THE RED HILL VALLEY PROJECT
STORMWATER MANAGEMENT DESIGN

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ABSTRACT

The Red Hill Valley Project – Stormwater Management Design – Abstract

The City of Hamilton is recommencing the construction of one of the most controversial road projects in Ontario's history. The Red Hill Creek Expressway has been in various stages of planning, design and construction since the 1950's. Over 60% of this 20 km ring road is built and operating with the remaining 8 kms now underway after 10 years of political, fiscal, legal and aboriginal challenges. Among the many environmental improvements that have been made to the project in the last 6 years, is the stormwater management approach.

Starting with the development of a Watershed Plan for Red Hill Creek, the project team used this important initiative to develop an integrated solution that addresses the challenges of a degraded creek system, flood protection for the QEW/Expressway, water quality concerns of the Hamilton Harbour Remedial Action Plan, and respect for prominent ecological, cultural and recreational features found in the Valley.

The end result is a carefully designed and integrated stormwater management system that achieves the following objectives:

- treatment of runoff from all new pavement
- treatment of runoff from existing contaminant sources
- flood protection of the QEW and proposed Expressway
- balance of flow and sediment regimes for realigned watercourse
- enhancement of remnant creek zones

1. INTRODUCTION

This paper provides a summary of the impacts and associated mitigation, specifically related to stormwater management, of the proposed North-South section of the Red Hill Creek Expressway and the interchange connections at the Q.E.W. (including Burlington Street) on the surface water and stormwater quality of the Red Hill Creek.

2. BACKGROUND INFORMATION

The Red Hill Valley Project has had an extensive and controversial history. Over the years, stormwater management needs, requirements and design approaches for the expressway and valley system have changed, consistent with the changes in public and legislative directions. In 1985, as part of the Joint Board Decision (as modified by Cabinet Conditions of Approval), the size of channel works, culverts and on-line stormwater management systems was specified. Stormwater management at the time included the use of existing railway embankments to temporarily impound flood waters.

Subsequently, in 1989, a Drainage Study was prepared for the Mountain East-West and North-South Transportation Corridor (ref. Philips Planning and Engineering Limited, 1989). This report, and associated preliminary design, provided direction for addressing flooding and erosion potential within the valley/roadway system. The plan was premised on optimizing the size of drainage infrastructure (bridges, culverts, channels) through the use of distributed water quantity facilities. Three grade separations were constructed on the basis of this design at TH&B, King Street and Queenston Road (involving concrete-lined channels and bridges) and a headwater stormwater management (quantity only) was also constructed at the Dartnall Road Interchange (500,000 m^3 storage).

As stormwater management technology and related science evolved, so did the proposed measures for dealing with issues associated with the land use changes in the Red Hill Creek watershed. In 1996/7, a Watershed Planning process for the Red Hill Creek was initiated, culminating in an award-winning plan in 1998. This modern approach fully integrated land use and environmental planning along with impact mitigation. The resultant direction for stormwater management involved contemporary principles related not only to flooding and erosion management, but also water quality impact mitigation, natural channel design and combined sewer overflow management. The Watershed Plan continues to serve as the area's "roadmap" for responsible environmental management.

Ultimately in 2003, the City of Hamilton completed its "Impact Assessment and Design Process" for numerous disciplines, as required through the Ontario Ministry of the Environment. This process validated the current design of the roadway and associated valley projects using applicable legislation and standards. Stormwater management was specifically addressed in a report on Surface Water and Stormwater Quality (ref. Philips Engineering Ltd., April 2003), while natural channel treatment was addressed in a companion report (ref. Water Regime Investigations and Simulations Ltd., 2003).

3. GOVERNING POLICY AND PROJECT-SPECIFIC TARGETS

Government policy and legislation relating to control of surface water flow (flooding and erosion and water quality) is based on three primary sources:

- Riparian Law (Common Law)
- Statute Law and Regulations
- Site specific plans (Remedial Action Plans, Watershed Plans)

Riparian Law or Common Law provides the basic principles, which govern the rights and obligations of riparian landowners (landowners adjacent to watercourses).

