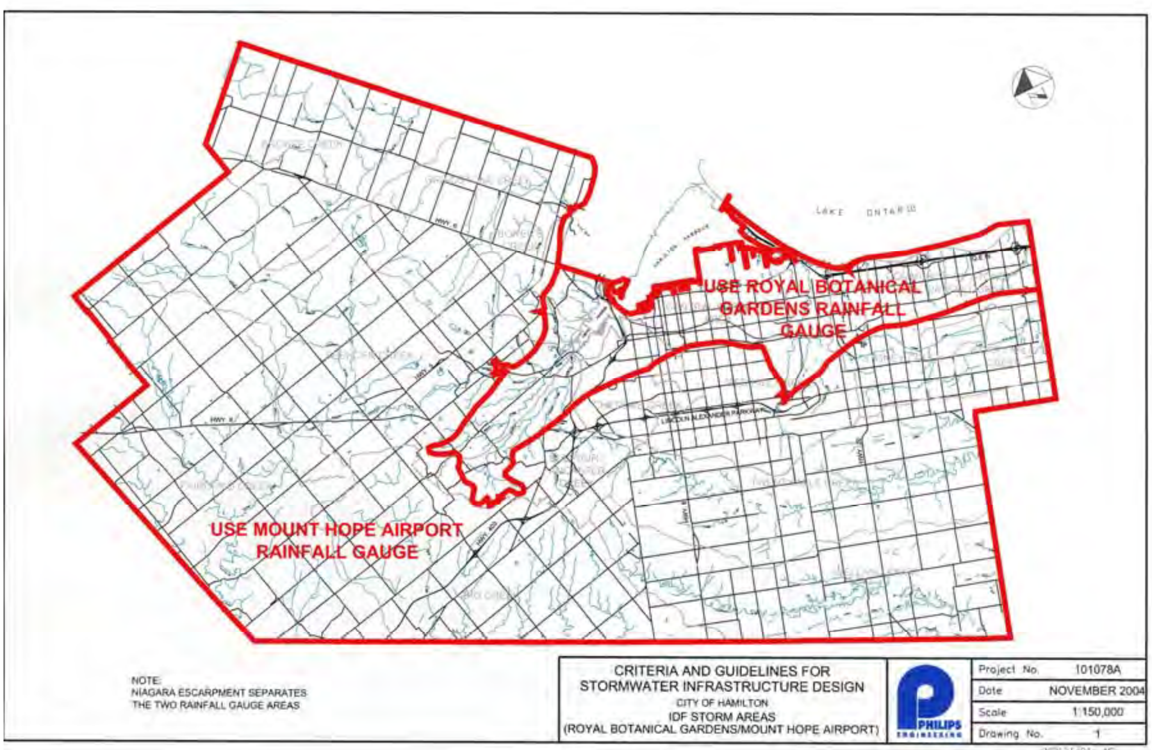


Figure 5.4: The Locations of Mount Hope Airport and Royal Botanical Gardens Rainfall Gauge Areas (Philips Engineering Limited, 2005)

Mount Hope Airport Rainfall Gauge data was selected and applied to the model in the former City of Hamilton, Ancaster, Dundas, Flamborough and Glanbrook while Royal Botanical Gardens Rainfall Gauge data was adopted and applied in the Stoney Creek model. The models were then run with 2, 5, 10 and 25-year events for all six former municipalities while the 50 and 100-year events could be simulated only in the Stoney Creek model due to hydraulic limitations (the flow computation process is terminated whenever overflow height is higher than 10 meters above the ground elevation of manhole).

A Mount Hope 6 hr Chicago 2-year hyetograph is shown in tabular form and graphically below (Figures 5.5 and 5.6):

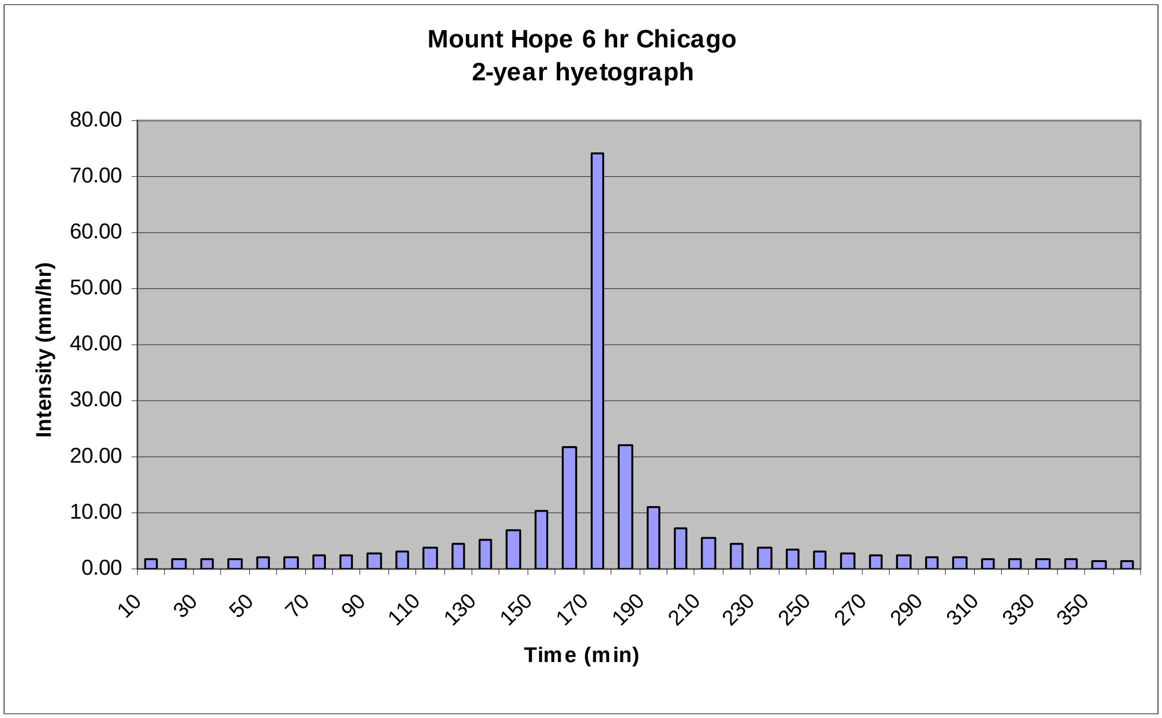


Figure 5.5: Mount Hope 6 hr Chicago 2-year hyetograph in tabular form

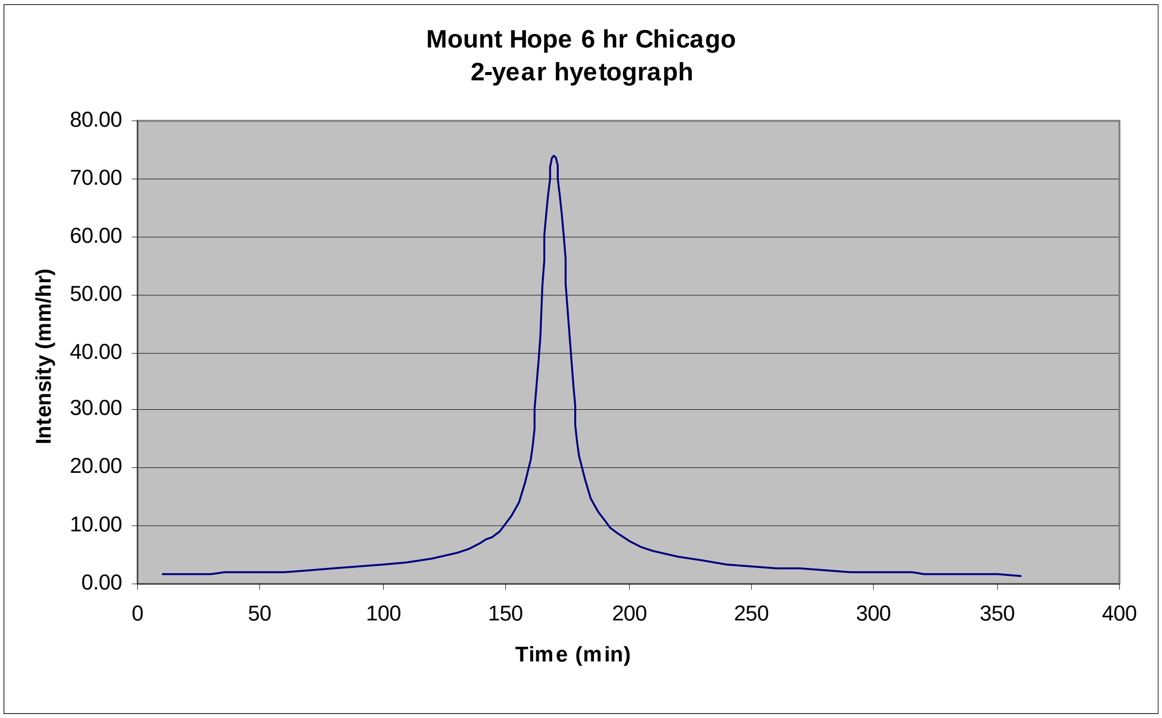


Figure 5.6: Mount Hope 6 hr Chicago 2-year hyetograph in graphical format.

The accumulative volumes for different storm events are summarized in table below:

Accumulative Volumes for Different Storm Events
(6-hour Chicago Distribution Design Storm – Mount Hope and Royal Botanical Gardens)

Storm Event	Cumulative Volumes (mm) Mount Hope	Cumulative Volumes (mm) Royal Botanical Gardens
2-Year	38.3	36.2
5-Year	54.4	48.6
10-Year	65.2	57.1
25-Year	78.9	67.3
50-Year	88.2	75.3

MOUSE Model Specific Parameters

The primary parameters that influence the peak flow rate and shape of hydrograph are listed below:

- Sub-Catchment Area
- Percent Impervious
- Infiltration
- Depression Storage
- Flow Path Length
- Catchment Roughness Coefficient

A description of each of these parameters is provided below.

Sub-Catchment Area

A sub-catchment area is defined as the area that drains to the storm sewer pipe (Figure 5.7).

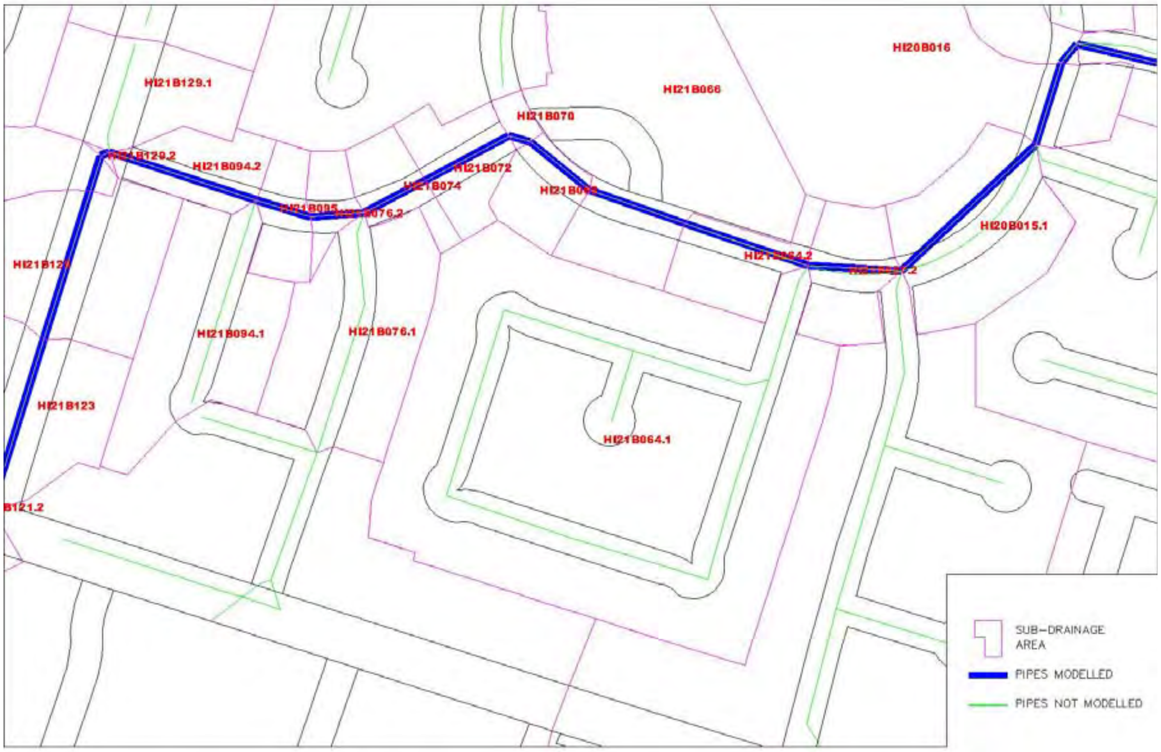


Figure 5.7: Trunk Storm Sewer Running Along Different Catchment Areas

The City provided all sub-catchment areas. The sub-catchment areas were defined based on the size of the storm sewer running through it. In areas where the storm sewers were not modeled (because the sewer size did not meet the minimum size) the sub-catchment areas were aggregated (green thin lines). For other areas (blue thick lines) where the storm sewer was modeled, the sub-catchment area tributary to the storm sewer was used.

Percent Impervious

There were approximately 4000 sub-catchments within the study area and it was not practical to define the percentage of imperviousness for each area. In addition, many catchment areas are relatively similar. For instance, a single family residential area in one part of Ancaster is more likely the same as a single family residential area in another part of Ancaster in terms of the land use characteristics. As a result, representative areas (51 in total) were chosen based on different land uses and locations in order to provide average statistics of the percentage of impervious cover for each distinct land use. The City provided different land uses from the local and regional Official Plan (OP). a detailed assessment of percent impervious was then undertaken for a representative area for each distinct land use.

Several representative examples that illustrate distinct land uses are shown below (Figures 5.8 to 5.12):

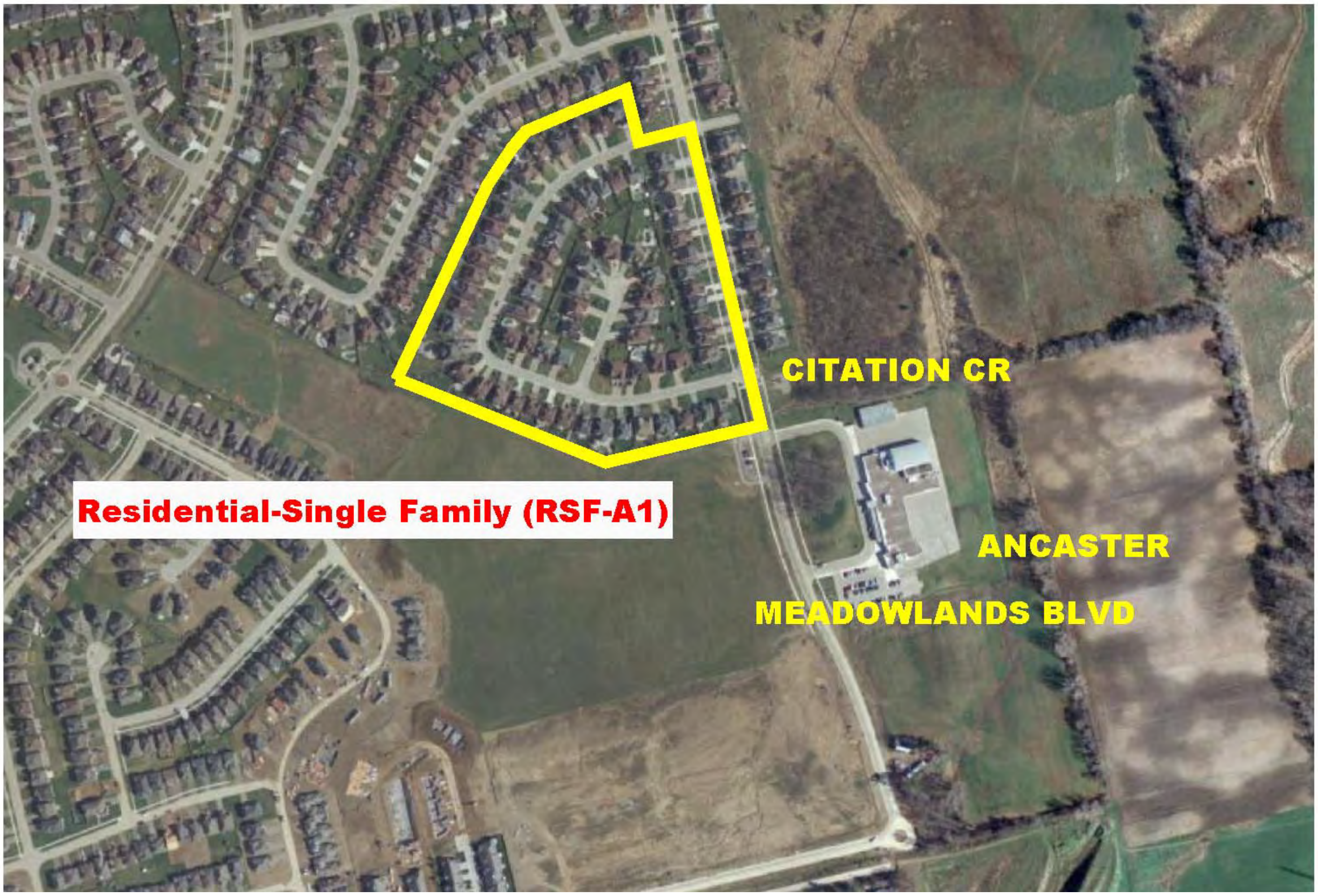


Figure 5.8: Single Family Residential – Ancaster (RSF-A1), illustrates that single-detached houses and local roads are the primary components for this sub-catchment area.

Figure 5.9: Community Shopping Centre – Hamilton City (CCS1), illustrates that the shopping centre building, parking lot and roads are the main components for this sub-catchment area.

Figure 5.10: Agricultural Farms – Glanbrook (OSA2), illustrates that farm fields and local roads are the main components for this sub-catchment area.

Figure 5.11: Standard Industrial Property – Stoney Creek (ILI1), indicates that the industrial building, parking lot and grass area are the main components for this sub-catchment area.

Figure 5.12: Open Space Park – Hamilton City (OSP1), illustrates that grassed areas and pathway are the main components for this sub-catchment area.

Table 5.2 illustrates the representative percent impervious values that were used for each of the 51 distinct land uses.

Table 5.2: Representative Percent Impervious Values

Community	Primary	Secondary	Code	CAREA	Steep (Roof)		Flat	Road	Sidewalk		**Total**	Grass/Farm	**Total**
	Land use	Land use					(Roof/Driveway/Parking)						
					Imp Area	% Imp Area Steep	Imp Area	Imp Area	Imp Area	% Imp Area Flat	**% Imp**	Pervi Area	**% Per**
Ancaster	Residential	Single Family	RSF-A1	67991	17782	26.2%	4680	7454	520	18.6%	44.8%	37555	55.2%
Ancaster	Residential	Single Family	RSF-A2	47849	9838	20.6%	4900	8540	0	28.1%	48.6%	24571	51.4%
Dundas	Residential	Single Family	RSF-D1	17384	3983	22.9%	1484	2245	410	23.8%	46.7%	9262	53.3%
Dundas	Residential	Single Family	RSF-D2	48711	8342	17.1%	3960	10522	0	29.7%	46.9%	25887	53.1%
Flamborough	Residential	Single Family	RSF-F1	58028	12456.11	21.5%	5400	6704	1605	23.6%	45.1%	31863	54.9%
Flamborough	Residential	Single Family	RSF-F2	13614	3894	28.6%	1460	2278	613	32.0%	60.6%	5369	39.4%
Hamilton City	Residential	Single Family	RSF-H1	29710	9265	31.2%	3240	4573	0	26.3%	57.5%	12632	42.5%
Hamilton City	Residential	Single Family	RSF-H2	69894	15093.29	21.6%	4700	20349	0	35.8%	57.4%	29752	42.6%
Glanbrook	Residential	Single Family	RSF-G1	153989	40036	26.0%	19331	17771	2729	25.9%	51.9%	74122	48.1%
Glanbrook	Residential	Single Family	RSF-G2	30594	9600	31.4%	2800	3277	0	19.9%	51.2%	14917	48.8%
StoneyCreek	Residential	Single Family	RSF-S1	37688	9757	25.9%	3972	2257	1146	19.6%	45.5%	20556	54.5%
StoneyCreek	Residential	Single Family	RSF-S2	66445	19175	28.9%	7040	8973	1741	26.7%	55.6%	29516	44.4%
Hamilton City	Residential	Semi Detached	RSD1	15843	3996	25.2%	1022	1945	0	18.7%	44.0%	8880	56.0%
Hamilton City	Residential	Semi Detached	RSD2	10983	2958	26.9%	687	1858	0	23.2%	50.1%	5480	49.9%
Hamilton City	Residential	Town Houses	RTH1	15587	2821	18.1%	2200	2252	347	30.8%	48.9%	7967	51.1%
Ancaster	Residential	Town Houses	RTH2	24250	8820	36.4%	0	5187	0	21.4%	57.8%	10243	42.2%
StoneyCreek	Residential	High Rise	RHR1	13393	0	0.0%	9313	1091	206	79.2%	79.2%	2783.4	20.8%
StoneyCreek	Residential	High Rise	RHR2	10948	0	0.0%	7357	848	0	74.9%	74.9%	2743	25.1%
Hamilton City	Residential	High Rise	RHR3	9082	0	0.0%	2291	851	510	40.2%	40.2%	5430	59.8%
Hamilton City	Institutional/	Universities/Colleges	EUC	219448	0	0.0%	38325	7509	0	20.9%	20.9%	173614	79.1%
Hamilton City	Educational	Local Schools/Churches	ELC1	62518	0	0.0%	17406	8099	284	41.3%	41.3%	36729	58.7%
Hamilton City		Local Schools/Churches	ELC2	5766	0	0.0%	2635	533	64	56.1%	56.1%	2534	43.9%
Hamilton City		Hospitals	IHP	191386	0	0.0%	67463	24664	0	48.1%	48.1%	99259	51.9%
StoneyCreek		Community Centres	ICC	35721	0	0.0%	17847	2445	182	57.3%	57.3%	15247	42.7%
Hamilton City	Office	Office Building	OOB	8621	0	0.0%	5756	2312	0	93.6%	93.6%	553	6.4%
Hamilton City		Commercial Condominium	OCC	4601	0	0.0%	3927	579	0	97.9%	97.9%	95	2.1%
Hamilton City	Commercial	Community Shopping Centre	CCS1	283480	0	0.0%	249052	7944	0	90.7%	90.7%	26484	9.3%
Ancaster		Community Shopping Centre	CCS2	422972	0	0.0%	337249	28206	5822	87.8%	87.8%	51696	12.2%
Flamborough		Community Shopping Centre	CCS3	124588	0	0.0%	100711	8252	2176	89.2%	89.2%	13449	10.8%
Ancaster		Neighborhood Shopping Centre	CNS1	80512	0	0.0%	66358	4953	0	88.6%	88.6%	9201.4	11.4%
Hamilton City		Neighborhood Shopping Centre	CNS2	36998	0	0.0%	30984	4662	97	96.6%	96.6%	1255	3.4%
Flamborough		Commercial Accomodations-Hotels/Motels	CCA	15288	0	0.0%	6154	1301	408	51.4%	51.4%	7425	48.6%
Hamilton City	Wholesale	Warehousing	WWH	13039	0	0.0%	9113	1731	0	83.2%	83.2%	2195	16.8%
StoneyCreek	Industrial	Light Industry-Industrial Mall	ILI1	55954	0	0.0%	33597	2428	0	64.4%	64.4%	19929	35.6%
Hamilton City		Light Industry-Industrial Mall	ILI2	52299	0	0.0%	40288	4829	0	86.3%	86.3%	7181	13.7%
StoneyCreek		Medium Industry-Standard Industrial Propert	IMI1	51242	0	0.0%	41287	2041	0	84.6%	84.6%	7914.2	15.4%
Hamilton City		Medium Industry-Standard Industrial Propert	IMI2	64690	0	0.0%	52119	3524	444	86.7%	86.7%	8603	13.3%
Hamilton City		Heavy Industry-Heavy Industrial Properties	IHI1	47840	0	0.0%	39151	2036	0	86.1%	86.1%	6653	13.9%
Hamilton City		Heavy Industry-Heavy Industrial Properties	IHI2	20871	0	0.0%	19873	903	0	99.5%	99.5%	95	0.5%
Hamilton City	Utilities	Transportation-Highway	UTH	6356	0	0.0%	0	4669	0	73.5%	73.5%	1687	26.5%
StoneyCreek	Open Space	Open Space	OSO	96803	172	0.2%	0	4949	0	0.0%	0.2%	96631	99.8%
Hamilton City		Parks	OSP1	167167	407	0.24%	14933.8	3312	1047	11.5%	11.8%	147467	88.2%
StoneyCreek		Parks	OSP2	58025	0	0.0%	1727	1321	466	0.0%	0.0%	58025	100.0%
Ancaster		Golf Course	OSG	1257497	3685	0.3%	0	11937.9	0	0.9%	1.2%	1241874	98.8%
Hamilton City		Burial Facilities-Cemetery	OSB	172019	147	0.1%	8602	4352.9	0	7.5%	7.6%	158917	92.4%
Ancaster		Woodlots	OSW	20332	187	0.9%	0	914.6	0	4.5%	5.4%	19230	94.6%
Hamilton City		Agricultural-Farms	OSA1	39112	0	0.0%	0	1625	0	4.2%	4.2%	37487	95.8%
Glanbrook		Agricultural-Farms	OSA2	225812	0	0.0%	0	2138	0	0.9%	0.9%	223674	99.1%
Hamilton City		Vacant Land	OSV1	47381	0	0.0%	0	0	698	1.5%	1.5%	46683	98.5%
Hamilton City		Vacant Land	OSV2	75520	0	0.00%	0	0	0	0.0%	0.0%	75520	100.0%
Glanbrook	Mixed Use	Residential/Retail	MUR	4880	1096	22.46%	1914	972	0	59.1%	81.6%	898	18.4%

For each of the representative areas, the percentage of steep roof (house) and the percentages of flat roof (apartment, commercial and industrial roof, road, parking, driveway and sidewalk) were determined by using 2004 aerial photographs. The different parameters (percentage of impervious and pervious areas) were calculated by overlaying the aerial photographs onto the catchment area map. Illustrations of the remaining distinctive land uses are provided in Appendix C.

Infiltration

Infiltration is the water loss to the lower storage caused by the porosity of the catchment surface. It is assumed that the infiltration starts when the wetting of the surface has been completed. Infiltration is a complex phenomenon, dependent on the soil porosity, moisture content, groundwater level, surface conditions, storage capacity, etc. Soil maps provided by the City were used to identify locations and types of different soil materials by overlaying these maps onto the catchment area map. Up to three levels of infiltration (small, medium and large infiltration) may be defined for each catchment area.

Provided below is an overview as to how the infiltration values were defined for each surface type area.

Surface type areas [% of total area] – fractions of the catchment surface belonging to different surface types:

- impervious steep – sloped roof area (e.g.: Residential Houses - Single Detached, Semi-Detached and Town House)
- impervious flat – flat roof area (e.g.: Condominium, High Rise Building, University/College, School, Hospital, Community Centre, Office Building, Community & Neighboring Centre, Commercial Accommodation-Hotel/Motel, Warehousing, Industrial Property, Highway, Local Road, Driveway and Parking)
- pervious – small impermeability (e.g.: Clays, Clay loams)
- pervious – medium impermeability (e.g.: Loams, Clayey silt)
- pervious – large impermeability (e.g.: Sandy soils)

The infiltration hydrological parameters set for each sub-catchment are shown below:

Start infiltration [m/s] – defines the maximum rate of infiltration (Horton) for the specific surface type.

The default value depends on the surface type (see Table 5.3).

End infiltration [m/s] – defines the minimum rate of infiltration (Horton) for the specific surface type.

The default value depends on the surface type (see Table 5.3).

Horton's Exponent – time factor "characteristic soil parameter" [s^{-1}]. Determines the dynamics of the infiltration capacity rate reduction over time during rainfall. The actual infiltration capacity is made dependent of time since the rainfall start only.

The default value depends on the surface type (see Table 5.3).

Inverse Horton's Equation [s^{-1}] – time factor used in the "inverse Horton's equation", defining the rate of the soil infiltration capacity recovery after a rainfall, i.e. in a drying period.

The default value depends on the surface type (see Table 5.3).

<u>Wetting Losses</u>

This parameter represents the depth of rain required to "wet" the surface of the land type. No storage or runoff can occur until the wetting losses have been satisfied.

The default value for all surface types is 5.00E-5 m.

<u>Depression Storage</u>

The surface storage is the loss due to filling the depressions and holes in the terrain. The model begins with the surface storage calculation after the wetting process is completed. The surface storage is filled only if the current infiltration rate is smaller than the actual precipitation intensity reduced by evaporation.

For impervious flat area, the depression storage is 6.00E-4 m,
For pervious small infiltration area, the depression storage is 1.00E-3 m,
For pervious medium infiltration area, the depression storage is 1.00E-3 m,

For previous large infiltration area, the depression storage is 2.00E-3 m.

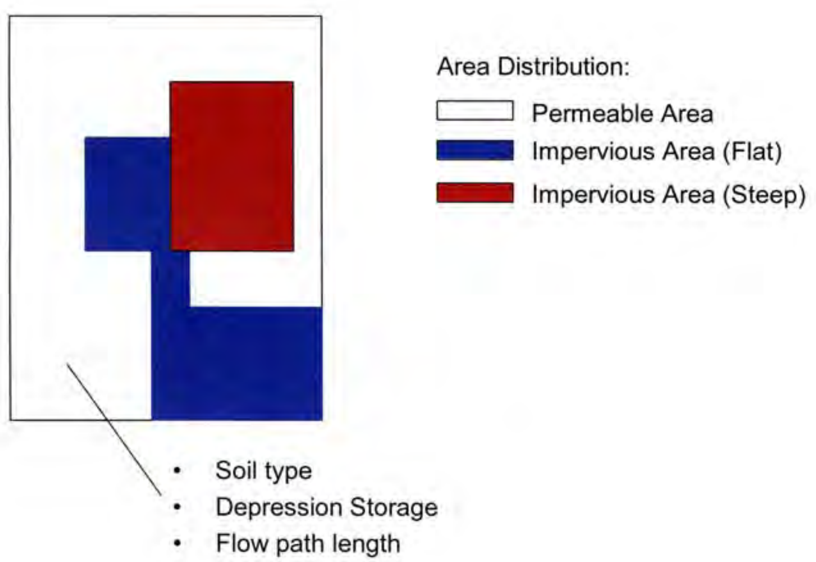
The model applies different hydrological parameters for each of the surface types as summarized in the table below:

Table 5.3: Default hydrological parameters for surface runoff model B

Parameter	Impervious		Pervious		
	Roof	Flat area	Small Infiltration	Medium Infiltration	Large Infiltration
Wetting (m)	5.00E.-5	5.00E.-5	5.00E.-5	5.00E.-5	5.00E.-5
Storage (m)	-	6.00E.-4	1.00E.-3	1.00E.-3	2.00E.-3
Start Infiltration (m/s)	-	-	1.00E.-6	1.00E.-5	2.00E.-5
End Infiltration (m/s)	-	-	5.00E.-7	1.00E.-6	5.00E.-6
Exponent (s^{-1})	-	-	1.50E.-3	1.50E.-3	1.50E.-3
Inverse Exp. (s^{-1})	-	-	5.00E.-6	1.00E.-5	5.00E.-5

Flow Path Length

The length of the flow path was used as a means of approximating the lag time observed between the commencement of rainfall and the occurrence of flows in the storm sewer system. In cases where the sub-catchment area drains directly to a sewer which was modeled the travel time from the sub-catchment area to the sewer needed to be defined. In cases where the sub-catchment area drains to a sewer which was not modeled then the travel time in the sewer also had to be determined.



Three examples which illustrate how the flow path length was determined are provided on the following page:

Example No. 1: A single storm sewer segment (included in model) located in the sub-catchment area

For impervious areas – roof and flat areas, Manning's "n" values are approximately equal to the Manning's "n" for the storm sewer.

Flow path length = (2/3)l + L

L: storm sewer segment length
l: length of building lot

For pervious areas – grass area Manning's "n" (assuming we used 30) is 80/30 = 2.67 larger, and therefore the equation will be

Flow path length = (2/3)l * 2.67 + L

Example No. 2: Storm sewer segments (not included in model) connected to other storm sewer segment (included in model) located in the sub-catchment area

For impervious and pervious areas – the calculation formula is the same as Example No.1 and simply picks the longest distance running along the sewer segments as "L".

Example No. 3: Rural or agricultural area

For rural areas – overland (grass) area Manning's "n" (assuming we use 4), therefore the length (l) has to be multiplied by 80/4 = 20

Flow path length = (2/3)l * 20 + L

L: storm sewer segment length
l: longest distance in area

Outlined is a simple way to determine the small "l" value

For	Residential	l = 40m
	Institutional	l = 200m
	Office	l = 100m
	Commercial	l = 60 m
	Warehouse	l = 150m
	Industrial	l = 150m

Open Space, determining the "l" value may require measurements (200m is the default value).

<u>Catchment Surface Roughness</u>

The velocity of overland flow is dependant on the surface roughness of the catchment. A lower surface roughness value will result in a high surface runoff velocity.

Manning's Roughness Coefficients for various surfaces are listed on the following page:

Table 5.4: Manning's Roughness Coefficients for Various Surfaces

Surface Type	Manning's Roughness Coefficients
Impervious steep roof area: (e.g.: Asphalt Shingles)	0.013 = 1/80
Impervious flat roof area: (e.g.: Concrete)	0.014 = 1/70
Pervious small infiltration area: (e.g.: Clays)	0.033 = 1/30
Pervious medium infiltration area: (e.g.: Clayey Silt)	0.033 = 1/30
Pervious large infiltration area: (e.g.: Sandy soils)	0.083 = 1/12

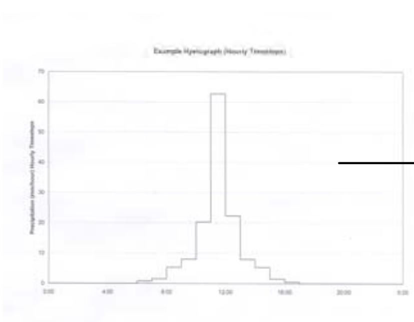
Default values for hydrological parameters – Runoff Model B

Parameter	Impervious		Pervious		
	Steep area	Flat area	Small Infiltration	Medium Infiltration	Large Infiltration
Manning ($m^{1/3} s^{-1}$)	80	70	30	30	12

<u>Determination of a Representative Flow Hydrograph</u>

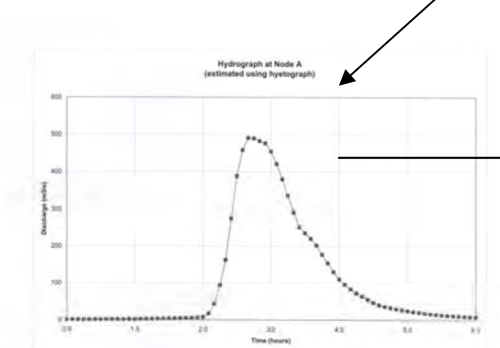
A **hydrograph** is a chart that displays the change of a hydrological variable over time.

Precipitation (hyetograph) is the primary mechanism for transporting water from the atmosphere to the surface of the earth. Rainfall runoff reaches the ground surface (catchment area) and travels at a distinct velocity (runoff hydrograph) depending on the slope and land use of the area. Surface runoff enters the storm sewer network system via catch basins and manholes.

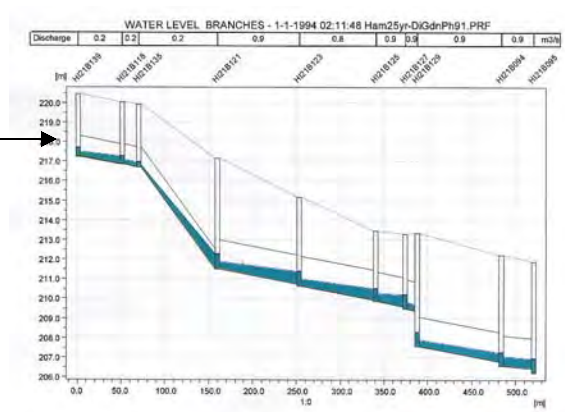


Hyetograph (Rainfall)

Catchment area



Hydrograph (Surface Runoff)



Storm sewer network

5.2.4 Determination of Sewer System Flows

The MOUSE Surface Runoff Module, as noted previously, determines the Surface Runoff Hydrograph to the storm sewer inlet. The MOUSE Hydrological Pipe Flow Model (HD), as explained below, then determines the water levels within the storm sewer system.

MOUSE Pipe Flow Module (HD)

MOUSE Hydrological Pipe Flow Model (HD) solves the complete set of St. Venant (dynamic flow) equation throughout the drainage network (looped and dendritic), which allows for modeling of backwater effects, flow reversal, surcharging in manholes, free-surfaces and pressure flow, tidal outfalls and storage basins. The program has been designed to handle any type of pipe network system with alternating free surface and pressurized flows as well as open channel network.

The computational scheme uses an implicit, finite-difference numerical solution of the St. Venant flow equations. The numerical algorithm uses a self-adapting time-step, which provides efficient and accurate solutions in multiple connected branched and looped pipe networks. This computational scheme is applicable to unsteady flow conditions that occur in pipes ranging from small-profile collectors for detailed urban drainage, to low-lying, often pressurized, sewer mains affected by varying outlet water levels. Both sub-critical and supercritical flows are treated by means of the same computational scheme that adapts to the local flow conditions. Moreover, flow phenomena, such as backwater effects and surcharges, are precisely simulated. The model may also be used to incorporate stormwater management ponds.

5.2.5 Required Parameters for the MOUSE Pipe Flow Module

Provided below is a description of the parameters which must be defined in order to run the MOUSE Pipe Flow Module (HD)

Ground and Invert Elevations of Node

Ground elevation is the surface elevation of the node, while the invert elevation is the subsurface elevation between the node and link’s connection.

There are several types of nodes, each of them representing some structural element of a real drainage network:

- **manhole**, used to model all network nodes where the shape and volume can be sufficiently accurate approximated by a vertical cylinder of a specified diameter;
- **basin**, an arbitrarily shaped structure, resembling sump pump, detention basins (stormwater management facilities) or other structures with a significant volume;
- **storage node**, a dimensionless node used for a controlled routing of e.g. surcharging water; and
- **outlet**, a node where the modeled system interacts with receiving waters

The City provided the location, size, ground and invert elevations of the manholes and outlets. Staff at Aquafor Beech Limited input the detailed information for the stormwater management facilities (basins) into the storm sewer network model.

Length, Size and Slope of Link

The links represent various types of conduits, both closed (pipes and tunnels) and open (canals). By default, a link is assumed to be a straight line connecting two nodes – the upstream node and the downstream node. The system calculates the length on the basis of a straight connection; however, this length can be overridden by a user-specified pipe length. The order of the node specification does not have any effect on the computations, but only on the sign of the flow. The flow in the downstream direction is assumed as positive flow.

The following types of links are available:

- **standard pipes**, including circular, rectangular, square, natural channels and two types of egg-shaped pipes;
- **arbitrarily shaped links**, open or closed, specified through the cross section database

Sewer Roughness Coefficient

The velocity of pipe flow is dependent on the surface roughness of the sewer. A lower surface roughness results in a higher velocity.

The City also provided the location, size, length, shape, material type, slope, roughness coefficient, and invert elevation of the links (pipes).

Weirs and Orifices

Two nodes can also be connected by some of the functional relations, which resemble various structural elements of a drainage network:

- **Fixed weir**, a model element describing a fixed external (i.e. discharging out of the system) or internal (i.e. between two model nodes) overflow structure. The flow can be computed according to a standard weir formula or a user-specified Q-H relation.
- **Orifice**, an arbitrary-shaped closed opening (external or internal). The shape can be specified through the cross-section database. The flow is computed on the basis of a built-in algorithm.

The City of Hamilton provided the location, size, type and invert elevation of the weirs and orifices. Aquafor Beech confirmed the information that was supplied by the City, and verified and revised the inaccurate information in the model. Aquafor Beech abstracted any missing information of above physical data into the drainage network model from existing information sources, including sewer maps and plans; topographic maps and plans, land-use maps and plans, and soil maps. Any assumed information made in determining MOUSE Pipe Network Model input parameters by Aquafor Beech was documented and a sample of the comment table (Table 5.5) and a sample figure (Figure 5.13) are shown on the next page:

Table 5.5: Sample Comment Table for the MOUSE Pipe Network Model

LINKID	FROMNODE	TONODE	DIAMETER	UPLEVEL	DWLEVEL	SPECIFIEDLENGTH	COMMENT
FD34B002.1	FD34B002	FD34B004	0.375	227.012	226.043	64.6	
FD34B004.1	FD34B004	FD34B006	0.45	1	1	59.2	Assumed Updream and Downstream Invert level
FD34B006.1	FD34B006	FD34B008	0.45	223.5495	222.453	73.1	
FD34B010.1	FD34B010	FD34B012	0.525	219.982	219.193	52.6	
FD34B012.1	FD34B012	FD34OF01	0.75	219.158	218.729	28.6	
FD35B002.1	FD35B002	FD34B002	0.375	230.599	227.012	48.6	
FD35B004.1	FD35B004	FD35B002	0.375	233.899	230.594	40.8	Assumed Downstream Invert level
FD35B006.1	FD35B006	FD35B004	0.375	238.261	233.904	79.1	
FD35B008.1	FD35B008	FD35B006	0.3	239.924	239.276	36.2	
FD35B010.1	FD35B010	FD35B008	0.3	240.523	239.939	45.1	
FD35B012.1	FD35B012	FD35B010	0.3	240.905	240.663	33.3	
FD35B014.1	FD35B014	FD35B012	0.3	241.014	240.89	31.2	
FD35B016.1	FD35B016	FD35B014	0.3	241.536	241.089	48.6	
FB06B012.1	FB06B012	FB06B014	0.525	268.94	268.48	76.4	
FB06B014.1	FB06B014	FB06B016	0.6	268.33	267.96	70.2	
FB06B016.1	FB06B016	FB06B018	0.675	267.85	267.39	76.5	Assumed Pipe Size
FB06B018.1	FB06B018	FB06B020	0.75	267.29	266.89	69.8	
FB06B020.1	FB06B020	FB06B022	0.75	266.83	266.27	93.7	
FB06B022.1	FB06B022	FB06B024	0.525	266.17	265.66	112.5	
FB06B024.1	FB06B024	FB06OF01	0.9	265.64	265.0685	45	
FB06B028.1	FB06B028	FB06B026	0.525	267.15	266.19	71.7	
FB06B030.1	FB06B030	FB06B028	0.525	268.38	267.26	68.6	
FB06B042.1	FB06B042	FB06OF02	0.45	262.2	261.71	48.4	

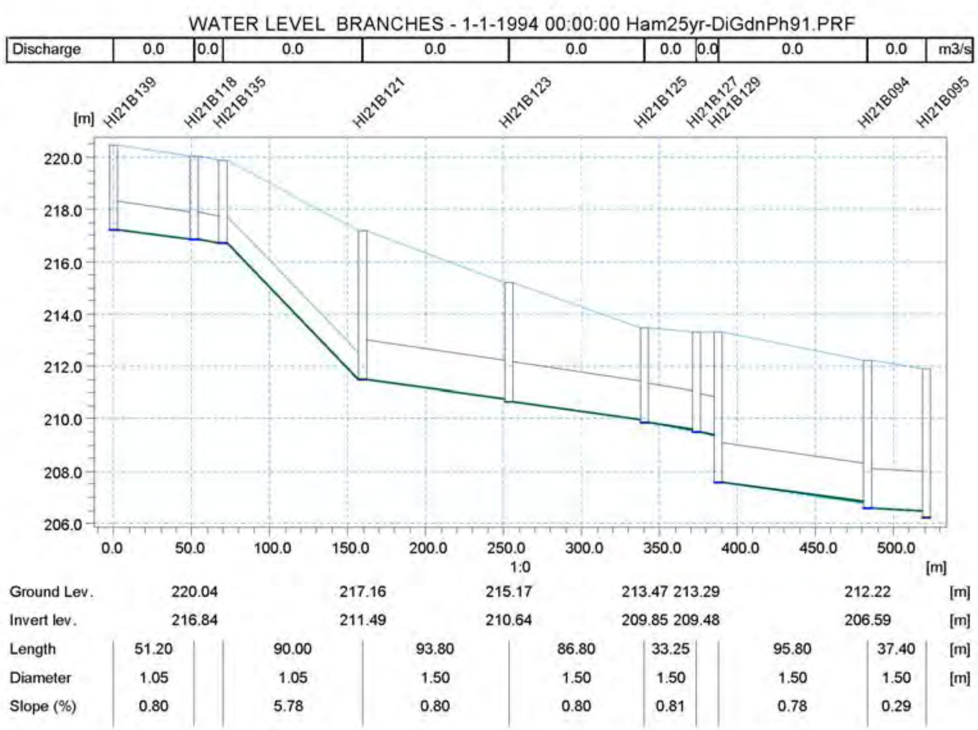


Figure 5.13: Sample Figure of MOUSE Pipe Network Model

The MOUSE model included the following separate storm sewer system components:

- Within the former City of Hamilton, in the area not serviced by combined sewers – all separate storm sewer segments which are larger than or equal to 600 mm in diameter, height or width.

- Within Stoney Creek – all separate storm sewer segments which are larger than or equal to 600 mm in diameter, height or width.
- Within Carlisle, Freelton, Glanbrook, Greensville and Lynden – all separate storm sewer segments.
- Within the remaining portions of Ancaster, Dundas and Flamborough – all separate storm sewer segments which are larger than or equal to 525 mm in diameter, height or width.

In total, approximately 4,000 storm sewers segments were modeled (see Figure 5.14)

Parameters Required for Stormwater Management Ponds

In 2005, Aquafor Beech was retained to conduct a study entitled A Physical Inventory of Stormwater Management Ponds in the City of Hamilton. The study was undertaken to collect missing information and provided a better information base of the existing stormwater management facilities. The information may also be used as a basis for developing an operation and maintenance program and to provide the location and type of facility for the Public Health unit. A field investigation was conducted for each of the facilities. A Basic Level or Enhanced Level of investigation was undertaken depending upon the amount of information that existed in City records.

Basic Level of Field Inspection

This level of inspection was undertaken where existing information (e.g.: reports and design drawing) were well documented. The inspection involved measurements of physical structures (e.g. inlet and outlet structures) to confirm sizing, and spot checks of elevations to confirm conditions and concerns. Other information on the forms was filled in based on reports, drawings or as part of the inspection.

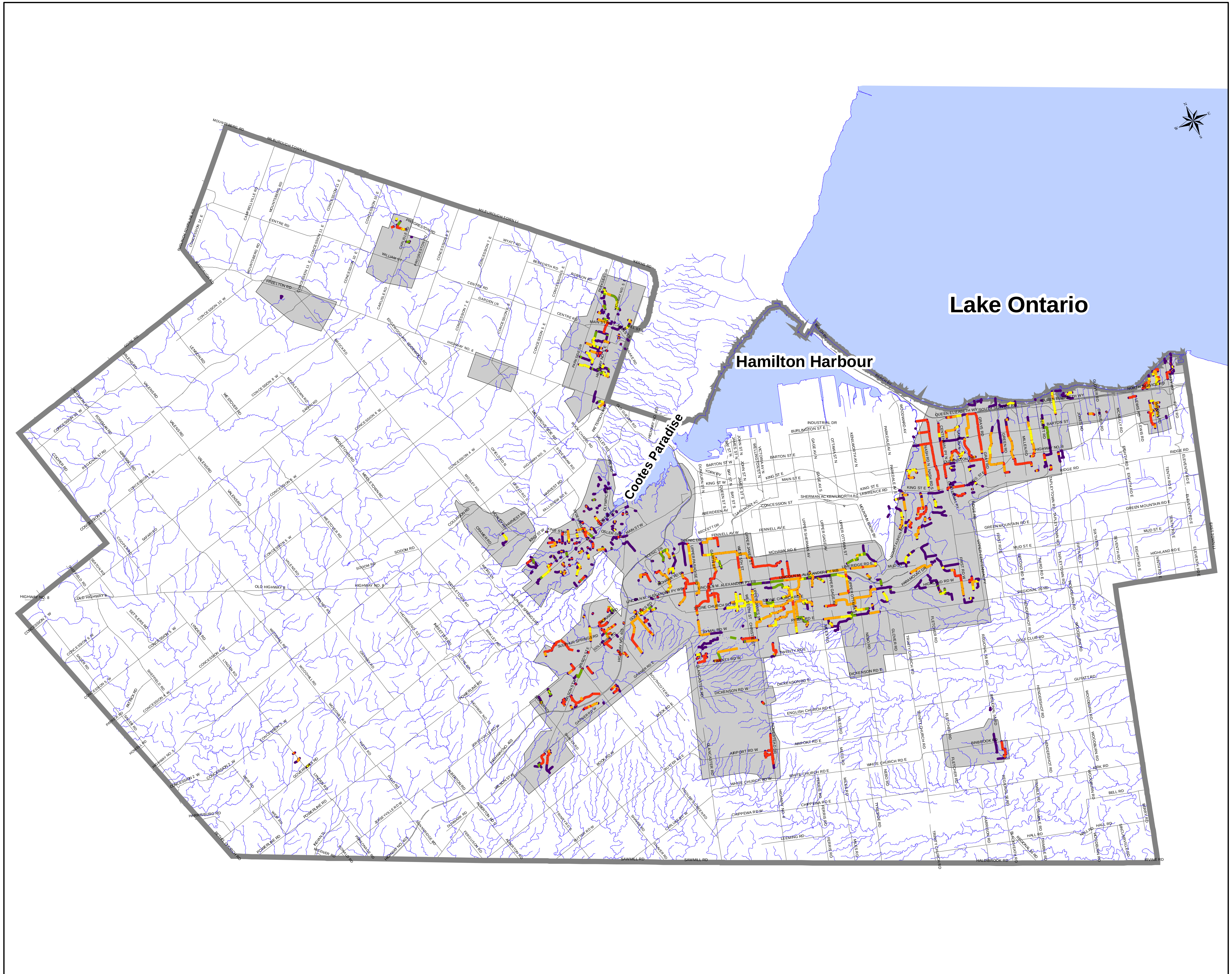
Enhanced Level of Field Inspection

This level of inspection was undertaken where existing information was sparse, or where the field inspection clearly showed a difference between design drawings and as constructed conditions. In this case, a total station survey was undertaken in order to provide missing information, to correct wrong information or to provide information below the water surface.

After the detailed information was collected and analyzed from the field inspection, pond storage volumes and areas were calculated to create stage-storage curve relationships, and similarly, outlet structure dimensions were also measured to build stage-discharge curves relationships. These relationships and other pond features (inlet and outlet locations, sizes and elevations, etc) were then included in the model. Consequently, the model was then used to determine the maximum storage volume and outflow rate based on those relationships.

Sample Presentation of Results

Several figures (Figures 5.15 to 5.19) are shown below to illustrate how water levels increase and decrease in the storm sewers during the course of a rainfall event (hyetograph).



KEY MAP

LEGEND:

- City of Hamilton Boundary
- Approximate Study Area

Existing Storm Sewer Capacity

- 2 Year
- 5 Year
- 10 Year
- 25 Year
- Greater Than 25 Year

NOTES:

0 2.5 5 10
Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Storm Sewer System Capacity Based on Existing Conditions

FIGURE: 5.14

DATE: 18 April 2007

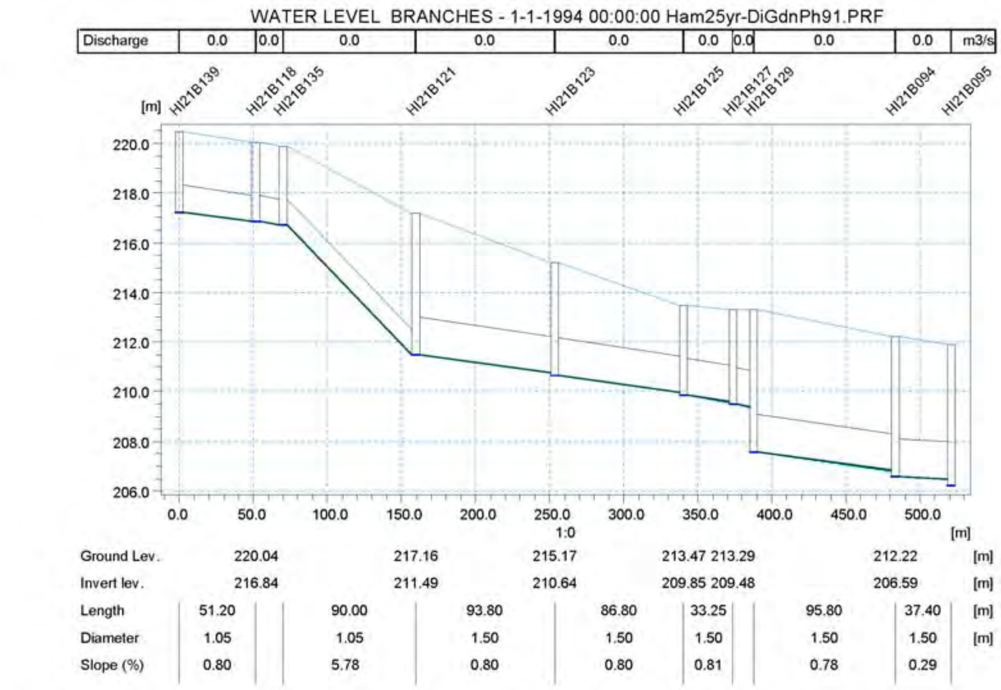


Figure 5.15: Illustrates the slope, size and length of storm sewer segments. There is no flow in the system at the beginning of the rainfall event.

