


Stoney Creek and Battlefield Creek Flood and Erosion Control Class Environmental Assessment

Final Report

September 2011

STONEY AND BATTLEFIELD CREEK
FLOOD AND EROSION CONTROL
CLASS ENVIRONMENTAL ASSESSMENT

FINAL REPORT

HAMILTON CONSERVATION AUTHORITY

September 2011

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PURPOSE/ OVERVIEW

The Battlefield Creek and Stoney Creek Watershed (ref. Drawing 1) has a drainage area of approximately 3090 ha to the outlet at Lake Ontario. The two watersheds confluence upstream of Barton Street. The watershed is divided by the Niagara Escarpment, with land use above the Escarpment being primarily agricultural and below the Escarpment being historically mixed urban uses. As development below the Escarpment is of an older form, it typically does not have any stormwater management controls which has resulted in increased flow rates within both watercourses. Both creeks have been straightened or modified over time in several locations, with development encroachment within the Regulatory floodplain.
There are several areas of both Battlefield Creek and Stoney Creek that have exhibited flooding and erosion; an example of this is the extensive flooding in the vicinity of Donn Avenue and Collegiate Avenue as a result of the July 26, 2009 storm event. The stability of the Stoney Creek and Battlefield Creek has also been compromised in several localized reaches. Severe erosion has caused stream bank widening and slope stability issues for some neighbouring property and municipal infrastructure.

This study has been initiated by Hamilton Conservation Authority as numerous complaints and concerns have been provided to Hamilton Conservation Authority and the City of Hamilton regarding flooding along portions of the watercourses and localized creek erosion. Solutions to address remedial flooding and erosion problems are to be developed as part of this Conservation Ontario Class Environmental Assessment study process to protect the public, municipal infrastructure, and private property while enhancing the natural heritage system and protecting the archaeological environment.

As required by the Conservation Ontario Class Environmental Assessment for Remedial Flood and Erosion Control Projects", January 2002 process, the study has included an assessment of the existing creek system including hydrologic (flows), hydraulic (flood levels and velocities), stream morphology (creek processes), fisheries (instream habitat), terrestrial systems (vegetation and wildlife), and archaeology (civilizations). Based on the existing creek flooding and erosion issues, flood and erosion control alternatives and management practices have been advanced and assessed. Short-term (0-15 years) preferred solutions have been derived to effectively address the local flooding and creek erosion conditions, within the local physical, ecological, and social environments. In addition medium-term (15 to 25 years) erosion control projects have been established and long-term (25 years and beyond) flood and erosion control management practices have been determined.

SUMMARY OF EXISTING CONDITIONS

Hydrogeology (Groundwater)

Hydrogeology is the study of the movement of water through the ground and the interaction of this groundwater with surface water. The study area is covered by clays which tend to minimize infiltration of water except in areas where the clay is thin. Water infiltrating above the Niagara Escarpment will move downward horizontally towards Lake Ontario below the Escarpment where limited amounts of groundwater may discharge to the creeks as baseflow. Baseflow in these creek reaches is considered to be minimal and generally less than 10 litres per second, which is considered low for watersheds of this size.

Hydrology (Flows)

Hydrology is the science of determining the amount of water moving through various processes within a watershed, based on meteorologic conditions. Hydrologic modelling allows for the determination of a runoff rate from a particular land form in response to a rainfall or snowmelt event.

Previous hydrologic analyses for Stoney Creek and Battlefield Creek were completed as part of the City of Stoney Creek Flood Damage Reduction Stud*y*, Philips Planning and Engineering Limited, June 1989. The 1989 study determined peak flows for each creek using a synthetic 12-hour rainfall distribution.

This study has used a calibrated QUALHYMO hydrologic model to determine storm peak flow rates with varying frequencies. The results of this analysis suggests that peak flows are generally higher in comparison to the 1989 FDRP event based peak flows, although they are considered reasonable compared to other similar watersheds flow response rates.

No flood control is currently provided in Stoney Creek or Battlefield Creek via formal stormwater management quantity controls, therefore peak flows from previously developed lands are not attenuated (reduced) by stormwater management.

Hydraulics (Water Levels and Velocities)

Hydraulic modelling of both creek systems below the Niagara Escarpment has determined that the flow capacity of a number of crossings (bridges/culverts) is considered inadequate based on the flooding depths and velocities that are incurred during the less frequent storm events. Flooding of private property is considered likely during the Regional Storm (Hurricane Hazel) event which may result in a risk to life and limb and cause flood-related damages.

Stream Morphology (Creek Forming Processes)

Both Stoney Creek and Battlefield Creek have undergone extensive change due to urbanization below the Niagara Escarpment. These creeks have been lined and straightened in various reaches. The increase in flows resulting from on-going urbanization has resulted in creek bank erosion in varying degrees along each creek.

Based on field reconnaissance the creeks in the study area exhibit low stream health and are in state of transition. The dominant creek forming process occurring in both creeks appears to be channel widening. Some of the previously installed bank treatments have been observed to be failing and are in clear need of repair in order to restore their original functionality.

Aquatic Environment (Fisheries and Benthic Invertebrates)

Fish habitat within the Battlefield Creek and Stoney Creek has been significantly degraded due to historical watercourse straightening, the addition of culverts and a “flashy” flow regime (i.e. due to urbanization water runs off quickly and also recedes quickly). In the intermittent portions of Stoney Creek and Battlefield Creek, the absence of base flow is the most significant factor limiting fish productive capacity and fish community diversity. As baseflow is lacking in both creeks, rainfall directly affects the success of fish migration, distribution and resident communities. Below the Niagara Escarpment, there are no significant artificial barriers to fish movement. Downstream of Queenston Road is where the greatest diversity of permanently wetted habitats exist, as spawning, nursery and feeding areas for a number of fish species from Lake Ontario.

Water Quality (In-stream)

The level of stormwater quality provides the basis for the success (or failure) of existing fisheries habitat within Stoney Creek and Battlefield Creek. The Stormwater Quality Management Strategy for the Community of Stoney Creek Master Plan (Philips Engineering Ltd., June 2004) (2004 Master Plan) identified the Stoney Creek and Battlefield Creek watercourse system as a high-priority system with reasonably good water quality. Water quality improvements have been recommended as part of the 2004 Master Plan, including five (5) new stormwater management facilities, four of which would involve storm sewer outfall retrofits. Baseflow augmentation, riparian plantings and erosion control would also provide water quality improvements.

Terrestrial Resources (Vegetation and Wildlife)

Based on background information and vegetative surveys conducted in 2008, it has been determined the whole study area constitutes significant valley lands and that that any proposed flood and erosion controls works would have to demonstrate no negative impacts. Within the study area there are extensive forested areas that constitute significant woodlands protected under the 2005 Provincial Policy Statement. Site alteration within these areas must demonstrate that there will be no negative impacts on these features or their ecological functions. There are also two designated Environmentally Significant Areas of the study area, one designated on the basis of its hydrological function and for providing habitat for significant species. The other is designated based on a Significant Earth Science Feature, and also for its ecological functions.

Channel Bank Stability and Erosion

In addition to the stream morphology assessment, a separate geotechnical slope inspection of the east valley wall adjacent to 79 Donn Avenue has also been conducted. Based on the assessment, the valley wall should be protected by creek and valley wall works. The precise extent of the works would have to be determined as part of a subsequent detailed stream morphology assessment.

Archaeological (Civilizations)

A Stage 1 Archaeological Assessment has been conducted as part of this study within the lower Stoney Creek and Battlefield Creek to provide a preliminary assessment of possible archaeological resources in the potential creek work areas. The assessment has provided information about the property's geography, history, previous archaeological fieldwork and current land condition. Based on the archaeological assessment results, a Stage 2 property assessment would be required when detail design of flood and erosion control works is conducted.

CONSULTATION ACTIVITIES

Notification

A Notice of the Study Commencement and Public Information Centre (PIC) was issued on October 23rd, 2009 through a mail out to the land owners and the public approval agencies and October 23rd and October 30th, 2009 in the Hamilton Spectator Newspaper and Stoney Creek News.

Public Consultation

Public Consultation has occurred through a study area mail out and two Public Information Centres (PIC). PIC No. 1 held on Wednesday November 4, 2009 at Cardinal Newman Catholic Secondary School. The fist PIC was well attended, with 74 (+/-) people signing in and approximately 90 to 100 people estimated to have been in attendance. The PIC was conducted in an open house format with display boards and the Hamilton Conservation Authority, City of Hamilton staff and AMEC Team available for any questions or comments from those attending.

PIC No. 2 was held on Wednesday January 20, 2011 at the Stoney Creek Municipal Office – 777 Highway 8, Stoney Creek. A presentation of the foregoing was also made by the Study Team in the Council Chambers. Approximately 50 people attended the PIC with 32 people signing in.

PREFERRED ALTERNATIVES

A long-list of possible alternatives to address flooding and erosion risk in Stoney Creek and Battlefield Creek has been screened to a short-list of feasible short-term and practical alternatives. These short-listed alternatives have been further evaluated on a reach by reach basis (ref. Figure SM-3) by each of the disciplines involved in this Conservation Ontario Class EA.

In addition to short-term flood and erosion protection alternatives considered to be implemented in the 0 to 15 year timeframe, medium and long-term management practices (15 to 25 years, 25 years +) have also been determined. Table 1 provides a summary of the preferred alternatives and management practices.

Flood control measure have been identified for each reach, however for the most vulnerable creek reaches with highest flood risk, the recommended alternatives such as flood protection berming will not reduce the risk significantly. As such a Phasing and Prioritization Plan has primarily been established on the basis of a combined perspective which has also included erosion sensitivity of the creek reaches, the current condition of creek erosion and the potential impacts to both private and public property. Input from the public, Hamilton Conservation Authority and the City of Hamilton has been incorporated the proposed project prioritization.

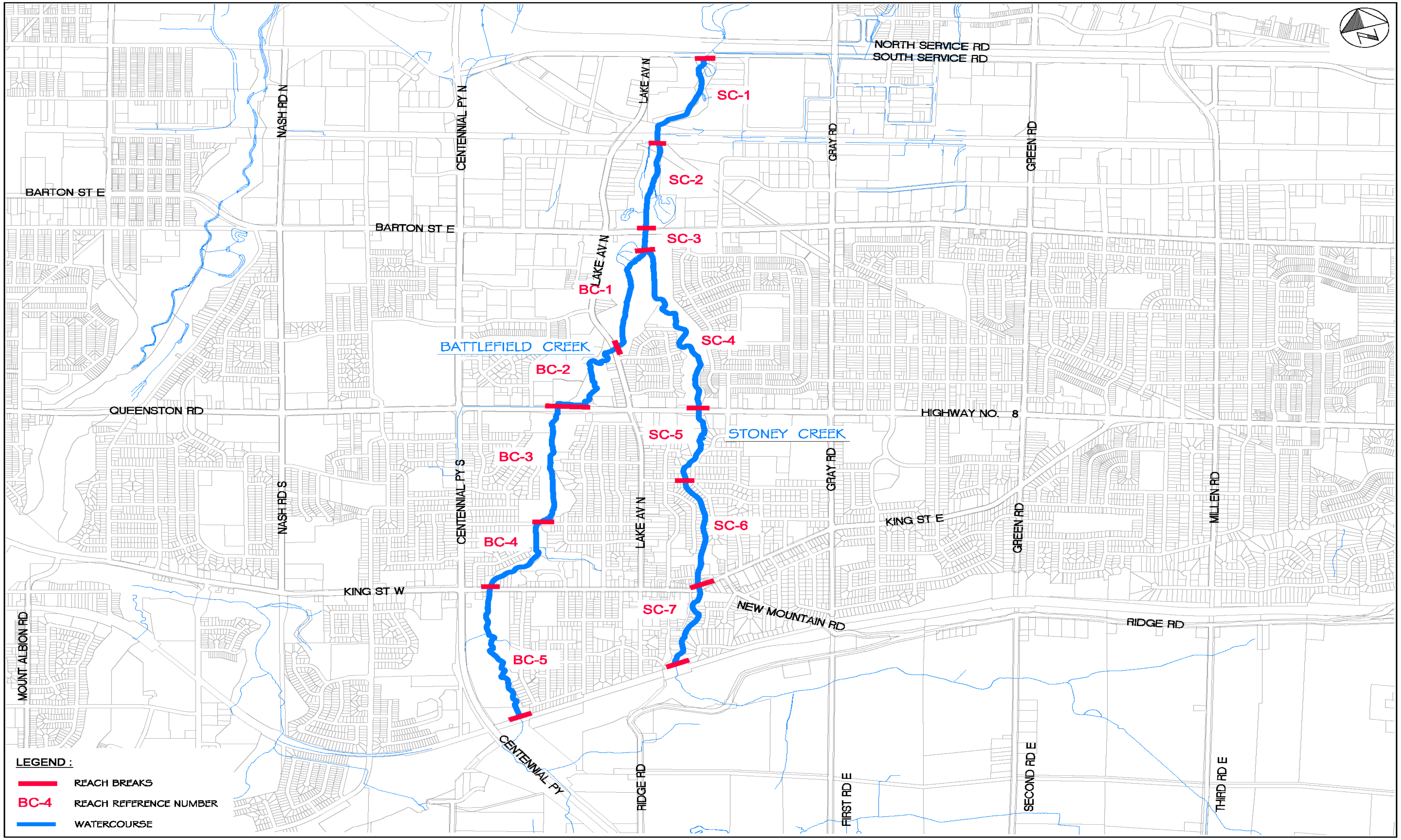

Figure SM-3: Delineated reaches along Stoney Creek (SC) and Battlefield Creek (BC) in the study area. (Watercourses and reach breaks are shown in blue and red, respectively.)

Table 1: Integrated Implementation Plan

Priority Sequence	Rating	Reach	Specific Site of Works	Short-term Erosion Control Remedial Works	Erosion Control Additional Notes	Short-term Flood Mitigation Works	Flood Mitigation Additional Notes	Proponency/Additional Study Requirements/ Permitting
1	High	SC-7	North side of King Street West to CNR Rail Line	• Replacement of existing bank protection along both banks (with regrading if constraints allow). • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $770,000.	Feasibility dependant on landowner buy-in Incorporates conceptual design for Priority Erosion Sites ES20, ES21, ES22 and ES23.	Localized flood protection berm to Regional Storm standard. Preliminary cost estimate of $110,000 to $220,000	Most of the creek is privately owned within this reach, therefore flood protection may be difficult to implement successfully	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City, NEC and potentially DFO and MNR
2	High	SC-5	Mid-reach adjacent to Donn Avenue / Dale Avenue intersection.	• Localized realignment and bank protection to protect property line on east bank. • Regrading of area of slope instability on east bank. • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $450,000	Incorporates conceptual design for Priority Erosion Sites ES9.	Localized flood protection berm to Regional Storm standard. Preliminary cost estimate of $290,000 to $580,000.	Most of the creek is privately owned within this reach, therefore flood protection may be difficult to implement successfully. Land management or easements required.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City and potentially DFO and MNR
			Downstream of Collegiate Avenue	• Replacement of existing bank protection along both banks (with regrading if constraints allow). • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $165,000.	Incorporates conceptual design for Priority Erosion Sites ES13 and ES14.			
3	High	SC-6	Collegiate Avenue to north side of King Street West	• Replacement of existing bank protection along both banks (with regrading if constraints allow). • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $979,000.	Feasibility dependant on landowner buy-in Incorporates conceptual design for Priority Erosion Sites ES15, ES16, ES18 and ES19.	Localized flood protection berm to Regional Storm standard. Preliminary cost estimate of $160,000 to $320,000.	Most of the creek is privately owned within this reach, therefore flood protection may be difficult to implement successfully.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City and potentially DFO and MNR
4	High	BC-4	Downstream of King Street West, upstream of Hopkins Park	• Localized realignment and bank protection to protect private property line on east bank. • Localized repair and protection of stormwater outfall. • Preliminary cost estimate of $450,000.	Incorporates conceptual design for Priority Erosion Sites ES6 and ES7.	Localized flood protection berm to Regulatory standard of residential buildings on Friarcourt Drive Preliminary cost estimate of $250,000 to $500,000.	Properties on the north side of King Street would remain within the 100 year and Regional Storm floodplain.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City and potentially DFO and MNR
5	Medium	BC-5	Upstream of proposed works by City of Hamilton (ref. Appendix 'E')	• Localized bank protection to protect municipal property (museum and bridge). • Preliminary cost estimate of $27,500.	Works to protect museum lands and bridge currently being progressed by City of Hamilton.	Localized flood protection berm to Regulatory standard for properties on the south west side of King Street West and the creek. Preliminary cost estimate of $130,000 to $260,000.	Would have to consider grading limitations within Battlefield Park.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City, NEC and potentially DFO and MNR
6	Medium	SC-4	Boundary with first property upstream of the confluence on the west bank.	• Localized bank regrading and bank protection to protect property line on west bank. • Preliminary cost estimate of $77,000.	Section of creek likely to retain natural channel planform. Can potentially be used as a reference reach.	No actions required.		• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City and potentially DFO and MNR
			Downstream of pedestrian footbridge, near Huckleberry Place	• Localized realignment and bank protection to protect sanitary maintenance chamber. • Localized regrading and protection of bed at sanitary sewer crossing using riffle structure. • Preliminary cost estimate of $108,000.	Design of realignment tie into existing planform will need to take into account proximity to sanitary sewer upstream.			

Table 1: Integrated Implementation Plan

Priority Sequence	Rating	Reach	Specific Site of Works	Short-term Erosion Control Remedial Works	Erosion Control Additional Notes	Short-term Flood Mitigation Works	Flood Mitigation Additional Notes	Proponency/Additional Study Requirements/ Permitting
7	Medium	BC-2	Two meander bends on west bank in contact with valley wall upstream of Lake Avenue North	• Localized regrading of channel banks combined with bank protection on the west bank. • Preliminary cost estimate of $165,000.		Property flood protection berm to Regulatory standard of apartment complex property on Lake Avenue North. Flood protection of single commercial property on south side of Lake Avenue. Preliminary cost estimate of $125,000 to $250,000	Assessment required for flood storage and Regional Storm flood elevation impacts. Two residential properties adjacent to the creek on Lake Avenue North would continue to be flooded during the 100 Year storm. Grading required on private property.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City and potentially DFO and MNR
			Downstream of Queenston Road through Henry and Beatrice Warden Park.	• Localized realignment of channel away from sanitary sewer • Localized regrading and protection of bed at sanitary sewer crossing using riffle structure. • Localized repair and protection of stormwater outfalls • Preliminary cost estimate of $396,000	Realignment needs to take into account location of existing stormwater outfalls Incorporates conceptual design for Priority Erosion Site ES3. Works could be integrated with new multi-purpose trail.			
8	Medium	BC-3	Immediately upstream of Queenston Road	• Localized repair and protection of stormwater outfall. • Preliminary cost estimate of $30,000		Flood protection berm to Regulatory standard for Hydro Transformer station and adjacent homes. Preliminary cost estimate of $130,000 to $260,000.	Hydro property would require re-graded access off Queenston Road. Storm sewer in vicinity of property. Lands are private.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City and potentially DFO and MNR
			Mid-reach adjacent to Avalon Avenue	• Localized bank regrading and bank protection on east bank to protect property line. • Localized protection of outfall on west bank. • Preliminary cost estimate of $110,000	Sanitary sewer is located on west bank.	Localized flood protection berm to Regulatory standard of Valley Drive to facilitate vehicle access. Preliminary cost estimate of $60,000 to $120,000.	Lands are public	
			Downstream of Randall Avenue through Green Acres Park.	• Localized realignment and replacement of failing bank protection on east bank to protect road crossing. • Preliminary cost estimate of $180,000	Sanitary sewer is located on west bank. Works to replace bank protection to protect trail adjacent to baseball pitch currently being progressed by City of Hamilton.	Localized flood protection berm to Regulatory standard of most southerly/west property on Valley Drive. Preliminary cost estimate of $20,000 to $60,000.	Grading could be on public lands.	
9	Low	SC-2	Downstream of Barton Street East	• None identified		Uses alternatives from SC-1. Localized flood protection berm to Regional Storm standard for industrial properties on the west side of the creek immediately upstream of the CNR crossing. . Preliminary cost estimate of berm works $110,000 to $220,000	Grading would be within public lands.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority and City
10	Low	BC-1	Between Lake Avenue North and confluence with Stoney Creek.	• Do Nothing	Sanitary sewer is located on east bank.	Property flood protection berm to Regulatory standard at Blueberry Drive, Huckleberry Drive and southwest corner of Delewana Drive and Lake Avenue North. Preliminary cost estimate of $240,000 to $480,000.	Assessment required for flood storage and Regional Storm flood elevation impacts. Grading on private property required.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City

Table 1: Integrated Implementation Plan

Priority Sequence	Rating	Reach	Specific Site of Works	Short-term Erosion Control Remedial Works	Erosion Control Additional Notes	Short-term Flood Mitigation Works	Flood Mitigation Additional Notes	Proponency/Additional Study Requirements/ Permitting
11	Low	SC-3	Between confluence with Battlefield Creek and Barton Street East.	• None identified		Localized flood protection berm to Regional storm standard for residential properties located immediately upstream of Queenston Road. Preliminary cost estimate of $85,000 to $170,000.	Grading would be within public lands.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority and City
12	Low	SC-1	Downstream of rail culvert	• None identified		Localized flood protection berm to Regional Storm standard for industrial properties. Upgrade the CNR crossing by either a supplemental culvert or replacement bridge to provide Regional Storm flood protection to industrial lands. Flow area required would be approximately 12 m by 3.5 m. Preliminary cost estimate of CNR works $1.5 Million to $2 Million. Berm works $140,000 to $280,000.	CNR crossing upgrade would remove industrial lands from the Regulatory floodplain upstream of the CNR to Barton Street.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City and potentially DFO, MNR and Coastguard

NEXT STEPS

The Hamilton Conservation Authority and the City of Hamilton will commence the implementation of the preferred erosion and flood protection based on the priority sequence outlined Table 1. Construction of the highest priority erosion and flood protection works has been targeted for 2012 based on detail design commencing in late 2011, early 2012. Medium-term erosion control projects such as reach scale creek realignments should be considered subsequent to the short-term project completion in the 15 to 25 year timeframe. Long-term flood and erosion control projects should be considered in the 25 year (+) time frame with consideration to potential future changes to flood and erosion risk, City of Hamilton resources and social values regarding creek corridor management.

1. INTRODUCTION

1.1. Purpose/ Overview

The Hamilton Conservation Authority has conducted a Conservation Ontario Class Environmental Assessment Study of the existing flooding and erosion conditions, to develop an implementation plan for the management of flooding and erosion along the Stoney and Battlefield Creeks below the Niagara Escarpment in the former City of Stoney Creek. The existing ecological processes and significant natural features will need to be protected and enhanced, as part of the establishment of flood and erosion solutions.

The study has been initiated by Hamilton Conservation Authority as numerous complaints and concerns have been provided to Hamilton Conservation Authority and the City of Hamilton regarding flooding along portions of the watercourses and localized creek erosion.

As required by Conservation Ontario Class Environmental Assessment for Remedial Flood and Erosion Control Projects", January 2002 process, this study has examined the need and feasibility for improvements to Battlefield Creek and Stoney Creek in conjunction with area land use. In order to best address these deficiencies, the study has explored a number of improvement alternatives, as well as the impact of such improvements on the social and natural environments involving extensive background review in order to develop an understanding of existing conditions. Both hydrology and hydraulics have been assessed to determine flow conditions and flow characteristics. Other disciplines involved in defining the nature of existing conditions within the study area include:

- Stream morphology – form and behaviour of creeks
- Aquatic Ecology – fish species and habitat
- Terrestrial ecology – plant and tree species and communities
- Hydrogeology – groundwater conditions
- Water quality – water chemistry
- Archaeology – historical human society

The intent of this study has been to develop a comprehensive plan of flood and erosion mitigation measures to reduce the risk of flooding and erosion on municipal and private property. The Hamilton Conservation Authority and the City of Hamilton have collaborated to provide direction and input to the study process and findings, leading ultimately to the preferred solutions in accordance with the planning process of the Conservation Ontario Class Environmental Assessment (Class EA). The Class EA project has been conducted in three (3) phases, Baseline Inventory (Characterization), Alternative Assessment and Implementation Strategy.

1.2. Description of Study Area

The Battlefield Creek and Stoney Creek Watershed (ref. Drawing 1) is approximately 3089 ha at the outlet to Lake Ontario. Battlefield Creek confluences with Stoney Creek upstream of Barton Street and has a drainage area of 767 ha +/-. The watershed is divided by the Niagara Escarpment with the 2360 ha area above the Niagara Escarpment primarily being in agricultural use and the 729 ha below the Escarpment being of mixed urban land uses consisting mostly of residential and employment lands and to a lesser extent commercial, institutional and open space. Development below the Niagara Escarpment has typically been conducted with a lack of stormwater management controls resulting in increased flow rates within both watercourses. Each watercourse has been straightened or modified over time, with development encroaching on the watercourses and within the Regulatory floodplain. Neither watercourse has been enclosed, as has been common for other watercourses within southern Ontario urban areas.

There are several areas of both Battlefield Creek and Stoney Creek that have exhibited flooding and erosion, most recently the July 26, 2009 storm event in the vicinity of Donn Avenue and Collegiate Avenue caused extensive flooding. The City of Hamilton has implemented erosion control works on both Battlefield Creek and Stoney Creek since 2005. Both creek systems have defined valley features north of King Street to just upstream of the QEW highway.

1.3. Background

The Stoney and Battlefield Creek hydrology and hydraulics was initially developed as part of the Stoney Creek Flood Damage Reduction Program (FDRP) in 1989 for the Hamilton Conservation Authority. The hydrology and hydraulics developed as part of the FDRP are considered to be dated due to the current land use and the associated modelling techniques and as such should be updated, using current land use and more contemporary modelling platforms.

In addition to the foregoing, the City of Hamilton as part of its Criteria and Guidelines for Stormwater Infrastructure Design, September 2007 has updated the governing design rainfall for the City of Hamilton based on more recent precipitation records. The rainfall used in the FDRP to determine the runoff response, is considered out of date as it was based on data up to 1986.

Flooding and erosion conditions along the Stoney Creek and Battlefield Creek continue to deteriorate and impact private property and municipal infrastructure based on the limited historical application of stormwater management and erosion mitigation works implemented since 1989 and previously.

1.4. Problem Statement

In recent years, flooding and erosion have become more of a concern. The stability of the Stoney and Battlefield Creeks has been compromised in localized reaches. Severe erosion has caused stream bank widening and slope stability issues for some neighbouring property and municipal infrastructure.

Solutions to address remedial flooding and erosion problems are to be developed within this Conservation Ontario Class EA study process to protect public safety, municipal infrastructure, and private property and enhance the natural heritage system and protect the archaeological environment.

Since the Hamilton Conservation Authority conducted the City of Stoney Creek Flood Damage Reduction Study there has been no comprehensive study update of Stoney Creek and Battlefield Creek conditions and as such, the work completed more than 20 years ago is considered to be out of date and in need of updating.

1.5. Class Environmental Assessment

The "Class Environmental Assessment for Remedial Flood and Erosion Control Projects", Conservation Ontario, January 2002, along with the "Five-Year Review Report (2002-2006)", Conservation Ontario, January 31, 2007 clearly outline the process and approach related to addressing remedial flooding and erosion problems in riverine settings. The Conservation Ontario Class EA document defines the respective undertakings, which are governed by this process as follows:

> *Remedial Flood and Erosion Control Projects refer to those projects undertaken by Conservation Authorities, which are required to protect human life and property, in previously developed areas, from an impending flood or erosion problem. Such projects do not include works which facilitate or anticipate development.*

The Class Environmental Assessment for Remedial Flood and Erosion Control Projects establishes a planning and approval process for a variety of projects that may be carried out by Conservation Authorities in Ontario. The Conservation Ontario Class EA process categorizes proposed municipal projects according to their anticipated environmental impact, and calls for increasingly stringent review requirements as the magnitude of the anticipated environmental impact increases.

The Conservation Ontario Class EA requires notification of, and consultation with, relevant stakeholders. The Project Team has ensured that stakeholders were notified early in the planning process, and throughout the study. In the event that stakeholders raise issues that could not be resolved through discussion, these concerns would be referred to the Ministry of Environment for resolution.

Figure 1.1 illustrates a simplified version of the Conservation Class EA process for this project.

1.6. Schedule

The study was initiated in April 2008. Project milestones are summarized as follows:

April 28, 2008	-	Start up meeting
October 23, 2009	-	Notice of Intent and Public Information Centre Number 1 published in newspapers, on the Hamilton Conservation Authority's website and sent by mail to those within 200 m of the study area.
Fall 2011	-	Completion of profile of study area and identification of need and justification for improvements.
November 4, 2009	-	Identification of preliminary preferred alternatives and hosting of Public Information Centre Number 1.
January 7, 2011	-	Notice of Public Information Centre Number 2 published in newspapers, on the Hamilton Conservation Authority's website and sent by mail to all who expressed interest.
January 20, 2011	-	Hosting of Public Information Centre Number 2
Summer 2011	-	Documentation of Preliminary Preferred Solutions.
Fall 2011	-	Notice of Filing of Environmental Study Report published in newspapers and sent by mail to all who expressed interest.

1.7. Project Organization

The Project Team consisted of staff from the following organizations:

Proponent: **Hamilton Conservation Authority**
Hazel Breton
Patrick Ragaz
Lisa Jennings

City of Hamilton
Margaret Fazio
Udo Ehrenberg
Nahed Gbhn
Enzo Florio
Tricia Rosa
Peter DeIulio

Consultants and Sub-Consultants
AMEC Earth & Environmental (Project Management)
Blackport and Associates
C. Portt and Associates
Parish Geomorphic Limited
Dougan and Associates
Terraprobe Limited

1.8. Stakeholder and Agency Consultation

1.8.1. Notice of Intent and Initiate Class EA

A joint Notice of Study of Commencement and Public Information Centre Number 1 (PIC No. 1) detailing the study area, summarizing the objectives of the study and requesting comments was sent to stakeholders and agencies by mail on October 23, 2009. Approximately 1500 notices were mailed out by Hamilton Conservation Authority to residents within 200 m of the main branch of the Stoney Creek and Battlefield Creek. The Notice was also published in the Hamilton Spectator and the Stoney Creek News on October 23 and October 30, 2009 and on the Hamilton Conservation Authority's website. Copies of the newspaper advertisement, letters to stakeholders and agencies and copies of all comments received and written responses are contained in Appendix 'A'.

1.8.2. Public Information Centre No. 1

Public Information Centre Number 1 (PIC No. 1) was held on Wednesday November 4, 2009 at Cardinal Newman Catholic Secondary School. PIC No. 1 was the first opportunity for the general public to meet with the Project Team, and to review the study scope and discuss issues related to the project, including background information, local flooding and erosion issues and environmental considerations. Display boards were prepared that presented the following information (ref. Appendix 'B'):

- Conservation Ontario Class Environmental Assessment for Remedial Flood and Erosion Control Projects (2002);
- Background Information;

- Purpose and Objective of Study;
- Problem Statement and Study Area;
- Existing and Future Land Use;
- Hydrogeology;
- Hydrology and Hydraulics;
- Regulatory Floodplain Map;
- Stream Morphology;
- Aquatic Habitat;
- Water Quality;
- Terrestrial Resource, and
- Next Steps.

The fist PIC was well attended, with 74 (+/-) people signing in and approximately 90 to 100 people estimated to have been in attendance. People expressed concerns with respect to flooding of basements, private lands and the erosion of creek banks within rear yards. A large group of residents from the Donn Avenue and immediate neighbourhood adjacent to Stoney Creek voiced concerns of basement flooding resulting from the June 26, 2009 storm event and migrating creek banks threatening the loss of private property. Copies of all comments received and written responses are contained in Appendix ‘A’.

1.8.3. Public Information Centre Number. 2

The Public and Agencies were notified of Public Infomation Centre Number 2 by letter and newspaper advertisement. Public Information Centre Number. 2 (PIC No. 2) was held on Wednesday January 20, 2011 at the Stoney Creek Municipal Office – 777 Highway 8, Stoney Creek. PIC No. 2 provided the general public an opportunity to ask questions from the Project Team, review the preliminary preferred alternatives and discuss issues related to the project, including local flooding and erosion issues and environmental considerations. Letters to stakeholders and agencies, copies of all comments received and written responses are contained in Appendix ‘A’. Display boards were prepared that presented the following information (ref. Appendix ‘B’):

- Conservation Ontario Class Environmental Assessment for Remedial Flood and Erosion Control Projects (2002);
- Study Area
- Background Information
- Problem Statement and Purpose
- Short-listed Flooding Alternatives
- Short-listed Erosion Alternatives
- Land Management Practices
- Flood and Erosion Short-list of Alternatives

- Flooding and Erosion Control Preliminary Preferred Alternatives for Reaches SC-1 to SC-7 and BC-1 to BC-5
- Next Step.

A presentation of the foregoing was also made by the Study Team in the Council Chambers. Approximately 50 people attended the PIC with 32 people signing in. The majority of comments and/or questions on the presentation related to the timing of creek works to address on-going creek bank erosion which could result in the loss of private property.

1.8.4. Filing of the Environmental Study Report

All parties having expressed an interest in the project have been notified by letter, regarding the completion of the project and filing of the ESR. In addition, a Notice of Completion was placed in the local newspaper, Hamilton Spectator and the Stoney Creek News on TBD and TBD and on the Hamilton Conservation Authority's website, in accordance with the requirements of the Class EA.

Copies of the Environmental Study Report were made available at the following locations:

City of Hamilton	Hamilton Conservation Authority
Office of the City Clerk	Woodend
City Hall	838 Mineral Springs Road
71 Main St. W., 1st Floor	P.O. Box 81067
Hamilton, Ontario, Canada	Ancaster, Ontario, Canada
Hours: Mon-Fri: 8:30 a.m. to 4:30 p.m.	Hours: Mon-Fri: 8:30 a.m. to 4:30 p.m.

A review period of not less than thirty (30) days will be provided, during which comments will be received from stakeholders and agencies. Should stakeholders raise issues that cannot be resolved through discussion with Hamilton Conservation Authority and Consultant staff, the stakeholder may request the Minister to require the Hamilton Conservation Authority to complete an individual EA in accordance with Part II of the EA Act. This is known as a "Part II Order" (formerly known as a 'Bump-up'). However, it is anticipated that all concerns will be resolved through discussion between Hamilton Conservation Authority and the concerned party.

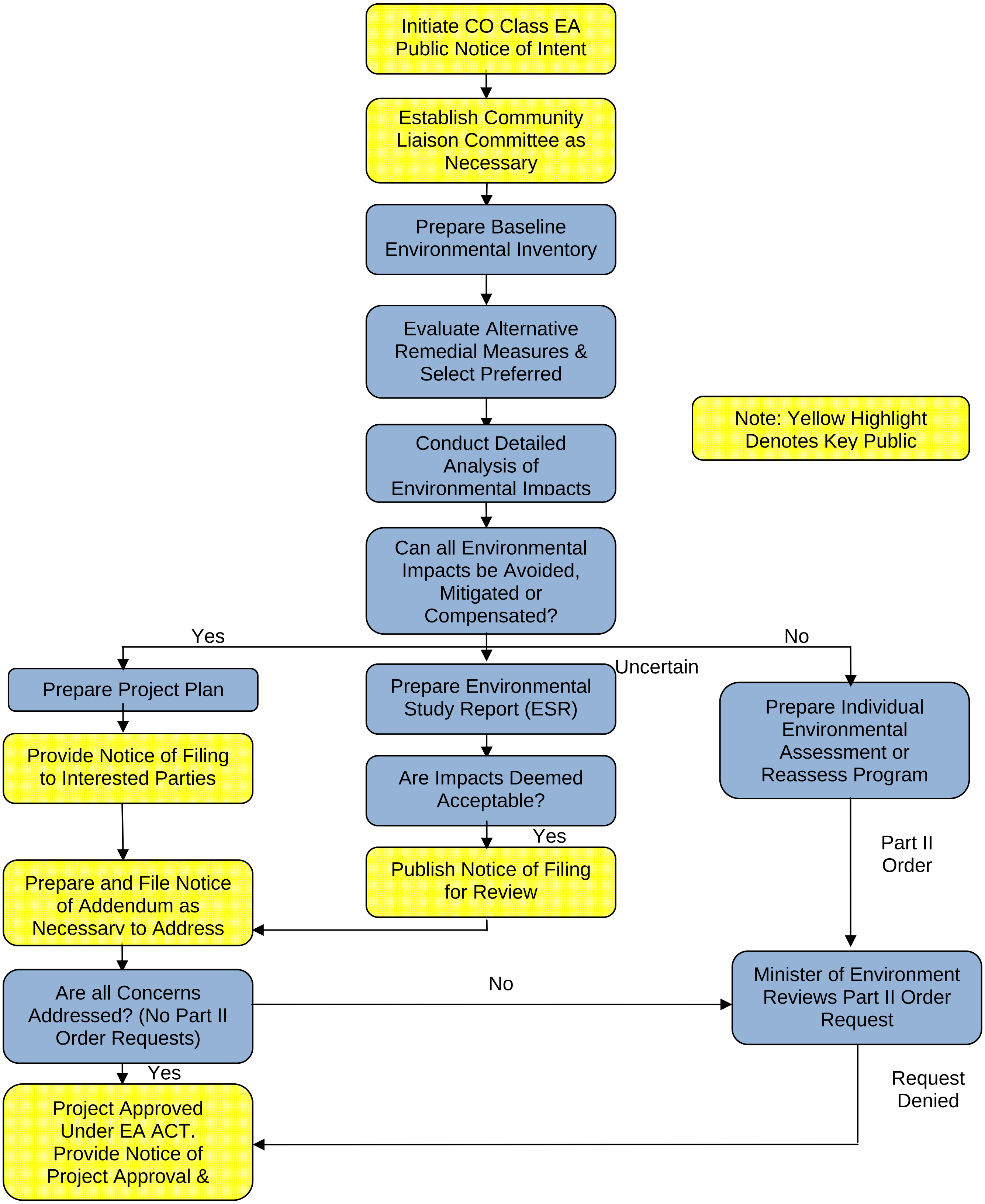

Figure 1.1 Planning and Design Process Class Environmental Assessments
[Note: Figure reproduced from Conservation Ontario, 2002]

2. BACKGROUND INVENTORY

2.1. Reports, Studies and Mapping

This section provides a summary of the background information, which has been collected and reviewed for this study. Numerous documents have been made available for the current study; this section however, focuses attention to that information, which specifically pertains to the water resources and environmental aspects of the study area.

This section provides a brief summary of the reports and studies relevant to the current undertaking.

1. *City of Stoney Creek Flood Damage Reduction Study, June 1989* (Philips Planning and Engineering Limited)

   This study documents the hydrologic and hydraulic conditions for Stoney Creek, Battlefield Creek and Watercourses 1 to 12 within Stoney Creek. Additionally, the study provides recommendations to reduce or prevent flooding at various flood-prone sites. The current Conservation Ontario Class EA analyses have been based upon the initial hydrologic and hydraulics conditions from this study.

2. *Stormwater Quality Management Strategy, Community of Stoney Creek, Master Plan, June 2004* (Philips Engineering Ltd.)

   The former City of Stoney Creek and subsequently the City of Hamilton required a Master Plan for providing stormwater quality control for proposed development within the Community of Stoney Creek. The Master Plan provides recommendations for stormwater quality facilities, retrofit facilities considered to be Direct Opportunities and outlines general Indirect Opportunities such as sensitive hydrogeological area considerations.

   Recommendations for Stoney Creek and Battlefield Creek included stormwater management retrofit facilities at four locations and one new ‘Greenfield’ stormwater management facility above the Niagara Escarpment within the Nash Neighbourhood. Water quality inlets for spill control for specific industrial land uses were also recommended. Indirect Opportunities included consideration of hydrogeological sensitive areas through the development process, riparian plantings, and erosion control.

3. *Stoney Creek Ravine Slope Stabilization and Sanitary MH Exposure Class Environmental Assessment, November 2004* (Philips Planning and Engineering Ltd.)

   This study led to the construction of slope stability works and a creek realignment to protect both municipal infrastructure and private property located north of Queenston Road and upstream of the confluence with Battlefield Creek.

4. *Hamilton Groundwater Resources Characterization and Wellhead Protection Partnership Study*, *November 2004* (SNC Lavalin)

   The study constitutes a master plan for the protection of groundwater resources within the City of Hamilton. The study outlines recommendations for the protection of groundwater quantity and quality and develops a hydrogeological framework for land use policies.

2.1.1. Technical Drawings and Maps

The following maps and drawings have been provided for the current study:

- 2002 Digital contour mapping within the City of Hamilton (1 m contour intervals).
- 2007 Digital mapping of roads, buildings, creek locations within the City of Hamilton
- 2005 Aerial photograph of the study area
- Hamilton Conservation Authority's digital ecological land classification (ELC), regulated area, environmentally sensitive area (ESA), natural area of interest (NAI) mapping

2.1.2. Models

The OTTHYMO-83 hydrologic model and the HEC-2 hydraulic models, which were developed for the City of Stoney Creek Flood Reduction Study (Philips Planning and Engineering Limited, June 1989), have been obtained. Based on consultation with the Hamilton Conservation Authority and City of Hamilton staff, these are the most current approved models for the Stoney Creek and Battlefield Creek apart from hydraulic modelling which was completed for the Stoney Creek Ravine slope stabilization work completed in 2005 and a local reach of Battlefield Creek immediately upstream of the Lake Avenue that received bank repair work in 2003.