Statute laws concerning surface water flow include Federal, Provincial and Municipal policies and regulations, which prescribe standards and approval requirements for construction of drainage works, restrictions on alteration to watercourses and floodplains, as well as restrictions on construction within flood susceptible areas.

Legislation related to water quality include Federal and Provincial standards and objectives for drinking water and surface water bodies (i.e. streams lakes ponds etc), Provincial guidelines for stormwater treatment. as well as Provincial regulations and Municipal by-laws, which govern the quality of effluent which is discharged to receiving water bodies.

Objectives and targets for the quality of runoff in the Red Hill Creek have also been set through the Hamilton Harbour Remedial Action Plan (RAP), as well as through the current Red Hill Creek - Watershed Plan.

The project-specific targets relating to the Red Hill Valley project associated with stormwater management include:

• Flooding	-	No increase in Regulatory Flood elevations (Hurricane Hazel).
	-	Highway not to flood during 100 year event.
• Erosion	-	Stream to be stable over the long term..
	-	Natural channel design principles to be adopted.
• Water Quality	-	Level 1 (Highest) Management Standards to be applied to roadway development.
	-	No net increase in contaminant loading to harbour.
• Fisheries	-	No net impact/net gain for fisheries habitat.

4. STUDY AREA

The Red Hill Creek Watershed encompasses an area of approximately 68 km^2. The watershed is located within the limits of the amalgamated City of Hamilton, draining lands within the former limits of the City of Hamilton, Township of Glanbrook and City of Stoney Creek (ref. Figure 1).

The Red Hill Creek Watershed exhibits a primarily urban land use, with development historically proceeding from the creek's outlet at Hamilton Harbour (Windermere Basin), southerly towards the headwater areas located above the Niagara Escarpment.

Approximately 60% of the watershed's land surface drains via urban sewer systems. Approximately 45% of the sewer systems within the Red Hill Creek Watershed are combined (storm and sanitary sewer systems). Urban developments within the former City of Hamilton limits typically feature direct connection of roof leaders to the storm sewer system, and hence a relatively high level of impervious areas are directly connected to the storm sewer system.

The remaining 40% of the watershed features "natural drainage" in which runoff has a greater opportunity to flow across pervious land surfaces to ditches and/or watercourses, which in turn discharge to the Red Hill Creek main branch and its tributaries. In some cases, drainage from open watercourses is conveyed through storm sewer systems or enclosures, prior to discharging to the Red Hill Creek.

5. IMPACT ASSESSMENT PROCESS AND RESULTS

5.1 Hydrologic Modelling

The HSP-F hydrologic model of the watershed, produced as part of the Watershed Plan, has been used to assess impacts and mitigation opportunities relating to surface water flow associated with the roadway development.

A primary focus of the hydrologic analysis for the Red Hill Creek Expressway and Q.E.W. Interchanges, has been the assessment and recommendation of a program of flood control facilities to reduce peak flow rates in key locations along the Red Hill Creek, in order to address existing flood potential at the Q.E.W. and future flood potential of the Expressway.

Previous analysis, confirmed by current assessment, indicates that optimal stormwater quantity control would be provided to the Q.E.W. and proposed Red Hill Creek Expressway through implementation of the existing Dartnall Road facility and two additional flood control facilities, one at Greenhill Avenue (just downstream of the Greenhill Combined Sewer Outfall) and one at Davis Creek (proposed at the existing Mount Albion/King Street access).

In order to define hydrologic impacts of the proposed North-South Expressway (i.e. without mitigation) on peak flow rates within the Red Hill Creek, an event based hydrologic assessment has been undertaken using the HSP-F simulation model.

5.2 Hydraulic Impact Assessment

Hydraulic models (HEC-2 and HEC-RAS) have been used to determine the flood levels of the Red Hill Creek and valley adjacent the Red Hill Creek Expressway, and at the Q.E.W. interchanges. This model has also been used to assess the benefits of various mitigation strategies, in terms of drainage infrastructure sizing. Predicted flood levels have been based on proposed culvert and bridge sizes required for flood conveyance to regulatory standards and stable stream morphology.