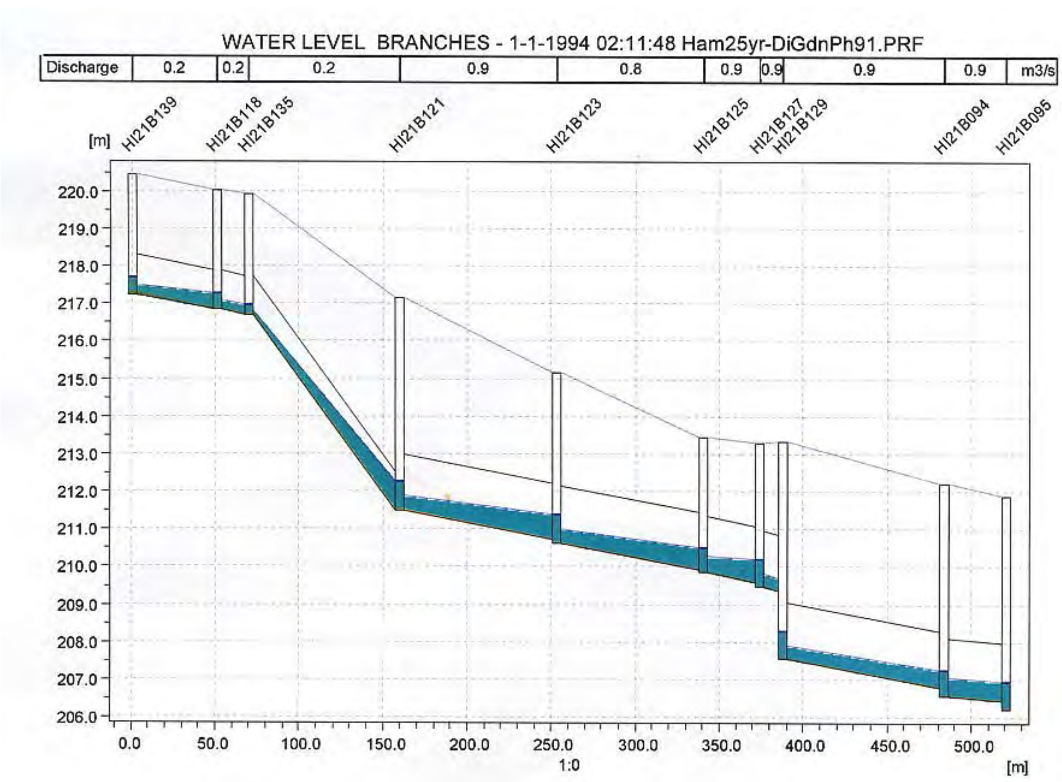


Figure 5.16: Illustrates how the water levels in the storm sewers begin to rise during the initial, less intense, stage of the rainfall event.

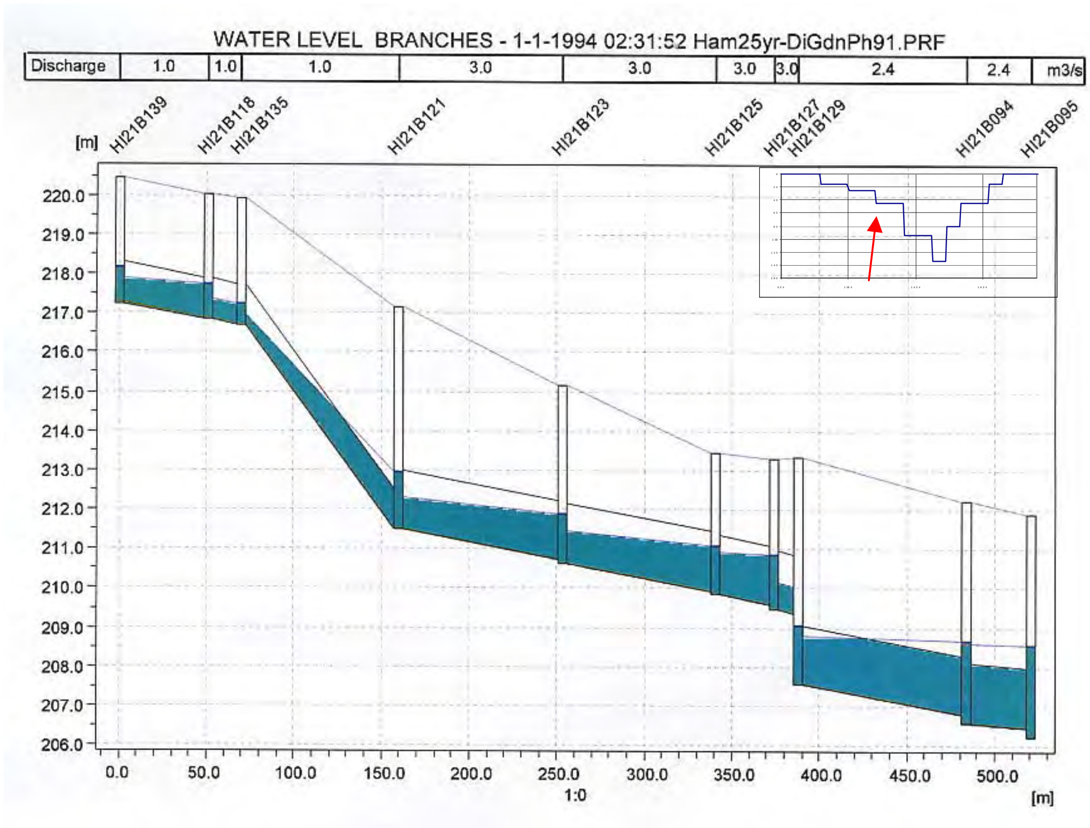


Figure 5.17: Illustrates how the water levels continue to increase as the event continues. It can be seen that some of the sewer segments are near, or at capacity, while others still have additional capacity.

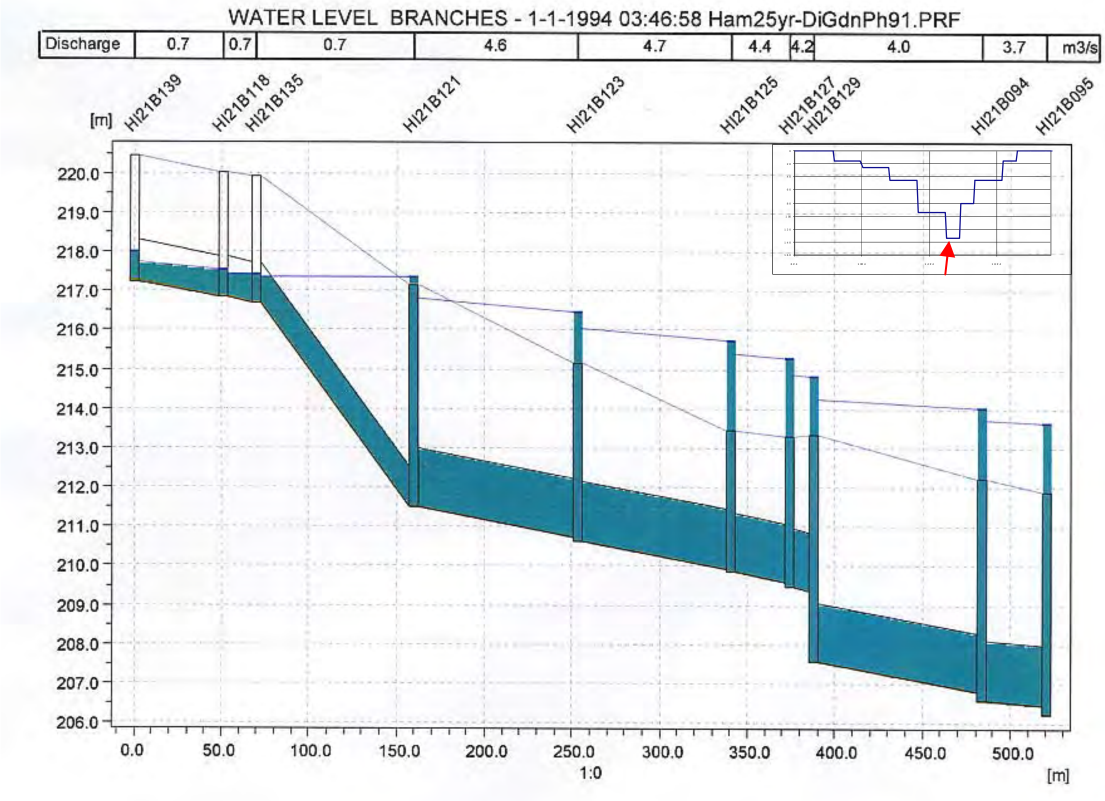


Figure 5.18: Illustrates surcharging (water level exceeds the obvert of the pipe) in a majority of the storm sewer segments in the lower part of the sewer system. Note how there is still additional capacity in the three upstream sewer segments.

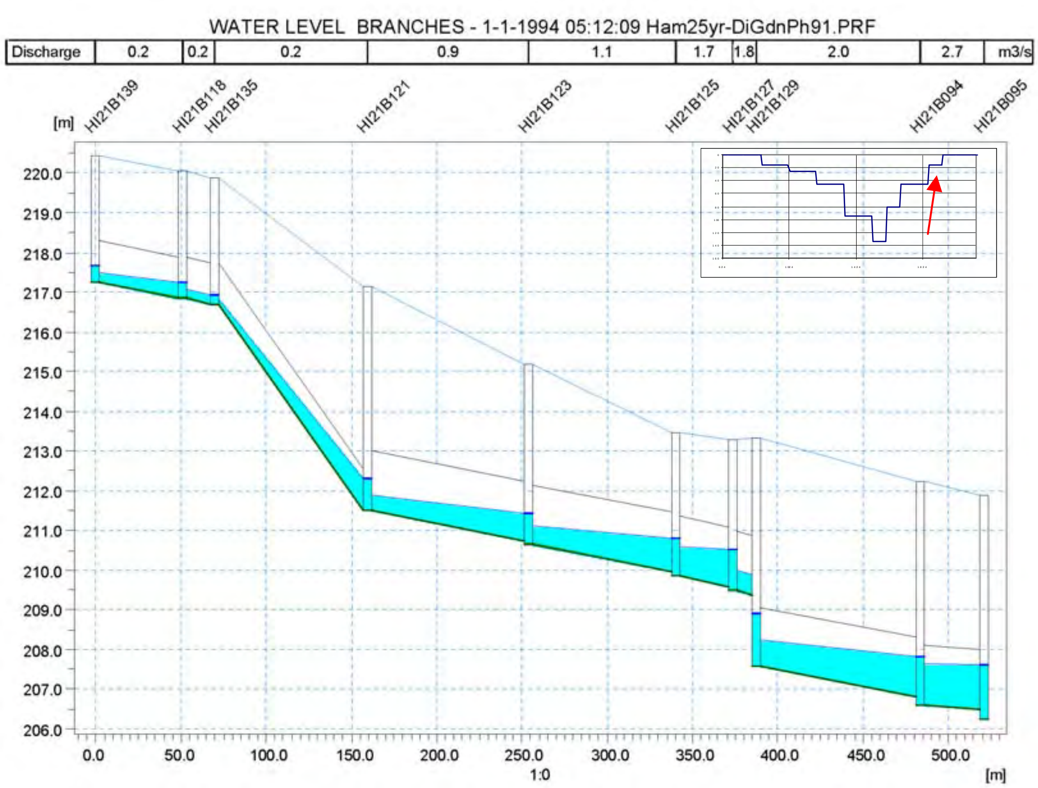


Figure 5.19: Illustrates that the water levels are subsiding as the rainfall intensity reduces.

5.2.6 Storm Sewer Modeling Simulations

One of the objectives of the modeling exercises was to define the relative level of service for each of the approximate 4,000 storm trunk sewer segments. For the purpose of this study, level of service was defined as the return period storm (e.g. 5 year, 10 year) for which the sewer capacity equals or exceeds the peak flow for the given return period storm. Determination of the level of service is a useful tool for identifying when (i.e. for what return period storm) problems associated with surcharging of the storm sewer system may occur. The results from this study may also be compared to the intended level of service (see Minor System Criteria, Table 5.4.1) which was established using more conventional approaches.

The results for each of the 4,000 sewer segments are illustrated in the Figure 5.14 (a large scale map is provided in Appendix C). In reviewing the results it should be emphasized that the results are only intended to provide an indication as to the relative level of service provided throughout the City. In this regard, the following points should be noted:

i) The model has not been calibrated or validated;
ii) The approach assumes that all flows enter the storm sewer system unattenuated. In some areas the flows into the storm sewer system will be attenuated as a result of restrictions in inlet capacity (i.e. catch basins, goss traps);
iii) In some areas, for example the former City of Hamilton and Stoney Creek, exceedance of the storm sewer capacity may result in significant damage due to basement flooding (in these areas, the foundation drains are connected directly to the storm sewer). In other areas (e.g. Ancaster), exceedance of the sewer capacity might not be as severe as sump pumps have been installed in buildings to counteract the impacts associated with surcharging sewer systems.

5.3 Watershed Model

5.3.1 Overview of Water Quality Spreadsheet Model

In order to characterize pollutant loads from rural and urban land uses within the study area and also to provide a relative comparison of the effect of applying different Best Management Practices to these lands, a simple mass balance spreadsheet model was developed. Variations of this model have been used for watershed studies in the Don River, Credit River, Dingman Creek, Rideau River, and more recently for studies within Conservation Halton (LOSACC) and Hamilton (Cootes Paradise).

5.3.2 Model Description

The model is based on estimating dry and wet weather runoff from different land use and soil characteristics in the watershed and can be descretized into up to 30 subcatchment areas. The model requires inputs on percent land use, percent soil type, runoff coefficients for different land use / soil types, event mean concentrations of different contaminants of interest, and total runoff for permeable versus impermeable surfaces. In addition, inputs for dry weather flows (quality and quantity), point source discharges (eg. sewage treatment plants) (quality and quantity) and groundwater discharge (quality and quantity) can be added. The model outputs include mean concentration, total loading for each subcatchment, as well as cumulative loadings and concentrations for selected locations (the model has a routing capability built in).

The model can be calibrated to account for the effects of instream processes and bio-chemical processes, for example bacterial dieoff. Once calibrated, the model can simulate various BMP's by modifying the volume, EMC, and process-related variables on a subcatchment basis, in order to predict the effect of implementing measures either throughout the watershed or within selected subcatchments. Up to 5 land uses for each of Agricultural, Pasture and Urban land use types can be characterized.

The model can be run for a single event, a season, annually or any other time period of interest, provided that the key input variables can be estimated.

For this study, the model was simplified by setting up each of the watersheds as a single catchment.

The study objective, as noted previously, was to determine daily loadings at the mouths of each tributary for the period of 1989 to 2003. In determining the loadings, two points were considered. These are summarized briefly below:

i) Concentrations, and therefore loadings, from urban versus rural areas may be different. An effort was therefore made to determine pollutant concentrations separately for both the urban and rural areas.
ii) Concentrations, and therefore loadings, may vary for dry (non-precipitation) and wet (precipitation) conditions. An effort was therefore made to determine pollutant concentrations for both dry and wet weather conditions.

In order to achieve the study objective, the following steps were undertaken:

i) All background information was reviewed and assessed. Relevant information included land use information, flow data, meteorological data, water quality data, as well as other general information including reports.
ii) Determine, based on the available water quality data, representative total phosphorus (TP), suspended solids (TSS), copper (Cu) and E. coli (Ec) concentrations for the following conditions;

    - Rural land use; dry weather (rd) – TPrd, TSSrd, Curd, Ecrd
    - Rural land use; wet weather (rw) – TPrw, TSSrw, Curw, Ecrw
    - Urban land use; dry weather (ud) – TPud, TSSud, Cuud, Ecud
    - Urban land use; wet weather (uw) – TPuw, TSSuw, Cuuw, Ecuw

iii) Determine daily flow rates at the mouth of each tributary. In general, this involved using records from the available flow gauges and prorating the daily flows to the mouths of each tributary based on drainage area and land use. The daily flow data was then split into dry versus wet "days" by reviewing corresponding daily precipitation data. Dry weather conditions were considered to correspond to any days when precipitation was 4 mm or less.
iv) Establish pollutant loadings at the mouth of each tributary on a daily basis for the years 1989 – 2003.

5.3.3 Sources of Data

Water quality data from existing sources (primarily MOE PWQMN stations) was summarized by calculating mean dry and wet weather concentrations. This was done by comparing stream flow/precipitation records on the day that each water quality sample was collected and classing it as a wet or dry sample. Results are summarized in Table 2.5. These results provide a general indication of typical water quality conditions for Hamilton area watercourses. They also reflect typical instream water quality for different land uses, since some watercourses, for example Spencer and Bronte Creeks are predominantly rural, while others, for example Red Hill Creek are predominantly urban.

EMC data for selected pollutants for urban and rural land use types were chosen based on local values as well as EMC reference data that was summarized and used in both the City of Toronto's Wet Weather Flow Management Strategy and the Credit Valley Conservation's Credit River Watershed Study. These EMC values are therefore based on extensive reference data collected through studies in the US and Canada.

In order to examine the effectiveness of various Urban and Rural BMP's, both volume and pollutant reductions were applied to the appropriate EMC values. Again the sources for these volume reductions and pollutant removal efficiencies were obtained from the above noted studies, as well as the MOE BMP Stormwater Planning and Design Manual (2004). Rural pollutant removal efficiencies were based on the federal SWEEP studies.

The rationale for selecting each contaminant is as follows:

Total Phosphorus (TP): Total phosphorus is a limiting nutrient in surface waters. Its presence in large concentrations typically indicates both urban and rural loadings of fertilizers and manure and results in algal blooms

Total Copper (Cu): Total copper is a trace metal that is typically found in elevated concentrations in urban environments. It is fairly toxic to plants and aquatic invertebrates.

Total Suspended Solids (TSS): TSS is fine particulate matter that is suspended in the water column. Sources include road runoff, soils from agricultural lands and stream banks. TSS also carries trace metals and nutrients that become attached to soils particles. At high concentrations, TSS can suffocate fish eggs on spawning grounds and clog fish gills.

E. Coli (EC): E. Coli is a bacteria found in association with the intestinal tract of humans and animals. Its presence in surface water indicates potential contamination by human and animal wastes and the potential for other disease causing micro-organisms to be present. It is used as a trigger for closing swimming beaches.

The following are the EMC concentrations used to set up the model:

Parameter	**Urban - Wet**	**Urban - Dry**	**Rural - Wet**	**Rural - Dry**
TP (mg/l)	0.19	0.032	0.156	0.052
Copper (mg/l)	0.025	0.019	0.0042	0.0024
TSS (mg/l)	100	16	86	10
E.coli (#/100ml)	25,000	15,000	10,000	800

5.3.4 Evaluation of Scenarios

A total of six (6) scenarios were tested using the model, including existing conditions and five stormwater control scenarios. Outputs were provided as total annual loads (dry and wet weather; urban and rural land use) and average instream concentrations. Although the model outputs are in absolute terms, the results should only be interpreted in terms of relative changes in concentrations and loadings, given the simple nature of the model. Chapter 10 provides further details on the variety of urban and rural BMP's and their associated uptake rates that were used for each scenario. The final removal efficiency listed below represents a "blended" rate of all of the BMP's (a cumulative estimate of the product of removal efficiency and uptake rate for each BMP). Chapter 8 discusses the results of the water quality modeling.

Existing Conditions

Existing flow data and the corresponding EMC concentrations for each of the 4 pollutants were used to calculated total annual loads and average concentrations for each watershed, either at its point of discharge to Cootes Paradise, Hamilton Harbour, Lake Ontario, or at the boundary of the City of Hamilton. Note that only portions of the watersheds within the City of Hamilton were modeled.

The portion of each daily flow attributable to runoff versus baseflow was determined using a threshold flow based on a flow frequency analysis. The 95% flow exceedence value was used as the threshold between wet and dry flows. Where gauged flows did not exist, flow data from either Red Hill Creek ("urban" catchment) or Spencer Creek ("rural" catchment) were extrapolated to the watershed based on watershed area.

Land use was based on the preferred land use identified in the GRIDS study. Rural land uses were determined based on OMAFRA land use data.

Scenario 1 - Future Conditions with No Runoff Controls/BMP's

Future growth areas from the preferred GRIDs land use study were modeled and included the following:

- Intensification
- Approved development
- New Business Park
- Airport Expansion
- Potential Urban boundary

Flow volumes for future growth were assumed to be twice the existing (rural) volume. The threshold for wet weather (runoff) was reduced by 50%. EMC values were the same as for existing conditions.

Scenario 2 - Future Conditions with Traditional Runoff Controls/BMP's

Flow volumes for future growth were the same as Scenario 1, but the runoff threshold was increased by 100%. Removal efficiencies for traditional runoff controls (assumed to be wet ponds) were based on the MOE SWMP study (1992), as follows:

- TP – 42%; Cu – 48%; TSS – 80%; E.coli – 53%

Scenario 3 - Future Conditions with State-Of-The-Science Runoff Controls/BMP's

This scenario assumed that a treatment train approach to SWM was applied that included source (eg roof downspout disconnection), conveyance controls (perforated pipe), end-of-pipe controls (wet ponds, infiltration systems, wetlands). This scenario also assumes that a water balance approach is taken to maintain pre-development condtions. Based on soil conditions, approximately 75% of the area has AB/BC soils that would be considered moderately to highly permeable and 25% of the area has CD soils that would be considered as low permeability soils. Flow volumes for AB/BC soils were reduced by a factor of 2 to equal rural volumes, and flow volumes for CD soils were reduced to 1.5 times rural volumes, while keeping the runoff threshold the same as existing conditions. The removal efficiencies were as follows (based on MOE 2004):

- TP – 65%; Cu – 65%; TSS – 80%; E.coli – 65%

Scenario 4 - Scenario 2 with Urban Retrofit Implementation

This scenario assumes that traditional runoff controls/BMP's are applied to new growth areas, while 25% of the existing urban area is retrofitted with state-of-the-science runoff controls/BMP's. For the retrofitted area (25% of the existing urban area), flow volumes were reduced by a factor of 2 to equal rural flow volumes, while in the remaining 75% of the existing urban area, flow volumes and EMC values were kept the same. The runoff threshold flow was kept the same. The removal efficiencies were as follows (based on MOE 2004):

- TP – 65%; Cu – 65%; TSS – 80%; E.coli – 65%

Scenario 5 - Scenario 2 with Rural BMP Implementation

This scenario assumes that traditional runoff controls/BMP's are applied to new growth areas, and rural BMP's are implemented in 50% of the agricultural lands. The BMP's were considered to be non-structural and include conservation tillage, buffer strips and livestock fencing. The runoff threshold was not changed. The removal efficiencies depend on the type of agricultural land use and were as follows:

- Pasture: TP – 25%; Cu – 0%; TSS – 40%; E.coli – 40%
- Cropland: TP – 60%; Cu – 50%; TSS – 60%; E.coli – 0%

Since it was not possible to predict where the rural BMP's would be applied, the removal efficiency was multiplied by the implementation rate and the product removal efficiency was applied to all agricultural lands in each category.

Tables 5.6 to 5.8 show the results for the various scenarios based on Total Phosphorus loadings at the mouths of each watercourse. Table 5.8 shows the variation in total annual Phosphorus loads for the reference year (1989), Tables 5.6 and 5.7 show the monthly distribution in Phosphorus loads for the reference year and the range in annual loads from 1989 to 2003 for Spencer Creek, respectively. From this data, a number of trends are apparent:

- There is a wide variation in total phosphorus loads among the watercourses, which is largely dependent on the watershed area within the City and the dominant type of land use (urban versus rural)

- The impact of each scenario in reducing total phosphorus loads also varies by watershed depending on the amount of land use change that occurs, and the amount of either urban or rural land that exists in the watersehed. These results are discussed in detail in chapter 8. Reductions of 10 - 20% in total phosphorus loads occur in most watersheds, for the most effective scenario.
- March and April are typically the months with the greatest total phosphorus loading, with August and September typically the months with the lowest loading.
- The annual variation in total phosphorus loadings greatly exceeds the typical percent reduction in phosphorus loadings achieved by the various scenarios..
- For Bronte Creek, Forty Mile Creek and Fairchild Creek, the watersheds area within City of Hamilton have no urban development. As a result, these watersheds do not have loading for scenario 1, 2, 3 or 4.

Table 5.6: Spencer Creek Year 1989 to 2003 Annual TP Loading for Different Scenario

Scenario	EC*	1	2	3	4	5
1989	4803.0	4835.4	4804.0	4777.7	4695.1	4079.9
1990	5456.5	5496.6	9092.6	9042.9	8887.5	7737.2
1991	4481.9	4511.3	7795.4	7752.7	7621.2	6659.9
1992	5589.1	5626.9	9411.4	9359.9	9199.9	8021.5
1993	4556.1	4586.5	8565.3	8518.5	8369.8	7252.2
1994	3377.7	3401.9	6387.3	6352.4	6240.7	5396.0
1995	4633.2	4666.9	8665.5	8618.2	8466.2	7312.2
1996	8059.5	8112.3	13058.1	12986.7	12762.4	11092.4
1997	4750.0	4784.5	8353.5	8307.7	8166.9	7138.9
1998	3669.8	3697.2	5784.9	5753.2	5656.6	4958.0
1999	1862.6	1876.5	3862.6	3841.5	3774.2	3265.6
2000	4415.5	4444.0	8311.9	8266.6	8121.0	7017.6
2001	3505.9	3532.0	6651.2	6614.9	6500.1	5642.5
2002	2909.8	2930.7	5071.8	5044.1	4957.8	4322.1
2003	4151.6	4181.7	7808.0	7765.3	7629.3	6603.0

* Existing Conditions
TP Loading unit = kg

Table 5.7: Spencer Creek Year 1989 Monthly TP Loading for Different Scenario

Scenario	EC*	1	2	3	4	5
January	365.4	483.7	365.6	363.6	378.0	315.2
February	147.5	254.1	147.8	146.9	144.8	132.3
March	905.1	1018.1	905.2	900.3	884.5	765.6
April	995.9	1110.3	995.9	990.5	973.1	841.5
May	432.0	478.2	432.0	429.7	422.1	364.7
June	616.6	661.3	616.6	613.2	602.3	518.8
July	193.3	239.5	193.4	192.3	189.0	165.4
August	63.2	104.8	63.3	62.9	62.0	56.3
September	78.6	121.4	78.7	78.3	77.1	69.3
October	233.5	275.9	233.6	232.3	228.3	198.7
November	610.4	654.3	610.4	607.1	596.3	513.6
December	161.4	206.8	161.5	160.6	158.0	138.7

* Existing Conditions
TP Loading unit = kg

Table 5.8 City of Hamilton Wastersheds Year 1989 Annual TP Loading for Different Scenario

Watersheds		EC*	1	2	3	4	5
Conservation Halton	**Bronte Creek**	2327.7					1945.9
	Brorer's Creek	651.8	766.6	684.2	615.3	650.4	589.0
	Grinstone Creek	1994.0	2127.8	2031.0	1950.1	1985.8	1714.0
Hamilton Conservation Authority	**Spencer Creek**	4803.0	4835.4	4804.0	4777.7	4695.1	4079.9
	Sulphur Creek	1080.6	1293.8	1114.6	1028.8	986.0	1085.1
	Chedoke Creek	897.5	951.8	891.0	841.5	730.3	0.0
	Red Hill Creek	2072.0	2401.2	2151.6	1948.1	1794.2	2146.5
	Stoney Creek	671.7	775.5	692.1	620.1	637.3	630.7
	Community of Stoney Creek Watercourses	880.8	911.6	887.7	868.2	757.0	846.6
Niagara Peninsula Conservation Authority	**Forty Mile Creek**	519.4					392.6
	Twenty Mile Creek	2758.6	3616.9	3018.3	2501.3	2960.0	2454.6
	Welland River	2915.2	3482.4	3086.6	2743.5	3032.0	2504.3
Grand River Conservation Authority	**Fairchild Creek**	4555.7					3631.7
	Big Creek	3422.0	3675.1	3498.5	3353.8	3444.0	2778.1

* Existing Conditions
TP Loading unit = kg

6.0 PUBLIC CONSULTATION

6.1 Public Information Centres No. 1

The first Public Information Centres were held at the Redeemer College in Ancaster (June 20, 2005), Hamilton City Hall, Council Chambers (June 21, 2005) and the Limeridge Mall (June 23, 2005). The first two Centres included:

- A joint presentation of the Transportation, Water/Wastewater and Stormwater Master Plans
- A series of posters which defined:
  - The study area
  - The study purpose
  - The Class Environmental Assessment Process
  - Problem Statement
  - Existing Environmental Conditions
  - Existing Stormwater Infrastructure
  - Storm Trunk Sewer Capacity
  - A Long List of Urban Best Management Practices
- A workbook to be used for the breakout groups

The third Centre, which was held at Limeridge Mall, included a select number of posters and a questionnaire. The format was more informal. The Workbook contained the following questions:

- As you think about the Stormwater Master Plan project, what 4 or 5 pressing issues or concerns will the project need to address? What outcomes or results would you like to see the Master Plan accomplish?
- A guiding principle and some goals and objectives being considered for the Master Plan are shown on the opposite page. What changes or additions would you suggest? Are some goals or objectives more important than others…why?
- Looking at the “long list” of potential alternative solutions on the opposite page…
  - What alternatives do you see as priorities? Why?
  - What alternatives (if any) should not be considered? Why?
  - Are there any additional alternatives that should be considered?
- Thinking about the City’s current stormwater system and local conditions, is there any specific information, data or circumstances that you think the City and consultant team should know about in developing the Master Plan?

The Workbook, together with a presentation, was also used at the Stakeholder Workshops for the Infrastructure Master Plans (water / wastewater and stormwater) on June 21 and 22, 2005.

A copy of the poster boards, workbook and summary of responses is provided in the Public Consultation Appendix.

7.0 EVALUATION OF ALTERNATIVE GROWTH OPTIONS

7.1 General

Hamilton's Growth-Related Integrated Development Strategy (GRIDS) was undertaken to help determine where the future growth of the City will take place over the next thirty years. The approach integrates land use, transportation, water/wastewater, and stormwater planning into one project. The study considered some fundamental options to its growth pattern, including:

- no expansion to the urban area boundary;
- distribute the development across the City, with some degree of urban area expansion; and
- encourage development along nodes and corridors, with some degree of urban area expansion.

The City and public developed and evaluated a range of growth concepts. From these concepts, a "short list" of five alternative GRIDS growth options were developed. The alternative growth options are illustrated in Figures 7.1 to 7.5 and summarized below:

Option 1: No Expansion to the Urban Boundary Area. For this option, all new residential growth takes place on lands within the existing urban area boundary through intensification and build-out of vacant lands

Option 2: Distributed Development. For this option, new residential growth takes place on lands within the existing urban area boundary through intensification and build-out of vacant lands and also through greenfield development in a new urban expansion area. For this option, the new urban expansion is concentrated in the southeastern fringe of the existing urban area.

Option 3: Distributed Development. This option is similar to Option 2, however, the new urban expansion is distributed along the fringe of the existing urban area boundary. This option also considers growth within the Pleasantview area.

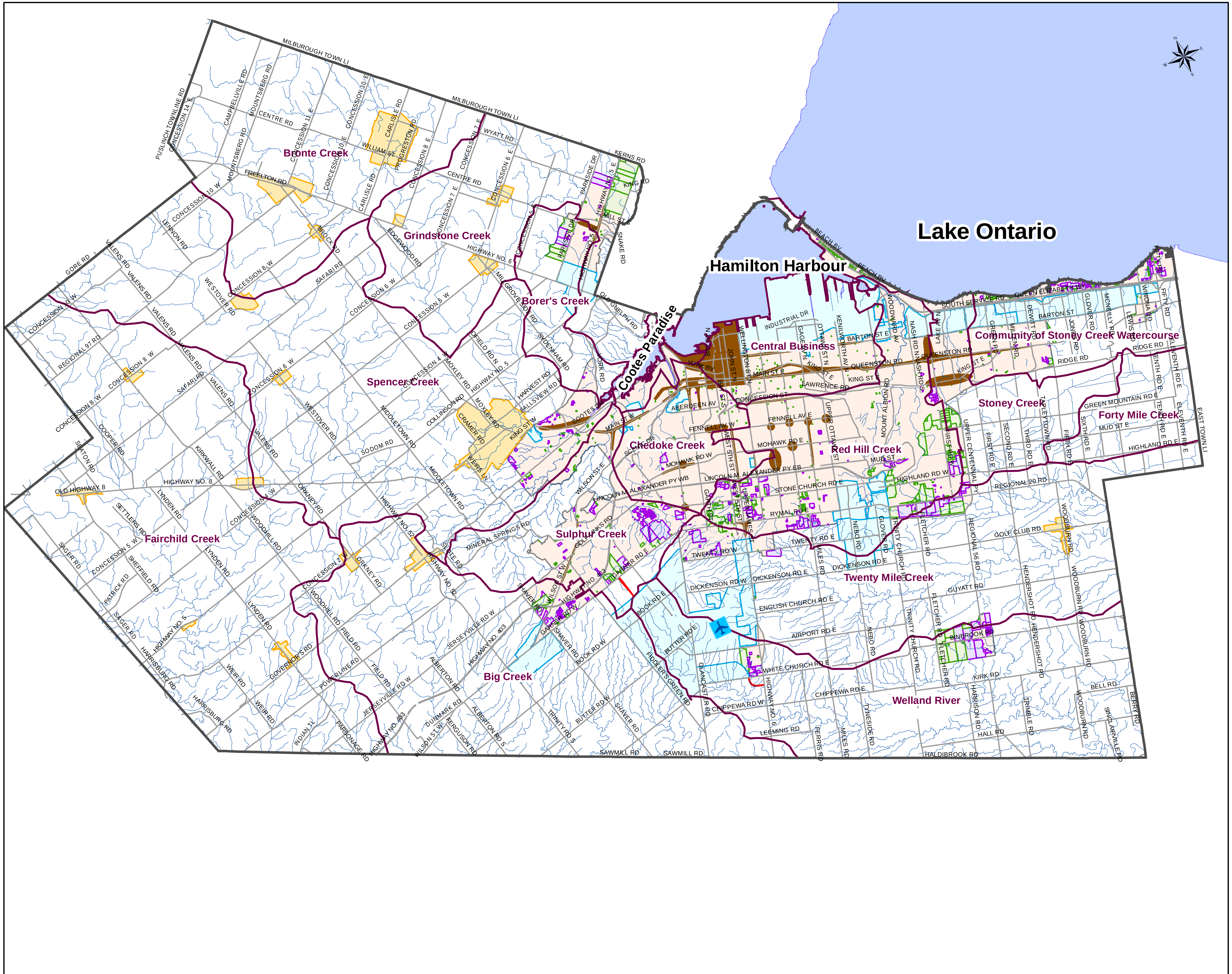
Option 4: Distributed Development. This option is very similar to Option 3, however, no growth is proposed within the Pleasantview area.

Option 5: Nodes and Corridors. This option allocates growth in downtown cores, community cores, suburban nodes and corridors. Similar to Option 2, urban boundary expansion is concentrated in the southeastern fringe of the existing urban area.

Each of the five growth options were then assessed using a "triple bottom line" (TBL) approach. The TBL approach evaluates the options in terms of:

1. community well-being;
2. economic well-being; and
3. ecological well-being.

The TBL criteria were then evaluated in terms of land use impacts, transportation impacts, water/wastewater impacts, and stormwater impacts.



KEY MAP

Legend

- City of Hamilton Boundary
- Watershed Boundary
- Settlement Area
- Business Park/Employment Centre
- Vacant Residential Lands (area with plans*)
- Vacant Residential Lands (area with no plans)
- Existing Urban Boundary
- Intensification Area

NOTES:

*Areas with plans include draft approved, registered plans and plans pending approval.

Proposed Land Uses as shown were established as part of GRIDS process.

0 5 10

Kilometers

Aquafor Beech Limited

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

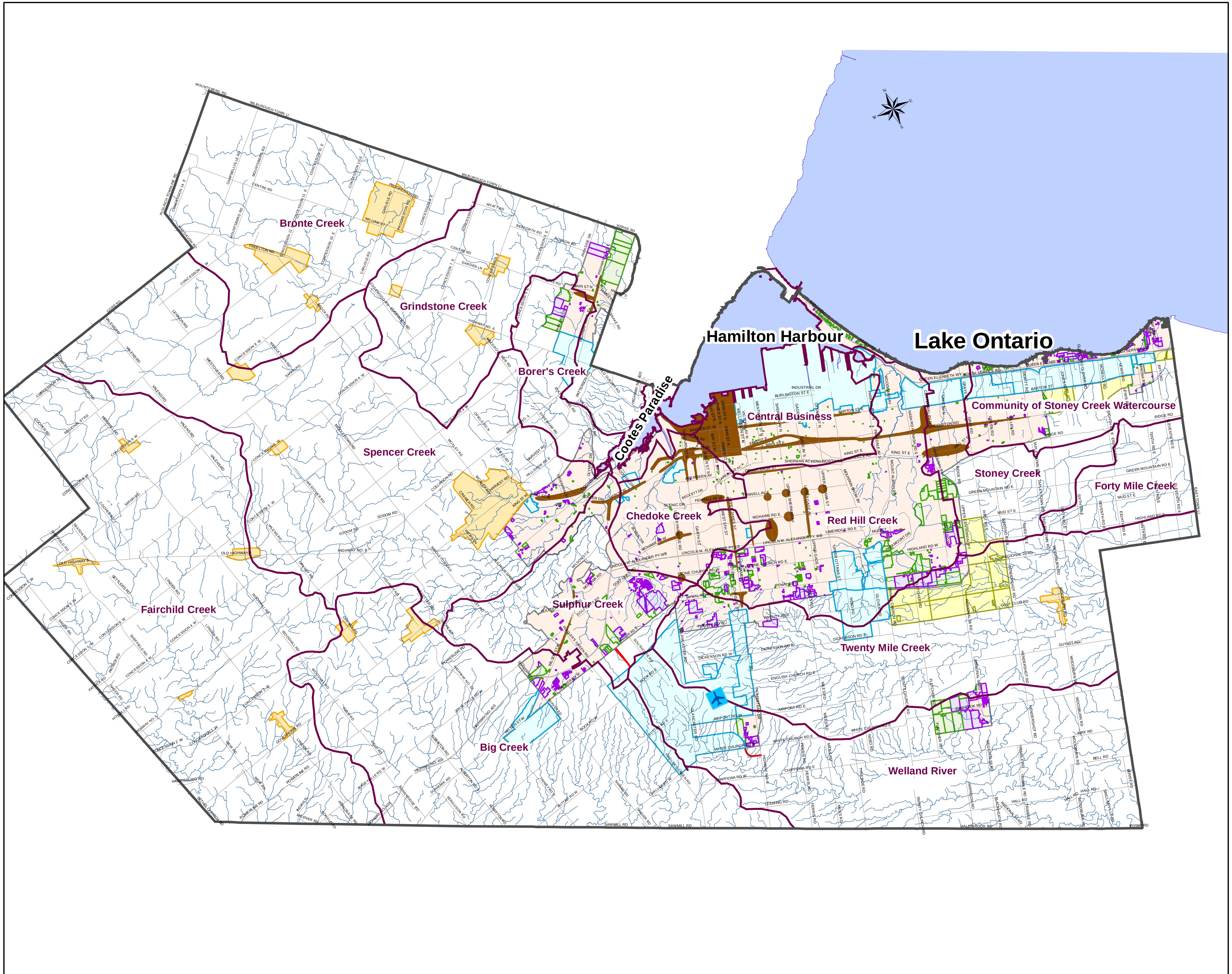
STORMWATER MASTER PLAN

Option 1

No Expansion to Urban Boundary Area

FIGURE: 7.1

DATE: 18 April 2007



KEY MAP

Legend

- City of Hamilton Boundary
- Watersheds Boundary
- Settlement Area
- Business Park/Employment Centre
- Vacant Residential Lands (area with plans*)
- Vacant Residential Lands (area with no plans)
- Potential Urban Boundary Expansion Area
- Existing Urban Boundary
- Intensification Area

NOTES:
*Areas with plans include draft approved, registered plans and plans pending approval.

Proposed Land Uses as shown were established as part of GRIDS process.

0 5 10
Kilometers

Aquafor Beech Limited

Hamilton

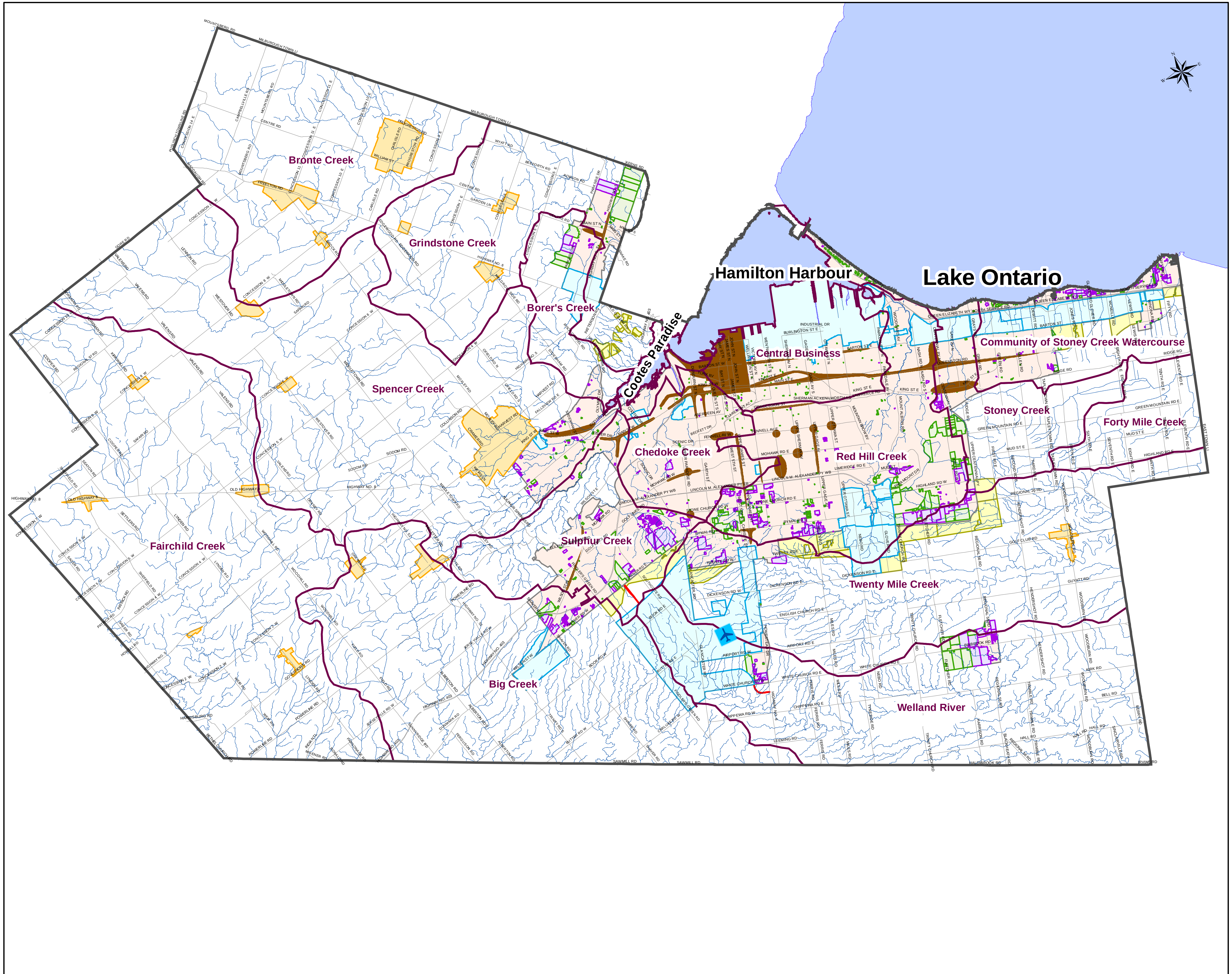
Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN
Option 2
Distributed Development

FIGURE: 7.2

DATE: 18 April 2007



KEY MAP

Legend

- City of Hamilton Boundary
- Watersheds Boundary
- Settlement Area
- Business Park/Employment Centre
- Vacant Residential Lands (area with plans*)
- Vacant Residential Lands (area with no plans)
- Potential Urban Boundary Expansion Area
- Existing Urban Boundary
- Intensification Area

NOTES:

*Areas with plans include draft approved, registered plans and plans pending approval.

Proposed Land Uses as shown were established as part of GRIDS process.

0 5 10

Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

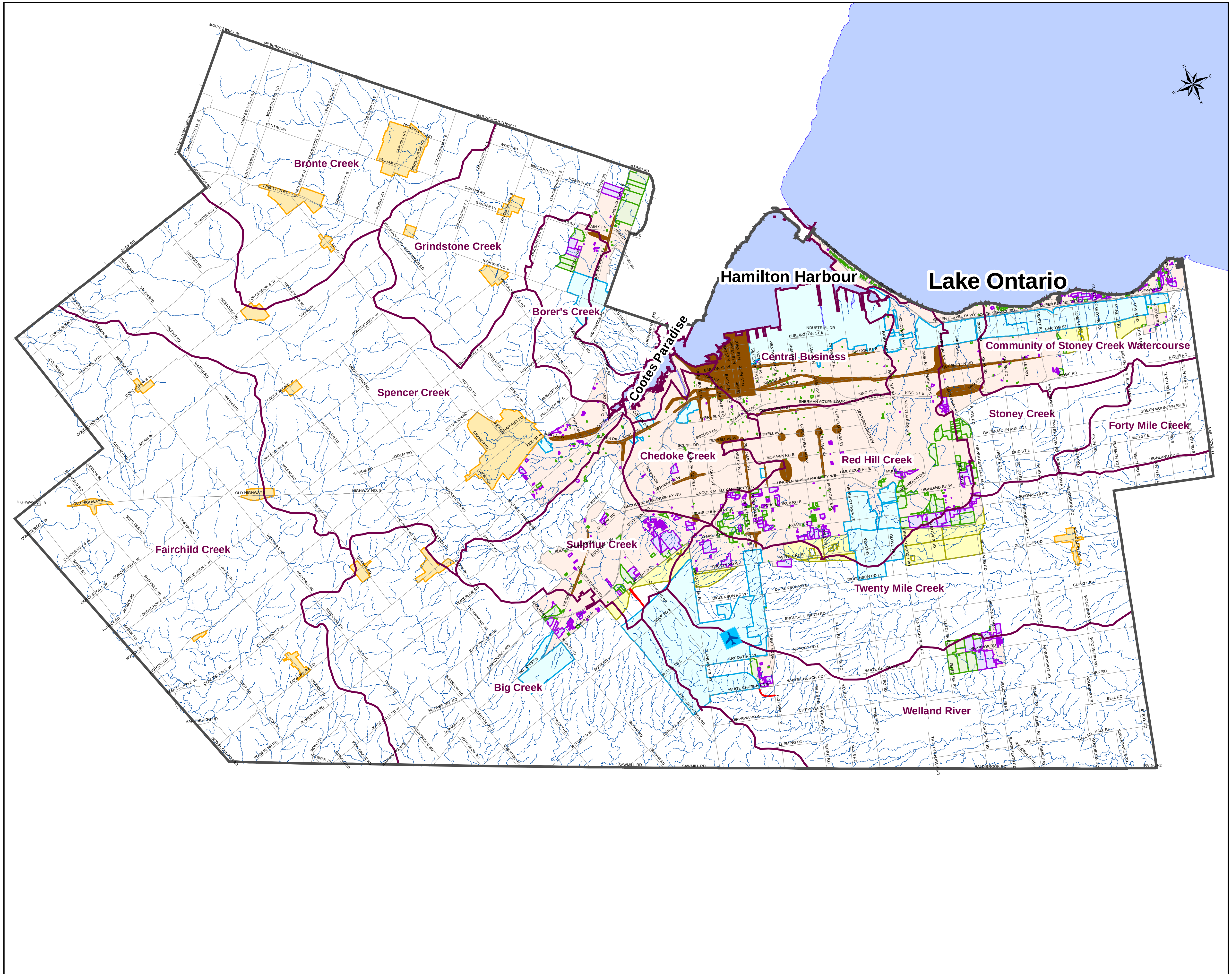
STORMWATER MASTER PLAN

Option 3

Distributed Development

FIGURE: 7.3

DATE: 18 April 2007



Legend

- City of Hamilton Boundary
- Watersheds Boundary
- Settlement Area
- Business Park/Employment Centre
- Vacant Residential Lands (area with plans*)
- Vacant Residential Lands (area with no plans)
- Potential Urban Boundary Expansion Area
- Existing Urban Boundary
- Intensification Area

NOTES:

*Areas with plans include draft approved, registered plans and plans pending approval.

Proposed Land Uses as shown were established as part of GRIDS process.

0 5 10

Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

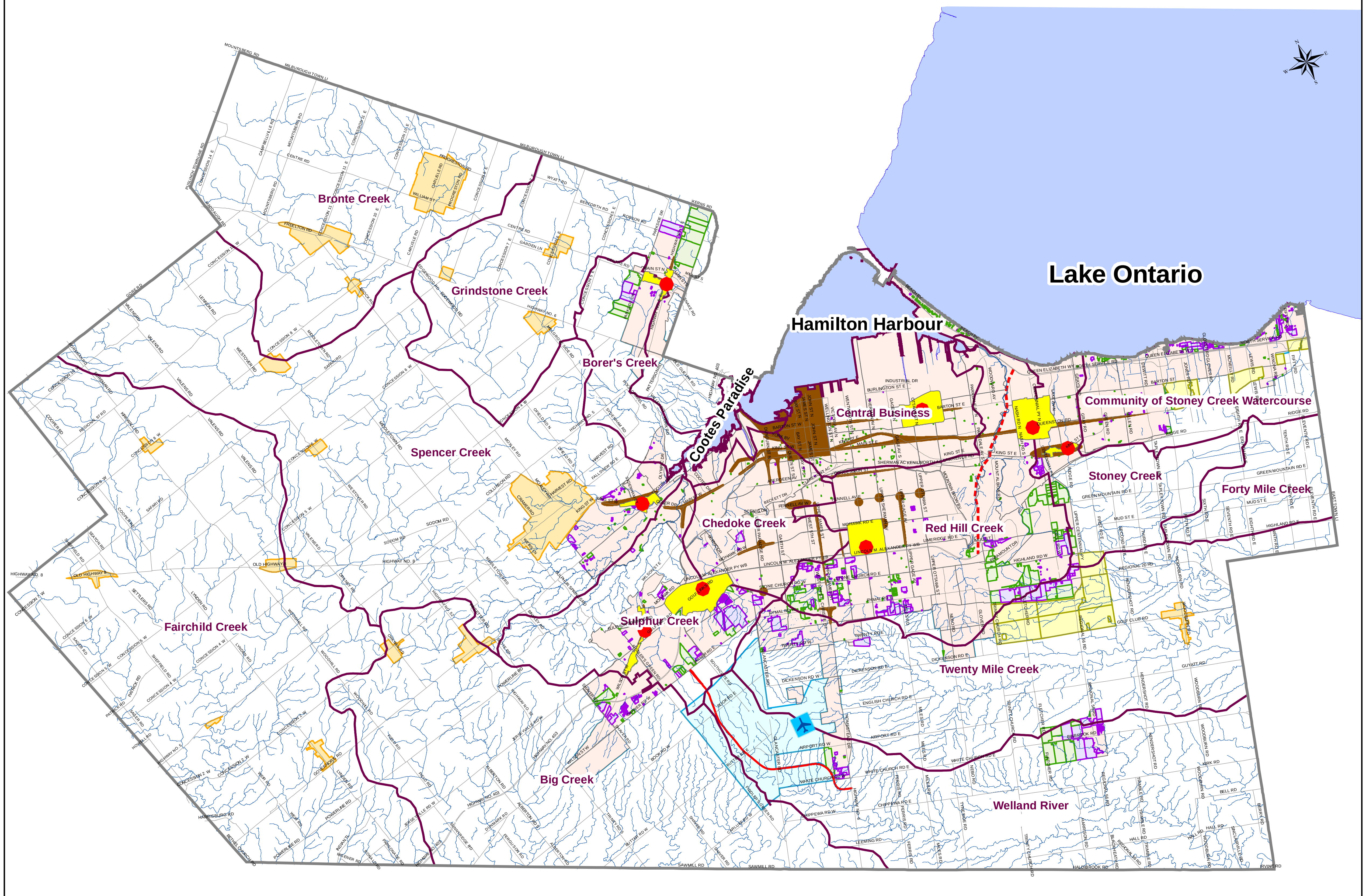
77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Option 4
Distributed Development

FIGURE: 7.4

DATE: 18 April 2007



KEY MAP

Legend

- City of Hamilton Boundary
- Watersheds Boundary
- Settlement Area
- Potential Urban Boundary Expansion Area
- Vacant Residential Lands (area with plans*)
- Vacant Residential Lands (area with no plans)
- Community Core
- Community Service Centre
- Existing Urban Boundary
- Intensification Area

NOTES:
*Areas with plans include draft approved, registered plans and plans pending approval.