3. BASELINE INVENTORY

The Conservation Ontario Class EA process requires that a baseline inventory of the study area be completed. The baseline inventory was completed for this study in order to document the background information and assess the existing conditions of Stoney and Battlefield Creeks in various disciplines relevant to the identified flooding problem, including hydrology, hydraulics, aquatic and terrestrial natural inventories, stream morphology, and land use conditions.

3.1. Hydrogeology

3.1.1. Background

Hydrogeology is the study of the movement of water through the ground and the interaction of this groundwater with surface water. It is important to understand the inter-relationship between the hydrogeologic conditions, the hydrological conditions and the subwatershed ecosystem in order to assess and develop targets and controls for potential land use changes and existing issues.

It is important to understand how hydrogeologic conditions influence the water movement and the hydrologic cycle. Water from precipitation percolates or infiltrates into the ground until it reaches the water table. Groundwater recharge areas are where water moves downward and away from the water table and/or away from the ground surface. These areas are generally in areas of topographically high relief. Areas where groundwater moves upwards towards the water table and/ ground surface are known as discharge areas. These generally occur in areas of topographically low relief, such as stream valleys. Groundwater that discharges to streams is the water that maintains the baseflow of the stream. Wetlands are often fed by groundwater discharge. Recharge and discharge can occur locally or on a regional scale.

There are different types and rates of recharge and discharge. Water percolating into the ground at a specific location may discharge to a small stream a short distance away. This is local recharge and local discharge. Some water may recharge a certain area and discharge to a larger river basin a long way from the source of recharge. This is known as regional recharge and regional discharge.

Permeable geologic materials through which groundwater moves are known as aquifers. Aquifers are "water bearing" formations meaning that water can be easily extracted from these units. The less permeable units are known as aquitards, and although water can move through these units, it moves slowly and it is difficult to extract water from these units. How these aquifers are connected within a hydrogeologic setting is what controls much of the movement of groundwater.

A delineation of the flow system(s) in this way will identify where groundwater originates, where it discharges and the most prominent paths it travels between these points (e.g. the aquifer pathways or more permeable hydrostratigraphic units). Having done this, one can assess the relative sensitivity of the linkage from the groundwater system to the aquatic or terrestrial systems. Knowing the level of sensitivity of the receptor one can determine the impacts of particular types and scales of land uses or land use changes on the groundwater flow system and other linked ecosystem components. Best management practices can then be developed to prevent unacceptable impacts from occurring.

The overall objectives of the hydrogeological inventory component are:

- Identify the geological and hydrogeological setting for the study area watershed and

- Identify the linkages between the watershed's hydrogeology and hydrology.

3.1.2. Methods

A detailed summary of the geology and hydrogeology was provided in Philips, 2004. Any additional information was expected to be updated and incorporated into the current Watershed Characterization Report (Source Water Protection, January 2008).

In addition to the background review, streamflow measurements were carried out to assess baseflow quantities at selected streamflow measurement locations.

Spot baseflow measurements were taken throughout the study area on April 23, 2008, September 25, 2008, May 25, 2009 and September 20, 2009. The measurement locations are shown on Figure GW-1 (ref. Appendix 'C').

Spot baseflow measurements are used to determine the distribution of baseflow within the watershed. Based on the distribution of volumetric flow along the watercourses within the study area it is possible to determine the general locations of groundwater discharge areas. Municipal infrastructure may reduce groundwater elevations locally and provide conduits for groundwater to travel along in between storm events thus adding to baseflow at the storm drain discharge locations.

The streamflow method used was a cross-sectional velocity survey. This method gives an accurate site-specific representation of streamflow conditions at the time of measurement. In order to accurately compare streamflow measurements taken along a tributary or the entire system, the measurements must be taken within a short time span; preferably the same day in unchanging (dry) weather conditions.

This technique involves first measuring the width of water surface at each location. The water depth and velocity is then measured at regular intervals across the stream. The depth, velocity and distance (from stream-edge) for each measuring point are recorded in the field along with the total stream width. The first and last measurements are taken at the respective stream edges.

The total streamflow is then calculated using the “mean-section” method. This method calculates the cross-sectional area of the “panel” between measuring points, and the average velocity within that panel. The area and velocity are multiplied to obtain a flux (discharge). The summation of the flux across the panels equals the total stream discharge at that location at that time.

Drivepoint piezometers were installed at streamflow sites 11, 12 and 5 to determine water table height and the potential for groundwater discharge to the local stream reach.

3.1.3. Results

Physiography

The study area straddles three physiographic regions based on interpretations by Chapman and Putnam, 1951 (i) The Haldimand Clay Plain (ii) The Niagara Escarpment and (iii) the Iroquois Plain. The Haldimand Clay Plain is generally flat to rolling. The soils consist of clay and silt sediments draped over a series of subdued moraines. The Vinemount Moraine and Niagara Falls Moraine transect the Haldimand Clay Plain parallel to the Niagara Escarpment accounting for some of the local relief. The southern limit of the watershed is delineated in part by the Niagara Falls Moraine which serves as a groundwater divide between Twenty Mile Creek, Forty Mile Creek and the study area. The Niagara Escarpment represents a significant physiographic region which extends as a band across Ontario from Niagara Falls to the east to the Bruce Peninsula to the northwest. The Niagara Escarpment is capped with a resistant dolostone of the Lockport Formation which is typified by a steep rock bluff above a talus till covered slope. Soil cover along the crest of this feature is limited whereas soils at its base can be in the order of 15 m thick. Bedrock is very close to ground surface through a large portion of the study area below the Niagara Escarpment. Above the Niagara Escarpment overburden is generally less than 8 m thick except in the morainic areas. The Iroquois Plain represents a north sloping plain with several stranded shoreline features located between the Niagara Escarpment and present day Lake Ontario.

Total surface relief for the watershed is in the order of 140 m, most of which is due to the height of the Niagara Escarpment which is approximately 70 m.

Surficial Geology

The Haldimand Clay Plain, on top of the Niagara Escarpment, consists of glaciolacustrine clay and silt deposits overlying the Vinemount and Niagara Falls Moraines. These moraines consist of Halton Till which were deposited during the Port Huron Stage of the late Wisconsinian Stage. The overlying clay and silt were deposited shortly thereafter during the same stage at the northern margin of an extensive pre-glacial lake, Lake Warren.

The Iroquois Plain, below the Niagara Escarpment, consists of up to 25m of Halton Till deposited onto the Queenston Shale or the Escarpment rock during the same era as the moraines above the Escarpment. Following retreat of the Ontario lobe of the glacier the area below the Escarpment was exposed and re-submerged on various occasions. Based on the depositional history of this area it is interpreted that the Halton till had not yet been penetrated at this location and the interbedded sand and silts were likely deposited when the area was submerged by Lake Iroquois.

The surficial geology, as presented in the Watershed Characterization Report, is shown in Figure GW-2 (ref. Appendix 'C').

Bedrock Geology

Bedrock geology in the area ranges from Middle Silurian (Lockport Dolostone) above the Niagara Escarpment to Upper Ordovician (Queenston Shale) below the Escarpment. The bedrock of the Niagara Escarpment represents the transition between the Appalachian Basin and the Algonquin Arch sedimentary environments. The depositional sequence is summarized below:

Lockport Formation

- Eramosa Member: Greyish brown to grey dolostone
- Goat Island Member: Light brown dolostone with chert nodules (Ancaster Chert Bed)
- Gasport Member: Light to medium grey medium crystalline crinoidal dolomite

Sequential Formations

Decew Formation: Grey to brownish grey agrillacious microcrystalline dolomite
Rochester Formation: Dark grey shale interbedded with crinoidal dolomite
Irondequoit Formation: Grey crinoidal dolomite
Reynales Formation: Grey to greenish grey dolostone with thin shale partings
Thorold Formation: Greenish grey sandstone and shale
Grimsby Formation: Red and green sandstone, siltstone and shale

Cabot Head Formation: Grey, green interbedded shale, siltstone and dolostone
Whirlpool Formation: Tan to grey sandstone with siltstone inclusions
Queenston Formation: Red shale with inclusions of green siltstone

The surficial topography generally reflects the bedrock topography through a majority of the watershed. The bedrock topography slopes towards the Escarpment.

Hydrostratigraphy

Hydrostratigraphy is a term used to describe geological units and their functions in the hydrogeological system.

Within the study area much of the surficial overburden consists of clay material which typically is of a low permeability, that is, it does not transmit water readily. When the clay overburden is thin and overlies a more permeable unit, which acts to underdrain the overburden, extensive fracturing in the clay generally occurs. Throughout the upper portion of the watershed the underlying dolostone bedrock can be highly fractured in the upper 10 m. This bedrock fracturing allows for ready transmittal of groundwater both in the vertical and horizontal direction. The fracturing within the clay is known to occur to depths of 8 m (25 feet) and allows for a significant amount infiltration and movement of groundwater vertically. The horizontal hydraulic connection of the clay fractures is much weaker. Below the Escarpment the underlying bedrock is a low permeable shale which may not provide as significant an underdrain and as such will likely not lead to extensive fracturing in the overlying clay tills. There are deposits of permeable sands along the west central boundary of the study area which will allow for significant infiltration and transmittal of groundwater on a more local scale.

Above the Niagara Escarpment, where the overburden is generally less than 8 metres thick, precipitation infiltrates through the overburden to the upper bedrock. The groundwater moves horizontally through the fractured dolostones of the Guelph, Eramosa and Gasport Units and would normally discharge to the creek and local tributaries, generally where topographic breaks occur and the bedrock outcrops. This does not appear to occur to any great degree within this portion of the study area. The Vinemount Shale will tend act as an aquitard or a barrier to the vertical transmittal of significant amounts of groundwater.

Groundwater is transmitted to depth under relatively strong hydraulic gradients (i.e. differences in water levels in the various units). The amount transmitted is a smaller percentage of that groundwater which moves through the shallow horizontal flow system due to the low vertical permeability of a number of the geological units, in particular the shale units.

In areas along the face of the Niagara Escarpment, groundwater may discharge as diffuse seeps. This water tends to be lost to evapotranspiration.

Groundwater at depth, in the Queenston Shale, tends to move towards the lake. In addition, below the Escarpment the potential for groundwater discharge is greater within the local permeable sand units. Groundwater may discharge in limited quantities where there are topographic breaks and where streams cut into the shale. As discussed, relatively higher rates of infiltration occur where the overburden is thin or permeable.

It is important to recognize the prior to and through the course of this study above average precipitation has occurred and higher water tables may exist as a result. This may influence the location and quantities of groundwater discharge to the various stream reaches.

The general water table contours, as derived within the Watershed Characterization Report are presented in Figure GW-1 (ref. Appendix 'C').

Baseflow observations can be found in Table 3.1.1. The locations for these streamflow sites can be found on Figure GW-1. Streamflow generally correlates with field observations carried out during the fisheries study. The Main Branches of Battlefield and Stoney Creek below the escarpment consistently show groundwater discharge as well reaches in the vicinity of baseflow locations 8 and 6. Baseflow is likely influenced by leakage though storm drains and was observed at the Battlefield Creek culvert at King Street. The expected higher water tables resulting from above average precipitation would give rise to this infrastructure contribution.

Table 3.1.1: Baseflow Measurements

Site	Date / Spot Flow (L/s) April 23/08	Sept 25/08	May 25/09	Sept 20/09
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	trace	trace	3.2	2.8
7	0	0	0	0
8	2.4	3.6	4.4	3
9	6.3	5.1	3.6	8
10	12.5	7.4	8.4	18
11	3.2	0	trace	3
12	10.2	4	6	12
13	8.6	4.6	5.2	6.5
14	5.5	2.1	4.5	5
15	12	8.2	11	14

Water levels from the 3 drivepoint piezometers (Table 3.1.2, the DP numbers refer the streamflow sites shown in Figure GW-1) show the potential for groundwater discharge in the reaches at Queenston Road. The drivepoint piezometer installed at 3rd Road East (DP5) shows a relatively high water table within the overburden, however also shows the losing nature of Stoney Creek above the escarpment and the lack of potential for groundwater discharge.

Table 3.1.2: Water Level Monitoring Results Summary

Date	Water Level Relative to Stream Level (m)		
	DP11	DP12	DP5
May 25/09	0.13	0.04	-0.46
September 20/09	0.00	0.01	-0.31

Note: (negative value = below stream level)

3.1.4. Summary of Findings

- The study area is covered by clays which tend to minimize infiltration of water except in areas where the clay is thin.
- Underlying the clay is dolostone/limestone bedrock above the escarpment and shale below the escarpment.
- Water infiltrating above the escarpment will move downward through the clay and bedrock and then move horizontally towards Lake Ontario below the escarpment where limited amounts of groundwater may discharge to the creeks.
- The general direction of groundwater flow follows the contours of the water table.
- Groundwater discharge to the creeks, known as baseflow, was measured and occurs almost entirely below the escarpment.
- Baseflow in these creek reaches is generally less than 10 litres per second.
- Contributions from infrastructure drainage may be significant in local reaches.

3.2. Hydrology

3.2.1. Background

Hydrology is the science of determining the amount of water moving through various processes within a watershed, based on various meteorologic conditions. Hydrologic modelling allows for the determination of a runoff rate from a particular land form in response to a rainfall or snowmelt event.

For this study, the hydrologic analyses have been completed to produce the frequency flows (flow regime) in Stoney Creek and Battlefield Creek. In the Hydraulics Section 3.3, the frequency flows have been used to evaluate the existing flow conveyance capacity of hydraulic infrastructure. Combined, hydrology and hydraulics provided the tools for developing a better understanding of the effectiveness of various flood and erosion mitigation alternatives.

This section provides a summary of the approach and steps used in preparing the hydrologic models for use in the assessment of runoff response and flooding mechanisms in the Stoney Creek and Battlefield Creek watershed.

3.2.2. Methods

3.2.3. Hydrologic Model Development

Hydrologic analyses for Stoney and Battlefield Creeks have been completed previously (ref. City of Stoney Creek Flood Damage Reduction Stud*y*, Philips Planning and Engineering Limited, June 1989). The 1989 study applied the OTTHYMO-83 hydrologic model; which adopted the 12-hour SCS Type II rainfall distribution.

The OTTHYMO-83 hydrologic model is a discrete event model, and is not structured for true continuous simulation. The event-based approach does not account for the effects of seasonal variations in hydrologic conditions, varying antecedent conditions and the inherent variations in hydrograph shape (i.e. runoff volume). For these reasons, a continuous simulation approach, which is based upon observed historic rainfall and temperature within the study area, has been traditionally considered a more rigorous means of analyzing the hydrology of a watershed under various land use conditions and is generally accepted as being more reliable then event methodology. OTTHYMO-83 is incapable of simulating snow accumulation and melt, and is not set up for a continuous simulation. For the purpose of completing continuous simulation for the current study, the QUALHYMO model has been selected as the most appropriate modelling platform given the study objectives. Both the OTTHYMO-83 and QUALHYMO models have been derived from a similar methodology, hence the conversion from one to other is generally less biased. While the QUALHYMO model uses similar parameterization for developing runoff response, certain parameters are different including the following:

- The OTTHYMO model simulates the effects of urbanization using the CATCHMENT command, which simulates the runoff from the pervious portion of the subcatchment using the SCS Method, Horton Infiltration Equation or Green and Ampt Equation. Urbanized areas are simulated in QUALHYMO based upon the Williams Unit Hydrograph, which calculates runoff from pervious portion of the subcatchment based upon maximum and minimum values of soil storage. The parameters for the SCS parameterization is convertible to values of soil storage used within QUALHYMO.
- The OTTHYMO model simulates the hydrologic effects of undeveloped subcatchments using the SCS Unit Hydrograph and a runoff Curve Number (CN) for the subcatchment, based upon the soil type. The QUALHYMO methodology also applies the Nash Unit Hydrograph to simulate runoff from undeveloped

subcatchments, however soil storage is entered rather than the CN. Nevertheless, values of soil storage can be obtained based upon the CN provided.

- The QUALHYMO methodology is more complex than the OTTHYMO methodology, and as such includes a greater number of parameters for simulating runoff from subcatchments. The following is a partial list of the additional parameters in the QUALHYMO methodology which are used to simulate runoff from developed and undeveloped subcatchments:

  - A variable (S) relating soil storage to antecedent precipitation.
  - A baseflow calibration factor (BAFCR)
  - A baseflow storage constant (SK1)
  - A baseflow coefficient (SK2)
  - A baseflow recession constant (SLOSK1)
  - A baseflow reduction factor (SLOSK2)

The values for the above parameters are determined by calibrating the model, whereby the parameters are modified as required to simulate flow corresponding to observed flows using corresponding rainfall data.

QUALHYMO uses directly connected impervious coverage rather than directly connected and total impervious coverage used in OTTHYMO. Land use directly connected impervious ratios used within the hydrologic modelling have been provided within Table 3.2.1

Table 3.2.1: Impervious Coverage by Land Use

Land Use	Directly Connected Imperviousness (%)
Cult. land - without cons.	0
- with cons.	0
Pasture/Range - poor	0
- good	0
- 50/50	0
Meadow	0
Orchard	0
Forested Land - thin	0
- good	0
Open spaces - grass +75%	0
- grass 50-75%	0
Commercial (85% imp.)	68
Industrial (72% imp.)	68
Residential -1/8 ac., 65% imp. (townhouses)	20
1/4 ac. 38% imp.	11
1/3 ac. 30% imp. (ave. lot)	9
1/2 ac. 25% imp.	3.7
1 ac. 20% imp.	3
Parking Lots (paved, includes landscaped area)	80
Streets/Roads – paved (only paved area)	100

Storage-discharge relationships were obtained for routing elements such as creek reaches below the Niagara Escarpment using the flood storage values from a HEC-RAS model (ref. this section) with bridges in place for hydrologic model calibration and without bridges in place for establishing frequency flow rates. Above the Niagara Escarpment, aerial mapping, topographic mapping, in addition to field observations, have been used to establish watercourse cross-sections to develop flood storage rating curves for use in the hydrologic model.

Parameters for simulating snow accumulation and melt have been used from an approved application of a similar hydrologic model within a study area of similar climactic conditions. A QUALHYMO model was developed for the Georgetown West and Georgetown South Master Drainage Plan Update Study (Philips Planning and Engineering Limited, October 1996). This model ran a continuous simulation, and included parameters for the simulation of snow accumulation and melt. Given that Halton is in proximity to the study area, the snowmelt parameters provided in the QUALHYMO hydrologic model of the Georgetown study have been deemed satisfactory for the current assessment of Stoney Creek and Battlefield Creek, and have been incorporated into the QUALHYMO model.

The 1989 FDRP drainage area plan has been used as the basis for developing the current drainage area plan, with boundaries being adjusted based on the 2007 topographic mapping, storm sewer mapping and field truthing. Catchment discretization has been increased from the 1989 FDRP, based on providing peak flows at each tributary confluence with the main branch and at all hydraulic crossings downstream of the Niagara Escarpment (ref. Drawing 2).

Meteorological Data

The QUALHYMO hydrological model has been executed in both continuous and event based modes. An hourly precipitation data set has used the 34 years of continuous rainfall record from the most local long-term gauge [Royal Botanical Gardens rainfall gauge (1962 to 1995 inclusive)]. Temperature data has come from the Toronto Pearson International Airport.

For modelling design storm events, the City of Hamilton intensity duration frequency relationships (IDF) have been used for the 2 year through 100 year storms. As per the FDRP the SCS Type II 12-hour temporal distribution has been used. The Regional Storm (i.e. Hurricane Hazel) is a historic storm, and the rainfall data for this event was obtained from the “Flood Plain Management in Ontario Technical Guidelines”, published by the Ontario Ministry of Natural Resources in 2002.

3.2.4. Model Calibration

The QUALHYMO hydrologic model has been calibrated to observed flows and rainfall data. The calibration process has included the use of data from a stream flow gauge and level logger located on Battlefield Creek, upstream of the confluence with Stoney Creek and downstream of Lake Avenue (ref. Drawing 2). Rainfall data and stream flow data has been provided from the Hamilton Conservation Authority's rainfall gauge located at Queenston Road, next to the Stoney Creek. The flow data provided by Hamilton Conservation Authority has been reviewed and has not been used as part of the calibration process as the data has been considered unreliable, as the creek bed where the flow gauge is located is not stable, therefore resulting in a depth/ flow rating curve that continually changes.

Flow monitoring has been conducted as part of this Conservation Ontario Class EA from April 15, 2008 to November 21, 2008. Topographic survey of the flow monitoring location has been conducted to facilitate the generation of a flow-depth rating curve. The rating curve for the flow monitoring location was established based on observed depth and velocity measurements during storm events and then compared to the hydraulic modelling results for the reach (ref. Appendix 'D').

Based on the observed rainfall during the monitoring period, 6 events have been selected for hydrologic model calibration. The calibration results include the rainfall hyetographs and flow hydrographs in addition to tables presenting the observed and simulated runoff volumes, runoff coefficients and peak flows. The hydrologic simulated results have been included on the hyetographs-hydrographs for comparison to the observed results (ref. Appendix 'D').

The calibration process has led to the following revisions to parameterization of the existing land use conditions hydrologic model for the Battlefield flow monitoring location.

Pervious Initial Abstraction (IA) decreased by 40%
Baseflow recession constant (SLOSKA) increased from 0.00001 to 0.001
Baseflow reduction factor (SLOSKB) decreased from 0.25 to 0.24
Baseflow Calibration Factor (BFARC) =0.20
Minimum Baseflow (BASMIN) =0.02 (@ Catchment 2006)

The soil parameters are a function of the SCS Curve Number (CN). The Baseflow Reduction Factor is a dimensionless parameter used to calibrate baseflow. To obtain an improved calibration of the model, the Pervious Initial Abstraction and Soil Parameters (SMIN, SMAX and API) have been altered to within the limits of reasonable values for the study area being considered (SMIN: 31 to 217, SMAX: 145 to 1187 and API: 65.1 to 495.4).

The calibration process has been conducted to obtain a reasonable comparison between the observed and simulated flow data, using appropriate parameterization. Peak flow observed versus simulated has an R^2 of 0.79 and when using a one to one ratio has an R^2 of 0.77 (ref. Appendix 'D'). Runoff coefficient correlation observed versus simulated has an R^2 of 0.52 based on some unrealistic observed values such as 0.07 for a 18.70 mm storm as shown in Table 3.2.2. Figure 3.2.1 provides the graphical form of the results in Table 3.2.2, showing a good correlation between observed versus simulated peak flows.

Table 3.2.2: Calibration Results

Rainfall Event	Duration	Amount	Runoff Volume (m^3)		R^2	Runoff Coefficient		R^2	Event Peak (m^3/s)		R^2
Date	(hrs)	(mm)	Observed	Simulated		Observed	Simulated		Observed	Simulated	
5/3/2008 @ 12:00:00 PM	8.00	14.50	30590	28015	0.69	0.28	0.26	0.52	0.78	0.75	0.77
6/15/2008 @ 8:45:00 PM	4.00	18.50	11502	34382		0.08	0.25		0.88	1.05	
8/9/2008 @ 3:00:00 PM	7.00	33.50	169976	139895		0.67	0.55		1.60	2.21	
8/14/2008 @ 9:15:00 PM	2.00	30.20	73688	88879		0.32	0.39		2.35	2.29	
9/30/2008 @ 3:00:00 AM	5.00	18.70	9794	32905		0.07	0.23		1.53	1.51	
11/15/2008 @ 3:30:00 AM	23.50	31.20	186578	99092		0.79	0.42		1.41	1.22	

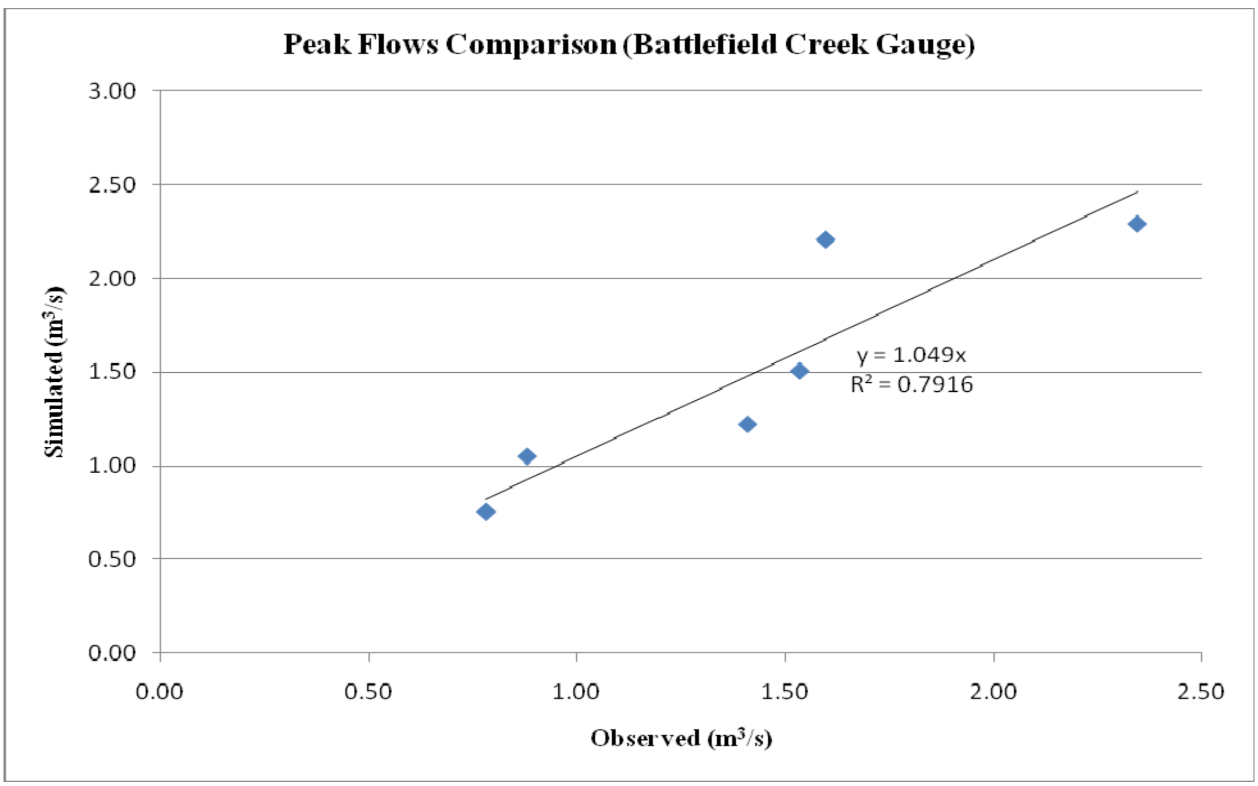

Figure 3.2.1: Observed vs. Simulated Peak Flow Comparison at Battlefield Creek Gauge

As part of the calibration process for the form of the observed versus simulated hydrographs has been assessed. As discussed previously, soil parameterization has been adjusted during the calibration process to achieve a closer correlation on peak flows, runoff volumes and hydrograph form. Figures 3.2.2 and 3.2.3 provide examples of how the simulated hydrographs closely matches the observed hydrographs, including rising and receding limbs, limited baseflow and peak flows, thereby adding additional assurance to the level of calibration.

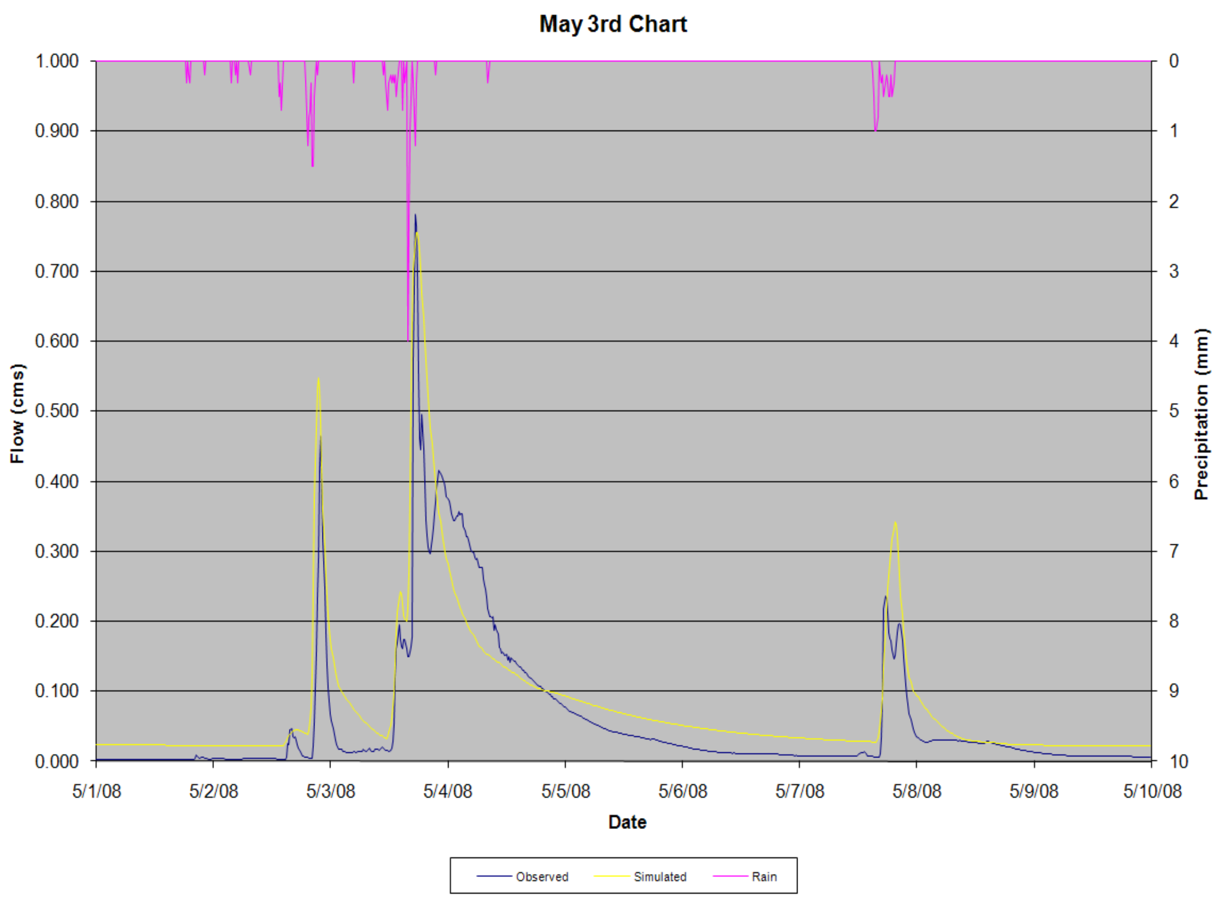

Figure 3.2.2 Observed vs. Simulated Hydrographs for the May 3rd, 2008 Storm Event

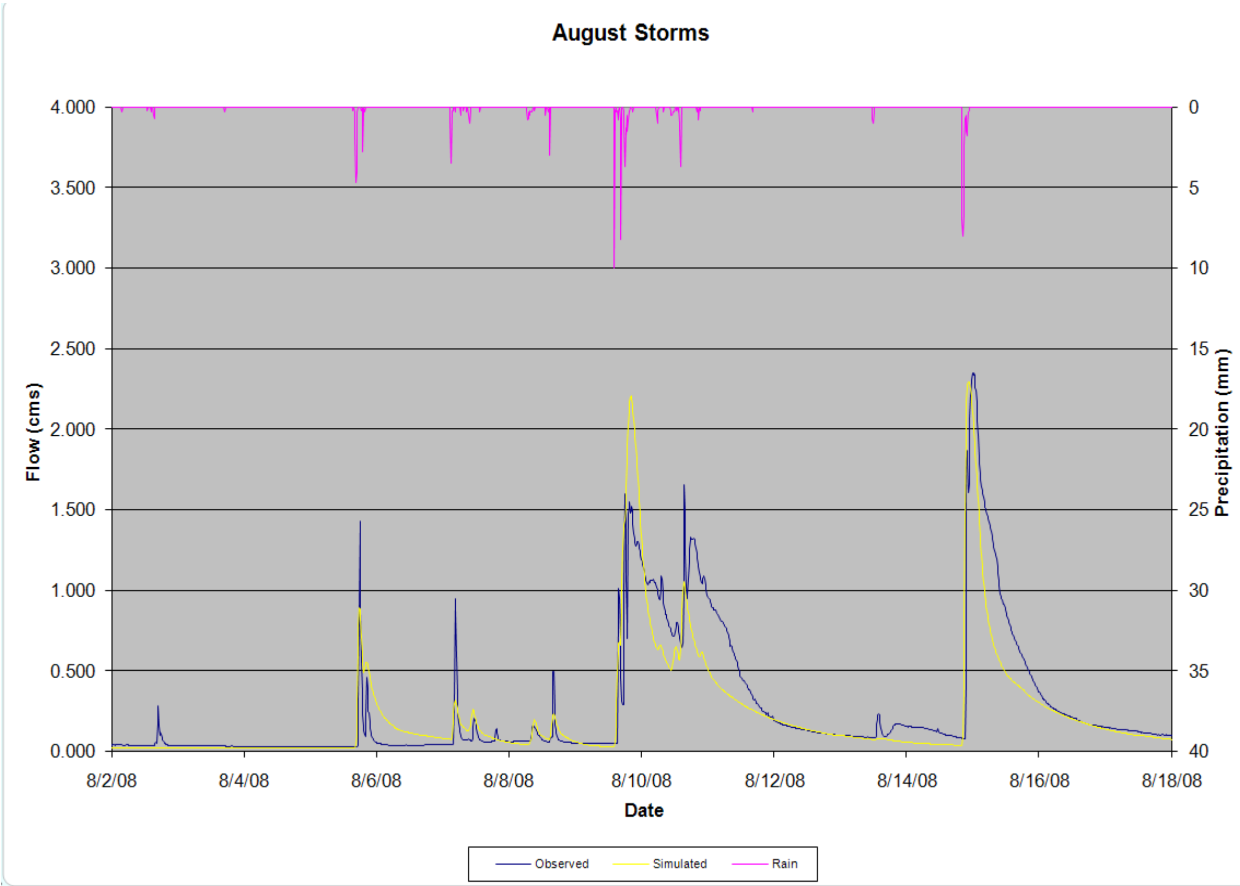

Figure 3.2.3 Observed vs. Simulated Hydrographs for the August 2008 Storm Events

Further verification of the QUALHYMO model has been conducted using Regional Storm Hurricane Hazel unitary flow rates from watercourses located within southern Ontario. Regional Storm flows have been compared for the Credit River, Humber River and Stoney Creek and Battlefield Creeks within Figure 3.2.4. The Credit River hydrologic modelling was conducted using HSP-F, while the Humber River hydrologic model used SWMHYMO, with each model being calibrated. Unitary Regional Storm peak flows for Stoney Creek and Battlefield Creek have been compared from both the 1989 FDRP and the current study. The unitary Regional Storm flows for the QUALHYMO hydrologic model for Stoney Creek and Battlefield Creek within Figure 3.2.4 are within a reasonable range, although considered to be slightly higher than the FDRP. Reasons for the unitary Regional Storm flows being above the FDRP are considered to be related to updated land use, hydrologic modeling platform and improved flow routing below the Niagara Escarpment.

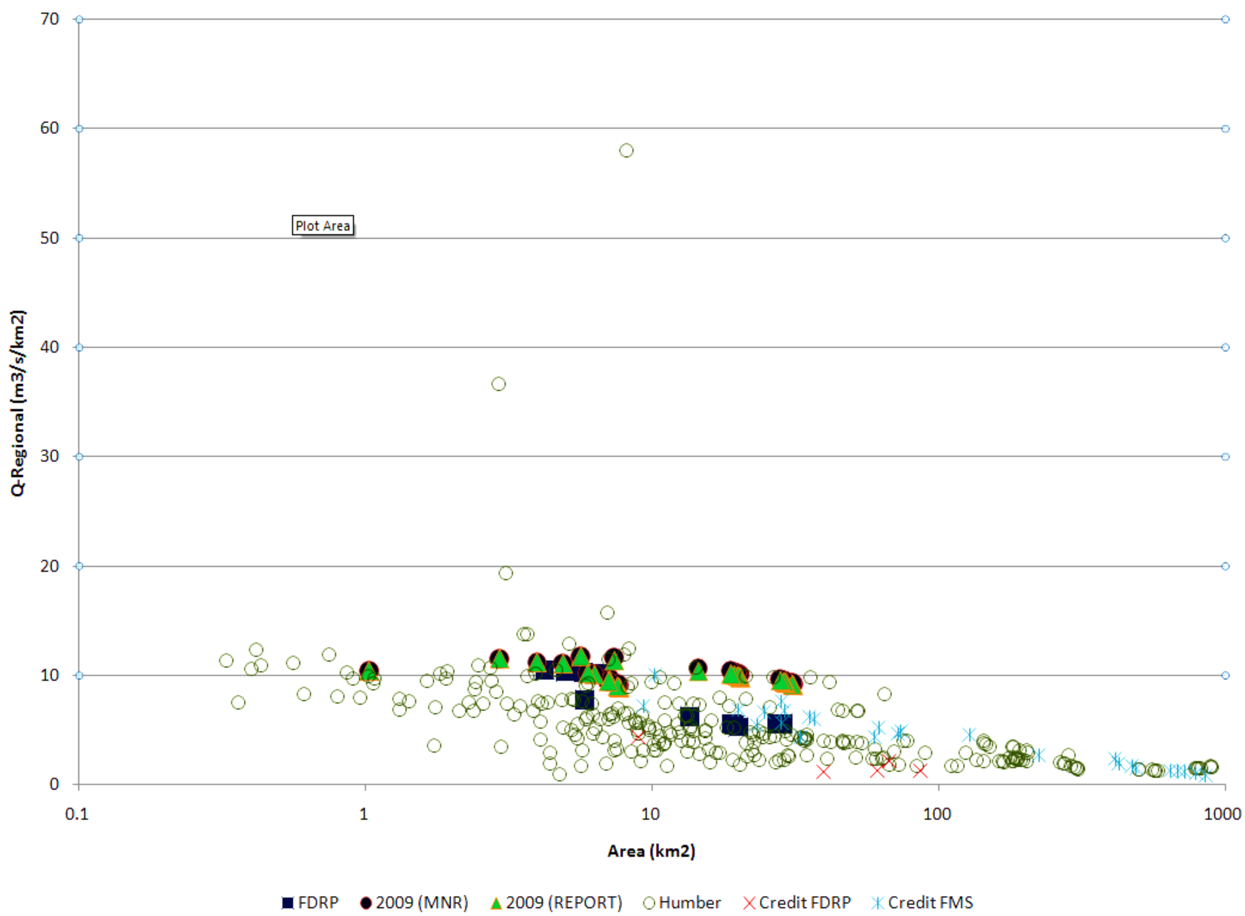

Figure 3.2.4 Comparison of Normalized Regional Storm Flows

Further verification has been conducted using unitary flow rates for the event and continuous based frequency peak flows presented in the hydrologic results Section 3.2.1.

3.2.5. Results

Hydrology

Hydrologic modelling has been conducted for both existing (2008) and future land use conditions. Peak flows have been determined for each land use conditions and compared to the peak flows from the 1989 FDRP.

Existing Land Use Condition

Table 3.2.3 compares the event based peak flows reported in the 1989 FDRP using OTTHYMO-83 based on the 12 hour SCS Type II distribution for the existing (2008) land use condition with those obtained using the QUALHYMO model for the existing land use condition (ref. Drawing 3). The QUALHYMO modelling has adopted design storms based on the updated City of Hamilton Intensity Duration Frequency (IDF) relationship. The relative difference between the flows simulated by the two models is provided in Table 3.2.4.