5.3 Results (Hydrology/Hydraulics)

Results of the hydrologic and hydraulic analysis provide direction on the potential impacts on:

- design flow rates
- runoff volume
- flood levels
- flood storage
- channel/floodplain velocities

Peak Flows

The analysis has demonstrated that Expressway impacts on peak flows would be entirely mitigated by the existing stormwater management facility at Dartnall Road, exclusive of any other "approved" or "considered" stormwater management facilities elsewhere within the watershed. Notwithstanding, additional stormwater quantity management opportunities have been considered to reduce flood elevations within the valley, and thereby further reduce the Expressway height and overall footprint, as well as reduce flood impacts on the Q.E.W.

Runoff Volume

An assessment of changes in annual runoff volumes, due to the proposed expressway has been undertaken based on the change in impervious coverage, associated with the expressway corridor. The changes in volume are provided in comparison to total runoff volumes for the Red Hill Creek Watershed.

TABLE 5.1
ANNUAL STORMWATER RUNOFF VOLUME (m^3)

Proposed Expressway Corridor Without Highway	Proposed Expressway Corridor with Highway	Remainder of Red Hill Creek Watershed	Net Difference (%) in Watershed (instream) runoff volume)
35,000	232,000	21,000,000	+1.1

The minor increase in runoff volume would be partially offset by the capture and storage of stormwater runoff in stormwater quality and erosion control facilities. The volume detained in these facilities would be released over the 24 to 48 hours following storm events, hence there would be essentially no adverse impact on hydrologic processes.

Flood Storage

Changes in floodplain storage have been calculated using the hydraulic model, which conservatively includes the maximum flood storage throughout the creek system including storage upstream of road crossings. Table 5.2 provides a summary of changes in flood storage for both mitigated and unmitigated conditions.

TABLE 5.2
COMPARISON OF FLOOD STORAGE WITH AND WITHOUT
RED HILL CREEK EXPRESSWAY

SURFACE WATER FLOOD STORAGE FOR REGULATORY FLOOD EVENTS (m^3)				
Location	Existing Valley Conditions		With Proposed Expressway in Valley	
	100 Year Storm	Regional Storm	100 Year Storm	Regional Storm
Brampton Street to upstream of TH&B	2,000,000	4,100,000	1,240,000	3,150,000

The reduction in floodplain storage with the expressway in-place is actually a direct function of the larger culvert openings proposed at major crossings. Natural storage is unlikely to be affected as equalization culverts across the highway are being provided to facilitate flood access to the whole of the floodplain. Additional storage will also be provided by floodplain grading associated with the creek works and stormwater management facilities, located largely on the east side of the proposed expressway.

Channel and Floodplain Velocities

Changes in channel and floodplain velocities have been determined for the Red Hill Creek based on average cross-sectional velocities calculated using the hydraulic model throughout each reach of the Red Hill Creek. Table 5.3 provides a summary of average channel and floodplain velocities under existing and proposed conditions.

TABLE 5.3
COMPARISON OF CHANNEL AND FLOODPLAIN VELOCITIES
WITH AND WITHOUT RED HILL CREEK EXPRESSWAY

SURFACE WATER, STREAM CHANNEL AND FLOODPLAIN VELOCITIES									
Location	Event Return Period (Years)	Flow Range (m^3/s)		Channel and Floodplain Velocities (m/s)					
				Existing			Proposed		
		Existing	Proposed	Channel	Flood Plain	Mean	Channel	Flood Plain	Mean
From 700 m d/s of CNR to 700 m u/s of TH&B	1	16 - 20	20 - 28	1.63	0.09	1.61	1.8	0.30	1.29
	10	78 - 105	54 - 70	1.71	0.15	1.30	2.33	0.46	1.50
	100	122 - 172	75 - 101	1.98	0.21	1.30	2.48	0.47	1.56

Floodplain and creek velocities generally increase due in part to upgraded culvert and bridge crossings, as well as a more hydraulically efficient creek section, in its realigned form. The realigned channel, however, would be inherently more stable and more resistant to these minor increases in velocity, due to the application of natural channel design principles (WRIS, 2003). The natural channel design has adopted the velocities set out above.