Proposed Land Uses as shown were established as part of GRIDS process.

0 5 10
Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Option 5
Nodes and Corridors

FIGURE: 7.5

DATE: 18 April 2007

7.2 Assessment of Five Growth Options

This section summarizes the advantages and disadvantages of the GRIDS options for each of the TBL evaluation criteria. The evaluation was completed by ranking each option from best (1) to least preferred (4) from a **stormwater management** perspective. Similar evaluations were also undertaken for land use planning, transportation, and water/wastewater.

7.2.1 TBL Criteria: Community Well-Being

Consideration: *Potential for Disruption to Communities Resulting from Stormwater Infrastructure Works*

For the community well-being criterion, the GRIDS options were assessed in terms of the potential to cause disruptions within the existing community. With respect to stormwater impacts, the potential for disruption is directly related to the extent of the stormwater infrastructure upgrades required to service these growth options. The required stormwater infrastructure works can be classified into two general groups:

- upgrades to existing infrastructure due to intensification within existing urban areas; and
- construction of new infrastructure to service new development such as the vacant residential lands, business/employment centres, and urban boundary expansion areas.

The first group is more disruptive as the works take place in existing areas, on public roadways, and is more "visible" to existing residents and commuters.

The second group of works is usually less disruptive to existing communities, as they generally take place in association with new construction sites on private lands, with less exposure to existing residents, and commuters. In this case, disruptions would typically take the form of a temporary increase in truck/construction traffic adjacent to the existing community, rather than within the community.

Table 7.1 summarizes the Community Well-Being Rankings.

Table 7.1: Evaluation of Community Well-Being

GRIDS Options Rankings for Potential Disruption to Communities Resulting from Stormwater Infrastructure Works	
GRIDS Option	**Community Well-Being Ranking**
1-No Expansion	4
2-Distributed Development	1
3-Distributed Development	2
4-Distributed Development	1
5-Nodes & Corridors	2

Option 1 requires that all new residential development be accommodated within the existing urban boundary, and therefore represents the highest level of intensification. As a result, this option requires the highest level of stormwater infrastructure upgrades and represents the most disruptive of the five options. Option 1 is given a ranking of 4.

Option 2 and Option 4 involve expansion of the urban boundary to accommodate new growth areas, with less intensification in the existing urban area. As such, Option 2 and Option 4 represent the least disruptive alternatives, and are given a ranking of 1. Option 3 is similar to Option 2 and 4. However, Option 3 includes an expansion of the Pleasantview urban boundary, and therefore, may result in the need for storm sewer upgrades within this existing community, making it slightly less preferred than Options 2 and 4. Option 3 is given a ranking of 2.

The level of intensification associated with Option 5 is significantly less than that of Option 1, but slightly higher than Options 2 through 4. Option 5 is given a ranking of 2.

7.2.2 TBL Criteria: Economic Well-Being

Table 7.2 summarizes the Economic Well-Being Rankings.

Table 7.2: Evaluation of Economic Well-Being

GRIDS Options Rankings for Ability to Use Existing Stormwater Infrastructure		
GRIDS Option	**Portion of Existing Storm Sewer Network Requiring Upgrades**	**Ranking**
1-No Expansion	15%	**4**
2-Distributed Development	8%	**1**
3-Distributed Development	8%	**1**
4-Distributed Development	8%	**1**
5-Nodes & Corridors	10%	**2**

GRIDS Options Rankings for Cost, Feasibility and Ease of Construction						
GRIDS Option	**Cost**	**Space Limitations**	**Potential Conflict with Existing Municipal Services**	**Need for unique groundwater/ geologic measures**	**Sum**	**Ranking**
weight:	**25%**	**25%**	**25%**	**25%**		
1-No Expansion	4	4	4	1	3.25	**4**
2-Distributed Development	1	1	1	4	1.75	**2**
3-Distributed Development	1	1	1	2	1.25	**1**
4-Distributed Development	1	1	1	2	1.25	**1**
5-Nodes & Corridors	2	2	2	4	2.5	**3**

Overall Economic Well-Being Rankings				
GRIDS Option	**Ability to Use Existing Infrastructure**	**Cost, Feasibility and Ease of Construction**	**Sum**	**Economic Well-Being Ranking**
weight:	**50%**	**50%**		
1-No Expansion	4	4	4	**4**
2-Distributed Development	1	2	1.5	**2**
3-Distributed Development	1	1	1	**1**
4-Distributed Development	1	1	1	**1**
5-Nodes & Corridors	2	3	2.5	**3**

Consideration: *Ability to Use Existing Stormwater Infrastructure*

The ability of each GRIDS option to effectively make use of existing stormwater infrastructure and minimize additional investments is dependent on the location of new development within the respective options. Intensification within existing urban areas will increase stormwater runoff volumes. Traditionally, storm sewer infrastructure upgrades would be required to maintain sufficient capacity. However, other approaches to stormwater management can also be used to control runoff on-site, without replacing the existing storm sewer system. Hydraulic modeling was undertaken to estimate the level of stormwater infrastructure upgrades required with the traditional servicing approach (Section 5.2). These upgrade requirements are presented in Table 7.2, together with the ranking for each of the GRIDS options.

Consideration: *Stormwater Infrastructure Requirements, Cost, Feasibility and Ease of Construction*

In terms of stormwater infrastructure requirements and costs, GRIDS options 2, 3, and 4 have the lowest levels of intensification, and therefore require less investment in stormwater infrastructure by the City. Instead, these options involve expansion of the urban boundary to accommodate new growth areas, the servicing for which is typically funded by the development community. These options are considered least expensive to the City. Option 5 has a marginally higher level of intensification than Options 2, 3 and 4, and therefore would require a higher level of investment by the City. Option 1, with the highest level of intensification, represents the costliest option to the City. Stormwater infrastructure requirements and costs for vacant residential lands and airport lands are equal for all GRIDS options.

In terms of feasibility and ease of construction, the GRIDS options with the highest level of intensification would represent a greater challenge and would be technically more difficult than the GRIDS options with more “greenfield” development. For example, the construction of stormwater works in existing areas must account for additional constraints such as:

- limited space for stormwater storage facilities;
- avoiding disruption to other existing municipal services ; and
- public health and safety;

With respect to the first point above, it may be difficult to fully implement source controls in areas of intensification to offset impacts associated with increased flow volume and deterioration of water quality.

For those GRIDS options with urban boundary expansions, feasibility issues relate to the ability to prevent significant hydrologic changes in the headwaters of rural watersheds, such as increased runoff volumes, erosion and flooding, and increased urban contaminant loadings. However, the urban boundary expansion would take place in “greenfield” developments with no space limitations for stormwater management controls. Therefore, the feasibility and range of options available for mitigating potential stormwater impacts from urban expansion (i.e. “greenfield”) areas is greater than for development related to intensification in existing urban areas.

For those GRIDS options with proposed urban boundary expansion into the Twenty Mile Creek subwatershed, the design of stormwater management measures will have to account for the unique geology and groundwater resources in the area. The largest area of future urban boundary expansion within Twenty Mile Creek is represented by GRIDS options 2 and 5. Therefore, design and construction of new stormwater management systems for GRIDS options 2 and 5 will be somewhat more complex than for GRIDS options 3 and 4 which have less future development in Twenty Mile Creek. GRIDS option 1 proposes no urban boundary expansion within Twenty Mile Creek.

Based on the above considerations, the ranking of the GRIDS options with respect to cost, feasibility and ease of construction is derived in Table 7.2.

Summary Rankings: Ecologic Well-Being

The above criteria were used to derive an overall ranking in terms of economic well-being. As shown in Table 7.2, GRIDS options 2 and 3 were given a ranking of 1, GRIDS option 2 was given a ranking of 2, GRIDS option 3 was given a ranking of 3, and GRIDS option 1 was given a ranking of 4.

7.2.3 TBL Criteria: Ecological Well-Being

Table 7.3 summarizes the Ecological Well-Being Rankings.

Table 7.3: Evaluation of Ecological Well-Being

GRIDS Options Rankings for Water Quality and Erosion Impacts						
	Intensification	**Urban Boundary Expansion & Development of Vacant Lands**				
GRIDS Option	**Chedoke, Red Hill, Stoney Creeks**	**Stoney Creek**	**Borer's Sulphur, Red Hill Creeks**	**Grindstone Creek**	**Sum**	**Ranking**
weight:	**25%**	**25%**	**25%**	**25%**		
1-No Expansion	4	1	2	1	2	**1**
2-Distributed Development	1	4	2	1	2	**1**
3-Distributed Development	1	4	4	2	2.75	**3**
4-Distributed Development	1	3	4	1	2.25	**2**
5-Nodes & Corridors	2	4	2	1	2.25	**2**

GRIDS Options Rankings for Flooding Impacts						
GRIDS Option	**Stoney Creek**	**Borer's Sulphur, Red Hill Creeks**	**Twenty Mile Creek**	**Grindstone Creek**	**Sum**	**Ranking**
weight:	**25%**	**25%**	**25%**	**25%**		
1-No Expansion	1	2	1	1	1.25	**1**
2-Distributed Development	4	2	4	1	2.75	**3**
3-Distributed Development	4	4	3	2	3.25	**4**
4-Distributed Development	3	4	3	1	2.75	**3**
5-Nodes & Corridors	4	2	4	1	2.75	**3**

GRIDS Options Rankings for Groundwater and Geologic Impacts				
GRIDS Option	**Twenty Mile Creek**	**Borer's, Sulphur, Red Hill Creeks**	**Sum**	**Ranking**
weight:	**50%**	**50%**		
1-No Expansion	1	1	1	**1**
2-Distributed Development	4	2	3	**3**
3-Distributed Development	3	4	3.5	**4**
4-Distributed Development	3	4	3.5	**4**
5-Nodes & Corridors	4	2	3	**3**

GRIDS Options Rankings for Terrestrial and Aquatic Impacts				
GRIDS Option	Borer's, Sulphur, Red Hill Creeks (PSW's, ESA's, coldwater fishery)	Twenty Mile Creek (PSW's)	**Sum**	**Ranking**
weight:	**50%**	**50%**		
1-No Expansion	1	1	1	**1**
2-Distributed Development	2	4	3	**3**
3-Distributed Development	4	3	3.5	**4**
4-Distributed Development	4	3	3.5	**4**
5-Nodes & Corridors	2	4	3	**3**

Overall Ecologic Well-Being Rankings						
GRIDS Option	**Water Quality and Erosion**	**Flooding**	**Groundwater and Geology**	**Terrestrial and Aquatic**	**Sum**	**Ranking**
weight:	**25%**	**25%**	**25%**	**25%**		
1-No Expansion	1	1	1	1	1	**1**
2-Distributed Development	1	3	3	3	2.5	**2**
3-Distributed Development	3	4	4	4	3.75	**4**
4-Distributed Development	2	3	4	4	3.25	**3**
5-Nodes & Corridors	2	3	3	3	2.75	**2**

Consideration: *Potential Impacts to Water Quality and In-Stream Erosion*

The proposed urban intensification within the existing urban boundary is concentrated within the Chedoke, Red Hill and Stoney Creek watersheds. As such, these streams would be impacted the most by future increases in runoff volume and pollutant loadings associated with urban intensification. These impacts would be greatest for GRIDS option 1, with the highest level of intensification, and lowest for options 2, 3, and 4 (lowest level of intensification).

In addition to impacts from intensification, development within proposed urban boundary expansion areas could also impact water quality and erosion. Water quality and erosion within Stoney Creek would be impacted most by GRIDS options 2, 3 and 5, slightly less by option 4, and least by option 1 which has no urban boundary expansion. Erosion issues which have been identified within Borer's, Sulphur, and Red Hill Creeks would also be impacted by urban boundary expansion (options 3 and 4) and/or development of vacant residential and business/employment lands (all options).
Other potential water quality and erosion impacts which have been identified but are very similar for all GRIDS options include the following:

- Potential increased glycol, metals, and solids loadings to Twenty Mile Creek and Welland River from future Airport-related development;
- Potential impacts to erosion in the Grindstone Creek watershed as a result of future development of vacant residential lands (all options), and future urban boundary expansion in Pleasantview (GRIDS option 3 only); and

- Potential impacts to headwater agricultural streams in the Big Creek watershed due to the development of vacant residential, business/ employment lands.

Consideration: *Potential Impacts to Flooding*

Existing flood-susceptible sites have been identified in several watersheds which could potentially be affected by the increased runoff volumes and flow rates associated with future development within the City of Hamilton.

- The potential for surface flooding within Stoney Creek would be impacted most by the urban boundary expansion associated with GRIDS options 2, 3 and 5, slightly less by option 4, and least by option 1 which has no urban boundary expansion.
- Flooding within Borer's, Sulphur, and Red Hill Creeks would also be impacted by urban boundary expansion (options 3 and 4) and/or development of vacant residential and business/employment lands (all options).
- Downstream flood-susceptible sites in Twenty Mile Creek would be impacted most by urban boundary expansion and development of vacant residential/employment lands with GRIDS options 2 and 5, and slightly less by options 3 and 4. Option 1 has no urban boundary expansion would have the lowest impact.

Other potential flooding and hydrologic impacts which have been identified but are very similar for all GRIDS options include the following:

- Existing downstream flood damage sites within Grindstone Creek could be impacted by future development of vacant residential lands (all GRIDS options) and future urban boundary expansion in Pleasantview (GRIDS option 3 only);
- Potential impacts to headwater agricultural streams in the Big Creek watershed due to the development of vacant residential, business/ employment lands.

Consideration: *Potential Impacts to Groundwater and Geology*

Any future urban boundary expansion into the Twenty Mile Creek subwatershed will have to account for the unique karst geology and groundwater recharge in the area. This feature results in underground flow in some areas and represents a risk of groundwater contamination by future urban development. The largest area of future urban boundary expansion within Twenty Mile Creek is represented by GRIDS options 2 and 5, with slightly less in GRIDS options 3 and 4. GRIDS option 1 proposes no urban boundary expansion within Twenty Mile Creek. Similar karst geologic features are also located at the Escarpment within the Grindstone Creek subwatershed. However, development of vacant residential lands within Grindstone Creek at this location is the same for all GRIDS options, making none preferable to any other.

Areas of high groundwater recharge are also present at select locations within the Borer's, Sulphur, and Red Hill Creek subwatersheds. Review of the GRIDS options indicates that the highest level of future urban boundary expansion within these subwatersheds, and thus the highest potential for future groundwater impacts, is associated with options 3 and 4. Options 2 and 5 have a relatively small amount of urban boundary expansion, while option 1 has none.

Consideration: *Potential Impacts to Terrestrial and Aquatic Habitat*

Previous subwatershed studies have identified and inventoried the location of sensitive terrestrial and aquatic features, including coldwater fisheries, provincially significant wetlands (PSW's) and Environmentally Significant Areas (ESA's) in the Borer's, Spencer, Sulphur, and Red Hill Creek watersheds. Although development would not take place within these features, they could still be negatively impacted by future adjacent development though changes to the hydrologic and groundwater characteristics of the area. Within these watersheds, the highest level of future urban development, and thus potential impact, is represented by GRIDS options 3 and 4. Options 2 and 5 have a relatively small amount of urban boundary expansion, while option 1 has none.

Downstream PSW features have also been identified in Twenty Mile Creek. Within this watershed, the highest level of future urban development, and thus potential impact, is represented by GRIDS options 2 and 5. Options 3 and 4 have a marginally less urban boundary expansion, while option 1 has none.

Summary Rankings: Ecologic Well-Being

The above criteria were used to derive an overall ranking in terms of ecologic well-being. An equal weighting has been applied to each of the ecologic considerations. As shown in Table 7.3, GRIDS option 1 was given a ranking of 1, GRIDS options 2 and 5 were given a ranking of 2, GRIDS option 4 was given a ranking of 3, and GRIDS option 3 was given a ranking of 4.

7.2.4 Overall TBL Rankings

In summary, the GRIDS Options have been evaluated above in terms of stormwater management considerations based on the individual "Triple Bottom Line" criteria of community, economic, and ecologic well-being. An overall ranking, based on the combined "TBL" criteria is provided in Table 7.4. In establishing the overall stormwater rankings, economic and ecologic criteria have been given twice the weight of the community criteria. This is due to the greater number of economic and ecologic issues which were identified and due to the fact that the community well-being issue (potential disruption to communities) is also partially reflected in the economic rankings (ability to use existing stormwater infrastructure, conflict with other existing infrastructure).

For the final overall ranking, the GRIDS Options were scored from 1 (most preferred) to 5 (least preferred). As shown in Table 7.4, in terms of stormwater management, GRIDS Options 2 and 4 are tied for the most preferred option with a ranking of 1, Options 3 and 5 are tied with a ranking of 3, and Option 1 is the least preferred option. These rankings were used as input, together with other criteria, in order to select the Preferred Growth Option.

Table 7.4: Overall "Triple Bottom Line" Rankings

GRIDS Option	Community Well-Being	Economic Well-Being	Ecologic Well-Being	Sum	Ranking
weight:	**20%**	**40%**	**40%**		
1-No Expansion	4	4	1	2.8	**5**
2-Distributed Development	1	2	2	1.8	**1**
3-Distributed Development	2	1	4	2.4	**3**
4-Distributed Development	1	1	3	1.8	**1**
5-Nodes & Corridors	2	3	2	2.4	**3**

7.3 Public Consultation

7.3.1 Public Information Centres No. 2

The second set of Public Information Centres were held at the Winterberry Heights Church (Novemeber 28, 2005), St. Mary's High School (November 30, 2005) and the Dundas Municipal Centre (December 5, 2005). Each of the Information Centres included:

- A series of poster boards which defined:
  - A summary of the environmental impacts for each of the five Alternative Growth Options
  - A long list of Urban Best Management Practices
- A questionnaire containing the following questions:
  - Are there other growth opportunities you wish to make the team aware of? Did we miss any advantages or disadvantages of the growth options?
  - Did we miss anything you think should be considered in evaluating the growth options and selecting a preferred way for Hamilton to grow?
  - Do you have any comments on the Employment information presented?
  - Do you have any comments or concerns that the infrastructure master plan teams should be aware of as they move forward to look at specific infrastructure alternatives?
  - Do you have any comments on residential intensification? Are there other tools you think we should / the City should consider when implementing residential intensification?

A copy of the poster boards, questionnaire and summary responses is provided in the Public Consultation Appendix.

8.0 DEVELOPMENT AND ASSESSMENT OF ALTERNATIVE MANAGEMENT STRATEGIES

8.1 General

The Recommended Growth Option was adopted by Council in May 2006. The next step in this study involved the development and assessment of Alternative Stormwater Management Strategies in order to determine the effectiveness of each strategy with respect to protecting, enhancing and restoring the natural resources of the watersheds located within the City under present conditions and as land use changes occur in the future.

For the purpose of this study a Stormwater Management Strategy was defined as a set of Best Management Practices (BMP's) which, when implemented collectively, will attempt to address impacts associated with land uses within the watersheds. The land uses under consideration include existing urban and rural land uses as well as proposed urbanization.

As noted above, the Alternative Management Strategies address impacts associated with existing urban and rural land uses, as well as proposed urbanization. The assessment, in part, was undertaken using the results from the modeling. Furthermore, where appropriate, social, economic and environmental criteria were defined and used to further develop specific components of the Alternative Strategies.

As illustrated below, the approach used for developing and evaluating alternatives is, where appropriate, consistent with the planning and design process for Master Planning projects as described in the Municipal Class Environmental Assessment document. This approach has been used for measures which are located outside proposed development areas (i.e. stream restoration works, stormwater pond retrofit works). For other measures, such as the construction of stormwater measures for proposed development, or the implementation of a proposed City Wide program (i.e. disconnection of roof downspouts) general direction as to the types of measure, or proposed programs will be provided. Subsequent studies (i.e. Subwatershed Studies, Master Drainage Plans) or programs (i.e. pilot projects to determine feasibility of implementing a variety of source control measures) would be required to provide further details for these initiatives.

8.2 Development of Alternative Management Strategies

Urban land uses within the City of Hamilton comprise approximately 15 percent of the total land area. Of the remaining 85 percent, approximately 61 percent of the lands are classified as rural. Proposed development, which includes the development of vacant lands within the existing Official Plan and lands outside the existing urban boundary, will increase the percentage of urban lands from 15 percent to 21 percent.

Findings from the Existing Conditions component of the study (see Chapter 3) suggest that existing environmental conditions are degraded in some areas within the City. Issues include degraded water quality, loss of fish habitat, erosion, lack of baseflow and groundwater concerns.

The above points would suggest that the Alternative Management Strategies, if they are to be effective, must deal with impacts associated with existing urban and rural land uses as well as proposed land uses.

The Alternative Management Strategies should also take into consideration the fact that approaches for dealing with the impacts associated with stormwater are evolving and that current practices do not adequately address several impacts, particularly those related to erosion and the provision of a water balance (Aquafor 2006). It is therefore necessary to look forward and develop and assess Management Alternatives that overcome the present limitations of current practices.

A total of five Alternative Management Strategies have been brought forward for assessment. The five Strategies are defined as:

- Do Nothing Management Strategy;
- Business as Usual Management Strategy;
- Comprehensive Urbanization Approach Management Strategy;
- Business as Usual with Urban Retrofits Management Strategy; and
- Business as Usual with Rural Retrofits Management Strategy.

The five strategies are described in more detail in the subsequent sections. Also provided are a series of Tables which help explain the assumptions used to develop the strategies as well as representative impacts on flow volumes, peak flows, baseflow changes and pollutant removal rates. Further description of the modeling approach that was used can be found in Section 5.3 and in Appendix C.

8.2.1 Do Nothing Management Strategy

This strategy, as the name suggests, would mean that no stormwater works are carried out in any of the existing urban or rural lands or within any proposed development or redevelopment areas.

An assessment as to the impacts associated with the implementation of this strategy is required as part of undertaking a Municipal Class Environmental Assessment Study.

Table 8.1 illustrates the potential implications should this strategy be implemented. These include increased flooding and erosion potential, together with reduction in infiltration (and corresponding baseflows) and increased pollutant loadings and instream concentrations. These impacts would occur as a result of the proposed land use changes.

8.2.2 Business as Usual Management Strategy

Stormwater management practices would only be implemented within proposed development or redevelopment areas. Typically, the proposed works would consist of stormwater management ponds which are constructed to address issues related to flooding, erosion and water quality. Conventional storm sewer systems would be installed and source control measures on private property would be limited to a majority of roof downspouts being discharged to the surface.

As illustrated in Table 8.1, implementation of this strategy would result in higher flow volumes, an increase in erosion potential and reduced infiltration.

8.2.3 Comprehensive Urbanization Approach Management Strategy

Consistent with the Business as Usual Management Strategy, stormwater management practices would be implemented within proposed development or redevelopment areas. Alternative approaches on private property (source controls) and within the municipal right of way (conveyance controls) would be used in conjunction with a variety of end-of-pipe measures in order to comprehensively address impacts associated with development. Alternative development forms (e.g. Low Impact Development) would also be considered.

For the purpose of undertaking the evaluation as to the effectiveness of this Management Strategy a series of assumptions as to the types of Best Management Practices that would be included in this strategy was made. The types of measures that have been assumed, together with the changes to the flow components and water quality pollutant levels are shown in Tables 8a and 8b respectively.

8.2.4 Business as Usual with Urban Retrofits Management Strategy

This strategy is consistent with the Business as Usual Strategy in that conventional stormwater management practices would be implemented within proposed development or redevelopment areas. The Business as Usual Strategy would be augmented, however, by implementing a variety of source, conveyance and end-of-pipe measures within existing urban areas.

The proposed type of measures that would be implemented within the existing urban areas together with the assumed adoption rate (the adoption rate is defined as the percentage of stakeholders that are willing to implement the proposed measure) is provided in Table 10.2. Table 8.1 provides an overview as to the change in flow and water quality components that would be associated with the implementation of this strategy.

8.2.5 Business as Usual with Rural Retrofits Management Strategy

This strategy is consistent with the Business as Usual Strategy in that conventional stormwater management practices would be implemented within proposed development or redevelopment areas. The Business as Usual Strategy would be augmented, however, by implementing a variety of source, conveyance and end-of-pipe measures within existing rural areas.

The proposed types of measures that would be implemented within the existing rural areas together with the assumed adoption rate is provided in Section 10.7. Table 8.1 provides and overview as to the change in flow and water quality components that would be associated with the implementation of this strategy.

Table 8.1: Representative Flow Changes and Pollutant Removal Rates for Each Stormwater Management Strategy

Applicable Land Uses and Flow Changes / Removal Rates	ALTERNATIVE STORMWATER MANAGEMENT STRATEGIES				
	Do Nothing Management Strategy	**Business as Usual Management Strategy**	**Comprehensive Urbanization Approach Management Strategy**	**Business as Usual with Urban Retrofits Management Strategy**	**Business as Usual with Rural Retrofits Management Strategy**
Applicable Land Uses where Strategies would be Applied	No Areas	Proposed Development Areas and Redevelopment Areas	Proposed Development Areas and Redevelopment Areas	Existing Urban Areas plus Development / Redevelopment Areas	Existing Rural Areas plus Development / Redevelopment Areas
Representative Flow Changes	Substantial Increase in Runoff	Moderate Increase in Runoff with Decreased Baseflow	Moderate Reduction in Runoff in Urbanizing Areas	Moderate Reduction in Runoff in Urban Areas	Current Condition
Representative Pollutant Removal Rates	Current Condition	Moderate Increase in Pollutant Removal Rates	Substantial Increase in Pollutant Removal Rates	Substantial Increase in Pollutant Removal Rates	Moderate Increase in Pollutant Removal Rates

[1] Flow changes and pollutant removal rates are based on changes as compared to existing conditions.

8.3 Evaluation of Alternative Management Strategies

8.3.1 General

The effectiveness of each of the five Stormwater Management Strategies was evaluated on a subwatershed basis for each of the fourteen major creek and river systems within the City. Hydrologic and water quality modelling was undertaken to estimate the impact of future urban development, and to assess the effectiveness of the strategies in terms of their ability to meet the stormwater management goals and objectives, including:

- the ability to maintain or enhance water quality, both within the watercourse and the receiving water bodies of Cootes Paradise, Hamilton Harbour, the Niagara River, and Lake Ontario;
- the ability to preserve and re-establish the natural hydrologic cycle in order to minimize impacts to groundwater levels, baseflows, flood risk and erosion potential; and
- the ability to protect, enhance or restore aquatic and terrestrial resources.

Each of the fourteen creeks and rivers is different, with different environmental resources, sensitivities, land uses, and development pressures. Therefore, different strategies are likely to be recommended for different watersheds. For example, some watersheds are already primarily urban and will require a stormwater strategy to mitigate impacts from existing development. Other watersheds will have significant development pressures and will require a strategy focused on preventing impacts from future urban development. Others still may be rural watersheds with little or no development pressure, and will require a strategy to mitigate existing agricultural impacts. And some watersheds will have specific issues which will require consideration, such as groundwater recharge-baseflow interactions, downstream flood constraints, or sensitive fisheries.

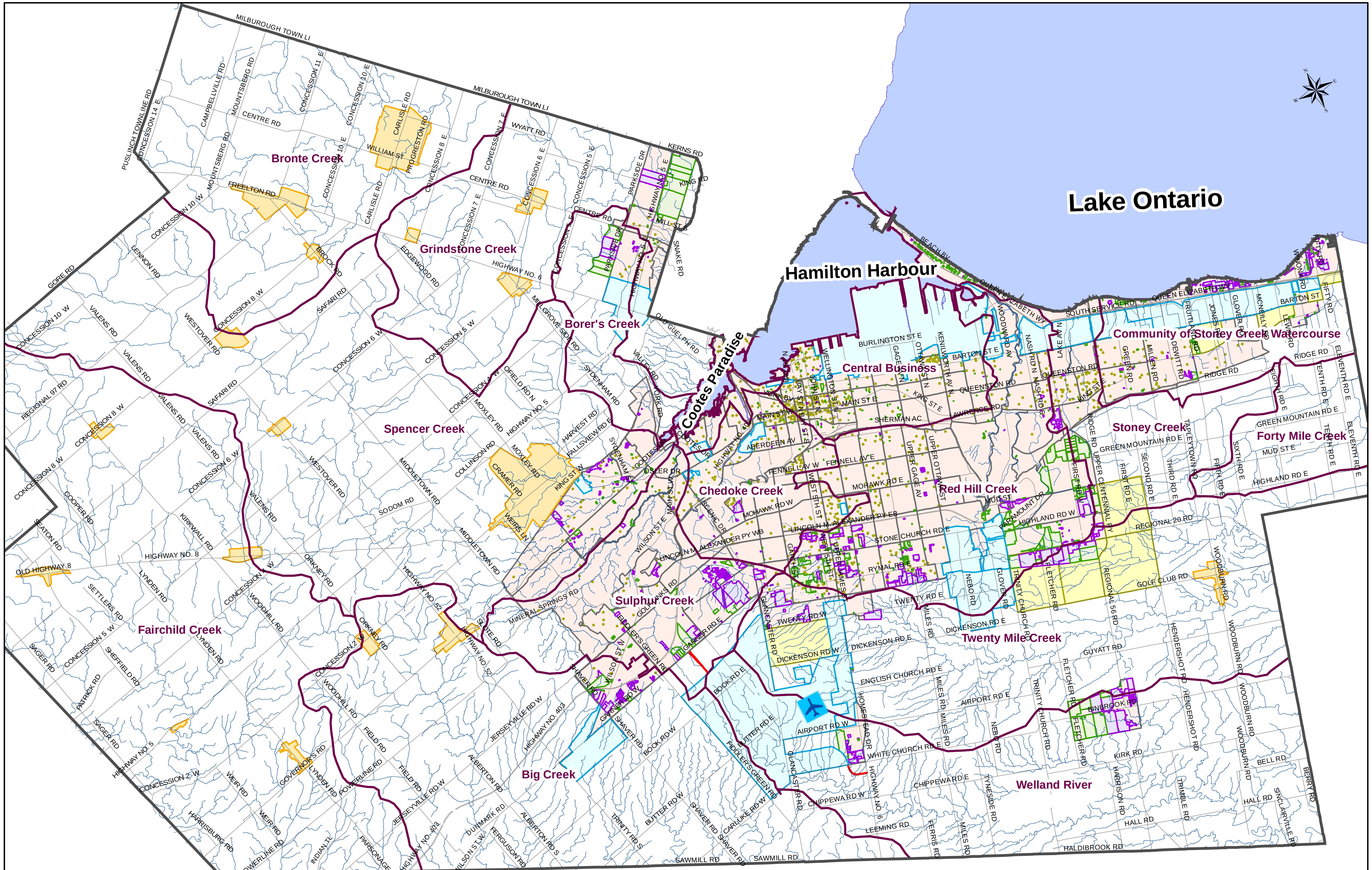
The City's preferred Growth Option is illustrated in Figure 8.1. This growth strategy was selected on the combined basis of stormwater management considerations, water/wastewater servicing, and transportation considerations. The following sections evaluate the effectiveness of the alternative stormwater strategies to meet the stormwater management goals and objectives for the City's preferred Growth Option.

8.3.2 Evaluation of Strategies – Hamilton Conservation Authority

8.3.2.1 Sulphur Creek

<u>Description</u>

The headwaters of Sulphur Creek are located above the Escarpment. From here, the creek drains northward over the Escarpment to Spencer Creek, and ultimately outlets into Cootes Paradise. A significant portion of the watershed is already developed in the Ancaster area. The City's preferred growth strategy will see continued urban growth in the watershed, with approximately 550 ha of additional urban development representing roughly 13% of the watershed area within the City. The majority of the future urban growth is associated with the development of a business park adjacent to the Hamilton Airport.



LEGEND:

- City of Hamilton Boundary
- Watershed Boundary
- Settlement Area
- Business Park/Employment Centre
- Vacant Residential Lands (area with plans*)
- Vacant Residential Lands (area with no plans)
- Potential Urban Boundary Expansion Area
- Intensification Area, 1 dot = 30 units (dots are distributed by traffic zone and are not intended to be place specific)

NOTES:

*Areas with plans include draft approved, registered plans and plans pending approval.

Proposed Land Uses as shown were established as part of GRIDS process.

0 5 10

Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

GRIDS Recommended Growth Option

FIGURE: 8.1

DATE: 18 April 2007

Environmental Resources and Issues

Soils within the Sulphur Creek watershed consist of relatively permeable silty loam and sandy loam material. These soils provide a groundwater recharge function, which in turn supplies baseflows to the creek.

On-going erosion and flooding concerns have been identified within the watershed. As such, quantity and erosion control will be an important consideration in future stormwater management planning for development in the headwaters.

With respect to fisheries, Sulphur Creek supports both coldwater and warmwater fish communities. The watershed also contains several Environmentally Significant Areas (ESA's), areas of natural and scientific interest (ANSI's), and the Tiffany Creek Headwaters Wetland Complex, classified as a provincially significant wetland (PSW).

Potential Development Impacts

Hydrologic and water quality modeling results indicate the following potential development impacts on Sulphur Creek:

- significant hydrologic impacts including increased runoff volumes (+ 10%), and increased erosion potential;
- reduction in groundwater recharge (approx. -7%). and reduced baseflows in streams;
- significant increase in contaminant loadings, particularly urban contaminants:
  - Total Phosphorous +20%;
  - Copper +28%;
  - E-coli +25%
  - Suspended Solids +4%;
- negative impacts on the existing coldwater fishery due to reductions in baseflows, increased erosion potential, and increased contaminant loadings.

Alternative Stormwater Strategy Evaluation

Modeling results for the alternative management strategies are presented in Figure 8.2. As shown, the "Comprehensive Urbanization Approach" and "Business as Usual with Urban Retrofits" strategies are the most effective strategies for preventing or minimizing future impacts. Of these two strategies, the "Business as Usual with Urban Retrofits" approach was selected as the recommended strategy. This strategy provides the best opportunity to improve water quality and runoff characteristics from the existing urban areas while preventing further impacts to the existing erosion and flood-risk sites through stormwater controls within future urban developments.

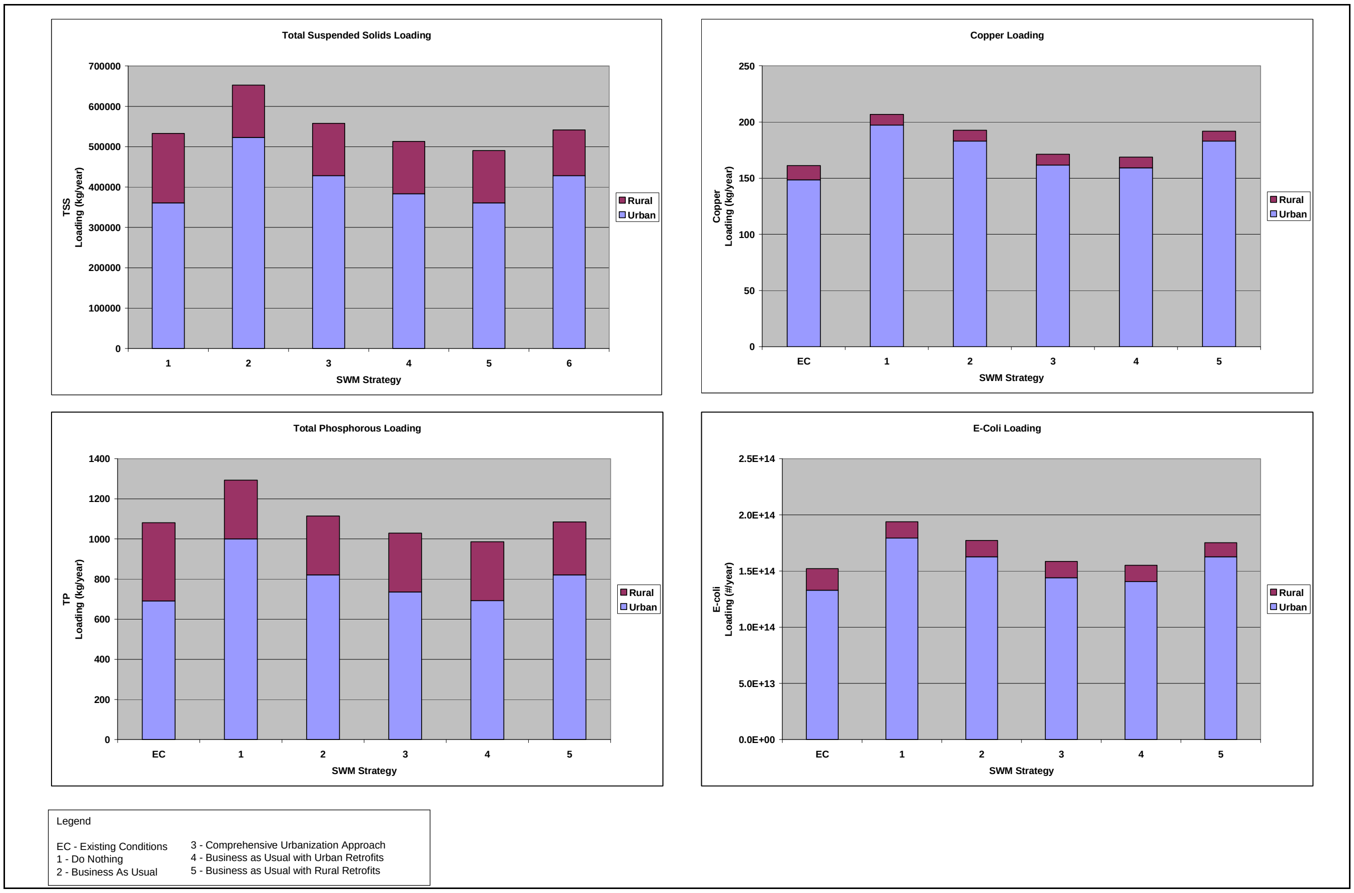


Figure 8.2: Evaluation of Alternative Stormwater Management Strategies for Sulphur Creek

8.3.2.2 Spencer Creek

Description

The headwaters of Spencer Creek are located within the western area of Hamilton above the Escarpment. The Creek drains in an easterly direction, outletting to Cootes Paradise. There is a significant amount of existing development within the lower reaches near Dundas, while land uses in the mid and upper reaches are predominantly rural. The City's preferred growth strategy contains a relatively small amount of new urban development (approximately 30 ha), and intensification of the existing urban areas.

Environmental Resources and Issues

Only limited background information and environmental reporting is available for Spencer Creek. Environmental mapping indicates that the headwaters of the creek contain significant areas of permeable soils which provide a groundwater recharge function. Some tributaries have been classified as potential coldwater fisheries habitat. The watershed also contains a significant amount of provincially significant wetlands (PSW's), and Environmentally Significant Areas (ESA's), mainly located in headwaters upstream of the urban development.

Potential Development Impacts

Given the relatively small amount of future urban development within Spencer Creek, significant hydrologic impacts are not anticipated on a watershed basis. However, local hydrologic and water quality impacts would occur on smaller tributaries draining the future urban development lands, such as Spring Creek. For these smaller tributaries, impacts may include increased runoff volumes, increased rates of flooding and erosion, increased loadings of urban contaminants, and fish habitat degradation.

Alternative Stormwater Strategy Evaluation

Modeling results for the alternative management strategies are presented in Figure 8.3. As shown, the "Business as Usual with Urban Retrofits" and "Business as Usual with Rural Retrofits" strategies are the most effective strategies for preventing or minimizing future impacts. Of these two strategies, the most effective, on a watershed basis, is the "Business as Usual with Rural Retrofits" strategy. This strategy provides the best opportunity to improve water quality from the predominantly rural watershed, while preventing impacts from future development areas on local tributaries through "business as usual" stormwater management practices.

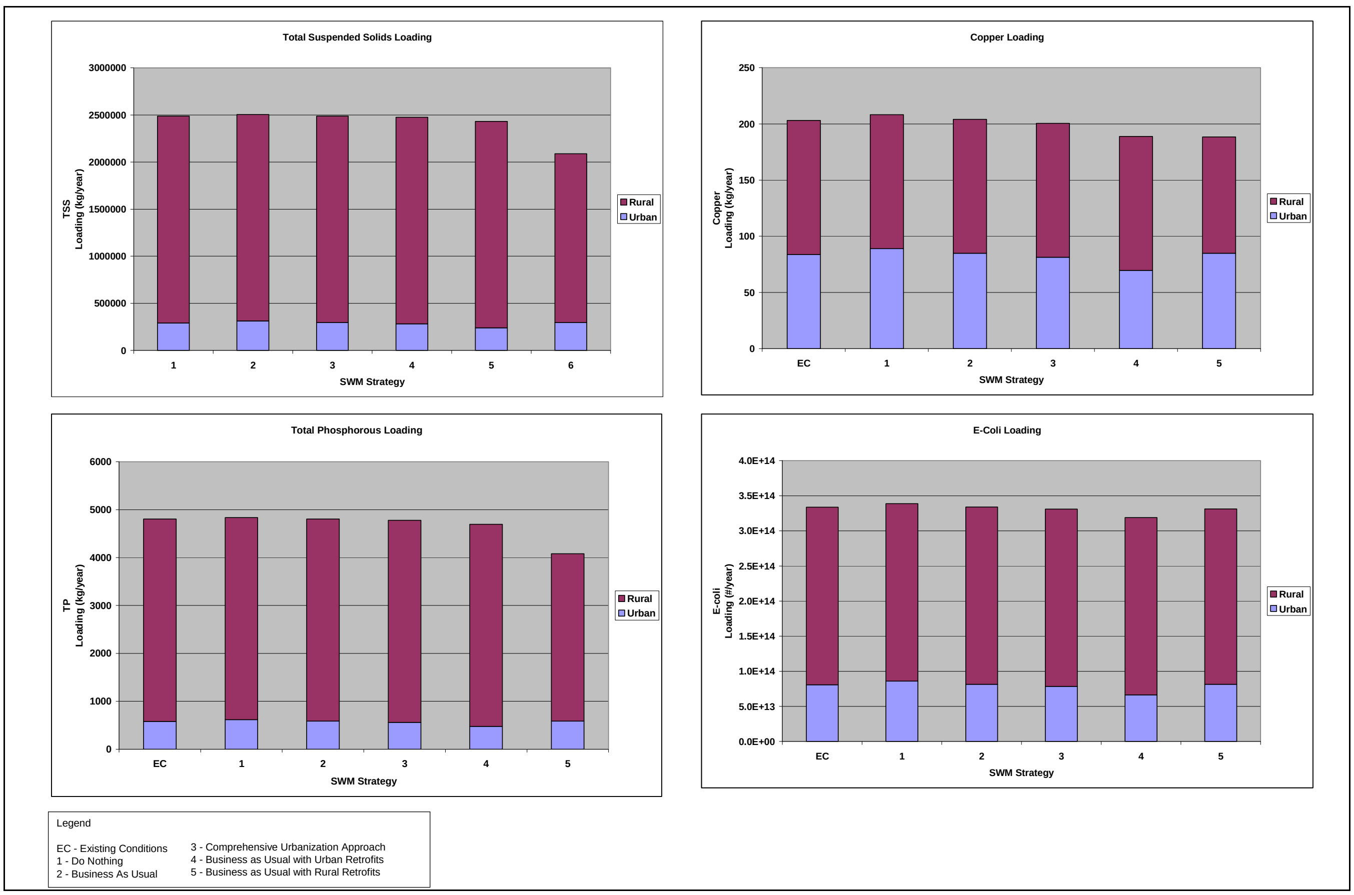


Figure 8.3: Evaluation of Alternative Stormwater Management Strategies for Spencer Creek

8.3.2.3 Borer's Creek

Description

The headwaters of Borer's Creek are located above the Escarpment within the Waterdown area. This primarily rural watershed drains southeasterly to Cootes Paradise. The City's preferred growth strategy will see an additional 12% of the watershed area, or 260 ha, developed with urban land uses in Waterdown.

Environmental Resources and Issues

Soils within the Borer's Creek watershed consist of predominantly loam and sandy loam. The headwaters of the creek represent a significant groundwater recharge zone, providing baseflow to the streams and maintaining a high water table.

Previous studies have identified on-going stream erosion as a significant issue and that the stream is sensitive to further urban development.

With respect to fisheries, Borer's Creek supports a warmwater fish community, and may have coldwater potential in the lower reaches. The watershed also contains several Environmentally Significant Areas (ESA's), and the provincially significant wetland (PSW's), including Cootes Paradise and the Waterdown North Wetlands.

Potential Development Impacts

Hydrologic and water quality modeling results indicate the following potential development impacts on Borer's Creek:

- significant hydrologic impacts including increased runoff volumes (+ 12%), and increased erosion potential;
- reduction in groundwater recharge (approx. -6%), and reduced baseflows in streams;
- significant increase in contaminant loadings, particularly urban contaminants:
    - Total Phosphorous +18%;
    - Copper +59%;
    - E.coli +39%
    - Suspended Solids +17%;
- negative impacts on the existing fisheries due to reductions in baseflows, increased erosion potential, and increased contaminant loadings.

Alternative Stormwater Strategy Evaluation

Modeling results for the alternative management strategies are presented in Figure 8.4. As shown, the "Comprehensive Urbanization Approach" and "Business as Usual with Rural Retrofits" strategies are the most effective strategies for preventing or minimizing future impacts. Of these two strategies, the "Comprehensive Urbanization Approach" was selected as the recommended strategy. This strategy seeks to minimize hydrologic impacts through source control and conveyance control infiltration techniques, and preservation of the hydrologic cycle is an important consideration given the issues identified in this watershed, namely, groundwater recharge, downstream erosion risk, fisheries, and downstream sensitive PSW's and ESA's.

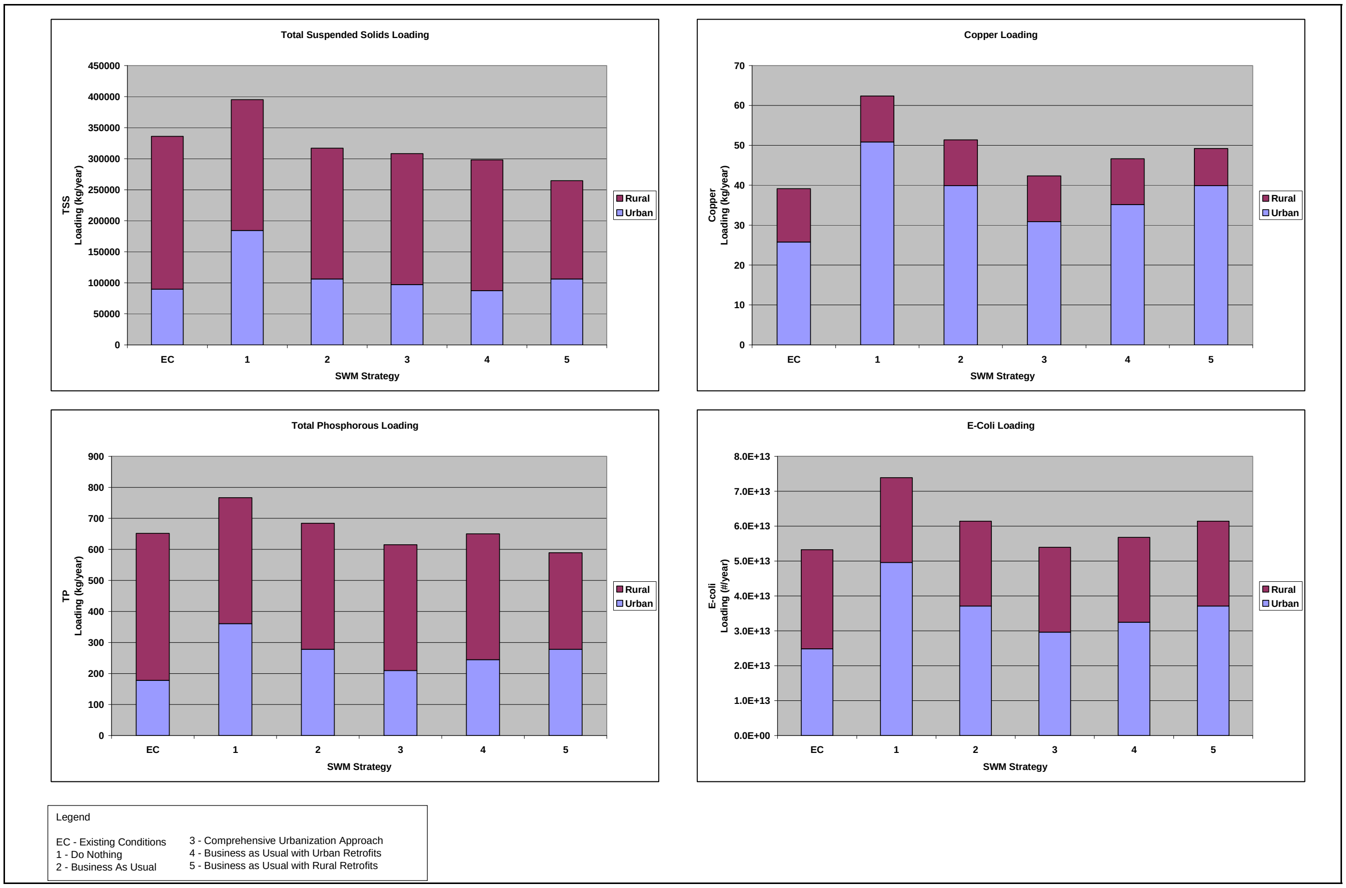


Figure 8.4: Evaluation of Alternative Stormwater Management Strategies for Borer's Creek

8.3.2.4 Chedoke Creek

<u>Description</u>

Chedoke Creek is an urban watershed, draining northwesterly from its headwaters above the Escarpment to Cootes Paradise. Very little new urban development (<1%) will occur within Chedoke Creek. Most of the planned growth within this watershed would occur through intensification in the existing urban areas.

<u>Environmental Resources and Issues</u>

Very little background information or environmental reporting is available for Chedoke Creek, however, environmental mapping was reviewed and indicates that there are small areas with permeable soils within the headwater areas.

Typical of an urban watershed, Chedoke Creek is characterized by high runoff volumes, channelized reaches, and few terrestrial resources.

Potential Development Impacts

Given that the Chedoke Creek watershed is already a fully urban watershed, very little impact is anticipated due to the minimal amount of future development. Hydrologic and water quality modeling results indicate only moderate increases in contaminant loadings.

Alternative Stormwater Strategy Evaluation

Modeling results for the alternative management strategies are presented in Figure 8.5. As shown, the "Business as Usual with Urban Retrofits" strategy is the most effective. This strategy provides the best opportunity to improve water quality and runoff characteristics from the existing urban watershed.

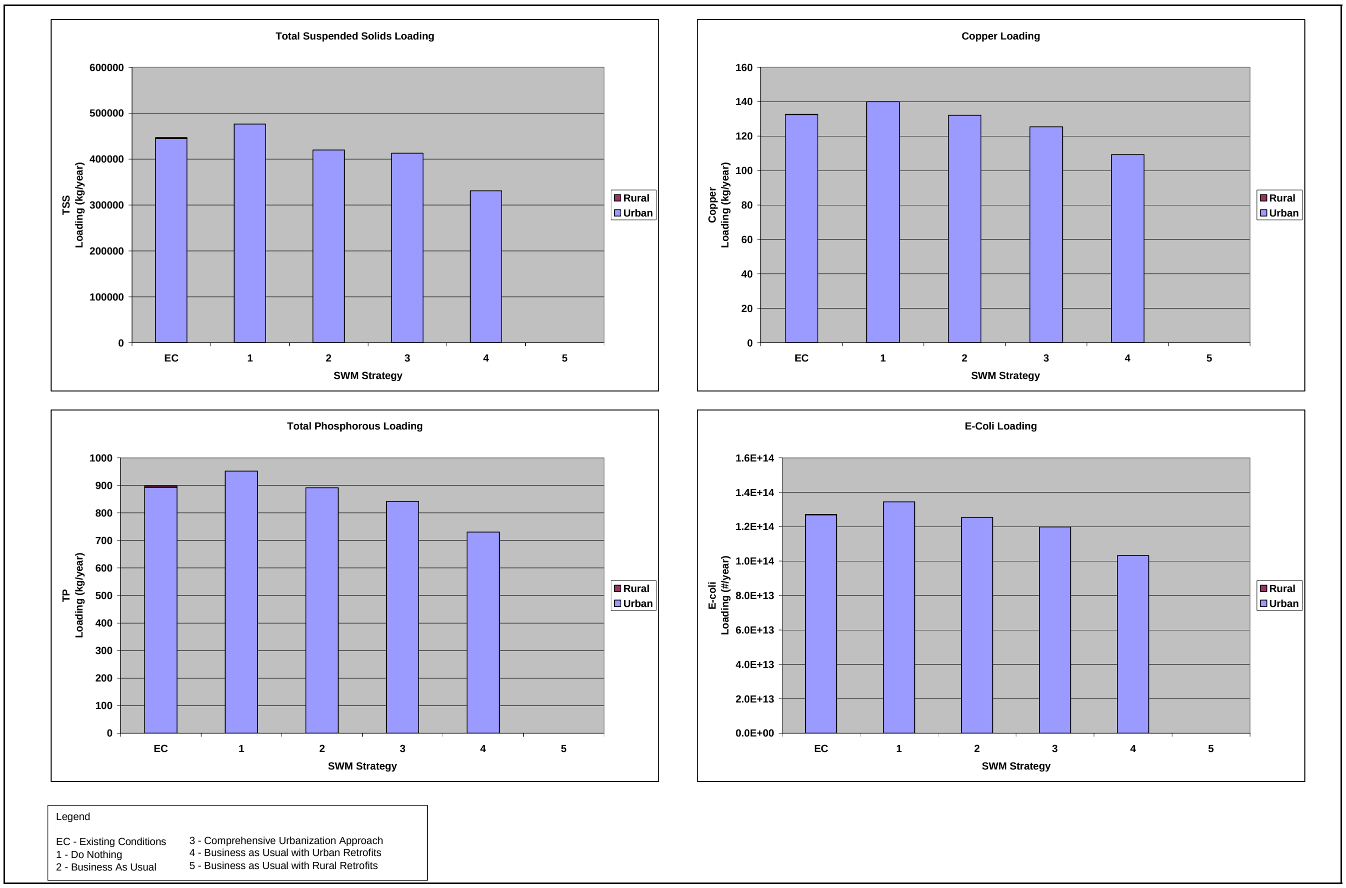


Figure 8.5: Evaluation of Alternative Stormwater Management Strategies for Chedoke Creek

8.3.2.5 Red Hill Creek

Description

Red Hill Creek drains in a northerly direction from the headwaters located above the Escarpment to Hamilton Harbour. Much of the watershed has already been developed with urban land uses, however a significant amount of further urban development will take place. The City's preferred growth strategy will see a further 17% of the watershed, or 1,200 ha, developed with urban land uses, together with intensification in the existing urban areas.