Table 3.2.3: Comparison of Simulated Design Event Flows (2008 Land Use) (m^3/s)

Location/Model	Return Period (Years)						
	2	5	10	20/25	50	100	Regional
1989 FDRP							
Stoney Creek							
Confluence near Tapleytown Rd. and Green Mountain Rd.	3.65	6.7	9.16	11.60	14.97	17.63	84.33
Edge of Escarpment	4.02	7.70	10.84	13.77	17.86	21.13	105.43
King St.	4.08	7.78	10.95	13.90	18.01	21.30	105.48
Highway 8	6.17	8.50	11.17	14.16	18.31	21.64	105.72
Battlefield/Stoney Creek Confluence	8.29	11.88	14.78	18.72	24.32	28.83	150.40
CNR	8.68	12.77	16.12	19.91	25.95	30.82	156.05
QEW	7.84	12.39	16.34	20.64	26.53	31.75	158.18
Lake Ontario	7.49	12.14	16.08	20.31	26.35	31.27	158.14
Battlefield Creek							
Confluence near Centennial Parkway	4.05	7.31	9.77	12.28	15.73	18.43	44.13
Edge of Escarpment	4.28	7.75	10.39	13.09	16.75	19.66	51.46
King St.	4.68	8.47	11.40	14.44	18.61	21.86	59.11
Highway 8	5.75	9.20	12.44	15.65	20.19	23.81	66.99
QUALHYMO 12 Hour SCS Type II Distribution							
Stoney Creek							
Confluence near Tapleytown Rd. and Green Mountain Rd.	5.18	10.89	16.36	22.54	27.48	32.72	105.19
Edge of Escarpment	6.72	13.50	20.31	27.78	34.50	41.39	135.98
King St.	6.97	13.86	20.77	28.37	35.19	42.18	138.31
Highway 8	7.42	14.46	21.48	29.28	36.26	43.37	142.11
Battlefield/Stoney Creek Confluence	10.64	20.15	29.36	39.54	48.71	57.93	185.63
CNR	11.11	20.84	30.10	40.57	49.85	59.14	188.44
QEW	12.13	22.29	31.81	42.73	52.30	61.89	194.71
Lake Ontario	12.15	22.34	31.85	42.81	52.38	61.98	194.78
Battlefield Creek							
Confluence near Centennial Pkwy	1.74	3.35	4.86	6.53	8.08	9.62	29.92
Edge of Escarpment	2.02	3.87	5.59	7.39	9.17	10.93	35.33
King St.	2.43	4.51	6.42	8.43	10.40	12.34	39.82
Highway 8	3.25	5.54	7.57	9.86	11.98	14.10	44.56

Table 3.2.4: Percent Difference in Simulated Peak Flows Current Study to FDRP (2008 Land Use) (%)							
Location/Model	**Return Period (Years)**						
	2	**5**	**10**	**20/25**	**50**	**100**	**Regional**
Stoney Creek							
Confluence near Tapleytown Rd. and Green Mountain Rd.	41.92	62.54	78.60	94.31	83.57	85.59	24.74
Edge of Escarpment	67.16	75.32	87.36	101.74	93.17	95.88	28.98
King St.	70.83	78.15	89.68	104.10	95.39	98.03	31.12
Highway 8	20.26	70.12	92.30	106.78	98.03	100.42	34.42
Battlefield/Stoney Creek Confluence	28.35	69.61	98.65	111.22	100.29	100.94	23.42
CNR	28.00	63.19	86.72	103.77	92.10	91.89	20.76
QEW	54.72	79.90	94.68	107.03	97.14	94.93	23.09
Lake Ontario	62.22	84.02	98.07	110.78	98.79	98.21	23.17
Battlefield Creek							
Confluence near Centennial Parkway	-57.04	-54.17	-50.26	-46.82	-48.63	-47.80	-32.20
Edge of Escarpment	-52.80	-50.06	-46.20	-43.54	-45.25	-44.40	-31.34
King St.	-48.08	-46.75	-43.68	-41.62	-44.12	-43.55	-32.63
Highway 8	-43.48	-39.78	-39.15	-37.00	-40.66	-40.78	-33.48

The results show that the calibrated hydrologic model is estimating peak flows significantly higher than the FDRP. Based on the FDRP using OTTHYMO-83 and the current modelling being conducted in QUALHYMO, differences in peak flows would be expected. Table 3.2.7. provides a comparison of unitary flow rates for design storm events. Based on the comparison the currently determined unitary flow rates are reasonable, with the FDRP unitary rates being low compared to all other watersheds.

The calibrated QUAHYMO hydrologic model has been run for the 34 year continuous simulation period. The annual maximum flows have been obtained from the model results in order to complete frequency analyses at selected locations. The frequency analysis has been conducted using the Consolidated Frequency Analysis (CFA) program. Two distributions have been assessed: Three Parameter Lognormal Distribution and Log Pearson Type III Distribution. As per the Ministry of Natural Resources guidelines for conducting frequency analysis, the Coefficient of Skew has been checked to determine which distribution is the most appropriate. Frequency analysis testing of both distributions has been conducted at the confluence and downstream at Lake Ontario limit. The Log Pearson Type III Distribution has been selected based on best fit of data within the scatter graphs and positive Coefficient of Skew.

Table 3.2.5 provides the simulated frequency flows as determined by continuous simulation and frequency analysis. Table 3.2.6 provides the percent difference between the FDRP design event peak flows and the QUALHYMO continuous based frequency flows. The QUALHYMO frequency event peak flow rates are considered to be reasonable.

Table 3.2.5: Frequency Flows for Existing (2009) Land Use Condition Based on Continuous Simulation (m^3/s)									
Location	Return Period (Years)[2]								
	1.05	1.25	2	5	10	20	50	100	Regional[1.]
Stoney Creek									
Confluence near Tapleytown Rd. and Green Mountain Rd.	2.13	3.25	5.62	10.6	15.1	20.3	28.6	36.0	105.19
Edge of Escarpment	2.73	4.18	7.17	13.2	18.6	24.8	34.5	43.1	135.98
King St.	2.84	4.32	7.35	13.5	19.0	25.3	35.2	43.9	138.31
Highway 8	3.04	4.55	7.65	14.0	19.6	26.0	36.1	45.1	142.11
Battlefield/Stoney Creek Confluence	4.66	6.67	10.80	19.2	26.6	35.2	48.6	60.5	185.63
CNR	4.92	6.98	11.20	19.6	27.1	35.6	48.9	60.6	188.44
QEW	5.64	7.62	11.80	20.6	28.6	37.9	52.7	65.9	194.71
Lake Ontario	5.66	7.63	11.80	20.6	28.6	37.9	52.7	66.0	194.78
Battlefield Creek									
Confluence near Centennial Parkway	0.81	1.17	1.87	3.28	4.5	5.89	8.04	9.93	29.92
Edge of Escarpment	0.99	1.41	2.25	3.88	5.28	6.86	9.28	11.4	35.33
King St.	1.27	1.73	2.65	4.49	6.09	7.92	10.7	13.2	39.82
Highway 8	1.86	2.24	3.15	5.29	7.39	10.0	14.4	18.5	44.56

NOTE: [1.] Regional Storm flow obtained using event methodology.

Table 3.2.6: Percent Difference Between Current QUALHYMO Frequency Flows Based on Continuous Simulation and FDRP Event Flows(%)									
Location	Return Period (Years)								
	1.05	1.25	2	5	10	20	50	100	Regional
Stoney Creek									
Confluence near Tapleytown Rd. and Green Mountain Rd.	N/A	N/A	53.97	58.21	64.85	75.00	91.05	104.20	24.74
Edge of Escarpment	N/A	N/A	78.36	71.43	71.59	80.10	93.17	103.98	28.98
King St.	N/A	N/A	80.15	73.52	73.52	82.01	95.45	106.10	31.12
Highway 8	N/A	N/A	23.99	64.71	75.47	83.62	97.16	108.41	34.42
Battlefield/Stoney Creek Confluence	N/A	N/A	30.28	61.62	79.97	88.03	99.84	109.85	23.42
CNR	N/A	N/A	29.03	53.48	68.11	78.80	88.44	96.63	20.76
QEW	N/A	N/A	50.51	66.26	75.03	83.62	98.64	107.56	23.09
Lake Ontario	N/A	N/A	57.54	69.69	77.86	86.61	100.00	111.06	23.17
Battlefield Creek									
Confluence near Centennial Parkway	N/A	N/A	-53.83	-55.13	-53.94	-52.04	-48.89	-46.12	-32.20
Edge of Escarpment	N/A	N/A	-47.43	-49.94	-49.18	-47.59	-44.60	-42.01	-31.34
King St.	N/A	N/A	-43.38	-46.99	-46.58	-45.15	-42.50	-39.62	-32.63
Highway 8	N/A	N/A	-45.22	-42.50	-40.59	-36.10	-28.68	-22.30	-33.48

A comparison of QUALHYMO design event and continuous frequency flows has been provided in Tables 3.2.7 and 3.2.8, demonstrating that peak flows are typically within a ten percent difference of each other.

Table 3.2.7 : Comparison of Simulated Design Event Flows (2008 Land Use) (m^3/s)							
Location/Model	**Return Period (Years)**						
	2	**5**	**10**	**20/25**	**50**	**100**	**Regional**
QUALHYMO 12 Hour SCS Type II Distribution							
Stoney Creek							
Confluence near Tapleytown Rd. and Green Mountain Rd.	5.18	10.89	16.36	22.54	27.48	32.72	105.19
Edge of Escarpment	6.72	13.50	20.31	27.78	34.50	41.39	135.98
King St.	6.97	13.86	20.77	28.37	35.19	42.18	138.31
Highway 8	7.42	14.46	21.48	29.28	36.26	43.37	142.11
Battlefield/Stoney Creek Confluence	10.64	20.15	29.36	39.54	48.71	57.93	185.63
CNR	11.11	20.84	30.10	40.57	49.85	59.14	188.44
QEW	12.13	22.29	31.81	42.73	52.30	61.89	194.71
Lake Ontario	12.15	22.34	31.85	42.81	52.38	61.98	194.78
Battlefield Creek							
Confluence near Centennial Parkway	1.74	3.35	4.86	6.53	8.08	9.62	29.92
Edge of Escarpment	2.02	3.87	5.59	7.39	9.17	10.93	35.33
King St.	2.43	4.51	6.42	8.43	10.40	12.34	39.82
Highway 8	3.25	5.54	7.57	9.86	11.98	14.10	44.56
QUALHYMO Frequency Flows							
Stoney Creek							
Confluence near Tapleytown Rd. and Green Mountain Rd.	5.62	10.6	15.1	20.3	28.6	36	105.19
Edge of Escarpment	7.17	13.2	18.6	24.8	34.5	43.1	135.98
King St.	7.35	13.5	19	25.3	35.2	43.9	138.31
Highway 8	7.65	14	19.6	26	36.1	45.1	142.11
Battlefield/Stoney Creek Confluence	10.8	19.2	26.6	35.2	48.6	60.5	185.63
CNR	11.2	19.6	27.1	35.6	48.9	60.6	188.44
QEW	11.8	20.6	28.6	37.9	52.7	65.9	194.71
Lake Ontario	11.8	20.6	28.6	37.9	52.7	66	194.78
Battlefield Creek							
Confluence near Centennial Pkwy	1.87	3.28	4.5	5.89	8.04	9.93	29.92
Edge of Escarpment	2.25	3.88	5.28	6.86	9.28	11.4	35.33
King St.	2.65	4.49	6.09	7.92	10.7	13.2	39.82
Highway 8	3.15	5.29	7.39	10	14.4	18.5	44.56

Table 3.2.8: Relative Difference Between Design Frequency And Design Event Flows (Existing Land Use Condition) Based on Continuous Simulation (%)									
Location	Return Period (Years)								
	1.05	1.25	2	5	10	20	50	100	Regional
Stoney Creek									
Confluence near Tapleytown Rd. and Green Mountain Rd.	N/A	N/A	7.83	-2.74	-8.34	-11.03	3.92	9.11	0.00
Edge of Escarpment	N/A	N/A	6.28	-2.27	-9.19	-12.02	0.00	3.97	0.00
King St.	N/A	N/A	5.17	-2.67	-9.32	-12.13	0.03	3.92	0.00
Highway 8	N/A	N/A	3.01	-3.29	-9.59	-12.62	-0.44	3.84	0.00
Battlefield/Stoney Creek Confluence	N/A	N/A	1.48	-4.95	-10.38	-12.33	-0.23	4.25	0.00
CNR	N/A	N/A	0.80	-6.33	-11.07	-13.96	-1.94	2.41	0.00
QEW	N/A	N/A	-2.80	-8.20	-11.22	-12.74	0.76	6.08	0.00
Lake Ontario	N/A	N/A	-2.97	-8.45	-11.36	-12.96	0.61	6.09	0.00
Battlefield Creek									
Confluence near Centennial Parkway	N/A	N/A	6.95	-2.13	-8.00	-10.87	-0.50	3.12	0.00
Edge of Escarpment	N/A	N/A	10.22	0.26	-5.87	-7.73	1.19	4.12	0.00
King St.	N/A	N/A	8.30	-0.45	-5.42	-6.44	2.80	6.52	0.00
Highway 8	N/A	N/A	-3.17	-4.73	-2.44	1.40	16.81	23.78	0.00

Verification of event and continuous frequency flows has been conducted by comparing unitary flow rates in Tables 3.2.9 and 3.2.10 from various studies and watercourse systems within the Golden Horseshoe area. The results indicate that the 1989 FDRP results are slightly below the range of most watercourse systems, with the current results being closer to the unitary flows for Red Hill Creek. Based on the calibration and this further verification of results, the hydrologic modelling results can be considered to be in the expected range of values.

Table 3.2.9: Watercourse Unitary Peak Flow Comparison (/ha)									
Land Use	Location	Area (ha)	Unitary Flow Rates ($m^3/s/ha$) for Design Storm						
			2	5	10	20	50	100	Reg
Rural	North Waterdown	466.9	0.006	0.011	0.014	0.018	0.021	0.023	0.090
Rural	Sixteen Mile Creek	444.4	0.003	0.006	0.009	0.012	0.016	0.019	0.075
Rural+Urban	Unnamed Grand River Trib. (City of Kitchener)	57.77	0.025	0.040	0.052	0.067	0.089	0.109	0.108
Rural+Urban	Red Hill Creek	6800	0.007	0.011	0.014	0.017	0.022	0.026	0.069
2009 Rural Urban	Stoney (Escarp.)	1873.3	0.004	0.007	0.011	0.015	0.018	0.022	0.073
	Battlefield(Escarp.)	487.1	0.004	0.008	0.011	0.015	0.019	0.022	0.073
	Stoney (Outlet)	3089.72	0.004	0.007	0.010	0.014	0.017	0.020	0.063
FDRP Rural Urban	Stoney (Escarp.)	1893	0.002	0.004	0.006	0.007	0.009	0.011	0.056
	Battlefield(Escarp.)	499	0.009	0.016	0.021	0.026	0.034	0.039	0.103
	Stoney (Outlet)	2847	0.003	0.004	0.006	0.007	0.009	0.011	0.056

Table 3.2.10: Watercourse Unitary Peak Flow Comparison (/km^2)								
Situation	Location	Unitary Response Comparison (m^3/s/km^2) for Freq. Storm						
		2	5	10	20	50	100	Reg
Rural	Sheldon Creek	0.79	1.64	2.37	3.14	4.2	5.06	8.57
Rural/ Urban	Fourteen Mile Creek	0.81	1.05	1.24	1.58	1.73	2.47	5.7
Urban	Indian Creek (before confluence)	1.54	2.74	3.12	4.14	5.24	7.31	13.22
Urban	Indian Creek @ Outlet	1.16	1.79	2.19	2.87	3.37	4.61	9.41
Rural	North Waterdown	0.59	1.10	1.44	1.75	2.11	2.33	9.01
Rural	Milton	0.31	0.63	0.89	1.17	1.56	1.87	7.49
Urban	Unnamed Grand River Trib. (City of Kitchener)	2.54	3.96	5.21	6.66	8.93	10.94	10.78
Urban	Red Hill Parkway	0.67	1.07	1.38	1.72	2.22	2.63	6.91
2009	Stoney (Outlet)	0.39	0.72	1.03	1.39	1.70	2.01	6.30
FDRP	Stoney (Outlet)	0.26	0.43	0.56	0.71	0.93	1.10	5.55

Future Land Use Condition

The future land use condition includes the future development areas as identified within the City of Hamilton 2011 to 2013 Development Staging Plan (ref. Drawing 4). Within the Stoney Creek and Battlefield Creek there is limited planned development with the largest area of development being the Nash Neighbourhood located west of Upper Centennial and north of Mud Street.

The QUALHYMO hydrologic model has been updated and both event based and continuous frequency peak flows have been developed. Tables 3.2.11 to 3.2.14 provide the results of the future land use hydrologic modelling and the comparison to the 1989 FDRP.

Table 3.2.11: Comparison of Simulated Design Event Flows (Future Land Use) (m3/s)							
Location/Model	**Return Period (Years)**						
	2	**5**	**10**	**25**	**50**	**100**	**Regional**
1989 FDRP							
Stoney Creek							
Confluence near Tapleytown Rd. and Green Mountain Rd.	4.02	7.34	10.01	12.66	16.29	19.13	83.80
Edge of Escarpment	4.32	8.32	11.48	14.59	18.93	22.39	105.64
King St.	4.37	8.40	11.59	14.72	19.08	22.56	105.69
Highway 8	6.19	8.59	11.81	14.98	19.38	22.90	105.93
Battlefield/Stoney Creek Confluence	8.35	11.99	14.90	18.91	24.59	29.22	150.13
CNR	8.75	12.90	16.33	20.33	26.45	31.54	155.82
QEW	7.93	12.60	16.69	20.98	27.11	32.45	157.97
Lake Ontario	7.57	12.32	16.33	20.61	26.77	31.88	158.26
Battlefield Creek							
Confluence near Centennial Parkway	4.02	7.31	9.79	12.33	15.81	18.54	44.08
Edge of Escarpment	4.25	7.76	10.45	13.31	17.17	20.17	51.37
King St.	4.68	8.59	11.59	14.76	19.14	22.55	59.05
Highway 8	5.81	9.37	12.71	16.03	20.87	24.76	67.03
QUALHYMO 12 Hour SCS Type II Distribution							
Stoney Creek							
Confluence near Tapleytown Rd. and Green Mountain Rd.	5.19	10.92	16.41	22.60	27.56	32.82	105.49
Edge of Escarpment	6.73	13.53	20.36	27.84	34.57	41.50	136.27
King St.	7.21	14.21	21.19	28.91	35.84	42.92	140.88
Highway 8	7.43	14.49	21.53	29.35	36.34	43.47	142.40
Battlefield/Stoney Creek Confluence	10.99	20.62	29.90	40.23	49.41	58.70	185.51
CNR	11.49	21.34	30.69	41.31	50.60	59.96	188.31
QEW	12.51	22.78	32.39	43.45	53.05	62.69	194.50
Lake Ontario	12.53	22.83	32.44	43.53	53.14	62.77	194.58
Battlefield Creek							
Confluence near Centennial Parkway	1.74	3.35	4.86	6.53	8.08	9.62	29.92
Edge of Escarpment	2.18	4.10	5.88	7.81	9.64	11.45	35.34
King St.	2.77	4.97	6.98	9.14	11.19	13.22	40.02
Highway 8	3.51	5.90	8.13	10.55	12.70	14.89	44.63

Table 3.2.12: Percent Difference in Simulated Design Event Peak Flows Current Study to FDRP (Future Land Use) (%)							
Location/Model	Return Period (Years)						
	2	5	10	25	50	100	Regional
Stoney Creek							
Confluence near Tapleytown Rd. and Green Mountain Rd.	29.10	48.77	63.94	78.52	69.18	71.56	25.88
Edge of Escarpment	55.79	62.62	77.35	90.82	82.62	85.35	28.99
King St.	64.99	69.17	82.83	96.40	87.84	90.25	33.30
Highway 8	20.03	68.68	82.30	95.93	87.51	89.83	34.43
Battlefield/Stoney Creek Confluence	31.62	71.98	100.67	112.74	100.94	100.89	23.57
CNR	31.31	65.43	87.94	103.20	91.30	90.11	20.85
QEW	57.76	80.79	94.07	107.10	95.68	93.19	23.12
Lake Ontario	65.52	85.31	98.65	111.21	98.51	96.89	22.95
Battlefield Creek							
Confluence near Centennial Parkway	-56.72	-54.17	-50.36	-47.04	-48.89	-48.11	-32.12
Edge of Escarpment	-48.71	-47.16	-43.73	-41.32	-43.86	-43.23	-31.20
King St.	-40.81	-42.14	-39.78	-38.08	-41.54	-41.37	-32.23
Highway 8	-39.59	-37.03	-36.03	-34.19	-39.15	-39.86	-33.42

Table 3.2.13: Frequency Flows For Future Land Use Condition Based On Continuous Simulation (m^3/s)									
Location	Return Period (Years)[2]								
	1.05	1.25	2	5	10	20	50	100	Regional[1.]
Stoney Creek									
Confluence near Tapleytown Rd. and Green Mountain Rd.	2.13	3.26	5.64	10.6	15.1	20.4	28.7	36.2	105.49
Edge of Escarpment	2.73	4.19	7.19	13.3	18.7	24.9	34.6	43.2	136.27
King St.	2.95	4.44	7.52	13.8	19.3	25.7	35.7	44.6	140.88
Highway 8	3.04	4.55	7.66	14	19.6	26.1	36.2	45.1	142.40
Battlefield/Stoney Creek Confluence	4.84	6.83	11	19.5	27	35.8	49.6	61.9	185.51
CNR	5.13	7.18	11.4	20	27.5	36.2	49.9	61.9	188.31
QEW	5.77	7.81	12.1	21	28.9	38.2	52.8	65.8	194.50
Lake Ontario	5.78	7.83	12.1	21	28.9	38.2	52.8	65.8	194.58
Battlefield Creek									
Confluence near Centennial Parkway	0.81	1.17	1.87	3.28	4.5	5.89	8.04	9.93	29.92
Edge of Escarpment	1.06	1.47	2.3	3.97	5.43	7.1	9.7	12	35.34
King St.	1.44	1.87	2.78	4.7	6.43	8.46	11.7	14.6	40.02
Highway 8	1.92	2.36	3.35	5.52	7.57	10	14	17.7	44.63

NOTES: [1.] Regional Storm flow obtained using event methodology.

Table 3.2.14: Percent Relative Difference Between QUALHYMO Frequency Flows Based on Continuous Simulation and OTTHYMO Event Flows (%)

Location	Return Period (Years)								
	1.05	1.25	2	5	10	20	50	100	Regional
Stoney Creek									
Confluence near Tapleytown Rd. and Green Mountain Rd.	N/A	N/A	40.30	44.41	50.85	61.14	76.18	89.23	25.88
Edge of Escarpment	N/A	N/A	66.44	59.86	62.89	70.66	82.78	92.94	28.99
King St.	N/A	N/A	72.08	64.29	66.52	74.59	87.11	97.70	33.30
Highway 8	N/A	N/A	23.75	62.98	65.96	74.23	86.79	96.94	34.43
Battlefield/Stoney Creek Confluence	N/A	N/A	31.74	62.64	81.21	89.32	101.71	111.84	23.57
CNR	N/A	N/A	30.29	55.04	68.40	78.06	88.66	96.26	20.85
QEW	N/A	N/A	52.59	66.67	73.16	82.08	94.76	102.77	23.12
Lake Ontario	N/A	N/A	59.84	70.45	76.97	85.35	97.24	106.40	22.95
Battlefield Creek									
Confluence near Centennial Parkway	N/A	N/A	-53.48	-55.13	-54.03	-52.23	-49.15	-46.44	-32.12
Edge of Escarpment	N/A	N/A	-45.88	-48.84	-48.04	-46.66	-43.51	-40.51	-31.20
King St.	N/A	N/A	-40.60	-45.29	-44.52	-42.68	-38.87	-35.25	-32.23
Highway 8	N/A	N/A	-42.34	-41.09	-40.44	-37.62	-32.92	-28.51	-33.42

Based on the calibrated existing land use condition hydrologic model producing similar results to the future land use condition hydrologic model, the difference in the event peak flows between the FDRP results and the current hydrologic model are considered to be expected.

A comparison between the QUALHYMO design event and continuous frequency flows in Tables 3.2.15 and 3.2.16, as per the existing land use peak flow comparison, demonstrates relative differences of 10% (+/-).

Table 3.2.15: Comparison of Frequency Flows and Simulated Design Event Flows (Future Land Use) (m3/s)							
Location/Model	**Return Period (Years)**						
	2	**5**	**10**	**25**	**50**	**100**	**Regional**
QUALHYMO 12 Hour SCS Type II Distribution Design Event							
Stoney Creek							
Confluence near Tapleytown Rd. and Green Mountain Rd.	5.19	10.92	16.41	22.60	27.56	32.82	105.49
Edge of Escarpment	6.73	13.53	20.36	27.84	34.57	41.50	136.27
King St.	7.21	14.21	21.19	28.91	35.84	42.92	140.88
Highway 8	7.43	14.49	21.53	29.35	36.34	43.47	142.40
Battlefield/Stoney Creek Confluence	10.99	20.62	29.90	40.23	49.41	58.70	185.51
CNR	11.49	21.34	30.69	41.31	50.60	59.96	188.31
QEW	12.51	22.78	32.39	43.45	53.05	62.69	194.50
Lake Ontario	12.53	22.83	32.44	43.53	53.14	62.77	194.58
Battlefield Creek							
Confluence near Centennial Parkway	1.74	3.35	4.86	6.53	8.08	9.62	29.92
Edge of Escarpment	2.18	4.10	5.88	7.81	9.64	11.45	35.34
King St.	2.77	4.97	6.98	9.14	11.19	13.22	40.02
Highway 8	3.51	5.90	8.13	10.55	12.70	14.89	44.63
QUALHYMO Frequency Flows							
Stoney Creek							
Confluence near Tapleytown Rd. and Green Mountain Rd.	5.64	10.6	15.1	20.4	28.7	36.2	105.49
Edge of Escarpment	7.19	13.3	18.7	24.9	34.6	43.2	136.27
King St.	7.52	13.8	19.3	25.7	35.7	44.6	140.88
Highway 8	7.66	14	19.6	26.1	36.2	45.1	142.40
Battlefield/Stoney Creek Confluence	11	19.5	27	35.8	49.6	61.9	185.51
CNR	11.4	20	27.5	36.2	49.9	61.9	188.31
QEW	12.1	21	28.9	38.2	52.8	65.8	194.50
Lake Ontario	12.1	21	28.9	38.2	52.8	65.8	194.58
Battlefield Creek							
Confluence near Centennial Parkway	1.87	3.28	4.5	5.89	8.04	9.93	29.92
Edge of Escarpment	2.3	3.97	5.43	7.1	9.7	12	35.34
King St.	2.78	4.7	6.43	8.46	11.7	14.6	40.02
Highway 8	3.35	5.52	7.57	10	14	17.7	44.63

Table 3.2.16: Relative Difference Between Design Frequency and Design Event Flows (Existing Land Use Condition) Based on Continuous Simulation (%)									
Location	Return Period (Years)								
	1.05	1.25	2	5	10	20	50	100	Regional
Stoney Creek									
Confluence near Tapleytown Rd. and Green Mountain Rd.	N/A	N/A	7.98	-3.02	-8.68	-10.78	3.97	9.34	0.00
Edge of Escarpment	N/A	N/A	6.40	-1.73	-8.88	-11.81	0.09	3.94	0.00
King St.	N/A	N/A	4.12	-2.97	-9.79	-12.49	-0.39	3.77	0.00
Highway 8	N/A	N/A	3.00	-3.50	-9.85	-12.45	-0.39	3.61	0.00
Battlefield/Stoney Creek Confluence	N/A	N/A	0.09	-5.74	-10.74	-12.37	0.38	5.17	0.00
CNR	N/A	N/A	-0.79	-6.70	-11.60	-14.12	-1.40	3.13	0.00
QEW	N/A	N/A	-3.39	-8.48	-12.08	-13.74	-0.47	4.73	0.00
Lake Ontario	N/A	N/A	-3.55	-8.71	-12.25	-13.95	-0.64	4.60	0.00
Battlefield Creek									
Confluence near Centennial Parkway	N/A	N/A	6.95	-2.13	-8.00	-10.87	-0.50	3.12	0.00
Edge of Escarpment	N/A	N/A	5.22	-3.27	-8.29	-10.00	0.62	4.58	0.00
King St.	N/A	N/A	0.36	-5.74	-8.55	-8.04	4.36	9.45	0.00
Highway 8	N/A	N/A	-4.78	-6.88	-7.40	-5.50	9.29	15.88	0.00

3.2.6. Summary of Findings

- The calibrated QUALHYMO hydrologic model has been used to determine continuous frequency peak flow rates, which are generally higher in comparison to the 1989 FDRP event based peak flows, although are considered reasonable compared to other watershed unitary flow rates.
- No flood control is currently provided in Stoney Creek and Battlefield Creek via stormwater management quantity controls, therefore frequency flows from developed lands are not attenuated.

3.3. Hydraulic Modelling

3.3.1. Background

Hydraulics provides insight into the conveyance capacity associated with sewers, creeks, culverts, bridges, etc. It provides an indication of the velocity and depth associated with various flow rates.

The 1989 FDRP involved the preparation of hydraulic modelling of both Stoney and Battlefield Creek below the Niagara Escarpment for the purpose of developing Regulatory Floodplain mapping. The hydraulic modelling was conducted using HEC-2, for the FDRP design event 2 to 100 year storms and Regional Storm peak flows.

3.3.2. Methods

The hydraulic modelling for this current study has been developed using the FDRP HEC-2 model as a base model. The HEC-2 model has been converted to a HEC-RAS Version 3.1.3 hydraulic model. Hydraulic crossings have been geodetically field surveyed and the updated crossing information incorporated into the hydraulic model. Table 3.2.3 lists the crossings that have been surveyed. In addition, City of Hamilton 2007 topographic mapping has used to update hydraulic cross-sections. Manning's roughness coefficients used within the FDRP, have been reviewed for accuracy, although no significant adjustments have been considered necessary. The hydraulic modelling has been conducted using the frequency peak flows from QUALHYMO continuous modelling and the peak flows resulting from Regional Storm Hurricane Hazel. The downstream boundary condition for the hydraulic modelling is the long-term Lake Ontario surface water elevation of 75m.

3.3.3. Results

Hydraulic results have been summarized within Table 3.3.1, with the flow capacity and relative flow frequency for each hydraulic structure noted. The HEC-RAS cross-section location and Regulatory floodplain plan is provided in Drawing No. 5. The simulated water surface elevations are provided in Appendix 'D'.

Crossing Location	Culvert Surveyed (Yes/No)	Size of Opening (span x rise) (m x m)	Inverts (m)		Top of Road/Crossing (m)	Flow Capacity[1] (m^3/s)	Flow Frequency (year)
			Upstream	Downstream			
Stoney Creek							
King Street	Y	5.88m x 2.56m concrete box	99.28	99.11	102.17	32.10	25
Jones Road	Y	7.33m x 1.41m concrete box	98.09	98.12	99.94	21.65	10
Collegiate Ave.	Y	7.30m x 1.43m concrete box	89.78	89.59	91.93	24.75	25
Queenston Rd.	Y	4.60m x 2.10m concrete box	84.68	83.04	89.00	47.75	100
Pedestrian Bridge #1	N	15.4m span bridge	79.64	79.64	82.60	62.00	100
Barton Street	Y	7.85m ∅ CSP Arch	76.18	76.03	82.77	78.50	100
CNR	N	4.6m span concrete arch	80.95	80.84	83.65	84.50	100
South Service Rd.	Y	5.60m x 2.85m and 6.75m x 2.60m concrete box	74.08	74.13, 74.26	78.50	108	100
Confederation Park	Y	5.44m x 2.90m concrete box	73.96	74.13	78.12	108	100
Battlefield							
Driveway	Y	Twin 1.40m CSP	77.32	77.26	79.33	7.15	10
Lake Ave.	Y	Twin 2.0m x 1.5m concrete box	77.80	77..69	80.72	36.75	Regional
Pedestrian Bridge #2	N	7.0m span bridge	-	-	-	-	-
Queenston Road	Y	3.05m x 2.13m concrete box	81.44	81.34	87.36	36.50	Regional
Green Acres School Bridge	Y	9.40m span bridge	82.46	82.47	84.23	20.00	Regional
Randall Ave Pedestrian Bridge	Y	10.13m span bridge	89.54	89.56	91.72	33.75	Regional
King Street	Y	7.33m x 1.68m concrete box	97.12	96.90	99.22	25.75	Regional
Pedestrian Bridge #3	Y	7.26m x 1.77m concrete box	98.56	98.67	101.324	30.25	Regional

Table 3.3.1: Hydraulic Structure Summary

1. To point of overtopping.

Some of the crossings listed in Table 3.2.14 on Battlefield Creek and Stoney Creek are of concern due to the limited flow capacities prior to overtopping, resulting in flood depths and velocities over roadways that prevent vehicle passage. The product of maximum flooding depths and velocities is typically above the Ministry of Natural Resources guideline of 0.4 m^2/s for vehicular safety.

Table 3.2.14: Hydraulic Structure Overtopping Summary			
Crossing Location	**Maximum Flooding Depth (m)**	**Maximum Flooding Velocity (m/s)**	**Maximum Depth-Velocity Ratio**
Stoney Creek			
Jones Road	0.53	1.59	0.84
Collegiate Ave.	0.64	1.89	1.21
Queenston Rd.	1.16	1.76	2.04
CNR	0.61	1.30	0.79
South Service Rd.	1.16	1.14	1.32
Confederation Park	1.16	1.14	1.32
Battlefield Creek			
Queenston Road	0.46	0.69	0.32
King Street	0.26	0.78	0.20
Pedestrian Bridge #3	0.26	0.51	0.13

In addition to the overtopping of the above listed crossings, certain reaches of Battlefield Creek and Stoney Creek flood private property during the Regional Storm (ref. Drawing 5). Flooding of private property is most noticeable between King Street and Queenston Road on Battlefield and Stoney Creeks. Based on verbal input from the public at Public Information Centre No. 1 flooding on Battlefield Creek at Collegiate Avenue occurred during the July 26, 2009 storm and this is corroborated by the hydraulic results (ref. Drawing 5).

3.3.4. Summary of Findings

- Hydraulic modelling of both creek systems below the Niagara Escarpment has determined that the flow capacity of a number of crossings is considered inadequate based on the flooding depths and velocities that are incurred during the less frequent storm events.
- Based on the hydraulic modelling results, the flooding of private property is prevalent during the Regional Storm event which has the potential for a risk to life and limb and cause flood-related damages.

3.4. Stream Morphology

3.4.1. Background

The study area of Stoney Creek runs from South Service Road to Alba Street whereas the study area for Battlefield Creek extends from just south of Barton Street East to Alba Street (Figure SM-1). The confluence of these creeks is located south of Barton Street East and from this point downstream Stoney Creek drains into Lake Ontario.

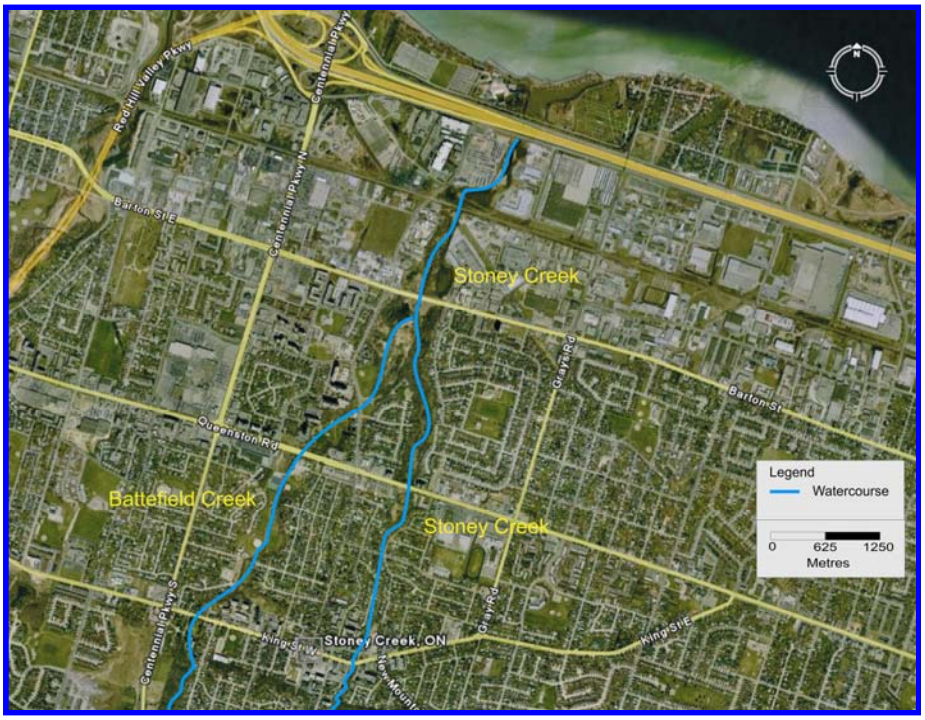

Figure SM-1: Location of Stoney Creek and Battlefield Creek in the study area

A review of literature specific to the study area reveals that past studies have been conducted in the vicinity of the study area. In 2002, a report was prepared by Philips Engineering titled *Stoney Creek Trunk Sewer Sanitary Manhole Exposures Class Environmental Assessment* and submitted to City of Hamilton. The fluvial geomorphology component of this report was provided by Parish Geomorphic. The purpose of this report was to address the safety and environmental concerns associated with exposed access chambers in a reach of Stoney Creek stretching from Queenston Rd. to its confluence with Battlefield Creek. It was determined that these access chambers became exposed due to cross-valley erosion. A channel re-alignment with bank treatments was ultimately constructed late 2003 / early 2004 in order to mitigate channel erosion to the infrastructure. Post-construction monitoring of the realignment site performed by Parish Geomorphic in November 2004 and October 2005 indicated no concern for overall channel stability associated with the remedial work.

3.4.2. Methods

The methodology employed for assessing stream morphology was based on desktop analyses. The desktop analyses involved gathering aerial photography and using these images as a reference for charting changes in land use patterns and channel planform. For this particular study, aerial photographs from 1954 (1:16,868), 1959 (1:30,000), 1978 (1:11,551), and 1979 (1:23,957), as well as more recent online digital images, were used.

Reach breaks were delineated as part of the desktop analyses. The characteristics of the flow or channel materials can change along a creek or stream. In order to account for these changes, channels are separated into reaches – normally several hundred metres to several kilometres in length. A reach displays similarity with respect to its physical characteristics, such as channel form, function, and valley setting. Delineation of a reach considers sinuosity, gradient, hydrology, local geology, degree of valley confinement, and vegetative control using methods outlined in *Geomorphological protocols for subwatershed studies* (Parish Geomorphic, 2001).

A field reconnaissance program was conducted on June 2008 in order to substantiate and verify the findings based on desktop analyses. Basic data about the physical dimensions of the delineated reaches was also gathered during the field walks.

3.4.3. Results

The aerial photos span a period of fifty-one years, from 1954 – 2005. The interpretation of these aerial photos was based on two time periods, 1954 -1978 and 1978 – 2005. These aerial photos provided documentation of changes in land use pattern and channel planform.

Land-use Changes

1954-1978 - The 1954 aerial photograph revealed land-use to be primarily agricultural near Stoney Creek from South Service Rd. to Queenston Rd. Residential development was fairly well-established along Stoney Creek between Queenston Rd. and King St. W. A general trend of increased development was observed within the entire study site from 1954 to 1978 with industrial development being prominent in the downstream sections of Stoney Creek. Marked residential development appears to have occurred between Bow Valley Drive and Grays Road. The area south of the confluence of Stoney Creek and Battlefield Creek remained largely agricultural. Aside from increased residential density, the land-use in the upstream sections of Stoney Creek seems to have remained relatively unchanged. Generally, all the major streets crossed the channel in 1954, however, a smaller residential street, Randall Avenue, did not cross Battlefield Creek in 1954, however, in 1978 it was a crossing. Also, Jones Street, crossed Stoney Creek in 1978, however, it was not present in the 1954 aerial photography.

1978-2005 - The area south of the confluence of Stoney Creek and Battlefield Creek and north of Queenston Rd. displayed the most significant change in land-use. Previously agricultural, this area is now occupied by a residential community of approximately 90 homes (near Strawberry Drive). Over this time period, the study showed a slight increase in residential density. All the street crossings over the channel areas remained the same from 1978 to 2005.

Changes in Channel Planform

Changes in the channel form are typically quantified by means of migration rates. These migration rates represent a measure of lateral and downstream distance a channel planform travels over time and as such these rates permit prediction of future planform changes. For this particular study area, it was not possible to identify natural channel planform changes due to the presence of vegetative cover and shadows, the low resolution of the aerial photographs and artificial realignment of the creek.

Although natural migration rates could not be determined, the confluence of Stoney Creek and Battlefield Creek exhibited significant change in planform (Figure SM-2). Aerial photography indicates that the confluence between these two channels was realigned between 1954 and 1978, likely due to the widening of Barton Street and new residential development. In 1954, the confluence is downstream of Barton Street, while in 1978 the confluence is shown north of Barton Street.

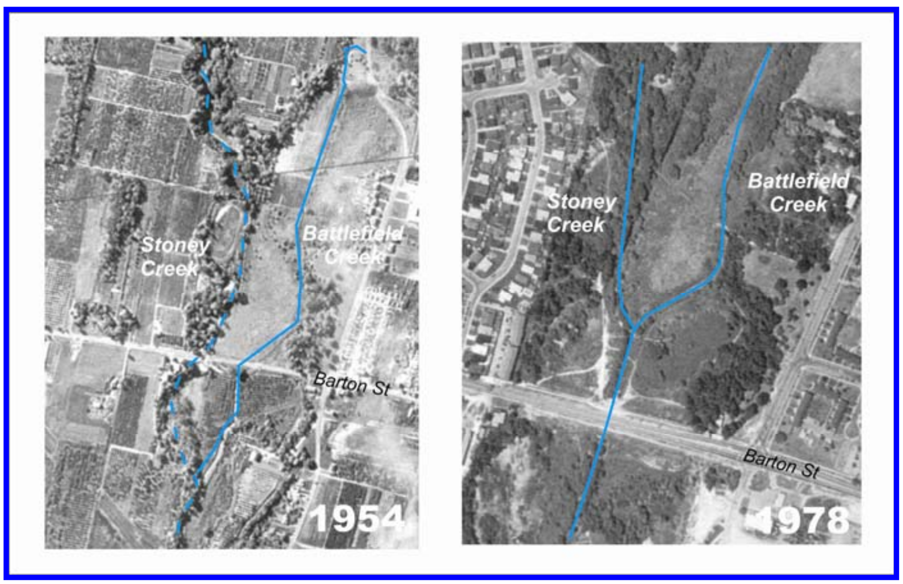

Figure SM-2: Change in planform at the confluence of Stoney and Battlefield Creek between 1954 to 1978.