Flood Levels

Implementation of the proposed surface water quantity mitigation measures would typically reduce 100 year and Regional storm event flood levels throughout the majority of the Red Hill Creek. This is primarily due to the provision of larger bridge openings, which improve hydraulics, and is also due to the existing and proposed flood control facilities at Dartnall, Greenhill and Davis Creek that reduce peak flow rates in the downstream reaches of the Red Hill Creek.

The proposed mitigation measures would provide flood protection to the Red Hill Creek Expressway up to 100 year storm conditions with isolated violations of the 1.0 m freeboard/clearance standards. Providing flood protection to the 100 year storm event standard, as is proposed (through upstream flood control storage), is similar to the Provincial Standard used for 400 series highways.

The Expressway would remain susceptible to flooding and damage under a Regional storm event; notwithstanding the low probability of occurrence, damage to the expressway may be significant during such an event. Potential for flood damage under Regional Storm conditions is common to many public roadways, which cross, or are located adjacent to, watercourses. Primary mitigation for potential impacts associated with a Regional Storm event would include a flood contingency plan to allow co-ordinated closure and evacuation of the expressway.

5.4 Stormwater Quality Impacts

The source of in-stream water quality impairment within the Red Hill Creek is, to a large extent, due to inputs from the surrounding land use, rather than from sources within the Red Hill Creek Valley. Notwithstanding, highway runoff typically contains suspended sediments, heavy metals, nutrients, hydrocarbons and polycyclic aromatic hydrocarbons (PAH's), de-icing agents as well as bacteria and other pollutants. Therefore, runoff from the North-South Expressway and Q.E.W. Interchanges would be expected to exhibit a higher concentration of these pollutants than the current open space land use within the Red Hill Creek Valley and other open space areas. Pollutant loading from highways is generally derived from the following sources:

- Vehicle Inputs
  - direct vehicle inputs (emissions and frictional parts wear)
  - indirect vehicle inputs (particles which accumulate on vehicle and are washed off, often during storm events)

- Atmospheric Deposition
  - dustfall (airborne particles deposited on highway during dry weather)
  - precipitation (airborne particles within rainfall)

In addition, the type of drainage system used in the highway design can also effect pollutant contributions. The total pollutant loading from the Red Hill Creek Expressway and Q.E.W. Interchanges would therefore be dependent on a number of factors including: traffic volume, highway drainage system design and precipitation characteristics.

The base mass balance model prepared as part of the Red Hill Creek Watershed Plan has been modified for use in this assessment to predict impacts of the Project.

Pollutant loading estimates, due to the Red Hill Creek Expressway (North-South section) and Q.E.W. Interchanges, have been obtained by modifying the existing land use base model to reflect changes in land use, (hence hydrologic response), as well as changes to Event Mean Concentrations (EMC's) for various contaminants, to reflect pollutant contributions from the proposed highway surfaces.

Table 5.4 provides a summary of annual pollutant loading (without mitigation) due to the proposed Project.. It should be noted that the assessment has conservatively assumed that there would be no complementary reduction in contaminant loading due to reduced traffic on other roadways within the watershed resulting from the construction of the expressway.

TABLE 5.4
SUMMARY OF PREDICTED ANNUAL POLLUTANT LOADING

Parameter	Annual Pollutant Loading (kg/yr)		Net Change in Pollutant Loading Without Mitigation (%)
	Existing Land Use	Existing Land Use With Expressway (Without Mitigation)	
BOD_5	127 085	134 919	6.2
Cu	375	419	11.7
F.C. [1.]	5.036×10^{15}	5.039×10^{15}	0.1
PAH	17.40	18.15	4.3
TP	4340	4466	2.9
TSS	2 094 406	2 139 021	2.1
Zinc	2823	2934	3.9

[1.] Units for F. Coliforms Total Counts/Year

6. SUMMARY OF MITIGATION AND MANAGEMENT WORKS

6.1 Flood and Erosion Control

Stormwater Management (Quantity)

Control of stormwater quantity (flooding) is primarily focussed on control of infrequent storm events, which typically exhibit extremely high peak flow rates and runoff volumes. In the watershed context, it is necessary to control flows not from the expressway, but rather from the developed and yet to be developed, subwatersheds with a focus on protecting the future expressway and existing Q.E.W.