Environmental Resources and Issues

Soils within the Red Hill Creek watershed consist mainly of clay tills with silty clay deposits. Unique "karst" geology features have been identified along the Escarpment within the Hannon Creek and Davis Creek tributaries. Groundwater recharge in headwaters (upstream of Mud Street) supplies baseflow to the creek via the shallow overburden and the karst features. The underground flow routes associated with the karst geology represents a risk of groundwater contamination from urban runoff.

Typical of an urban watershed, Red Hill Creek is characterized by high runoff volumes, erosion, and poor water quality, including high levels of nutrients, metals, and bacteria. Wet weather flows also result in combined sewer overflows.

The past urban impacts, including erosion, channelization, and poor water quality have contributed to the loss of many native fish species above the Escarpment. The natural features of the valley system are designated as an Environmentally Significant Area (ESA).

Potential Development Impacts

Hydrologic and water quality modeling results indicate the following potential development impacts on Red Hill Creek:

- hydrologic impacts including increased runoff volumes (+ 11%), and increased erosion potential;
- reduction in groundwater recharge (approx. -9%), and reduced baseflows in streams;
- increased contaminant loadings:
  - Total Phosphorous +16%;
  - Copper +22%;
  - E.coli +21%
  - Suspended Solids +17%;

Alternative Stormwater Strategy Evaluation

Modeling results for the alternative management strategies are presented in Figure 8.6. As shown, the "Business as Usual with Urban Retrofits" strategy is the most effective. This strategy provides the best opportunity to improve water quality and runoff characteristics from the existing urban areas while preventing further impacts to the existing erosion sites through stormwater controls within future urban developments.

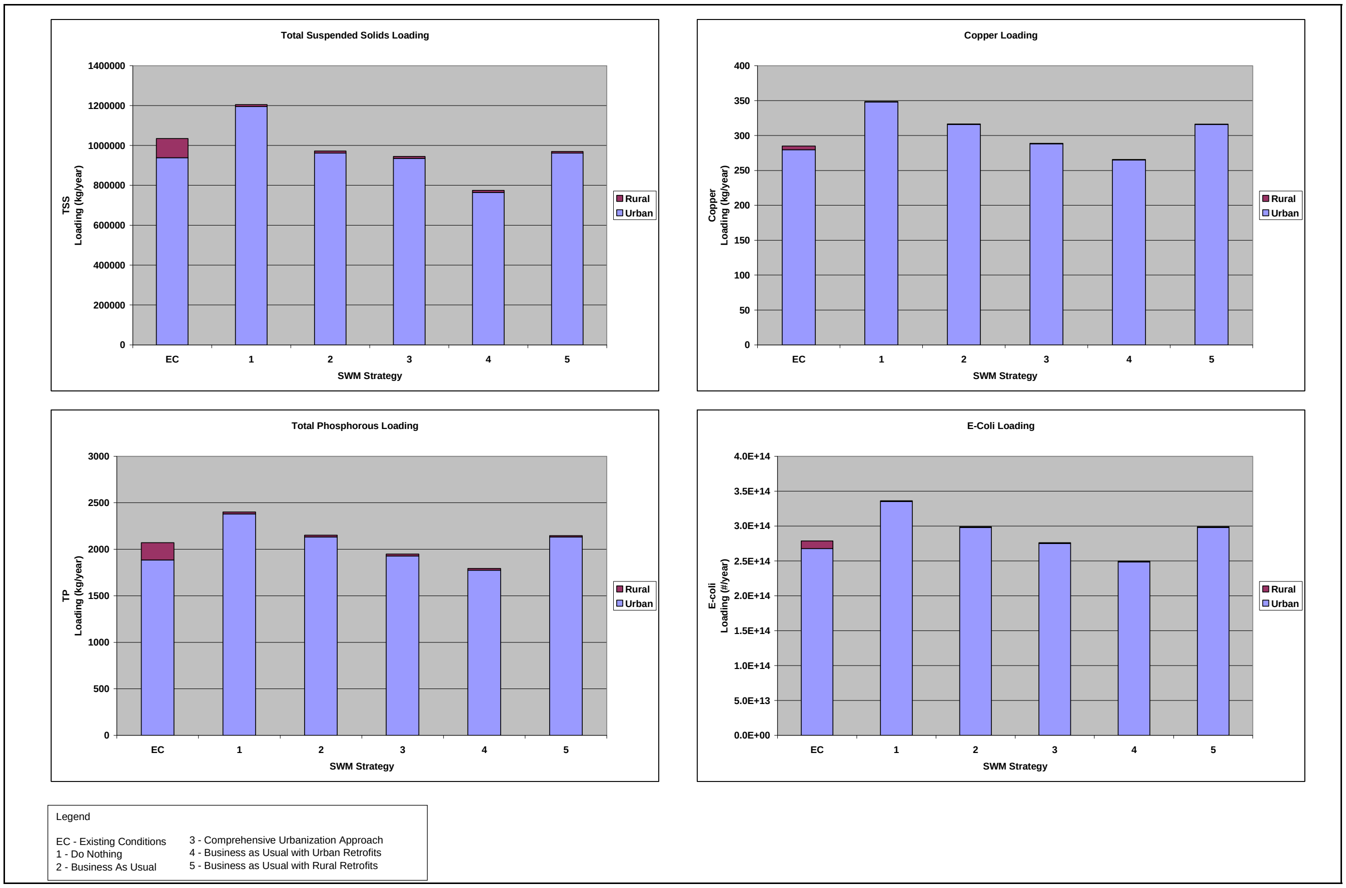


Figure 8.6: Evaluation of Alternative Stormwater Management Strategies for Red Hill Creek

8.3.2.6 Stoney Creek

<u>Description</u>

The headwaters of Stoney Creek originate above the Escarpment and drain northerly to Lake Ontario. The watershed is primarily urban below the Escarpment, but primarily rural above the Escarpment. The City's preferred growth strategy will see intensification of the existing urban areas and a further 10% of the watershed, or 300 ha, developed with urban land uses. This growth will occur in headwaters of Stoney Creek.

<u>Environmental Resources and Issues</u>

Soils within the watershed consist of clays and silt deposits with rock at the Escarpment, and some sandy deposits between the base of the Escarpment and Lake Ontario. The headwater areas have high groundwater recharge potential where soil thickness is low.

Many of the stream reaches have been channelized. Water quality is characterized as impaired with high temperatures and low dissolved oxygen. The downstream reaches near the outlet may be susceptible to flooding.

Fisheries within the watershed are impaired by low baseflows and poor water quality. Resource mapping indicates a provincially significant wetland (PSW) and Environmentally Significant Area (ESA) located in headwaters, upstream of the proposed future development areas.

Potential Development Impacts

Hydrologic and water quality modeling results indicate the following potential development impacts on Stoney Creek:

- hydrologic impacts including increased runoff volumes (+ 11%), and increased flood and erosion potential;
- reduction in groundwater recharge (approx. -5%), and reduced baseflows in streams;
- increased contaminant loadings:
    - Total Phosphorous +15%;
    - Copper +34%;
    - E.coli +24%
    - Suspended Solids +13%;
- negative impacts on the existing fisheries due to reduced baseflows, increased erosion potential, and increased contaminant loadings

Alternative Stormwater Strategy Evaluation

Modeling results for the alternative management strategies are presented in Figure 8.7. As shown, the "Comprehensive Urbanization Approach" and "Business as Usual with Urban Retrofits" strategies are the most effective strategies for preventing or minimizing future impacts. Of these two strategies, the "Business as Usual with Urban Retrofits" approach was selected as the recommended strategy. This strategy provides the best opportunity to improve water quality and runoff characteristics from the existing urban areas while preventing further impacts from future urban developments through stormwater controls.

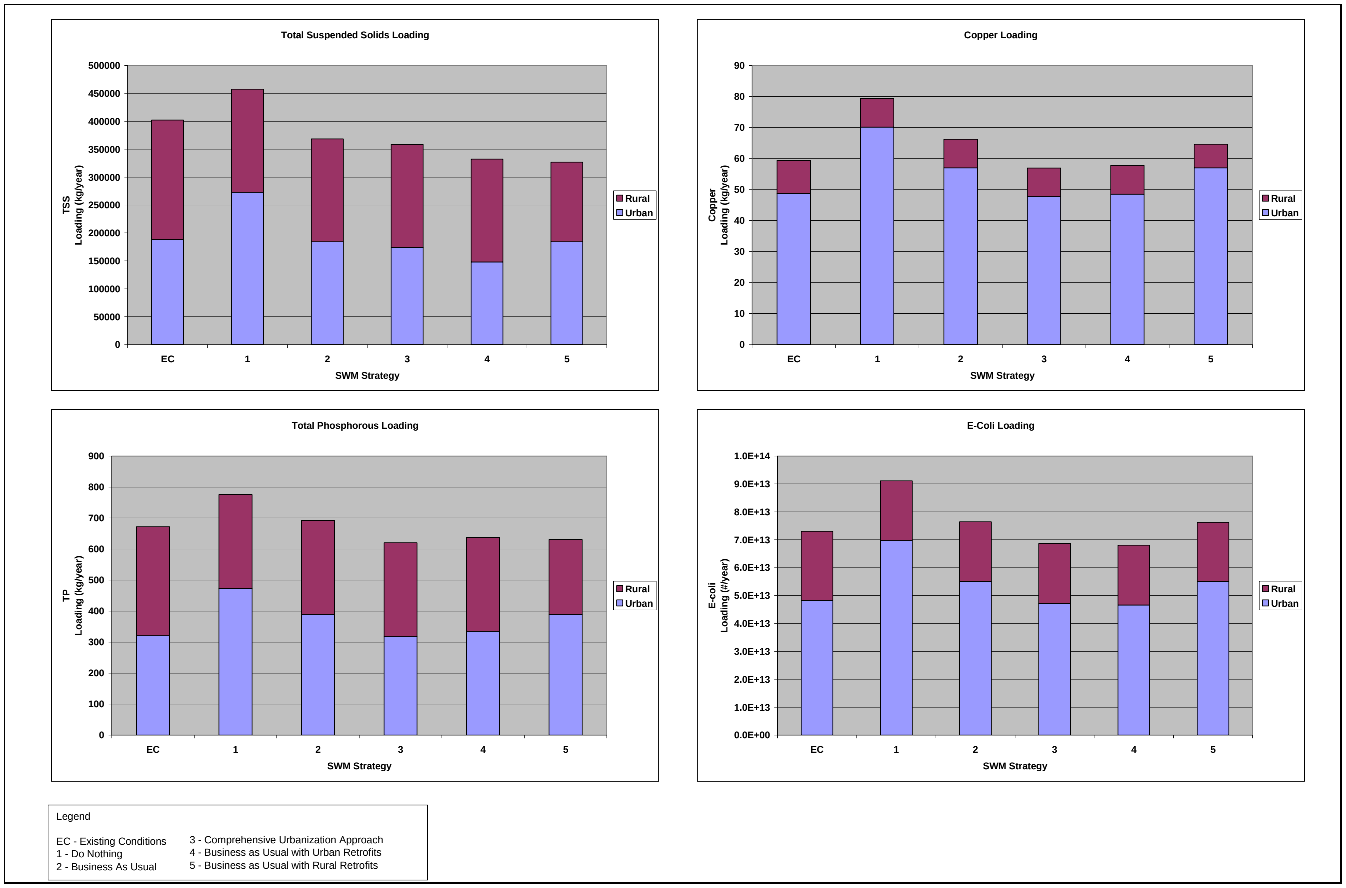


Figure 8.7: Evaluation of Alternative Stormwater Management Strategies for Stoney Creek

8.3.2.7 Community of Stoney Creek Watercourses

<u>Description</u>

This series of watercourses drain northward from the Escarpment to Lake Ontario. A significant portion of this watershed is urban, with development concentrated around the QEW corridor. The City's preferred growth strategy will see intensification of the existing urban areas and a further 3% of the watershed, or 100 ha, developed with urban land uses. This growth will occur within the drainage areas of the central and eastern watercourses.

<u>Environmental Resources and Issues</u>

Soils within the watershed consist of clays and silt deposits with rock at the Escarpment, and some sandy deposits between the base of the Escarpment and Lake Ontario

Most of the stream reaches downstream of the escarpment have been channelized, and some of the tributaries have been piped through the urban area. As a result, there are capacity constraints in some of these reaches which may pose a flood risk. Water quality is characterized as impaired with high temperatures and low dissolved oxygen.

Fisheries within the watershed are impaired by low baseflows and poor water quality. Resource mapping indicates an Environmentally Significant Area (ESA) located in headwaters (Escarpment), upstream of the proposed future development areas.

Potential Development Impacts

Hydrologic and water quality modeling results indicate the following potential development impacts on Stoney Creek:

- hydrologic impacts including a moderate increase in runoff volumes (+ 2%), and increased flood and erosion potential;
- a moderate reduction in groundwater recharge (approx. -1%), and reduced baseflows in streams;
- increased contaminant loadings:
    - Total Phosphorous +3%;
    - Copper +5%;
    - E.coli +4%
    - Suspended Solids +3%;
- negative impacts on the existing fisheries due to reduced baseflows, increased erosion potential, and increased contaminant loadings

Alternative Stormwater Strategy Evaluation

Modeling results for the alternative management strategies are presented in Figure 8.8. As shown, the “Business as Usual with Urban Retrofits” strategy is the most effective for preventing or minimizing future impacts. This strategy provides the best opportunity to improve water quality and runoff characteristics from the existing urban areas while preventing further impacts from future urban developments through stormwater controls.

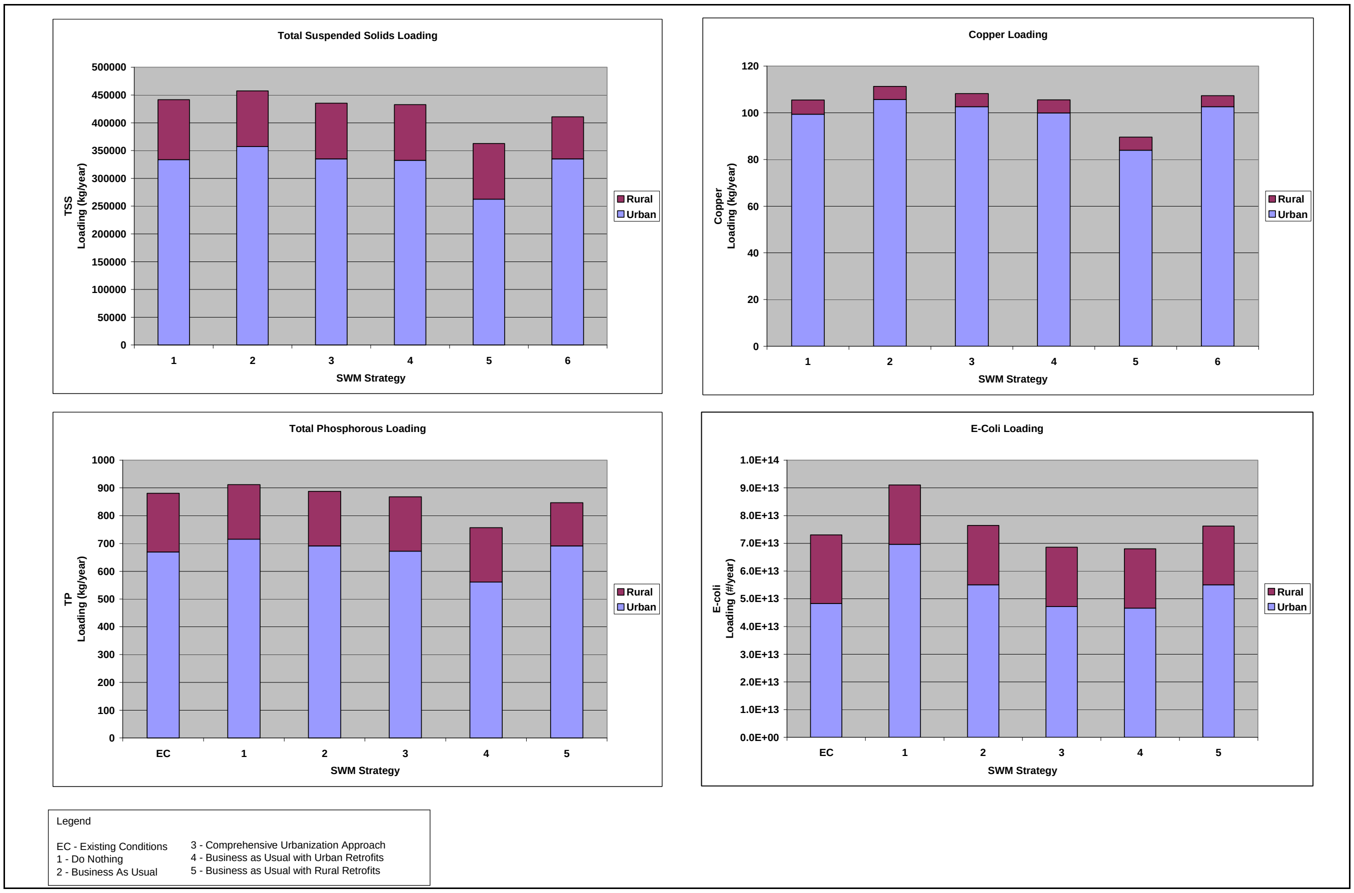


Figure 8.8: Evaluation of Alternative Stormwater Management Strategies for Community of Stoney Creek Watercourses

8.3.3 Evaluation of Strategies – Niagara Peninsula Conservation Authority

8.3.3.1 Twenty Mile Creek

Description

The headwaters of Twenty Mile Creek are located within the Glanbrook area on the south side of Hamilton. The creek drains northeast towards Lake Ontario at Jordan Harbour. Existing land uses within the watershed are primarily rural, however, significant future development will take place. The City's preferred growth strategy will see approximately 21% of the watershed area within the City, or 2,300 ha, developed with urban land uses.

Environmental Resources and Issues

The significant amount of future urban growth over existing rural lands could have significant impacts within the watershed.

Soils within the Twenty Mile Creek watershed consist mainly of silty clays. Unique "karst" geology features have been identified at two areas within the watershed:

- Stoney Creek Mountain (Rymal Road East and Trinity Church Road); and
- Sinkhole Creek (Westbrook Road and Highway 20);

Karst features include cracks or caves within the bedrock. Surface flows within the streams may temporarily "disappear" underground for long distances, ultimately discharging further downstream in the watershed. This underground flow route represents a risk of groundwater contamination from urban runoff as the surrounding lands are developed.

Baseflows within Twenty Mile Creek are low, resulting in intermittent flow conditions, and water quality sampling indicates elevated levels of nutrients. This lack of baseflow, combined with urban/agricultural loadings result in sever odour problems and algae blooms in some locations.

Hydraulic modeling and floodplain mapping have identified 3 flood-susceptible areas in the Town of Smithville downstream of Hamilton, with others in the Town of Lincoln, below the Escarpment. Therefore, flood control will be an important consideration in future stormwater management planning.

The watershed contains a diverse warmwater fishery. Although the stream reaches within Hamilton have not been classified according to MNR Fish Habitat Classification, the Main Branch and Sinkhole Creek are classified as "critical Type 1" habitat immediately east of Hamilton, in West Lincoln.

Other natural features which should be consideration when evaluating alternative watershed strategies include:

- the Jordan Harbour Marsh Provincially Significant Wetland (PSW);
- Environmentally Significant Areas (ESA's) along the main branch; and
- 2 Areas of Natural Scientific Interest:
  - north of Airport Road, between Nebo Road and Trinity Church Road;
  - south of Golf Club Road, between Regional Road 56 and Hendershot Road

<u>Potential Development Impacts</u>

Hydrologic and water quality modeling results indicate the following potential development impacts on Twenty Mile Creek:

- significant hydrologic impacts including increased runoff volumes (+ 17%), and increased erosion potential;
- reduction in groundwater recharge (approx. -10%), and reduced baseflows in streams;
- significant increase in contaminant loadings, particularly urban contaminants:
  - Total phosphorous +31%;
  - Copper +161%;
  - E.coli +76%
  - Suspended Solids +28%;

<u>Alternative Stormwater Strategy Evaluation</u>

Modeling results for the alternative management strategies are presented in Figure 8.9. As shown, the "Comprehensive Urbanization Approach" and "Business as Usual with Rural Retrofits" strategies are the most effective strategies for preventing or minimizing future impacts. Of these two strategies, the "Comprehensive Urbanization Approach" was selected as the recommended strategy. This strategy seeks to minimize hydrologic impacts through source control and conveyance control infiltration techniques, and preservation of the hydrologic cycle is an important consideration given the issues identified in this watershed, namely, a lack of baseflow, downstream flood risk, groundwater sensitivity, and downstream sensitive fisheries and terrestrial features.

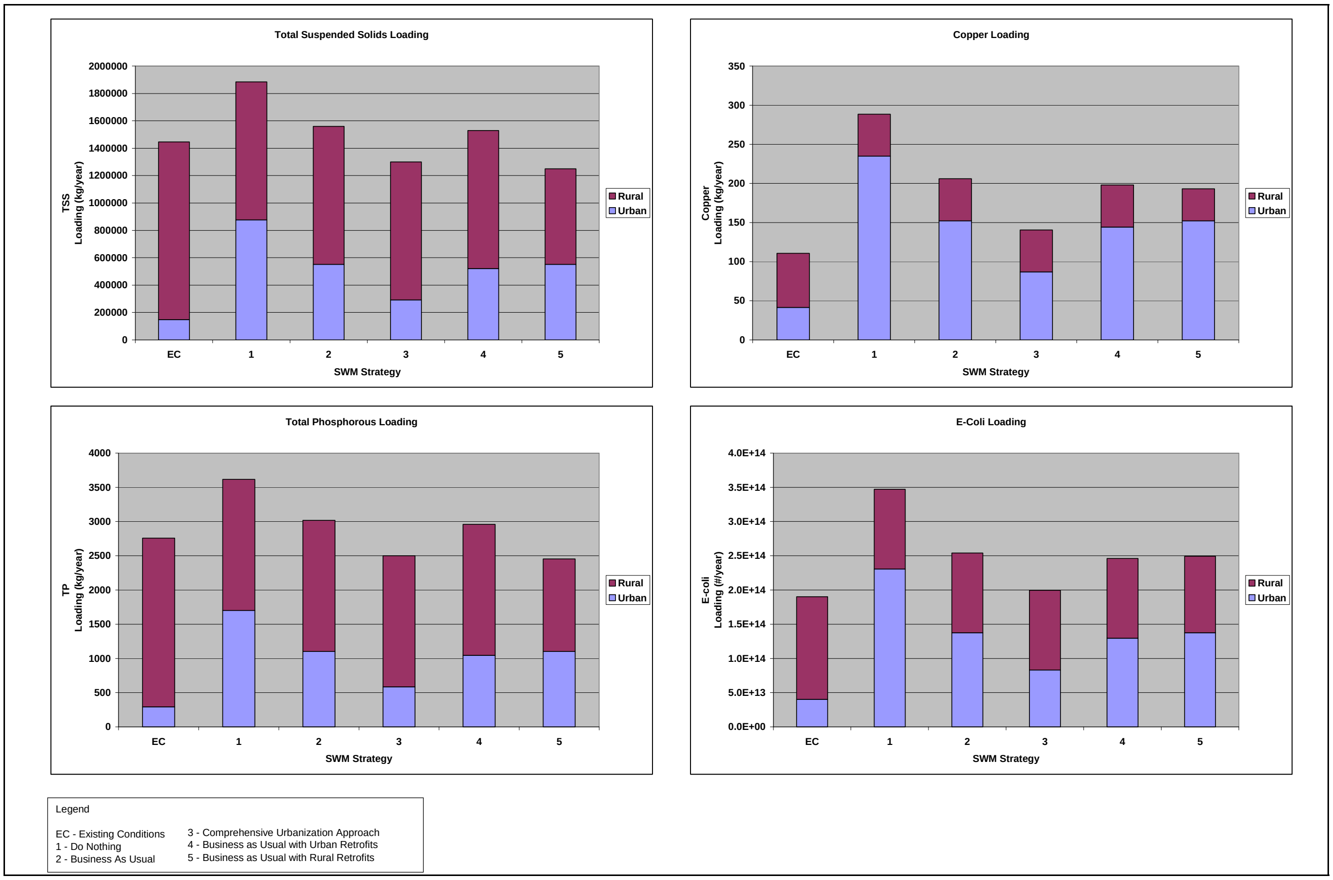


Figure 8.9: Evaluation of Alternative Stormwater Management Strategies for Twenty Mile Creek

8.3.3.2 Welland River

Description

The headwaters of the Welland River are located above the Escarpment near Ancaster and the Hamilton Airport. The river drains eastward, ultimately draining to the Niagara River, and comprises a significant portion (81%) of the Niagara River “Area of Concern” within the Great Lakes basin. The natural outlet was the Niagara River, but the Welland River now drains to the Queenston-Chippewa Power Canal. The Binbrook Dam and Reservoir was built on the Welland River for flood control and flow augmentation.

Existing land uses within the watershed are primarily rural, however, significant future development will take place. The City’s preferred growth strategy will see approximately 13% of the watershed area within the City, or over 1,300 ha, developed with urban land uses. Most of this future urbanization is associated with the development of a business park adjacent to the Hamilton Airport.

Environmental Resources and Issues

The significant amount of future urban growth over existing rural lands could have significant impacts within the watershed.

Soils within the Welland River watershed consist mainly of clay and clay loam with low infiltration potential.

Water quality is considered degraded and characterized by elevated loadings of suspended sediment, phosphorous and bacteria. De-icing activities at the Airport also affect the water quality near the headwaters. Sediment accumulation behind weir and dam structures from upstream erosion has also been identified as an issue.

The river supports a warmwater fishery, but has a lack of migratory fish and forage species. Movement of fish within the river is restricted by the Binbrook Dam and other barriers.

In terms of terrestrial features, the watershed is characterized by a lack of riparian vegetation, low forest cover, and wetland cover.

Potential Development Impacts

Hydrologic and water quality modeling results indicate the following potential development impacts on the Welland River:

- hydrologic impacts including increased runoff volumes (+ 13%), and increased erosion potential;
- reduction in groundwater recharge (approx. -7%), and reduced baseflows in streams;
- significant increase in contaminant loadings, particularly urban contaminants:
    - Total Phosphorous +19%;
    - Copper +75%;
    - E.coli +35%
    - Suspended Solids +10%;

Alternative Stormwater Strategy Evaluation

Modeling results for the alternative management strategies are presented in Figure 8.10. As shown, the “Comprehensive Urbanization Approach” and “Business as Usual with Rural Retrofits” strategies are the most effective strategies for preventing or minimizing future impacts. Of these two strategies, the “Comprehensive Urbanization Approach” was selected as the recommended strategy as it is the most effective in minimizing impacts from metals and bacteria loadings while also reducing nutrient and suspended sediments loadings.

This strategy seeks to minimize hydrologic impacts through source control and conveyance control infiltration techniques. Preservation of the hydrologic cycle is an important consideration given the issues identified in this watershed, namely, a lack of baseflow, erosion/sedimentation problems and fisheries.

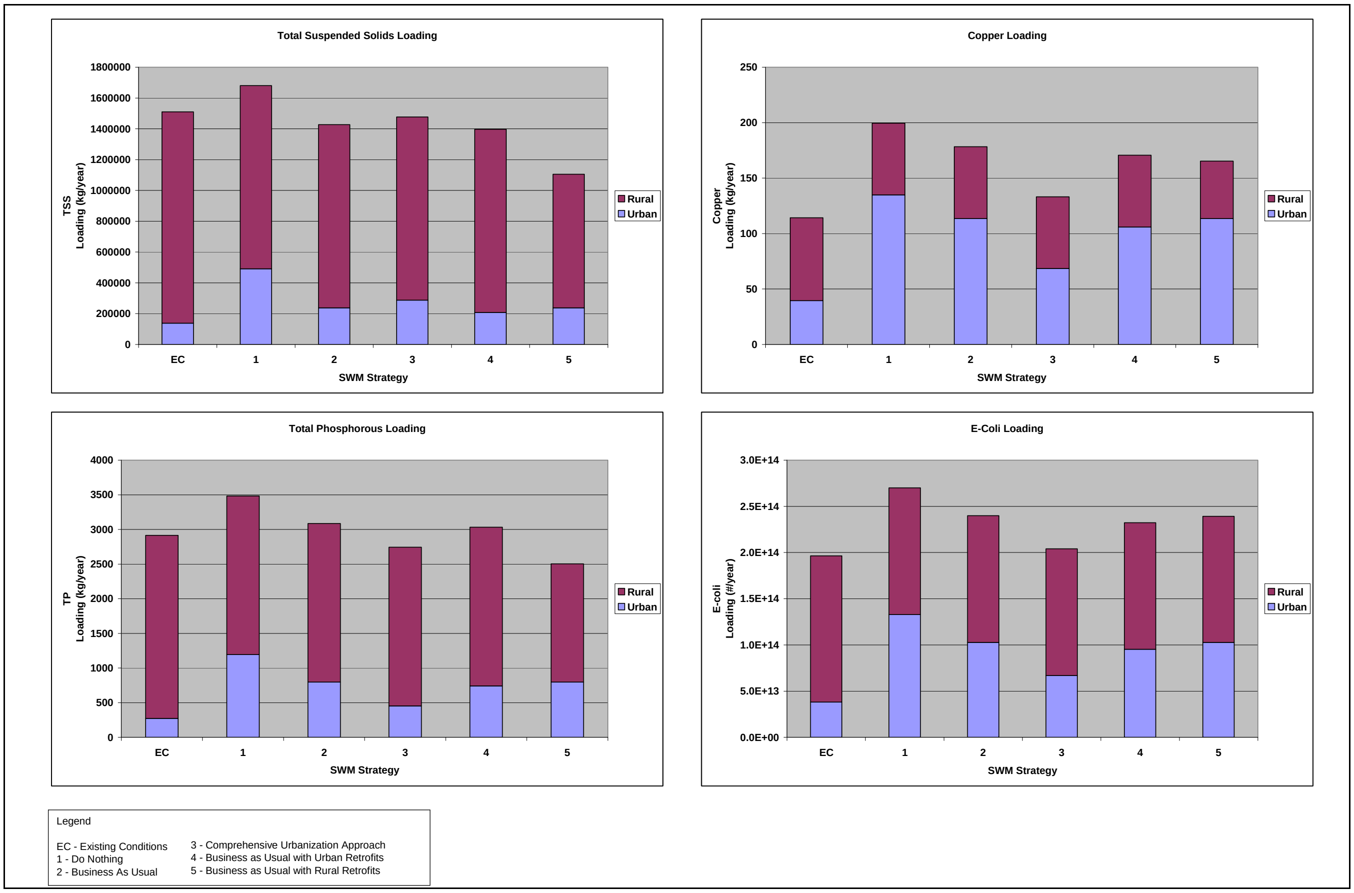


Figure 8.10: Evaluation of Alternative Stormwater Management Strategies for Welland River

8.3.3.3 Forty Mile Creek

Description

The headwaters of Forty Mile Creek are located near the eastern limits of the City of Hamilton. Within the City limits, Forty Mile Creek is a rural watershed. The City's preferred growth strategy does not include any urban development within the watershed.

Environmental Resources and Issues

Very little background information or environmental reporting is available for Forty Mile Creek, however, environmental mapping was reviewed. The available mapping identifies Forty Mile Creek as supporting a warmwater fishery. Further, a portion of a provincially significant wetland (PSW) and Environmentally Significant Area (ESA) are also located within the subwatershed.

Potential Development Impacts

No urban development impacts are expected in Forty Mile Creek, as the City's preferred growth strategy does not include any urban development within the watershed.

Alternative Stormwater Strategy Evaluation

Modeling results for the alternative management strategies are presented in Figure 8.11. Due to the rural nature of the watershed and lack of future urban development, the urban stormwater management strategies were not considered. The “Business as Usual with Rural Retrofits” strategy is recommended as it would result in significant reductions in contaminant loadings over existing conditions or the “Do Nothing” strategy. The reduced contaminant loadings would have a positive impact on the downstream fisheries and PSW’s.

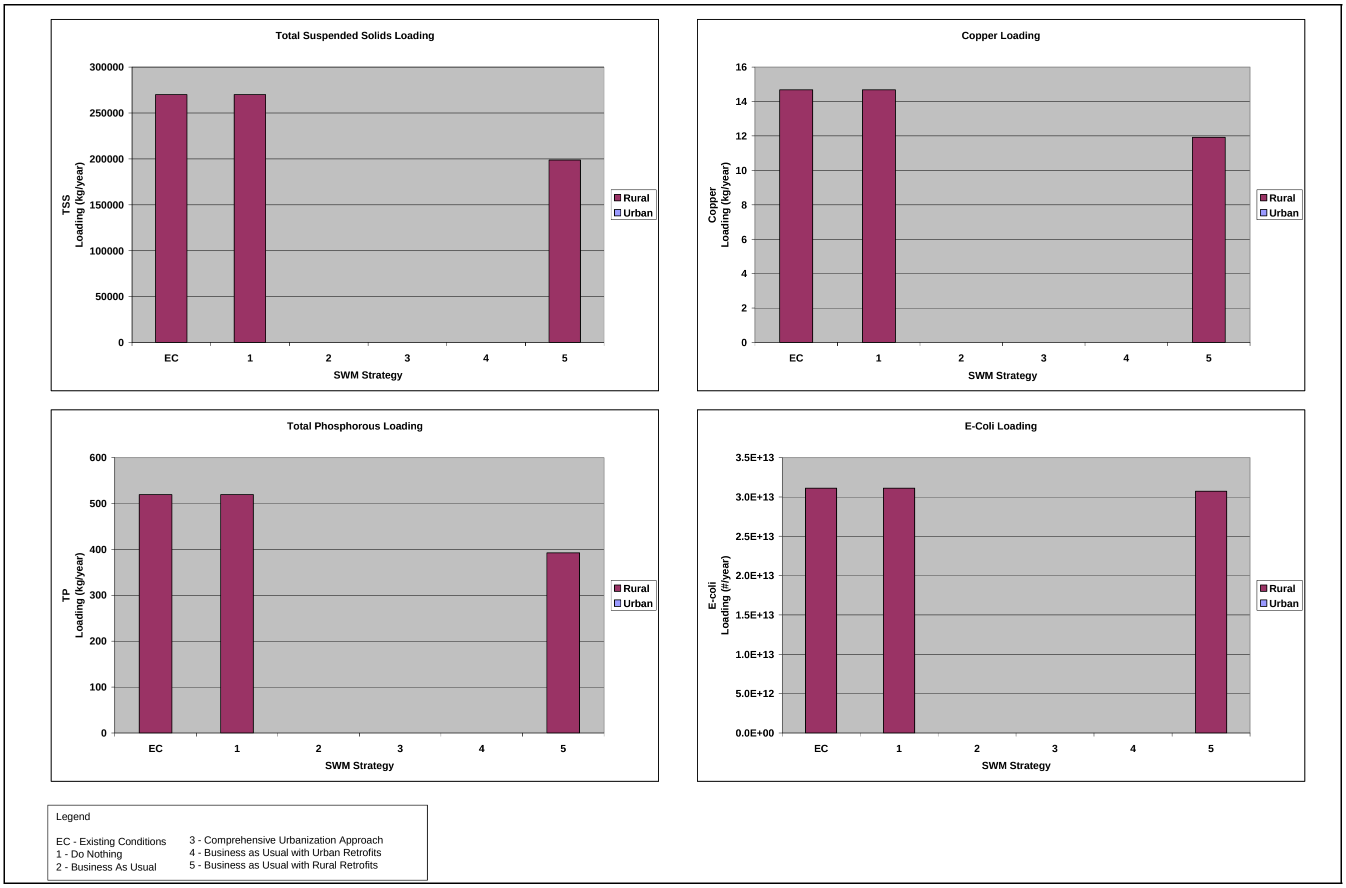


Figure 8.11: Evaluation of Alternative Stormwater Management Strategies for Forty Mile Creek

8.3.4 Evaluation of Strategies – Conservation Halton

8.3.4.1 Bronte Creek

Description

The headwaters of Bronte Creek are located in the northwest limits of the City of Hamilton, including the Main Branch headwaters, Strabane Creek, Mountsberg Creek, and Flamboro Creek tributaries. Within the City limits, Bronte Creek is primarily a rural watershed. The City’s preferred growth strategy does not include any urban development within the watershed.

Environmental Resources and Issues

Above the Escarpment, soils within the Bronte Creek watershed consist of predominantly loam and sandy loam, with clay loam below the Escarpment. The headwaters of the creek represent a significant groundwater recharge zone, providing baseflow to the streams and drinking water to more than 25% of the watershed residents.

Hydraulic modeling and floodplain mapping have identified several flood-susceptible areas within the watershed, including 134 structures. Therefore, flood control will be an important consideration in future stormwater management planning.

Water quality monitoring indicates that most pollutants meet MOE objectives, however, phosphorous and bacteria levels are often elevated.

Bronte Creek supports healthy coldwater and warmwater fish communities. However, existing on-line dams/ponds tend to increase instream temperatures and represent barriers to fish migration.

The watershed also contains several Environmentally Significant Areas (ESA's), provincially significant wetlands (PSW's) and areas of natural and scientific interest (ANSI's);

Potential Development Impacts

No urban development impacts are expected in Bronte Creek, as the City's preferred growth strategy does not include any urban development within the watershed.

Alternative Stormwater Strategy Evaluation

Modeling results for the alternative management strategies are presented in Figure 8.12. Due to the rural nature of the watershed and lack of future urban development, the urban stormwater management strategies were not considered. The "Business as Usual with Rural Retrofits" strategy is recommended as it would result in significant reductions in contaminant loadings over existing conditions or the "Do Nothing" strategy. The reduced contaminant loadings would have a positive impact on the downstream fisheries and PSW's.

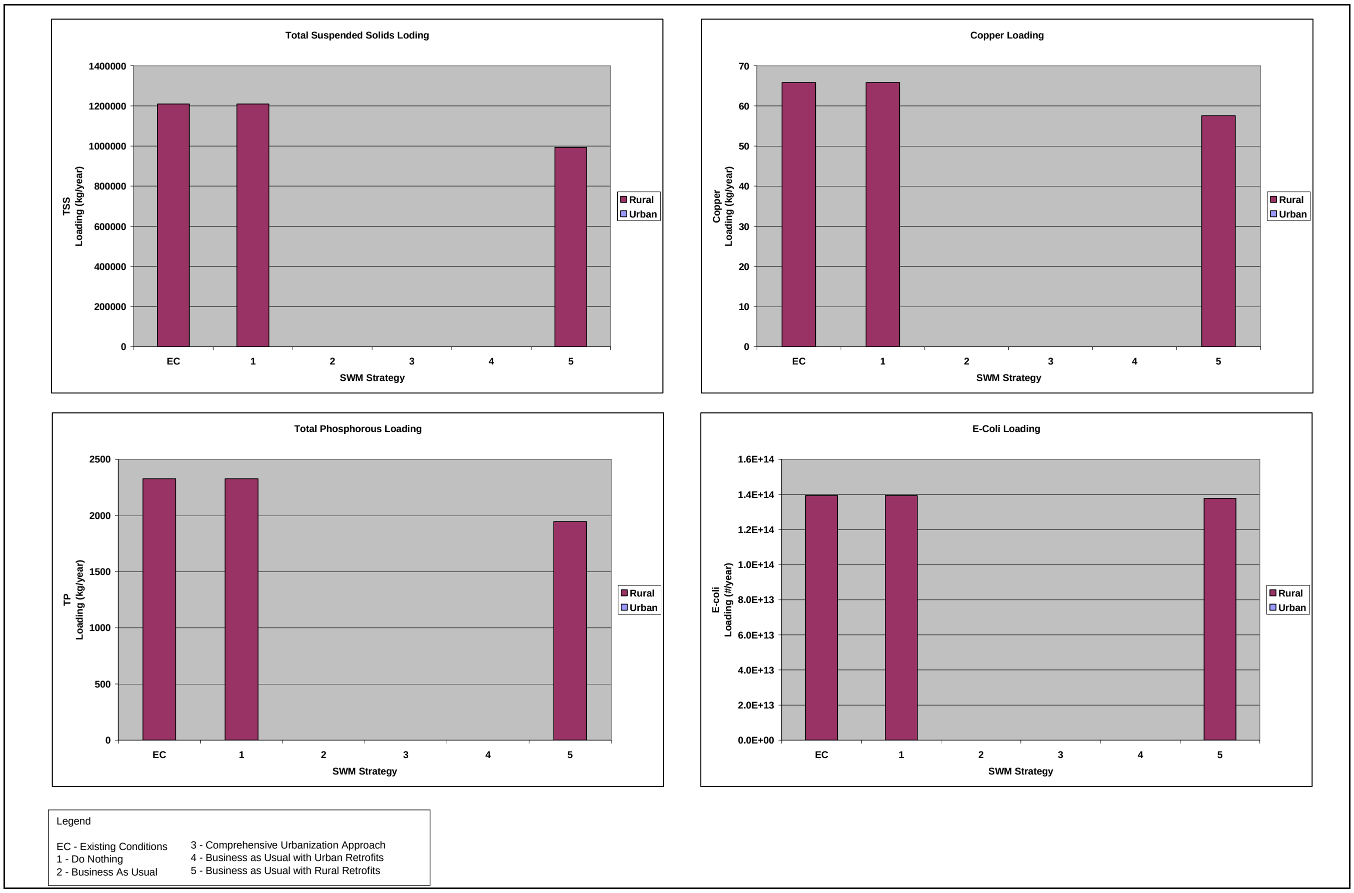


Figure 8.12: Evaluation of Alternative Stormwater Management Strategies for Bronte Creek

8.3.4.2 Grindstone Creek

Description

Grindstone Creek originates in the rural lands above the Escarpment. The creek drains southeasterly through Waterdown to Hamilton Harbour. The City's preferred growth strategy includes future urban development on south side of Waterdown. In total, approximately 300 ha of future urban development is planned, representing roughly 4% of the watershed area within the City.

Environmental Resources and Issues

Above the Escarpment, soils within the Grindstone Creek watershed consist of predominantly sandy loam, with loamy soils below the Escarpment. The headwaters of the creek represent a significant groundwater recharge zone, providing cool baseflow to Grindstone Creek and Logies Creek (Spencer Creek watershed). Karst geologic features are found along the Escarpment, providing further infiltration potential. The bedrock cracks, caves, and underground flow routes associated with karst represent a risk of groundwater contamination from urban runoff as the surrounding lands are developed.

Hydraulic modeling and floodplain mapping have identified flood-susceptible areas in Millgrove and Hidden Valley. Therefore, flood control will be an important consideration in future stormwater management planning.

Water quality monitoring indicates high suspended solids, phosphorous, and bacteria levels. High phosphorous levels are attributed in part to the Waterdown wastewater treatment plant which also supplies approximately 20% of the baseflow in the creek.

Given the steep channel slopes and exposure of shale bedrock below the Escarpment, there is an increased risk of channel erosion.

With respect to fish communities, the creek reaches located downstream of the Escarpment are classified as coldwater. Above the Escarpment, the main branch and some tributaries are classified as warmwater and/or potential coldwater.

There is also considerable wetland coverage in the watershed (approximately 13%), including five provincially significant wetland (SPW) complexes. Forest cover accounts for approximately 25% of the watershed. The Grindstone Creek watershed also includes several ESA's, primarily associated with wetlands and woodlots.

<u>Potential Development Impacts</u>

Hydrologic and water quality modeling results indicate the following potential development impacts on Grindstone Creek:

- significant hydrologic impacts including increased runoff volumes (+ 8%), and increased erosion potential;
- reduction in groundwater recharge (approx. -2%), and reduced baseflows in streams;
- increased contaminant loadings, particularly urban contaminants:
    - Total Phosphorous +7%;
    - Copper +32%;
    - E.coli +17%
    - Suspended Solids +7%;
- negative impacts on the existing coldwater fishery due to reductions in baseflows, increased erosion potential, and increased contaminant loadings.

<u>Alternative Stormwater Strategy Evaluation</u>

Modeling results for the alternative management strategies are presented in Figure 8.13. As shown, the "Comprehensive Urbanization Approach" and "Business as Usual with Rural Retrofits" strategies are the most effective strategies for preventing or minimizing future impacts. Of these two strategies, the "Comprehensive Urbanization Approach" was selected as the recommended strategy as it is the most effective in minimizing impacts from metals and bacteria loadings while also reducing nutrient and suspended sediments loadings.

This strategy seeks to minimize hydrologic impacts through source control and conveyance control infiltration techniques. The preservation of the hydrologic cycle is an important consideration given the issues identified in this watershed, namely, high infiltration rates supplying baseflows to the resident coldwater fisheries, downstream flood and erosion risks and sensitive terrestrial features.

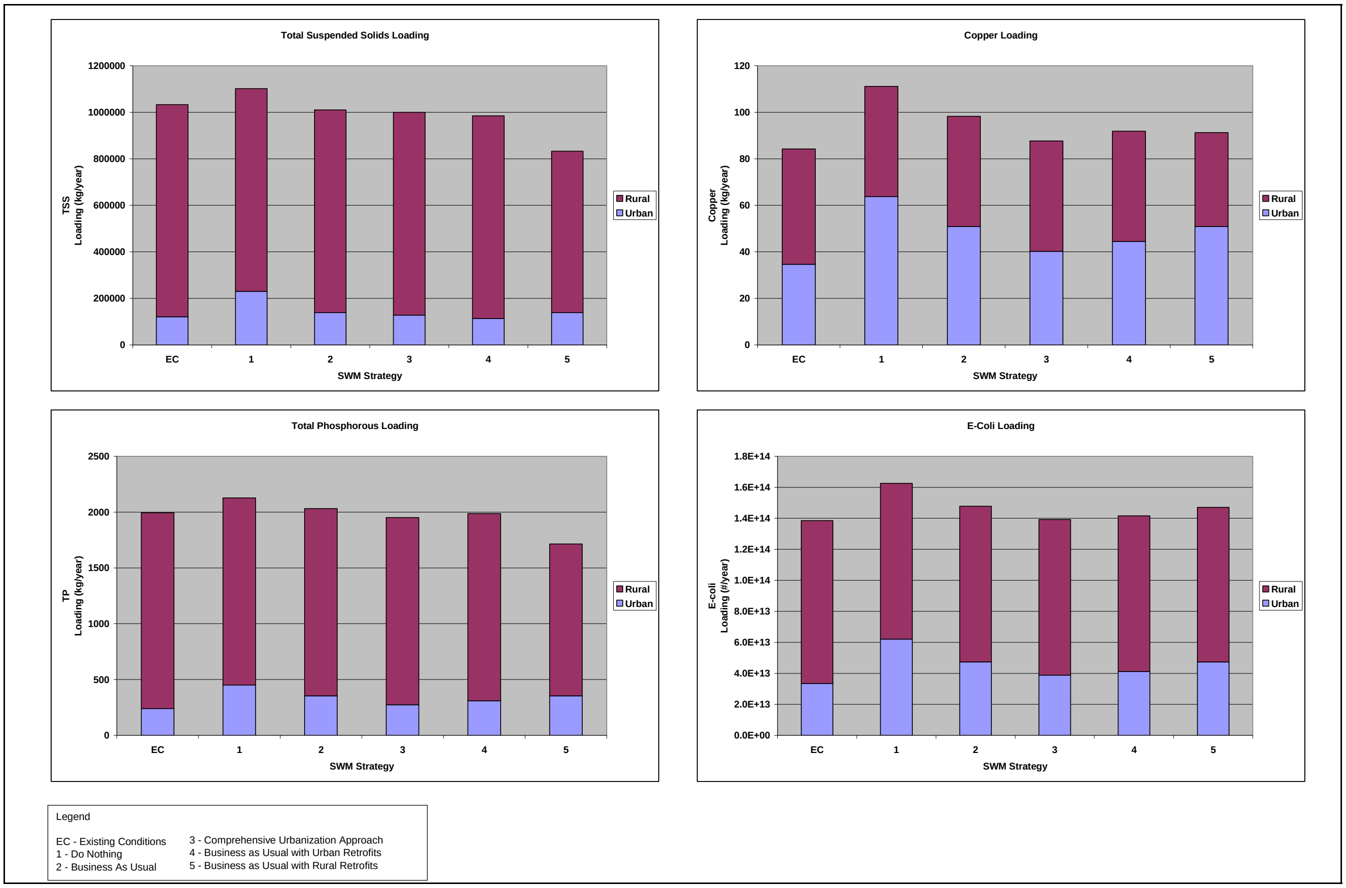


Figure 8.13: Evaluation of Alternative Stormwater Management Strategies for Grindstone Creek

8.3.5 Evaluation of Strategies – Grand River Conservation Authority

8.3.5.1 Big Creek

<u>Description</u>

Big Creek is a tributary of the Grand River, with the headwaters located near Ancaster. Land uses within the watershed are primarily rural, with a small amount of existing urban development in Ancaster. The City's preferred growth strategy will see approximately 5% of the watershed area within the City, or roughly 600 ha, developed with urban land uses. The growth strategy includes a future business park development near Ancaster and Hamilton Airport.

<u>Environmental Resources and Issues</u>

Very little background information or environmental reporting is available for Big Creek, however, environmental mapping was reviewed. The available mapping indicates that soils in the headwaters consist of highly permeable material with high groundwater recharge potential.

Big Creek is classified as a warmwater fishery. Further, the watershed is also home to downstream Environmentally Significant Areas (ESA's).

Potential Development Impacts

Hydrologic and water quality modeling results indicate the following potential development impacts on the Big Creek watershed:

- hydrologic impacts including increased runoff volumes (+ 5%), and increased erosion potential;
- reduction in groundwater recharge (approx. -4%), and reduced baseflows in streams;
- significant increase in contaminant loadings, particularly urban contaminants:
  - Total Phosphorous +7%;
  - Copper +40%;
  - E.coli +20%
  - Suspended Solids +7%;

Alternative Stormwater Strategy Evaluation

Modeling results for the alternative management strategies are presented in Figure 8.14. As shown, the “Comprehensive Urbanization Approach” and “Business as Usual with Rural Retrofits” strategies are the most effective strategies for preventing or minimizing future impacts. Of these two strategies, the “Business as Usual with Rural Retrofits” was selected as the recommended strategy as it is the most effective in reducing suspended sediment and nutrient levels which would, in turn, help to improve water quality in the receiving Lower Grand River system.

This strategy seeks to minimize hydrologic impacts through source control and conveyance control infiltration techniques. Preservation of the hydrologic cycle is an important consideration given high groundwater recharge characteristics of the existing permeable soils.