Reach Delineation

A total of twelve reaches were delineated: five reaches for Battlefield Creek and seven reaches for Stoney Creek (Figure SM-3). The reaches have been labelled SC for Stoney Creek and BC for Battlefield Creek. The characteristics of the reaches are shown in Table 3.3.1. Sinuosity Index is calculated by dividing the channel length by the valley length within the reach.

Table 3.4.1: Summary of Reach Characteristics for Stoney Creek (SC) and Battlefield Creek (BC).					
Reach	***Channel Length (m)***	***Sinuosity Index***	***Gradient (%)***	***Bankfull Width (m)***	***Bankfull Depth (m)***
BC-1	611	1.06	0.25	4 - 7	0.5 - 1
BC-2	639	1.14	0.94	5 - 9	0.5 - 1
BC-3	702	1.02	0.71	1.5 - 10	0.75 – 1.25
BC-4	506	1.04	1.38	6 - 10	0.75 – 1.5
BC-5	859	1.12	2.79	7 - 10	0.75 – 1.5
SC-1	592	1.02	0.34	10 - 35	0.5 - 2
SC-2	510	1.03	1.18	7 - 10	0.5 - 2
SC-3	126	1.02	1.98	5 - 8	0.5 – 1.25
SC-4	1109	1.15	0.86	6 - 12	0.5 – 1.25
SC-5	467	1.07	0.64	8 - 15	1 – 1.5
SC-6	635	1.02	1.42	7 - 12	1 – 1.5
SC-7	511	1.10	2.15	8 - 12	0.75 - 2

N.B. Reach locations are illustrated in Figure SM-3

From Table 3.4.1, it can be inferred that reaches along both Battlefield Creek and Stoney Creek exhibit low to moderate sinuosity with scores generally in the range of 1.02 – 1.15. A review of the channel gradients indicates that, in the case of Battlefield Creek, there is a general trend of decreasing gradient with increased distance downstream; Stoney Creek channel gradients show no discernible pattern. The range of channel gradients is not unexpected for these two creeks. The bankfull widths for both creeks appear to be in the same range with the key exception being SC-1 where it is significantly wider than the other reaches; SC-1 is the reach where water ultimately empties into Lake Ontario.

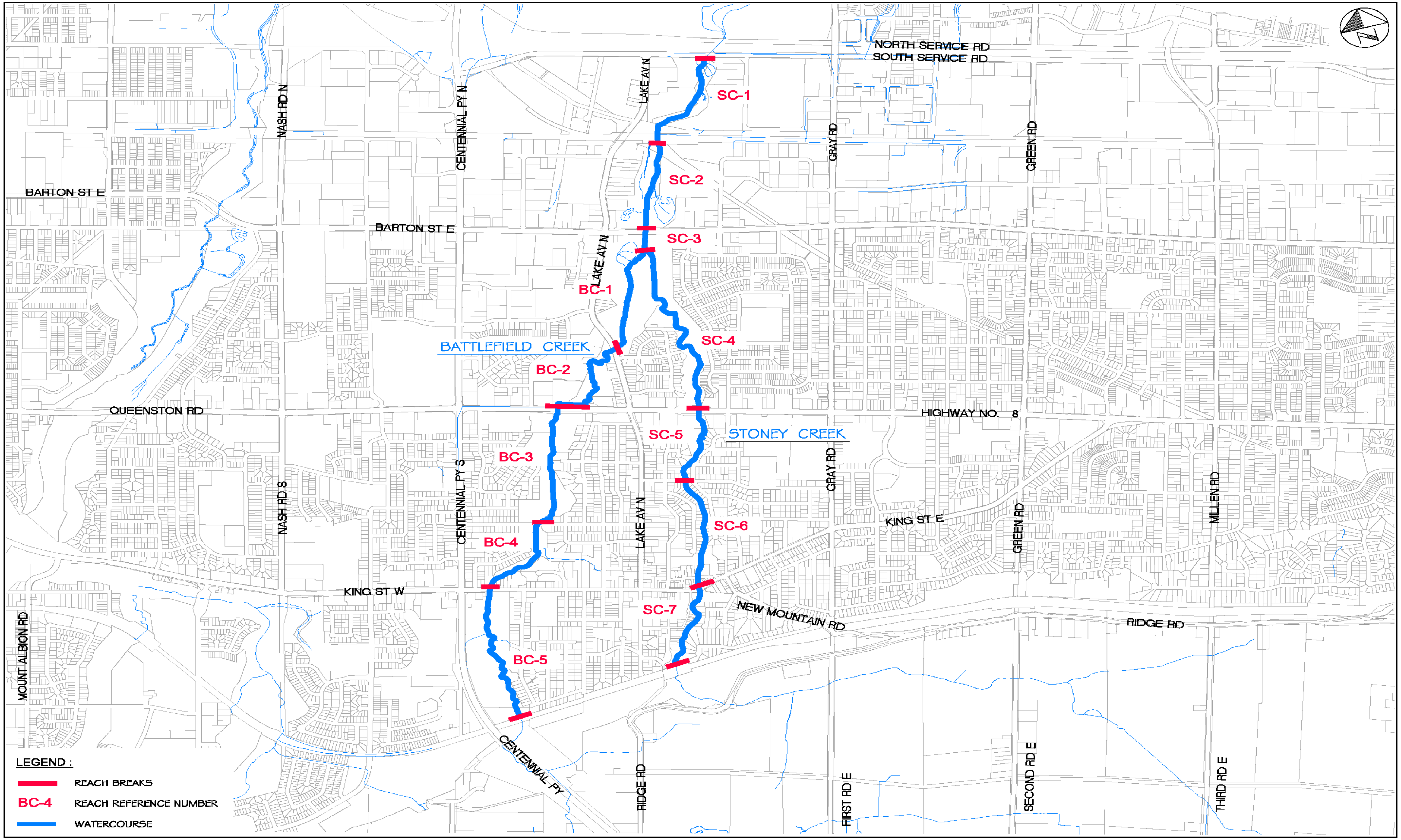

Figure SM-3: Delineated reaches along Stoney Creek (SC) and Battlefield Creek (BC) in the study area. (Watercourses and reach breaks are shown in blue and red, respectively.)

3.4.4. Summary of Findings

A desktop analysis of Stoney Creek and Battlefield Creek permitted an initial understanding of the channel reaches. Historical aerial photography provided documentation of changes in land use pattern and channel planform. Generally, 1954 aerial photography revealed land-use to be primarily agricultural near Stoney Creek from South Service Rd. to Queenston Rd. Residential development was fairly well-established along Stoney Creek between Queenston Rd. and King St. W. From 1978 to 2005, the area south of the confluence of Stoney Creek and Battlefield Creek and north of Queenston Rd. displayed the most significant change in land-use. Due to the dense vegetation near the channel, any changes in channel planform were difficult to discern. Based on the digital base mapping provided by the client, 12 reaches were delineated. Each of these reaches displayed similar physical characteristics. The field reconnaissance was based on these individual reach units.

3.5. Aquatic Environment

3.5.1. Background

It is not known if Stoney Creek was a perennial flowing watercourse before the land was cleared when the first settlers arrived, however, it was described by Lady John Graves Simcoe in 1796 as a “small stream”, “so named from the stoney nature of its bottom” (Quoted from <u>The Diary of Mrs. John Graves Simcoe</u> (Robertson, 1934) *In* Mobberley *et al*, 1999). By 1875 the land within the Stoney Creek watershed had likely been cleared for many years, and it is described in the <u>Historical Sketch of the County of Wentworth</u> (Kernighan, 1875), in terms which accurately reflect how Stoney Creek also appears today, as follows.

Stony Creek was a stream which took its rise in a swampy tract of woodland some miles beyond or south of the ridge of land known as the “mountain”, the same ridge over which the great Niagara thunders – and running northwest poured over this; then, winding northward through the present village emptied into a small lagoon which stretches in from the shore of Lake Ontario. The creek is not perennial, but in the spring and autumn a most beautiful falls is formed at the escarpment where the water pours over the summit in one unbroken descent of 80 or 100 feet...............After leaving the foot of the falls its waters dash gaily down over rocky ledges to the level below and then course over a complete bed of small loose stones to its outlet. From this it derives its name of “Stony Creek”. Our ancestors spelt it “Stoney” and that error is now a confirmed custom with the inhabitants.

The <u>Historical Sketch of the County of Wentworth</u> (Kernighan, 1875), in a section dealing with the battle at Stoney Creek in 1813, describes what must be the floodplain and associated low valley walls of Battlefield Creek just upstream of King Street, as follows.

A small tributary stream of Stoney Creek ran down past Gage's house, distant about half a mile at that point from the main stream, and was enclosed by a low, level, woodless strip of ground called the "flat", which was itself walled in on either side by an abrupt bank about ten feet high.

In 1972, the streamflow of Stoney Creek was described as "during the summer the streamflow is very, very low or it dries up completely" (Quoted from <u>The Eco-Inventory Report</u> (Hamilton Federation of Environmental Groups, 1972) *In* Mobberley *et al*, 1999).

During a fish survey undertaken by the Hamilton Naturalists' Club in 1991, no flow was observed in Stoney Creek above the escarpment, where it generally consisted of a series of disconnected pools at culverts and bridges. That study also noted that the lack of flow detention areas and the sparse riparian habitats provided little attenuation of storm flows (Hamilton Naturalists' Club, 1995). The known fish community of Stoney Creek below the escarpment, from a few collections undertaken in 1975, 1980, and 1991 and reported by the Hamilton Naturalists' Club (1995), consisted of goldfish (*Carassius auratus*), lake chub (*Couesius plumbeus*), common carp (*Cyprinus carpio*), blacknose dace (*Rhinichthys atratulus*), white sucker (*Catostomus commersonii*), central mudminnow (*Umbra limi*), and pumpkinseed (*Lepomis gibbosus*).

The first complete overview of fisheries within Stoney Creek was conducted in 1999 by the Hamilton Region Conservation Authority (Mobberley *et al*, 1999). This study recorded maximum water temperatures of 30°C in the pond at the mouth of Stoney Creek, 28°C at the confluence of Stoney Creek and Battlefield Creek, 29°C at the walking bridge adjacent to Vittorito Road downstream of Queenston Road, and 30°C in Battlefield Creek about 250 m upstream of its confluence with Stoney Creek. Flow in Stoney Creek occurred downstream of the Niagara Escarpment, but it was dry to standing pools above the escarpment. A subsequent visit in mid-July prompted Mobberley *et al.* (1999) to observe that the entire section above the escarpment had become dry. Fish collections reported in Mobberley *et al.* (1999) are provided in Table 1, Appendix 'F', and the collection locations are provided in Appendix 'F', Figure 1. These data are supplemented by fish collections undertaken as part of the study area inventory during Phase 1 of a Stormwater Quality Management Strategy prepared for the City of Stoney Creek (Philips Engineering Ltd., 2004), as well as the fish collection results of the monitoring program for the Stoney Creek ravine slope re-stabilization, creek realignment and maintenance access project (C. Portt and Associates, 2005).

3.5.2. Methods

Background fisheries and habitat information was obtained from the Hamilton Conservation Authority, and from existing study reports. Fisheries information collected by C. Portt and Associates in support of the Stormwater Quality Management Strategy (Philips Engineering Ltd., 2004), and the Class Environmental Assessment and follow-up monitoring for the Stoney Creek Ravine Slope and Creek Remediation (Philips Engineering Ltd., 2003; C. Portt and Associates, 2005) was also used.

Field investigations were conducted during the present study by G. Coker on April 25 and 30, and May 7, and by G. Coker and J. Reid on August 7 and September 23, 2008. Additional field examinations were conducted by G. Coker on September 21 and December 22, 2009. All watercourses were examined at selected locations, usually at road crossings. All field investigations were pre-planned with the aid of aerial photographs. Electrofishing was conducted on August 7 and September 23, 2008 (G. Coker, J. Reid), at selected locations using a Smith-Root Model 12 Backpack Electrofisher. Most of the electrofishing undertaken during the course of this project was conducted on top of the Niagara Escarpment, as this area was under-represented in past sampling programs. Electrofishing effort was commensurate with the habitats available for sampling. At some locations the available habitat was limited to a small isolated pool at the end of a culvert, and so the amount of electrofishing that occurred was very small. At other locations, where electrofishing was unconstrained by available habitat, all habitat types in the vicinity were sampled. No block nets were used at electrofishing stations, as the purpose of electrofishing was only to determine the fish species present. Digital photographs for future reference were taken extensively during the field examinations. Field observations and photograph locations were located (geo-referenced) using a hand-held global positioning device (model: Garmin GPSmap 76CSx). Distances were determined from an orthorectified aerial photograph using GPS TrackMaker Pro software.

The existing fish habitat was characterized based upon field observations of the presence or absence of water and flow, channel form, substrate, aquatic vegetation, groundwater inputs, riparian habitat, fish communities, and anthropogenic impacts or modifications. Barriers to upstream fish migration were also noted. Habitat was classified according the Evaluation, classification and management of headwater drainage features (CVC and TRCA, 2009).

The classes of headwater drainage features are as follows:

1. Permanent - Provides direct habitat onsite (e.g. feeding, breeding, and/or migration) as a result of year round groundwater discharge and/or permanent standing surface water within a storage feature (i.e. ponds, wetlands). Habitat may be either existing or potential (i.e. isolated by a barrier). Permanent habitat also may include critical fish habitat (i.e. habitat that is limited in supply, essential to the fish life cycle, and generally habitat that is not easily duplicated or created). Hydrogeological studies and/or water balance calculations may be required to confirm groundwater contributions, as appropriate, with regard to the scale of the development application(s).

2. *Seasonal* - Provides limited direct habitat onsite (e.g. feeding, breeding, migration and/or refuge habitat), as a result of seasonally high groundwater discharge or seasonally extended contributions from wetlands or other surface storage areas that support intermittent flow conditions, or rarely ephemeral flow conditions. Occasionally, limited permanent refuge habitat may be identified within seasonal habitat reaches.

3. *Contributing* - Provides indirect (contributing) habitat to downstream reaches – functions generally increase with flow and/or as flows move downstream with increasing length of channel or channel density (e.g. extent of contributing area). There are two types of contributing habitat:

i) *Complex contributing habitat* – generally as a result of intermittent (or less commonly ephemeral) surface flows, can have marginal sorting of substrates – generally well vegetated features that influence flow conveyance, attenuation, storage, infiltration, water quality, sediment, food (invertebrates) and organic matter/nutrients (i.e. there are two types of nutrients, e.g. dissolved nutrients, and course/fine matter that can be used as cover). Generally, two types: a) defined features with natural bank vegetation consisting of forest, scrubland/thicket or meadow (as defined in OSAP or ELC); or b) poorly defined features (swales) typically distinguished by hydrophilic vegetation.

ii) *Simple contributing habitat* – generally as a result of ephemeral (or less commonly intermittent) surface flows – generally not well-vegetated features that influence flow conveyance, attenuation, storage, infiltration, water quality and sediment transport. Generally two types: a) defined features characterized by crop cultivation, mowing of vegetation; or b) poorly defined features (swales) may contain terrestrial vegetation.

4. *Not Fish Habitat* - The pre-screened drainage feature has been field verified to confirm that no features and/or functions associated with headwater drainage features is present – generally characterized by no definition or flow, no groundwater seepage or wetland functions, and evidence of cultivation, furrowing, presence of a seasonal crop, lack of natural vegetation, and fine textured soils (i.e. clay and/or silt).

5. *Recharge Zone* - Coarse-textured soils described as sand and/or gravel have been confirmed through field verification; majority of potential flow will be infiltrated. These features may have ill-defined channels as a relict of past flows; however the key function is groundwater recharge and maintenance of downstream aquatic functions via

groundwater connections to streams. No direct fish habitat or indirect contributions through surface flow conveyance, allochthonous or sediment transport is provided.

3.5.3. Results

Streamflow

Flow within Stoney and Battlefield Creeks varies significantly between years, though Stoney Creek has been considered intermittent since at least 1875 (Kernighan, 1875). During the drought years of 1998 and 1999 both creeks had no surface flow upstream of Queenston Road, and flow downstream of Queenston Road was slight. Some isolated pools occurred upstream of Queenston road below the Niagara Escarpment, nourished by subsurface flow within the coarse substrate, apparently emanating from groundwater seeps at the slope of the escarpment and possibly from other locations along the stream channel. As an indication of the groundwater seeping into Stoney Creek in the vicinity of Queenston Road, a series of temperatures taken on July 6 and again on September 7, 2004, found that the water temperature was about 2°C less immediately downstream of Queenston Road compared to upstream areas, and that the temperature began to rise again several hundred metres downstream of Queenston Road (ref. field notes for Stoney Creek ravine slope re-stabilization, creek realignment and maintenance access monitoring program 2003 – 2005).

During the fall of 1998 and in July of 1999, most of the watershed on top of the Niagara Escarpment, even at road culverts, was apparently dry (Appendix ‘F’, Figure 1), though there must have been a number of locations in which water persisted, based upon the fact that a fish community has been sustained there. The summers of 2008 and 2009 have been wetter and cooler than usual, resulting in standing water covering rather extensive areas on top of the Niagara Escarpment, and modest flows being maintained downstream of the Escarpment throughout the summer.

Fish Community

At present there are nineteen known fish species that have been found in Stoney and Battlefield Creeks (ref. Section 3.5.1 and Tables 1 and 2 in Appendix ‘F’). Some of these species are only found in the lower portion of Stoney and Battlefield Creeks due to the connection with Lake Ontario, and the barrier to upstream fish movement and migration presented by the Niagara Escarpment.

Emerald shiner (Table 1, Appendix ‘F’) is a lake dwelling minnow that is known to enter the lower gradient portions of watercourses, adjacent to the Great Lakes, in large numbers during the spring and early summer, but not apparently as part of a spawning migration. Spottail shiner is similar in this regard, but usually not seen in the same large numbers. As expected, these two species have only been found in the lower, flatwater portion of Stoney Creek near Lake Ontario.

Lake chub, white sucker, and rainbow trout are generally lake dwelling species that enter Stoney and Battlefield Creeks to spawn. In this regard, the spawning run of lake chub is largely unknown, but is likely not very big, based upon the lack of known observations of this species in Stoney Creek.

Rainbow trout enter the creek in late winter and early spring to spawn, but rapidly rising water temperatures likely result in a general lack of recruitment success. Young-of-the-year rainbow trout have only been found in Stoney Creek on one occasion, and that was in 2004, where a deeper than typical pool had been constructed the previous winter as part of the Stoney Creek Ravine Slope and Creek Remediation project (Philips Engineering, 2003), where ground water was found to cool water temperatures (C. Portt and Associates, 2005). This pool had subsequently been filled by bedload when examined in 2005.

White sucker is likely the most abundant and successful spawning fish from Lake Ontario, with a large spawning run observed in Stoney and Battlefield Creeks, and juveniles and young-of-the-year commonly found throughout the watershed, downstream of the perched culverts beneath the Toronto, Hamilton, and Buffalo (T.H.&B.) railway at the base of the Niagara Escarpment.

The remaining fishes listed in Section 3.5.1 and Tables 1 and 2 in Appendix ‘F’ are typical residents of streams in southern Ontario, distributed within the watershed based upon habitat preferences and the location of barriers to movement. Yellow perch, goldfish and common carp are typical of still, deep sections, more likely found near a lake or deep pond, and so are found in the pond and pond-like section of Stoney Creek near Lake Ontario.

Creek chub and blacknose dace are typical of stony pool/riffle sections, and so are mostly found where these habitats occur, between the Niagara Escarpment and the flatwater areas nearer Lake Ontario. However, the numbers of these two species have always been low in past sampling events, likely due to the timing of sampling that corresponded to drought years.

Green sunfish, pumpkinseed, central mudminnow, brook stickleback, fathead minnow, and brown bullhead are found throughout the creek in pools, ponds, and sections of streams with low flow velocity. Green sunfish, pumpkinseed, central mudminnow, brook stickleback and fathead minnow are adept at surviving in small isolated pools during the summer months, and so are common throughout Stoney and Battlefield Creeks, especially in such harsh summer conditions as typically found upon the Niagara Escarpment.

Central mudminnow can also survive in very low oxygen conditions by gulping air into its swim bladder which has a respiratory capability (Scott and Crossman, 1973). The single brassy minnow that was found near Lake Ontario in Stoney Creek in 1999 is considered to be an anomaly, possibly the result of a bait bucket introduction or a misidentification.

Northern redbelly dace are typically found in swampy habitats, and so it was not unexpected to find this species at one location adjacent to the large swampy area that stretches between Fifth Road East and Eighth Road East on top of the escarpment. A single banded killifish was found at station C5 (Appendix 'F', Figure 1), and is likely part of a population that is known to occur a few kilometres east, in the headwaters of Forty Mile Creek. In the vicinity of station C5, where the division between the Stoney Creek watershed and Forty Mile Creek watershed is somewhat blurred, there are several direct watercourse connections between the two watersheds.

Habitat

The classification of physical habitat in Stoney and Battlefield Creeks, using the system outlined in CVC and TRCA (2009) is presented in Appendix 'F', Figure 2. Generally, there are three main types of habitat within this watershed. Marshy, pond or pond-like habitat, with low velocity flow and fine substrates, dominate the lower section from Lake Ontario to approximately Location A in Appendix 'F', Figure 2. From Location A, upstream to the Niagara Escarpment, pool/riffle habitat with higher velocity flow and coarse stone substrate dominates. Upstream of the Niagara Escarpment the headwaters occupy a fairly flat, often poorly drained area, in which many of the watercourses have been ditched and/or straightened to facilitate drainage for agricultural purposes. Watercourse substrate on top of the escarpment is dominated by soil or fine substrates, with areas of bedrock appearing more prevalent nearer the escarpment brink, and with occasional areas of coarser substrate. At a few locations on top of the escarpment, streamflow drains into Karst features.

There are only two known artificial barriers to fish migration within Stoney and Battlefield Creeks, and both are perched culverts beneath the T.H.&B. railway line (Appendix 'F', Figure 1). However, these barriers are at the base of the Niagara escarpment, which in itself forms a natural barrier to fish movement, and therefore the removal of these two artificial barriers would have little positive benefit upon watershed fisheries resources.

3.5.4. Summary of Findings

- The fish community that is found at each location is generally appropriate, in species and abundance, for the habitat and streamflow at that location, as well as accessibility with regard to fish migration and movement.

- In the intermittent portions of Stoney and Battlefield Creeks, the absence of base flow is the most significant factor limiting fish productive capacity and fish community diversity.

- Since most of the watershed lacks significant groundwater sources, year to year differences in rainfall has a direct affect upon the year to year differences observed in condition and distribution of the resident fish community, as well as the success of migratory fishes that utilize Stoney Creek for spawning.

- The Niagara Escarpment is an insurmountable barrier to upstream fish movement, setting an upstream limit to available spawning habitat for migratory fishes from Lake Ontario, and highlighting the value of low-flow refuges for the maintenance of the fish community on top of the escarpment.

- There are no significant artificial barriers to fish movement within Stoney and Battlefield Creeks.

- Many of the watercourse channels on top of the Niagara Escarpment have been channelized, or are artificially constructed ditches.

- The habitats that likely provide the greatest contributions to off-site fish productivity, are situated downstream of Queenston Road, where a diversity of permanently wetted habitats exist as spawning, nursery and feeding areas for a number of fish species from Lake Ontario.

3.6. Water Quality

3.6.1. Background

Stormwater quality provides the basis for the existing fisheries habitat within Stoney Creek and Battlefield Creek. The Stormwater Quality Management Strategy for the Community of Stoney Creek Master Plan (Philips Engineering Ltd., June 2004) (2004 Master Plan) identified the watercourse system as a high-priority unit with reasonably good water quality. As part of the 2004 Master Plan recommendations for the watercourse included enhancement opportunities of the habitat through potential increases in baseflow and improved water quality. The 2004 Master Plan provides the basis for the existing water quality baseline conditions.

3.6.2. Methods

Background information from the 2004 Master Plan has been used to interpret water quality in the study area. No stream sampling water quality sampling programs have been undertaken as part of this study, as per the study terms. To-date no stream sampling data collected by Hamilton Conservation Authority has been provided for Stoney Creek and Battlefield Creek. Although no data is currently available, Hamilton Conservation Authority conducts surface water monitoring of watercourses through a program called BioMap. The BioMap program has been used to determine the surface water quality through the monitoring of aquatic animals and invertebrates, similar as to the work conducted for the 2004 Master Plan. To-date the BioMap program has conducted surface water quality monitoring in the Spencer Creek Watershed and not the Stoney Creek and Battlefield Creek Watershed.

3.6.3. Results

Benthic sampling completed for the 2004 Master Plan indicated improved water quality in Stoney Creek downstream from the Niagara Escarpment versus at the Escarpment. Battlefield Creek benthic sampling results suggested slightly improved water quality closest to Lake Ontario versus at the Escarpment. Stoney Creek and Battlefield Creek were both recommended for water quality improvements, based on the benthic sampling results, the significance of aquatic habitat and baseflow conditions.

The 2004 Master Plan included a mass balance of contaminants for existing conditions, future conditions without stormwater management and future conditions and future with recommended stormwater management. The mass balance results are summarized in Tables 3.6.1 and 3.6.2. For the Stoney Creek and Battlefield Creek, five stormwater management facilities were identified (ref. Appendix 'D'), with four of the facilities being storm sewer outfall retrofits along the lower reach of the Stoney Creek as shown in Table 3.6.3. In addition, a centralized water quantity/quality facility in the vicinity of the Devils Punchbowl, was identified in the headwater system above the escarpment. The storm sewer outfall retrofits were to be located on public lands. The watershed below the Niagara Escarpment is fully developed with the primary development being the infill variety which would constitute less than 2% of the drainage area.

Table 3.6.1: Summary of Annual Pollutant Loadings (kg/year)

Scenario	Ammonia	BOD_5	Copper	F. Col[1.]	PAH	TKN	TP	TSS	Zinc
Existing	2994.2	29995.8	94.8	5.27E+14	5.3	9911.3	1559.0	1163390.0	502.3
Future No SWM	2994.1	30703.8	96.4	5.45E+14	5.3	10011.4	1572.2	1167300	515.2
Future with SWM	2943.8	26946.6	84.2	5.09E+14	-<MDL_2	9864.2	1524.4	1121953.0	476.4

1. Units = Counts/year
2. MDL (Less than minimum detection limit)

Table 3.6.2: Summary of Annual Pollutant Loadings Percentage Difference (%)

Scenario	Ammonia	BOD_5	Copper	F. Col[1.]	PAH	TKN	TP	TSS	Zinc
Future No SWM	0.0	2.4	1.7	3.5	1.3	1.0	0.8	0.3	2.6
Future with SWM	-1.7	-10.2	-11.1	-3.4	-156.7	-0.5	-2.2	-3.6	-5.2

With the recommended stormwater management facilities in place, mass balance water quality results from the 2004 Master Plan indicate the following improvements in water quality.

Table 3.6.3: Summary of Quantity/ Quality Stormwater Management Facilities

Reference	Quantity/ Quality	Status	Type/ Level	Storage (m3)	Cost ($)2	Comments
Nash ‘A’	Quality	Planned/ Greenfield	Wet pond/ Normal	3,700 +/-	$641,800	Facility to provide water quality enhancement to 5,00m of watercourse
Queenston Rd.	Quality	Storm Outfall Retrofit	Wetland/ Normal	1,300 +/-	$279,028	Facility to provide water quality enhancement to 2600m of watercourse
Barton St.	Quality	Storm Outfall Retrofit	Wetland/ Normal	6,724 +/-	$845,126	Facility to provide water quality enhancement to 1500m of watercourse
Lake Ave. N. and Huckleberry Dr.	Quality	Storm Outfall Retrofit	Wetland/ Normal	2,582 +/-	$263,119	Facility to provide water quality enhancement to 2000m of watercourse
Lake Ave. N. and Warrington St.	Quality	Storm Outfall Retrofit	Wetland/ Normal	1,923 +/-	$251,177	Facility to provide water quality enhancement to 1000m of watercourse
Devil’s Punch Bowl	Quality	New Facility (Required further Assessment)	Wet pond/ (Required further assessment)	Required Further Assessment	Required Further Assessment	Facility was to be located within the floodplain and to be in operation during water quality storm events or greater.

Other recommendations for the watercourse from the 2004 Master Plan included enhancement opportunities of the habitat through riparian plantings, erosion control and baseflow improvements.

3.6.4. Summary of Findings

- Water quality within both Stoney Creek and Battlefield Creek has been noted as reasonable, with improvements in closer proximity to Lake Ontario
- Water quality improvements have been recommended as part of the 2004 Master Plan, including five stormwater management facilities, four of which are storm sewer outfall retrofits.
- Baseflow augmentation, riparian plantings and erosion control would also provide water quality improvements.

3.7. Terrestrial Resources Inventory

3.7.1. Background

The study area encompasses the Battlefield Creek and Stoney Creek riparian zones, with the Niagara Escarpment forming the southern boundary and Barton Street East forming the northern boundary (ref. Appendix ‘H’, Figure T1).

An inventory and analysis of the terrestrial features and functions within the study area has been conducted. This work was conducted in accordance with the Stoney Creek and Battlefield Creek Terms of Reference (2007), refined through negotiation with the Hamilton Conservation Authority.

Many of the terrestrial features and functions within the study area are protected under policies of the Provincial Policy Statement (PPS) 2005, the City of Hamilton Draft Urban Official Plan (2009), or the Stoney Creek Official Plan, or under the Hamilton Conservation Authority Regulation. Given that the City's Urban Official Plan is currently under appeal, the Stoney Creek Official Plan is the appropriate planning reference for policies on protection of features and functions.

The following sections summarize what is currently known about the terrestrial features and functions of the study area in the context of the natural heritage policy framework that govern development and site alteration. The summary is based on existing background information on the terrestrial features and functions on the site, together with additional information gathered from on-site studies. Areas of constraint were identified within the two valley systems. Once the scope of the potential channel works is determined, constraints and opportunities within each affected area will be assessed, along with the potential impacts of the proposed works. Mitigation approaches will be recommended and net impacts of the proposed alignments will be summarized.

3.7.2. Methods

Background Review

A background review was performed to characterize general baseline conditions, and to highlight any potential constraints or sensitivities reported for the biophysical resources in the study area and its environs. Literature and maps consulted include:

- Dougan & Associates. 2001. Stoney Creek Ravine Sanitary Sewer Extension Environmental Impact Statement. Prepared for the City of Hamilton.
- Philips Engineering Ltd. January 2003. Stoney Creek Trunk Sewer Sanitary Manhole Exposures and Slope Stability: Class Environmental Assessment. Baseline Inventory. Prepared for the City of Hamilton, January 2003.
- Ontario Natural Heritage Information Centre (NHIC) Database Natural Heritage Geographic Query -search for rare element occurrences (NHIC, 2008)
- Hamilton Conservation Authority (Data Request) (HCA, 2008)
- 2008 colour digital orthogonally rectified imagery (Google Earth, 2008)
- Atlas of the Mammals of Hamilton (Vlasman, 2005)
- The Herpetofauna of Hamilton (Lamond and Duncan, 2003)
- Hamilton Natural Areas Inventory 2003 – Site Summaries and Species Checklists (Dwyer, 2003).

Field Inventory

The field investigation collected supplementary site-specific data on biophysical resources within the study area and its vicinity. This information was used to provide more detailed descriptions of existing biophysical conditions, constraints and sensitivities.

Vegetation Resources

Field investigations of vegetation resources were conducted on May 28, July 18, and August 12, 2008. Natural features located within the study area were mapped as polygons onto digital ortho-photography at a scale of 1:3000 and transferred to a digital base. The polygons were classified using the Ecological Land Classification for Southern Ontario (ELC) (Lee *et al*., 1998). A cumulative vascular plant species list was compiled and appears in Appendix 'H-3'. Federal rarity status was based on the Canadian Species at Risk Listing (COSEWIC, 2008). Provincial rarity status of plant species was based on the Natural Heritage Resources of Ontario: Rare Vascular Species List (Oldham, 1999), and the Species List for Provincially-Tracked Vascular Plants (NHIC, 2008). Rarity in the Hamilton Region was determined using *The Vascular Plants of Hamilton, Ontario* (Goodban, 2003). Nomenclature for plant species follows the Ontario Plant List (Newmaster *et al*, 1998) with updates from Newmaster and Ragupathy (2005).

Wildlife Resources

Two amphibian surveys were conducted, following the techniques outlined by the Marsh Monitoring Protocol (BSC, 2003). In addition, two breeding bird surveys were conducted at the Battlefield Creek study area. Due to its size, the area was broken down into two areas: north and south of Queenston Road. These two areas were surveyed on consecutive mornings. The area south of Queenston Road was surveyed on June 12 and June 28, 2008, and the area north of Queenston Road was surveyed on June 13 and June 27, 2008. These surveys followed the protocols outlined by the Ontario Breeding Bird Atlas (OBBA, 2001). The status of breeding birds in the study area was based on *The Breeding Birds of Hamilton, Ontario* (Curry, 2003), while the provincial and federal status of birds was based on the Canadian Species at Risk Listing (COSEWIC, 2008) and the Species at Risk in Ontario List (OMNR, 2006). Appendix 'H-1' summarizes the wildlife survey visits.

3.7.3. Results

Significant Woodlands

The study area contains significant woodlands that are protected under the PPS (2005), but identified and designated according to the City of Hamilton Urban OP (2009) which is currently under appeal (ref. Appendix 'H', Figure T1). Development and site alteration within any of these features is not permitted unless the City of Hamilton and the Hamilton Conservation Authority can demonstrate through this Conservation Ontario Class EA that there will be no negative impacts on these features or their ecological functions (PPS 2005, Pol. 2.1.4).

Significant Valleylands

The City of Hamilton has yet to establish criteria for identifying Significant Valleylands within the municipality. However, according to the City of Hamilton OP, these features should be identified during the course of the Environmental Assessment. According to the OP, a Significant Valleyland is "a natural area that occurs in a valley or other landform depression that has water flowing through or standing for some period of the year which is ecologically important in terms of features, functions, representation or amount of contributing to the quality and diversity of an identifiable geographic area or natural heritage system" (PPS, 2005, amended). The valleylands through the study site meet this criteria; therefore we have assumed that these areas constitute Significant Valleyland. These areas, with natural cover, are mapped on Figure T1 in Appendix 'H'. As with Significant Woodlands, development and site alteration within any of these areas is not permitted unless the City of Hamilton and the Hamilton Conservation Authority demonstrate through this Conservation Ontario Class EA that there will be no negative impacts on these features or their ecological functions (PPS 2005, Pol. 2.1.3 and 2.1.4).

Significant Wildlife Habitat

Significant Wildlife Habitat (SWH) is protected under the Provincial Policy Statement (2005). General practices to identify Significant Wildlife Habitat are defined in the *Significant Wildlife Habitat Technical Guide* (OMNR, 2000). The table in Appendix 'H-2' of this report reflects the specific criteria from the Technical Guide and where they potentially apply within the study area. Under the provisions of the PPS, SWH are intended to be identified on regional basis using criteria that have been refined to reflect the habitats and conditions in that region. The City of Hamilton has not developed specific SWH criteria and polices for their jurisdiction.

The identification of Significant Wildlife Habitat was not a primary focus of this study and the results presented in Appendix 'H-2' indicate that only a few categories are potentially triggered based on the available data. Additional field studies guided by region-specific criteria would help refine the features or functions that would qualify as SWH and exactly where they are found.

The Province's *Natural Heritage Reference Manual* (OMNR, 1999) and Significant Wildlife Habitat Technical Guide (OMNR, 2000) identify four major categories of significant wildlife habitat, as follows:

a. Seasonal Concentration Areas: Areas where, at certain times of the year, some species of wildlife are highly concentrated within relatively small areas. These areas provide important cover and protection from inclement weather conditions and predators. They may also provide access to abundant food sources or nesting and breeding sites.

b. Rare Vegetation Communities or Specialized Habitats for Wildlife: Areas that contain a provincially or regionally/locally rare vegetation community and areas that support wildlife species that have highly specific habitat requirements, with exceptionally high species diversity or community diversity, or that provide habitat that greatly enhances a species' survival.

c. Habitats for Species of Conservation Concern: Includes species identified as nationally endangered or threatened by COSEWIC (but not regulated under Ontario's *Endangered Species Act*), listed as a species of Special Concern on SARO list, provincially rare or historical in Ontario, in substantial decline in Ontario, having a high percentage of their global population in Ontario (and rare or uncommon in the planning area), subjects of recovery programs, or important to the municipality.

d. Animal Movement Corridors: Elongated, naturally vegetated parts of the landscape used by animals to move from one habitat to another that exist at different scales and frequently link or border natural areas.

Significant Portions of the Habitat of Endangered and threatened species

Our 2008 field investigations encountered one plant species considered at risk by COSEWIC (2008). Butternut (*Juglans cineria*), which is Endangered both federally and provincially, was found at two locations along the west side of Battlefield Creek, in the Battlefield Park NHS (ref. Appendix 'H', Figure T1). With regards to wildlife species, there were none detected during the field surveys that are ranked provincially, and none are designated as species-at-risk federally or provincially.

The significant habitat of the Butternut is protected according to Policy 2.3.1a of the PPS (2005) and the Hamilton OP (2009). According to the City of Hamilton OP, new development and site alteration are not permitted in these areas (Hamilton OP 2009, Pol. 2.5.2). Butternut are Endangered due to a fungal canker disease which is often fatal to individual trees. Any works that are proposed in the vicinity of identified trees must undertake a process to evaluate the health of the trees, and to determine whether the trees can be removed if they are at a significant stage of infection, or protected with an adequate buffer if they are determined to be healthy. The health assessment must be conducted by a trained evaluator, and the results submitted to the MNR.

It should be noted that the anticipated erosion control alternatives identified for this area do not involve any construction work being performed within the avicinity of the identified Butternut trees; therefore, at this time, a Butternut Health Assessment (BHA) is not recommended for the two Butternut trees that were identified on the west side of Battlefield Creek. If the location of construction activities changes and is moved such that the Butternut trees may be negatively impacted, then a BHA would be warranted.

A literature review was also conducted to determine whether others had identified any of these species within the study area. There are some historical records of some rare wildlife species for the Stoney Creek Ravine ESA, but there have been no records of their occurrence since 1979, and all of these species occurred at the mouth of the creek which is outside the study area. Within the Devil's Punchbowl Escarpment ESA, a referenced study also indicated some wildlife species at risk; however, the portion of the ESA within the study area is very small and therefore the probability of their occurrence is limited. These species were not observed within the 2008 field investigations. The following summarizes the results of this review.

A query of the NHIC database revealed no significant species occurrences in the study area (NHIC, 2008). A review of the Atlas of the Mammals of Hamilton (Vlasman, 2005) revealed no significant mammal records. A similar review of the Herpetofauna of Hamilton (Lamond and Duncan, 2003) revealed no significant records of reptiles or herpetiles.

Dougan and Associates (2001) conducted an Environmental Impact Statement for the Regional Municipality of Hamilton-Wentworth in 2000 for a sanitary sewer extension in the Stoney Creek ravine, with the project area lying partly within the Stoney Creek Ravine Environmentally Sensitive Area (#51). The extent of the terrestrial assessment was from Queenston Road south to Collegiate Avenue (Dougan and Associates, 2001). Of the 70 species of vascular plants detected, none are considered significant provincially or federally (COSEWIC, 2008; OMNR, 2006), nor uncommon or rare in Hamilton (Goodban, 2003). Six species of birds and two species of mammals were detected, with none of these being significant federally (COSEWIC, 2008), provincially (OMNR, 2006) or regionally (Curry, 2003).

Dougan and Associates also assessed terrestrial resources as part of a Phillips Engineering Ltd. Class Environmental Assessment conducted for the City of Hamilton of access chambers exposures and slope stability along Stoney Creek (PEL, 2002). The study area was along Stoney Creek, between Queenston Road and its confluence with Battlefield Creek. The field inventories performed in 2002 found three herpetile species, 16 bird species and seven mammal species. None of these species identified were provincially, federally or regionally significant. Of the 135 plant species documented, one species with significance was detected that was not found during the 2008 field inventory: Black Oak (*Quercus velutina*), which is considered regionally uncommon (Goodban, 2003).

The Hamilton Conservation Authority has vegetation and wildlife data for the Stoney Creek Ravine Environmentally Sensitive Area (ESA #51) area of the site on their Natural Heritage Database. The database documents the presence of 160 plant species, along with 37 bird species, seven herpetile species, and six mammal species. Of these, none are ranked as federally or provincially significant (COSEWIC, 2008; NHIC, 2008). There are historical records for the ESA of Common Musk Turtle (*Sternotherus odoratus*) and Blanding's Turtle (*Emydoidea blandingii*), which are both considered Threatened (COSEWIC, 2008; OMNR, 2006)), as well as Black Tern (Special Concern (OMNR, 2006)). However, there are no new records for these three species since 1978, 1987 and 1979, respectively. In addition, all three species occurred only at the mouth of the creek (Heagy 1993; Dwyer 2003) and not further upstream.