A range of SWM facility combinations has been evaluated as part of the Impact Assessment and Design Process. Based on the discrete event analysis, the preferred combination of Dartnall, Greenhill and Davis facilities has been adopted. The total storage provided at these sites has resulted in reducing the peak 100 year flow rate to approximately 106 m^3/s at the Q.E.W.

The proposed Greenhill Stormwater Quantity Management facility design has been significantly altered from the approach considered in the Watershed Plan, to improve the compatibility of the proposed stormwater management facility with stream forming processes. Specifically, the alterations have involved a re-design of the facility to operate as a "pseudo off-line" facility rather than the previously advanced on-line configuration. These changes to the operational characteristics of the facility promote sediment transport through the facility during storm events, as required to preserve natural fluvial processes in the Red Hill Creek during operation of the SWM facility, while managing downstream flows to the required control level.

Mainline Hydraulic Crossings

The size of bridges and culverts, which cross the Red Hill Creek, affects a range of issues including:

- Upstream flood levels
- Stream flow velocity and channel erosion/stability
- Fish passage
- Recreational Access
- Wildlife movement

Hence, the sizing of bridge and culvert structures is based on achieving size requirements for each of these issues. Ultimately, the design of each crossing structure size has been based on a composite of each of these issues.

Equalization Culverts

A unique aspect of the design of the Red Hill Creek Expressway has included culverts across the roadway at strategic locations and elevations to allow floodwaters 'free' access to the valley storage on both sides of the expressway. The purpose of these systems is to avoid the circumstance whereby flooding would occur on the west side of the expressway while the east side would essentially have an area of under-utilized storage. Hence, these culverts will equalize flood elevations on both sides of the expressway.

Natural Channel Design

A fundamental component of the Red Hill Valley Project involves the realignment and restoration of approximately 7 km of the Red Hill Creek. The stream system has, over the years, become degraded due to high flows and contaminated runoff. The design proposes to re-instate the watercourse through a dynamically stable stream cross-section and alignment, compatible with the future managed runoff, expressway alignment and physical properties of the valley.

6.2 Stormwater Quality

Stormwater quality management criteria, typically applied to highway projects, are based on managing the water quality impacts from new pavement or impervious areas, in accordance with Ministry of Environment and Ministry of Transportation Policies. Typically, stormwater management facilities are sized to provide water quality performance commensurate with the sensitivity and value of the aquatic habitat of the receiving watercourse. The maximum pollutant removal efficiency of stormwater management practices ranges from 50-90% depending on the specific pollutant constituent and the specific practise.

Based on the current "stressed" condition of the Red Hill Creek, and objectives of initiatives such as the Hamilton Harbour Remedial Action Plan (RAP), and Red Hill Creek Watershed Plan, the stormwater quality mitigation criteria which has been established for the Red Hill Creek Expressway and Q.E.W. Interchange is more stringent than typically applied to highway/development projects. Specifically, the Federal Department of Environment and Provincial Agencies have indicated the Expressway project should result in no further degradation of in-stream water quality.

Stormwater Management (Quality)

Based on the limitations in pollutant removal performance of stormwater management facilities (i.e. maximum removal 50-90%), mitigation for stormwater quality must focus on providing treatment to existing developed lands, as well as new pavement areas, such that no net increase, and where possible a net reduction in pollutant loading, is achieved.

Constructed wetlands, wet ponds, grassed swales and buffer/filter strips have been determined to be the most appropriate stormwater management practices for this section of the project (ref. Figure 4 and Figure 5).

The location of stormwater management facilities (i.e. wetlands and wet ponds) has been based on the following factors:

- Size of expressway or interchange drainage area that can be conveyed to each location. A minimum drainage area of 3 - 5 hectares is typically required to sustain a stormwater wetland.

- Expressway grading; wherever possible, facilities have been proposed within interchange loops and along the inner side (low side) of super-elevated sections.