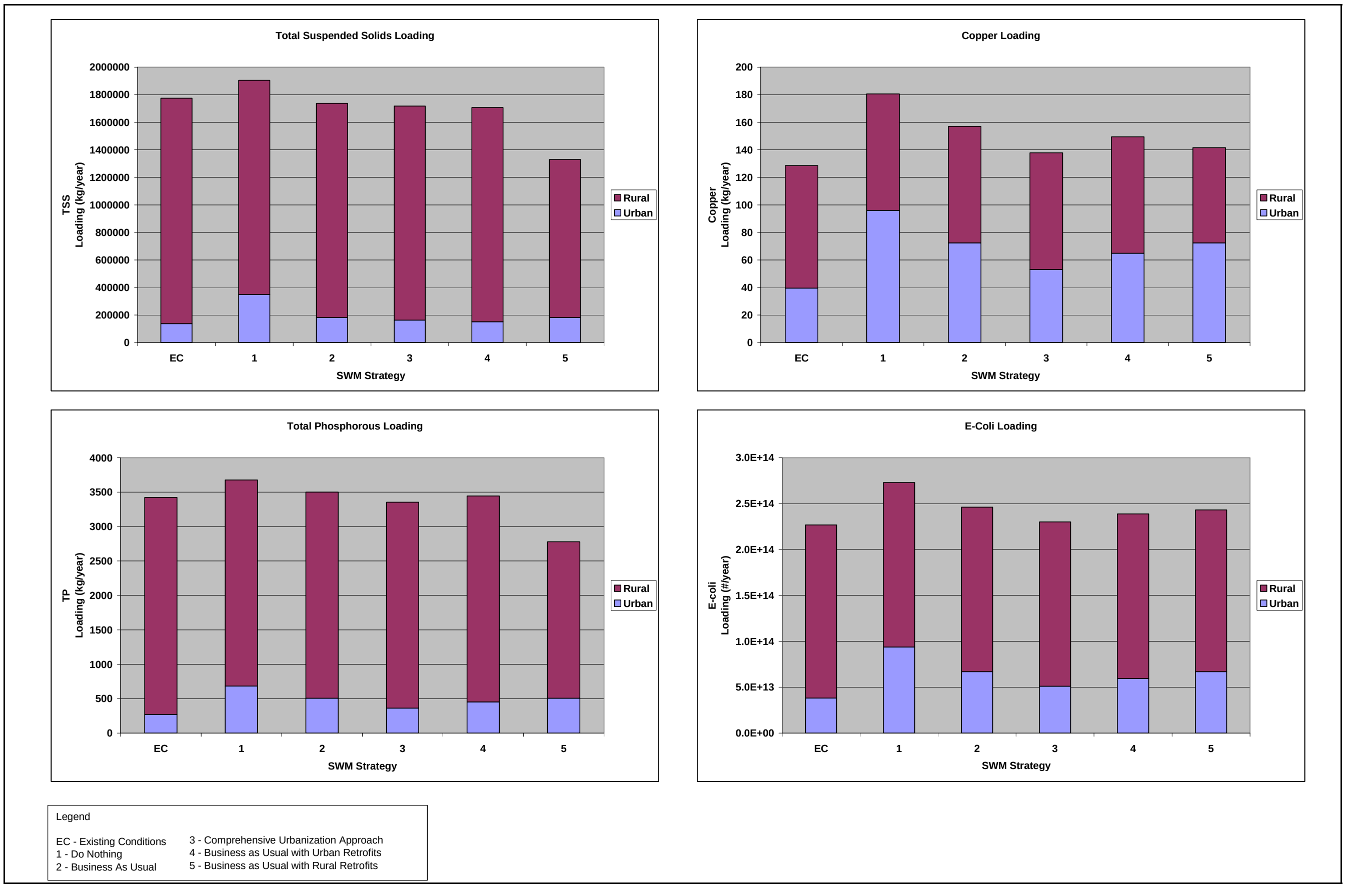


Figure 8.14: Evaluation of Alternative Stormwater Management Strategies for Big Creek

8.3.5.2 Fairchild Creek

<u>Description</u>

Fairchild Creek is a tributary of the Grand River, with the headwaters located in the west side of Hamilton near Glanbrook. Within the City limits, Fairchild Creek is a rural watershed. The City's preferred growth strategy does not include any urban development within the watershed.

<u>Environmental Resources and Issues</u>

Very little background information or environmental reporting is available for Fairchild Creek, however, environmental mapping was reviewed. The available mapping indicates that soils in the watershed consist of highly permeable material with high groundwater recharge potential.

Fairchild Creek is classified as a warmwater fishery. Further, the watershed contains extensive coverage of provincially significant wetlands (PSW's), Environmentally Significant Areas (ESA's) and areas of natural and scientific interest (ANSI's).

<u>Potential Development Impacts</u>

No urban development impacts are expected in Fairchild Creek, as the City's preferred growth strategy does not include any urban development within the watershed.

Alternative Stormwater Strategy Evaluation

Modeling results for the alternative management strategies are presented in Figure 8.15. Due to the rural nature of the watershed and lack of future urban development, the urban stormwater management strategies were not considered. The “Business as Usual with Rural Retrofits” strategy is recommended as it would result in significant reductions in contaminant loadings over existing conditions or the “Do Nothing” strategy. The reduced contaminant loadings would have a positive impact on the downstream fisheries and PSW’s.

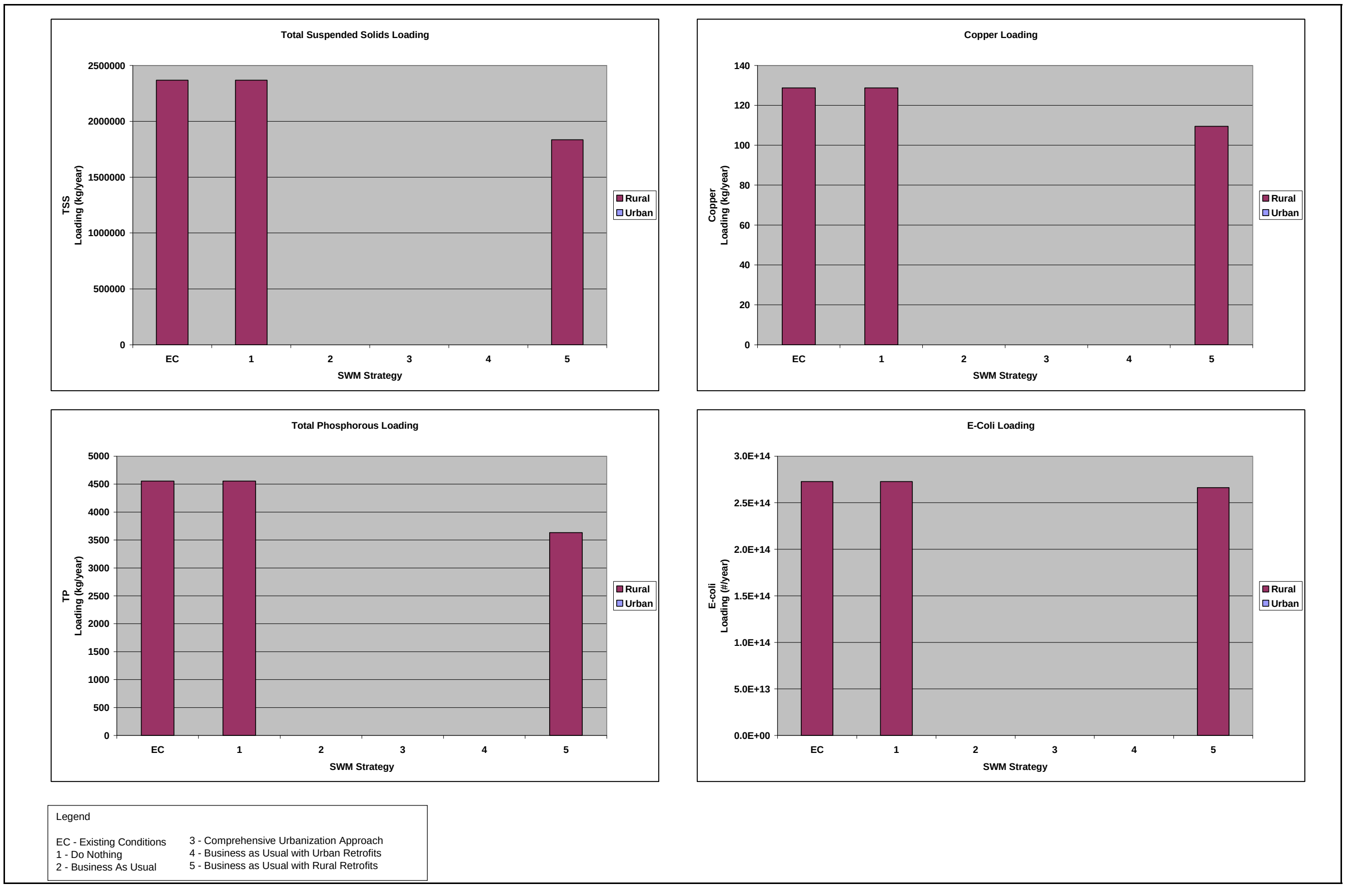


Figure 8.15: Evaluation of Alternative Stormwater Management Strategies for Fairchild Creek

8.3.6 Evaluation of Strategies – Remedial Action Plans

In the 1970’s, the US and Canadian governments identified areas within the Great Lakes Basin and Connecting Channels, where severe water quality impairment occurred. A total of 41 Areas of Concern were identified, many occurring in association with major harbours and industrialized waterfronts. Two of these, Hamilton Harbour and the Niagara River are the “receiving waters” of the majority of the watercourses within the City. Studies to identify the sources of the problems, the degree of impact and a list of remedial measures were assimilated into Remedial Action Plans were for each of these Areas of Concern. Based on the RAP documents, implementation programs are underway for each AOC including a long term monitoring and evaluation program. The long term objective of each RAP is to restore the beneficial uses (environmental and human) that have been impaired by historic and current land use activities. These programs are administered by a multi-stakeholder implementation committee that includes government, industry, environmental and citizens groups.

The Welland River is considered to be part of the Niagara River AOC and specific targets and remedial measures have been identified for the watershed, specific to the restoration of beneficial uses in the Niagara River. These can be briefly summarized as follows:

- Total phosphorus concentrations = 0.03 mg/l (this acknowledges the reduction of other nutrients such as nitrate and ammonia). The focus of remedial works is on control of urban and agricultural non-point sources with respect to the Welland River
- E.coli concentrations = 100 counts/100 ml.
- Total Suspended Solids = 80 mg/l (non-storm related). The focus of remedial works is on reduction of sediment generating erosion sites

For the Hamilton Harbour AOC, a number of rivermouth targets were established to reduce pollutant loadings to Hamilton Harbour and Cootes Paradise. These are as follows:

- A 30% reduction in Total Phosphorus loadings (from 90 kg/da to 65 kg/da)
- Total phosphorus concentrations = 0.017 mg/l (Hamilton Harbour); 0.065 mg/l (Cootes Paradise/Grindstone Creek)
- Unionized ammonia < 0.02 (Hamilton Harbour, Cootes Paradise, Grindstone Creek)
- Total Suspended Solids = 25 mg/l (Cootes Paradise)
- E.coli = 100 counts/100 ml (beach areas)

This would apply to the following watercourses: Chedoke, Red Hill, Spencer, Sulphur, Borer's and Grindstone Creeks.

In addition, both RAP's include objectives related to the following:

- Restoration of healthy fish populations/communities, including sportsfish that are free of contaminants
- Reduction of nutrient concentrations to the point where nuisance levels of algal blooms are eliminated

Finally, the Welland River Watershed Plan includes a number of key targets that are generally linked to the achievement of the Niagara RAP objectives:

- A watershed in which man-made flows and migratory barriers do not interfere with natural water flow, sediment and nutrient transport or fish migration
- A watershed that supplies the flow regime, habitat structure, woody debris and leaf litter input to support a healthy and diverse aquatic community. In order to meet this objective, it is suggested that the following habitat targets be met:

    - 70% of first to third order streams with a 30 m buffer of natural vegetation
    - 30% of the watershed area is in natural forest/wetland
    - 10% of the watershed area is in wetland
    - Baseflow is a minimum of 20% annual flow
    - A minimum of 4% of warmwater riverine habitat is riffle habitat
    - A minimum of 15% of riverine pools are covered by stumps, logs, trees, rock or vegetation

- Water quality meets or exceeds PWQO's for all key parameters including:

    - o Total suspended solids = 80 mg/l
    - o E.coli = 100 counts/100 mls
    - o Total phosphorus = 0.03 mg/l
    - o Dissolved oxygen > 4 mg/l

These targets established for the Niagara River (and Welland) are generally similar to watershed targets established for other watersheds within the City.

As part of this study meetings were held with Welland and Hamilton Remedial Action Plan members. The general approach that was discussed involved the development of a long term strategy that would reduce pollutant loadings to the receiving stream as noted above.

8.3.7 Evaluation of Strategies – Storm Sewer Infrastructure

8.3.7.1 Assessment of Intensification on Storm Sewer Infrastructure

The Recommended Growth Option includes 26,500 units for intensification. A further 31,900 units are located within the existing urban boundary.

Chapter 10 provides different stormwater alternatives which address a variety of environmental impacts (increased peak flows, reduced baseflows, increased pollutant loadings) that occur as a result of intensification. The objective of this section is to provide an estimate as to the percentage of storm trunk sewers that would need to be replaced (upgraded) if intensification were to occur and on-site controls were not implemented.

The level of replacement is, in part, based on the type of intensification, together with the proposed location for intensification. The process used to estimate the percentage of trunk sewers that would need to be replaced together with the associated cost was as follows:

- The Residential Intensification Study (Metropolitan Knowledge International, 2005) was used as a basis for defining the location and extent of intensification
- The MOUSE model was updated to incorporate the proposed intensification and associated hydrologic impacts
- The level of replacement was based on upgrading sewer segments until an equivalent level of service (as defined by existing conditions) was established

Based on the above process it was determined that between 5 to 10 percent of the existing 4000 storm trunk sewers would have to be replaced. Using a unit replacement cost of $3,000/m the estimated cost to replace the sewers was between $50,000,000 and $100,000,000.

8.3.8 Evaluation of Stormwater Management Facility Retrofit Opportunities

8.3.8.1 General

The City recently completed a Surface Water Monitoring Assessment Study (XCG, 2004). As part of this study, the general location of all stormwater facilities was identified. A subsequent study (Aquafor,

2005) was then undertaken to identify the type (i.e. wet pond, dry pond), characteristics (i.e. size, stage / storage / discharge relationship) and general operation and maintenance requirements.

There are over 130 stormwater management facilities which are located within the City of Hamilton. Several of the facilities were constructed in the 80's and early 90's and were designed solely for the purpose of flood protection. Many of the newer facilities provide a number of functions including flood control, erosion control and water quality control.

Several municipalities in Ontario have recently undertaken Stormwater Management Facility Retrofit Studies. The primary objective of these studies is to assess the feasibility of retrofitting existing facilities in order to provide additional functions such as erosion and water quality control; thereby improving environmental conditions in downstream streams and rivers and lakes.

The objective of this study was to utilize information from studies that were recently completed and to develop evaluation criteria in order to prioritize the potential for retrofitting each of the existing facilities. Consistent with the overall approach of this study, the intent was to undertake the level of detail necessary to satisfy Phases 1 and 2 of the Class EA process.

8.3.8.2 Description of Evaluation Criteria

A two step approach was used to prioritize the potential for retrofitting each of the 130 existing facilities.

The first step involved defining the existing stormwater functions provided by each facility. The potential functions include flood control, erosion control and water quality control. If the existing facility provided all three functions then no further assessment of the facility was undertaken. This step also involved the determination of a series of criteria to define whether or not it was feasible to retrofit the existing stormwater facility. These criteria included criteria such as drainage area and access.

The second step involved the development of a series of evaluation criteria to further prioritize the remaining stormwater facilities. Physical / Natural Environment, Social / Cultural and Economic criteria were selected.

A score was then established for each facility for each of the eight criteria that were established. The score ranged between 1 and 4. If a score of 1 was assigned then the potential to retrofit the given facility, for the criteria being considered, was low. Alternatively, a score of 4 meant that the opportunity to retrofit, for the given criteria, was high.

The overall potential to retrofit a given facility was then based on the aggregate score. The intent was to provide a general prioritization (each facility was assigned an overall score between 1 (lowest potential to retrofit) and 4 (highest potential to retrofit)).

The first step in the evaluation process reduced the potential number of facilities to be retrofit from 130 to 29. Provided in Table 8.2 is a summary of the criteria that were used in the evaluation process. Tables 8.3, 8.4, and 8.5 provide further information with respect to description of the criteria and the method used for assigning a score to each criterion.

Table 8.2: Criteria Used in Evaluation Process for Retrofitting Existing Stormwater Facilities

Environmental Assessment Categories	Criteria
Physical / Natural Environment	• Potential Aquatic Habitat Benefit • Potential Water Quality Benefit • Potential Erosion Control Benefit
Social / Cultural	• Aesthetics / Recreation • Potential Increase in Property Value • Compatibility with Adjacent Land Uses
Economic	• Construction Costs • Operation and Maintenance

Table 8.3: Description of Physical / Natural Environment Criteria Used for Evaluation Process – Retrofitting Existing Stormwater Facilities

Criteria	Description of Criteria	Measures for Assigning Scores
• Potential Aquatic Habitat Benefit	• Potential to improve aquatic habitats or systems. Scoring based on sensitivity of stream (fish type) and stream order (size of stream)	• Scoring ranges from 4 for a sensitive stream to 1 for a non-sensitive high order stream
• Potential Water Quality Benefit	• Potential to improve water quality based on existing water quality conditions in stream and ability to provide required water quality control	• Scoring ranges from 4 if existing stream has poor water quality and there is a high potential to retrofit pond for water quality control to 1 is existing stream has good water quality and there is a low potential to retrofit pond for water quality control
• Potential Erosion Control Benefit	• Potential to reduce erosion in receiving stream based on existing condition of stream and ability to provide required erosion control volume	• Scoring ranges from 4 if existing stream is stable and there is a high potential to retrofit pond for erosion control to 1 if existing stream is unstable and there is a low potential to retrofit pond

Table 8.4: Description of Social / Cultural Criteria Used for Evaluation Process – Retrofitting Existing Stormwater Facilities

Criteria	**Description of Criteria**	**Measures for Assigning Scores**
• Aesthetics / Recreation	• Potential for retrofit facility to be an asset to the community by integrating facility into activities such as walking, jogging, hiking	• Scoring ranges from 4 if there is a good potential to integrate facility into existing activities to 1 if there is minimal potential
• Potential to Increase Property Value	• Studies have shown that homeowners value a variety of open space types and will pay a premium to back onto stormwater facilities	• Scoring ranges from 4 if proposed retrofit is in a residential area to 1 if it is in an industrial area
• Compatibility with Adjacent Land Uses	• There are potential impacts associated with construction of facilities, particularly with respect to land uses such as residential, old age homes and schools. Access / egress also needs to be considered	• Scoring ranges from 4 if there are no impacts associated with construction and access / egress for operation / maintenance to 1 if sensitive land uses are located adjacent to proposed facility and access / egress will be limited

Table 8.5: Description of Economic Criteria Used for Evaluation Process – Retrofitting Existing Stormwater Facilities

Criteria	**Description of Criteria**	**Measures for Assigning Scores**
• Construction Costs	• The relative cost of retrofitting the facility based on factors such as location, access / egress and area to dispose material	• Scoring ranges from 4 if the relative cost, based on the factors, is low to 1 if the relative cost is high
• Operation and Maintenance Costs	• The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	• Scoring ranges from 4 if the relative cost, based on the factors, is low to 1 if the relative cost is high

A summary of the evaluation process used for retrofitting the 29 existing stormwater facilities is provided in Table 8.6. As is shown in the Table, a total of 7 facilities received an overall score of 4. These facilities have, using the evaluation process as outlined above, the highest potential for being retrofit. A total of 17 facilities were assigned an overall score of 3; suggesting that these facilities also have a good potential for being retrofit.

Table 8.6: Retrofitting of Existing Stormwater Management Facilities

Facility Number[1]	Local Municipality	Major Intersection	Watershed	Relative Priority[2]
3	Ancaster	Galley Crt & Speers Rd	Big Creek	3
6	Ancaster	Amberly Blvd & Stadacona Ave	Big Creek	3
9	Ancaster	Garner Rd W & Braithwaite Ave	Big Creek	3
12	Ancaster	Morwick Dr & Shawer Rd	Big Creek	3
14	Ancaster	Miller Dr & Garner Rd E	Sulphur Creek	4
22	Ancaster	Harrington Place & Lover's Lane	Sulphur Creek	3
25	Dundas	Wainwright Blvd & Governor's Rd	Spencer Creek	3
30	Flamborough	Blackberry Pl. & Acredale Dr.	Bronte Creek	3
35	Flamborough	Hwy 6 & Hwy 5	Grindstone Creek	4
36	Flamborough	Noble Kirk Dr. & HWY 6	Bronte Creek	3
37	Flamborough	Ofield Rd & Hwy 5	Spencer Creek	2
48	Flamborough	Centre Rd and Con. 11 E	Bronte Creek	3
49	Flamborough	Hwy 8 & Rosebough St.	Bronte Creek	2
52	Glanbrook	Twenty Rd E & Hwy 6	Twenty Mile Creek	4
53	Glanbrook	Hwy 6 & Dickenson Rd W	Twenty Mile Creek	3
54	Glanbrook	Marion St & Spitfire Dr	Twenty Mile Creek	4
55	Glanbrook	Twenty Rd & Garth St	Twenty Mile Creek	3
60	Hamilton	Scenic Dr & Sanatorium Dr	Chedoke Creek	3
65	Stoney Creek	Hwy 20 & Highland Rd	Stoney Creek	3
67	Stoney Creek	Rymal Rd E & Whitedeer Rd	Twenty Mile Creek	4
68	Stoney Creek	Fruitland Rd & Hwy 8	Community of Stoney Creek Watercourses	4
69	Stoney Creek	Winterberry Dr & Paramount Dr	Red Hill Creek	1
70	Ancaster	Hwy 403 & Golf Links Rd	Sulphur Creek	3
71	Ancaster	Golf Links Rd & Meadowlands Blvd	Sulphur Creek	3
72	Ancaster	Golf Links Rd & Meadowlands Blvd	Sulphur Creek	3
75	Glanbrook	Regional Rd 56 & Binbrook Rd	Welland River	4
82	Stoney Creek	Arvin Av. / Glover Rd	Community of Stoney Creek Watercourses	2
83	Hamilton	Garth St. / Lincoln M Alexander Pkwy	Red Hill Creek	1
85	Hamilton	Upper Wentworth St. / L. M A. Pkwy	Red Hill Creek	1

Note:
[2] **4** = Highest Priority, **1** = Lowest Priority

The location of all 130 existing stormwater management facilities are shown on Figure 8.16. The facilities that were eliminated from further evaluation as a result of the first step level of screening are shown as are the 29 facilities that were subject to a more detailed evaluation.

8.3.9 Evaluation of Stream Restoration Opportunities

8.3.9.1 General

The City of Hamilton recently completed a Development Charge Background Study (C.N. Watson, 2006). As part of this study the type of stormwater servicing and associated costs to accommodate proposed development were identified. The components of the stormwater servicing works that were identified (Appendix F, Stormwater) include:

- Open Watercourses: Erosion Control and Channel System Improvements (identified projects);
- Open Watercourses: Erosion Control – Estimated Future Works;
- Stormwater Management (Quality and / or Quantity Facilities);
- Oversizing of Trunk Storm Sewers; and
- Culverts and Bridges: Estimated Future Works.

The objective of this strategy is to utilize information with respect to erosion control, identified projects and estimated future works and to develop evaluation criteria in order to prioritize the proposed works. Consistent with the overall approach of this study, the intent was to undertake the level of detail necessary to satisfy Phases 1 and 2 of the Class EA process.

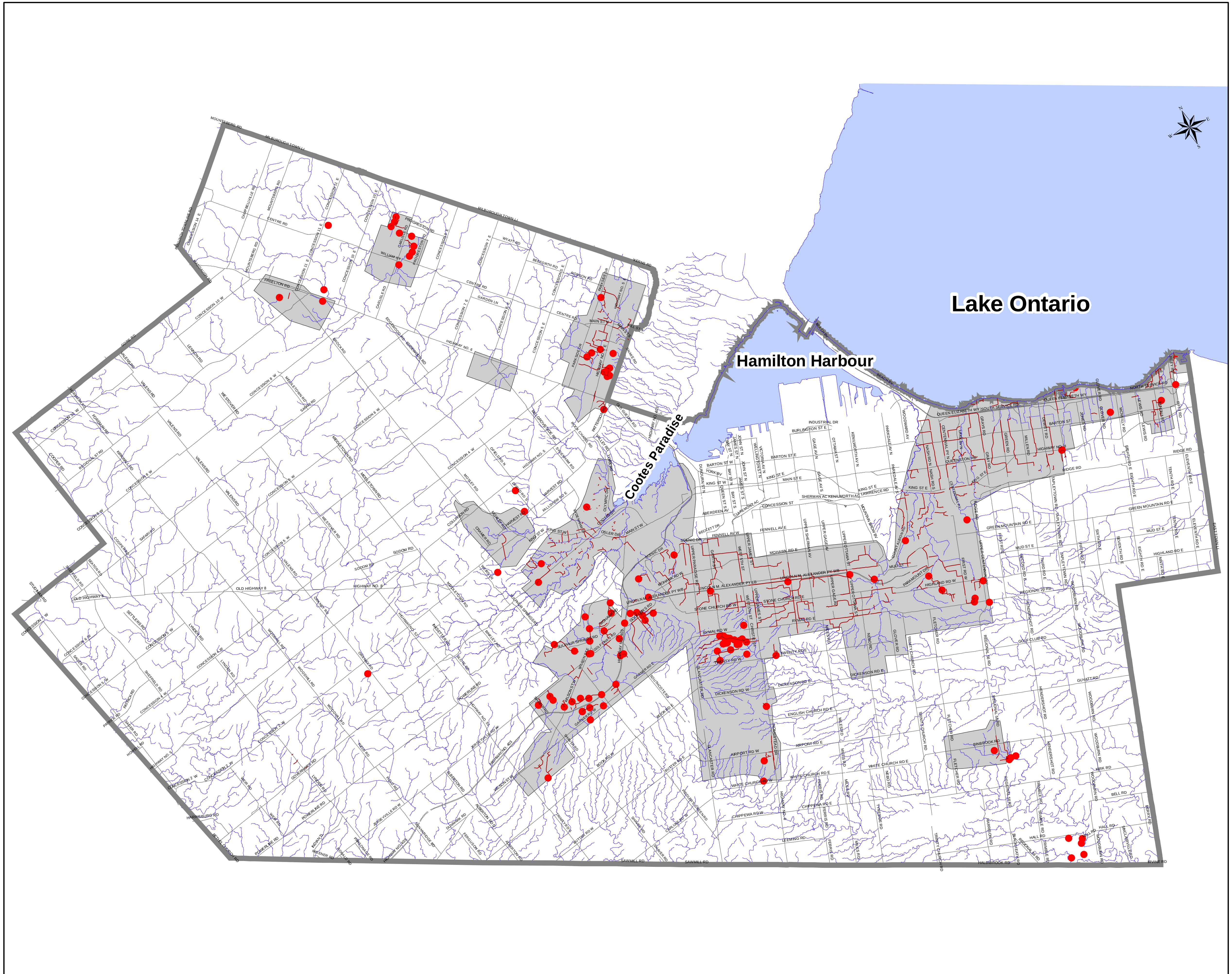
The proposed approach for prioritizing stream restoration opportunities is described in the subsequent section. In reviewing the approach it should be noted that only watercourses downstream of proposed development were included in the analysis. Section 11.3 discusses a potential approach for considering stream restoration opportunities on a City wide basis.

8.3.9.2 Description of Evaluation Criteria

The evaluation criteria that were used to prioritize the stream restoration opportunities are provided below. The approach used is similar to the approach used for prioritizing the existing stormwater management facilities. A series of Physical / Natural Environment, Social / Cultural and Economic criteria were selected. A score was then assigned to each potential erosion control project (a total of 53 projects were considered). The score ranged between 1 and 4. If a score of 1 was assigned then the potential benefit associated with implementing the proposed project was considered to be low. Alternatively, a score of 4 meant that the potential benefit was considered to be high.

The overall potential benefit associated with the implementation of a particular stream restoration project was then based on an aggregate score. The intent was to provide a general prioritization as to the value of implementing a specific stream restoration project (each project was assigned an overall score of between 1 (lowest benefit) to 4 (highest benefit).

Provided in Table 8.7 is a summary of the criteria that were used in the evaluation process. Tables 8.8, 8.9 and 8.10 provide further information with respect to the description of the criteria and the method used for assigning a score to each criterion.



KEY MAP

LEGEND:

- City of Hamilton Boundary
- Approximate Study Area
- Storm Sewer
- Stormwater Management Pond

NOTES:

0 2.5 5 10
Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Storm Sewer and
Stormwater Management Pond Locations

FIGURE: 8.16

DATE: 18 April 2007

Table 8.7: Criteria Used in Evaluation Process for Defining Benefit of Stream Restoration Projects

Environmental Assessment Categories	Criteria
Physical/Natural Environment	• Potential Aquatic Habitat Benefit • Erosion Sensitivity • Potential Terrestrial Habitat Benefit
Social/Cultural	• Public Health and Safety • Potential for Disruption to Community • Potential Benefit to Community • Land Ownership
Economic	• Construction Costs • Operation and Maintenance

Table 8.8: Description of Physical/Natural Criteria Used for Evaluation Process – Stream Restoration Projects

Criteria	Description of Criteria	Measures for Assigning Scores
• Potential Aquatic Habitat Benefit	• Potential to improve aquatic habitats or systems. Scoring based on sensitivity of stream (fish type) and stream order (size of stream)	• Scoring ranges from 4 for a sensitive stream to 1 for a non-sensitive high order stream
• Erosion Sensitivity	• The sensitivity of a stream to erosion is based, in part, on the soils type and age of development within the catchment area	• Scoring ranges from 4 if the stream has sensitive soils and development within the catchment area is new to 1 if the soils are not sensitive and development is old
• Potential Terrestrial Habitat Benefit	• Potential to improve terrestrial habitats or systems within the valleylands	• Scoring ranges from 4 if there is a significant presence of streamside vegetation to 1 if there is an absence of vegetation

Table 8.9: Description of Social/Cultural Criteria Used for Evaluation Process – Stream Restoration Projects

Criteria	Description of Criteria	Measures for Assigning Scores
• Public Health and Safety	• Public health and safety includes risk to private property, parking lots, roads, footbridges and public trails	• Scoring ranges from 4 if there is significant public health or safety risks that presently exist, or could exist, to 1 if there is minimal risk
• Potential for Disruption to Community	• The potential for disruption to the community will be based on the proximity of the proposed works to private property, schools, parks, etc.	• Scoring ranging from 4 if there is nothing close to the proposed works to 1 if the proposed works are close to private property, schools, parks, etc.
• Potential Benefit to Community	• There is potential benefit to the community as a result of restoring degraded streams	• Scoring ranges from 4 if the local community (i.e. schools, parks, residents) would benefit as a result of the proposed works being completed to 1 if there are no community benefits
• Land Ownership	• Land ownership, private vs. public, will have an impact on the ability to implement the proposed measures	• Scoring ranges from 4 is the proposed works are located within public lands within the existing urban boundary to 1 if the works are located on private lands outside the existing urban boundary

Table 8.10: Description of Economic Criteria Used for Evaluation Process – Stream Restoration Projects

Criteria	Description of Criteria	Measures for Assigning Scores
• Construction Costs	• The cost of constructing the proposed stream restoration works, as provided in the DC study	• Scoring ranged from 4 for the least costly works to 1 for the most costly works
• Operation and Maintenance	• Operation and Maintenance costs based on a percentage of the capital cost	• Scoring ranged from 4 for the least costly works to 1 for the most costly works

A summary of the evaluation process used for restoring the 53 stream reaches is provided in Table 8.11. As shown in the table, a total of 8 stream reaches received an overall score of 4. These stream reaches have, using the evaluation process as outlined above, the highest potential for being restored. A total of 15 reaches were assigned an overall score of 3; suggesting that these reaches also have a good potential for being restored.

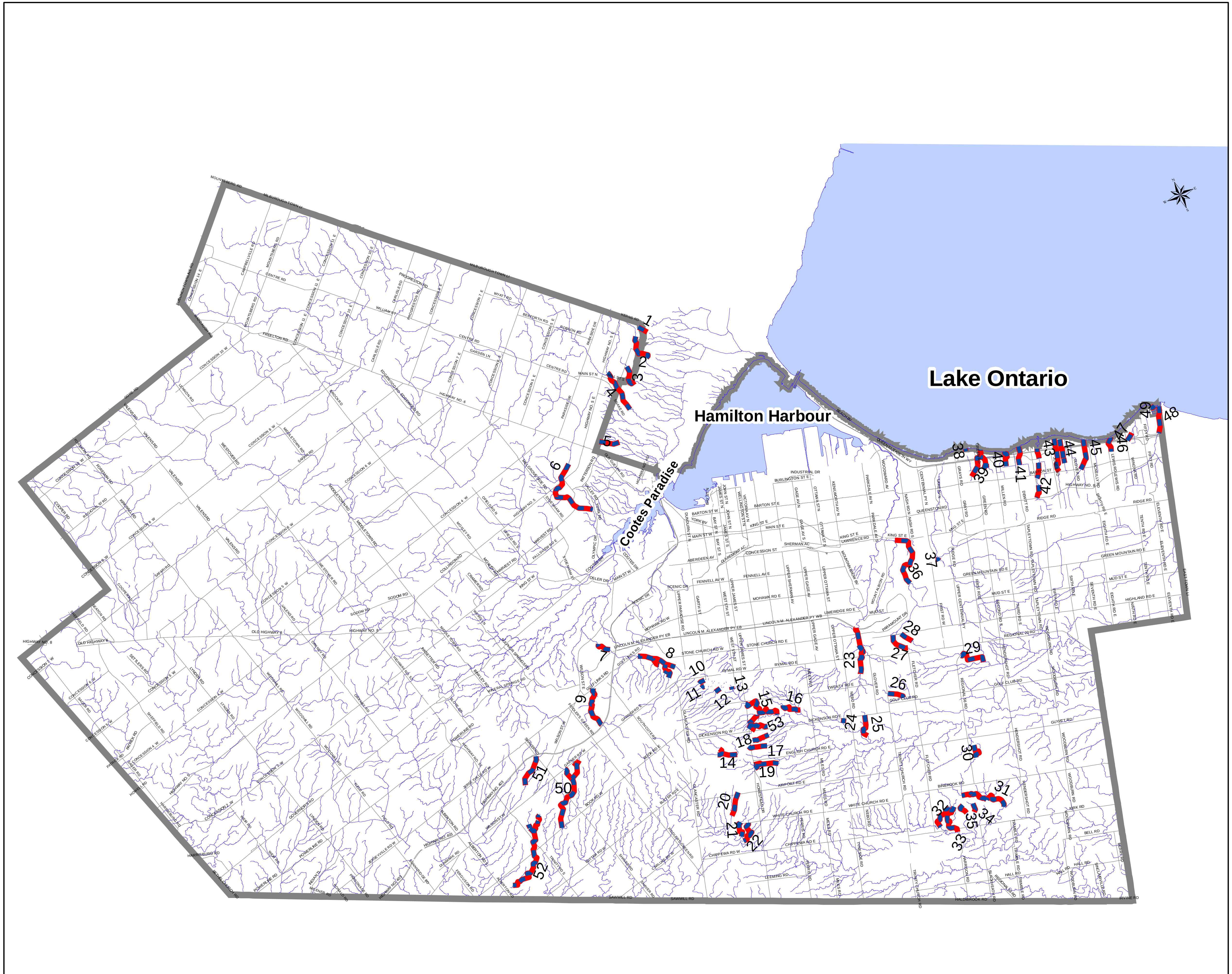
The location of all 53 restoration projects is shown on Figure 8.17.

8.4 Selection of Preferred Stormwater Management Strategy

8.4.1 General

The selection of the Preferred Stormwater Management Strategy is provided in the next section.

The selection was based on input from the consulting team, City of Hamilton staff, staff from the four Conservation Authorities, Agencies, stakeholders and the public. The Preferred Strategy is consistent with the Study Goals and Objectives together with the goals, objectives and criteria as outlined in other documents (ie: Hamilton, Niagara River and Welland River Remedial Action Plans). It is intended that the Preferred Stormwater Management Strategy form the basis for implementing the proposed measures, undertaking future studies (e.g. Subwatershed Plans) and developing policies and standards in order to ensure that the study goal and objectives are achieved over the planning horizon (30 years) for this study.



KEY MAP

LEGEND:

City of Hamilton Boundary

Erosion Sites

NOTES:

0 5 10

Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Location of Erosion Stream Reaches

FIGURE: 8.17

DATE: 18 April 2007

Table 8.11: Stream Restoration Work

Reach Number	CRITERIA									Relative Priority
	Physical/Natural/Environmental			*Social/Cultural*				*Financial*		
	Potential Aquatic Habitat Benefit	Erosion Sensitivity	Potential Terrestrial Habitat Benefit	Public Health and Safety	Potential Disruption to Community	Potential Benefit to Community	Land Ownership	Construction Costs	Operation and Maintenance Costs	
1	4	3	4	1	2	4	2	4	4	*4*
2	4	3	4	2	4	1	2	2	2	*4*
3	4	3	4	2	2	3	2	3	3	*4*
4	4	4	4	2	4	3	4	1	1	*4*
5	4	3	4	2	2	1	2	3	3	*4*
6	3	3	2	2	2	3	4	1	1	*3*
7	2	3	4	2	2	2	4	2	2	*3*
8	2	2	4	1	1	2	4	1	1	*2*
9	2	2	4	1	1	4	4	1	1	*3*
10	2	2	1	1	1	1	1	4	4	*2*
11	2	2	1	1	1	1	1	4	4	*2*
12	2	2	1	1	1	1	4	4	4	*3*
13	2	1	1	1	1	1	4	4	4	*2*
14	2	2	1	1	1	1	4	2	2	*2*
15	2	1	3	1	3	1	2	1	1	*1*
16	2	2	1	1	4	1	2	2	2	*2*
17	2	2	1	2	2	1	4	3	3	*3*
18	2	2	1	2	2	1	4	3	3	*3*
19	2	1	1	1	1	3	2	2	2	*1*
20	2	2	1	1	4	1	1	3	3	*2*
21	2	2	1	1	4	1	1	3	3	*2*
22	2	2	1	1	2	1	2	2	2	*1*
23	1	2	1	2	1	2	4	1	1	*1*
24	2	1	1	2	1	1	2	4	4	*2*
25	2	2	1	2	4	1	2	3	3	*3*
26	2	2	1	1	2	1	1	3	3	*2*
27	1	2	4	2	1	1	1	3	3	*2*
28	1	3	4	2	1	1	1	4	4	*3*
29	2	2	1	2	4	1	1	2	2	*2*
30	2	1	3	1	2	1	2	3	3	*2*
31	2	2	2	1	1	1	1	1	1	*1*
32	2	2	3	1	4	1	2	2	2	*2*
33	2	2	1	2	4	1	2	2	2	*2*
34	2	2	1	1	4	1	2	4	4	*3*
35	2	2	1	1	4	1	2	4	4	*3*
36	1	3	4	2	1	4	4	1	1	*3*
37	1	2	4	2	4	1	2	4	4	*4*

38	**1**	**4**	**4**	**1**	**1**	**1**	**4**	**4**	**4**	***4***
39	**1**	**4**	**2**	**2**	**3**	**1**	**1**	**1**	**1**	***2***
40	**1**	**4**	**1**	**2**	**3**	**1**	**4**	**3**	**3**	***3***
41	**1**	**4**	**1**	**2**	**1**	**1**	**4**	**3**	**3**	***3***
42	**1**	**4**	**1**	**2**	**1**	**4**	**1**	**1**	**1**	***2***
43	**1**	**4**	**1**	**2**	**1**	**1**	**1**	**1**	**1**	***1***
44	**1**	**4**	**1**	**2**	**1**	**1**	**1**	**3**	**3**	***2***
45	**1**	**4**	**1**	**2**	**1**	**1**	**1**	**2**	**2**	***1***
46	**1**	**4**	**1**	**2**	**4**	**1**	**4**	**4**	**4**	***4***
47	**1**	**4**	**1**	**2**	**1**	**1**	**1**	**4**	**4**	***2***
48	**1**	**4**	**1**	**1**	**1**	**1**	**4**	**4**	**4**	***3***
49	**1**	**4**	**1**	**1**	**1**	**1**	**4**	**2**	**2**	***2***
50	**2**	**2**	**2**	**2**	**4**	**1**	**1**	**1**	**1**	***2***
51	**2**	**2**	**4**	**2**	**4**	**2**	**2**	**2**	**2**	***3***
52	**2**	**2**	**1**	**2**	**4**	**1**	**2**	**1**	**1**	***2***
53	**2**	**1**	**1**	**1**	**3**	**1**	**2**	**2**	**2**	***1***

4 = Highest Priority
1 = Lowest Priority

8.4.2 Selection of Preferred Stormwater Management Strategy

The five Alternative Management Strategies were evaluated using a modeling approach and by comparing the existing conditions and findings from each of the Strategies to the study objectives like mitigating erosion and flooding hazards, improvements in water quality and aquatic/terrestrial life.

Components of the Strategy that relate directly to the Municipal Class Environmental Assessment process were also evaluated with respect to the natural environment, social environment, and financial implications as follows:

<table>
<tr><th colspan="2">Criteria</th><th>Impact Indicator</th></tr>
<tr><td rowspan="4">Natural Environment</td><td>Potential Aquatic Habitat Benefit</td><td>• Potential to improve aquatic habitats or systems
• Scoring based on fish type and size of stream</td></tr>
<tr><td>Potential Water Quality Benefit</td><td>• Scoring based on existing conditions in stream and ability to provide improvement</td></tr>
<tr><td>Potential Erosion Control Benefit</td><td>• Scoring based on existing condition of stream and ability to reduce erosion potential</td></tr>
<tr><td>Potential Terrestrial Habitat Benefit</td><td>• Potential to improve terrestrial habitats or systems within valleylands
• Scoring based on significance of existing vegetation features</td></tr>
<tr><td rowspan="3">Social Environment</td><td>Aesthetics/Recreation</td><td>• Potential for proposed works to be an asset to community
• Scoring based on ability of proposed measure to be integrated into community</td></tr>
<tr><td>Compatibility with Adjacent Land Uses</td><td>• Potential impacts associated with construction or maintenance of proposed works</td></tr>
<tr><td>Public Health and Society</td><td>• Scoring based on potential of proposed works to reduce/increase public health and safety</td></tr>
<tr><td rowspan="2">Financial</td><td>Construction costs</td><td>• The cost of constructing the proposed works</td></tr>
<tr><td>Operation and Maintenance Costs</td><td>• Operation and Maintenance costs associated with the proposed works</td></tr>
</table>

The selection of a Preferred Strategy for each of the 15 watersheds was based on the process described above. The intent of the evaluation was to provide a framework for future development (including intensification) and implementation of a new approach for the municipality and agencies to undertake works in a collaborative manner in existing urban and rural areas.

The Preferred Strategy also provides direction for issues relating to the impact of urban and rural land uses on the Hamilton and Niagara River Remedial Action Plans.

Different Preferred Strategies have been selected for each watershed based on existing and proposed land uses, existing environmental conditions and issues within the watershed, Remedial Action Plan requirements, and the ability of each Alternative Strategy to meet the study objectives. The Master Plan report provides, for each watershed, details with respect to a description of existing environmental conditions, potential impacts associated with land use, and the proposed measures to be undertaken in order to protect, enhance, and restore the natural resources within the watershed.

Part of the Preferred Strategies also consist of recommendations with respect to the retrofitting (to provide improved water quality and/or erosion control) of 29 existing stormwater management facilities together with the prioritization of 53 stream restoration projects. Retrofitting of existing stormwater ponds and stream restoration projects are carried out as Schedule B projects under the Municipal Class Environmental Assessment process.

One of the objectives of this study was to identify the present capacity (or level of service) of the storm trunk sewers within areas serviced by separated storm and sanitary sewer systems. In light of the basement and surface flooding that has occurred in recent years and as a result of the proposed level of intensification (26,500 units), a preliminary assessment of the alternatives for servicing lands undergoing intensification and the impact on the present level of service was undertaken. The three general alternatives that were considered include:

- i) provision of on-site controls to limit flows to allowable levels
- ii) undertaking source control (e.g. downspout disconnection) and conveyance control (e.g. perforated pipe systems) measures on a City wide basis to offset the impacts of proposed intensification
- iii) upgrading the existing storm sewer system to accommodate the increase in flows associated with intensification

The preferred alternative to offset the impact of intensification will depend upon a number of factors which are discussed in Section 10.6 and Section 11.3.7.

9.0 PUBLIC CONSULTATION

9.1 Public Information Centres No. 3

The third set of Public Information Centres were held at the Winterberry Heights Church (September 25, 2006) and the Chedoke Presbyterian Church (September 26, 2006). Each of the Information Centres included:

- A series of posters which defined:
    - The Environmental Assessment process
    - The GRIDS process
    - The Recommended Growth Option
    - Problem Statement and Goals
    - Existing Conditions
    - Alternative Management Strategies
    - Preliminary Preferred Strategy
    - Proposed Stormwater Facility Retrofit Locations
    - Proposed Stream Restoration projects
- A comment sheet was distributed to attendees, and involved the following questions:
    - A number of different types of Best Management Practices (BMP’s) have been presented (i.e.: Source Controls, Conveyance Controls, End-of-Pipe Controls, Restoration Measures and Rural Structural and Non-Structural Measures). Which types of BMP’s do you think are important components of any Management Strategy that should be considered?
    - A number of Best Management Practices that have been shown would be implemented by homeowners, or owners of commercial or industrial properties. Which of the following factors may reduce your willingness to implement the Best Management Practices as illustrated?
    - Do you agree with the five Management Strategies that have been presented? Are there other Strategies that could be considered?
    - A Preliminary Preferred Strategy has been presented for each of the watersheds within the City of Hamilton. Do you agree with each of the strategies that have been presented? If not, which strategies do you disagree with, and why?

A copy of the poster boards, comment sheet and summary responses is provided in the Public Consultation Appendix.

This information centre was held in conjunction with the Transportation Master Plan. Comments from attendees were limited in comparison with the Transportation Plan.

10.0 DESCRIPTION OF THE PREFERRED STORMWATER MANAGEMENT STRATEGY

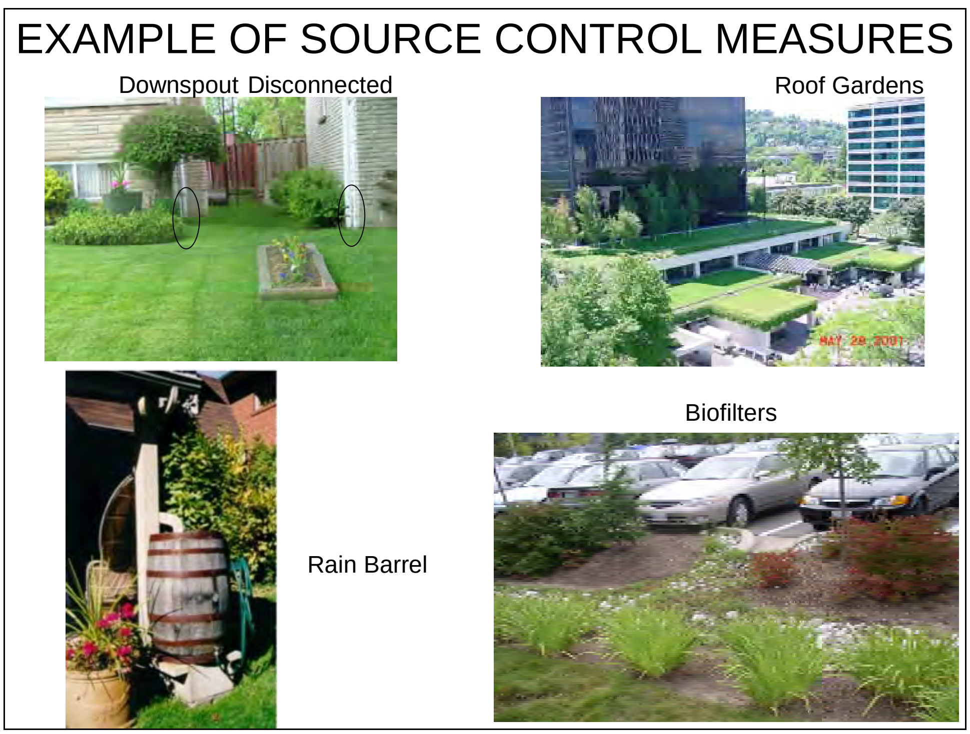
10.1 General

Previous chapters have defined existing environmental conditions, opportunities and constraints, provided a set of study principals, goals and objectives and described the process for evaluating individual Best Management Practices and selecting the Preferred Stormwater Management Strategy for each Subwatershed. As has been shown, a variety of measures will need to be undertaken in proposed development areas. Restorative or retrofit works will also be required in existing urban and rural areas.

This chapter will provide an overview as to the types of measures that will need to be undertaken in the proposed development areas as well as existing urban and rural areas. Chapter 11 will discuss implementation of the Preferred Strategy. Implementation involves many items including setting up groups to administer the proposed works, undertaking further studies, developing the appropriate policies and standards and acquiring the necessary funding to implement the proposed strategy.

10.2 Source Control Measures

Source control measures are physical measures that are located at the beginning of a drainage system, generally on private property. Source controls can be installed within a variety of land uses including residential, commercial, industrial and institutional properties. Source control measures can be retrofit into existing areas and implemented in existing areas.



Source control measures are also being incorporated into new developments in various municipalities within North America. Several municipalities are incorporating source control measures into a new urban design, referred to as Low Impact Development. Examples of innovative source control measures that have been implemented within North America in recent years are illustrated above.

The general types of source control measures that could be considered for urbanizing areas as well as existing urban areas are shown in Table 10.1. Also shown in Table 10.1 are representative adoption rates which have been used in the modeling of the Alternative Management Strategies. The adoption rates are applicable to the existing urban areas and have been selected based on the physical conditions within the City of Hamilton together with the results of several recent studies which assessed the willingness of homeowners to implement a range of different measures (Lura 1999, Aquafor 2004, Freeman and Associates 2006).

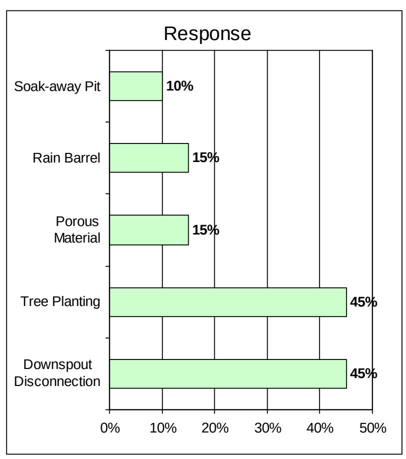
There are a number of physical constraints (i.e. topography, soil type) which limit the implementation of some source control measures. General guidelines for implementation are provided in the MOE Stormwater Management Planning and Design Manual (MOE, 1999) as well as the City of Hamilton Criteria and Guidelines for Stormwater Infrastructure Design (Phillips 2004).

Implementation of a variety of source control measures has become more common in the last decade. One of the key factors impacting the success of source control programs is the willingness of landowners to implement them. In this regard, many municipalities have initiated pilot projects to define variables such as the landowners awareness of the impacts from stormwater, their willingness to implement, the importance of public funding, and the adoption rates for each of the proposed measures (see accompanying box which summarizes the willingness of homeowners in the Bloor West Area in the City of Toronto to adopt various BMPs, Lura Consulting 1999). Other municipalities have developed programs involving how-to manuals, in-house assistance and financial programs in order to kick start the programs.

BLOOR WEST VILLAGE - SOCIAL MARKETING STUDY

Topics:

- Awareness of impacts from stormwater
- Willingness to implement
- Importance of public sector funding



Adoption Rate of Various Techniques to Reduce Stormwater Pollutants

Approximate costs to implement source control measures on a City-wide basis were established. The costs were developed for the area serviced by a separate storm sewer system. The estimates are based on the measures and uptake rates (the uptake rate is defined as the percentage of homes or buildings that, in the long term, would be expected to implement the proposed measure, for the given land use) as shown in Table 10.1 and unit costs developed from studies undertaken for other municipalities within Ontario. Details provided in Table 10.2 summarize the component costs based on existing land uses. The total cost to implement the source control program is $35,000,000.