The ESA documentation for the Devil's Punchbowl Escarpment ESA (#54) was reviewed to determine whether it listed any endangered and threatened wildlife or vegetation species (City of Hamilton, 2003). Of the close to 300 species of vascular plants documented in the Devil's Punchbowl Escarpment Environmentally Sensitive Area to date, none are considered provincially or federally threatened, endangered or of special concern (COSEWIC, 2008; OMNR, 2008). A number of wildlife species are listed for this ESA that are either of Special Concern or Threatened. Only a very small portion of the ESA lies within the study area. The species are listed below including our opinion regarding the probability of their occurrence within the study site based on their habitat needs.

- Monarch (*Danaus plexippus*) – Special Concern (COSEWIC 2008); definitely occurs in the study area during summer and fall. However, this species utilizes open areas (where its food plant, Milkweed, occurs) in both the summer breeding season and in fall, when it is migrating south. Given the forested nature of the study area, it is not likely to occur as a breeder, and would only be present occasionally and in small numbers during spring and fall migration.
- Jefferson Salamander (*Ambystoma jeffersonianum*) – Threatened (COSEWIC, 2008) and SRank of S2 (NHIC, 2008); this species is rare in the City of Hamilton (Lamond and Duncan 2003), and inhabits deciduous and mixed forest with

temporary pools of water for breeding (MacCulloch 2002). Therefore, it is possible that this species occurs within the study area, but unlikely considering its overall rarity and the lack of ephemeral bodies of water, such as vernal pools.

- Milksnake (*Lampropeltis triangulum*) – Special Concern (COSEWIC, 2008; OMNR, 2006); this species prefers diverse habitats such as meadows, cultivated areas, open forests and forest edges (MacCulloch 2002), so it is possible that it occurs within the study area.
- Canada Warbler (*Wilsonia canadensis*) – Threatened (COSEWIC, 2008) and rare as a breeder in the City of Hamilton (Curry, 2003); therefore, it is unlikely to occur as a breeding species in the study area. However, given its overall status as a common migrant within the City of Hamilton (Curry, 2006) and the presence of suitable stopover habitat within the study area, it is likely that this species will occasionally be present in small numbers during spring and fall migration.

Environmentally Significant Areas

Two Environmentally Significant Areas (ESAs), the Stoney Creek Ravine ESA (ESA # 51) and the Devil's Punchbowl ESA (ESA # 54), extend into the study area and are protected according to Hamilton's draft Official Plan. The Stoney Creek Ravine received its designation as an ESA based on the following criteria: 1) It serves an important hydrological function; and 2) the site provides habitat for significant species. The Devil's Punchbowl ESA received its designation based on presence of a Significant Earth Science Feature (regionally significant landform); and its significant ecological functions. More specifically it contains 1) significant species, 2) rare biotic communities, 3) facilitates movement between natural areas along the Niagara Escarpment, and 4) is representative of the natural features of the Niagara Peninsula section of the Niagara Escarpment. According to the OP, the City of Hamilton and the Hamilton Conservation Authority must demonstrate through the EA that there will be 1) no negative impacts to these ESAs and their ecological functions; 2) connectivity for surface/ground water, plants and wildlife between the ESAs will be maintained to ensure their movement across the landscape; and 3) the removal of "other natural features" will be minimized through planning and design (City of Hamilton OP 2009, Pol. 2.5.8). The ESAs are illustrated in Figure T1 in Appendix 'H'.

A literature review was also conducted to determine whether any regionally rare vegetation or wildlife species had been recorded within the ESAs.

Stoney Creek ESA (#51)

Data obtained from the Hamilton Conservation Authority Natural Heritage Database documents the presence of 160 plant species, along with 37 bird species, seven herpetile species, and six mammal species within the ESA as a whole, but it is not known whether they were found within the study site. Although historic records exist for a few threatened or special concern species that are either ranked as federally or provincially significant, no regionally or municipally rare species are noted within this inventory. Five species of vascular plants that are considered rare in the City of Hamilton (Goodban, 2003) were documented including Beach Grass (*Ammophila breviligulata*), Head-like Sedge (*Carex cephaloidea*), Hawthorn (*Crataegus dissona*), Tansy Mustard (*Descurainia pinnata brachycarpa*), and Hairy Wild-rye (*Elymus villosus*). Given the habitat needs of these five species, it is possible they could be growing within the study area, but they were not noted within the 2008 field studies.

Devil's Punchbowl Escarpment ESA (#54)

Only a small portion of the Devil's Punchbowl Escarpment Environmentally Sensitive Area (ESA #54) lies within the study site (ref. Appendix 'H', Figure T1). The following Municipally rare species are listed for the ESA, but were not observed in the 2008 field studies. The small portion of the ESA lying within the study area limits the probability of these species being present. The species are listed below including our opinion regarding the probability of their occurrence within the study site based on their habitat needs.

- Yellow-billed Cuckoo (*Coccyzus americanus*) – rare in the City of Hamilton (Curry, 2003); may occur as a breeder in the study area, but in very limited numbers. It is also an uncommon migrant (Curry, 2006) and, as such, could occur in open woodlands and edge habitats during spring and fall migration.
- Carolina Wren (*Thryothorus ludovicianus*) – rare in the City of Hamilton (Curry, 2003); likely occurs in the study area as a resident breeder but in limited numbers.

Close to 300 species of vascular plants are documented within the Devil's Punchbowl Escarpment ESA (Goodban, 2003). Thirteen of these plant species are considered rare in the City of Hamilton (Goodban, 2003) and may occur in the Battlefield Creek-Stoney Creek study area; of these, all but two species have SRanks of S4 or S5 (NHIC, 2008). The thirteen species are as follows: Smooth Rock-cress (*Arabis laevigata*), Yellow False Foxglove (*Aureolaria flava*), Canada Brome (*Bromus pubescens*), Head-like Sedge (*Carex cephaloidea*), Umbellate Sedge (*Carex umbellate*), Spotted Spurge (*Chamaesyce nutans*), Cancer-root (*Corallorhiza maculate*), Downy Hawthorn (*Crataegus mollis*), Goldie's Wood Fern (*Dryopteris goldiana*), American Burnweed (*Erechtites hieracifolia*), Panicled Hawkweed (*Hieracium paniculatum*), Nimble Will

(*Muhlenbergia schreberi*), and Striate Knotweed (*Polygonum achoreum*). The only two species with SRanks of S1 to S3 are Yellow False Foxglove (S3) and Panicled Hawkweed (S2) (NHIC, 2008).

Linkage Areas

There are two small municipally-designated linkage areas shown on OP schedules. According to the OP, linkage areas are “natural areas within the landscape that connect Core Areas” (in this case the two ESAs) (OP Policy 2.7, P. C.2). New development and site alteration within these areas requires a Linkage Assessment that 1) identifies and assesses the linkage features and functions, 2) assesses the potential impacts of the site alteration on these features and functions; and 3) makes recommendations on how to protect, enhance or mitigate these impacts through planning, design and construction practices (OP 2009, pol. 2.7.7). The need for this assessment will be reviewed when alterative channel remediation scenarios are available for evaluation.

3.7.4. Summary of Findings

This terrestrial assessment summarizes what is currently known about the terrestrial features and functions on the study site in the context of the natural heritage policy framework that govern development and site alteration. The summary is based on existing background information on the terrestrial features and functions on the site, together with wildlife and vegetation surveys conducted by Dougan and Associates in the spring and summer of 2008. The following summarizes the key findings of the assessment:

- There are extensive forested units that constitute significant woodlands protected under the PPS (2005). Site alteration within these areas must demonstrate there will be no negative impacts on these features or their ecological functions (PPS 2005, Pol. 2.1.3 and 2.1.4).

- The whole study area constitutes significant valley landa. Site alteration within these areas must demonstrate there will be no negative impacts on these features or their ecological functions (PPS 2005, Pol. 2.1.3 and 2.1.4).

- There are two Butternut trees whose habitats constitute areas of significant habitat of endangered species and threatened species. They are protected according to the PPS 2005; site alteration are not permitted in these areas (Hamilton OP 2009, Pol. 2.5.2).

- There are two designated Environmentally Significant Areas within the study area, one designated on the basis of its hydrological function and for providing habitat for significant species. The other was designated based on a Significant Earth Science Feature, and also for its ecological functions.

- There are two small linkage areas identified in the OP. Site alteration in these areas requires a linkage assessment to identify and assess linkage functions, impacts of site alteration on linkage functions and mitigation measures

- Five plant species observed are considered rare in the City of Hamilton.

- Four bird species are considered uncommon in the City of Hamilton and four are uncommon regionally.

- 20 vegetation communities were classified according to the Ecological Land Classification system, including nine forest and six wetland community types.

- Site alteration in and around the wetlands will require a permit from the Hamilton Conservation Authority.

3.8. Channel Bank Erosion and Stability

3.8.1. Background

As part of this Conservation Ontario Class EA initiated to address flooding and erosion concerns associated with Stoney Creek and Battlefield Creek (near Hamilton, Ontario) within the study area from a watershed perspective, a fluvial geomorphology study has been undertaken. The study area of Stoney Creek runs from South Service Road to Alba Street whereas the study area for Battlefield Creek extends from just south of Barton Street East to Alba Street (ref. Figure SM-1). The confluence of these creeks is located south of Barton Street East and from this point downstream Stoney Creek drains into Lake Ontario.

A geotechnical slope inspection of the east valley wall adjacent to 79 Donn Avenue has also been conducted by Terraprobe Limited. The inspection has been conducted (ref. Appendix ‘I’) to provide a preliminary assessment of the oversteepened valley wall.

3.8.2. Methods

The assessment of channel bank erosion and stability is largely rooted in the implementation of a field reconnaissance program. In particular, this field program permits a synoptic level survey of the system. The purpose of the rapid stream assessment is to document areas of active erosion, refine reach breaks, collect basic channel dimensions, and gain an understanding of the active channel processes along each reach. Two instruments typically used in the assessment of a fluvial system from a geomorphic viewpoint are the Rapid Geomorphic Assessment (RGA) and the Rapid Stream Assessment Technique (RSAT). A RGA documents observed indicators of channel instability (MOE, 1999). Observations are quantified using an index that identifies channel sensitivity based on evidence of aggradation, degradation, channel widening, and planimetric adjustment. The index produces values that indicate whether the channel is stable/in regime (score <0.20), stressed/transitional (score 0.21-0.40), or adjusting (score >0.41).

The RSAT provides a broader view of the system by also considering the ecological functioning of the stream (Galli, 1996). Observations include in-stream habitat, water quality, riparian conditions, and biological indicators. Additionally, the RSAT approach includes semi-quantitative measures of bankfull channel dimensions, type of substrate, vegetative cover, and channel disturbance. RSAT scores rank the channel as maintaining a low (<20), moderate (20-35), or high (>35) degree of stream health.

3.8.3. Results

Field walks were conducted in April 2008. Appendix 'E-1' provides photographs along Donn Avenue during the rapid stream assessment. Appendix 'E-2' provides photographs along both creeks taken during field reconnaissance. Table 3.8.1 provides a summary of the RGA and RSAT scores for the reaches along Battlefield Creek and Stoney Creek. The RGA score for each reach is presented in Appendix 'E-3'.

Table 3.8.1: Summary of RGA and RSAT Assessments.

Reach$_1$	*RGA score*	*Condition*	*RSAT score*	*Condition*
BC-1	0.32	Transitional	22	Moderate
BC-2	0.27	Transitional	18.5	Low
BC-3	0.25	Transitional	19	Low
BC-4	0.22	Transitional	17	Low
BC-5	0.25	Transitional	16	Low
SC-1	0.24	Transitional	17	Low
SC-2	0.33	Transitional	16	Low
SC-3	0.09	In Regime	20	Moderate
SC-4	0.30	Transitional	21	Moderate
SC-5	0.34	Transitional	16.5	Low
SC-6	0.22	Transitional	17.5	Low
SC-7	0.17	In Regime	19	Low

RGA Score: In regime/stable (score <0.20), stressed/transitional (score 0.21-0.40), or adjusting (score >0.41)
RSAT Score: low (<20), moderate (20-35), or high (>35) degree of stream health.

Data from Table 3.8.1 suggests that the majority of the reaches along both Stoney Creek and Battlefield Creek are in a state of transition and exhibiting low stream health. The key geomorphic process occurring along these reaches appears to be channel widening with aggradation occurring to a lesser degree. The low stream health rating is due primarily to a combination of relatively poor channel stability, clear evidence of basal scour, and low quality (and quantity of) in-stream aquatic habitat. Notes from the RSAT for each reach are summarized below.

BC-1

The channel was moderately sinuous flowing through dense vegetated banks composed of tall grasses with a recreational park located at the upstream portion of the reach. The channel bankfull widths ranged from 4 – 7 m and the bankfull depths were in the range of 0.15 – 0.60 m. The pool-riffle sequences were low to moderately defined, with the riffles composed of sands and gravels and the pools were of finer substrate. The bed substrate was very sandy substrate with several depositional bar features. The banks were composed of sands and clay with bank heights ranging from 0.5 – 1.5 m. Moderate amount of scour was observed throughout the reach. A large debris jam was observed in the upstream portion of the reach. Bridges were found at the upstream and downstream extent of this reach. The dominant geomorphic processes that were occurring were aggradation and widening. This was seen by siltation in pools, bar formation, occurrence of large organic debris and exposed tree roots.

BC-2

The channel was sinuous flowing through parkland. The bankfull widths were typically 5 – 9 m and flow depths 0.15 – 0.50 m. The riffles were composed of pebble to cobble substrate and the pools were of sands and clay. There were several bar formations composed of small cobble substrate. The bank height varied from 0.75 – 4 m and composed of clay and sands. Tall grasses and herbs dominate the banks. Erosion processes were active along this reach as evidenced by logs spanning some 20 – 25 m along the east bank being used as a bank treatment; pipes were exposed along east bank just upstream of elevated outfall In-stream woody debris jams were noted. Channel disturbance occurs in the form of a foot bridge, tractor crossing, and outflow pipes. The dominant geomorphic process that was occurring was widening.

BC-3

The reach was relatively a straight channel flowing through a vegetative corridor (trees, shrubs and tall herbs). The bankfull widths were in the range of 1.5 – 10 m and bankfull depths were 0.05 – 0.35 m. There were no pool-riffle sequences observed along this reach with the bed substrate composed of cobble, gravel, sands and consolidated clay. There was moderate to major amounts of wood debris in the channel and on the banks. There was evidence of heavy equipment passing through the channel at the time of the field investigation. There were several channel hardening techniques used within this reach such as the installation of retaining walls (i.e. 2 @ 5 m each), and gabion baskets at the crossings. The dominant geomorphic processes that were occurring were degradation and widening.

BC-4

The reach was relatively a straight channel flowing through a vegetative corridor (trees, shrubs and tall herbs). There was moderate to major amounts of wood debris in the channel and on the banks. The channel gradient for this watercourse was moderate for most of the reach length except at the upstream end where it is was steeper. The range of bankfull widths and flow depths were 6 – 10 m and 0.05 – 0.35 m, respectively. There was no pool-riffle sequences observed along this reach with the bed substrate composed of dominantly cobble material. There was a large gabion wall along the west bank at mid-stream and upper limit of the reach. The dominant geomorphic process that was occurring was widening seen through the undermining of gabion baskets and tree roots.

BC-5

The reach was a moderately sinuous channel flowing through a vegetative corridor (trees, shrubs and tall herbs). There was a park located at the downstream section of the channel. The bankfull width varied between 7 – 10 m and bankfull depths were in the range of 0.10 – 0.40 m. Pool-riffle sequence morphology was evident with spacing approximately 15 – 20 m. Cobble-sized material dominated the bed substrate. There were high banks throughout the reach (1.5 – 3.5 m) composed of clay and sand material. Large accumulation of woody debris was found in some sections of the reach. Significant scour was noted along the east bank in the upstream section of the reach. The dominant geomorphic process was widening.

SC-1

This is a low gradient reach flowing through a vegetative corridor (trees, shrubs and tall herbs). A large pond, densely populated with cattails, is situated along the east bank at the downstream end of the reach. The downstream end of the reach was quite wide, spanning approximately 35 m. Large woody debris was observed along this reach. Bankfull widths were in the range of 10 – 35 m and bankfull depths were in the range of 0.25 – 1 m. Bank scour was noted at mid-reach. Pool-riffle morphology was evident with spacing approximately 15 – 20 m. Bridges cross the channel at the upstream and downstream extent of the reach. The flows in this reach were very slow which was part attributable to accumulation large wood debris in the stream. The dominant geomorphic process was widening with an RGA score of 0.25.

SC-2

This reach is a low gradient channel flowing through a vegetative corridor (trees, shrubs and tall herbs). The bankfull widths ranged from 7- 10 m and the bankfull depths ranged from 0.2 – 1.0 m. Very slow, almost stagnant flows were observed due to numerous major in-stream debris jams, both woody material and urban matter (e.g. tires). Two large ponds were located beyond both banks at the upstream end of channel. Train tracks at downstream end are elevated 3 – 4 m above the channel. Pool-riffle morphology was evident with spacing approximately 15 – 25 m. The riffles and pools were composed of clay to sand substrate. The dominant geomorphic process was planimetric form adjustment. This was evident by cut-off channels, formation of islands and the thalweg alignment out of phase of meander form.

SC-3

This reach was relatively straight with a low gradient. The flows were typically very slow to near stagnant at the time of investigation. Bankfull widths ranged from 5 – 8 m with bankfull depths of 0.3 – 0.75 m. The channel was moderately entrenched, with bank heights ranging from 0.75 - 1.5 m. Both banks showed evidence of scouring. Tall grasses and immature trees are found only at the top of the slope. Minor woody debris was noted in this channel. No pool-riffle morphology was clearly defined in this channel. The bed substrate was composed of clay, silts and sands. This reach was in regime with a RGA score of 0.09.

SC-4

The channel exhibited moderate sinuosity, moderate gradient, and flowed through a vegetative corridor. The bankfull widths and depths ranged from 6 – 12 m and 0.15 – 0.60 m, respectively. Tall grasses, herbs, and mature trees line the banks. A significant amount of woody debris and some urban debris (e.g. plastic bag, tire) was observed along the reach. Pool-riffle morphology was evident with spacing of approximately 10 - 15 m. The riffles were composed of small cobbles and the pools consisted of silt and sand substrate. Exposed pipes were found along the east bank at approximately 20 m downstream of the upstream reach limit. Channel disturbance included a bridge at the upstream extent of reach, a foot bridge at mid-reach, and an old concrete wall along the west bank. A section of this reach (near Queenston Rd.) was realigned in late 2003 / early 2004 due to river erosion presenting a hazard to the local sewer system (access chamber) infrastructure.

SC-5

The channel flows through a residential and open space area. The bankfull widths within the reach ranged from 8 – 15 m while bankfull depths ranged from 1 – 1.5 m. The bed substrate composed of small and medium cobbles. The banks were moderately steep and consisted of clay and sand material. The field reconnaissance found this reach to exhibit low stream health and in a transitional or stressed state. The dominant geomorphic process was widening and degradation with some evidence of aggradation and planform adjustment. Bank protection was failing extensively due to erosion and weathering. Sections of failing cement retaining walls have completely collapsed into the channel while gabion baskets have been undermined and outflanked. It was deemed that river erosion has begun to affect property located adjacent to the watercourse.

The slope inspection at 79 Donn Avenue determined that the east valley wall is near vertical and is exposed to creek flows. Downstream of this site the valley wall is in a similar condition but is protected from toe erosion due to a gabion wall. The natural process of the Queenston shale slope regression is not dissimilar in comparison from the protected to the non-protected valley wall sections, indicating a slow slope regression when no erosion occurs from the creek. Based on the foregoing, impacts to tableland in the short-term would be considered low, although the integrity of the slope should be protected in the long-term. Slope protection could include creek realignment and slope flattening. The extent of the protection works could be expanded downstream, depending on a detailed stream morphology assessment of stream migration.

SC-6

The channel is relatively straight and flows through a vegetated corridor. Bankfull widths within the reach vary from 7 – 12 m and bankfull depths range from 0.05 – 0.30m. Channel modification includes the use of gabions, wood, and concrete as bank protection measures. Banks were vegetated with trees, shrubs, and tall herbs. Some woody debris was observed along the banks and in-stream. The banks upstream of Collegiate Street was characterized by a series of bank treatments - each installed by the respective property owner – in an effort to protect the banks from river erosion. The channel bed did not exhibit a pool-riffle morphology. The bed substrate was composed of cobble. The dominant geomorphic process was widening with a RGA score of 0.22.

SC-7

The reach was moderately sinuous and less confined than Reach SC-6. The bankfull widths ranged from 8 – 12 m and depths ranged from 0.10 – 0.35 m. The bed substrate was composed of cobbles, pebbles and very coarse sand. Pool and riffle spacing was approximately 10 – 15 m. A few herbs, grasses, and mature trees were found along the banks. A large retaining wall can be seen along the west bank, upstream from King St. East. Gabion baskets were observed along both banks in some sections. Some woody debris was noted in this channel. The reach was deemed to be geomorphically stable with an RGA score of 0.17.

3.8.4. Summary of Findings

The field reconnaissance was performed in order to assess the existing fluvial geomorphological conditions along both Stoney Creek and Battlefield Creek. In general, both creeks in the study area exhibit low stream health and are in state of transition. The dominant geomorphic process occurring in both creeks appear to be channel widening and aggradation to a lesser degree. Both creeks have well-vegetated banks. Water flow through Stoney Creek is typically slow as a result of the accumulation of in-stream woody debris (and urban debris to a lesser degree). Some of the previously installed bank treatments were observed to be failing. These bank treatments are in clear need of repair in order to restore their original functionality. In the specific case of reach SC-4, the upstream end near Queenston Rd. has already been re-aligned in 2003/2004 for enhanced channel stability and to protect local infrastructure.

The long-term east valley wall stability adjacent to 79 Donn Avenue should be protected by potential creek and valley wall works. The extent of the works should be determined once the detailed stream morphology work is conducted.

3.9. Archaeology

3.9.1. Background

A Stage 1 Archaeological Assessment (ref. Appendix 'J') has been to conducted within the lower Stoney and Battlefield Creek to provide a preliminary assessment of archaeological resources in potential creek work areas. The objectives of a Stage 1 background study are:

i. To provide information about the property's geography, history, previous archaeological fieldwork and current land condition;
ii. To evaluate in detail the property's archaeological potential which will support recommendations for Stage 2 property assessment for all or parts of the property if warranted; and,
iii. To recommend appropriate strategies for Stage 2 property assessment if warranted.

Archaeological potential is determined through the assessment of criteria outlined by the Ontario Ministry of Tourism and Culture. Several factors including, but not limited to, proximity to water, proximity to natural resources and raw materials, the presence of well-drained soils, elevated topography suitable for habitation, access to historically important transportation routes, proximity to historic infrastructure, settlement, and industry, and the presence of previously identified archaeological resources, all serve to increase a study area’s potential to contain archaeological resources as they would have increased the likelihood of past human occupation and use of the study area.

The current study area consists of the floodplains of Stoney Creek and Battlefield Creek located between Lake Ontario and the CP Rail Line ROW south of King Street West/East in Hamilton, Ontario. The study area is situated within the Iroquois Plain physiographic region of Ontario (Chapman and Putnam 1984: 113). The Iroquois Plain physiographic region encompasses lowland areas bordering Lake Ontario, from the Niagara River to the Trent River. This physiographic region was inundated in the Late Pleistocene by Lake Iroquois (Chapman and Putnam 1984: 190). More specifically, the subject lands are located within the Niagara Fruit Belt of the Iroquois Plain. Overall, this area is cut by a number of small streams, including Stoney Creek, which produce lagoons or marshes cut off from Lake Ontario by a barrier beach (Chapman and Putnam 1984: 190). The soil within the study area was derived from the underlying Queenston Formation and is heavy in texture and low in permeability. Queenston shale, which is found between Lake Ontario and the escarpment, is characterized by a very distinctive red shale with green streaks and includes thin siltstone, fine sandstone and calcareous interbeds (McCann, 1987: 17). The topsoils within the study area consist of Brunisols (formerly called Brown Forest soils) which are sandy in texture (fine sandy loam) and may be calcareous at approximately 60 cm in depth (Bunting, 1987: 56). This area is also characterized by broad gravel ridges with well-drained loams (Chapman and Putnam 1984: 190).

The Iroquois Plain became the first settled area in this part of Ontario due to its favourable climate, proximity to Lake Ontario and its accessibility to transportation. Toronto and Hamilton are the largest cities of this region and both have spread significantly beyond their original borders (Chapman and Putnam 1984: 196). Based on the demand from the above-mentioned cities, the Iroquois Plain has become an area of specialized farming. The Niagara Fruit Belt historically lent itself to the growing of fruits, particularly pears (Chapman and Putnam 1984: 191). However, various other advantages are found in this region, among which are abundant fresh water, and a variety of easily accessible raw building materials (Chapman and Putnam 1984: 196).

3.9.2. Methods

The Stage 1 background study has been conducted in accordance with the Technical Standards defined in the draft *Standards and Guidelines for Consultant Archaeologists, 2009,* set out by the Ontario Ministry of Tourism and Culture, and with the Ontario Heritage Act, R.S.O. 1990, c. 0.18. Archaeological potential for the study area has considered: topography, drainage, soils, vegetation, and proximity to important resources and transportation routes. Potential for historic occupation has been assessed through an examination of historical atlases and other archival sources. Property inspections have been conducted to document current land conditions, verify areas of archaeological potential versus no potential and to note areas where archaeological potential has been removed through recent disturbance. In addition *Historic Horizon Inc*. have been consulted, who have done extensive archaeological work at the southern end of the study area, in order to obtain the most current information regarding known archaeological sites in the vicinity and the identification of specific areas of archaeological sensitivity.

3.9.3. Results

Overall, the results of the background research indicate that all parts of the study area exhibit potential for archaeological resources and warrant a Stage 2 assessment, with the exception of areas that have been thoroughly disturbed, are excessively sloped and not eroding, or are low-lying and wet. All eroding slopes should be visually inspected to determine whether residual artifacts from remnant sites are present. Moreover, older roadways, parking lots and slab-on-grade structures that may ostensibly appear to be completely disturbed, may in fact have capped intact archaeological deposits. As such, if these areas are to be impacted by construction activities, they require a preliminary archaeological review of soil borehole data, if available, and/or monitoring by a licensed archaeologist. The above evaluation of archaeological potential is based on four main factors: the presence of primary and secondary water sources within the study area; the presence of fourteen previously registered archaeological sites within a two-kilometre radius; the possibility that *in situ* evidence may have survived from one or more the early structures depicted in the area in the historical maps consulted; and the fact that the southern portion of the study area, alongside Battlefield Creek, corresponds to the War of 1812 Stoney Creek Battlefield.

3.9.4. Summary of Findings

Based on the results of the Stage 1 assessment of the study area, consisting of the floodplains of Stoney Creek and Battlefield Creek between Lake Ontario and the CP Rail Line ROW to the south of King Street West/East, a Stage 2 assessment is recommended for all portions of the property, with the exception of those areas that are demonstrably thoroughly disturbed, excessively sloped or low-lying and wet. It should be noted that eroding slopes should be visually inspected to determine whether residual artifacts from remnant sites are present. Stage 2 assessment of these lands should include a pedestrian survey of all former and current agricultural fields where ploughing is viable, and a test pit survey elsewhere. Since older roadways, parking lots and structures without basements may have capped intact archaeological deposits, an archaeological review of soil borehole data to determine whether buried soil horizons are present and/or monitoring by a licensed archaeologist is recommending during future construction activities in those areas. A map indicating the areas that require Stage 2 assessment is provided in Appendix ‘J’ along with initial impressions regarding the viability of ploughing. Stage 2 assessment is recommended at these locations prior to any land development or topsoil disturbance. The remainder of the study area may be considered free of any further archaeological concern.

3.10. Land Use

Stoney Creek and Battlefield Creek are subdivided by the Niagara Escarpment. Most of the lands above the Escarpment are agricultural and consist of approximately 60 % of the watershed while the 40% of the watershed is under development for residential, commercial industrial and institutional uses. Land use has been determined using the City of Hamilton land use mapping for both existing and future conditions (ref. Drawings 3 and 4).

Out of the 3089 ha (+/-) drainage area for the watershed, future development consists of only the following:

- Residential 20 ha (0.6 %)
- Institutional 2 ha (0.06%)
- Commercial 2 ha (0.06 %)

Total 24 ha

Based on the foregoing, future development within the watershed is considered minimal based on watershed area.

4. LONG-LIST OF ALTERNATIVES

The December, 2009 Draft Characterization Report provided a baseline condition of the existing conditions within the Stoney Creek and Battlefield Creek study area relevant to the identified flooding and erosion problems. This Alternative Assessment Working Paper builds upon the findings of the Characterization Report and identifies and assesses potential flood and erosion mitigation alternatives, leading to preliminary preferred alternatives.

4.1. Flooding Alternatives

In order to address the identified riverine-based flooding potential within the Stoney Creek and Battlefield Creeks, a long-list of potential remediation alternatives has been established. The long-list of remediation measures have been screened based on various functional aspects including engineering principles for the effectiveness of improving flood protection; this has resulted in a short-list of alternatives for more detailed consideration. The next step has involved developing specific evaluation factors to assess each short-listed alternatives with consideration of the technical and functional aspects, specific to addressing the problems as already identified in the baseline inventory, as well as environmental (physical and social and economic considerations.

The flooding problems within Stoney Creek and Battlefield Creek occur due to the following mechanisms:

i) Inadequate Channel (Conveyance System) Capacity
ii) Inadequate Floodplain Capacity
iii) Spill-Prone Areas where flow exceeds capacity and moves away from the watercourse
iv) Limited Culvert/Bridge Flow Capacity
v) Lack of Stormwater Control
vi) Creek blockages due to debris
vii) Obstruction Zone (Debris/Ice)

The flooding mechanisms are considered general and as part of the assessment of alternatives a local understanding of mechanisms needs to be established. The long-list of alternatives for reducing flooding risk has been subdivided into three categories, “Do-Nothing”, Structural/ Capital Alternatives and Non-Structural Alternatives as follows:

4.1.1. “Do-Nothing”

Base line condition to compare the technical performance of all other alternatives.

4.1.2. Structural/Capital Alternatives

The following structural/capital flood mitigation alternatives have been listed and described within the "Conservation Ontario Class Environmental Assessment for Remedial Flood and Erosion Control Projects", January 2002, amended September 2009.

1. Culvert/ Bridge Upgrades – Replace/ Supplement
2. Floodplain/ Channel Improvements
3. Roadway Profile Modifications
4. Flood proofing Buildings
5. Eliminate/Reduce Potential Culvert Blockages
6. Diversions
7. Combinations

Alternative 1: Culvert/Bridge Upgrade – Replace/Supplement: Should a culvert/bridge crossing's flow capacity restrict conveyance and produce upstream flooding conditions, a mitigation approach could include either replacing or supplementing the capacity of the existing culvert/bridge crossing.

Alternative 2: Floodplain/Channel Improvements: Improve channel and floodplain flow conveyance capacity by widening the channel, local grading improvements, removal of flow obstructions within the channel and the floodplain and possible channel profile improvements.

Alternative 3: Roadway Profile Modifications: Roadway profiles can be modified to reduce the amount and extent of upstream flooding.

Alternative 4: Flood proofing buildings: Buildings can be flood proofed by sealing low openings with various types of construction practices or alternatively local berming and/or flood walls can be constructed to prevent direct flooding to the building.

Alternative 5: Eliminate/Reduce Potential Culvert Blockages: Debris blockage of the channel and some culverts has been an issue for both Battlefield Creek and Stoney Creek. Typically debris has accumulated at the upstream side of a roadway crossing and/or around instream areas, such as shopping carts. Eliminating or reducing potential culvert and/ or creek blockages can reduce the potential for future flooding.

Alternative 6: Diversions: Drainage may be able to be locally diverted from one location to another within the Battlefield Creek or Stoney Creek watershed or to another adjacent watershed, such as Red Hill Creek or the neighbouring Watercourse 1 to the east to reduce flooding conditions. Drainage diversions are possible within developed areas, however, may be limited by existing infrastructure, development and property ownership and other environmental factors. It should be noted that significant diversions to other drainage networks are typically not supported by Conservation Authorities.

Alternative 7: Combinations: Combinations of various alternatives that would reduce flooding conditions may be possible, when a stand-alone alternative does not provide fully adequate flood remediation.

4.1.3. Non-Structural Alternatives

1. Regulation (updated)
2. Flood Forecasting and Warning
3. Emergency Preparedness
4. Creek Maintenance Plan

Alternative 1: Regulation (updated): Hamilton Conservation Authority regulates Battlefield Creek and Stoney Creek and associated flood-prone or Hazard areas through Ontario Regulations 42/06, and 146/06 to 182/06 (Development, Interference and Alteration Regulations). The Conservation Authority applies regulations to ensure that flooding conditions are not negatively impacted by creek or floodplain alterations/development.

Alternative 2: Flood Forecasting and Warning: Hamilton Conservation Authority maintains a flood warning systems that advises City of Hamilton staff of potential flooding conditions within the Conservation Authority's jurisdiction. The Conservation Authority has a working knowledge of the creek systems that they regulate, that assists in the prediction of flood conditions. Conservation Authority staff notify the City of Hamilton of potential flooding conditions, in order that City staff can mobilize and prepare required emergency planning tasks prior to flooding conditions.

Alternative 3: Emergency Preparedness: Both Conservation Authority staff and City of Hamilton emergency services staff are active prior to, and during, flooding conditions. Conservation Authority staff, following forecasting of the flooding conditions and notifying City of Hamilton staff, monitors flooding conditions on a per need basis using available staff throughout the area watercourses including the Battlefield Creek and Stoney Creek and the other watersheds within the City of Hamilton's limits. This effort is intended to assist in determining where flooding conditions may require emergency services. Emergency services staff is made aware of potential flooding conditions in order to evacuate citizens in flood-prone areas prior to flooding and during flooding.

Alternative 4: Creek Maintenance Plan: A Creek Maintenance Plan would facilitate regular inspection of all creek reaches to determine flooding issues such as debris accumulation and culvert blockages and the subsequent removal of each blockage. The Maintenance Plan would also facilitate observation of on-going or emerging erosion issues.

The generic long-list of alternatives has been screened initially based on a feasibility assessment for implementation in the study area as follows:

4.1.4. Initial Screening

Structural/Capital Alternatives

Alternative 5: Eliminate/ Reduce Potential Culvert Blockages: As a standalone solution to the existing flooding problems, elimination or reduction of the culvert and bridge blockages would not resolve flooding potential and risk along Battlefield Creek and Stoney Creek, as it has been noted that the limited flow conveyance capacity of unblocked crossings, such as the CNR crossing, contributes to upstream flooding even without blockage. This alternative should be considered as an operational improvement in conjunction with the preferred solutions.

Alternative 6: Diversion: Diverting flows to either the Red Hill Creek Watershed or to Watercourse 1 has been reviewed and based on this assessment considered infeasible. Also, limited benefit would result from flows being internally diverted within Battlefield Creek and Stoney Creek due to the narrow configuration of the watershed below the Niagara Escarpment and the resulting minimal reduction in peak flows. Diversion of flows within the Battlefield Creek and Stoney Creek watershed would require construction of large enclosures due to the limited potential for surface based overland flow diversion routes, therefore local diversions would also be cost prohibitive.

Both Red Hill Creek and Watercourse 1 have existing flow capacity restrictions of their own and would incur increased localized flooding, and are therefore not considered suitable creeks for receiving additional flow from either the Battlefield Creek or Stoney Creek. In addition to the foregoing, existing water balance conditions within Battlefield Creek and Stoney Creek and the receiving creek systems would be altered and would require in-depth environmental analysis to determine the associated impacts which are considered potentially significant. Hence, diversions have been screened from further consideration.

Non Structural Alternatives

Alternatives 1 to 4: Non-structural alternatives such as Regulation, Flood Forecasting, Warning and Emergency Preparedness and a Creek Maintenance Plan are required to reduce the threat to life and property, but would not reduce existing flooding conditions and risk within the study area. As such these alternatives should be considered as potential areas for operational improvement in conjunction with the preferred solutions.

Short-Listed Flood Mitigation "Short-Term" Alternatives

The following alternatives have been short-listed as potential short-term alternatives based on the initial screening results:

Alternative 1: Culvert/Bridge Upgrades – Replace/Supplement
Alternative 2: Floodplain/Channel Improvements
Alternative 3: Roadway Profile Modifications
Alternative 4: Flood Proofing Buildings
Alternative 9: Combinations

4.1.5. Land Management Practices

The short-listed flood alternatives are considered short-term solutions to the existing flooding conditions. A category of works termed "Land management practices" may offer potential future longer term opportunities for flood reduction, particularly if there is a significant change in the flood risk and/or a change in the social vision of overall creek management. Funding mechanisms for any land management practices would have to be determined in consultation with land owners at the time. Any potential significant land management measures would need to be considered in the long-term, greater than 25 years (+/-).

Flood Control Via Stormwater Quantity Controls (Ponds): Stormwater quantity controls whether on-line or off-line can reduce flows within watercourses and thereby reduce the extent of flooding.

The existing development within Stoney Creek and Battlefield Creek does not have stormwater quantity management, as it generally preceded this management practice in the City of Hamilton. As part of the Community of Stoney Creek Stormwater Quality Management Strategy Master Plan 2004, water quality retrofits to existing storm outfalls were proposed to improve water quality being discharged from the storm sewer system. The stormwater quality retrofit sites would provide limited flow attenuation based on the total cumulative 6,292 m^3 of extended detention and no available flood storage (ref. Table 4.1.1) and would only marginally reduce the major flooding that currently occurs for any of the significant storm events such as the 100 year or Regional Storm. Based on the QUALHYMO hydrologic modelling, the impact of the currently planned 6,292 m^3 extended detention on the frequency flows (Note: assuming it is available during major storms) has been shown in Tables 4.1.2 and 4.1.3.

Table 4.1.1: Stormwater Quality Retrofits Facilities

Facility/ Creek	Drainage Area (ha)	Impervious Coverage (%)	Facility Type/Protection	Water Quality Requirements (m^3/ha)	Permanent Pool (m3)	Extended Detention
Queenston (BC)	27.21	53.3	Wetland 2	88.7	1,325 (600)1	1,088
Barton (BC/SC)	76.90	51.6	Wetland 2	87.4	3,648	3,076
Huckleberry (BC)	32.70	40.3	Wetland 2	79.0	1,308	1,308
Warrington (BC/SC)	20.50	58.8	Wetland 2	93.8	820	820

Table 4.1.2: Frequency Flows for Future Land Use Condition Based on Continuous Simulation with Stormwater Quality Retrofits In-Place (m^3/s)

Location	Return Period (Years)								
	1.05	1.25	2	5	10	20	50	100	Regional
Stoney Creek									
Confluence near Tapleytown Rd. and Green Mountain Rd.	2.13	3.26	5.64	10.6	15.1	20.4	28.7	36.2	83.80
Edge of Escarpment	2.73	4.19	7.19	13.3	18.7	24.9	34.6	43.2	105.64
King St.	2.95	4.44	7.52	13.8	19.3	25.7	35.7	44.6	105.69
Highway 8	3.04	4.55	7.66	14	19.6	26.1	36.2	45.1	105.93
Battlefield/Stoney Creek Confluence	4.53	6.90	11.20	19.40	26.50	34.80	48.10	60.20	184.61
CNR	4.86	7.29	11.70	20.00	27.10	35.50	48.70	60.70	187.36
QEW	5.36	7.91	12.50	21.00	28.40	36.90	50.40	62.70	192.69
Lake Ontario	5.37	7.92	12.50	21.00	28.40	36.90	50.40	62.70	192.73
Battlefield Creek									
Confluence near Centennial Parkway	0.81	1.17	1.87	3.28	4.5	5.89	8.04	9.93	44.08
Edge of Escarpment	1.06	1.47	2.3	3.97	5.43	7.1	9.7	12	51.37
King St.	1.44	1.87	2.78	4.7	6.43	8.46	11.7	14.6	59.05
Highway 8	1.74	2.39	3.53	5.57	7.29	9.25	12.30	15.10	43.51

Table 4.1.3. Percent Relative Difference In Frequency Flows with and Without Stormwater Quality Retrofits Based on Continuous Simulation (%)

Location	Return Period (Years)								
	1.05	1.25	2	5	10	20	50	100	Regional
Stoney Creek									
Confluence near Tapleytown Rd. and Green Mountain Rd.	0	0	0	0	0	0	0	0	0
Edge of Escarpment	0	0	0	0	0	0	0	0	0
King St.	0	0	0	0	0	0	0	0	0
Highway 8	0	0	0	0	0	0	0	0	0
Battlefield/Stoney Creek Confluence	-6.40	1.02	1.82	-0.51	-1.85	-2.79	-3.02	-2.75	-0.49
CNR	-5.26	1.53	2.63	0.00	-1.45	-1.93	-2.40	-1.94	-0.50
QEW	-7.11	1.28	3.31	0.00	-1.73	-3.40	-4.55	-4.71	-0.93
Lake Ontario	-7.09	1.15	3.31	0.00	-1.73	-3.40	-4.55	-4.71	-0.95
Battlefield Creek									
Confluence near Centennial Parkway	0	0	0	0	0	0	0	0	0
Edge of Escarpment	0	0	0	0	0	0	0	0	0
King St.	0	0	0	0	0	0	0	0	0
Highway 8	-9.38	1.27	5.37	0.91	-3.70	-7.50	-12.14	-14.69	-2.51

The limited reduction (1.94% to 14.69%) in the 100 Year Storm frequency peak flows downstream of the planned stormwater quality retrofits would not reduce flooding conditions in the downstream reaches within both Battlefield Creek and Stoney Creek. Previous studies have also raised the potential for major flood storage on the Niagara Escarpment to over control headwater flows and reduce downstream flood risks.