Table 10.1: Long Term Representative Uptake Levels for Various Source Control Options

SOURCE CONTROL OPTION	REPRESENTATIVE UPTAKE RATE
Residential (low/medium/high density)	
Roof Disconnection	40%
Rain Barrel (one/house)	15%
Storm Garden – Stormwater	5%
Soak-away/Infiltration	5%
Lot Regrading (number of lots that would apply)	5%
More Trees	5%
Previous Driveway (number of lots that would apply)	15%
Residential (High Rise)	
Parking Lot to Grass (% of parking area)	25%
More Trees	60%
Regrade Parking Lot to Grass (including biofilter) (number of parking lots that would apply)	5%
Roof Drainage to Wetland (% of the roofs that pass screening criteria)	5%
Previous Pavement (% of walkway area)	5%
Commercial/Institutional	
Roof Top Restrictors (% of roofs that would apply)	25%
Roof Garden	5%
Parking Lot to Grass	20%
Pervious Pavement	5%
Regrade Parking Lot to Underground Storage, Biofilter	5%
Industrial	
Roof Top Restrictors	25%
Roof Garden	5%
Parking Lot CB Restrictors	10%
Route Parking Lot to Grass, including Biofilter	10%
Pervious Pavement	5%
More Trees	40%
Open Space – Urban Park (uptake as % of area)	
Route Parking Lot to Grass	25%
More Trees	5%
Ditch/Swale Drainage with Restrictors	70%
Open Space – Valley Land (uptake as % of area)	
More Trees/Bushes	25%
Ditch/Swale Drainage	95%

Table 10.2: Component Costs for Source Control Programs

Source Control Option	Action	Application	Unit Cost (Installation)		Soil Category	Total area	Percent Impervious	Uptake rate	Total cost	Comments
			Cost	Units						
Residential (Low,Medium and High Density)										
1. Source Controls - Limited Effort	Roof disconnection		12,867	$/ impervious ha.	all	3100	55%	40%	$8,780,000	23houses/ha, average %imp = 0.55, $500 per house includes $100 for minor lot grading,
	Rain barrels		5,600	$/ impervious ha.		5865	55%	15%	$2,710,000	23houses/ha, average %imp = 0.55, 2 barrels per house, $60 per barrel, $75 installation per house. Cost for rain barrel obtained from City of Toronto
	Additional trees and bushes		2,750	$/ pervious ha, i.e. different amounts for 3 different densities		5865	55%	5%	$360,000	Assumes 25% existing coverage increased by 25% using 50 mm caliper trees spaced for complete cover at maturity plus shrubs to cover area between trees in interim.
2. Source Controls – Moderate Effort (Includes all limited effort actions)	Rear Yard Storm Pond		12,000	$/impervious ha.		5865	55%	5%	$1,940,000	For practicality, assume typical pond is 4 m long x 2 m wide and 1 m deep for a storage of 8 m^3. $1,500 per pond. Assuming 27 houses per ha as for soakaway pit, total cost per ha impervious is approx. Assume 200 extra for restoration. $40,500.(round off to $40,000)
	Soakaway Pit		30,000	$/impervious ha.	ab/bc, 20% roof area	1173	55%	5%	$970,000	Max storage volume for soakaway pit is 20mm over roof area (MOE Design Manual); typical roof area = 75 m2 therefore expected volume of runoff per house = 1.5 m3 (say 2m3); labour & material cost is $1,000 per pit; assuming roof area is 20% of impervious area for each ha, number of houses per ha is about 27; total cast is $27,000 (round off to $30,000).
3. Source Controls – Maximum Effort(Includes all limited & moderate effort actions)	Major lot regrading		20,909	$/ha	assume 25% of lots	1466	55%	5%	$1,530,000	$2000 per house, 23 houses per ha, 55% impervious, 25% of houses regraded
	Pervious driveway		16,200	$/impervious ha.	ab/bc, 20% driveway area	1173	55%	15%	$1,570,000	23houses/ha, average %imp = 0.55, $3360 per house (avg driveway 28m2 cost $120/m2), clean with power washer once a year. Paving stone cost obtained from RS Means Building Construction Cost Data
Residential High Rise										
1. Source Controls – Limited Effort	Route parking lot runoff to grassed areas if possible		640	$/impervious ha.		577	80%	25%	$10,000	10% of parking lot can be regrading to grass (minimal effort), 13% of total area is parking lot, 10% of regraded parking lot needs yearly repairs
2. Source Controls – Moderate Effort (Includes all limited effort actions)	All limited effort actions									
	More trees and bushes (75 % of area for high rise)	High Rise	1,700	$/ha		577	80%	60%	$590,000	

	Regrade parking lot to runoff to grassed areas		6,400	$/impervious ha	25% lot area	144	80%	5%	$10,000	higher level of regrading, 13% of total area is parking lot, 10% of parking needs yearly repairs, excavation/regrading = $3.76/m3 (assume150mm depth), Repaving $1.40/m2, 0.80 impervious
3. Source Controls – Maximum Effort (Includes all limited & moderate effort actions)	All moderate effort actions									
	Route roof drainage to pocket wetland/cistern		125,000	$/ha (50/50 - wet./cis.)		577	80%	5%	$1,260,000	35% of total area is roof, 20mm rainfall, for a total of 700 m3 of storage. Assume 50% split to wetland and cistern. 350m3 to Cistern @ $500/m3; 350m3 to wetland, excavation/planting $25 per m3, 0.20m deep wetland.
	Pervious pavements for driveway/parking areas		56,400	$/impervious ha	-	577	80%	5%	$250,000	19% of total area is driveway/parking areas, clean once a year power washer, paving stone installation, %impervious = 0.8, pavement = $120/m2
Commercial and Institutional										
1. Source Controls – Limited Effort	Rooftop Restrictors	Strip Mall	250	$/ ha	25% roof area	395	90%	25%	$10,000	Apply to 25% of roof area, assume 1 drain per 250 sq.m. @ $125 per drain incl. labour to fit control weir to existing drain
	Route parking lot runoff to grassed areas if possible		640	$/impervious ha		1580	85%	20%	$20,000	10% of parking lot can be regrading to grass (minimal effort), 13% of total area is parking lot, 10% of regraded parking lot needs yearly repairs
2. Source Controls – Moderate Effort (Includes all limited effort actions)	Rooftop Gardens	Strip Mall	52,000	$/ ha	25% roof area	395	90%	5%	$260,000	Apply to 25% of roof area. Use $130/ sq.m. based on Soprema Supratature system incl. new waterproof membrane
	More trees and bushes (n/a to institutional)	Institutional	5,560	$/ ha		1580	90%	60%	$5,270,000	Same rationale as for residential applied to 75% of pervious area for Hi-rise
3. Source Controls – Maximum Effort (Includes all limited & moderate effort actions)	Pervious pavement in parking lots		23,000	$/impervious ha		1580	90%	5%	$1,640,000	Porous pavement installed, requires vacumn sweeper and power washing twice a year, based on replacement of existing pavement, 90%impervious, from Metro Washington BMP Manual pg 7.16 cost $75054/acre, assume 1.55 increase since 1987, 1.5 for the US dollar = $70,616 per ha
	Use of filters/bio-retention		33,300	$/ ha		427	90%	5%	$710,000	250 mm storage on 5% of parking area (27% of total area) @ $390/cu.m. based on US study.
Industrial (Prestige and Heavy Industry [Big Box])										
1. Source Controls – Limited Effort	Rooftop Restrictors	Prestige	375	$/ ha	25% roof area	172	85%	25%	$10,000	
		Big Box	4,444	$/ ha		271	85%	25%	$80,000	Same rationale as for Commercial
	Route parking lot runoff to grassed areas if possible		640	$/impervious ha		443	85%	10%	$10,000	10% of parking lot can be regrading to grass (minimal effort), 13% of total area is parking lot, 10% of regraded parking lot needs yearly repairs
	Additional trees and bushes on 25% of pervious area	Prestige	2,300	$/ ha		172	85%	40%	$160,000	
		Big Box	800	$/ ha		271	85%	40%	$90,000	Same rationale as for Commercial

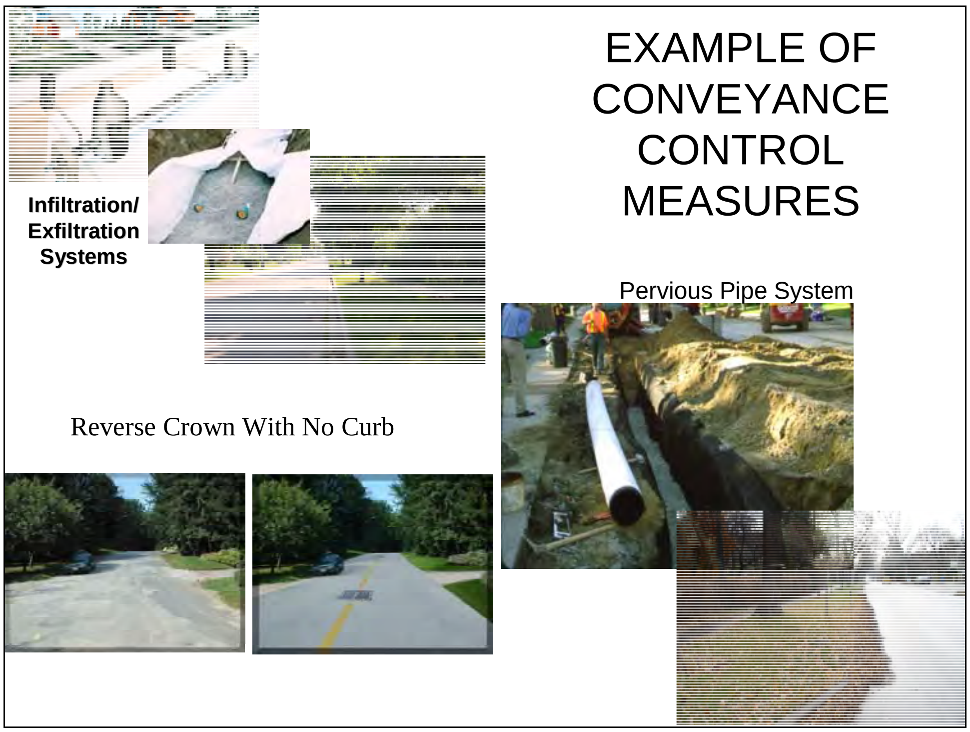
2. Source Controls – Moderate Effort (Includes all limited effort actions)	Regrade parking lots to permit catchbasin restrictors		6,400	$/impervious ha		443	85%	10%	$30,000	higher level of regrading, 13% of total area is parking lot, 10% of parking needs yearly repairs
	Rooftop Gardens	Prestige	97,500	$/ ha	25% roof area	172	85%	5%	$210,000	
		Big Box	146,500	$/ ha		271	85%	5%	$500,000	Same rationale as for Commercial
3. Source Controls – Maximum Effort (Includes all limited & moderate effort actions)	Pervious pavement in parking lots		23,000	$/impervious ha	-	443	85%	5%	$430,000	Porous pavement installed, requires vacumn sweeper and power washing twice a year, based on replacement of existing pavement, 85% impervious
Open Space										
1. Source Controls – Limited Effort	Route parking lot runoff to grassed areas if possible		640	$/impervious ha		10730	10%	25%	$20,000	10% of parking lot can be regrading to grass (minimal effort), 13% of total area is parking lot, 10% of regraded parking lot needs yearly repairs
	Additional trees and bushes on 25% of pervious area	Valley	2,750	$/ha		2682.5	10%	25%	$1,840,000	
		Parks	2,750	$/ha		8047.5	10%	5%	$1,110,000	Same rationale as residential applied to 25% of pervious area
2. Source Controls – Moderate Effort (Includes all limited effort actions)	Additional trees and bushes on 75% of pervious area	Valley	2,750	$/ha		2682.5	10%	25%	$1,840,000	
		Parks	2,750	$/ha		8047.5	10%	5%	$1,110,000	Same rationale as residential applied to 75% of pervious area
Total Cost									**$35,330,000**	

10.3 Conveyance Control Measures

Conveyance control measures are physical measures that are located within the road right-of-way where flows are concentrated and are being conveyed along the right-of-way. Conveyance measures include swales, ditches, culverts, catch basins, manholes and storm sewers.

The primary objective of this strategy is to incorporate infiltration measures into the design of the conveyance system. For existing or urbanizing areas, this may include the incorporation of a perforated pipe system into the design of the storm sewer system or enhanced use of grass swales or vegetated buffer strips in order to maximize infiltration opportunities.

A variety of infiltration facilities have been constructed within the road right of way since the early 1990's. Municipalities that have incorporated them into the road design process include Toronto and Ottawa. Several of the facilities have also been monitored for performance by the Stormwater Assessment Monitoring and Performance Program (SWAMP, 2002).



Incorporation of conveyance control measures for urbanizing areas should be considered as part of the planning and design process.

For existing urban and rural areas, the opportunity to incorporate conveyance control measures will likely come as a result of redevelopment pressures (which require replacement of the infrastructure) or replacement due to deteriorating condition of the infrastructure. In the latter case, replacement of the drainage infrastructure may well occur as part of the overall reconstruction of the roadway.

A number of municipalities (including Ottawa, Niagara-on-the-Lake, Toronto) have undertaken studies and pilot projects (which included monitoring of effectiveness) in order to determine the feasibility and effectiveness of alternative conveyance systems. The results of several pilot projects have been published as part of the Stormwater Assessment Monitoring and Performance (SWAMP) program.

There are a number of physical constraints for implementing conveyance control measures; the most notable being soils type and depth to groundwater table. Issues with respect to the type of stormwater being infiltrated will also have to be addressed, particularly in areas where groundwater is used as a potable source. For the purpose of this study it has been assumed that conveyance control measures would be installed within 15 percent of existing urban areas. Furthermore, conveyance control measures would be considered as part of an integrated approach to stormwater management for all urbanizing areas.

The target infiltration rates will vary based on soils type and range from 3 to 5mm for clay soils to 12 to 15mm for sandy soils.

An approximate cost to implement conveyance control measures on a City-wide basis was established. The costs were developed for the area serviced by a separate storm sewer system. The estimate is based on an uptake rate of 15 percent, an average road length of 7 ha/km and an additional cost of $125 per linear meter to install a pervious pipe system which would be constructed together with the conventional storm sewer. It has also been assumed that the conveyance system would be installed as existing storm sewer infrastructure is replaced as a result of age, or due to redevelopment requiring replacement of existing infrastructure. The estimated cost to implement the conveyance control program is $32,000,000.

10.4 End of Pipe Measures

End of pipe measures include Best Management Practices that are installed at the end of the storm sewer system prior to discharge to the stream or river. Typical end of pipe measures which are used to treat stormwater include stormwater ponds (dry or wet), wetlands, or infiltration basins.

End of pipe measures are the most commonly used measure in urbanizing areas. Currently, there are approximately 130 stormwater management ponds within the City of Hamilton. Furthermore, as part of the 2006 Development Charges Update Study (C.N. Watson and Associates Ltd., 2006) 29 additional ponds are recommended to accommodate proposed development within the existing urban boundary. The total estimated cost to construct the stormwater management ponds is $19,140,000.

Stormwater management facilities provide a number of functions including flood control, erosion control, and water quality improvement. With respect to water quality control, the Ministry of Environment Stormwater Management Planning and Design Manual (MOE, 2003) provides direction with respect to sizing of proposed stormwater facilities. The sizing of the proposed facilities is based on the federal Fisheries Act (subsection 36/3) which prohibits “the deposit of a deleterious substance of any type in water frequented by fish or in any place under any conditions where the deleterious substance or any other deleterious substance that results from the deposit of a deleterious substance may enter any such water.”

Three levels of protection are provided in the manual; with the goal of maintaining or enhancing existing aquatic habitat, based on the suspended solids removal performance for the different end-of-pipe stormwater management facilities that are proposed.

City of Hamilton staff, together with Hamilton Conservation Authority staff and representatives at the Hamilton Remedial Action Plan met several times in 2006 to determine the required level or protection for watercourses discharging to Cootes Paradise or Hamilton Harbour. Based on these discussions (reference letter) it was agreed that Level 1 (Enhanced) would be required for stormwater facilities servicing new developments.

Based on a review of the fisheries information available and discussions with staff from the other three Conservation Authorities, the required level of protection was also defined for the other watersheds. The findings are summarized in Table 10.3.

Table 10.3: Level of Protection for Watersheds within the City Of Hamilton

Watershed	Conservation Authority Jurisdiction	Level of Protection
Bronte Creek	Halton	Level 1 - Enhanced
Borer's Creek	Hamilton	Level 1 – Enhanced
Grindstone Creek	Halton	Level 1 – Enhanced
Spencer Creek	Hamilton	Level 1 – Enhanced
Sulphur Creek	Hamilton	Level 1 – Enhanced
Chedoke Creek	Hamilton	Level 1 – Enhanced
Red Hill Creek	Hamilton	Level 1 – Enhanced
Stoney Creek	Hamilton	Level 2 – Normal
Community of Stoney Creek Watercourses	Hamilton	Level 2 – Normal
Forty Mile Creek	Niagara Peninsula	Level 2 – Normal
Twenty Mile Creek	Niagara Peninsula	Level 2 – Normal
Welland River	Niagara Peninsula	Level 2 – Normal
Fairchild Creek	Grand River	Level 1 – Enhanced
Big Creek	Grand River	Level 2 – Normal

The City recently completed a Surface Water Monitoring Assessment Study (XCG, 2004). As part of this study, the general location of all stormwater facilities was identified. A subsequent study (Aquafor, 2005) was then undertaken to identify the type (i.e. wet pond, dry pond), characteristics (i.e. size, stage/storage/discharge relationships) and general operation and maintenance requirements.

There are over 130 stormwater management facilities which are located within the City of Hamilton. Several of these facilities were constructed in the 1980's and early 1990's and were designed solely for the purpose of flood protection. Many of the newer facilities provide a number of functions including flood control, erosion control and water quality control.

The objective of this strategy was to utilize information from studies that were recently completed and to develop evaluation criteria in order to prioritize the potential for retrofitting each of the existing facilities. Consistent with the overall approach of this study, the intent was to undertake the level of detail necessary to satisfy Phases 1 and 2 of the Class EA process.

A two step approach was used to prioritize the potential for retrofitting each of the 130 existing facilities.

The first step involved defining the existing stormwater functions provided by each facility. The potential functions include flood control, erosion control and water quality control. If the existing facility provided all three functions then no further assessment of the facility was undertaken. This step also involved the determination of a series of criteria to define whether or not it was feasible to retrofit the existing stormwater facility. These criteria included factors such as drainage area and access.

The second step involved the development of a series of evaluation criteria to further prioritize the remaining stormwater facilities. Physical/ Natural Environment, Social/Cultural and Economic criteria were selected.

A score was then established for each facility for each of the eight criteria that were established.

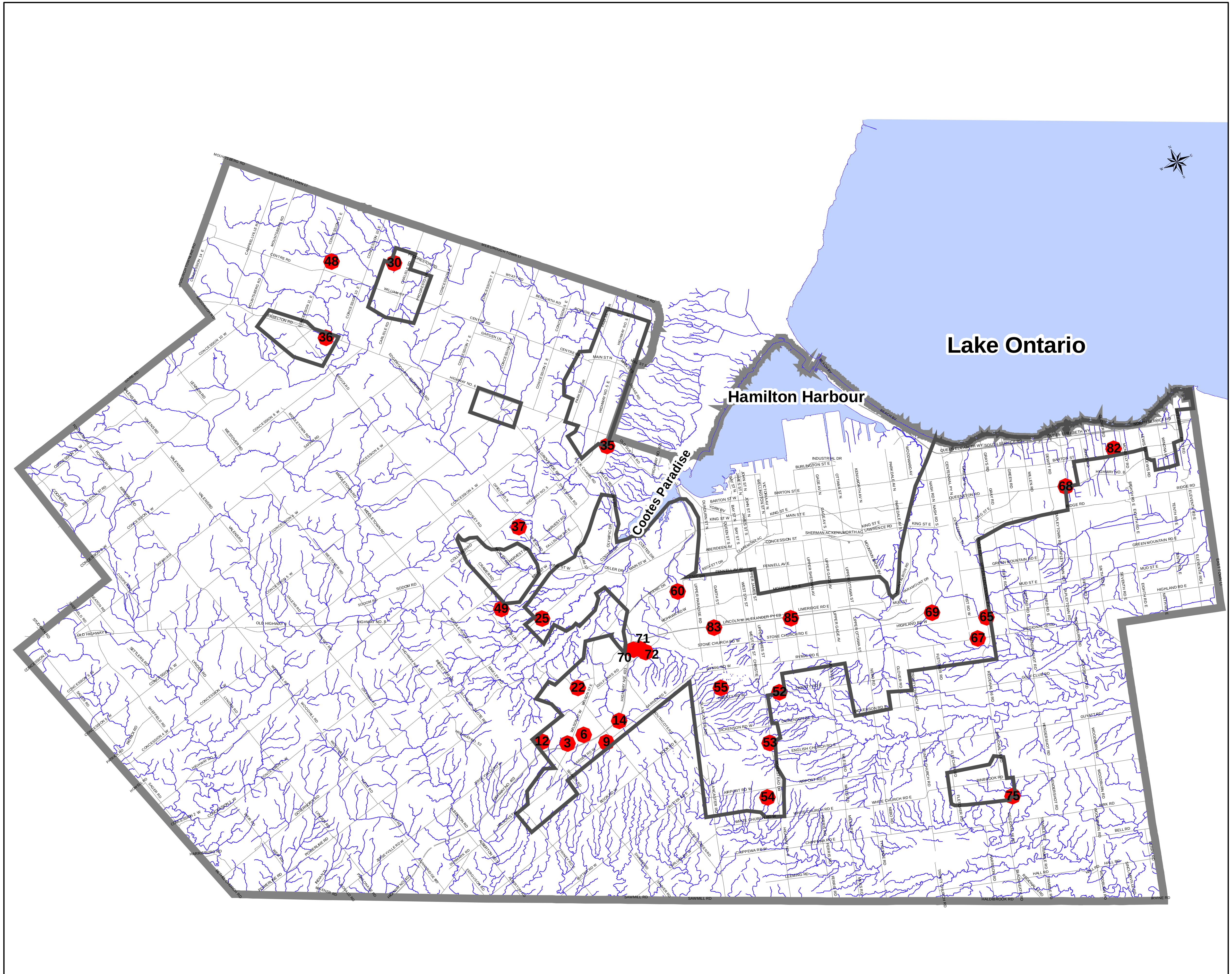
The overall potential to retrofit a given facility was then based on the aggregate score. The intent was to provide a general prioritization (each facility was assigned an overall score between 1 (lowest potential to retrofit) and 4 (highest potential to retrofit)).

The first step in the evaluation process reduced the potential number of facilities to be retrofit from 130 to 29.

Table 10.4 summarizes the findings from the evaluation process and provides estimated costs for the 29 stormwater facilities. Figure 10.1 shows the location of the 29 facilities. Also provided are the Field Inspection Forms and photographs for Pond 68 (Figures 10.2a through 10.2d) located in Stoney Creek; in the Fruitland Road and Highway No. 8 area. This facility was constructed to provide a flood control function and could be retrofit to provide erosion and water quality control benefits.

The costs, as shown in Table 10.4, are based on recent projects completed in Southern Ontario. A unit cost of $\$120/m^3$ of water quality storage was used. In addition, a minimum cost of $400,000 per facility was used. The costs, in general, include mobilization, excavation and removal of excess material, grading, inlet/outlet works and landscaping. The total cost estimate to retrofit the 29 stormwater management facilities is $19,140,000.

Photos 10.1 and 10.2 illustrate before and after photographs of stormwater facilities and stream restoration project that were retrofit in the Town of Markham and City of Toronto.



KEY MAP

LEGEND:

- City of Hamilton Boundary
- Approximate Study Area
- Pond Location to be Retrofitted

NOTES:

0 5 10

Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Location of Ponds to be Retrofitted

FIGURE: 10.1

DATE: 18 April 2007

CITY OF HAMILTON
Stormwater Master Plan
Pond Inventory
Pond 68

Photo 68-1: Inlet

Photo 68-2: Inlet

Photo 68-3: Outlet

Photo 68-4: General Plan

Hamilton

Figure: 10.2a

Aquafor Beech Limited

SWM POND FIELD INSPECTION FORM
CITY OF HAMILTON

GENERAL

Pond Reference No.:	**Pond 68**
Type of Facility:	**Single Celled Dry Pond**
Function of Facility	**Flood Control**
Detail Design Brief/MDP/MESP/Conceptual SWM Report	Name: **Fruitland Meadows Subdivision** Date: **January 2, 2002** Consultant: **S. Llewellyn & Associates Limited**
Predominant Land Use	**Residential**

LOCATION

Local Municipality:	**Stoney Creek**
Subdivision Name:	**Fruitland Meadows**
Nearest Major Intersection	**Fruitland Rd & Hwy 8**
Watershed	**Community of Stoney Creek Watercourses**
Facility Location	**Off Line**

MAPPING INFORMATION

Northing/Easting	**4778554.304** / **587740.06**

Figure 10.2b

SWM POND FIELD INSPECTION FORM
CITY OF HAMILTON

DESIGN CRITERIA

Total Contributing Drainage Area (ha)	**107.8**	
Controlled Drainage Area (ha)	**29.6**	
Total Area of SWM Facility Block (ha)	**1.96**	
	Flood Control	
Stage\Discharge Relationship	Stage (m)	Discharge (m3/s)
	0	**0**
	0.25	**0.06**
	0.50	**0.22**
	0.75	**0.52**
	1.00	**1.52**
	1.25	**2.31**
	1.50	**3.22**
	1.75	**4.24**
	2.00	**7.23**
	2.25	**8.12**
	2.50	**8.92**
	2.75	**9.65**
	3.00	**10.33**
Outlet structure type/Size/Discription	**800mm DIA CSP, 2x1200 DIA CSP**	
Maximum Release Rate (m3/s)	**10.331**	
Inlet structure type/Size/Discription	**1050mm DIA Concrete (N), 1800mm DIA Concrete (E)**	
Drawing Number	**86-S-134**	
Drawing located in *Pond Inventory* binder	**Sheet 13**	
Consultant consistency between Physical Inventory report and drawings	**Yes**	

Figure 10.2c

SWM POND FIELD INSPECTION FORM
CITY OF HAMILTON

RETROFIT FEASIBILITY

Ratio of Required Water Quality Storage/ Available Storage (%)	**n/a**
Potential for Facility Expansion (ie. Adjacent landu use, ownership etc.)	**Poor**
Potential for Excavation and Grade Modification (ie. Existing vegetation etc.)	**Moderate**
Pontential for Retrofit	**High**

STATUS

Pictures	**Yes**
Design Status	**Basic**
Date Visited	**September 17, 2004**
Construction Status	**Build (Date Not Available)**

COMMENTS

1. Photo 68-1: Inlet
Photo 68-2: Inlet
Photo 68-3: Outlet
Photo 68-4: General Plan

n/a

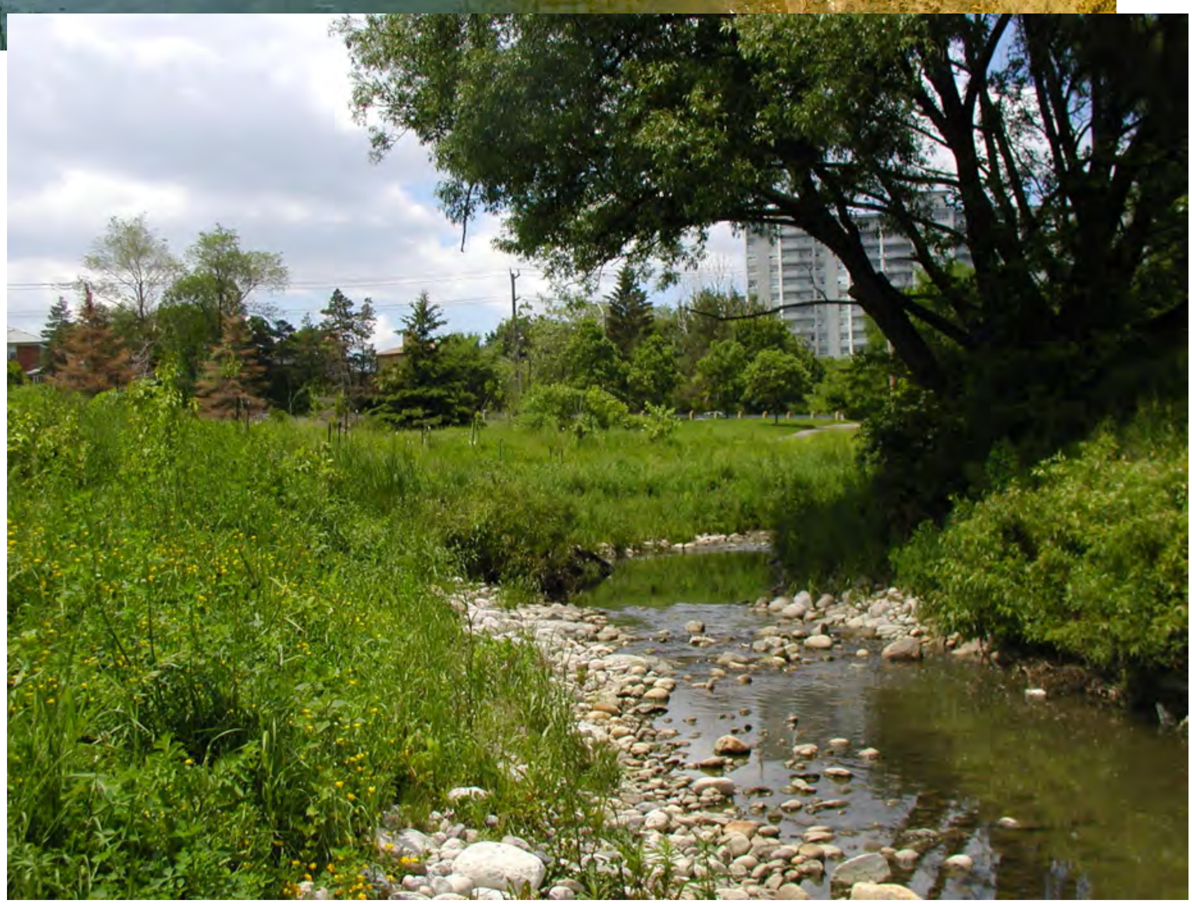
MAINTENANCE ISSUES

Access	**Good**
Access Road	**Yes**
Sediment Buildup	**No**
Storage/Cleanup	**Fair**

Figure 10.2d

Photo 10.1 - Pre and Post Construction - Stormwater Facility Retrofit - Town of Markham

PRE CONSTRUCTION



POST CONSTRUCTION

Photo 10.2 - Pre and Post Construction - Stream Restoration Project - City of Toronto

Table 10.4: Stormwater Management Facility Retrofit Costs

Facility Number	Local Municipality	Major Intersection	Watershed	Relative Priority	Capital cost	Class EA Schedule
3	Ancaster	Galley Crt & Speers Rd	Big Creek	*3*	$420,000	B
6	Ancaster	Amberly Blvd & Stadacona Ave	Big Creek	*3*	$470,000	B
9	Ancaster	Garner Rd W & Braithwaite Ave	Big Creek	*3*	$400,000	B
12	Ancaster	Morwick Dr & Shaver Rd	Big Creek	*3*	$510,000	B
14	Ancaster	Miller Dr & Garner Rd E	Sulphur Creek	*4*	$1,380,000	B
22	Ancaster	Harrington Place & Lover's Lane	Sulphur Creek	*3*	$400,000	B
25	Dundas	Wainwright Blvd & Governor's Rd	Spencer Creek	*3*	$400,000	B
30	Flamborough	Blackberry Pl. & Acredale Dr.	Bronte Creek	*3*	$400,000	B
35	Flamborough	Hwy 6 & Hwy 5	Grindstone Creek	*4*	$400,000	B
36	Flamborough	Noble Kirk Dr. & HWY 6	Bronte Creek	*3*	$400,000	B
37	Flamborough	Ofield Rd & Hwy 5	Spencer Creek	*2*	$400,000	B
48	Flamborough	Centre Rd and Con. 11 E	Bronte Creek	*3*	$400,000	B
49	Flamborough	Hwy 8 & Rosebough St.	Bronte Creek	*2*	$400,000	B
52	Glanbrook	Twenty Rd E & Hwy 6	Twenty Mile Creek	*4*	$400,000	B
53	Glanbrook	Hwy 6 & Dickenson Rd W	Twenty Mile Creek	*3*	$400,000	B
54	Glanbrook	Marion St & Spitfire Dr	Twenty Mile Creek	*4*	$400,000	B
55	Glanbrook	Twenty Rd & Garth St	Twenty Mile Creek	*3*	$1,030,000	B
60	City of Hamilton	Scenic Dr & Sanatotium Dr	Chedoke Creek	*3*	$400,000	B
65	Stoney Creek	Hwy 20 & Highland Rd	Stoney Creek	*3*	$400,000	B
67	Stoney Creek	Rymal Rd E & Whitedeer Rd	Twenty Mile Creek	*4*	$400,000	B
68	Stoney Creek	Fruitland Rd & Hwy 8	Community of Stoney Creek Watercourses	*4*	$1,430,000	B
69	Stoney Creek	Winterberry Dr & Paramount Dr	Red Hill Creek	*1*	$1,110,000	B
70	Ancaster	Hwy 403 & Golf Links Rd	Sulphur Creek	*3*	$3,920,000	B
71	Ancaster	Golf Links Rd & Meadowlands Blvd	Sulphur Creek	*3*	$570,000	B
72	Ancaster	Golf Links Rd & Meadowlands Blvd	Sulphur Creek	*3*	$400,000	B
75	Glanbrook	Regional Rd 56 & Binbrook Rd	Welland River	*4*	$700,000	B
82	Stoney Creek	Arvin Av. / Glover Rd	Stoney Creek Watercourses	*2*	$400,000	B
83	City of Hamilton	Garth St. / Lincoln M Alexander Pkwy	Red Hill Creek	*1*	$400,000	B
85	City of Hamilton	Upper Wentworth St. / Lincoln M. Alexander Pkwy	Red Hill Creek	*1*	$400,000	B
				Total Cost	***$19,140,000***	

Note:
4 = Highest Priority, **1** = Lowest Priority

10.5 Stream Restoration Measures

Impacts of urbanization on the natural processes that occur within a watershed are generally understood to result in alterations of the receiving watercourse. Specific impacts include hydrology, erosion, sediment transport and water quality degradation. Each of these impacts can create a risk to public health and safety, and affects the quality of terrestrial and aquatic habitat. The City of Hamilton has recognized these impacts and, like many other municipalities, imposes Development Charges against land to pay for increased capital costs required due to increased needs for services arising from development through its Development Charges by-law.

The 2006 Development Charges Update Study identified two components of drainage works that were considered to required development funding. These include:

- Open Watercourses: Erosion Control and Channel System Improvements for identified projects. These works include erosion control and conveyance works (including channelization and major culverts) that have been identified along watercourses to address the impacts of growth, such as peak flows, volumes, and duration of erosive flows.
- Open Watercourses: Erosion Control for Estimated Future Works. These works include on-site and off-site erosion control and conveyance works not yet identified along watercourses in order to mitigate the impact of growth.

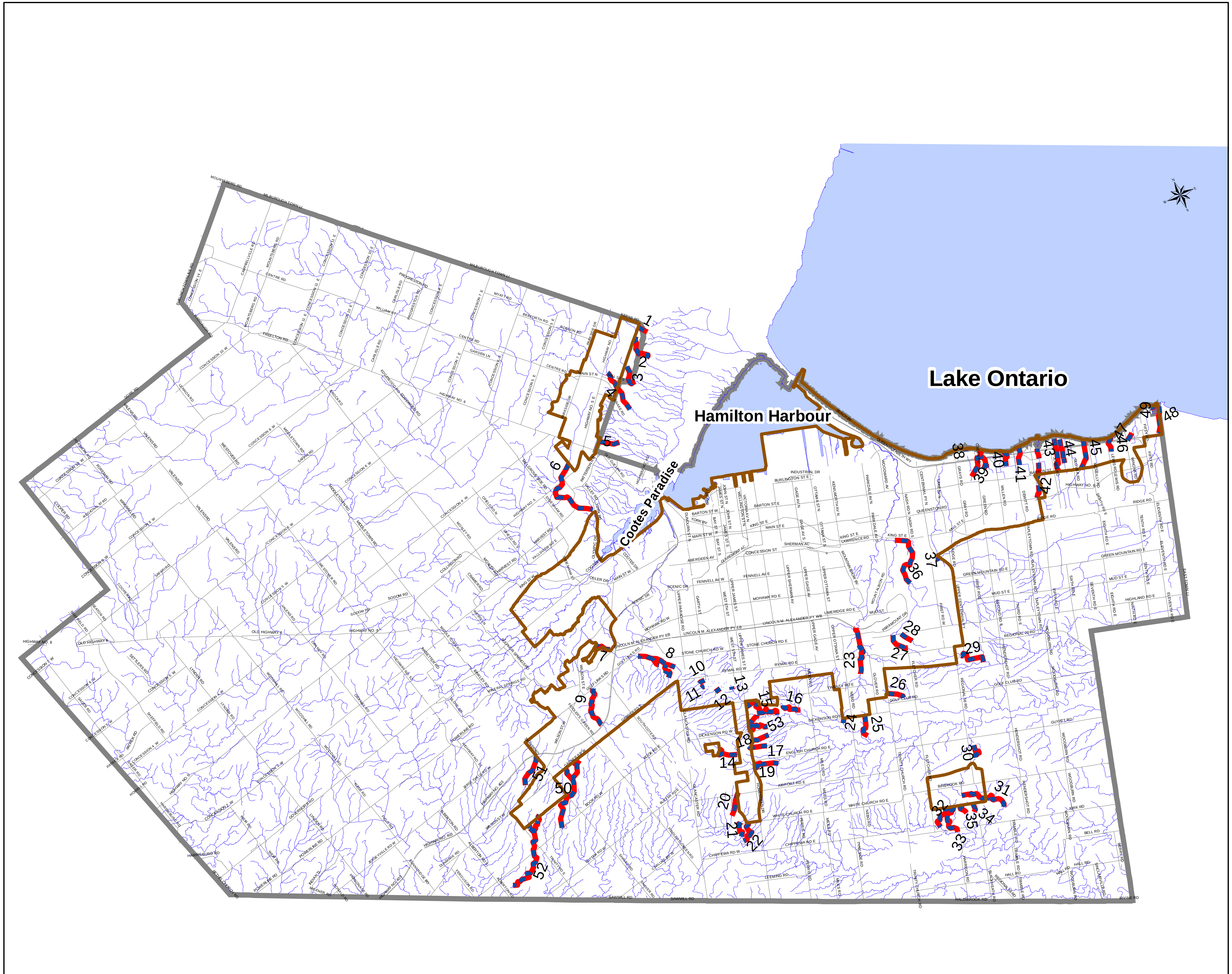
The objectives of this strategy were to utilize information with respect to erosion control, identified projects and estimated future works and to develop evaluation criteria in order to prioritize the proposed works. Included in the proposed projects are 5 sites located within the City of Burlington, downstream of proposed development within the City of Hamilton. Consistent with the overall approach of this study, the intent was to undertake the level of detail necessary to satisfy Phases to satisfy Phases 1 and 2 of the Class EA process.

The evaluation criteria that were used to prioritize the stream restoration opportunities are provided in Chapter 9. The approach used is similar to the approach used for prioritizing the existing stormwater management facilities. A series of physical/Natural Environment, Social/Cultural and Economic criteria were selected. A score was then assigned to each potential erosion control project (a total of 53 projects were considered).

The overall potential benefit associated with the implementation of a particular stream restoration project was then based on an aggregate score. The intent was to provide a general prioritization as to the value of implementing a specific stream restoration project (each project was assigned an overall score of between 1 (lowest benefit) to 4 (highest benefit).

The findings from the evaluation process are provided in Table 10.5, as are the associated costs for each project. Figure 10.3 shows the location of the proposed stream restoration works. The estimated costs, as shown, were taken from the 2006 Development Charges Update Study. A 20 percent increase in costs was added to allow for increased construction costs.

In reviewing the findings in Table 10.5 it should be noted that only projects downstream of proposed development within the current Official Plan were identified. Therefore, stream restoration works that may be required elsewhere in the City, or as a result of proposed development outside of the current City boundary have not been identified. Section 11.3 discusses a potential approach for considering stream restoration opportunities on a City-wide basis.



KEY MAP

LEGEND:

- Erosion Sites
- City of Hamilton Boundary
- Urban Boundary

NOTES:

0 5 10
Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Location of Proposed Stream Restoration Works

FIGURE: 10.3

DATE: 18 April 2007

Table 10.5: Stream Restoration Costs

Site Number	Local Municipality	Watershed	Relative Priority	Capital Cost	Class EA Schedule
1	Flamborough	Grindstone	4	$141,000	B
2	Flamborough	Grindstone	4	$430,000	B
3	Flamborough	Grindstone	4	$312,000	B
4	Flamborough	Grindstone	4	$613,000	B
5	Flamborough	Grindstone	4	$281,000	B
6	Flamborough	Borer's Creek	3	$1,092,000	B
7	Ancaster	Sulphur Creek	3	$212,000	B
8	Ancaster	Sulphur Creek	2	$952,000	B
9	Ancaster	Sulphur Creek	3	$624,000	B
10	Glanbrook	Twenty Mile Creek	2	$100,000	B
11	Glanbrook	Twenty Mile Creek	2	$100,000	B
12	Glanbrook	Twenty Mile Creek	3	$100,000	B
13	Glanbrook	Twenty Mile Creek	2	$100,000	B
14	Glanbrook	Twenty Mile Creek	2	$352,000	B
15	Glanbrook	Twenty Mile Creek	1	$899,000	B
16	Glanbrook	Twenty Mile Creek	2	$301,000	B
17	Glanbrook	Twenty Mile Creek	3	$260,000	B
18	Glanbrook	Twenty Mile Creek	3	$236,000	B
19	Glanbrook	Twenty Mile Creek	1	$429,000	B
20	Glanbrook	Welland River	2	$335,000	B
21	Glanbrook	Welland River	2	$245,000	B
22	Glanbrook	Welland River	1	$386,000	B
23	Stoney Creek	Red Hill Creek	1	$767,000	B
24	Glanbrook	Twenty Mile Creek	2	$100,000	B
25	Glanbrook	Twenty Mile Creek	3	$335,000	B
26	Glanbrook	Twenty Mile Creek	2	$229,000	B
27	Stoney Creek	Red Hill Creek	2	$309,000	B
28	Stoney Creek	Red Hill Creek	3	$183,000	B
29	Glanbrook	Twenty Mile Creek	2	$451,000	B
30	Glanbrook	Twenty Mile Creek	2	$255,000	B
31	Glanbrook	Welland River	1	$784,000	B
32	Glanbrook	Welland River	2	$383,000	B
33	Glanbrook	Welland River	2	$527,000	B
34	Glanbrook	Welland River	3	$166,000	B
35	Glanbrook	Welland River	3	$122,000	B
36	Stoney Creek	Red Hill Creek	3	$887,000	B
37	Stoney Creek	Community of Stoney Creek Watercourses	4	$100,000	B
38	Stoney Creek	Community of Stoney Creek Watercourses	4	$100,000	B
39	Stoney Creek	Community of Stoney Creek Watercourses	2	$685,000	B
40	Stoney Creek	Community of Stoney Creek Watercourses	3	$240,000	B
41	Stoney Creek	Community of Stoney Creek Watercourses	3	$262,000	B
42	Stoney Creek	Community of Stoney Creek Watercourses	2	$540,000	B
43	Stoney Creek	Community of Stoney Creek Watercourses	1	$488,000	B
44	Stoney Creek	Community of Stoney Creek Watercourses	2	$338,000	B
45	Stoney Creek	Community of Stoney Creek Watercourses	1	$423,000	B
46	Stoney Creek	Community of Stoney Creek Watercourses	4	$215,000	B
47	Stoney Creek	Community of Stoney Creek Watercourses	2	$117,000	B
48	Stoney Creek	Community of Stoney Creek Watercourses	3	$100,000	B
49	Stoney Creek	Community of Stoney Creek Watercourses	2	$370,000	B
50	Ancaster	Big Creek	2	$1,301,000	B
51	Ancaster	Big Creek	3	$450,000	B
52	Ancaster	Big Creek	2	$1,433,000	B
53	Glanbrook	Twenty Mile Creek	1	$397,000	B
			Total Cost	**$21,557,000**	

Note:
4 = Highest Priority, 1 = Lowest Priority

10.6 Municipal Infrastructure Measures

The Recommended Growth Option includes 26,500 units for intensification of lands within the existing urban boundary. Intensification of lands typically results in an increase in the level of imperviousness which, in turn, results in an increase in flows to the existing storm sewer system. If an equivalent level of service is to be maintained (with respect to basement and surface flooding) then measures to offset the increase in flows must be considered.

In Chapter 8, three general alternatives for offsetting the impacts of intensification were considered. These include:

i) provision of on-site controls to limit flows from proposed intensification sites to allowable levels
ii) undertaking source control (e.g. downspout disconnection) and conveyance control (e.g. perforated pipe systems) measures on a City-wide basis to offset the impacts of proposed intensification
iii) upgrading the existing storm sewer system to accommodate the increase in flows associated with intensification

A study was undertaken in 2005 by Metropolitan Knowledge International. One of the objectives of this study was to identify the potential types and locations of proposed intensification. As noted in the study, the types of proposed intensification vary significantly; from replacement of single family homes with townhouses, to upgrading existing underutilized shopping centres to redevelopment of key nodes and corridors throughout the City.

The information was used to determine, on a preliminary basis, the estimated cost to accommodate the proposed level of intensification and provide the same level of service if alternatives i) or ii) as noted above are not implemented. The results are summarized in Chapters 5 and 8.

In summary, the findings suggest that 5 to 10 percent of the existing storm trunk sewer system would need to be replaced in order to maintain an equivalent level of service and that the estimated cost to replace the infrastructure would be between $50 million and $100 million. A unit cost of $3,000 per linear meter of sewer was used to estimate the costs as provided. The percentage of sewers that would need to be replaced would be dependant upon the type and location

The approach for addressing the impact of intensification will likely be based on a combination of the three alternatives which were presented above. The objective of this strategy was to show the potential impact and range of costs necessary to upgrade infrastructure if the first two alternatives are not implemented. Chapter 11 will discuss the steps needed to be undertaken to ensure the existing level of service is maintained as the areas are redeveloped.

The above discussion was limited to areas within the existing urban boundary that are subject to intensification. The Recommended Growth Option also includes the proposed development of approximately 30,000 units within the existing urban boundary. The 2006 Development Charges Update Study addressed a number measures that will likely be required as a result of the development of these lands. These measures included stream restoration works and the construction of stormwater management facilities. Many of the proposed development sites are, however, relatively small and the construction of traditional stormwater facilities may be limited. Furthermore, most of the proposed development sites will discharge directly into existing storm trunk sewers.

Historically, the City sized the storm sewer system based on the Rationale Method. This approach is relatively straightforward and does not include a number of factors including the time dependency of flows, benefits of providing storage within the existing system, impacts of undersized sewers on upstream water levels and sewer system performance under surcharged levels. The Draft City of Hamilton Criteria and Guidelines for Stormwater Infrastructure Design provides a list of approved hydrologic/hydraulic models that may be used for determining flow rates and associated water levels in sewer systems as well as receiving streams. The MOUSE model was used in this study to define flow rates and water levels for a variety of different conditions.

Based on a review of the Draft City of Hamilton Criteria and Guidelines for Stormwater Infrastructure Design and discussions with City staff, the following approach is recommended to ensure that the potential impacts of proposed developments on the level of service provided by the existing storm sewer system is addressed.

i) That the Draft Criteria and Guidelines for Infrastructure Design and the Development Engineering Guidelines (2003) be used to design the minor and major systems
ii) That the allowable flow into the storm sewer system for the subject site be based on the Rationale Method.
iii) That a field reconnaissance be undertaken to identify the potential for surface flooding, including review of existing records, identification of low lying areas, depressed garages etc.
iv) That the MOUSE model, updated as required, be used to define downstream flow conditions, including level of surcharging
v) That the "Flow capacity of the proposed storm sewer shall be determined based on the receiving existing sewer remaining unsurcharged. The proposed storm sewer flow capacity would either be the 1 in 5 year standard or designed to allow the existing storm sewer to remain unsurcharged. Should the proposed storm sewer flow capacity be required to be less than the 1 in 5 year standard, to prevent downstream surcharging, inlet capacity for the storm sewer should be designed accordingly. Should the existing downstream system be already surcharged, the proposed upstream storm sewer should not increase the level of surcharging downstream". (Page 2 from Draft Criteria and Guideline for Stormwater Infrastructure Design Document). Also, as noted in this document, hydraulic analysis of the proposed and existing storm sewer system shall provide hydraulic grade lines for the inlet capacity and/or 1 in 5 year standard and 1 in 100 year standard. Hydraulic analysis should demonstrate that no negative impact on the receiving storm sewer system results from the proposed storm sewer which would provide clear indication of no liability to the City. The extent of the downstream off-site analysis needs to be verified with City staff prior to initiation, to ensure that downstream conditions are adequately accounted for in the analysis.

10.7 Rural Measures

The focus of implementation of Rural BMP's on agricultural lands is on stewardship initiatives, building on the current efforts of the four conservation authorities: Grand River Conservation Authority (GRCA), Niagara Peninsula Conservation Authority (NPCA), Hamilton Conservation Authority (HCA) and Conservation Halton (CH). The recommended plan is to implement non-structural rural BMP's on 50% of the farms within the City. This would require that implementation of the existing programs be accelerated, through the addition of municipal funding.

Within the rural portions of the watersheds, there are a number of high priority areas for implementation as follows (Figure 10.4):

- Intensive Agricultural lands (about 40,000 ha): these are generally lands used for crops such as corn, soybeans, market gardening, nurseries, etc. Conservation Farming BMP's would be implemented on these lands, with 3 m buffer strips (each side) along all unclassified streams.
- Cold, cool and warm water streams (120 km): these are the larger watercourses that provide important fish habitat. Rural BMP's to be implemented would include livestock fencing, stream buffers (minimum 15 m (each side)), and off-stream watering sites.

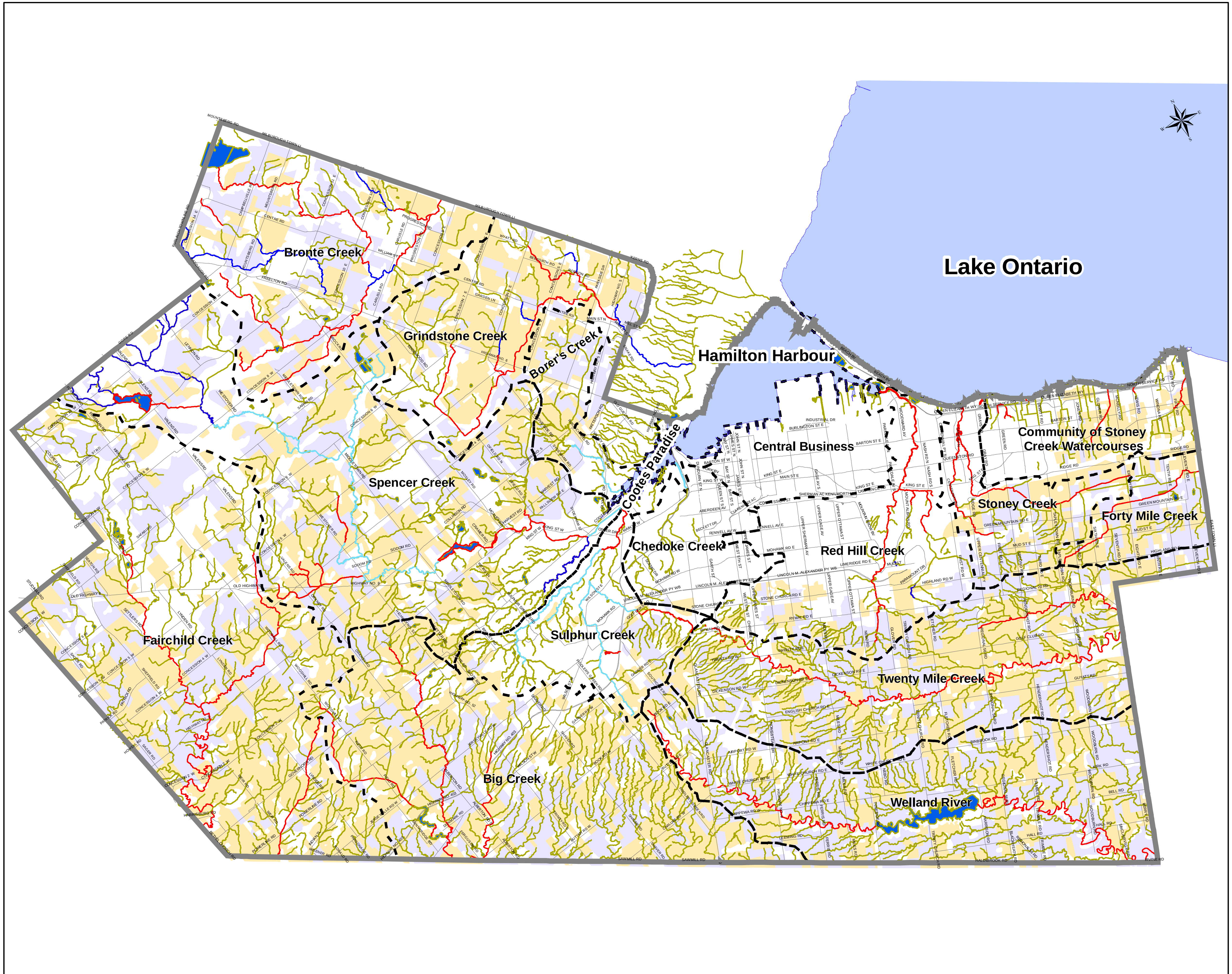
In addition, there are approximately 30,000 ha of agricultural land that is considered moderate priority areas for implementing rural BMP's. For the unclassified streams within the high and medium priority areas, 3m wide buffer strips, as recommended under the Nutrient Management Act would be recommended, combined with conservation farming BMP's

For ponds, lakes and reservoirs bordered by high and moderate priority agricultural lands, the buffer width along the shoreline will be the same as the adjacent stream classification i.e. 3m for unclassified streams and 15m (each side) for cold, cool and warmwater streams.

The focus of the Rural BMP program is on non-structural measures, including livestock fencing, buffer strip plantings, conservation tillage practices, nutrient management, clean water diversion and farmyard runoff control. The plan assumes that non-structural measures would be implemented on 50% of the agricultural lands, which represents a 50% uptake rate for all measures.

Rural Estate programs will include septic system replacement and inspection programs, inspection and review programs for Permits to Take Water and fertilizer / pesticide reduction programs. These programs will also involve Community Education and Outreach components.

Several examples of the types of Rural BMP's that would be implemented are shown below:



KEY MAP

LEGEND:

City of Hamilton Boundary

Stream Classification

- Cold (High Priority)
- Cool (High Priority)
- Warm (High Priority)
- Unclassified (Medium Priority)
- Watershed/Subwatershed Boundary

Priority Agricultural Lands

- High Priority Rural Lands
- Medium Priority Rural Lands

NOTES:

0 5 10
Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Implementation of Rural Measures

FIGURE: 10.4

DATE: 18 April 2007

Buffer Strips

Conservation Farm / Land Practices

It takes one acre of land to continuously supply the necessary food to sustain one person for a lifetime. Soil is the basis of the agriculture industry. Loss or degradation of this resource results in decreased productivity and increased costs. There are many different techniques that can be used around your farm to help control erosion and prevent sediment from entering waterways. Practices such as residue management, grassed waterways, cover crops and shelterbelts prevent erosion and reduce the movement of nutrients and pesticides. Farm practices that prevent erosion will help to protect surface water quality.

10.8 Description of Preferred Management Strategy

Previous sections of this chapter described the individual components which comprise the Preferred Management Strategy. This section will provide a summary of the proposed measures.

Findings from the Existing Conditions component of the study showed that existing environmental conditions are degraded in some areas within the City. Issues include degraded water quality, loss of fish habitat, erosion, lack of base flow and groundwater concerns.

Urban land uses within the City of Hamilton comprise approximately 15 percent of the total land area. Of the remaining 85 percent, approximately 61 percent of the lands are classified as rural. Proposed development, which includes the development of vacant lands within the existing Official Plan and lands outside the existing urban boundary, will increase the percentage of urban lands from 15 percent to 21 percent.

The above points would suggest that the Alternative Management Strategies, if they are to be effective, should deal with impacts associated with existing urban and rural land uses as well as proposed land uses.

The Alternative Management Strategies acknowledge that the way we deal with the impacts associated with stormwater are evolving. Current practices do not always adequately address several impacts, including those related to erosion and the provision of a water balance. It was therefore necessary to look forward and develop and assess Management Alternatives that overcome the present limitations of current practices.

A total of five Alternative Management Strategies were assessed. The five Strategies are defined as:

- Do Nothing Management Strategy
- Business as Usual Management Strategy
- Comprehensive Urbanization Approach Management Strategy
- Business as Usual with Urban Retrofits Management Strategy
- Business as Usual with Rural Retrofits Management Strategy

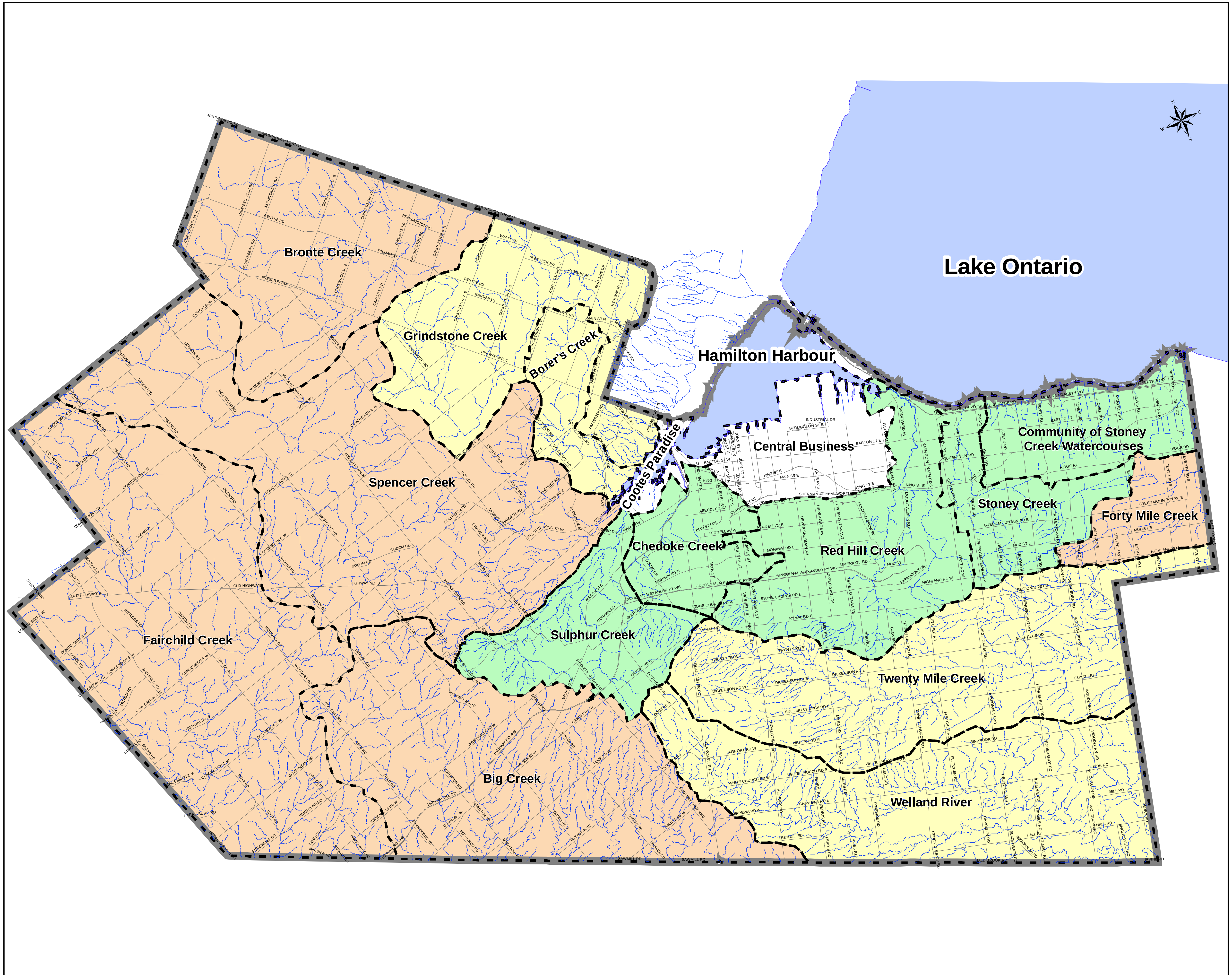
The selection of a Preferred Strategy for each of the 15 watersheds was based on the process described above. The intent of the evaluation was to provide a framework for future development (including intensification) and implementation of a new approach for the municipality and agencies to undertake works in a collaborative manner in existing urban and rural areas.

The Preferred Strategy also provides direction for issues relating to the impact of urban and rural land uses on the Hamilton and Welland River Remedial Action Plans.

Different Preferred Strategies have been selected for each watershed based on existing and proposed land uses, existing environmental conditions and issues within the watershed, Remedial Action Plan requirements, and the ability of each Alternative Strategy to meet the study objectives. The Master Plan report provides, for each watershed, details with respect to a description of existing environmental conditions, potential impacts associated with land use, and the proposed measures to be undertaken in order to protect, enhance, and restore the natural resources within the watershed.

The Preferred Strategy for each watershed located within the City of Hamilton is shown in Figure 10.5. In summary, the components which comprise the overall strategy include:

- Source and conveyance control programs in existing urban areas;
- Structural and non-structural measures in existing rural areas;
- Retrofitting of 29 existing stormwater management facilities;
- Restoration of 53 degraded stream reaches;



LEGEND:

City of Hamilton Boundary

Watershed/Subwatershed Boundary

Strategy

#3 - Comprehensive Urbanization Approach

#4 - Business as Usual with Urban Retrofits

#5 - Business as Usual with Rural Retrofits

NOTES:

0 5 10

Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Preferred Strategy for each Watershed within the City of Hamilton

FIGURE: 10.5

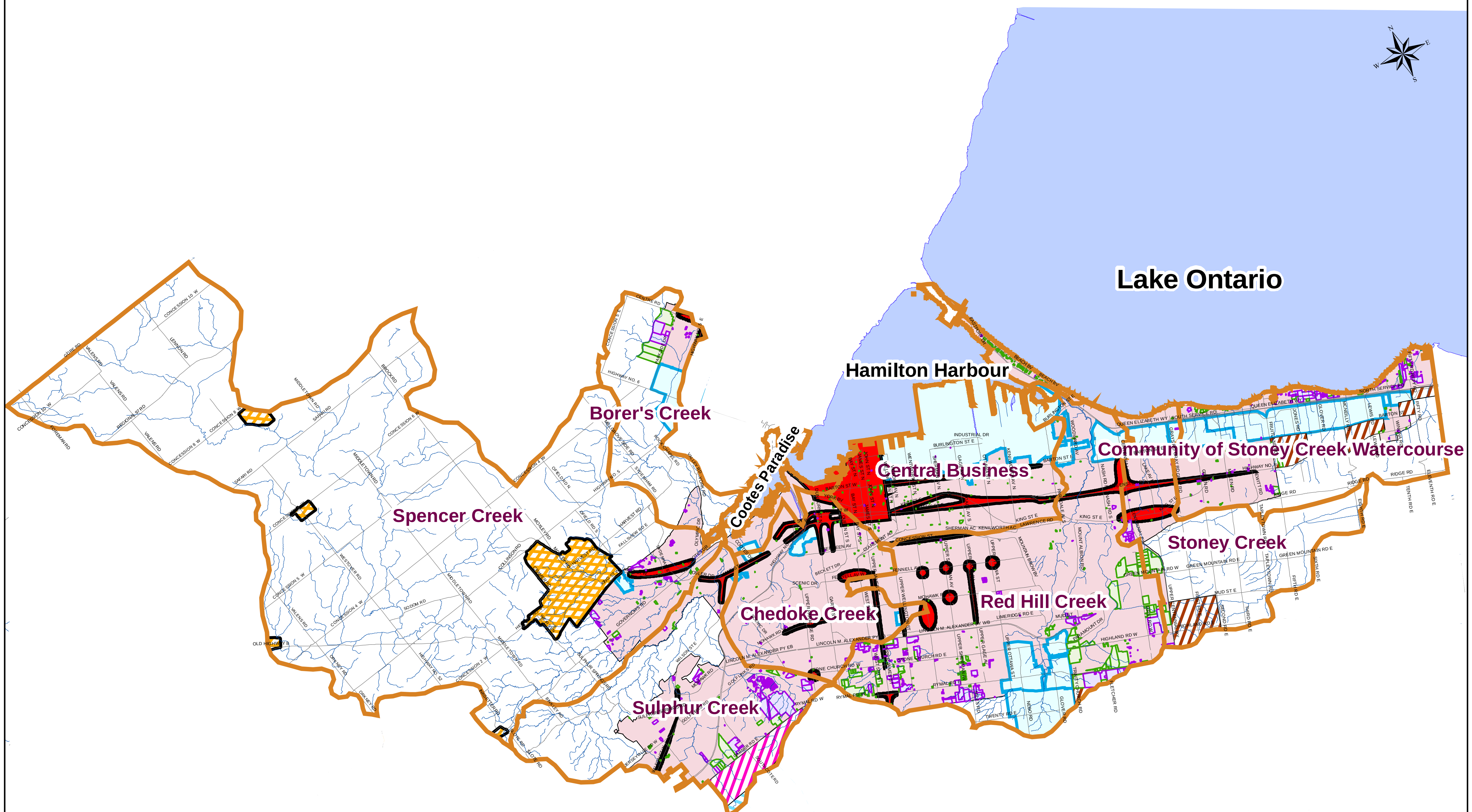
DATE: 18 April 2007

- Construction of a wide range of Best Management Practices to address water balance, sewer capacity, basement, surface and watercourse flooding, erosion and water quality issues within urbanizing areas
- On-site control works or upgrading of existing storm sewer infrastructure to offset potential impacts associated with intensification;

Collectively, implementation of the above measures will ensure that the study principle, goals and objectives including protection, enhancement and restoration of the natural resources of the watersheds and protection of the existing level of service for areas serviced by sewer systems are met.

The accompanying figures illustrate the Preferred Management Strategies for each of the 15 watersheds. Separate figures (Figure 10.6 to 10.9) are provided for each of the four Conservation Authorities. Each of the figures illustrates the Recommended Growth Option and provides:

i) A description of each watershed
ii) A summary of the key environmental resources within each watershed
iii) The potential development impacts associated with the proposed land use change
iv) The Preferred Strategy together with an overview as to the types of measures to be implemented.



KEY MAP

LEGEND:

- Hamilton Conservation Authority
- Vacant Residential Lands (area with plans*)
- Vacant Residential Lands (area with no plans)
- Rural Settlement Area
- Potential Urban Boundary Expansion Area
- Potential New Business Park (in Existing Airport SPA)
- Expansion to Airport SPA
- Business Park/Employment Centre
- Intensification Area

NOTES:

0 5 10
Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Preferred Strategy - Hamilton Conservation Authority Watersheds
(Figure 1 of 3)

FIGURE: 10.6

DATE: 18 April 2007

Subwatershed: Sulphur Creek

Description
- headwaters located above the Escarpment, draining northerly to Cootes Paradise;
- significant amount of existing urban development (Ancaster);
- significant new urban development (13%) proposed in the headwaters

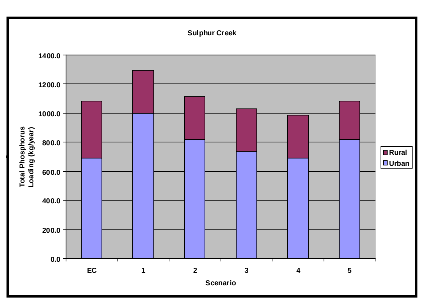
Land use	Existing	Future
urban	1,906 ha	2,453 ha
rural	2,222 ha	1,675 ha

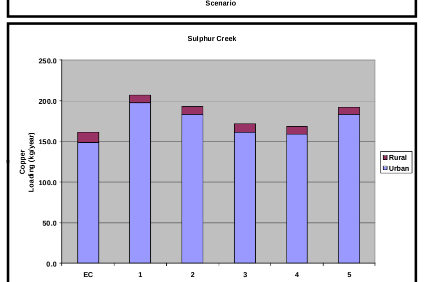
Environmental Resources
- permeable soils and groundwater recharge potential in headwaters;
- existing erosion in downstream reaches;
- warmwater and downstream coldwater fisheries;
- significant forest cover, including environmentally significant areas (ESA's) and areas of natural and scientific interest (ANSI's);

Potential Development Impacts
- hydrologic impacts including increased flow volumes (+10%), and erosion;
- increased urban contaminants (metals, etc.);
- less groundwater recharge (- 7%) and reduced baseflows in streams;
- potential negative impact to fisheries;

Preliminary Preferred Strategy and Proposed Stormwater BMP's
Preferred Strategy:
#4 - Business As Usual with Urban Retrofits

Proposed BMP's:
- infiltration BMP's
- stormwater facilities (flood, erosion, and water quality control);
- retrofit existing stormwater systems





Subwatershed: Spencer Creek

Description
- headwaters located above the Escarpment, draining easterly to Cootes Paradise;
- existing urban development within lower reaches (Dundas);
- minimal new urban development with intensification in existing urban areas;

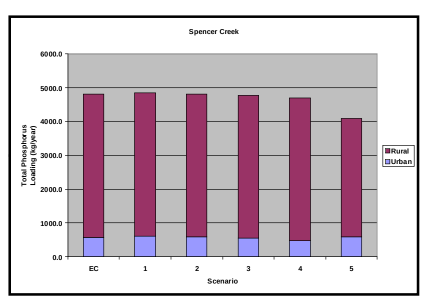
Land use	Existing	Future
urban	912 ha	941 ha
rural	16,156 ha	16,127 ha

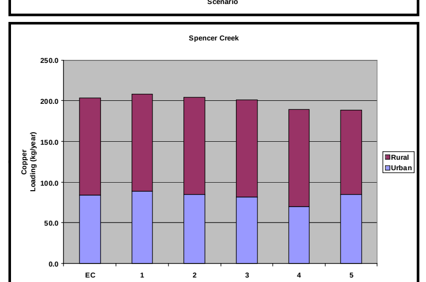
Environmental Resources
- significant areas of permeable soil and groundwater recharge potential in headwaters;
- significant amount of provincially significant wetlands (PSW's), and environmentally significant areas (ESA's), mainly located in headwaters upstream of urban development

Potential Development Impacts
- local hydrologic and water quality impacts to tributaries draining future urban development (Spring Creek) including increased flow volumes and erosion, and increased urban contaminants (metals, etc.);
- potential negative impact to fisheries;

Preliminary Preferred Strategy and Proposed Stormwater BMP's
Preferred Strategy:
#5 – Business As Usual with Rural Retrofis

Proposed BMP's:
- stormwater facilities (flood, erosion, and water quality control);
- rural BMP's





Subwatershed: Borer's Creek

Description
- primarily rural watershed draining southeasterly to Cootes Paradise;
- southern portion of Waterdown located in headwaters;
- future development proposed in southwest Waterdown;

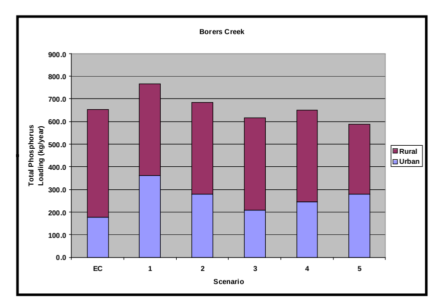
Land use	Existing	Future
urban	281 ha	541 ha
rural	1,811 ha	1,551 ha

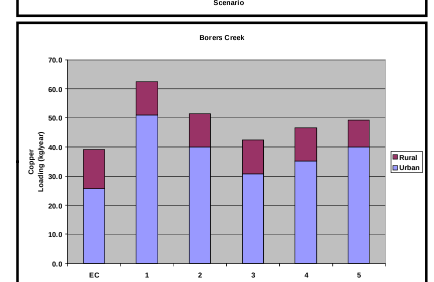
Environmental Resources
- headwaters have permeable soils and high groundwater levels;
- existing erosion;
- warmwater fishery with coldwater potential in the lower reaches;
- watershed has provincially significant wetlands (PSW's), and environmentally significant areas (ESA's);

Potential Development Impacts
- hydrologic impacts including increased flow volumes (+12%), and erosion downstream of Waterdown; increased urban contaminants (metals, etc.);
- less groundwater recharge (-6%) and reduced baseflows in streams;
- potential negative impact to fisheries;

Preliminary Preferred Strategy and Proposed Stormwater BMP's
Preferred Strategy:
#3 - Comprehensive Urbanization Approach

Proposed BMP's:
- infiltration BMP's
- stormwater facilities (flood, erosion, and water quality control)





Subwatershed: Chedoke Creek

Description
- headwaters located above the Escarpment, draining northwesterly to Cootes Paradise;
- primarily urban watershed;
- minimal new urban development (1%), with intensification in existing urban areas;

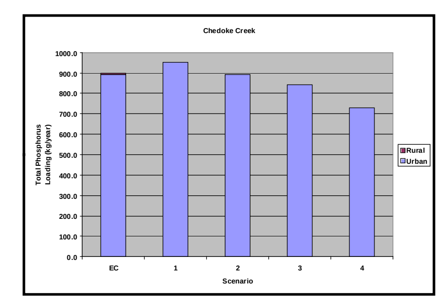
Land use	Existing	Future
urban	2,641 ha	2,657 ha
rural	16 ha	0 ha

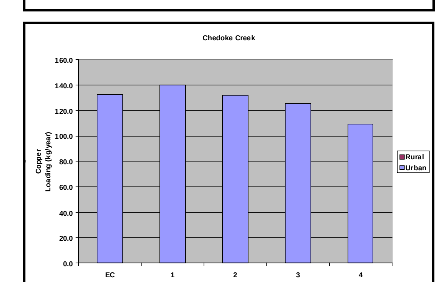
Environmental Resources
- high runoff volumes;
- existing channelized reaches;

Potential Development Impacts
- minimal impact from limited future urban development;

Preliminary Preferred Strategy and Proposed Stormwater BMP's
Preferred Strategy:
#4 – Business as Usual with Urban Retrofits

Proposed BMP's:
- stormwater facilities (flood, erosion, and water quality control);
- retrofit existing stormwater systems





KEY MAP

NOTES:

The accompanying graphs compare pollutant loading (flow X concentration) for a typical year to Existing Conditions.

Strategies:
EC = Existing Conditions
1 = Do Nothing
2 = Business as Usual
3 = Comprehensive Urbanization Approach
4 = Business as Usual with Urban Retrofits
5 = Business as Usual with Rural Retrofits

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Preferred Strategy - Hamilton Conservation Authority Watersheds
(Figure 2 of 3)

FIGURE: 10.6a

DATE: 18 April 2007

Subwatershed: Red Hill Creek

Description

- headwaters located above the Escarpment, draining northerly to Hamilton Harbour;
- primarily urban watershed;
- further urban development (17%) proposed in headwaters, including Hannon Creek and Davis Creek subwatersheds;
- intensification in existing urban areas;

Land use	Existing	Future
urban	5,571 ha	6,770 ha
rural	1,341 ha	143 ha

Environmental Resources

- groundwater recharge in headwaters provide cool baseflow to creek
- further infiltration via karst geology along the Escarpment;
- high runoff and existing channelized reaches result in downstream erosion;
- wet weather causes combined sewer overflows;
- poor water quality, including high levels of nutrients, metals, and bateria;
- many native fish species have been lost above the Escarpment;
- natural features of the valley are designated as an environmentally significant area (ESA);

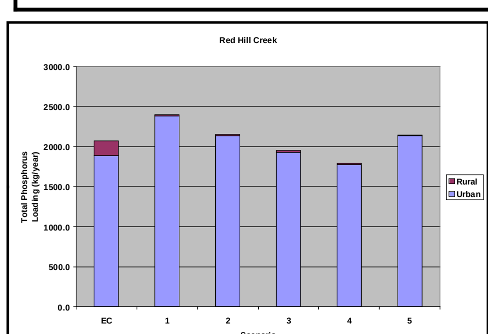
Potential Development Impacts

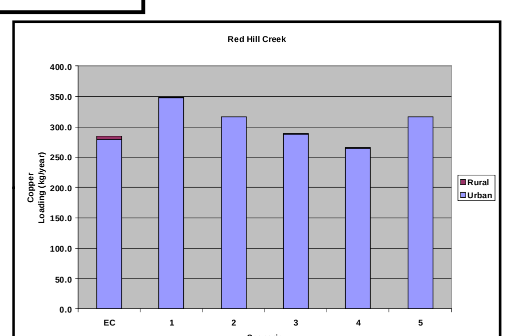
- hydrologic impacts including increased flow volumes (+ 11%), and erosion;
- increased urban contaminants (metals, etc.);
- less groundwater recharge (- 9%) and reduced baseflows in streams;

Preliminary Preferred Strategy and Proposed Stormwater BMP's

Preferred Strategy:
#4 - Business as Usual with Urban Retrofits

Proposed BMP's:
- infiltration BMP's
- stormwater facilities (flood, erosion, and water quality control);
- retrofit existing stormwater systems;
- channel restoration





Subwatershed: Community of Stoney Creek Watercourses

Description

- headwaters located along the Escarpment, draining northerly to Lake Ontario;
- urban landuses focused near the QEW corridor, with some rural lands in the southeast;
- further urban development (3%) proposed within the central and eastern Tributaries;
- intensification in existing urban areas;

Laduse	Existing	Future
urban	1,981 ha	2,088 ha
rural	1,510 ha	1,404 ha

Environmental Resources:

- some sandy deposits with groundwater recharge between Escarpment and Lake Ontario;
- water quality is characterized as impaired, with high temperatures and low dissolved oxygen;
- most streams have been channelized;
- fisheries are impaired by low baseflow, and poor water quality;
- environmentally sensitive area (ESA) located in headwaters (Escarpment) upstream of proposed future development;

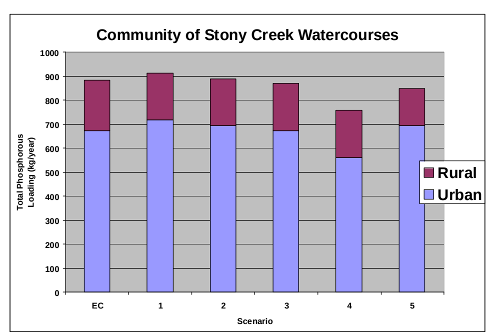
Potential Development Impacts

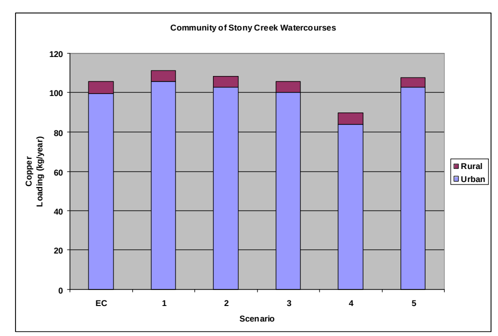
- hydrologic impacts including moderate increase in flow volumes (+ 2%), and erosion;
- increased urban contaminants (metals, etc.);
- moderate decrease in groundwater recharge (- 1%) and reduced baseflows in streams;

Preliminary Preferred Strategy and Proposed Stormwater BMP's

Preferred Strategy:
#4 - Business as Usual with Urban Retrofit

Proposed BMP's:
- infiltration BMP's
- stormwater facilities (flood, erosion, and water quality control);
- retrofit existing stormwater systems;
- channel restoration





Subwatershed: Stoney Creek

Description

- headwaters located above the Escarpment, draining northerly to Lake Ontario;
- primarily urban below the Escarpment, primarily rural above the Escarpment;
- further urban development (10%) proposed in headwaters
- intensification in existing urban areas;

Land use	Existing	Future
urban	843 ha	1,153 ha
rural	2,236 ha	1,927 ha

Environmental Resources

- headwater areas have high groundwater recharge potential where soil thickness is low;
- downstream reaches are flood-susceptible;
- fisheries are impaired by low baseflow and poor water quality;
- provincially significant wetland (PSW) / environmentally significant area (ESA) located in headwaters upstream of proposed future development;

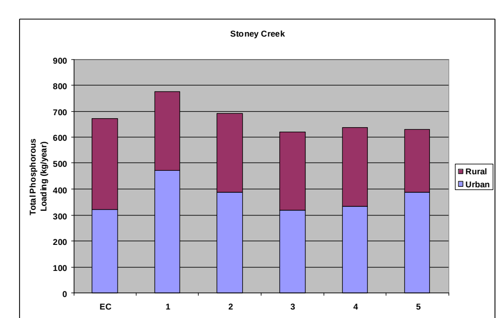
Potential Development Impacts

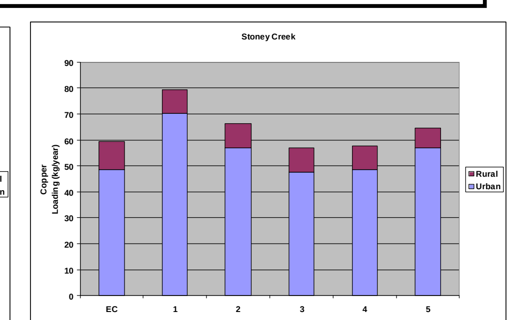
- hydrologic impacts including increased flow volumes (+ 11%), and erosion;
- increased urban contaminants (metals, etc.);
- less groundwater recharge (- 5%) and reduced baseflows in streams;

Preliminary Preferred Strategy and Proposed Stormwater BMP's

Preferred Strategy
#4 - Business as Usual with Urban Retrofit

Proposed BMP's:
- infiltration BMP's
- stormwater facilities (flood, erosion, and water quality control);
- stormwater facilities (flood, erosion, and water quality control);
- retrofit existing stormwater systems;





KEY MAP

NOTES:

The accompanying graphs compare pollutant loading (flow X concentration) for a typical year to Existing Conditions.

Strategies:
EC = Existing Conditions
1 = Do Nothing
2 = Business as Usual
3 = Comprehensive Urbanization Approach
4 = Business as Usual with Urban Retrofits
5 = Business as Usual with Rural Retrofits

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

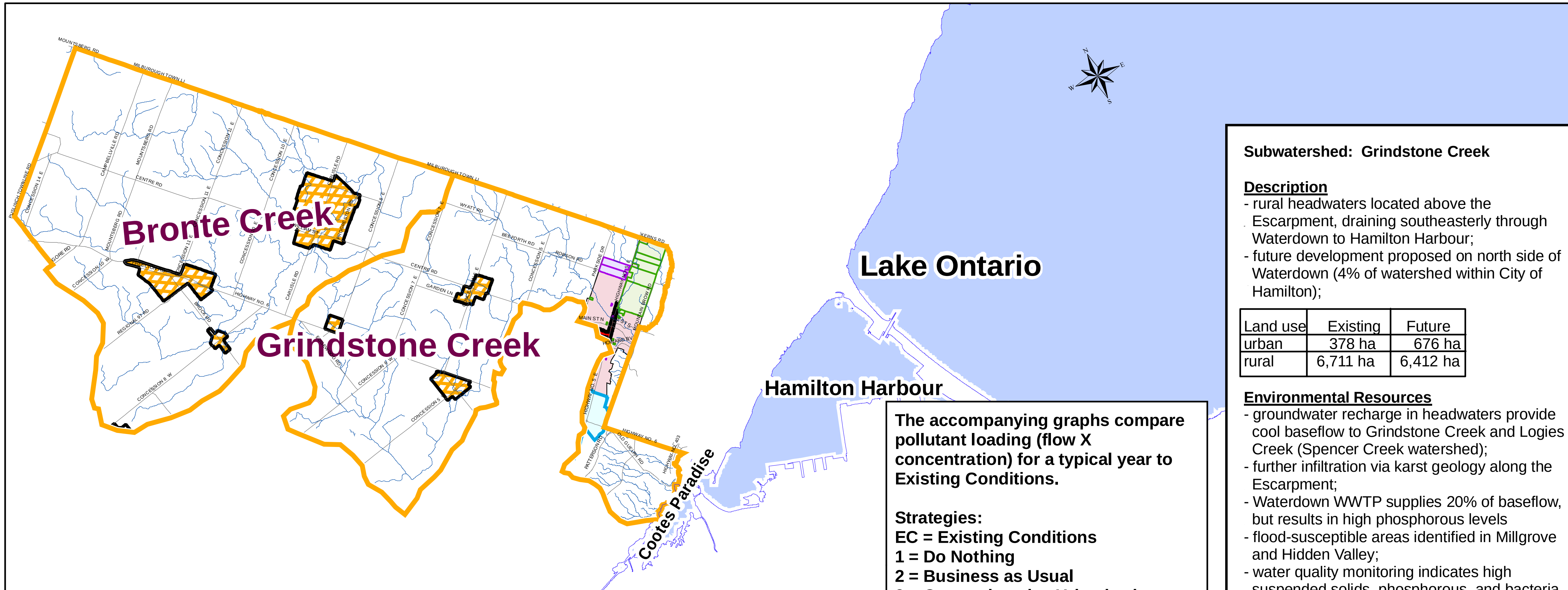
77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Preferred Strategy - Hamilton Conservation Authority Watersheds
(Figure 3 of 3)

FIGURE: 10.6b

DATE: 18 April 2007



KEY MAP

LEGEND:

- Conservation Halton
- Rural Settlement Area
- Vacant Residential Lands (area with plans*)
- Vacant Residential Lands (area with no plans)
- Intensification Area
- Business Park/Employment Centre

NOTES:

0 5 10
Kilometers

Subwatershed: Bronte Creek

Description
- headwaters located in northwest end of City of Hamilton;
- primarily rural landuses;
- no proposed future development;

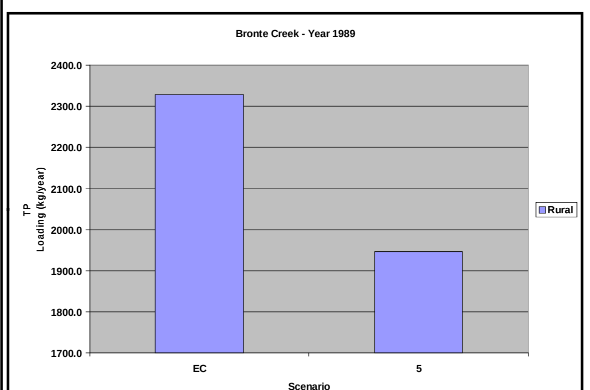
Land use	Existing	Future
urban	0 ha	0 ha
rural	8,902 ha	8,902 ha

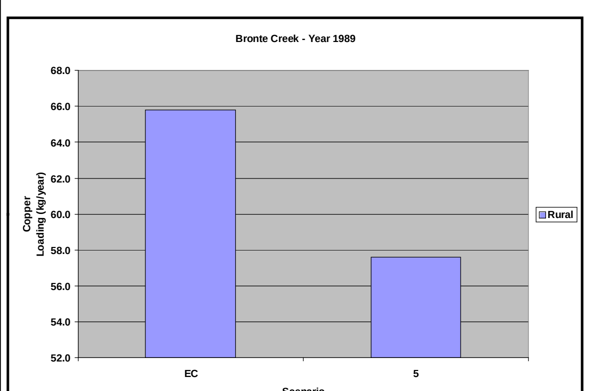
Environmental Resources
- loam and sandy loam soils provide significant groundwater recharge;
- healthy coldwater and warmwater fish communities;
- significant forest cover including environmentally significant areas (ESA's), as well as provincially significant wetlands (PSW's) and areas of natural and scientific interest (ANSI's);

Potential Development Impacts
- none

Preliminary Preferred Strategy and Proposed Stormwater BMP's
Preferred Strategy:
#5 - Business as Usual with Rural Retrofits

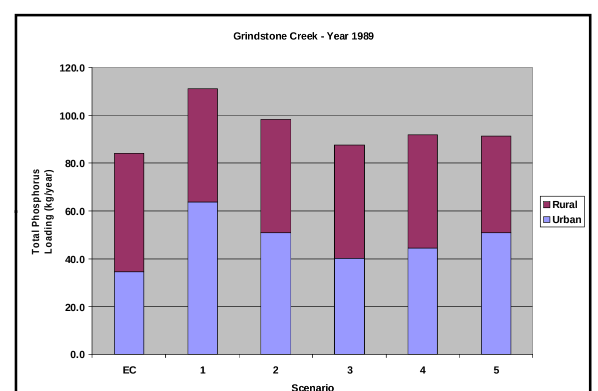
Proposed BMP's:
- rural BMP's

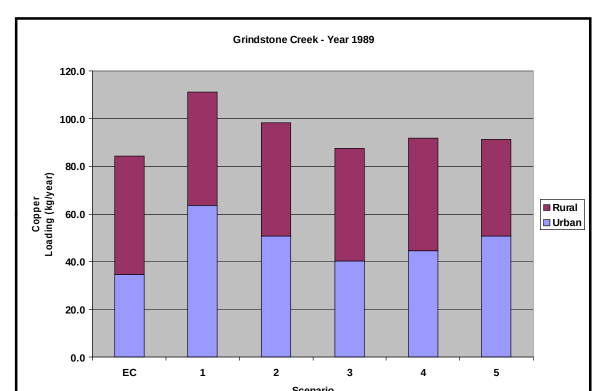




The accompanying graphs compare pollutant loading (flow X concentration) for a typical year to Existing Conditions.

Strategies:
EC = Existing Conditions
1 = Do Nothing
2 = Business as Usual
3 = Comprehensive Urbanization Approach
4 = Business as Usual with Urban Retrofits
5 = Business as Usual with Rural Retrofits





Subwatershed: Grindstone Creek

Description
- rural headwaters located above the Escarpment, draining southeasterly through Waterdown to Hamilton Harbour;
- future development proposed on north side of Waterdown (4% of watershed within City of Hamilton);

Land use	Existing	Future
urban	378 ha	676 ha
rural	6,711 ha	6,412 ha

Environmental Resources
- groundwater recharge in headwaters provide cool baseflow to Grindstone Creek and Logies Creek (Spencer Creek watershed);
- further infiltration via karst geology along the Escarpment;
- Waterdown WWTP supplies 20% of baseflow, but results in high phosphorous levels
- flood-susceptible areas identified in Millgrove and Hidden Valley;
- water quality monitoring indicates high suspended solids, phosphorous, and bacteria levels. Existing metals, pesticide and PAH concentrations are acceptable;
- high potential for erosion below the Escarpment due to steep slopes, and exposure of shale bedrock;
- coldwater fisheries downstream of the Escarpment. Above the Escarpment, the main branch and some tributaries are classified as warmwater and/or potential coldwater;
- wetlands cover approximately 13% of the watershed, including five provincially significant wetland complexes;
- forest cover accounts for approximately 25% of the watershed;
- several ESA's, primarily associated with wetlands and woodlots;

Potential Development Impacts
- hydrologic impacts including increased flow volumes (+ 8%), and erosion downstream of Waterdown;
- increased urban contaminants (metals, etc.);
- less groundwater recharge (- 2%) and reduced baseflows in streams;
- potential negative impact to fisheries;

Preliminary Preferred Strategy and Proposed Stormwater BMP's
Preferred Strategy:
#3 - Comprehensive Urbanization Approach

Proposed BMP's:
- infiltration BMP's
- stormwater facilities (flood, erosion, and water quality control)

Aquafor Beech Limited

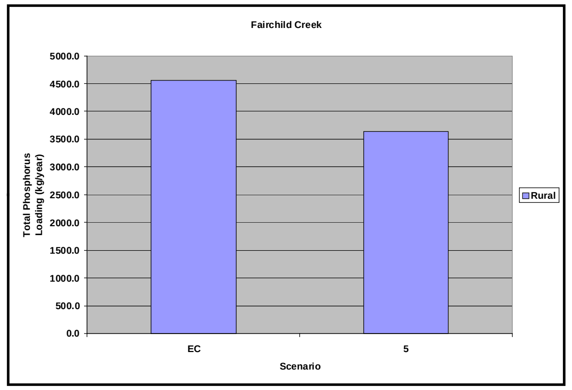
Hamilton

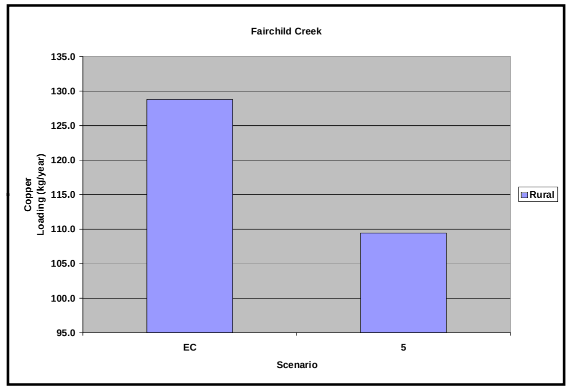
Capital Planning & Implementation Division
77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN
Preferred Strategy - Conservation Halton Watersheds

FIGURE: 10.7

DATE: 18 April 2007





Subwatershed: Fairchild Creek

Description

- headwaters located within west side of Hamilton (Glanbrook area);
- rural landuses,
- no proposed future development;

Land use	Existing	Future
urban	0 ha	0 ha
rural	17,421 ha	17,421 ha

Environmental Resources

- highly permeable soils and high groundwater recharge;
- warmwater fishery;
- significant coverage of environmentally significant areas (ESA's), provincially significant wetlands (PSW's) and areas of natural and scientific interest (ANSI's);

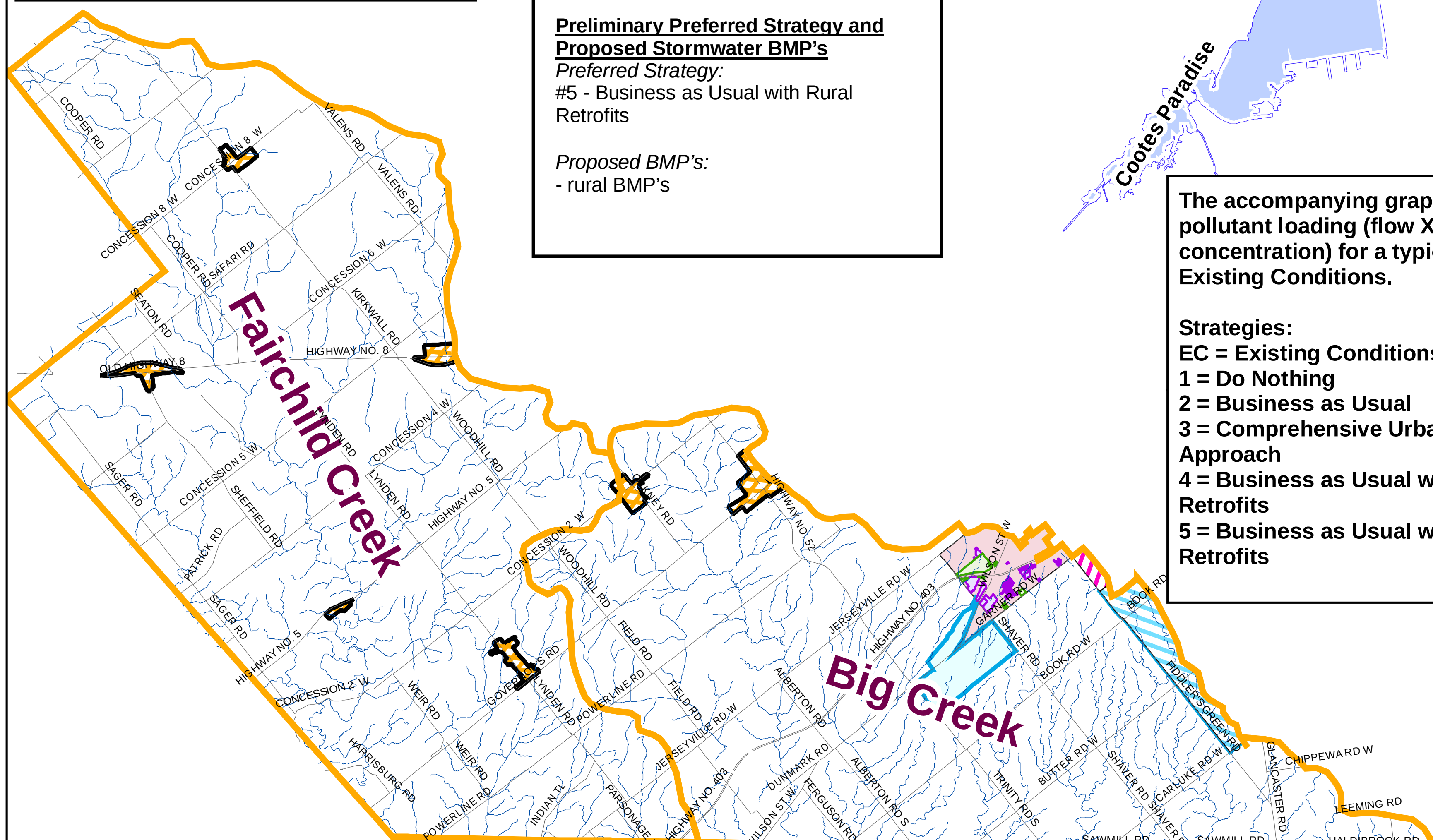
Potential Development Impacts

- none

Preliminary Preferred Strategy and Proposed Stormwater BMP's

Preferred Strategy:
#5 - Business as Usual with Rural Retrofits

Proposed BMP's:
- rural BMP's



The accompanying graphs compare pollutant loading (flow X concentration) for a typical year to Existing Conditions.

Strategies:
EC = Existing Conditions
1 = Do Nothing
2 = Business as Usual
3 = Comprehensive Urbanization Approach
4 = Business as Usual with Urban Retrofits
5 = Business as Usual with Rural Retrofits

Subwatershed: Big Creek

Description

- headwaters located near Ancaster;
- primarily rural landuses with small amount of existing development in Ancaster,
- future business park development to take place at the headwaters near Ancaster and Hamilton Airport (5 % of watershed within City);

Land use	Existing	Future
urban	431 ha	1,032 ha
rural	12,043 ha	11,442 ha

Environmental Resources

- permeable soils with high groundwater recharge at headwaters;
- warmwater fishery;
- environmentally significant areas (ESA's);

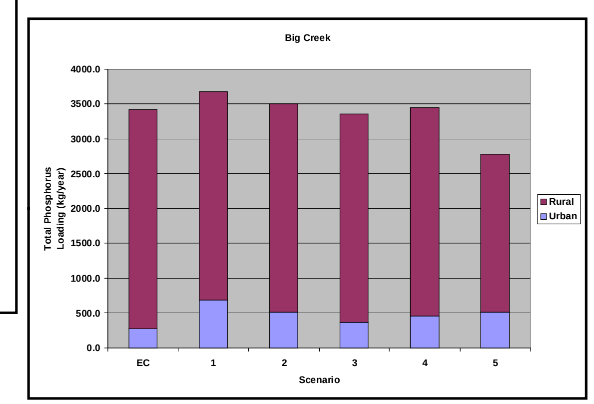
Potential Development Impacts

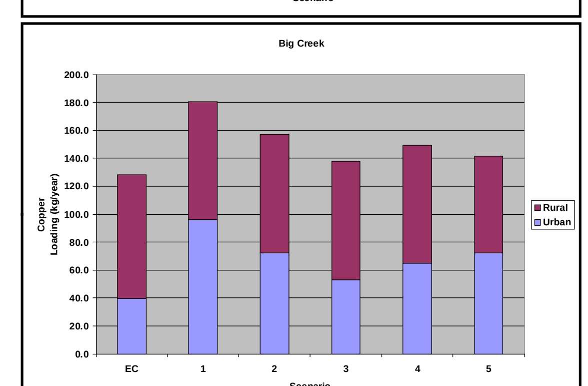
- hydrologic impacts including increased flow volumes (+ 5%), and erosion;
- significant increase in urban contaminants (metals, etc.);
- less groundwater recharge (- 4%);
- potential impact to fisheries;

Preliminary Preferred Strategy and Proposed Stormwater BMP's

Preferred Strategy:
#5 - Business as Usual with Rural Retrofits

Proposed BMP's:
- stormwater facilities (flood, erosion, and water quality control);
- rural BMP's





KEY MAP

LEGEND:

- Grand River Conservation Authority
- Vacant Residential Lands (area with plans*)
- Vacant Residential Lands (area with no plans)
- Rural Settlement Area
- Potential Urban Boundary Expansion Area
- Potential New Business Park (in Existing Airport SPA)
- Expansion to Airport SPA
- Business Park/Employment Centre
- Intensification Area

NOTES:

0 5 10
Kilometers

Aquafor Beech Limited

Hamilton

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

STORMWATER MASTER PLAN

Preferred Strategy - Grand River Conservation Authority Watersheds

FIGURE: 10.8

DATE: 18 April 2007

Subwatershed: Forty Mile Creek

Description

- headwaters located in east end of City of Hamilton;
- rural landuses;
- no proposed future development;

Land use	Existing	Future
urban	0 ha	0 ha
rural	1,986 ha	1,986 ha

Environmental Resources

- warmwater fishery;
- portion of a provincially significant wetland (PSW) and environmentally significant area (ESA) located within the subwatershed;

Potential Development Impacts

- none

Preliminary Preferred Strategy and Proposed Stormwater BMP's

Preferred Strategy:
#5 - Business as Usual with Rural Retrofits

Proposed BMP's:
- rural BMP's

Subwatershed: Welland River

Description

- primarily rural landuses;
- future business park development to take place at the headwaters near Hamilton Airport (13 % of watershed within City)

Land use	Existing	Future
urban	431 ha	1,779 ha
rural	10,103 ha	8,755 ha

Environmental Resources

- warmwater fisheries impaired by existing barriers;
- degraded water quality including high suspended solids, nutrients, and bacteria levels;
- watershed has provincially significant wetlands (PSW's), environmentally significant areas (ESA's), and areas of natural and scientific interest (ANSI's); lack of forest cover and wetlands;

Potential Development Impacts

- significant hydrologic impacts including increased flow volumes (+ 17%), and erosion; significant increase in urban contaminants (metals, etc.);
- reduction in groundwater recharge (approx. 10%) and reduced baseflows in streams; potential impact to fisheries;

Preliminary Preferred Strategy and Proposed Stormwater BMP's

Preferred Strategy:
#3 - Comprehensive Urbanization Approach

Proposed BMP's:
- infiltration BMP's
- stormwater facilities (flood, erosion, and water quality control)

Subwatershed: Twenty Mile Creek

Description

- headwaters located within south side of Hamilton (Glanbrook area);
- primarily rural landuses,
- significant (21%) future development potential;

Land use	Existing	Future
urban	511 ha	2,849 ha
rural	10,474 ha	8,136 ha

Environmental Resources

- karst geology;
- diverse warmwater fishery;
- low baseflow, resulting in intermittent flow conditions;
- flood-susceptible areas located downstream of Hamilton;
- high nutrient levels;
- watershed has provincially significant wetlands (PSW's), environmentally significant areas (ESA's), and areas of natural and scientific interest (ANSI's);

Potential Development Impacts

- significant hydrologic impacts including increased flow volumes (+ 17%), and erosion;
- significant increase in urban contaminants (metals, etc.);
- reduction in groundwater recharge (approx. 10%) and reduced baseflows in streams;
- potential impact to fisheries;

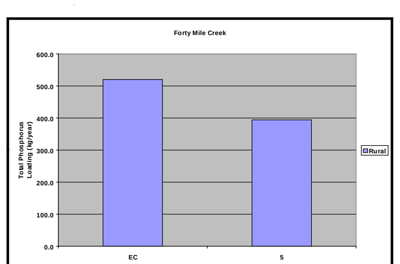
Preliminary Preferred Strategy and Proposed Stormwater BMP's

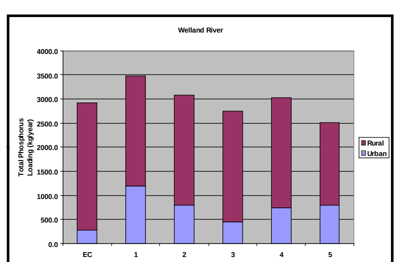
Preferred Strategy:
#3 - Comprehensive Urbanization Approach

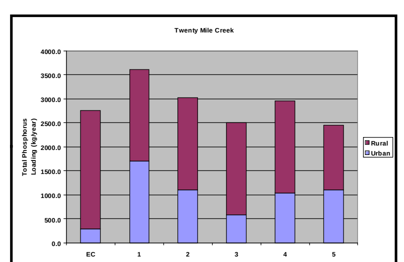
Proposed BMP's:
- infiltration BMP's
- stormwater facilities (flood, erosion, and water quality control)

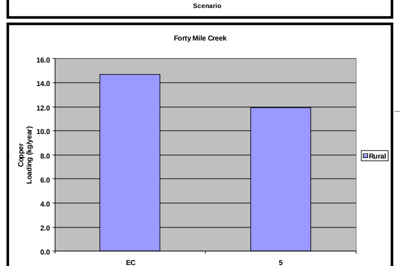
The accompanying graphs compare pollutant loading (flow X concentration) for a typical year to Existing Conditions.

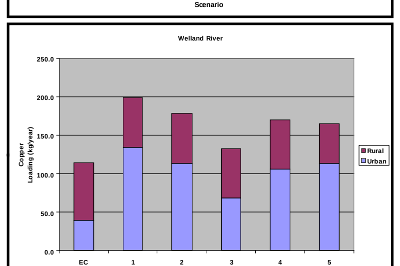
Strategies:
EC = Existing Conditions
1 = Do Nothing
2 = Business as Usual
3 = Comprehensive Urbanization Approach
4 = Business as Usual with Urban Retrofits
5 = Business as Usual with Rural Retrofits

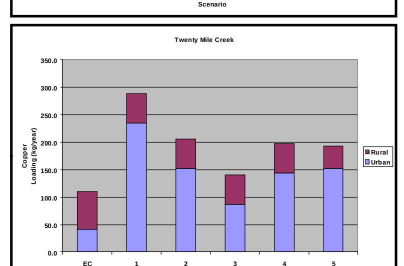


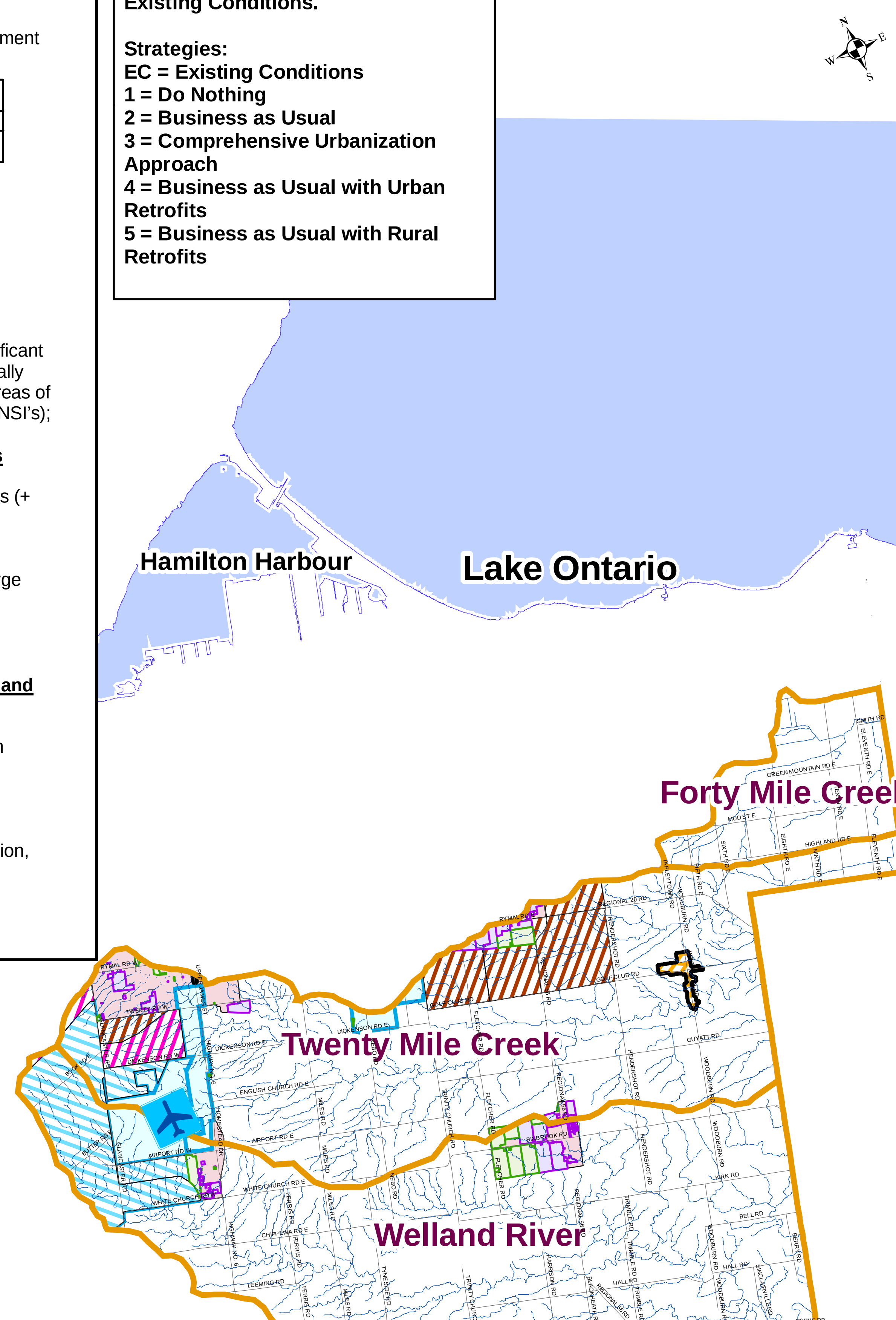












KEY MAP

LEGEND:

- Niagara Peninsula Conservation Authority
- Vacant Residential Lands (area with plans*)
- Vacant Residential Lands (area with no plans)
- Rural Settlement Area
- Potential Urban Boundary Expansion Area
- Potential New Business Park (in Existing Airport SPA)
- Expansion to Airport SPA
- Business Park/Employment Centre
- Intensification Area

NOTES:

0 5 10
Kilometers

Aquafor Beech Limited

Capital Planning & Implementation Division

77 James Street North
Hamilton ON
L8R 2K3
Phone: (905) 546-2424
Fax: (905) 546-4435

Hamilton

STORMWATER MASTER PLAN

Preferred Strategy - Niagara Peninsula Conservation Authority Watersheds

FIGURE: 10.9

DATE: 18 April 2007

11.0 IMPLEMENTATION

11.1 General

The previous chapters have, collectively:

- Identified a number of environmental and storm sewer infrastructure problems;
- Defined existing environmental conditions within each of the 15 watersheds;
- Established the level of service for the separated storm trunk sewer system;
- Defined the study principle, goals and objectives,
- Described the Recommended Growth Option, together with the potential impacts that may result due to land use changes;
- Defined and evaluated Alternative Management Strategies to address existing and future development; and
- Described the Preferred Management Strategy

This chapter provides recommendations on how to implement the City of Hamilton Stormwater Master Plan. In summary, implementation of the Preferred Management Strategy will, as compared to existing conditions, result in:

- Improved water quality conditions;
- Protection of the level of service provided by the existing storm sewer system;
- Improved conditions for resident fisheries and wildlife;
- Reduced potential for erosion; and
- Enhanced groundwater supply

During the course of the study, we arrived at the conclusion that current development practices are not sustainable; we therefore need to change the way we do things if growth is to continue. Furthermore, restoration plans in existing urban and rural areas need to be implemented if the study objectives are to be met.