However, flood storage beyond that planned for future development above the Niagara Escarpment is not available above the Escarpment on Stoney Creek, where 105.93 m^3/s out of the 158.26 m^3/s Regional Storm peak flows (66 %) at Lake Ontario occurs.

The potential ‘Devil’s Punchbowl’ stormwater retrofit site noted within the Community of Stoney Creek Stormwater Quality Management Strategy would have to be sited on private property and would require a significant amount of land and associated storage volume to result in any significant reduction in the peak flows for the larger storm events.

Further consideration of Stormwater Quantity Control as a Land Management Practice has been provided in Section 5.

Creek Corridor Land Management Practice: At risk properties that are located within the regulated floodplain may be able to be removed from the regulated floodplain by creek works or the reduction of peak flows by stormwater management. As such lands could be managed by the City in an effort to reduce flooding risk or to eliminate or reduce the threat to life to persons living or working on the property. Management of the foregoing lands by the City would typically not be considered, due to the high social and economic considerations involved; however as a longer term management strategy it may ultimately require reconsideration.

4.2. Erosion Alternatives

There are a number of erosion issues along Stoney Creek and Battlefield Creek, primarily located upstream of the confluence between the two creeks. The erosion issues are related to several factors including confinement of the channel by existing development, lack of historical application of stormwater management, locations of valley wall contact and existing structures that are failing. The dominant mode of adjustment along the majority of reaches is widening and aggradation.

The long-list of alternatives for reducing erosion has been subdivided into three categories, "Do-Nothing", Structural/ Capital Alternatives and Non-Structural Alternatives. Some of these alternatives also relate to modification of hydraulic processes, as well as geomorphologic processes, and have therefore also been assessed with reference to their local hydraulic impact (ref. Section 7). Conversely the alternatives being considered for flood risk management are also likely to influence geomorphologic processes and have therefore been assessed in terms of erosion control implications, where deemed influential.

4.2.1. Do Nothing

"Do Nothing" is identified as an alternative as a baseline against which all alternatives that involve implementing works can be assessed. In most of the reaches along Battlefield Creek and Stoney Creek there are significant risks to infrastructure and / or private property (primarily backyards), which may lead to future damage, loss of land and costs incurred in repairing or relocating the infrastructure / property line. The continuation of these risks, which are associated with the "Do Nothing" alternative, must be weighed against the cost of implementing alternatives to control the risks of further erosion.

4.2.2. Structural/Capital Alternatives

Reach-scale remedial alternatives aim to address erosion at specific sites but have limited influence or benefit beyond these sites. While these alternatives do not address the causes of erosion problems, they can be implemented as part of a strategic plan, in a watershed context, to help stabilize a modified channel in the short-term and within the existing constraints.

Reach-scale alternatives can broadly be divided into three categories identified in the document "Class Environmental Assessment for Remedial Flood and Erosion Control Projects", (Conservation Ontario, January 2002, amended September 2009):

- Protect from erosive energy of channel flows
- Stabilize bank or slope
- Reduce erosive energy of flows

Several methods / techniques may be used in implementing these alternatives, and are discussed in the paragraphs below; in some cases these alternatives may also be combined.

Alternative A1 –Localized Protection from Erosive Energy of Flows: Localized protection measures may be used to protect the banks and bed from the erosive energy of flows using several different techniques, whose suitability is dependent on the reach-setting. At many locations, existing bank protection is comprised of "ad-hoc" materials that have been installed by riparian landowners to protect their individual section of bank. More formalized short-term alternatives, such as bioengineering techniques, are likely to enhance existing conditions and reduce future instability that may be caused by discontinuity in structure/materials. Solutions may include installation or replacement of bank or bed protection (including use of bioengineering techniques that may enhance physical habitat conditions), localized channel realignment where erosion is in contact with the valley wall or installation of in-stream structures, such as deflectors, to direct higher velocity flows towards the centre of the channel under low flow conditions.

Alternative A2 – Stabilize Bank or Slope: Where there are steep banks / valley sides at risk of failure, regrading of the channel banks to create a more gentle bank slope profile could be used to improve bank stability. The implementation of this alternative typically requires the top of the channel bank to be set back to achieve the lower slope angle, and therefore may require additional land to facilitate implementation.

Alternative A3 – Vertical control structures
Where high gradient and bed degradation is a cause of erosion, in-stream structures can be used to create a step-pool system so that energy can be dissipated along the channel bed.

Alternative A4 – Reach-Scale Channel Re-meandering/Floodplain Connection: This alternative recognizes that Alternatives A1 and A3 can often be combined through Natural Channel Design and that application of channel re-meandering/floodplain connection, due to existing constraints, may only be feasible at a reach-scale.

4.2.3. Non-Structural Alternatives

In addition to structural interventions, measures may be implemented to remove infrastructure and property from areas of erosion risk (i.e. through land management and/or relocation outside of the stream corridor). Such "preventative" measures are exempt from the Environmental Assessment Act (Conservation Ontario, 2009) and are typically considered in advance of potential remedial actions. Such "preventative" alternatives are discussed below and their application to Stoney and Battlefield Creek investigated further in Section 8.

Alternative B1 - Debris Management: Stoney Creek and Battlefield Creek are urban watercourses and man-made debris was observed within the channel at several sites, particularly downstream of the confluence of the two creeks. Urban debris is not only aesthetically undesirable, it can also create blockages within the channel, potentially resulting in erosion of the banks around the blockage and ponding and deposition of sediment upstream. Significant lengths of the creeks are also tree lined, sourcing large woody debris to the channel. Large woody debris has an important role to play within river ecosystems. However, more large woody debris may be sourced to Stoney Creek and Battlefield Creek than that which would naturally occur, as a result of ongoing channel widening. Review and formalization of a debris management plan could help to reduce erosion, ponding and sedimentation related to debris dams. Such a plan would need to take into account the fact that beavers are reported to be present in the lower sections of the creek system. Debris management may also include management of riparian trees to prolong tree life, ensure appropriate shading and manage large woody debris generation. It may also be possible to reduce urban debris sourcing through public engagement and education.

Alternative B2 – Riparian Zone Management: During the field assessment, it was observed that, along a number of reaches through parkland, riparian vegetation was being mown to the top of the channel bank. Limiting the mowing to enable establishment of riparian zone vegetation is likely to assist in providing greater bank stability at these locations.

4.2.4. Initial Screening

The generic long-list of alternatives has been screened initially based on a feasibility assessment for implementation in the study area as, prior to consideration of the short-listed alternatives on a reach-by-reach basis.

Do Nothing

Since there are reaches where no municipal infrastructure is at risk, the "Do Nothing" alternative has been taken forward for consideration on a reach-by-reach basis.

Structural/Capital Alternatives

(i) Localized erosion control concerns will need to be implemented in the short-term if property and infrastructure are to be protected. Different reach-scale alternatives may be more suitable to address erosion concerns depending on the reach setting. Within Stoney Creek and Battlefield Creek, the dominant mode of adjustment is currently widening and aggradation resulting in erosion of the channel banks. Vertical control would therefore not address the erosion issues. In addition, such in-stream structures would create additional maintenance requirements, reduce continuity along the creek and may hinder movement of aquatic species. “Alternative A3 – Vertical control structures” has therefore been screened from further consideration. Alternatives “A1 – Localized Protection from Erosive Energy of Flows”, ”A2 – Stabilize Bank or Slope” and “A4 Reach Scale Channel Re-meandering / Floodplain Connection” have been short-listed as erosion management alternatives to be assessed on a reach-by-reach basis.

Non-structural Alternatives

(ii) With regard to debris management, it is recommended that maintenance practices are reviewed and formalized to develop a debris management plan for the Stoney Creek and Battlefield Creek watershed. However, this alternative relates to best practice river corridor management rather than only addressing erosion concerns. It is also unlikely that this alternative alone will be sufficient to remediate the sites of particular erosion concern identified. Alternative “C1 – Debris Management” has therefore not been short-listed as a stand-alone erosion remediation alternative for reach-by-reach assessment but will form part of recommendations for management and enhancement within the watershed, identifying particularly relevant reaches for attention.

(iii) With regard to riparian zone management, again this alternative relates to river corridor management best practices and it is unlikely that this alternative alone will be sufficient to address the localized sites of particular erosion concern identified. Alternative “B3 – Riparian zone management” has therefore not been short-listed as an erosion alternative for reach-by-reach assessment but will form part of recommendations for management, identifying particularly relevant reaches for attention. This alternative could also be effectively combined with Land Management Practices as part of a long-term strategy.

Short-listed Erosion Short-Term Alternatives

The following alternatives have thus been short-listed for consideration in the short-term as part of the reach-by-reach alternatives assessment, to be considered as part of a watershed approach and integrated with the flood alternatives:

- Alternative A1 – Localized protection from erosive energy of flows
- Alternative A2 – Stabilize bank or slope
- Alternative A4 – Reach-scale re-meandering/floodplain connection.

The application of the foregoing alternatives is to be considered for application in the short-term, within existing constraints. Long-term restoration of the creek system to a more natural system which allows for 'natural' creek lateral migration and meandering would require more space on either side of the creek block and land management (as part of a "Preventative" Program Area). Further discussion of potential land management requirements to facilitate long-term creek restoration has been provided within Section 8.

4.2.5. Land Management Practices

Land Management Practices may be divided into three key types, as identified within the "Class Environmental Assessment for Remedial Flood and Erosion Control Projects", (Conservation Ontario, January 2002, amended September 2009):

- Reduce erosive energy of channel flows
- Protect from erosive energy of channel flows
- Stabilize bank or slope

Such measures should be considered on a watershed basis in order to take account of the inter-dependencies of geomorphological processes, which may lead to impacts upstream and downstream as well as at the site of the works.

In the long-term, within urbanized watersheds such as Stoney Creek and Battlefield Creek where erosive energy has been increased as a result of human activities, it would be desirable to remove infrastructure and property from areas of erosion risk and reduce the erosive energy of channel flows by re-establishing more natural processes. This may involve decreasing the gradient of the channel through re-meandering, reconnection with the floodplain and/or flow attenuation through stormwater management. Adoption of such land management practices on a watershed scale may be limited or infeasible in the short-term as a result of existing constraints within the watershed (e.g. existing urban land use encroaching on the channel). However, in the medium to longer-term (15 to 25 years, 25 years +), a move towards such practices may be possible if there is a significant change in the erosion risk and/or a change in the social vision of land management for the creek corridor and is likely to represent a more sustainable way of managing erosion fully integrated with flood management practices. These medium to long-term land management practices are considered in the following paragraphs, together with the factors that currently constrain their implementation potential at a watershed-scale.

Reconnection of Channel and Floodplain Processes: Stoney Creek and Battlefield Creek have been disconnected from their floodplains throughout much of the study area. Re-connection of the creeks with their natural floodplain could help reduce erosion downstream by accommodating and reducing stormwater flows/velocities during events of greater frequency, thus reducing overall stream energy. Enhancement of floodplain functionality may also reduce aggradation by facilitating transfer of sediment from the channel to the floodplain. The feasibility of this land management practice is limited by the encroachment of existing development and the confined nature of the valley systems. However, if development constraints could be reduced in the long-term, this land management measure could be implemented using the principles of natural channel design.

Flow Attenuation through Stormwater Management: Flows from existing developed lands are currently not managed along Stoney Creek or Battlefield Creek for erosion mitigation. Attenuation of the flow regime through stormwater quantity management in the long-term may offer benefits in terms of hydraulics by extending the flow response to rainfall events over a greater time period and reducing the erosive energy of flows. This measure would not, however, facilitate transfer sediment to the floodplain.

Channel Re-meandering: Both Stoney Creek and Battlefield Creek have been subject to historic channel realignment and straightening, including at the confluence between the two creeks. The existing planform of the creeks is therefore largely modified as result, excepting isolated sections where the natural planform remains evident and should be preserved (e.g. BC-5 and central section of SC-4). Where the channel has been straightened, there are opportunities in the medium-term for enhancement through re-meandering of the channel to establish a more natural channel planform. In addition to improving physical habitat conditions, re-meandering (and creation of a shallower gradient) can help to attenuate flows and reduce flow velocities under bankfull conditions, although the extent of this is dependent on the scale of re-meandering.

Management of Property or Relocation of Infrastructure at Risk: Channel erosion is a natural process occurring in equilibrium with other channel functions, which commonly becomes an issue where either accelerated due to human activity or where development situated adjacent to the creek may be compromised. Management of and/or relocation of development or infrastructure in the long-term away from the creek can effectively remove the risk and is the most sustainable solution. However, adoption of this practice is likely to be constrained by high capital costs, social disruption, the potential number of stakeholders involved and associated implications for other infrastructure. Particular opportunities for land management and infrastructure relocation have been highlighted for consideration in the long-term within Section 8.

5. SHORT-LISTED ALTERNATIVE ASSESSMENT

5.1. Evaluation Methodology

In order to assess the various flooding and erosion control short-listed alternatives, an evaluation system, has been advanced to assess the suitability of each alternative against appropriate "evaluation factors". The evaluation factors consist of considerations related to a two-tier hierarchy of potential impacts/issues organized by Evaluation Category, which have been supplemented by more detailed and specific Evaluation Criteria.

Evaluation Category

A broad description of the type of impacts and issues under consideration includes:

(i) **Functional** – Impacts that the alternative may have on how a system is intended to work as related to flood and erosion mitigation.
(ii) **Environmental** – Potential impacts or benefits that alternatives may have on terrestrial and aquatic habitat. (The hydrogeologic sensitivity of the alternatives to baseflow is considered low but has been included in the aquatic habitat assessment.)
(iii) **Social** – Impacts/issues relating to the interaction of the community/neighbourhood with the implementation of the proposed alternative
(iv) **Economic** – Immediate and future costs and cost-benefit of the alternative including operations and maintenance.
(v) **Constructability** – Construction considerations related to accessibility for machinery and the potential impact of construction techniques and access on private property.

Evaluation Criteria:

Specific evaluation criteria relevant to each Evaluation Category has been summarized in Table 5.1.1.

Table 5.1.1: Flood and Erosion Mitigation Alternatives Evaluation Approach		
Evaluation Category	**Evaluation Criteria**	**Criteria Description**
Functional	Extent to which the alternative mitigates the Creek System Flow Capacity Deficiencies	Each alternative, to varying degrees, provides opportunities to improve the existing creek system flow capacity.
	Extent to which the alternative improves Local Drainage of Adjacent Lands	Reducing flood levels or protecting property from flooding would potentially allow for better use of adjacent lands
	Protection of existing municipal infrastructure.	Reflects the degree to which the alternative contributes to the immediate need for protection of municipal infrastructure.
	Long-term creek stability	Reflects the degree to which the alternative contributes to long-term, stability of the creek, as well as the potential requirements for future intervention.
Environmental	Impacts and Enhancements to Terrestrial Vegetation Communities	Depending on the alternative impacts to the existing terrestrial system may occur.
	Impacts/ Enhancements to Aquatic Habitat	Depending on the alternative, fish habitat may be enhanced or negatively impacted.
Social	Ability to Improve Public Safety	Depending on the configuration of the works, the study reaches may be considered safer when flooding potential is reduced.
	Impacts on Private Properties	Relates to the change in flood risk on private lands.
	Impact on Public Lands	Depending on the alternative there are varying degrees of impact to flooding conditions on public lands including parks and roadways.
Economic	Capital Costs	High costs are negative. Low costs are positive.
	Operations and Maintenance Costs	High costs are negative. Low costs are positive.
Constructability	Ease of Construction and Accessibility	Depending on the selected alternative, the machinery and materials required to construct will vary. The more aggressive the construction, the more difficult to construct, since larger and more extensive equipment will be required.
	Expected Temporary Disturbance to Existing Habitats	Depending on the scope of work, existing habitats will be disturbed to a varying degree by in both the short and long-term.

5.2. Reach-Scale Issues and Risks

In order to assess the applicability of the identified short-listed alternatives, it is important to understand the key flooding and erosion risks, as well as opportunities for enhancement.

5.2.1. Flooding

Flooding mechanisms vary on a reach by reach basis, ranging from restricted culvert flow capacity to development encroachment. Figures SC-1 to SC-7 and BC-1 to BC-5 graphically depict the 100 year and Regional Storm floodlines providing a better understanding of flooding conditions for each reach. Flood issues and key risks for each reach are detailed in Table 5.2.1.

5.2.2. Erosion Control

Key erosion issues are related to several factors including confinement of the channel by previous development, lack of historical application of stormwater management, locations of valley wall contact and existing structures that are failing. The dominant mode of adjustment along the majority of reaches is widening and aggradation. Figures SC-1 to SC-7 and BC-1 to BC-5 graphically depict existing erosion risks, which are detailed for each reach in Table 5.2.1.

Integration of the Watercourse Erosion Restoration Implementation Plan: The City of Hamilton has recently developed a Watercourse Erosion Restoration Implementation Plan (Aquafor Beech, 2010) which identifies priority erosion sites according to a City-wide ranking system. Seven of the top 30 ranked priority erosion sites have been identified within the Stoney Creek and Battlefield Creek watershed. A summary of the sites identified is provided in Table 5.2.2 and illustrated in Appendix ‘N’. Conceptual designs for these sites have been proposed as part of the City-wide Watercourse Erosion Restoration Implementation Plan. The short-listed alternative assessment has been undertaken using these conceptual designs as initial input to inform the process where appropriate. Further details relating to the specific conceptual designs at different sites will be discussed in the subsequent sections in order to develop an integrated plan for erosion control which includes all preferred solutions.

Battlefield Park and Green Acre Park Bank Stabilization: Plans for bank stabilization of localized sections of Battlefield Creek are currently being advanced by the City of Hamilton. The proposed works have been reviewed as part of this study and integrated into the alternatives assessment. It is noted that while this alternative addresses immediate erosion issues that are threatening the watercourse, it does not preclude the necessity for additional works in the future. A preferable approach in the long-term would be the management of land subject to erosion risk and creation of a fully functional stream corridor incorporating appropriate setbacks. Lands being protected under this project include Battlefield Park and a multi-use trail adjacent to a baseball pitch.

Table 5.2.1. Summary of Flood and Erosion Risks along Battlefield Creek and Stoney Creek					
Reach	**Flooding Mechanism**	**Flooding Risks**	**Existing Erosion**	**Existing Modification**	**Erosion Risks**
BC-1	Hydraulic Capacity of Barton Street crossing and floodplain encroachment. CNR crossing capacity – limited impact	• Rear yard of 1 house on Blueberry Dr. (Regional Storm) (< .5 m +/-) • 1 residential lot, 3 front yards on Huckleberry Dr (Regional Storm) (0 – 3 m +/-) • 2 rear yards and 5 front yards on Lake Ave. N. (Regional Storm) (0 – 2.5 m +-/)	Minor erosion -tree-lined banks prevent channel widening due to dense roots.	Historically realigned, particularly at confluence with Stoney Creek.	None identified. A sewer pipeline is present in the floodplain along the east bank, however, tree-lining limits lateral channel migration.
BC-2 (Henry & Beatrice Warden Park)	Hydraulic Capacity of Barton Street crossing and floodplain encroachment.	• 2 residential lots on Lake Ave. N. (< 100 year storm) (4 m +/-) • Apartment complex walkway on Lake Ave. (Regional Storm) (< .5 m +/-) • 1 front yard on Lake Ave. N. (Regional Storm) (< .5 m +/-)	Minor to moderate erosion. Channel is confined causing erosion to above top of bank. Localized valley wall contact Contains Priority Erosion Site*	Trees being used as ad-hoc bank protection. Historic realignment due to road crossing at downstream end.	Undermining of several stormwater outfalls. Bank erosion adjacent to Queenston Road. Queenston Road sanitary sewer.
BC-3 (Green acres Park)	Queenston Road crossing capacity, and floodplain encroachment. Queenston Road has a hydraulic impact on 50 year to Regional Storm flood elevations for 200 m +/- upstream.	• Hydro transformer station on Queenston Road (Regional Storm) (< 2 m +/-) • 3 rear yards on Galbraith Dr. (Regional Storm) (< 2.5 m +/-) • 1 rear yard on Avalon Ave. (rear yard) (< 1 m +/-) • 1 rear yard on Valley Dr. (< .5 m +/-) • Most flooding occurs upstream of hydraulic influence Queenston Rd.	Localized valley wall contact on east bank (2 locations).	Historically straightened. Failed bank protection adjacent to Randall Avenue. Ad-hoc bank protection on west bank by upstream baseball pitch. Trail and sewer run along west bank through most of the reach. Mowing to top of bank in places	Randall Avenue road crossing. Private backyards mid-reach. Undermined stormwater outfalls mid reach and upstream of Queenston Road.
BC-4 (Hopkins Park)	Floodplain encroachment. King St. overflow (Regional Storm)	• School property on Randall Ave., not building (Regional Storm) (< 1 m +/-) • 13 residential lots with at least half with homes flooded on Faircourt Dr. (< .5 m +/-) • 9 homes/apartments north of King St., 5 of which flood less than 100 year Storm and rest 100 year Regional (< 3 m +/-)	Localized erosion and valley contact on east bank where the channel still has sinuous planform. Contains 2 Priority Erosion Sites*	Historically straightened. Gabion bank protection on east bank mid-reach. Mowing to top of bank in places	Private backyards and driveway Undermined stormwater outfall
BC-5 (Battlefield Park)	King St. culvert flow capacity, but mostly floodplain encroachment.	• 3 properties immediately south of King St. (Regional Storm) (< 1 m)	Bank erosion due to incised nature of channel although banks are dominated by dense trees.	Mowing to top of bank in places downstream.	Property (Battlefield House Museum) in downstream section of the reach.

Table 5.2.1. Summary of Flood and Erosion Risks along Battlefield Creek and Stoney Creek

Reach	Flooding Mechanism	Flooding Risks	Existing Erosion	Existing Modification	Erosion Risks
SC-1	QEW corridor crossings resulting in significant Regional Storm backwater conditions. CNR crossing upstream results in spill for Regional Storm.	• Minor Regional Storm flooding of rear industrial lots (< 1m +/-)	Scouring of channel banks caused by backing up from lake during high flows. Localized valley wall contact on east bank but dense trees	Existing lake upstream of South Service Road. High amount of urban debris.	None identified.
SC-2	CNR crossing capacity resulting in Regional Storm backwater conditions.	• 16 industrial lots on either side of creek, during the Regional Storm, but with significant depth (0.5 to 1.0 m +/-)	Limited erosion. Currently slow flow and fine sediment deposition prevails. Issues relate to several large debris dams (natural and urban).	Historically straightened downstream of Barton Street East. Creation of debris dams due to beaver activity High amount of urban debris.	None identified.
SC-3	CNR crossing capacity resulting in Regional Storm backwater conditions.	• North end of townhouse complex at Bow Valley Dr. and Barton St. (Regional Storm) (< 0.5 m +/-)	Scouring of channel banks caused by backing up during high flows.	Historically straightened. Road culvert (7-8m wide) at downstream end. Not considered to be a restriction to flows (backing up is from CN Railway culvert downstream)	None identified.
SC-4	Queenston Rd. crossing hydraulic capacity – Regional Storm flood levels impacted for 200 m upstream of road. Development encroachment within floodplain and creek is completely within private property.	• Regional Storm flooding of residential yards along east side of creek (< 0.5 m) • Flooding of rear lots < 1.5 m for storm events less than a 100 year along west side of creek. • Flooding occurs mostly beyond backwater affect of Queenston Rd.	Channel entrenchment and confinement causing erosion to top of bank. Valley wall contact on west bank. Contains Priority Erosion Site MS2*	Pedestrian bridge mid-reach. Sewer runs on west bank then east bank crossing the creek mid-reach.	Private backyard Sanitary sewer crossing and maintenance hole downstream of pedestrian bridge
SC-5			Bank erosion undermining existing protection. Valley wall contact mid-reach at Donn Avenue causing slope instability Contains 3 Priority Erosion Site (ES9, ES13 & 14)*.	Failing existing bank protection in upstream section of reach. Development up to top of bank on in upstream section and mid-reach.	Private property at upstream and mid-reach sections.
SC-6	Development is encroached with the floodplain. Residential rear yards form part of the creek block.	• Flooding occurs at most storm frequencies. Regional Storm flood depths in the range of 0.3 +/- • Creek has a capacity of a 2 to 5 yr. storm flow capacity	Highly constrained channel due to urban development. Bank erosion undermining existing channel protection Contains 4 Priority Erosion Sites (ES15,16,18,19)*	Historical straightening Development to top of bank throughout the reach completely disconnecting the floodplain. Ad-hoc landowner bank protection.	Private backyards. Parking lot in upstream section.
SC-7	King St. culvert has a localized Regional Storm backwater effect of 1 m +/- for 100 mm +/-	• Rear yard flooding for most storm events, < 1.5 m, but lateral extent of flooding is limited due to slope of watercourse valley and rear yard grading.	Highly constrained channel due to urban development. Localized bank erosion Contains 4 Priority Erosion Sites (ES20-23)*	Development to top of bank throughout the reach completely disconnecting the floodplain. Ad-hoc landowner bank protection.	Parking lot in upstream section. Private backyards.

* Priority Erosion Sites identified in Watercourse Erosion Restoration Implementation Plan (City of Hamilton 2010)

Table 5.2.2. Priority Erosion Sites Identified in the City of Hamilton's' Watercourse Erosion Restoration Implementation Plan

Rank (of 30)	Erosion Site	Water-course	Reach	Relevant reach for this study	Risk	Conceptual Design	Benefit
5	MS 2	Stoney Creek	ST 3	SC-4	-Sanitary access chamber	-Realign channel to increase distance from access chamber -Repair and encase infrastructure as necessary -Build riffle over sanitary lateral	-Reduction in risk to access chamber and sanitary sewer -Aquatic habitat
7	ES 3	Battlefield Creek	BTF 2	BC-2	-Queenston Road Sanitary sewer -Exposed storm sewer outfalls	-Realign channel to a more sinuous form and reinstate floodplain access -Encase sanitary sewer at crossing and protect with riffle -Repair storm sewer outfalls and incorporate energy dissipation prior to confluence with channel	-Reduction in risk to Queenston Road and sanitary access chamber
9	ES 13-16	Stoney Creek	ST 6	SC-5 / SC-6	-Private property (yards and structures)	-Replace infrastructure in disrepair with toe protection, fascines, and vegetative cover	-Reduction in risk to private property
11	ES 9	Stoney Creek	ST 5	SC-5	-Private property	-Realign channel to a more sinuous form away from private property and reinstate floodplain access -Assess cover over sanitary sewer and provide protection as required	-Reduction in risk to private property -Reconnection to floodplain
15	ES 18-21	Stoney Creek	ST 7	SC-6 / SC-7	-Parking lot -Driveway -Private property -Buildings/structure	-Replace infrastructure in disrepair with toe protection, fascines, and vegetative cover	-Reduction in risk to private property, buildings, and parking lot
19	ES 6-7	Battlefield Creek	BTF 4	BC-4[1]	-Storm sewer outfall -Private driveway	-Minor adjustment of channel planform away from private property -Repair storm sewer outfall and provide energy dissipation	-Reduction in risk to private property -Aquatic habitat
29	ES 22-23	Stoney Creek	ST 8	SC-7	-Private property -Parking lot	-Remove existing bank protection that is in disrepair -Refill/regrade bank and vegetate to stabilize -Apply bioengineering and vegetation treatments to top of bank as property ownership allows	-Protection of private property -Aquatic habitat

1. Ref. Battlefield Park Re-development, AMEC, March 2011

5.2.3. Short-Listed Flood and Erosion Management Alternative Assessment Summary

Based on the evaluation of the suitability and effectiveness of the various alternatives, the next phase of assessment for the flood and erosion alternatives has been conducted using the evaluation criteria previously established. The detailed assessment has been provided in Appendix K and summarized within Table 5.2.3.

Table 5.2.3. Short-Listed Flood and Erosion Management Alternative Assessment Summary

		Flood Management Alternatives					Erosion Management Alternatives			
Reach	Do Nothing	Alt. 1 Culvert Bridge Upgrades	Alt. 2 Floodplain/ Channel Improvement	Alt 3 Roadway Profile Modifications	Alt. 4 Flood-Proofing Bldgs.	Alt. 8 Combinations	Do Nothing	Alternative A1 – Localized Protection from Erosion Energy of Flows	Alternative A2- Stabilize Bank or Slope	Alternative A4 – Reach-scale Re-meandering/Floodplain Connection
SC-1	SC	CF	SC	SC	CF	PPA	PPA	SC	SC	SC
SC-2	SC	SC	SC	NA	PPA	SC	PPA	SC	SC	SC / LM
SC-3	SC	SC	SC	SC	PPA	SC	PPA	SC	SC	SC
SC-4	SC	SC	SC	SC	PPA	SC	SC	PPA	PPA	SC
SC-5	SC	SC	SC	SC	PPA	SC	SC	PPA	PPA	SC
SC-6	SC	SC	SC	SC	PPA	SC	CF	PPA	SC	SC / LM
SC-7	SC	SC	SC	SC	PPA	SC	CF	PPA	SC	SC / LM
BC-1	SC	SC	SC	NA	PPA	SC	PPA	SC	SC	SC / LM
BC-2	SC	SC	SC	SC	PPA	SC	SC	PPA	PPA	PPA
BC-3	SC	SC	SC	SC	PPA	SC	SC	PPA	PPA	PPA
BC-4	SC	SC	SC	SC	PPA	SC	SC	PPA	PPA	SC / LM
BC-5	SC	SC	SC	SC	PPA	SC	SC	PPA	PPA	SC / LM

NA – Not Applicable
SC - Screened from Further Consideration
CF - Carried Forward
PPA - Preliminary Preferred Alternative
LM - Consideration for Land Management Practice (Medium and Long Term)

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6. DETAILED ASSESSMENT OF SHORT-LISTED ALTERNATIVES

The assessment of short-listed flood and erosion management alternatives has been conducted on a reach-by reach basis with consideration to the overall watershed scale. Integration of the assessment of flood and erosion management alternatives has been conducted with consideration of each technical environmental discipline.

6.1. Stoney Creek SC-1

6.1.1. Flood Management Alternatives

Reach SC-1 incurs flooding on primarily the west bank for only the Regional Storm Hurricane Hazel (Regulatory Event) with the 100 year event contained to the existing valley system. At the south end of the reach, the CNR Rail crossing overtops and spills to Lake Avenue under the Regulatory Event.

Culvert/ Bridge Upgrades

The CNR Rail crossing has a significant impact on upstream hydraulics within reach SC-1. The existing crossing is a 4.6 m by 3.5 m arch which produces a 5 m +/- backwater effect during the Regulatory Storm and overtops the tracks and spills to Lake Avenue North. Increasing the flow area of the crossing from 16.1 m^2 to approximately 42 m^2 would eliminate Regulatory Storm flooding of the industrial lands upstream and reduce the spill potential to Lake Avenue North. Preliminary capital costs for crossing improvements would be approximately $1.2 to $1.5 million.

Terrestrial impacts of improvements to the CNR Rail crossing would include temporary disturbance to locally common wildlife due to construction and minimal vegetation impacts to existing community, with opportunities for mitigation and/or enhancement plantings to compensate.

Floodplain/ Channel Improvements

Reach SC-1 has a well defined valley system with the Regulatory floodplain located mostly below the top of valley and with limited impacts on existing development. The well defined valley system does not inherently require floodplain or channel improvements, as the valley system provides adequate flow conveyance capacity up to the 100 year storm, with flooding during the Regulatory Event, primarily on the west bank. As such no floodplain/ channel improvements have been recommended for the purpose of flow capacity improvements for this reach.

Although floodplain and channel improvements are not required for flood control, there may be opportunities for terrestrial habitat improvements within this reach, as possible compensation for vegetation removals elsewhere on the project.

Roadway Profile Modifications

Reach SC-1 is upstream of the QEW, therefore adjusting the QEW profile to reduce upstream Regional Storm (Hurricane Hazel) flood elevations would entail lowering the QEW and increasing the Regional Storm flood depth on the highway, as such this alternative has not been considered any further.

If implemented, the terrestrial impacts of roadway profile modifications would include temporary disturbance to locally common wildlife and minimal vegetation impacts to existing community, with opportunities for mitigation and/or enhancement plantings to compensate.

Flood Proofing Buildings

Flood proofing buildings through flood berms or flood walls can be implemented when flooding depths are not significant and/or the objective is to increase the level of flood protection. For Reach SC-1 flooding of an industrial property on the west bank occurs only during the Regional Storm (Hurricane Hazel). Flood depths for the flood proofing would be approximately 0.5 to 1.0 m. Preliminary cost estimates for a flood protection berm would be approximately $140,000 to $180,000. This alternative has been carried forward.

The construction of flood berms or flood walls would have terrestrial impacts including temporary disturbance to locally common wildlife and minimal vegetation impacts to existing vegetation communities, with opportunities for mitigation and/or enhancement plantings to compensate.

Combinations

A combined alternative of the CNR culvert upgrades and flood protection berm could be implemented for Reach SC-1. This alternative would have minimal terrestrial impacts, with opportunities for mitigation and/or enhancement plantings to compensate for vegetation removals.

6.1.2. Erosion Management Alternatives

No infrastructure or property is identified to be at risk of erosion and very low flow velocities prevail on this reach. Potential opportunities for enhancement are limited, as the reach retains a meandering planform and a backwater effect occurs upstream of Lake Ontario limiting flow velocities.

Urban debris management may be considered, although the benefits of large woody debris need to be fully recognized. From a fisheries habitat perspective, any potential debris management efforts should differentiate between garbage and excess floating and high profile debris that should be removed, and the natural attached low-profile debris that will provide fish habitat structure without creating debris jams.

Although floodplain and channel improvements are not required for erosion control, there may be opportunities for terrestrial habitat improvement within this reach, as possible compensation for vegetation removals elsewhere on the project.

6.2. Stoney Creek SC-2

6.2.1. Flood Management Alternatives

Reach SC-2 incurs minimal Regulatory Storm flooding on only the west side of the valley feature, with limited Regulatory Storm flooding of one property. The 100 year storm event is contained to the existing valley system. The reach hydraulics are impacted by the backwater from the existing CNR rail crossing located within Reach SC-1. Industrial lands are flooded by the Regional Storm (Hurricane Hazel) flooding and a potential spill to Lake Avenue North, also occurs during the Regulatory Storm event.

Culvert/ Bridge Upgrades

The CNR Rail crossing within SC-1 has a significant impact on reach SC-2. The existing crossing produces a 5 m +/- backwater affect during the Regional Storm and floods both the east and west land located outside the valley. As-such the short-listed alternative to upgrade the CNR Rail crossing within SC-1 would also reduce the flooding potential within SC-2.

Most of the terrestrial impacts due to improvements to the CNR Rail crossing would be incurred within reach SC-1.

Floodplain/ Channel Improvements

Reach SC-2 has a well defined valley system with the flow conveyance capacity of storm events slightly above the 100 year storm. The valley system would require significant grading to realize a limited benefit to existing flood elevations. As such no floodplain/ channel improvements have been recommended for the purpose of flow capacity improvements for this reach.

Although floodplain and channel improvements are not required for flood control, there may be opportunities for terrestrial habitat improvement within this reach, as possible compensation for vegetation removals elsewhere on the project.

Roadway Profile Modifications

Reach SC-2 does not have any road crossings, therefore this alternative does not apply.

Flood Proofing Buildings

Flood proofing buildings and/or property through flood berms or flood walls would be feasible within Reach SC-2 due to the limited extent of the Regional Storm Hurricane Hazel flooding and only one property being involved.

If implemented, the construction of flood berms or flood walls would have limited terrestrial impacts due to the flood protection being located at the edge of the top of the valley slope. Impacts may include temporary disturbance to locally common wildlife and minimal vegetation impacts to existing community, with opportunities for mitigation and/or enhancement plantings to compensate for any potential loss.

Combinations

A combined alternative of culvert upgrades and flood proofing has not been considered based on those alternatives being screened from further consideration for this reach.

6.2.2. Erosion Management Alternatives

No infrastructure or property is identified to be at risk of erosion and low flow velocities and fine sediment deposition currently prevail. Several debris dams are causing upstream impoundment of flows, comprising both natural large woody debris and urban debris (e.g. tires). The CNR culvert upgrade being considered to reduce flooding would result in slightly higher flow velocities within this reach during frequent flood events and reduce the level of impoundment up to Barton Street during high flow events. Increased velocities and reduced impoundment may help to reduce aggradation currently occurring in the reach. However, the impact is also dependant on how debris is managed, since this currently has a strong influence on flow conditions and geomorphic processes.

The reach has historically been straightened and there is some opportunity in the medium-term for re-meandering / improved floodplain connectivity. However, this would only potentially benefit this reach and the downstream reach in terms of reduction of flow velocities, which are already low as a result of the impoundments. Works could also be integrated with stormwater quality retrofit plans for the area. From a fisheries perspective, localized realignment to re-introduce a more natural, meandering planform (where the channel has historically been straightened) will diversify and naturalize fish habitats, potentially increasing fish community diversity and providing more spawning and nursery habitats for migratory fishes. A potential exists to enhance baseflow where more permeable sediments are encountered.

Urban debris and tree management may be considered, although the benefits of large woody debris need to be fully recognized. From a fisheries habitat perspective, any potential debris management efforts should differentiate between garbage and excess floating and high profile debris that should be removed, and the natural attached low-profile debris that will provide fish habitat structure without creating debris jams.

Although floodplain and channel improvements may not be required for erosion control, there may be opportunities for terrestrial habitat improvement within this reach, as possible compensation for vegetation removals elsewhere on the project.

6.3. Stoney Creek SC-3

6.3.1. Flood Management Alternatives

Reach SC-3 consists of Stoney Creek from the downstream limit of Barton Street East to the confluence with Battlefield Creek, located immediately upstream of Barton Street. Flooding occurs within this reach only during Regional Storm conditions on either side of the valley system. There are approximately 6 homes on the east side of the valley and 4 homes on the west side of the valley that are located within the Regulatory Flood limits, with the rear yards only within the flood limits.

Culvert/ Bridge Upgrades

Barton Street is located at the downstream end of the reach. The Barton Street crossing would require significant upgrades to result in any meaningful reduction in the Regulatory Flood elevations within this reach and eliminate flooding in the rear yards. Culvert upgrades would be considered uneconomical to eliminate the low flood risk to private property within this reach.

If implemented however, terrestrial corridor improvements (to the Barton Street crossing) could include temporary disturbance to locally common wildlife and minor impacts to the moderate constraint wetland/woodland complex in this area, with opportunities for mitigation and/or enhancement plantings to compensate. Benefits would also arise from improved passage opportunities.

Floodplain/ Channel Improvements

Reach SC-3 has a well defined valley system with a flow conveyance capacity of slightly above the 100 year flood. The valley system would require significant grading to offer any further benefit to existing flood elevations. As such no floodplain/ channel improvements have been recommended to improve conveyance capacity for this reach.

Although floodplain and channel improvements may not be required for flood control, there may be opportunities for terrestrial habitat improvements within this reach, as possible compensation for vegetation removals elsewhere on the project.

Roadway Profile Modifications

Barton Street is overtopped only during the Regulatory Flood, therefore a lowering of the road profile to reduce upstream Regulatory flood elevations, would increase flood depths on Barton Street.

If implemented, terrestrial habitat of roadway profile modification to Barton Street would include temporary disturbance to locally common wildlife and minimal impacts to the moderate constraint wetland/woodland complex in this area, with opportunities for mitigation and/or enhancement plantings to compensate.

Flood Proofing Buildings

Flood proofing buildings through flood berms or flood walls would be feasible within Reach SC-3 as the extent of Regional Storm flooding is limited. This alternative has been carried forward.

The construction of flood berms or flood walls would have impacts on terrestrial habitat including temporary disturbance to locally common wildlife and minimal vegetation impacts to the moderate constraint wetland/woodland complex in this area, with opportunities for mitigation and/or enhancement plantings to compensate.

Combinations

A combined alternative of culvert upgrades and flood proofing has not been considered based on culvert upgrades being screened from further consideration for this reach.

6.3.2. Erosion Management Alternatives

No infrastructure or property is identified to be at risk of erosion. This is a very short reach between the confluence and Barton Street culvert with limited opportunity for significant enhancement. Localized enhancement in the medium-term may include creation of a low flow channel or pool features for fisheries benefit. Pool features may promote and maintain groundwater discharge given the expected proximity of the water table to ground surface.

Although floodplain and channel improvements may not be required for erosion control, there may be opportunities for terrestrial habitat improvement within this reach, as possible compensation for vegetation removals elsewhere on the project.

6.4. Stoney Creek SC-4

6.4.1. Flood Management Alternatives

Reach SC-4 is a significant valley feature that contains the Regional Storm apart from a short section on the east bank where two homes would incur rear yard flooding. The 100 year storm event is contained to the existing valley system.

Culvert/ Bridge Upgrades

Barton Street has an impact on the Regulatory Flood levels within this reach; therefore as the upgrade to the Barton Street culvert have been screened for Reach SC-3, culvert upgrades for Reach SC-4 have also been screened from further consideration, as local upgrades would be rendered ineffective.

If implemented, most of the impacts on terrestrial habitat related to improvements to the Barton Street crossing would be incurred within reach SC-3.

Floodplain/ Channel Improvements

As Reach SC-4 has a well defined valley system, grading improvements to reduce flood elevations have been screened from further consideration.

If implemented, any floodplain or channel improvements within reach SC-4 would have a moderate impact on the high constraint floodplain forest and temporary loss of habitat for locally common wildlife.

Roadway Profile Modifications

Reach SC-4 does not have any road crossings, therefore this alternative does not apply.

Flood Proofing Buildings

Flood proofing buildings through flood berms or flood walls would be feasible within Reach SC-4 due to the limited extent of Regional Storm flooding related to two to three rear yards.

The construction of flood berms or flood walls would have impacts on terrestrial habitat including temporary disturbance to locally common wildlife and minimal vegetation impacts to the high constraint floodplain forest, with limited opportunities for mitigation and/or enhancement plantings to compensate.

Combinations

A combined alternative of culvert upgrades and flood proofing has not been considered based on the culvert upgrades being screened from further consideration for this reach.

6.4.2. Erosion Management Alternatives

Toe erosion is currently occurring on the west bank adjacent to an area of valley wall contact adjacent to the end of Honeywell Drive. The channel has a meandering planform and erosion is occurring at the outside of the meander bend. Localized protection in the form of bioengineering (such as vegetated stone) combined with bank regrading could be used to protect the stability of the valley side (and the property located at the top of the valley wall). Care must be taken to ensure that tie-ins to the natural bank do not create discontinuity which would likely cause erosion at adjacent sections. In order to implement the bank regrading, it may be necessary to utilize some private land to achieve an appropriate slope gradient for which landowner assent would need to be sought. It is noted that while this alternative addresses immediate erosion issues that are threatening the watercourse, it does not preclude the necessity for additional works in the future. A preferable approach would be the management of land at the top of west bank and creation of a stream corridor incorporating appropriate setbacks.

A sanitary sewer crossing and maintenance hole downstream of the pedestrian bridge is also at risk of erosion. Localized realignment would help to increase the distance of the creek from the infrastructure is feasible at this location. Localized protection could subsequently be used to protect the maintenance hole and sewer crossing. The latter could be protected using a riffle structure, which may also enhance physical habitat conditions.

In addition to infrastructure at erosion risk, this reach contains the Water Survey of Canada flow monitoring station. Due to continual changes in bed profile, it has become impractical to accurately measure flow at this location. As indicated by findings of the

Rapid Geomorphic Assessment, the dominant processes within reaches of Stoney and Battlefield Creeks is widening and aggradation, as the channel responds to stormwater flows and most of the reaches are considered to be "Transitional or Stressed". The only reaches considered to be "In Regime" are reaches SC-R3 (which is subject to backwater effects from Barton Street culvert) and SC-R7, which is still experiencing some aggradation and widening (see Table 6.4.1). It is therefore difficult to recommend a suitable location that would not be impacted by some level of channel adjustment. Through localized intervention, it may be possible to prevent bed level changes at the weir but this may also result on impacts on geomorphological processes, as the channel adjusts and is in conflict with the long-term vision of re-naturalisation.

Table 6.4.1: RGA Scores for Reaches "In Regime" along Stoney Creek

Reach	Factor Value				Stability Index	Condition
	Aggradation	Degradation	Widening	Planimetric adjustment		
SC-R3	0.14	0.00	0.22	0.00	0.09	In Regime
SC-R7	0.29	0.00	0.40	0.00	0.17	In Regime

Re-meandering to re-introduce a more natural, meandering planform, where the channel has historically been straightened (in the downstream section of this reach), would diversify and naturalize fish habitats, potentially increasing fish community diversity and providing more spawning and nursery habitats for migratory fishes. A potential exists to enhance baseflow where more permeable sediments are encountered.

Floodplain and channel improvements for erosion control would have terrestrial impacts including temporary loss of habitat for locally common wildlife and moderate vegetation impacts to the high constraint floodplain forest, with limited opportunities for mitigation and/or enhancement plantings to compensate.

6.5. Stoney Creek SC-5

6.5.1. Flood Management Alternatives

Reach SC-5 located from Queenston Road (Former Highway No. 8) to Collegiate Avenue is a transition reach between the well defined valley system, with development located primarily out of the valley, to a lesser defined valley feature that has development encroaching upon its limits.

Culvert/ Bridge Upgrades

This reach incurs flooding primarily during the Regional Storm with either rear yard or side yard flooding. There are two homes at the south end of the reach within the Regulatory floodplain. Upgrades to the Queenston Road culvert at the north end of the reach would not address the flooding of the two homes at the reach's south end. Based on rear yards flooding only during the Regional Storm, and the 100 year event only impacting one house at the south end of the reach, culvert improvements are not considered cost effective in reducing the minor flood risk within the reach; as such culvert upgrades have been screened from further consideration.

If implemented, upgrades to the Queenston Road culvert would have impacts on terrestrial systems including temporary disturbance to locally common wildlife and minimal vegetation impacts to a low constraint community, with opportunities for mitigation and/or enhancement plantings to compensate.

Floodplain/ Channel Improvements

Floodplain/ channel improvements on this encroached valley system would have a limited benefit to the flood risk for this reach. The valley walls in part consist of rear yards, while the valley floor is flat. There is a possibility that creek alignment modifications may be advanced for this reach, however this would not effectively increase the flow conveyance of the creek reach.

If implemented, floodplain and channel improvements for flood control would cause temporary loss of habitat for locally common wildlife and moderate impacts to the low constraint vegetation communities within Reach SC-5, with opportunities for mitigation and/or enhancement plantings to compensate.

Roadway Profile Modifications

Queenston Road is overtopped during the Regional Storm event only and the 4.60m by 2.10m concrete box culvert effectively conveys the 100 year flood, therefore the flood risk is considered minimal and the creek crossing meets Provincial requirements.

If implemented, the impacts of roadway profile modification of Queenston Road on the terrestrial system would include temporary disturbance to locally common wildlife, minimal impacts to the low constraint vegetation communities within Reach SC-5, and opportunities for mitigation and/or enhancement plantings to compensate.

Flood Proofing Buildings

As most of the flooding during the Regulatory Storm event would be rear and side yards, there is a possibility of using localized flood proofing. To be effective in this reach, flood proofing would have to occur on private property, which will require input and approval from the local residents.

The construction of flood berms or flood walls would have impacts on terrestrial systems including temporary disturbance to locally common wildlife and minimal vegetation impacts to the low constraint vegetation communities within Reach SC-5, with opportunities for mitigation and/or enhancement plantings to compensate.

Combinations

A combined alternative of culvert upgrades and flood proofing has not been considered based on the culvert upgrades being screened from further consideration for this reach.

6.5.2. Erosion Management Alternatives

Property at the top of the valley wall on the east bank along Donn Avenue is currently at risk due to toe erosion and potential slope instability (ref. Priority Erosion Site ES9). Localized realignment could be used to maintain a sinuous planform while increasing the distance between the creek and the valley wall. Improvement of floodplain connectivity as part of the works may also help to reduce erosive energy at this location. Localized bed protection would be required over the sanitary sewer crossing and could take the form of a riffle feature. Regrading could be used to stabilize the existing slope. From a fisheries perspective, localized realignment to re-introduce a more natural, meandering planform, where the channel has historically been straightened, will diversify and naturalize fish habitats, potentially increasing fish community diversity and providing more spawning and nursery habitats for migratory fishes. A potential exists to enhance baseflow where more permeable sediments are encountered.

Existing bank protection further upstream along this reach is also failing with properties at risk of erosion (ref. Priority Erosion Sites ES13 and 14). Replacement of the existing bank protection with bioengineering solutions could help to improve riparian conditions, as well as providing erosion control. Instream habitat structure to enhance fish habitat may also be incorporated into any bank protection works. It is noted that while this alternative addresses immediate erosion issues that are threatening the watercourse, it does not preclude the necessity for additional works in the future. A longer term preferable approach would be the management of land at the top of the west bank and creation of a stream corridor incorporating appropriate setbacks.

Floodplain and channel improvements for erosion control would cause temporary loss of habitat for locally common wildlife with moderate terrestrial impacts to the low constraint vegetation communities within Reach SC-5, and opportunities for mitigation and/or enhancement plantings to compensate.

6.6. Stoney Creek SC-6

6.6.1. Flood Management Alternatives

Collegiate Avenue to King Street West is considered to be the Stoney Creek reach with the highest flood risk, as flooding would occur above the creek banks for a 10 year storm event and greater. The valley system is not well defined for this reach and the creek is located entirely within private property, with rear yards backing on to the creek. Encroachment of development within the Regulatory floodplain is the leading reason for private property being at a high flood risk.

Culvert/ Bridge Upgrades

Collegiate Avenue has a 7.30m by 1.43m concrete box culvert that results in storms greater than a 25 year frequency overtopping with a flood depth and velocity above Provincial requirements. The Jones Road culvert crossing is a 7.33m by 1.41m concrete box culvert that results in storms greater than a 10 year frequency overtopping the roadway. The culvert span and rise for both crossings have been maximized based on the creek block width and the local road profile, therefore effective upgrades to the culverts would not be considered possible. The culvert crossings are not the main flooding mechanism for Reach SC-6 and as such culvert upgrades have been screened from further consideration.

Floodplain/ Channel Improvements

Floodplain/ channel improvements on an encroached valley system would have limited to no impact on reducing the flood risk for this reach. The creek system consists of a straightened and partially lined system within rear yards. There is a possibility that creek works such as bank stabilization may occur for this reach, however that would not increase the flow conveyance of the creek reach.

Bank stabilization would cause temporary loss of habitat for locally common wildlife and have a moderate impact to the low constraint vegetation community within Reach SC-6, including significant loss of tree cover on private property, with very limited opportunities for mitigation and/or enhancement plantings to compensate.

Roadway Profile Modifications

Collegiate Avenue and the Jones Road crossings are flooded for storm events greater than 25 year and 10 year frequencies respectively. Reducing upstream flood depths would require increasing flood depths on both crossings which would not be considered feasible.

Flood Proofing Buildings

Flooding occurs on private property for relatively high frequency storm events such as the 10 year storm and above. Isolated reaches of the creek would be appropriate for flood proofing of buildings based on the Regulatory Storm floodline being located close to back of the rear yards.

The construction of flood berms or flood walls would have terrestrial impacts including temporary disturbance to locally common wildlife and minimal vegetation impacts to the low constraint vegetation communities within Reach SC-6, with very limited opportunities for mitigation and/or enhancement plantings to compensate.

Combinations

A combined alternative of culvert upgrades and flood proofing has not been considered based on the culvert upgrades being screened from further consideration for this reach.

6.6.2. Erosion Management Alternatives

The reach is almost completely confined by urban development. Existing bank protection adjacent to residential properties has been improvised and is being undermined by the creek. Due to the degree of confinement, it is not considered possible to realign the creek away from properties at risk. Existing bank protection could be replaced with a more appropriate formalized bioengineering solution in order to protect private property, while also improving riparian conditions. By providing more continuous bank materials, this approach may help to reduce bank instability. A bioengineered solution for bank protection may also contribute instream habitat structure, enhancing fish habitat to some degree. It is noted that while this alternative addresses immediate erosion issues that are threatening the watercourse, it does not preclude the necessity for additional works in the future. A preferable approach would be the management of land at the top of west bank and creation of a stream corridor incorporating appropriate setbacks.

The creation of deep pools may provide low-flow refugia for fish. Pool features may promote and maintain groundwater discharge given the expected proximity of the water table to ground surface.

Channel bank protection for erosion control would cause temporary loss of habitat for locally common wildlife and have moderate terrestrial impacts to the low constraint vegetation communities within Reach SC-6, with very limited opportunities for mitigation and/or enhancement plantings to compensate.

6.7. Stoney Creek SC-7

6.7.1. Flood Management Alternatives

King Street West to the base of Niagara Escarpment is considered to be a steep reach and although existing development encroaches on the creek, flooding of private property by the Regional Storm is not as extensive as Reach SC-6. Flooding on private property though does occur frequently as the creek is located within private property. That said, encroachment of development within the Regulatory floodplain is the leading reason for private property being at risk.

Culvert/ Bridge Upgrades

King Street has a 5.88 m by 2.56 m concrete box culvert concrete box culvert that results in only Regional Storm (Hurricane Hazel) overtopping the road, with a flood depth and velocity within Provincial requirements. The culvert span and rise has been maximized based on the available creek block width and the road profile, therefore upgrades to the culvert would not be considered possible and culvert upgrades have been screened from further consideration.

If implemented, upgrades to the King Street culvert would have terrestrial impacts including temporary disturbance to locally common wildlife, minimal vegetation impacts to the low constraint community within Reach SC-7, and limited opportunities for mitigation and/or enhancement plantings to compensate.

Floodplain/ channel Improvements

Floodplain/ channel improvements would not be possible based on the narrow creek block and the existing development encroaching on either side of the creek.

If implemented, floodplain and channel improvements would cause temporary loss of habitat for locally common wildlife, moderate terrestrial impacts to the low constraint vegetation community within Reach SC-7, and limited opportunities for mitigation and/or enhancement plantings to compensate.

Roadway Profile Modifications

King Street is overtopped only during the Regional Storm. Increasing the Regional Storm overtopping depth above the existing 1.4m would not be considered feasible.

If implemented, roadway profile modifications to King Street would cause temporary disturbance to locally common wildlife, minimal impacts to the low constraint vegetation community within Reach SC-7, and limited opportunities for mitigation and/or enhancement plantings to compensate.

Flood Proofing Buildings

As the creek is located within private property, flooding of private property occurs for relatively frequent events such as the 10 year storm and above. Isolated reaches of the creek would be appropriate for flood proofing of buildings based on the Regulatory floodline being located close to back of the rear yards.

The construction of flood berms or flood walls would have terrestrial impacts including temporary disturbance to locally common wildlife and minimal vegetation impacts to the low constraint vegetation communities within Reach SC-7, with limited opportunities for mitigation and/or enhancement plantings to compensate.

6.7.2. Erosion Management Alternatives

As for Reach SC-6, this reach is almost completely confined by urban development. Existing bank protection adjacent to residential properties is ad-hoc and is being undermined by the creek. Due to the degree of confinement, it is not considered possible to realign the creek away from properties at risk. Regrading of channel banks would reduce rear yards space. Existing bank protection could be replaced with a more appropriate formalized bioengineering solution in order to protect private property, while also improving riparian conditions. It is noted that while this alternative addresses immediate erosion issues that are threatening the watercourse, it does not preclude the necessity for additional works in the future. A preferable approach (long-term) would be the management of land at the top of west bank and creation of a stream corridor incorporating appropriate setbacks.

Channel bank protection for erosion control would cause temporary loss of habitat for locally common wildlife and moderate terrestrial impacts to the low constraint vegetation communities within Reach SC-7, with limited opportunities for mitigation and/or enhancement plantings to compensate.

6.8. Battlefield Creek BC-1

6.8.1. Flood Management Alternatives

Reach BC-1 is a significant valley feature that contains the Regional Storm (Hurricane Hazel). As rear yards have been placed within the valley feature, rear yard flooding occurs at homes east of Lake Avenue North and front and rear yard flooding occurs at homes at the base of Huckleberry Drive. The 100 year flood is contained to the existing valley system.

Culvert/ Bridge Upgrades

No culverts or bridges exist within this reach.

Floodplain/ Channel Improvements

As Reach BC-1 has a well defined valley system, grading improvements to reduce flood elevations have been screened from further consideration.

Although floodplain and channel improvements are not required for flood control, there may be opportunities for terrestrial habitat improvement within this reach, as possible compensation for vegetation removals elsewhere on the project.

Roadway Profile Modifications

Reach BC-1 does not have any road crossings; therefore this alternative does not apply.

Flood Proofing Buildings

Flood proofing buildings through flood berms or flood walls would be feasible within Reach BC-4 due to the limited extent of the Regional Storm (Hurricane Hazel) flooding.

The construction of flood berms or flood walls would have terrestrial impacts including temporary disturbance to locally common wildlife, minimal vegetation impacts to the moderate constraint wetland/woodland complex within Reach BC-1, and opportunities for mitigation and/or enhancement plantings to compensate.

Combinations

A combined alternative of culvert upgrades and flood proofing has not been considered based on the culvert upgrades being screened from further consideration for this reach.

6.8.2. Erosion Management Alternatives

No infrastructure or property is identified to be at risk of erosion. The reach upstream of the confluence with Stoney Creek has previously been straightened. There is opportunity to enhance the reach as a medium-term alternative through re-meandering and floodplain reconnection. This would contribute to the reduction of erosive energy during bankfull conditions, and improve fish habitat for resident and migratory fishes that utilize this portion of Battlefield Creek. A potential exists to enhance baseflow where more permeable sediments are encountered. Re-meandering could also be integrated with the provision of the new multi-use recreational trail that it is identified through Reaches BC-1 and BC-2 as part of the Hamilton Recreational Master Plan.

Floodplain and channel improvements for erosion control would cause temporary loss of habitat for locally common wildlife, moderate terrestrial impacts to the moderate constraint wetland/woodland complex within Reach BC-1, and opportunities for mitigation and/or enhancement plantings to compensate.

6.9. Battlefield Creek BC-2

6.9.1. Flood Management Alternatives

Reach BC-2 as per Reach BC-1 also has a significant valley feature that fully contains the Regional Storm. There are two homes that are located immediately upstream of Lake Avenue North that are within the 100 year storm floodplain, one house with a side yard at the same location and a walkway area around a parking structure for a high rise apartment located within the Regulatory floodplain at the north end of Lake Avenue North, therefore the overall flood risk in this reach is not considered significant.

Culvert/ Bridge Upgrades

Lake Avenue North is located at the downstream limit of the reach and has a twin 2.0 m by 1.5 m concrete box culvert that results in both the 100 year and Regional Storm overtopping the road. Flood depths and velocities on Lake Avenue North are within Provincial requirements, therefore culvert upgrades have not been considered further.

If implemented, upgrades to the Lake Avenue North culvert would cause temporary disturbance to locally common wildlife and minimal terrestrial habitat impacts to the moderate constraint vegetation communities of Reach BC-2, with opportunities for mitigation and/or enhancement plantings to compensate.

Floodplain/ channel Improvements

As Reach BC-2 has a well defined valley system, grading improvements to reduce flood elevations have been screened from further consideration.

Although floodplain and channel improvements are not required for flood control, there may be opportunities for terrestrial habitat improvement within this reach, as possible compensation for vegetation removals elsewhere on the project.

Roadway Profile Modifications

Reach BC-2's only road crossing is Lake Avenue North, which floods during the 100 year storm and Regional Storm event. The two homes located on the upstream side of Lake Avenue that flood during the 100 year storm event would not be removed from flooding during a significant storm event due to encroachment. Lowering the existing road profile would increase flooding depths and frequency over the roadway and would not alleviate flooding of the two homes previously mentioned.

If implemented, roadway profile modifications to Lake Avenue North may cause temporary disturbance to locally common wildlife and minimal impacts to the moderate constraint vegetation communities of Reach BC-2, with opportunities for mitigation and/or enhancement plantings to compensate.

Flood Proofing Buildings

Flood proofing buildings through flood berms or flood walls would be feasible within Reach BC-2 due to the limited extent of the Regional Storm flooding. The apartment building grounds and the one side yard within the Regulatory floodplain could be protected.

The construction of flood berms or flood walls would have terrestrial impacts including temporary disturbance to locally common wildlife, minimal vegetation impacts to the moderate constraint vegetation communities within Reach BC-2, and opportunities for mitigation and/or enhancement plantings to compensate.

Combinations

A combined alternative of culvert upgrades and flood proofing has not been considered based on the culvert upgrades being screened from further consideration for this reach.

6.9.2. Erosion Management Alternatives

Downstream of Queenston Road, several stormwater outfalls and a sanitary sewer are at risk of erosion (ref. Priority Erosion Site ES3). Localized protection of this infrastructure and Queenston Road could be achieved through realignment of the channel to a more sinuous form and reinstatement of floodplain access to reduce erosive energy during bankfull conditions. The sanitary sewer crossing could be protected using a riffle structure. Stormwater outfalls could be repaired to incorporate energy dissipation prior to discharge into the creek.

Toe erosion is currently occurring on the west bank adjacent to two areas of valley wall contact upstream of Lake Avenue. The channel is meandering in planform and realignment would involve shortening the length of the channel. It is therefore considered more preferable for localized protection and bank regrading to be used to protect the valley wall and provide for energy dispersal at this location using bioengineering, along the existing alignment. It is noted that while this alternative addresses immediate erosion issues that are threatening the watercourse, it does not preclude the necessity for additional works in the future. A preferable long-term approach would be the management of land at the top of west bank and creation of a stream corridor incorporating appropriate setbacks.

There is opportunity to enhance the reach in the medium-term through re-meandering and floodplain reconnection through Henry and Beatrice Warden Park. This would contribute to the reduction of erosive energy during bankfull conditions. Re-meandering could also be integrated with the provision of the new multi-use recreational trail that is identified through reaches BC-1 and BC-2, as part of the Hamilton Recreational Master Plan.

From a fisheries perspective, localized realignment to re-introduce a more natural, meandering planform, where the channel has historically been straightened, will diversify and naturalize fish habitats, potentially increasing fish community diversity and providing more spawning and nursery habitats for migratory fishes. The creation of deep pools, where possible, may provide low-flow refugia for fish, and nursery habitat for young-of-the-year white sucker. A potential exists to enhance baseflow where more permeable sediments are encountered and pool features may promote and maintain groundwater discharge given the expected proximity of the water table to ground surface.

Floodplain and channel improvements for erosion control would cause temporary loss of habitat for locally common wildlife, moderate terrestrial impacts to the moderate constraint vegetation communities within BC-2, and opportunities for mitigation and/or enhancement plantings to compensate.

6.10. Battlefield Creek BC-3

6.10.1. Flood Management Alternatives

Reach BC-3, located from Queenston Road (Former Highway No. 8) to Randall Avenue is a well defined valley system with development located mostly out of the valley. Development encroaches into the valley along Valley Drive.

Culvert/ Bridge Upgrades

The Queenston Road crossing is a 3.05m by 2.13m concrete box. The road crossing conveys the 100 year flood, but is overtopped by the Regional Storm. Flooding upstream of the crossing is limited primarily to the City of Hamilton Park area which would flood during most storm events and to a Hydro Station on the east side of the valley which would flood only during the Regulatory Event. Based on the relatively low risk of flooding on the roadway and immediately upstream, no culvert upgrades have been considered.

If implemented, upgrades to the Queenston Road culvert would cause temporary disturbance to locally common wildlife and minimal terrestrial impacts to a low constraint vegetation community, with opportunities for mitigation and/or enhancement plantings to compensate.

Floodplain/ Channel Improvements

Floodplain/ channel improvements on this reach would result in a limited reduction in flood risk. The valley sides are steep, while the valley floor is flat. There is a possibility that creek alignment improvements may occur for this reach, however this work would not increase the flow conveyance of the creek reach.

Although floodplain and channel improvements are not required for flood control, there may be opportunities for terrestrial habitat improvement within this reach, as possible compensation for vegetation removals elsewhere on the project.

Roadway Profile Modifications

Queenston Road is overtopped with a flood depth of 0.46 m only during the Regional Storm (Hurricane Hazel) and the 3.05m by 2.13m concrete box culvert conveys the 100 year storm, therefore the flood risk is minimal and the creek crossing meets provincial requirements.

If implemented, roadway profile modifications to Queenston Road would cause temporary disturbance to locally common wildlife and minimal impacts to the low constraint vegetation communities of Reach BC-3, with opportunities for mitigation and/or enhancement plantings to compensate.

Flood Proofing Buildings

There is a possibility of using localized flood proofing to the Hydro Station and to the rear yards of homes immediately upstream. One house at the south side of Valley Drive could be protected by localized flood protection.

The construction of flood berms or flood walls would have terrestrial impacts including temporary disturbance to locally common wildlife, minimal vegetation impacts to the low constraint vegetation communities within Reach BC-3, and opportunities for mitigation and/or enhancement plantings to compensate.

Combinations

A combined alternative of culvert upgrades and flood proofing has not been considered based on the culvert upgrades being screened from further consideration for this reach.

6.10.2. Erosion Management Alternatives

Toe erosion is currently occurring on the east bank adjacent to an area of valley wall contact near Avalon Avenue. The channel is meandering in planform and realignment is constrained by the location of a sewer and stormwater outfalls on the west bank. Localized protection and bank regrading could be used to protect the valley wall at this location using bioengineering. In order to implement the bank regrading, it may be necessary to utilize some private land to achieve an appropriate slope gradient for which landowner assent would need to be sought. Bank protection also provides an opportunity to incorporate instream habitat structure that could enhance local fish habitat. It is noted that while this alternative addresses immediate erosion issues that are threatening the watercourse, it does not preclude the necessity for additional works in the future. A preferable approach would be the management of land at the top of west bank and creation of a stream corridor appropriate incorporating setbacks.

Stormwater outfalls are at risk of erosion both mid-reach and upstream of Queenston Road. Stormwater outfalls could be protected and repaired to incorporate energy dissipation prior to discharge into the creek.

Existing bank protection is failing mid-reach adjacent to the most upstream baseball pitch. Replacement of this protection with bioengineering solution is planned for 2011 (ref. Dillon, 2010). There is opportunity to enhance the reach downstream of this point in the medium-term through re-meandering and floodplain reconnection through Greenacres Park. This would contribute to the reduction of erosive energy during bankfull conditions, as well as diversifying and naturalizing fish habitats, potentially increasing fish community diversity and providing more spawning and nursery habitats for migratory fishes. A potential exists to enhance baseflow where more permeable sediments are encountered.

Finally, Randall Road is at risk of erosion which could be managed through minor creek realignment and localized protection.

Floodplain and channel improvements for erosion control would cause temporary loss of habitat for locally common wildlife, moderate terrestrial impacts to the low constraint vegetation communities within Reach BC-3, and opportunities for mitigation and/or enhancement plantings to compensate.

6.11. Battlefield Creek BC-4

6.11.1. Flood Management Alternatives

Reach BC-4 located from Randall Avenue to the downstream side of King Street West is a transition reach between the well defined valley system, with development located primarily out of the valley, to a lesser defined valley feature that has development encroaching upon its limits.

Culvert/ Bridge Upgrades

There are two pedestrian crossings within this reach, both have little impact to the reach hydraulics and associated flood elevations, therefore no bridge upgrades have been recommended.

If implemented, upgrades to the pedestrian crossings would cause a very minimal terrestrial impact to a low constraint vegetation community, and opportunities for mitigation and/or enhancement plantings to compensate.

Floodplain/ Channel Improvements

The valley sides are either natural or consist of rear yards. The valley floor is quite flat. There is a possibility that creek alignment improvements may occur for this reach, however such work would not effectively increase the flow conveyance of the creek reach. Floodplain or channel improvements for the purpose of reducing flood risk have been screened from further consideration.

Although floodplain and channel improvements are not required for flood control, there may be limited opportunities for terrestrial habitat improvement within this reach, as possible compensation for vegetation removals elsewhere on the project.

Roadway Profile Modifications

No roadways exist within the reach therefore this alternative has been screened from further consideration.

Flood Proofing Buildings

Flooding would occur in rear and side yards during the Regulatory Storm event throughout the reach and for the 100 year storm event within rear yards immediately downstream of King Street West. To be effective in this reach, flood proofing would have to occur on private property, which will need input and approval from the residents.

The construction of flood berms or flood walls would have terrestrial impacts including temporary disturbance to locally common wildlife, minimal vegetation impacts to the low constraint vegetation communities within Reach BC-4, and opportunities for mitigation and/or enhancement plantings to compensate.

Combinations

A combined alternative of culvert upgrades and flood proofing has not been considered based on the culvert upgrades being screened from further consideration for this reach.

6.11.2. Erosion Management Alternatives

Downstream of King Street West, a stormwater outfall and private backyards are at risk of erosion (ref. Priority Erosion Sites ES6 and 7). Localized realignment would shift the creek away from the properties at risk, as well as diversifying and naturalizing fish habitats, potentially increasing fish community diversity and providing more spawning and nursery habitats for migratory fishes. A potential exists to enhance baseflow where more permeable sediments are encountered. Stormwater outfalls could be protected and repaired to incorporate energy dissipation prior to discharge into the creek. Further downstream, toe erosion is occurring adjacent to an area of valley wall contact within Hopkins Park. The channel is meandering in planform and realignment would involve shortening the length of the channel. Localized protection and bank regrading could be used to protect the valley wall at this location using bioengineering, also providing an opportunity to incorporate instream habitat structure that could enhance fish habitat locally. It is noted that while this alternative addresses immediate erosion issues that are threatening the watercourse, it does not preclude the necessity for additional works in the future. A preferable approach would be the management of land at the top of west bank and creation of a stream corridor appropriate incorporating setbacks.

Floodplain and channel improvements for erosion control would cause temporary loss of habitat for locally common wildlife, moderate terrestrial impacts to the low constraint vegetation communities within Reach BC-4, and opportunities for mitigation and/or enhancement plantings to compensate.

6.12. Battlefield Creek BC-5

6.12.1. Flood Alternatives

King Street West to the base of Niagara Escarpment is considered to be a steep reach and consists mostly of Battlefield Park. Encroachment of development within the Regulatory floodplain at King Street West is the only flooding area within the reach.

Culvert/ Bridge Upgrades

King Street has a 7.33 m by 1.68 m concrete box concrete box culvert that results in only the Regional Storm overtopping the road, with a flood depth and velocity within Provincial requirements. The culvert span and rise has been maximized based on the available creek block width and the road profile, therefore upgrades to the culvert would not be considered possible hence culvert upgrades have been screened from further consideration.

If implemented, upgrades to the King Street culvert would not cause temporary disturbance to the high constraint vegetation community within Reach BC-5, and limited opportunities for mitigation and/or enhancement riparian plantings to compensate.

Floodplain/ Channel Improvements

Floodplain and channel improvements for this reach are being conducted as part of a separate study by the City of Hamilton to address local erosion concerns within the lower reach. Major floodplain and channel improvements for the purpose of reducing flood risk have been screened from further consideration due to the flooding mechanism being encroachment and not the flow capacity of the creek and floodplain.

If implemented, floodplain and channel improvements would cause temporary loss of habitat for locally common wildlife, moderate terrestrial impacts to the high constraint vegetation community within Reach BC-5, and limited opportunities for mitigation and/or enhancement riparian plantings to compensate.

Roadway Profile Modifications

King Street is overtopped only during the Regional Storm therefore increasing the Regulatory flood depth above the existing 0.20 m would not be considered desirable based on increased flow depth to private properties on the north side of King Street.

If implemented, roadway profile modifications to King Street would cause temporary disturbance to locally common wildlife and minimal impacts to the high constraint vegetation communities of Reach BC-5, with limited opportunities for mitigation and/or enhancement riparian plantings to compensate.

Flood Proofing Buildings

Flooding occurs on private property for only the Regional Storm. There is a possibility that localized flood protection could be implemented around the one property at flood risk on the south side of King Street West.

The construction of flood berms or flood walls would have terrestrial impacts including temporary disturbance to locally common wildlife, minimal vegetation impacts to the high constraint vegetation communities within Reach BC-5, and limited opportunities for mitigation and/or enhancement riparian plantings to compensate.

Combinations

A combined alternative of culvert upgrades and flood proofing has not been considered based on the culvert upgrades being screened from further consideration for this reach.

6.12.2. Erosion Management Alternatives

A stormwater outfall is at risk of erosion in the vicinity of 24/26 Battlefield Drive and is associated with valley wall contact. This is a highly confined tributary to Battlefield Creek with no opportunity for realignment. Localized protection and bank regrading could be used to protect the valley wall at this location using bioengineering. The stormwater outfall should be protected and repaired to incorporate energy dissipation prior to discharge into the tributary.

Erosion is also occurring adjacent to museum lands and Battlefield Park. Within this reach the creek retains a meandering planform with the exception of immediately upstream of King Street West. Bank regrading would involve removal of mature tree lining that is currently helping to stabilize the banks. Non-structural measures such as improving riparian zone structure by not mowing to the bank top and managing / planting trees would help to further stabilize the banks. Localized bank protection works using bioengineering is being planned to protect the museum lands and banks around the bridge downstream. It is noted that while this alternative addresses immediate erosion issues that are threatening the watercourse, it does not preclude the necessity for additional works in the future. A preferable approach would be the creation of a stream corridor incorporating appropriate setbacks.

Localized protection and bank re-grading would cause temporary loss of habitat for locally common wildlife, moderate terrestrial impacts to the high constraint vegetation communities within BC-5, and limited opportunities for mitigation and/or enhancement riparian plantings to compensate.

7. ASSESSMENT OF LAND MANAGEMENT PRACTICES (LONG TERM)

The short-listed flood and erosion alternatives would be considered primarily short-term solutions to the existing flooding and erosion conditions within Stoney Creek. The short-listed alternatives are considered the most viable and effective in providing improved flooding protection and erosion control, based on the existing creek block and area land use. These would be the solutions that are considered short-term and economically viable. Long-term potential flood protection and erosion control land management practices initially discussed in Section 4 are further assessed here to determine potential long-term creek management opportunities.

7.1. Flooding Land Management Practices

7.1.1. Structural/Capital Land Management Practices

Flood Control Via Stormwater Quantity Controls:

Stormwater quantity controls whether on-line or off-line can reduce major flows within watercourses and thereby reduce the extent and risk of flooding. Section 5.1.5 provides an assessment of the impact of stormwater management on reducing future land use peak flows premised on implementing the proposed stormwater quality retrofits. The assessment demonstrated that peak flows for the significant storm events would not be reduced to any great extent to be effective as a stand-alone technique.

To obtain an understanding of the potential for other major flood controls as a long-term management measure via stormwater quantity systems, an assessment has been conducted for conceptual stormwater management facilities on the Niagara Escarpment upstream of the Devil's Punchbowl. Two conceptual facilities have been sited based on maximizing the amount of flood storage behind existing road crossings using the existing topography. One conceptual facility has been considered at Ridge Road and the other at Third Road. The general conceptual rating curves for each facility have been provided below in Tables 7.1.1. and 7.1.2 based on the area topography:

Table 7.1.1: Ridge Road Stormwater Management Facility Storage-Discharge Curve

Flow (m^3/s)	Volume (m^3)
0	0
131	5031
170	22136

Table 7.1.2: Third Road Stormwater Management Facility Storage-Discharge Curve

Flow (m^3/s)	Volume (m^3)
0	0
54	16347
164	68795

Table 7.1.3 100 Year And Regional Storm Peak Flows				
Location	**100 Year Flow (m^3/s)**	**100 Year with Stormwater Management Flow (m^3/s)**	**Regional Storm Flow (m^3/s)**	**Regional Storm with Stormwater Management Flow (m^3/s)**
Devil's Punchbowl	45.72	45.46	133.58	132.43
Battlefield/ Stoney Creek Confluence	62.86	62.51	184.30	182.92
Lake Ontario	66.94	66.41	193.23	190.88

Based on the performance assessment results in Table 7.1.3, the 100 year storm event and Regional Storm peak flows would have a negligible reduction locally, which would afford a nominal downstream benefit. This assessment has thus demonstrated that using existing storage behind the two conceptual crossings has had essentially no benefit to peak flow reduction and the existing flood risk downstream below the Escarpment.

To determine what the magnitude of flood control would be required to appreciably reduce the existing the flood risk within both Battlefield Creek and Stoney Creek, two further conceptual facilities have been sized based on the objective of reducing the Regulatory Storm peak flows to approximately the 100 year at key nodes. The Stoney Creek facility has been positioned above the Niagara Escarpment, while the Battlefield Creek facility has been positioned upstream of King Street. Each facility has been notionally sized to provide control of Regulatory flows to the 100 year peak flows throughout each creek. The 100 year peak flow has been selected based on the flood risk for existing development being significantly less than that of the Regulatory Storm. Tables 7.1.4 and 7.1.5 outline the required flood storage for each creek based on these objectives; premised on the significant volumes and the limited practicality of implementing flood controls of this magnitude, the long-term future viability this land management practice would have to be considered further in more detailed study. Table 7.1.6 provides the peak flows at key locations based on the stormwater management facilities rating curves in Tables 7.1.4 and 7.1.5.

Table 7.1.4. Battlefield Creek Stormwater Management Facility Storage-Discharge Curve	
Flow (m^3/s)	**Volume (m^3)**
0	0
7.59	1,672
9.29	19,470
10.97	238,197

Table 7.1.5 Stoney Creek Stormwater Management Facility Storage-Discharge Curve	
Flow (m^3/s)	**Volume (m^3)**
0	0
27.84	3,978
32.84	55,115
39.43	845,500

Table 7.1.6. Flood Control Facilities Peak Flows			
Location	**100 Year Flow (m^3/s)**	**Regional Storm Flow (m^3/s)**	**Regional Storm with Stormwater Management Flow (m^3/s)**
Stoney Creek			
Edge of Escarpment	41.50	136.27	41.39
King St.	42.92	140.88	42.14
Highway 8	43.47	142.40	42.57
Battlefield/Stoney Creek Confluence	58.70	185.51	58.37
CNR	59.96	188.31	67.67
QEW	62.69	194.50	75.65
Lake Ontario	62.77	194.58	76.64
Battlefield Creek			
King St.	13.22	40.02	13.04
Highway 8	14.89	44.63	15.24

7.1.2. Non-Structural Land Management Practices

Floodplain Management:

As discussed in Section 4.1.5 management of the lands inundated by the Regulatory floodplain for the purpose of reducing the threat to life is typically the last land management practice to be considered due to the high costs and the social implications to the residents and community. That said, an assessment has been completed to determine on a reach by reach basis approximately what land base would be required to be managed. Each reach has been assessed based on the number of properties within the both the 100 year and Regulatory floodplain.

Based on this assessment, there would be 104 properties in the Regulatory floodplain and 36 properties in the 100 year storm floodplain. The social cost of managing these properties would have to be assessed fully, prior to any additional consideration of the long-term viability of this land management practice.

7.2. Erosion Land Management Practices

Alternative A1: Management of Property or Relocation of Infrastructure at Risk: Channel erosion is a natural process when in equilibrium with other channel functions, which commonly becomes an issue when either accelerated due to human activity and/or where development is situated adjacent to a creek within an area subject to natural erosion. Management of property or relocation of infrastructure away from the creek can effectively remove the risk and is the most sustainable solution in the long-term. However, this land management practice is often one of the last to be considered, due to high economic costs and social implications to the community.

As described in Section 7.1.2, an assessment has been completed to determine approximately what would be required in terms of land management in order to remove property from the area subject to flood risk. Alongside this, and as part of a long-term vision for Stoney and Battlefield Creeks, an initial assessment has also been made regarding the land that may be required to be managed by the City of Hamilton to establish a functional stream corridor for Stoney Creek and Battlefield Creek and remove property from areas of fluvial erosion hazard. In addition, a functional stream corridor for Stoney and Battlefield Creeks would likely involve re-alignment of the creek and/or re-grading of the banks and valley wall. Along most reaches, the existing trees and understorey vegetation that would need to be cleared consists primarily of non-native invasive species. Mitigation for these vegetation impacts would include plantings of native trees and shrubs, thereby increasing native plant cover, biodiversity and wildlife habitat.

A broad scale meander belt width assessment has been undertaken on a reach basis according to Procedure 1 of the relevant *Belt Width Delineation Procedures* guidance, as applicable to planning studies (Parish Geomorphic, 2004). The purpose of the assessment has been to illustrate the location of the meander belt width in relation to existing land use and identify potential properties at risk of erosion, rather than providing quantified values for detailed planning or analytical purposes. The meander belt widths have been delineated within a GIS. The meander axis has been defined in a general down-valley direction and the meander belt widths have been subsequently determined by drawing parallel lines tangential to the outside of meander bends on a reach basis.

The fact that Stoney Creek and Battlefield Creek are confined, although undersized, fluvial systems (flowing in valleys that are likely to have been formed by glacial meltwater) has been used to inform the broad scale meander belt width assessment. However, detailed adjustments to the meander belt boundary to take into account the influence and characteristics of the valley wall have not been made at this stage. A standard 10% factor of safety has been applied either side of the meander belt width. It should be noted that this assessment has not taken into account historical planform change or geotechnical slope stability adjustments, which would be required for delimitation of erosion hazards. Geotechnical assessment is particularly significant in relation to confined channel systems as it is required to define the toe erosion and slope stability allowance components of erosion hazard assessment (Ontario Ministry of Natural Resources, 2001).

Based on the meander belt width assessment, approximately 116 properties currently within the meander belt width would have to be managed by the City of Hamilton. As per the floodplain land management, the social cost would require assessment prior to any additional consideration of the long-term viability of this practice. From a fisheries perspective, the reestablishment of a natural channel over significant lengths of Stoney and Battlefield Creeks would have a significant positive impact upon the resident and migratory fish community.