In this regard, a practical and implementable framework which introduces the changes needed in order to ensure a balance between the impacts associated with existing land uses and proposed development and the social, economic and environmental requirements must be presented if the objectives of the Stormwater Master Plan are to be achieved.

The question then becomes, how is change implemented for new development? And, how do we change our approach and find funding alternatives needed to restore/retrofit existing rural and urban areas?

Change in the context of this study refers to a number of items, including:

- Changing the mindset of consultants, the municipality, developers and agencies with respect to the current approach for undertaking stormwater management;
- The requirement to develop a progressive approach for integrating stormwater management measures into subdivision/site planning and design
- Revisiting/modifying existing municipal and agency policies and standards;
- Initiating pilot projects for stormwater management measures (e.g. green roofs, roof downspout disconnection; filtration systems, alternative municipal infrastructure systems);

- Considering alternative sources of funding for the proposed measures in order to ensure that the requirements as outlined are funded in a sustainable manner; and
- Consideration of incentives (credits) for progressive submissions.

This chapter describes the activities which must be undertaken if the Preferred Strategy is to be successfully implemented. In preparing the Implementation Plan, the following points were considered:

- Implementation must consider issues associated with the urbanizing areas and for existing land uses.
- The Implementation Plan must be flexible and realize that the approach to Watershed and Subwatershed planning will change as the knowledge base advances, that future studies will refine the findings from this study and that the natural environment is not a static system.
- Implementation must be consistent with the other components of the study, and recognize existing and proposed land uses.
- The success associated with implementing various steps will not only be dependent upon the development community, municipality and agencies, but will also be strongly dependent upon the support of residents within the watershed; and
- The Implementation Plan, as presented, is a starting point; it is fully expected that an Implementation Committee involving several City departments, the four Conservation Authorities and key stakeholders, will be formed and that this group will ensure that the Plan is advanced, implemented, updated and revised as appropriate.

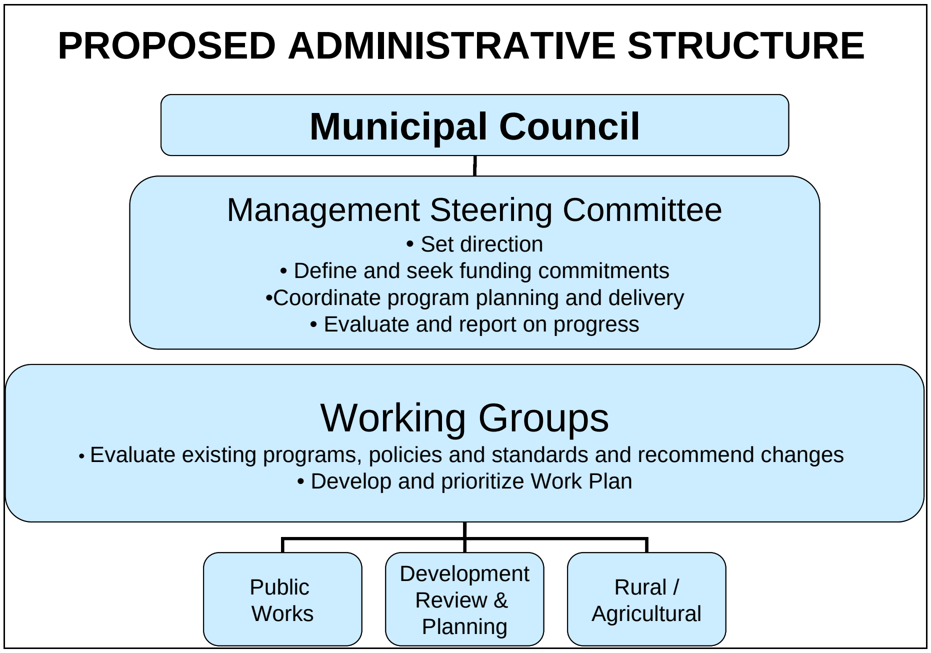
This chapter will provide implementation considerations for each type of measure, policy review and implications, administration, direction for future studies and staffing requirements.

11.2 Stormwater Master Plan Implementation

The Master Plan, as presented, is consistent with the requirements of the Municipal Class Environmental Assessment process and the GRIDS process. The completion of this plan together with the Water/Wastewater and Transportation Master Plans was a cooperative effort involving staff from several departments within the City, staff from each of the four Conservation Authorities, special interest groups and representatives from the public.

The recommendations as provided in this chapter were presented and discussed with the above noted groups and, as such, do provide a framework for implementing the plan. However, as noted in the previous section, it is recommended that the appropriate administrative structure be put in place in order to guide and oversee the implementation of the Strategy.

In terms of administration, it is recommended that a two tiered committee structure be formed. The structure would include a Management Steering Committee (MSC) and a number of Working Groups (WGs).



The overall objective of the Management Steering Committee and Working Groups would be to "promote and facilitate cooperative and collaborative efforts and actions by all public agencies that have a role in watershed management."

The objectives, general types of participants and frequency of meetings is summarized below for the Management Steering Committee and the Working Groups.

Management Steering Committee (MSC)

Objectives:
- Receive updates from the Working Groups
- Coordinate program planning and delivery
- Define funding alternatives and priorities
- Prepare progress reports on Implementation
- Prepare budget requests

Participants:
- Middle / Senior Management from municipality and agencies
- Council Members

Frequency of Meetings:
- Twice annually, one of which is prior to budget preparation

Working Groups (WGs)

Objective:
- Evaluate existing programs, policies, standards and recommend changes

Types of Groups:
- Public Works Group

- Development Review and Planning Group
- Rural / Agricultural Group

Participants:
- Municipality
- Agencies
- Development Groups
- Special Interest Groups
- Residents

Frequency of Meetings:
- As required, until program is up and running
- Twice annually thereafter

11.3 The Implementation Plan

11.3.1 General

The proposed measures which comprise the Preferred Strategy were presented in Chapter 10. The objective of this section is to outline the general steps that are required in order to implement each type of measure (i.e. source controls, rural measures).

Table 11.1 summarizes the types of different measures that form the Preferred Management Strategy. Also provided in the table are:

Key Next Steps: The key steps that need to be undertaken in order to continue the existing measure or to kick start a new program

Facilitator: The agency or group that will coordinate efforts to implement the measure

Contributor: The agency(ies) or groups(s) that will assist in implementing the measure by providing support in any number of ways, e.g., funding, labour, materials, technical expertise

Policy Consideration: Existing or proposed policies, standards that need to be considered

Implementation Mechanisms: Alternative methods for implementing the programs or measures

Time Frame: General timeframes; short (0-10 years), medium (11-20 years), and long (21-30 years) years, which reflect general prioritization for the steps needed to implement the measure.

Cost: Approximate cost of the measure assuming traditional funding sources (e.g. primarily municipal/provincial agency). It should be noted that the use of special interest groups and/or members of the public to implement several proposed measures and the pursuit of additional funding sources (e.g. provincial, federal, environmental foundations) may reduce funding requirements

Funding: Present source of funding for proposed measure

Funding Alternatives: General funding alternatives

Comments: Any other information/consideration relevant to implementation

Table 11.1: Implementation Considerations

Type	Key Next Steps	Facilitators/Contributors	Policy/Standards Considerations	Implementation Mechanisms	Time Frame	Cost	Present Funding	Funding Alternatives	Considerations
Source Control Program for Existing Urban Areas	• Review other Municipal Programs • Prioritize program • Undertake pilot project • Define successes and shortcomings • Define funding alternatives and requirements	City, residents and business groups	• Development of BMP standards • Criteria and Guidelines for Infrastructure Design	• City to develop guidelines, brochures, how to manuals/guides	Short, medium, long	$35,000,000	• none	• Municipal • Homeowners • Businesses • Environmental foundations • Federal	• The cost as shown is generally funded by the City's homeowners and businesses
Conveyance Control Programs for Existing Urban Areas	• Review programs in other jurisdictions • Define technical standards • Undertake pilot projects • Integrate into other programs • Define funding requirements	City	• Incorporate into Engineering Guidelines, Stormwater Infrastructure Design	• Incorporate costs into ongoing road reconstruction programs	Short, medium, long	$32,000,000	• Road reconstruction program	• Road reconstruction program	
Retrofitting Existing Stormwater Management Facilities	• Define funding alternatives • Undertake detail design • Implement proposed program	City	• Assess funding alternatives • Prepare Guidelines for Landscaping	• Undertake design, construction of prioritized facilities	Short, medium, long	$19,140,000	• Municipal Tax Base	• Cash in lieu • Storm Sewer Tax Rate • Municipal Tax Base • Development Charges • Federal	
Stream Restoration Program	• Undertake City wide stream restoration assessment • Undertake detail design • Implement proposed program	City, Conservation Authorities	• Assess funding alternatives • Define process for private property works	• City to develop Terms of Reference • City/CA's to coordinate implementation of program	Short, medium, long	$20,000,000 plus projects to be identified	• Development Charges	• Development Charges • Municipal Tax Base • Storm Sewer Tax Rate	• Funding allocated in DC study for 45 sites • Additional funding required for other areas
Best Management Practices for Proposed Developments	• Undertake subwatershed studies • Review recent approaches in other jurisdictions • Promote integrated approaches • Undertake pilot projects • Use working groups to update/modify standards/policies • Update funding requirements • Consider incentives for progressive submissions	City, Conservation Authorities, Consultants, Developers	• Various engineering, planning, landscape architectural policies, standards	• City, CA to approve Terms of Reference for Subwatershed Studies • City to update policies, standards	Short, medium, long	See comment under considerations	• Development Charges	• Development Charges	• A cost estimate has not been provided as the cost is generally attributed to proposed development through the Development Charges
Storm Sewer System Upgrades to offset Intensification	• Determine feasibility of on-site storage for different types of proposed development proposals • Coordinate potential City-wide source/conveyance program with Source Control program (see above) • Develop approach for different types of proposed developments	City	• As per source control	• As per source control	Short, medium, long	$50,000,000 to $100,000,000	• Development Charges • Road Reconstruction Programs	• Development Charges • Road Reconstruction Programs	• Costs shown assume on-site measures or City-wide source/conveyance measures are not implemented
Rural Stewardship Program	• Canvas landowners in target areas for support • Implement demonstration projects in high priority areas	City, Conservation Authorities, Landowners	• Nutrient Management Act • Clean Water Act • Remedial Action Plan (Great Lakes Water Quality Agreement)	• CA's have mechanisms in place	Short and medium	$40,000,000	• CA funding • RAP funding • Federal – Provincial funding	• Municipal funding	• Costs assume 50% funding by landowners; 50% by City / other partners

11.3.2 Source Control Measures

Source Control Measures are physical measures that are located at the beginning of a drainage system; generally on private property. Source controls can be installed within a variety of land uses including residential, commercial, industrial and institutional properties. Source control measures can be retrofit into existing areas and implemented in urbanizing areas.

Implementation of a variety of source control measures has become more common in the last decade. One of the key factors impacting the success of source control programs is the willingness to implement by landowners. In this regard, many municipalities have initiated pilot projects to define variables such as the landowners' awareness of the impacts from stormwater, their willingness to implement, and the importance of public funding to the adoption rates for each of the proposed measures. Other municipalities have developed programs involving how-to manuals, in-house assistance and financial programs in order to kick start the programs.

Existing efforts within the City to undertake a source control program have been limited. The primary group to implement this program would be the City. The groups that would be involved include Plant Capital and Planning, Strategic and Environmental Planning and Development Engineering. Other municipalities have had success in kick starting programs by involving local resident groups (particularly those who have experienced flooding) and businesses.

At the onset, the City will need to develop guidelines, brochures and how to manuals/guides in order to initiate programs. As the program progresses standards for individual Best Management Practices (e.g. downspout disconnection, green roofs) will be developed. The initial steps, as summarized below, would be initiated in the first few years of the program. Implementation would occur over the medium to long term.

The total cost of the program is estimated to be $35,000,000. Experience from other jurisdictions has shown that the cost is split between the municipality, homeowners and businesses.

In summary, the proposed Source Control Program would involve the following steps:

- Review Source Control Programs that have been undertaken by other jurisdictions;
- Define the framework of the proposed program (based on the overall measures and uptake rates identified in this study; and prioritize key elements (e.g.: downspout disconnection, tree planting);
- Define the funding alternatives and requirements;
- Select a pilot area(s) and undertake a public education program; and
- Define the success and shortcomings and then modify / expand the program.

11.3.3 Conveyance Control Measures

Conveyance control measures are physical measures that are located within the road right-of-way where flows are concentrated and being conveyed. Conveyance measures include swales, ditches, culverts, catch basins, manholes and storm sewers.

The primary objective for this strategy is to incorporate infiltration measures into the design of the conveyance system. For existing or urbanizing areas this may include the incorporation of a perforated pipe system into the design of the storm sewer system or enhanced use of grass swales or vegetated buffer strips in order to maximize infiltration opportunities.

Incorporation of conveyance control measures for urbanizing areas should be considered as part of the planning and design process.

For existing urban and rural areas, the opportunity to incorporate conveyance control measures will likely come as a result of redevelopment pressures (which require replacement of the infrastructure) or replacement due to the deteriorating condition of the infrastructure. In the latter case, replacement of the drainage infrastructure may well occur as part of the overall reconstruction of the roadway.

A number of municipalities (including Ottawa, Niagara-on-the-Lake, and Toronto) have undertaken studies and pilot projects in order to determine the feasibility and effectiveness of alternative conveyance systems. The results of several pilot projects have been published as part of the Stormwater Assessment Monitoring and Performance (SWAMP) program.

The primary groups within the city that would implement this program would be the Plant Capital and Planning, Strategic and Environmental Planning, Development Engineering, Design and Operation and Maintenance.

The initial steps, as summarized below, would involve review of projects in other municipalities, definition of technical standards and undertaking pilot projects. Design for systems to be constructed in tight (silts, clays) soils needs to be given consideration. The initial steps of the program would take place in the short term while implementation would occur over the medium to long term.

The total cost of the program is estimated at $32,000,000. This cost is based on the assumption that infiltration systems would be incorporated into 15 percent of reconstruction or redevelopment projects.

In summary, the key initial steps would include:

- Review programs that have been undertaken in other jurisdictions;
- Define the technical requirements and the design standards that are needed for a variety of alternative conveyance systems;
- Define funding implications;
- Undertake pilot projects for various settings (i.e.: different soil types, urban and rural cross sections); and
- Integrate the alternative conveyance systems into other programs; particularly road reconstruction.

11.3.4 End of Pipe Measures

End of pipe measures include Best Management Practices that are installed at the end of the storm sewer system prior to discharging to the stream or river. Typical end of pipe measures which are used to treat stormwater include stormwater ponds (dry or wet), wetlands or infiltration basins.

A number of end of pipe facilities have been proposed for urbanizing areas within the existing urban boundary as part of the 2006 Development Charges Study. These measures, together with others, will be discussed in Section 11.3.6.

This study also prioritized retrofitting 29 existing stormwater management facilities to improve water quality and reduce downstream erosion (see section 10.4).

The steps in this program would involve defining funding alternatives, undertaking preliminary and detail design of the proposed facilities and implementing the program. This study met schedule B requirements under the Municipal Class Environmental Assessment process. The preliminary and detail design should continue the public consultation process in order that potential issues with respect to safety, West Nile Virus, construction implications and impact on property values are addressed.

The total cost to undertake this program is estimated at $21,000,000. The present sources of funding include the Municipal Tax Base. A variety of potential funding alternatives (see also Section 11.5) exist. These include cash-in-lieu, development of a Storm Sewer Tax Rate and Development Charges. A few Federal programs (Green Municipal Fund and Great Lakes Renewal Fund) may also assist in funding.

The primary groups involved in this program would be Plant Capital and Planning, Strategic and Environmental Planning, Development Engineering, Design, Operation and Maintenance and Open Space Development and Parks Planning.

In summary, the key steps to undertake the End of Pipe program would include:

- Define funding requirements and alternatives
- Undertake preliminary and detail design of the proposed facilities
- Implement the proposed program

11.3.5 Stream Restoration Measures

Stream restoration measures are undertaken in order to restore degraded reaches as a result of hydrologic, water quality or erosive impacts associated with urbanization. The works may be undertaken in order to protect public property, infrastructure or safety, or to improve aquatic or terrestrial habitat.

The 2006 Development Charges Update Study identified a total of 53 projects that are required as a result of proposed development within the existing urban boundary. This study completed the Schedule B requirements for these projects. As noted in Section 10.5 the geographic extent of this study was limited to areas within, or downstream, of proposed development within the current Official Plan.

A review of existing information and discussions with City and Conservation Authority staff suggested that erosion problems do exist within other areas of the City. It is therefore recommended that a Stream Restoration Assessment study on a City-wide basis be undertaken. The primary objectives of this study would involve defining existing stream conditions, identifying areas of concern, prioritizing works and developing an implementation plan. The study should be undertaken under the Class Environmental Assessment process and include representatives from the City and Conservation Authorities. An outline of the proposed study is provided in Appendix E. The estimated cost is $100,000.

The steps in this program would involve undertaking a City-wide study, undertaking preliminary and detail design of the proposed works and implementing the program. This study met Schedule B requirements for the projects identified in the 2006 Development Charges Update Study. The preliminary and detail design should continue the public consultation program in order to address potential issues with respect to land ownership, construction implications and design alternatives.

The total cost to undertake the program as identified in the 2006 Development Charges Update Study is estimated at $20,000,000. The present source of funding for these works is Development Charges. Potential funding alternatives for other works that would be identified through the City-wide study include the Municipal Tax Base, Storm Sewer Tax Rate and Development Charges.

The primary groups involved in this program would be Strategic and Environmental Planning, Design, Open Space Development and Parks Planning and Operation and Maintenance.

In summary, the key steps to undertake the Stream Restoration program would include:

- Undertaking a City-wide Stream Restoration Assessment Study
- Identify funding alternatives
- Undertaking preliminary and detail design of the proposed projects
- Implementing the proposed program

11.3.6 Best Management Practices Program for Proposed Developments

The present focus for stormwater management for proposed developments is to construct a stormwater management facility to reduce flooding potential, reduce impacts associated with erosion and protect water quality. A wide range of source, conveyance and end of pipe Best Management Practices have been recommended (in this study) in order to address issues with respect to water balance, sewer capacity, basement, surface and watercourse flooding, erosion and water quality as a result of urbanization.

Successful implementation of this component of the study will require changing the mindset of consultants, the municipality, developers, and agencies with respect to the current approach and focus for undertaking stormwater management.

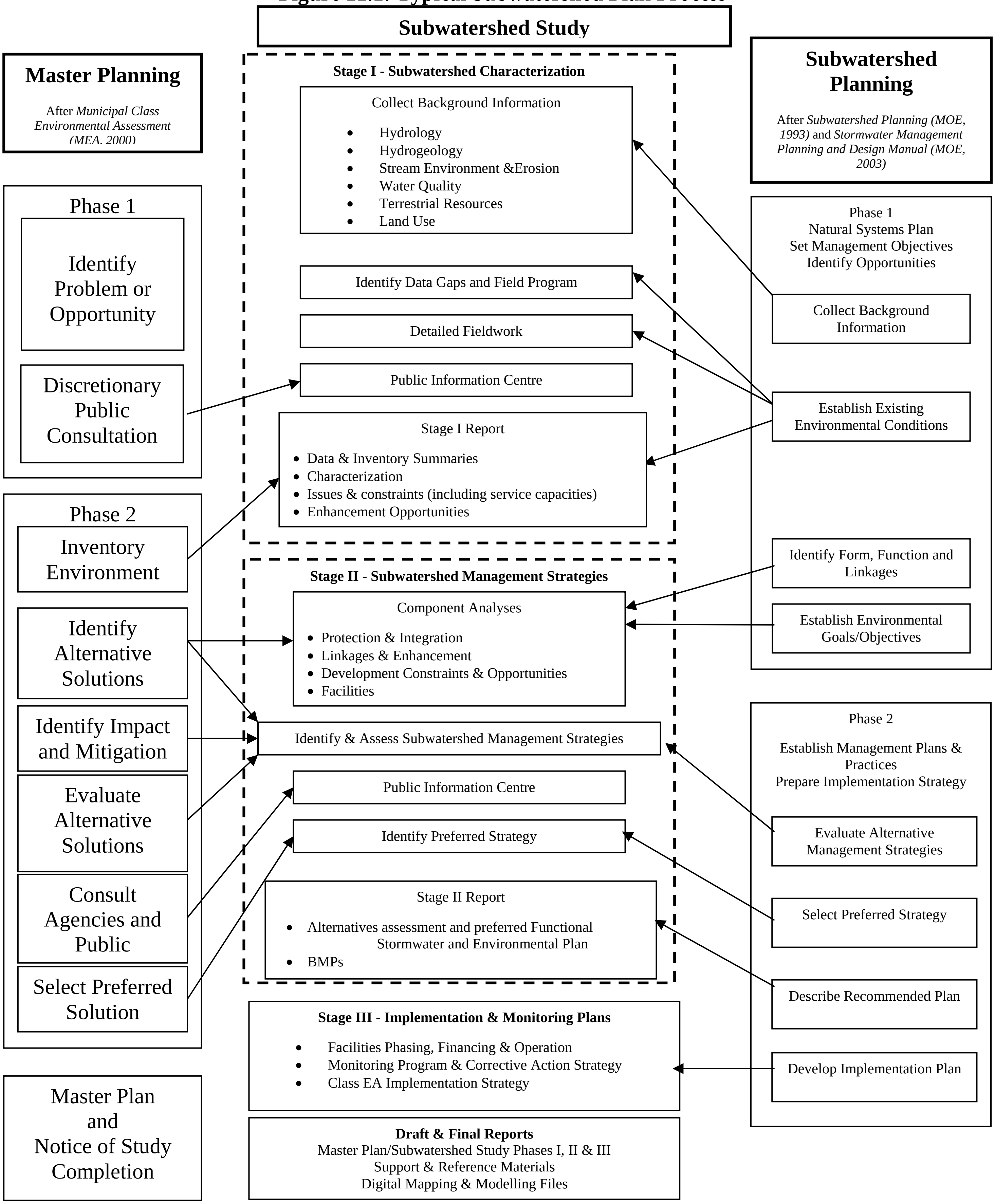
The initial steps in this program will involve:

- Undertaking subwatershed studies to refine the recommendations of this study, to address the impacts of urbanization and to determine the preferred approach
- Review recent approaches in other jurisdictions
- Promote a progressive approach for integrating stormwater management measures into subdivision/site planning and design;
- Using the Working Groups to update and modify current standards and policies
- Update funding approaches and requirements to reflect new approaches
- Consider incentives (credits) for progressive submissions

This study provides direction with respect to the proposed approach and focus for each of the 15 watersheds within the City (see Chapters 8 and 10). The City should continue with their current process of undertaking more detailed subwatershed studies. Typically, these studies are carried out in two phases as shown in Figure 11.1.

The primary groups that would participate in this program would be Plant Capital and Planning, Strategic and Environmental Planning, Development Engineering, Design, Operation and Maintenance and Open Space Development and Parks Planning.

Figure 11.1: Typical Subwatershed Plan Process



These studies, where possible, should be undertaken by the City and coordinated with the appropriate Conservation Authority. They should also, as is presently done, fulfill the first two phases of the Municipal Environmental Assessment process.

Recently, a number of progressive approaches for implementing stormwater have been undertaken in other jurisdictions. These include the installation of biofilters, sand filters, green roofs, and porous pavements as well as the concept of Low Impact Development.

Several municipalities have also undertaken progressive studies for integrating stormwater management measures into subdivision site planning and design. These approaches have resulted in cost and land savings and resulted in an integrated design based on planning, engineering and landscape architecture principles.

City staff should review these approaches, together with recent initiatives within the City in order to initiate the change in mindset.

The Working Groups and Management Steering Committee should coordinate program planning and delivery, update current standards and policies and update funding approaches and requirements to reflect changes as they occur.

Currently funding for these measures is dealt with through Development Charges. As noted above, it is likely that the current approach will likely have to be updated as new measures are incorporated into the development process.

11.3.7 Storm Trunk Sewer Upgrades

The Recommended Growth Option includes 26,500 units to be constructed as part of an intensification process identified within GRIDS. Three general alternatives for addressing the impacts of intensification on sewer system capacity were identified in Section 10.6. These include provision of on-site controls, undertaking source and conveyance control measures on a City-wide basis or upgrading existing infrastructure in order to accommodate the increase in flows associated with intensification.

The initial steps for this program will likely involve a review of recent intensification submissions to confirm the feasibility for different types of developments to provide on-site storage. The potential to offset impacts of proposed intensification by implementing a City-wide source and conveyance program should also be considered and could be coordinated with the source control program as discussed in Section 11.3.2. Once these steps have been completed, a coordinated program which provides guidelines and standards for each different type of proposed development should be developed. An update to the existing funding approach should also be undertaken.

The total cost to upgrade the existing storm trunk sewer system in order to offset impacts associated with intensification is estimated to be $50,000,000 to $100,000,000. This cost assumes that on-site measures or source/conveyance control programs are not implemented. Existing and proposed funding alternatives include Development Charges and Storm Sewer Infrastructure Programs.

11.3.8 Rural Stewardship Program

The focus of implementation of Rural BMP’s on agricultural lands is on stewardship initiatives, building on the current efforts of the four conservation authorities: GRCA, NPCA, HCA and Conservation

Halton (CH). The recommended plan is to implement non-structural rural BMP's on 50% of the farms within the City. This would require that implementation of the existing programs be accelerated, through the addition of municipal funding.

Within the rural portions of the watersheds, there are a number of high priority areas for implementation as follows:

- Intensive Agricultural lands (about 40,000 ha): these are generally lands used for crops such as corn, soybeans, market gardening, nurseries, etc. Conservation Farming BMP's would be implemented on these lands, with 3 m buffer strips (each side) along all unclassified streams.
- Cold and warm water streams (120 km): these are the larger watercourses that provide important fish habitat. Rural BMP's to be implemented would include livestock fencing, stream buffers (minimum 15 m (each side)), and off-stream watering sites.

In addition, there are approximately 30,000 ha of agricultural land that is considered moderate priority areas for implementing rural BMP's. For the unclassified streams, 3m wide buffer strips, as recommended under the Nutrient Management Act would be recommended, combined with conservation farming BMP's

With approximately 80,000 ha of agricultural land within the City of Hamilton, significant environmental benefits can be achieved through the implementation of an agricultural stewardship program. The focus of the Rural BMP program is on non-structural measures, including livestock fencing, buffer strip plantings, conservation tillage practices, nutrient management, clean water diversion and farmyard runoff control.

All four conservation authorities are actively implementing agricultural stewardship programs by combining funding programs from Remedial Action Plans, federal, provincial and even corporate/non-government agencies to encourage farmers to change their agricultural practices. While regulatory measures are in place to address agricultural sources of pollution through the Nutrient Management Act, stewardship measures and incentive programs have proven to be the most effective approach. Despite the existence of many funding programs, available resources fall short of meeting the need. Water quality modeling showed significant reductions in nutrient, bacteria and suspended sediment concentrations and loadings, when rural BMP's were targeted at a 50% implementation rate, assuming $10,000 per farm. The cost to implement these measures throughout Hamilton is in the order of $40,000,000 assuming a 100% grant or $20,000,000 assuming a 50% cost sharing with farmers.

11.4 Policy Considerations

11.4.1 General

The practices of land and resource development planning in Ontario are grounded within a formal policy and legislative framework. The Province provides the policy lead by defining areas of provincial interest and establishing planning standards and guidelines to be followed by municipalities and land resource development interests. Comprehensive policies and supporting legislation have been and continue to be put in place by the Province to guide development in a manner that protects, manages and allocates access to water and other natural resources for the shared and sustained benefit of all Ontarians. Those benefits are intended to encompass and integrate among environmental, economic and social interests.

Over the past five years, there has been an unprecedented introduction of new and amended provincial policy and legislation supportive of City of Hamilton Stormwater Master Plan directions and recommendations. Additional water resource protective policies and regulatory mechanisms are due out in 2007 under the proposed *Clean Water Act, 2005*.

The City of Hamilton, like their counterparts elsewhere throughout the Greater Toronto Area, are at varying stages in amending and updating their Official Plans to achieve conformity with these new directions. In doing so, they are required to consider watershed and inter-municipal servicing issues and opportunities. The land and resource development industries and interests also have to adjust to the new policies and requirements and find ways to lessen their impacts on the natural environment through more innovative design and improved practices.

The following sections highlight the primary policy and regulatory mechanisms and government roles that will be important to successful implementation of the Strategy. The focus of the review is on provincial policy as the City has recently completed two documents; Draft Criteria and Guidelines for Stormwater Infrastructure Design and Storm Drainage Policy which provide policy and standards with respect to the planning and design of stormwater infrastructure.

11.4.2 Federal Policy

The significance of Federal role in water management is less obvious and encompassing than that of the Province. A notable exception to this generalization, are the fisheries and aquatic habitat protection provisions and regulatory mechanisms under of the Federal *Fisheries Act.* Successful protection and management of the resident fisheries within each of the 15 watersheds in the face of ongoing development is, and will continue to be, critically linked to this legislation.

Under existing partnership agreements with DFO, each Conservation Authority acts as an initial review agency for any project that might alter or damage fish habitat contrary to provisions of 5.35 of the Fisheries Act. Conservation Authority staff determine whether the project is likely to result in “harmful alteration, disruption or destruction” of fish habitat and recommend mitigative measures to prevent or reduce such impacts. In the even that mitigation is not possible or is insufficient, staff will refer the project to DFO for further review and authorization.

11.4.3 Provincial Policy

Up until 2001 the primary Provincial policies directing and governing water quality and quantity management were directed at water takings, wastewater emissions and flood risk reduction. The main policy documents were the “Blue Book” or Water Management - Policies, Guidelines and Provincial Water Quality Objectives, 1994 and the Flood Plain Planning Policy Statement, 1988 which was subsequently incorporated into the Provincial Policy Statement, 2001.

Regulatory oversight for water was largely exercised through powers and provisions of the *Ontario Water Resources Act, Environmental Protection Act, Conservation Authorities Act,* and to a lesser extent the *Lakes and Rivers Improvement Act* and *Niagara Escarpment Planning Act.*

New and emerging policies and regulations are significantly expanding and strengthening provincial protection over water resources. They particularly focus on land use and the additional measures needed to safeguard water quality, conserve water resources and maintain natural hydrologic functions in the face of ongoing population and economic growth, widespread land-use change and the intensification of business and commercial activities. Key water-related elements and impacts of these initiatives are highlighted here in order of their introduction by the Province.

- *Nutrient Management Act, 2002*
- *Sustainable Water and Sewage Systems Act, 2002*
- *Greenbelt Act, 2004*
- *OWRA Water Taking and Transfer Regulation, 2004*
- *2005 Provincial Policy Statement*
- *Places to Grow Act, 2005*
- *Clean Water Act (proposed), 2005*

Nutrient Management Act, 2002

The purpose of the *Nutrient Management Act, 2002* is "to provide for the management of materials containing nutrients in ways that will enhance protection of the natural environment and provide a sustainable future for agricultural operations and rural development". The Act gives the Province powers over the siting, size and location of livestock production operations and over the storage, handling, transport and land application of manure and other prescribed materials including municipal sewage and industrial biosolids.

Requirements placed on farm operators, municipalities and/or others involved in nutrient production and nutrient management include the need to prepare nutrient management strategies and nutrient management plans, to participate in training, and, in some cases to obtain certification. Nutrient management plans must incorporate province-wide land-application standards that prescribe setbacks from watercourses and other sensitive features, restrict application on certain soils, limit the timing of application, and define the allowable application rates and appropriate application technologies.

The Act's initial regulations generally apply only to large existing operations and new operations based on an "animal units" exceedance determination. As a result of strong concerns expressed by both farmers and environmental interests, current regulations, implementation protocols and funding strategies are under review. Recently announced changes, when fully implemented, are expected to extend the Act's requirements to provide coverage of more and smaller farm operations and to provide additional government funding to assist farmers in preparing and implementing nutrient management plans. An experts' committee has been established to advise the government on appropriate "science-based" nutrient management standards and best management practices that would determine where and how the regulations would apply. The intent is to have full application by early 2008.

Given that the watersheds are home to smaller animal operations, the pending changes surrounding the *Nutrient Management Act* should enhance the level of water resource protection being offered through this legislation. Proper regard for, and enforcement of, the amended regulations may be a critical element in the attainment of surface and groundwater quality objectives in several subwatersheds within the City of Hamilton.

Sustainable Water and Sewage Systems Act, 2002

The *Sustainable Water and Sewage Systems Act, 2002* was introduced by the Province to enact requirements and provide mechanisms for ensuring long term sustainability in the delivery of municipal water and sewage services. When it receives final proclamation, the Act will require all municipalities who provide water and/or wastewater services to the public (either directly or through some other entity) to document the scope of services being provided and to determine the "full cost" associated with delivering those services. This report becomes the basis for the preparation of a "cost recovery plan" for submission to and approval by MOE. Full cost is defined as including "source protection costs, operating costs, financing costs, renewal and replacement costs and improvement costs".

The Act gives municipalities the power to impose and collect the revenues necessary to recover services costs and requires that those revenues be maintained within a dedicated reserve account.

In the context of this study, rules for determining the categories and amounts of eligible source protection costs may have a large bearing on roles and responsibilities in implementing significant portions of the strategy and on how related water resource protection and restoration activities will be funded. Regulations defining the scope of source protection costs and the mechanisms for recovering costs through charges have not yet been produced. It is anticipated that this is not likely to happen until the new *Clean Water Act* is in place.

Greenbelt Act, 2004

The *Greenbelt Act, 2004* and the Greenbelt Plan, 2005 are cornerstones to the Greater Golden Horseshoe Growth Plan. They identify where urbanization should not occur in order that permanent protection is provided to the agricultural land base and to ecological features and functions. In the case of this study, the Greenbelt Plan includes lands within the Niagara Escarpment planning area and builds upon the current legislation that guides development and protection of those lands. The Greenbelt Plan also contains geographically specific policies that apply to the broader "protected countryside" which includes the agricultural and natural systems, parkland, open space and trails, and settlement areas.

OWRA Water Taking and Transfer Regulation, 2004

The current *Water Taking and Transfer Regulation* (O. Reg. 387/04) was enacted in December 2004. It establishes a number of new provisions intended to strengthen and clarify provincial powers over the issuance of water taking permits (PTTWs). The regulation:

- Identifies a broad range of environmental and other factors the PTTW Director must consider in assessing and approving applications for new or expanded water withdrawals. Protection of natural ecological functions, demonstration of the applicant's commitment to conservation and efficient use, and recognition of the water needs of approved municipal growth are among the factors identified.
- Expands and clarifies consultation requirements to be undertaken by the Director and/or permit applicant prior to permit application and/or Ministry approval.
- Prohibits or restricts new or expanded surface and ground water withdrawals for certain purposes from watersheds identified "high use" or "medium use" due to year round or seasonal low water sensitivity.
- Commits the Director to address Ontario's obligations under the Great Lakes Charter
- Prohibits any new diversions or transfers of water out of or between major drainage basins. The Great Lakes is considered as a single basin.
- Requires all permit holders to monitor and report actual water usage. The requirement to report is being phased in over three years according to water use sector.

O. Reg. 387/04 ensures that Conservation Authorities and the City of Hamilton have the opportunity to consider permit applications and input to permit decision-making. In releasing the regulation, the

Minister of Environment indicated the Province's intent to look at and potentially introduce water efficiency standards based on water use sectors.

2005 Provincial Policy Statement

The 2005 Provincial Policy Statement (PPS) embodies the full range of provincial policies that guide land and resource development planning throughout the province. Policies are organized under the broad headings of Building Strong Communities, Wise Use and Management of Resources, and Protecting Public Health and Safety. The PPS defines areas of provincial interest, establishes a vision for Ontario's land use planning system and provides important guidance over land and resource use practices and the development of major infrastructure such as transportation, water and wastewater servicing.

Reintroduction of the requirement that municipal and provincial decision-making on all planning and development matters "shall be consistent with" PPS policies should strengthen government commitments and enhance public trust over the delivery of land use planning.

In the area of water resources protection, the Policy Statement contains provincial directions and standards for the protection of human life, health and property from flooding and other natural and human-made hazards, for protection and restoration of water quality, for maintenance of hydrologic systems and ecological functions, for use of best practices in managing stormwater, for protection and restoration of vegetative cover and pervious area, and for the conservation, efficient and sustainable use of surface and groundwater.

Places to Grow Act, 2005

The Greater Golden Horseshoe Growth Plan established under the PTG Act offers a vision and directions for growth within the area out to the year 2031. It establishes population and employment growth projections to be used in the planning of water, sewage and transportation infrastructure and other services, identifies urban growth centres, and sets intensification targets as a means of encouraging more compact development, more efficient use of services, avoidance of urban sprawl and protection of open space. The Act and Plan also reinforce the principles of water conservation, demand management, inter-municipal infrastructure planning, full cost recovery for water and sewage services, and innovative approaches for managing stormwater.

For Hamilton, the GGH Growth Plan establishes important directions for the development of remaining greenfield lands within the City, and for ongoing and future redevelopment of existing urban core areas. These directions represent an opportunity to incorporate the integrated stormwater management practices being put forward in the Strategy. For the rural areas, the Plan reinforces water resource protection objectives and strategies contained in the Greenbelt Plan, and the Niagara Escarpment Planning Act

Clean Water Act, 2006

The proposed *Clean Water Act* received Royal Assent on October 19, 2006. The Act requires the establishment of watershed-scale source water protection plans (SWPP). A SWPP requires that potential sources of contamination be identified, that significant threats to water supplies be reduced or eliminated. Since municipalities are responsible for providing drinking water and land use planning, they will have a strong role in developing and implementing SWPP. The Act established 19 source protection regions in Ontario.

Source water protection plans (SWPPs) are to be developed by source protection committees, under the same structure as conservation authority boards, made up of members appointed by municipal councils. In many cases this will require coordination between multiple municipal jurisdictions. The source protection committee will prepare terms of references, the risk assessment report and the (SWPP). The SWPP will identify existing and potential future risks to drinking water quality within their wellhead protection zones and intake protection areas and implement specific measures to prevent and or mitigate adverse impacts.

Municipalities will have the tools to implement SWPP by developing policies to reduce risks posed by specific activities, requiring adherence to existing regulatory approvals, through Zoning By-Laws, Official Plan Amendments, education or voluntary initiatives.

Stormwater Management Planning and Design Manual (2003)

The Ministry of the Environment prepared the Stormwater Management and Design Manual in 2003. The manual provides:

- An overview as to the impacts of urbanization;
- An approach for undertaking integrated planning for stormwater management;
- Environmental Design Criteria;
- Design considerations for a variety of source, conveyance and end of pipe measures;
- Approaches for dealing with infill developments, including funding alternatives;
- Operation, Maintenance and Monitoring considerations; and
- Capital and operational cost estimates for a variety of measures

The manual provides both direction and support for the recommendations as provided in this, and future studies.

11.4.4 Municipal and Conservation Authority Policy

The pressure on municipalities to manage growth and development and manage resulting impacts on the natural environment has increased dramatically in keeping with Provincial initiatives transferring more responsibility to the local level. This added pressure is partially offset by clarification of Provincial priorities and interests and by the addition of increased powers municipalities will have to restrict certain forms of development and regulate unsustainable land use practices.

The City of Hamilton, together with the four Conservation Authorities, has expressed support for the watershed approach and have indicated that development decision-making be guided by findings and recommendations of watershed and subwatershed plans. In order to effectively implement the recommendations of this and other subsequent studies, the City will have to update/revisit current level Official Plan and lower level planning policies and development design standards. This is particularly so in relation to more effective stormwater management, the protection of open space and the limitation of impervious area creation. Current policies and standards do not encourage, and in many cases work against, the hierarchical and integrated approach deemed essential if the Strategy's objectives and targets are to be met. The changes required are consistent with the requirements and expectations created by recent and ongoing Provincial planning reforms.

Given the scope and overlap of planning activities and processes imposed by the new and emerging provincial requirements, the City will be challenged to work together and to collaborate with the four Conservation Authorities to seek out efficiencies and harmonize approaches in water management. This will require even greater cooperation in sharing information, ideas, resources, problems and successes.

Provided below are some approaches that could be incorporated into various municipal policies, documents and standards.

Official Plan

The strength and comprehensiveness of policies relating to water resources protection and restoration as outlined in municipal Official Plans (OPs) are a primary determinant of how informed and focused subsequent development decision-making and the application of municipal resources will be in delivering on the Strategy. The proposed Official Plan should:

- Express support for the Strategy goals, objectives, measurable parameters and targets;
- Endorse the principle of valuing and managing rainfall and snowmelt as a resource;
- Adopt the use of a comprehensive and integrated approach to minimizing and managing runoff (in relation to both quality and quantity impacts) within all new development and redevelopment undertakings. The approach should commence at the source or lot level and move outward as appropriate to encompass conveyance and end-of-pipe controls;
- Encourage development submissions and decisions that incorporate an ecosystem approach perspective drawn from the collective expertise of planners, engineers and landscape architects;
- Promote the implementation of programs and funding mechanisms for addressing water quality and quantity concerns associated with existing development and land use practices within urban and rural areas; and
- Commit to supporting and participating in the activities of the Management Committee and Working Groups that will guide and oversee Strategy implementation.

Subwatershed Plans, Secondary Plans, Plans of Subdivision, Site Plan

Planning and development policy guidance and decisions at the secondary plan, site plan and related levels should similarly reflect the updated Official Plan, Secondary Plan and Strategy directions and be guided by more site-specific objectives, targets and protective measures as recommended in subwatershed plans and environmental impact assessment reviews. Existing subwatershed plans should be reviewed and updated as necessary to conform to the stormwater management principles and approaches recommended in the Strategy.

Subwatershed plans should also be undertaken at the Secondary Planning Stage in order to develop strategies for growth areas identified through GRIDS and to address issues related to existing urban and rural lands.

Development Standards and By-Laws

The Strategy's hierarchical approach to stormwater management runs counter to most existing municipal development, construction standards and by-laws in the areas of managing rooftop drainage, exercising lot-level runoff control, and encouraging groundwater infiltration in stormwater conveyance systems. The required changes will require extensive consultation with the development industry, site planners, municipal operations personnel and landowners. Funding support through local and senior governments for demonstration projects may provide an incentive for breaking down the expected barriers to change.

11.5 Funding

Section 11.3 presented the primary components which collectively form the Preferred Management Strategy. Also provided were cost estimates, present funding sources and potential funding alternatives.

One of the current hurdles to implementing studies of this type is a lack of funding, particularly for measures that are required in existing urban or rural areas. Several municipalities have recently undertaken studies to identify sources of funding. Presented below is a brief overview of several approaches that have been noted and could be considered further by the City. These approaches are in addition to approaches currently used by the City.

Storm Sewer User Fee

Several municipalities have recently enacted a Storm Sewer (or Stormwater) User Fee in order to fund the proposed measures. For example, the Town of Aurora has recently (2004) enacted a Flat Rate Storm Sewer Change for existing residential, commercial/industrial and multi-residential units. The rates are $55.40 per annum for residential properties and $673.80 per property per annum for metered commercial/industrial and multi-residential properties.

Other municipalities are considering increasing the sewer and water rates to reflect the true cost of services, promote conservation practices and to fund environmental and stormwater initiatives.

Perpetual Maintenance Fee

A number of municipalities including the Town of Halton Hills, City of Brampton, and City of Vaughan have prepared stormwater documents or policies which include collection of a fee for operation and maintenance of stormwater management facilities to ensure the proper operation, longevity, and aesthetic functioning of the proposed stormwater control measure. Typically, the fee equals approximately 10 to 20 percent of the construction cost.

Cash-in-lieu Policy

A number of municipalities including Mississauga, Brampton, Vaughan, Toronto and Markham have established a Cash in lieu or Fee in Lieu policy. The general intent of the policy is to collect monies for smaller infill developments where implementation of proper stormwater measures may be limited. The funding is then used to construct works in other locations.

The MOE Stormwater Management Planning and Design Manual (Section 5.4) provides details of the approaches used by several municipalities. Typically, fees range between $15,000 per hectare to in excess of 100,000 per hectare.

Provincial Funding Alternatives

There are a number of Federally funded agricultural stewardship programs including:

- Canada Ontario Farm Stewardship Program

- Greencover Canada
- Canada Ontario Water Supply Expansion Program
- Can-Adapt – Agricultural Environment Stewardship Initiative
- Habitat Stewardship Program

Together, these programs provide funding on a cost-shared basis, with the program covering 30 – 50 % to a maximum of $5,000 - $20,000 for a range of measures, including:

- Manure storage and handling facilities
- Farmyard runoff control
- Shelterbelts and windbreaks
- Farm waste management (storage and handling of hazardous materials)
- Riparian plantings and riparian management (including offstream watering sites)
- Water well management
- Erosion control – riparian lands and fragile lands
- Conservation farming practices – conservation tillage, strip cropping, equipment modifications, cover crops, integrated pest management, irrigation management)
- Ponds for agricultural purposes

These programs are delivered through local stewardship councils, with support from the Conservation Authorities and the local Soil and Crop Associations. All CA's within the City have access to these programs.

Several other important programs exist including:

- Canada – Ontario Agreement – Rural Water Quality Program: for example, GRCA has been implementing this program in several neighbouring municipalities and has signed MOU's with municipalities to provide additional local funding to this federal-provincial program.
- Hamilton – Halton Watershed Stewardship Program: a joint initiative between Conservation Halton and Hamilton Conservation Authority, sponsored through the Hamilton Harbour RAP (the Bay Area Restoration Council) that delivers agricultural stewardship programs to watersheds draining into the Hamilton RAP study area. Through this program, a stewardship and septic awareness questionnaire was delivered to over 4,000 landowners within the watersheds of the RAP.
- NPCA has a number of cost sharing programs with support from the Niagara RAP and the Niagara Water Quality Protection Strategy that target agricultural lands. Generally, grants are available from $5,000 - $12,000 representing 50 – 75 % of the project value and cover the range of projects lists under the federal programs above.

The level at which these programs are funded is generally insufficient to support a program of the magnitude outlined in this document. The recommended approach would be similar to the approach taken by GRCA for its Rural Water Quality Program, where the City would sign an MOU with a commitment of funding and the Conservation Authorities would implement the program with support from the existing federal and provincial programs.

General Programs

Several private sector and Federal programs do provide limited opportunities to fund projects. These programs include the Trillium Foundation as well as Provincial and Federal programs such as Municipal Green Enabling Fund and the Great Lakes Renewal Fund.

11.6 Staffing Requirements

As noted in Chapter 5, the MOUSE model has been used to determine flow rates, water levels and the associated level of service for approximately 4,000 storm sewers within the areas serviced by a separated storm sewer system. This model was also used in a similar manner for the areas within the City which are serviced by combined sewers.

It has also been recommended that the MOUSE model be used to address the impacts on the existing sewer system as a result of proposed developments including intensification. The model will also likely be used for future studies dealing with surface and/or basement flooding as a result of recent rainfall events.

Maintaining and updating the MOUSE model will require a considerable amount of time and will require proper technical skills and training. It is therefore recommended that one full-time staff be hired in order to address these requirements.

11.7 Future Studies

The City and the Conservation Authorities have been, and will continue to undertake, watershed and subwatershed studies. These studies may be undertaken in order to develop a plan in response to land use changes or to update the current environmental conditions and approach for environmental protection.

One of the objectives of this study was to provide direction for undertaking future studies including the type of proposed measures that should be considered. In this regard, meetings were held with City staff, Conservation Authorities, stakeholders and members of the public. Existing reports, documents and environmental baseline data was also reviewed.

As part of this study a series of Fact Sheets, one for each of the 15 watersheds, have been prepared.

The Fact Sheets may be to assist in the development of future studies.

In summary, the Fact Sheets provide direction for completing watershed or subwatershed studies under the following headings:

Existing Environmental Resources: an outline of the current environmental conditions within the watershed

Subwatershed Priorities and Environmental Protection Targets: a summary of the priorities and stormwater and environmental management targets that have been established for the watershed

Potential Best Management Practices: the recommended types of Best Management Practices to be implemented

Potential Study Requirements: a list of studies that need to be completed at the subsequent, more detailed, planning stage

The Fact Sheets are provided in Appendix C.

REFERENCES

Aquafor Beech Limited [1993] Metropolitan Toronto Wet Weather Outfall Study – Phase II. Report prepared for Ontario Ministry of Environment and Energy.

Aquafor Beech Limited (2003) Wet Weather Flow Master Management Plan – Study Area 5, Highland Creek, Rouge River and Waterfront Area. Report prepared for the City of Toronto.

Chapman L.J., and Putnam, D.F.
1984: The Physiography of Southern Ontario; Ontario Geological Survey, Special Volume 2, 270p. Accompanied by Map P.2715 (coloured), scale 1:600,000

Chapman L.J., and Putnam, D.F.
1984: The Physiography of Southern Ontario; Ontario Geological Survey, Special Volume 2. Ministry of Natural Resources.

City of Hamilton Storm Drainage Policy, Philips Engineering Limited, May 2004.

Draft City of Hamilton Criteria and Guidelines for Stormwater Infrastructure Design, Philips Engineering Limited, December 2006.

The Greenbelt Plan, Ministry of Municipal Affairs and Housing (February 28, 2005)

Growth Related Integrated Development Strategy: Growth Report – Report prepared for the City of Hamilton by Dillon Consulting Limited (May 2006)

Hamilton Groundwater Resources Characterization & Wellhead Protection Partnership Study, SNC – Lavalin, (2004)

Heagy, A.
1995: Hamilton-Wentworth Natural Areas Inventory: Vol. I. Hamilton Naturalists' Club. Hamilton, Ontario.

Karrow, P.F.
1987: Quaternary Geology of the Hamilton-Cambridge Area, Southern Ontario. Ontario Geological Survey Report 255. Ministry of Northern Development and Mines.

Municipal Engineers Association, Municipal Class Environmental Assessment, (June 2000)

Nature Counts Project Hamilton Natural Areas Inventory 2003 – Report prepared by Hamilton Naturalist's Club, Jill Dwyer, Jay Lindsay, Brian McHattie, Cathy Plosz (2003)

The Niagara Escarpment Plan (2005), Niagara Escarpment Commission, Office Consolidation (September 26, 2006)

Ontario Ministry of the Environment [2003] Stormwater Management Planning and Design Manual.

Performance Assessment of a Swale and Perforated Pipe Stormwater Infiltration System. Report prepared for Stormwater Assessment Monitoring and Performance Program, May 2002.

Places to Grow Growth Plan for the Greater Golden Horseshoe 2006, Ministry of Public Infrastructure Renewal, (June, 2006)

Provincial Policy Statement 2005, Ministry of Municipal Affairs and Housing, (2005)

Remedial Action Plan for Hamilton Harbour Stage 2 Update 2002 – Report prepared by Hamilton Harbour RAP Stakeholder Forum (June 2003)

Towards a Sustainable Region, Official Plan for the Regional Municipality of Hamilton-Wentworth, (April, 1998)

Vibrant, Healthy, Sustainable Hamilton a Study Guide for Hamilton's Growth Related Integrated Development Strategy (GRIDS), City of Hamilton (September, 2003)