Flow Attenuation through Stormwater Management: As part of potential future stormwater management being implemented, consideration should be given to the quantity and quality of any potential water infiltrating to the water table. Opportunities to enhance baseflow exist but should take into account the quality of infiltrating water.

To assess the potential viability of long-term erosion control through stormwater management, erosion critical flows have been determined for both Battlefield Creek and Stoney Creek. The critical flow represents the point at which sustained flows will tend to entrain and transport sediment. Critical flows were calculated using quantitative field data gathered for two of the detailed sites. This data included:

- Measurements of bankfull cross-sections at 10 locations reporting riffle, pool and transitional sections of the reach.
- Bank characterization.
- Bed substrate characterization using a modified Wolman pebble count to evaluate substrate characteristics.
- A long profile survey of channel bottom and bankfull elevations to determine local energy gradients, including top-of-riffle, bottom-of-riffle, maximum depth and any obstructions to flow.
- Digital photography showing each of the 10 cross-sections.

The calculations performed to determine the threshold discharge for bed materials were based on formulas for critical shear stress and permissible velocity and determined for all 10 cross-sections. Due to high variation in sediment characteristics, a reach-averaged D_{50} value was used (32.5mm). Selection of appropriate thresholds was, in part, dictated by indicators of active processes (e.g. widening), and channel substrate. For Reach BC-3, critical flows were calculated based on critical shear stress determined using Fishenich (2001) while for Reach SC-4 critical flows were calculated using a permissible velocity according to Komar (1987). Both of these methods are applicable for gravel bed streams and produced conservative values in comparison with the models tested.

The critical flows within Table 7.2.1 have been selected for each creek based on Reaches BC-3 and SC-4 being the most sensitive of the detailed sites, as indicated by Rapid Geomorphic Assessment findings. and as the reaches are the closest to the confluence. Downstream of the Battlefield and Stoney Creek confluence the dominant creek process is aggradation, due to backing up upstream of the Barton Street culvert, rail culvert and Lake Ontario.

Table 7.2.1. Critical Flow Assessment		
	Reach BC-3	**Reach SC-4**
Critical Discharge ($m^3 s^{-1}$)	1.17	1.47
Critical Velocity (ms^{-1})	1.32	1.38
Critical Depth (m)	0.32	0.41
Method Used	Fischenich (2001)	Komar (1987)
No. of Cross-Sections	10	10

As critical flows have been determined for Reaches BC-3 and SC-4, a duration assessment of flow nodes located at the confluence for each creek has been conducted for the future flow regime based on continuous simulation of the 34 year rainfall record (1962 to 1995). For the existing condition, the duration of flows above critical flows would be approximately 106 days or 0.98% of the full flow record as of 10,796 days for SC-4 and 90 days or 0.75% of the 12,266 day flow record for BC-3, therefore active erosive flows occur most of the time during wet events.

To assess the long-term potential of reducing the duration of erosive flows using stormwater management, an assessment using the future condition hydrologic model with the proposed stormwater quality retrofits in place and two conceptual erosion control facilities, one for each creek in the same locations as the flood control facilities, has been conducted. The stage storage discharge relationships have been provided within Tables 7.2.2 and 7.2.3. The relationships have been determined based on storing the 2 year design storm event runoff volume for 24 hours as an approximation of extended volume requirements, then conducting a continuous simulation to determine impact on durations.

Table 7.2.2. Battlefield Creek Stormwater Management Facility Storage-Discharge Curve	
Flow (m^3/s)	**Volume (m^3)**
0	0
0.46	19,872
150.0	48,000

Table 7.2.3. Stoney Creek Stormwater Management Facility Storage-Discharge Curve	
Flow (m^3/s)	**Volume (m^3)**
0	0
0.60	25,920
150.0	100,000

With erosion controls in place as per above, flow at or above critical flow for Reach SC-4 would occur 81 days or 0.66% of the flow record, and 58 days or 0.47% of the flow record for Reach BC-3. Reach SC-4 would realize a critical flow reduction of 106 to 81 days, while Reach BC-3 would realize a reduction of 90 to 58 days. The erosion controls would have limited benefit based on the number of days critical flow would occur.

Based on the volume requirements for each of the facilities, there would be a significant extended storage volume to be implemented within each creek protocol. Locations for the facilities of this size are limited, management of lands in the proximity of storm sewer outlets along each creek would be required to yield effective property for implementation of this alternative.

8. PREFERRED ALTERNATIVES

8.1. Summary of Preferred Flood Mitigation Alternatives

A summary of the preferred flood mitigation alternatives identified for Battlefield Creek and Stoney Creek has been provided in Table 8.1.1 and illustrated in Figures BC-1 to BC-5 and SC-1 to SC-7 respectively. It should be noted that flood mitigation alternatives shown in the figures are conceptual only and more detailed design and assessment would be required in subsequent studies.

Table 8.1.1. Summary of Preferred Flood Mitigation Alternatives

Reach	Specific site of works	Details of proposed works	Additional notes
Battlefield Creek			
BC-1	Between Lake Avenue North and confluence with Stoney Creek.	Property flood protection berm to Regulatory standard at Blueberry Drive, Huckleberry Drive and southwest corner of Delewana Drive and Lake Avenue North. Preliminary cost estimate of $240,000 to $480,000.	Assessment required for flood storage and Regional Storm flood elevation impacts. Grading on private property required.
BC-2	Two meander bends on west bank in contact with valley wall upstream of Lake Avenue North	Property flood protection berm to Regulatory standard of apartment complex property on Lake Avenue North. Flood protection of single commercial property on south side of Lake Avenue. Preliminary cost estimate of $125,000 to $250,000.	Assessment required for flood storage and Regional Storm flood elevation impacts. Two residential properties adjacent to the creek on Lake Avenue North would continue to be flooded during the 100 Year storm. Grading required on private property.
BC-3	Immediately upstream of Queenston Road	Flood protection berm to Regulatory standard for Hydro Transformer station and adjacent homes. Preliminary cost estimate of $130,000 to $260,000.	Hydro property would require re-graded access off Queenston Road. Storm sewer in vicinity of property. Lands are private.
	Mid-reach adjacent to Avalon Avenue	Localized flood protection berm to Regulatory standard of Valley Drive to facilitate vehicle access. Preliminary cost estimate of $60,000 to $120,000.	Lands are public
	Remaining Reach	Localized flood protection berm to Regulatory standard of most southerly/west property on Valley Drive. Preliminary cost estimate of $20,000 to $60,000.	Grading could be on public lands.
BC-4	Downstream of King Street West, upstream of Hopkins Park	Localized flood protection berm to Regulatory standard of residential buildings on Friarcourt Drive Preliminary cost estimate of $250,000 to $500,000.	Properties on the north side of King Street would remain within the 100 year and Regional Storm floodplain.

Table 8.1.1. Summary of Preferred Flood Mitigation Alternatives			
Reach	**Specific site of works**	**Details of proposed works**	**Additional notes**
BC-5	Immediately Upstream of King Street	Localized flood protection berm to Regulatory standard for properties on the south west side of King Street West and the creek. Preliminary cost estimate of $130,000 to $260,000.	Would have to consider grading limitations within Battlefield Park.
Stoney Creek			
SC-1	South Service Road to upstream of the CNR crossing.	Localized flood protection berm to Regional Storm standard for industrial properties. Upgrade the CNR crossing by either a supplemental culvert or replacement bridge to provide Regional Storm flood protection to industrial lands. Flow area required would be approximately 12 m by 3.5 m. Preliminary cost estimate of CNR works $1.5 Million to $2 Million. Berm works $140,000 to $280,000.	CNR crossing upgrade would remove industrial lands from the Regulatory floodplain upstream of the CNR to Barton Street.
SC-2	Downstream of Barton Street East	Uses alternatives from SC-1. Localized flood protection berm to Regional Storm standard for industrial properties on the west side of the creek immediately upstream of the CNR crossing. Preliminary cost estimate of berm works $110,000 to $220,000.	
SC-3	Between confluence with Battlefield Creek and Barton Street East.	Localized flood protection berm to Regional storm standard for residential properties located immediately upstream of Queenston Road. Preliminary cost estimate of $85,000 to $170,000.	Grading would be within public lands.
SC-4	From confluence to Queenston Road	No actions required.	
SC-5	Queenston Road to Collegiate Avenue	Localized flood protection berm to Regional Storm standard. Preliminary cost estimate of $290,000 to $580,000.	Most of the creek is privately owned within this reach, therefore flood protection may be difficult to implement successfully. Land Management or easements required.
SC-6	Collegiate Avenue to north side of King Street West	Localized flood protection berm to Regional Storm standard. Preliminary cost estimate of $160,000 to $320,000.	Most of the creek is privately owned within this reach, therefore flood protection may be difficult to implement successfully.
SC-7	North side of King Street West to CNR Rail Line	Localized flood protection berm to Regional Storm standard. Preliminary cost estimate of $110,000 to $220,000.	Most of the creek is privately owned within this reach, therefore flood protection may be difficult to implement successfully.

8.2. Summary of Preferred Erosion Management Alternatives

A summary of the preferred erosion management alternatives identified for Battlefield Creek and Stoney Creek has been provided in Table 8.2.1, divided into short-term remedial measures and long-term erosion control and enhancement and land management practices. The preferred alternatives are illustrated in Figures BC-1 to BC-5 and SC-1 to SC-7 respectively. Planforms shown in the figures are conceptual only and more detailed investigations would be required in order to determine an appropriate channel configuration.

Table 8.2.1. Summary of Preferred Erosion Management Alternatives

Reach	Specific site of works	Details of erosion control remedial works	Medium and long-term erosion control and enhancement and Land Management Practices	Additional notes
BC-1	Between Lake Avenue North and confluence with Stoney Creek.	• Do Nothing	• Medium Term re-meandering of the channel planform to increase sinuosity of historically straightened channel and improve fish habitat. • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $792,000	Sanitary sewer is located on east bank.
BC-2	Two meander bends on west bank in contact with valley wall upstream of Lake Avenue North	• Localized regrading of channel banks combined with bank protection on the west bank. • Preliminary cost estimate of $165,000.	• Long-term land management to remove private property from erosion risk and create a functional stream corridor.	
	Downstream of Queenston Road through Henry and Beatrice Warden Park.	• Localized realignment of channel away from sanitary sewer • Localized regrading and protection of bed at sanitary sewer crossing using riffle structure. • Localized repair and protection of stormwater outfalls • Preliminary cost estimate of $396,000	• Medium-Term continued realignment of-the channel planform downstream of second outfall to increase sinuosity of historically straightened channel and improve fish habitat. Preliminary cost estimate of $594,000 • Improved riparian zone management (limiting mowing) is recommended through the park.	Realignment needs to take into account location of existing stormwater outfalls Incorporates conceptual design for Priority Erosion Site ES3. Works could be integrated with new multi-purpose trail.
BC-3	Immediately upstream of Queenston Road	• Localized repair and protection of stormwater outfall. • Preliminary cost estimate of $30,000		

Table 8.2.1. Summary of Preferred Erosion Management Alternatives

Reach	Specific site of works	Details of erosion control remedial works	Medium and long-term erosion control and enhancement and Land Management Practices	Additional notes
	Mid-reach adjacent to Avalon Avenue	• Localized bank regrading and bank protection on east bank to protect property line. • Localized protection of outfall on west bank. • Preliminary cost estimate of $110,000	• Long-term land management to remove private property from erosion risk and create a functional stream corridor.	Sanitary sewer is located on west bank.
	Downstream of Randall Avenue through Green Acres Park.	• Localized realignment and replacement of failing bank protection on east bank to protect road crossing. • Preliminary cost estimate of $180,000	• Long-term land management to remove municipal infrastructure from erosion risk and create a stream corridor. • Medium-term re-meandering of channel to increase sinuosity of historically straightened channel and improve fish habitat through Green Aves Park. Preliminary cost estimate of $360,000 • Improved riparian zone management (limiting mowing) is recommended through the park.	Sanitary sewer is located on west bank. Works to replace bank protection to protect trail adjacent to baseball pitch currently being progressed by City of Hamilton.
BC-4	Downstream of King Street West, upstream of Hopkins Park	• Localized realignment and bank protection to protect private property line on east bank. • Localized repair and protection of stormwater outfall. • Preliminary cost estimate of $450,000.	• Long-term land management to remove private property and removal of infrastructure from erosion risk to create a functional stream corridor.	Incorporates conceptual design for Priority Erosion Sites ES6 and ES7.
BC-5	Upstream of proposed works by City of Hamilton (ref. Appendix 'E')	• Localized bank protection to protect municipal property (museum and bridge). • Preliminary cost estimate of $27,500.	• Long-term land management to remove private property and set back of municipal facilities from erosion risk to create a functional stream corridor	Works to protect museum lands and bridge currently being progressed by City of Hamilton.
SC-1	Downstream of rail culvert	• None identified	• None identified	
SC-2	Downstream of Barton Street East	• None identified	• Medium-term re-meandering of channel downstream of footbridge to increase sinuosity of historically straightened channel and improve fish habitat. • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $828,000.	Realignment design needs to take into account sanitary sewer crossing mid-reach.

Table 8.2.1. Summary of Preferred Erosion Management Alternatives				
Reach	**Specific site of works**	**Details of erosion control remedial works**	**Medium and long-term erosion control and enhancement and Land Management Practices**	**Additional notes**
SC-3	Between confluence with Battlefield Creek and Barton Street East.	• None identified	• Medium-term installation of in-stream structures to increase flow diversity and create pool features for fisheries benefit. • Preliminary cost estimate of $50,000.	
SC-4	Boundary with first property upstream of the confluence on the west bank.	• Localized bank regrading and bank protection to protect property line on west bank. • Preliminary cost estimate of $77,000.	• Long-term land management to remove private property from erosion risk and create a functional stream corridor	Section of creek likely to retain natural channel planform. Can potentially be used as a reference reach.
	Downstream of pedestrian footbridge, nr Huckleberry Place	• Localized realignment and bank protection to protect sanitary maintenance chamber. • Localized regrading and protection of bed at sanitary sewer crossing using riffle structure. • Preliminary cost estimate of $108,000.	• In the medium-term remove infrastructure erosion risk and create a functional stream corridor	Design of realignment tie into existing planform will need to take into account proximity to sanitary sewer upstream.
SC-5	Mid-reach adjacent to Donn Avenue / Dale Avenue intersection.	• Localized realignment and bank protection to protect property line on east bank. • Regrading of area of slope instability on east bank. • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $450,000	• Long-term land management to remove private property from erosion risk and create a functional stream corridor	Incorporates conceptual design for Priority Erosion Sites ES9.
	Downstream of Collegiate Avenue	• Replacement of existing bank protection along both banks (with regrading if constraints allow). • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $165,000.	• Long-term land management to remove private property from erosion risk and create a functional stream corridor	Incorporates conceptual design for Priority Erosion Sites ES13 and ES14.
SC-6	Collegiate Avenue to north side of King Street West	• Replacement of existing bank protection along both banks (with regrading if constraints allow). • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $979,000.	• Long-term land management to remove private property from erosion risk and create a functional stream corridor.	Feasibility dependant on landowner buy-in Incorporates conceptual design for Priority Erosion Sites ES15, ES16, ES18 and ES19.

Table 8.2.1. Summary of Preferred Erosion Management Alternatives				
Reach	**Specific site of works**	**Details of erosion control remedial works**	**Medium and long-term erosion control and enhancement and Land Management Practices**	**Additional notes**
SC-7	North side of King Street West to CNR Rail Line	• Replacement of existing bank protection along both banks (with regrading if constraints allow). • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $770,000.	• Long-term land management to remove private property from erosion risk and create a functional stream corridor	Feasibility dependant on landowner buy-in Incorporates conceptual design for Priority Erosion Sites ES20, ES21, ES22 and ES23.

9. IMPLEMENTATION STRATEGY

This section outlines the specifics associated with the implementation of the Flood and Erosion Control Class Environmental Assessment recommendations including:

- Phasing/ Prioritization Plan
- Financing
- Operations and Maintenance
- Monitoring Requirements
- Integrated Implementation Plan

9.1. Phasing and Prioritization Plan

Flood protection measures have been identified for each reach, but for the most vulnerable creek reaches with highest flood risk, the recommended alternatives such as flood protection berming will not reduce the risk significantly. As such the Phasing and prioritization plan has primarily been established based on the basis of erosion sensitivity of the creek reaches, the current condition of creek erosion and the potential impacts to both private and public property. Input has been received from the public at both PICs as to the most sensitive creek bank erosion locations where in the near future impacts to private property may occur. By walking the creeks and through discussions with the City of Hamilton, various municipal infrastructure has also been identified for erosion protection.

Table 9.1.1 has placed each erosion project in a prioritized sequence and assigned a “Low” to “High” Priority Rating accordingly. Notionally, the flood protection works would be designed and constructed at the same time as the recommended erosion control works. The exception to this flood protection works phasing strategy, would be the proposed upgrade to the CNR crossing, which would be conducted when the structural replacement or major repair of the existing crossing would be required. Flood protection works (berming or equivalent) for Reaches BC-1, SC-1 and SC-3 could also be conducted ahead of the long-term erosion control land management practices, such as meandering.

Creek erosion works should be conducted prior to further issues occurring on private property and/ or municipal infrastructure. Through discussions with the Hamilton Conservation Authority, funding has been made available to commence with the design of the highest priority erosion control works in the near term, with further details provided in the next section.

Table 9.1.1 Priority Staging Related to Proposed Erosion Management Works, Stoney Creek and Battlefield Creek						
Priority Sequence	**Rating**	**Reach**	**Specific site of works**	**Short-term erosion control remedial works**	**Medium Term/ Long-term erosion control and enhancement/ land management practices**	**Additional notes**
1	High	SC-7	• North side of King Street West to CNR Rail Line	• Replacement of existing bank protection along both banks (with regrading if constraints allow). • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $770,000.	• Long-term land management to remove private property from erosion risk and create a functional stream corridor	• Feasibility dependant on landowner support • Incorporates conceptual design for Priority Erosion Sites ES20, ES21, ES22 and ES23.
2	High	SC-5	• Mid-reach adjacent to Donn Avenue / Dale Avenue intersection.	• Localized realignment and bank protection to protect property line on east bank. • Regrading of area of slope instability on east bank. • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $450,000	• Long-term land management to remove private property from erosion risk and create a functional stream corridor	• Incorporates conceptual design for Priority Erosion Sites ES9.
			• Downstream of Collegiate Avenue	• Replacement of existing bank protection along both banks (with regrading if constraints allow). • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $165,000.	• Long-term land management to remove private property from erosion risk and create a functional stream corridor	• Incorporates conceptual design for Priority Erosion Sites ES13 and ES14.
3	High	SC-6	• Collegiate Avenue to north side of King Street West	• Replacement of existing bank protection along both banks (with regrading if constraints allow). • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $979,000.	• Long-term land management to remove private property from erosion risk and create a functional stream corridor	• Feasibility dependant on landowner buy-in • Incorporates conceptual design for Priority Erosion Sites ES15, ES16, ES18 and ES19.
4	High	BC-4	• Downstream of King Street West, upstream of Hopkins Park	• Localized realignment and bank protection to protect private property line on east bank. • Localized repair and protection of stormwater outfall. • Preliminary cost estimate of $450,000.	• Long-term land management to remove private property from erosion risk and create a functional stream corridor	• Incorporates conceptual design for Priority Erosion Sites ES6 and ES7.

Table 9.1.1 Priority Staging Related to Proposed Erosion Management Works, Stoney Creek and Battlefield Creek

Priority Sequence	Rating	Reach	Specific site of works	Short-term erosion control remedial works	Medium Term/ Long-term erosion control and enhancement/ land management practices	Additional notes
5	Medium	BC-5	• Upstream of proposed works by City of Hamilton	• Localized bank protection to protect municipal property (museum and bridge). • Preliminary cost estimate of $27,500.	• Long-term land management to remove private property and set back of municipal facilities from erosion risk to create a functional stream corridor	• Works to protect museum lands and bridge currently being progressed by City of Hamilton at present time.
6	Medium	SC-4	• Boundary with first property upstream of the confluence on the west bank.	• Localized bank regrading and bank protection to protect property line on west bank. • Preliminary cost estimate of $77,000.	• Long-term land management to remove private property from erosion risk and create a functional stream corridor	• Section of creek likely to retain natural channel planform. Can potentially be used as a reference reach.
			• Downstream of pedestrian footbridge, near Huckleberry Place	• Localized realignment and bank protection to protect sanitary maintenance chamber. • Localized regrading and protection of bed at sanitary sewer crossing using riffle structure. • Preliminary cost estimate of $108,000.	• In the medium-term remove infrastructure erosion risk and create a functional stream corridor	• Design of realignment tie into existing planform will need to take into account proximity to sanitary sewer upstream.
7	Medium	BC-2	• Two meander bends on west bank in contact with valley wall upstream of Lake Avenue North	• Localized regrading of channel banks combined with bank protection on the west bank. • Preliminary cost estimate of $165,000.	• Long-term land management to remove private property from erosion risk and create a functional stream corridor	
			• Downstream of Queenston Road through Henry and Beatrice Warden Park.	• Localized realignment of channel away from sanitary sewer • Localized regrading and protection of bed at sanitary sewer crossing using riffle structure. • Localized repair and protection of stormwater outfalls • Preliminary cost estimate of $396,000	• In the medium-term, continued realignment of-the channel planform downstream of second outfall to increase sinuosity of historically straightened channel and improve fish habitat. Preliminary cost estimate of $594,000 • Improved riparian zone management (limiting mowing) is recommended through the park.	• Realignment needs to take into account location of existing stormwater outfalls • Incorporates conceptual design for Priority Erosion Site ES3. • Works could be integrated with new multi-purpose trail.
8	Medium	BC-3	• Immediately upstream of Queenston Road	• Localized repair and protection of stormwater outfall. • Preliminary cost estimate of $30,000		

Table 9.1.1 Priority Staging Related to Proposed Erosion Management Works, Stoney Creek and Battlefield Creek

Priority Sequence	Rating	Reach	Specific site of works	Short-term erosion control remedial works	Medium Term/ Long-term erosion control and enhancement/ land management practices	Additional notes
			• Mid-reach adjacent to Avalon Avenue	• Localized bank regrading and bank protection on east bank to protect property line. • Localized protection of outfall on west bank.	• Long-term land management to remove private property from erosion risk and create a functional stream corridor	• Sanitary sewer is located on west bank.
			• Downstream of Randall Avenue through Green Acres Park.	• Localized realignment and replacement of failing bank protection on east bank to protect road crossing. • Preliminary cost estimate of $110,000	• Long-term land management to remove municipal infrastructure from erosion risk and create a stream corridor. • Medium-term re-meandering of channel to increase sinuosity of historically straightened channel and improve fish habitat through Green Aves Park. Preliminary cost estimate of $360,000 • Improved riparian zone management (limiting mowing) is recommended through the park.	• Sanitary sewer is located on west bank. • Works to replace bank protection to protect trail adjacent to baseball pitch currently being progressed by City of Hamilton.
9	Low	SC-2	• Downstream of Barton Street East	• None identified	• Medium-term re-meandering of channel downstream of footbridge to increase sinuosity of historically straightened channel and improve fish habitat. • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $828,000.	• Realignment design needs to take into account sanitary sewer crossing mid-reach.
10	Low	BC-1	• Between Lake Avenue North and confluence with Stoney Creek.	• Do Nothing	• Medium-term re-meandering of the channel planform to increase sinuosity of historically straightened channel and improve fish habitat. • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $792,000	• Sanitary sewer is located on east bank.
11	Low	SC-3	• Between confluence with Battlefield Creek and Barton Street East.	• None identified	• Medium-term installation of in-stream structures to increase flow diversity and create pool features for fisheries benefit. • Preliminary cost estimate of $50,000.	
12	Low	SC-1	• Downstream of rail culvert	• None identified	• None identified	

9.2. Financing

The proposed creek erosion mitigation works would commence design in 2011 with construction of the works as early as 2012. The creek erosion and flood mitigation works would be conducted on reach by reach basis with the possibility of some of the reaches with multiple recommendations being split up into multiple projects pending available financing. Whenever possible, it is recommended that reach works be grouped together as there are several benefits of implementing this approach as per the following:

- Simplified approval process with agencies
- Reduced costs due to one contract, including design fees and contract administration
- Reduced construction time
- Less disruption to environmental systems

Table 9.2.1 provides a cost summary of the preferred alternative preliminary costs, not including the long term flood and erosion mitigation works and/or land management practices. Based on implementing just the “High” priority erosion works approximately $2,814,000 would be required for construction, with additional funds required for engineering, approvals and contract administration. Based on the significant costs for the preferred erosion and flood mitigation works, a variety of funding sources will need to be secured.

TABLE 9.2.1 Short Term Erosion and Flood Mitigation Works Preliminary Construction Costs

Priority Sequence	Reach	Priority	Erosion Works	Flooding Works
1	SC-7	HIGH	$770,000	$220,000
2	SC- 5	HIGH	$615,000	$580,000
3	SC-6	HIGH	$979,000	$320,000
4	BC-4	HIGH	$450,000	$500,000
SUBTOTALS			**$2,814,000**	**$1,620,000**
5	BC-5	MEDIUM	$27,500	$260,000
6	SC-4	MEDIUM	$185,000	
7	BC-2	MEDIUM	$561,000	$250,000
8	BC-3	MEDIUM	$320,000	$440,000
SUBTOTALS			**$1,093,500**	**$950,000**
9	SC-2	LOW	$0	$220,000
10	BC-1	LOW	$0	$480,000
11	SC-3	LOW	$0	$170,000
12	SC1	LOW	$0	$1,280,000
SUBTOTALS			**$0**	**$2,150,000**
TOTALS			**$3,907,500**	**$4,720,000**

9.2.1. Funding Sources

The majority of the erosion and flooding mitigation works relates to problems associated with historical development practices and alterations of Stoney and Battlefield Creek. As such, new development would not be directly contributing to the proposed works herein. New development would contribute to the proposed stormwater quality retrofits as noted within the 2004 Stormwater Quality Management Strategy, Community of Stoney Creek, Master Plan. The proposed stormwater quality retrofits are located adjacent to proposed erosion mitigation and flood protection works. As such the possibility of using cash-in-lieu funding for potential common construction tasks related to erosion and flood works could be investigated during required Municipal Class Environmental Assessments for the retrofits

The City of Hamilton capital works budget would be the primary funding source for the proposed flood and erosion works, followed by Provincial and Federal Grant programs and other sources.

Funding by the City of Hamilton for flood and erosion works would benefit from a dedicated stormwater rate. A dedicated stormwater rate would provide improved and stable funding for projects related to drainage such as creek works and would reduce the time required to obtain other sources of funding for flood protection and erosion mitigation works.

9.3. Operations

Regular maintenance of the recommended flood protection and erosion mitigation works would be required, however is considered to be limited due to the form of the proposed works. The flood protection works would consist primarily of vegetated flood berms with the possibility of flood protection walls being used on a limited basis, depending on localized grading requirements. The flood protection berms typically only require landscape maintenance, while flood protection walls will require regular inspection and eventually replacement at the end of their engineered life span (50 to 100 years +/-).

The erosion works would consist of creek bank protection and creek realignments using natural channel design principles. Regular inspection of the constructed erosion mitigation works would be required following the 2 to 3 year monitoring period after construction. As the creek works use natural channel techniques there should be some adjustment subsequent to construction but dynamic stability should be provided therefore reducing potential long term maintenance requests. As per the flood protection berms, landscaping maintenance will be required on an as needed basis. In addition, regular removal of debris from the creek will be necessary due to the urban setting of the creek system.

9.4. Monitoring Opportunities

All recommended works whether short-term creek improvements such as bank stabilization or flood control such as flood protection berms, would have an impact upon the creek and associated environmental systems. To assess the performance of recommended works requires an appropriate level of monitoring, prior to, and after, assumption by the City of Hamilton. In this regard, each project would require a monitoring plan to be administered by the City of Hamilton or Hamilton Conservation Authority and possibly other partners such as Department of Fisheries and Oceans.

The purpose of a Monitoring Plan is to:

1. Evaluate the performance of the proposed flood protection and erosion control works (i.e. design and mitigation techniques).

2. Provide the necessary information to adjust and/or optimize the plan recommendations through a process of Adaptive Management.

The duration of the monitoring would usually be a minimum length of 2 to 3 years for creek works, depending on input received from approval agencies (Hamilton Conservation Authority, Department of Fisheries and Oceans, and Ministry of Natural Resources) for the scope of creek works entailed. Monitoring of recommended creek works should include the following:

Stream Morphology
- Stream Cross-sections (Controls)
- Erosion pins (Tractive Force, Critical Shear Stress)
- Bank Properties (Height, Angle, Material, Vegetation, Root Depth, Undercuts and In-situ Shear Strength)
- Longitudinal Profile Survey (Energy Gradient, Top and Bottom Riffles, Max Pool Depth)
- Photographic record

Natural Heritage System
- Community Structure/Health – Ecological Integrity, Habitat Boundary Integrity, Problem Species, Overall Species and Habitat Diversity, Buffer Effectiveness, Human Activity Impacts
- Local Hydrology (water levels, soil moisture, etc.)

Hydrometeorologic
- Rainfall - Continuous
- Streamflow- Storm Response
- Baseflow – Flow Rate (Spot measurements)

Water Quality/Biophysical (Optional since the focus of the EA is in quantity management only)

- Benthic Invertebrates – Community Structure
- Water Temperature – Continuous
- Water Chemistry – Standard Parameters including Nutrients, Metals and Bacteria
- Sediment- Total Suspended Solids
- Fisheries- (Electrofishing)

The monitoring plan(s) specifics would be determined as part of the approved conditions related to the subsequent detail designs for each creek reach. Monitoring details may also be identified through the normal permitting and authorization process and will be discussed consultatively with the City of Hamilton and with City staff.

9.5. Integrated Implementation Plan

An integrated implementation plan has been developed based upon the proposed flood protection and erosion mitigation works with consideration to phasing, constructions costs, project propency, and additional study requirements and permitting. This information has been provided within Table 9.5.1 and is intended as an abbreviated summary of the subsequent outcomes of this Class Environmental Assessment.

The Stoney Creek and Battlefield Creek Flood and Erosion Control Class Environmental Assessment (Conservation Ontario Class EA) has followed the requirements of the Conservation Ontario Class EA for Remedial Flood and Erosion Control Projects process. The proponent of the Conservation Ontario Class EA has been Hamilton Conservation Authority with input from the City of Hamilton. The next steps based on this Conservation Ontario Class EA meeting the Conservation Ontario Class EA process in demonstrating that environmental impacts could be avoided, mitigated or compensated, would be to conduct detail design for the proposed works. The detail designs would have to provide direction on mitigating environmental impacts as required by the Hamilton Conservation Authority and reviewing approval agencies. The proponent of detail designs would depend upon available funding and could therefore either be the City of Hamilton or the Hamilton Conservation Authority.

TABLE 9.5.1. Integrated Implementation Plan								
Priority Sequence	**Rating**	**Reach**	**Specific Site of Works**	**Short-term Erosion Control Remedial Works**	**Erosion Control Additional Notes**	**Short-term Flood Mitigation Works**	**Flood Mitigation Additional Notes**	**Proponency/Additional Study Requirements/ Permitting**
1	High	SC-7	North side of King Street West to CNR Rail Line	• Replacement of existing bank protection along both banks (with regrading if constraints allow). • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $770,000.	Feasibility dependant on landowner buy-in Incorporates conceptual design for Priority Erosion Sites ES20, ES21, ES22 and ES23.	Localized flood protection berm to Regional Storm standard. Preliminary cost estimate of $110,000 to $220,000	Most of the creek is privately owned within this reach, therefore flood protection may be difficult to implement successfully	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City, NEC and potentially DFO and MNR
2	High	SC-5	Mid-reach adjacent to Donn Avenue / Dale Avenue intersection.	• Localized realignment and bank protection to protect property line on east bank. • Regrading of area of slope instability on east bank. • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $450,000	Incorporates conceptual design for Priority Erosion Sites ES9.	Localized flood protection berm to Regional Storm standard. Preliminary cost estimate of $290,000 to $580,000.	Most of the creek is privately owned within this reach, therefore flood protection may be difficult to implement successfully. Land management or easements required.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City and potentially DFO and MNR
			Downstream of Collegiate Avenue	• Replacement of existing bank protection along both banks (with regrading if constraints allow). • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $165,000.	Incorporates conceptual design for Priority Erosion Sites ES13 and ES14.			
3	High	SC-6	Collegiate Avenue to north side of King Street West	• Replacement of existing bank protection along both banks (with regrading if constraints allow). • Creation of pool features for fisheries benefit. • Preliminary cost estimate of $979,000.	Feasibility dependant on landowner buy-in Incorporates conceptual design for Priority Erosion Sites ES15, ES16, ES18 and ES19.	Localized flood protection berm to Regional Storm standard. Preliminary cost estimate of $160,000 to $320,000.	Most of the creek is privately owned within this reach, therefore flood protection may be difficult to implement successfully.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City and potentially DFO and MNR
4	High	BC-4	Downstream of King Street West, upstream of Hopkins Park	• Localized realignment and bank protection to protect private property line on east bank. • Localized repair and protection of stormwater outfall. • Preliminary cost estimate of $450,000.	Incorporates conceptual design for Priority Erosion Sites ES6 and ES7.	Localized flood protection berm to Regulatory standard of residential buildings on Friarcourt Drive Preliminary cost estimate of $250,000 to $500,000.	Properties on the north side of King Street would remain within the 100 year and Regional Storm floodplain.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City and potentially DFO and MNR
5	Medium	BC-5	Upstream of proposed works by City of Hamilton (ref. Appendix 'E')	• Localized bank protection to protect municipal property (museum and bridge). • Preliminary cost estimate of $27,500.	Works to protect museum lands and bridge currently being progressed by City of Hamilton.	Localized flood protection berm to Regulatory standard for properties on the south west side of King Street West and the creek. Preliminary cost estimate of $130,000 to $260,000.	Would have to consider grading limitations within Battlefield Park.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City, NEC and potentially DFO and MNR
6	Medium	SC-4	Boundary with first property upstream of the confluence on the west bank.	• Localized bank regrading and bank protection to protect property line on west bank. • Preliminary cost estimate of $77,000.	Section of creek likely to retain natural channel planform. Can potentially be used as a reference reach.	No actions required.		• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City and potentially DFO and MNR
			Downstream of pedestrian footbridge, near Huckleberry Place	• Localized realignment and bank protection to protect sanitary maintenance chamber. • Localized regrading and protection of bed at sanitary sewer crossing using riffle structure. • Preliminary cost estimate of $108,000.	Design of realignment tie into existing planform will need to take into account proximity to sanitary sewer upstream.			
7	Medium	BC-2	Two meander bends on west bank in contact with valley wall upstream of Lake Avenue North	• Localized regrading of channel banks combined with bank protection on the west bank. • Preliminary cost estimate of $165,000.		Property flood protection berm to Regulatory standard of apartment complex property on Lake Avenue North. Flood protection of single commercial property on south side of Lake Avenue. Preliminary cost estimate of $125,000 to $250,000	Assessment required for flood storage and Regional Storm flood elevation impacts. Two residential properties adjacent to the creek on Lake Avenue North would continue to be flooded during the 100 Year storm. Grading required on private property.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City and

TABLE 9.5.1. Integrated Implementation Plan

Priority Sequence	Rating	Reach	Specific Site of Works	Short-term Erosion Control Remedial Works	Erosion Control Additional Notes	Short-term Flood Mitigation Works	Flood Mitigation Additional Notes	Proponency/Additional Study Requirements/ Permitting
			Downstream of Queenston Road through Henry and Beatrice Warden Park.	• Localized realignment of channel away from sanitary sewer • Localized regrading and protection of bed at sanitary sewer crossing using riffle structure. • Localized repair and protection of stormwater outfalls • Preliminary cost estimate of $396,000	Realignment needs to take into account location of existing stormwater outfalls Incorporates conceptual design for Priority Erosion Site ES3. Works could be integrated with new multi-purpose trail.			potentially DFO and MNR
8	Medium	BC-3	Immediately upstream of Queenston Road	• Localized repair and protection of stormwater outfall. • Preliminary cost estimate of $30,000		Flood protection berm to Regulatory standard for Hydro Transformer station and adjacent homes. Preliminary cost estimate of $130,000 to $260,000.	Hydro property would require re-graded access off Queenston Road. Storm sewer in vicinity of property. Lands are private.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City and potentially DFO and MNR
			Mid-reach adjacent to Avalon Avenue	• Localized bank regrading and bank protection on east bank to protect property line. • Localized protection of outfall on west bank. • Preliminary cost estimate of $110,000	Sanitary sewer is located on west bank.	Localized flood protection berm to Regulatory standard of Valley Drive to facilitate vehicle access. Preliminary cost estimate of $60,000 to $120,000.	Lands are public	
			Downstream of Randall Avenue through Green Acres Park.	• Localized realignment and replacement of failing bank protection on east bank to protect road crossing. • Preliminary cost estimate of $180,000	Sanitary sewer is located on west bank. Works to replace bank protection to protect trail adjacent to baseball pitch currently being progressed by City of Hamilton.	Localized flood protection berm to Regulatory standard of most southerly/west property on Valley Drive. Preliminary cost estimate of $20,000 to $60,000.	Grading could be on public lands.	
9	Low	SC-2	Downstream of Barton Street East	• None identified		Uses alternatives from SC-1. Localized flood protection berm to Regional Storm standard for industrial properties on the west side of the creek immediately upstream of the CNR crossing. . Preliminary cost estimate of berm works $110,000 to $220,000	Grading would be within public lands.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority and City
10	Low	BC-1	Between Lake Avenue North and confluence with Stoney Creek.	• Do Nothing	Sanitary sewer is located on east bank.	Property flood protection berm to Regulatory standard at Blueberry Drive, Huckleberry Drive and southwest corner of Delewana Drive and Lake Avenue North. Preliminary cost estimate of $240,000 to $480,000.	Assessment required for flood storage and Regional Storm flood elevation impacts. Grading on private property required.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City
11	Low	SC-3	Between confluence with Battlefield Creek and Barton Street East.	• None identified		Localized flood protection berm to Regional storm standard for residential properties located immediately upstream of Queenston Road. Preliminary cost estimate of $85,000 to $170,000.	Grading would be within public lands.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority and City
12	Low	SC-1	Downstream of rail culvert	• None identified		Localized flood protection berm to Regional Storm standard for industrial properties. Upgrade the CNR crossing by either a supplemental culvert or replacement bridge to provide Regional Storm flood protection to industrial lands. Flow area required would be approximately 12 m by 3.5 m. Preliminary cost estimate of CNR works $1.5 Million to $2 Million. Berm works $140,000 to $280,000.	CNR crossing upgrade would remove industrial lands from the Regulatory floodplain upstream of the CNR to Barton Street.	• City of Hamilton or Hamilton Conservation Authority. • Detail Design • Approvals required from Hamilton Conservation Authority, City and potentially DFO, MNR and Coastguard

10. CONCLUSIONS AND RECOMMENDATIONS

10.1. Conclusions

1. Flooding impacts on private property occur mostly upstream of Queenston Road to downstream of King Street on both creeks. The main flooding mechanism for each creek relates to development encroachment into the floodplain, which limits the success of most flood mitigating alternatives.

2. Upstream of the Battlefield and Stoney Creek confluence, moderate to highly eroded conditions exist as a result of past creek straightening, development encroachment into the creek corridor, the confined nature of the valley systems and flow regime modification as a result of urban development.

3. The proposed stormwater quality retrofits (ref. Stoney Creek Water Quality Master Plan, 2004) would offer limited flow reduction for the most significant storm events and provide limited opportunity for erosion control.

4. Both creeks are highly spatially constrained, particularly immediately downstream of King Street, due to private development, resulting in limited opportunity for sustainable creek improvements in the short-term. Recommended erosion control works are therefore limited to localized measures.

5. Stoney Creek and Battlefield Creek do not have fish passage barriers but are limited as productive fisheries habitat due to low baseflow conditions.

10.2. Recommendations

1. Preferred flooding risk reduction measures include CNR Rail culvert upgrades and isolated flood proofing of private properties through the implementation of grading adjustments, bermed flood walls, and other forms of flood proofing.

2. Preferred erosion control alternatives in the short-term include localized bank stabilization, regrading and realignment.

3. Flood and erosion control land management practices should be considered should flood and erosion conditions worsen significantly and/or the community's view of creek management facilitates a change in management approach.

4. Erosion and flood protection works are to be implemented based on the priority sequence established in Table 9.5.1. Construction of the highest priority erosion and flood protection works has been set for 2012 based on detail design commencing in 2011.

5. Medium-term erosion control projects such as reach scale creek realignments should be considered subsequent to the short-term project completion in the 15 to 25 year timeframe.

6. Long-term flood and erosion control projects should be considered in the 25 year (+) time frame with consideration to changes to flood and erosion risk, City of Hamilton resources and social values regarding creek corridor management.

7. Fisheries habitat should be improved by the creation of sanctuary pools integrated with creek works.

8. To minimize debris jams resulting in creek bank erosion and /or localized flooding it is recommended that a Debris Management Plan be implemented for the Stoney Creek and Battlefield Creek watershed. A Debris Management Plan would facilitate regular inspection of all creek reaches to determine flooding issues such as debris accumulation and culvert blockages and the subsequent removal of each blockage. The Debris Management Plan would also facilitate observation of on-going or emerging erosion issues.

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