- Remnant channel locations (i.e. where re-alignment of the creek channel is required the remnant have been considered for stormwater management). Use of these locations for stormwater management has benefits relating to minimizing requirements for grading, maintaining soil moisture conditions along the remnant channel banks, and opportunities to treat runoff from existing development where existing stormwater outfalls drain to these channel sections.

- Preservation of natural habitat; wherever possible facilities would be located to minimize impact on valued aquatic and terrestrial habitats.

- Location with respect to the Red Hill Creek channel and floodplain; wherever possible proposed stormwater management facilities have been proposed to be located outside of the Red Hill Creek channel and floodplain (i.e. on the opposite side of the expressway embankment). These locations would be less susceptible to stream induced flooding and hence would be less susceptible to re-suspension of pollutants during storm events.

Spill Mitigation

The proposed stormwater management facilities would also provide a measure of protection against accidental spills, whereby contaminants may be captured by the local storm sewer collection system and contained with the storm water management facility. The effectiveness of the proposed stormwater management facilities to capture accidental spills would to a large extent depend on the location of the accident and the materials involved. Stormwater Management facilities have incorporated spill management features into the facility design, including:

- submerged culverts with shut-off
- shut-off in outlet pipes
- perimeter swales to collect spills
- Goss traps in catchbasins
- oil/grit separators

CSO Works

A component of the works planned to improve the instream water quality includes the provision of a combined sewer overflow management system. Historically, Hamilton's combined sewer system overflows over 20 times into the Red Hill Creek in a typical year at 3 or 4 defined locations. In order to reduce the frequency and magnitude of these overflows, comprised of a mixture of storm runoff and untreated sanitary waste, a storage system has been proposed.

A storage tunnel has been proposed to intercept overflows and store the excess untreated runoff during the storm, and then post-storm, direct the runoff to the sewage treatment plant for treatment. This system is predicted to reduce the frequency of overflows to less than twice a year.

7. NEXT STEPS

The Red Hill Valley Project was initiated in 2003 with construction involving grade separations and structural work at CNR, Greenhill Avenue and Mud Street Interchange. In 2004, the major valley work involving creek realignment and highway corridor works, has been tendered and awarded. Construction on the Expressway and QEW interchanges is expected to be complete late 2007.

The stormwater management works will, during construction, also serve to protect the ecosystem from erosion and sediment. Once complete, the stormwater management system, including the creek system, will be monitored for a 10-year period, in accordance with permitting requirements of DFO and other environmental agencies. Adaptive management principles will be applied to ensure that the system continues to function as intended to reach the desired management targets.

8. REFERENCES

Aquafor Beech Ltd., *"Class EA: Red Hill Creek CSO control, ESR Draft Report"* Prepared for the Regional Municipality of Hamilton-Wentworth, 1997

C. Portt and Associates, *"Red Hill Creek Expressway Impact Assessment and Design Process Fisheries Existing Conditions and Predicted Impact Submission to the Department of Fisheries and Oceans. The Red Hill Creek Expressway (North South Section),"* 2002

Ministry of Environment and Energy (MOEE), *"Water Management Policies, Guidelines, Provincial Water Quality Objectives",* 1994

Philips Planning and Engineering Ltd. *"Opportunities for Management of Stormwater (Quantity and Quality), Streams and Groundwater - Red Hill Creek Watershed Plan",* January 1998

Philips Planning and Engineering*, "Mountain East-West and North-South Transportation Corridor - Drainage Study - Final Report"* - July 1989

Regional Municipality of Hamilton-Wentworth, *"First Generation Plan- Red Hill Creek Watershed Action Plan- Final Draft"*, April 1998

Regional Municipality of Hamilton-Wentworth, *"State of the Watershed Report, Red Hill Creek Watershed Planning"*, October 1997

Regional Municipality of Hamilton-Wentworth *"Exemption Order, Red Hill Creek Expressway North-South Section"*, May 1996

WRIS (Water Regime Investigations and Simulations Ltd.), *"A Stream Network Inventory, Fluvial Geomorphologic Assessment, Impact Assessment, And Preliminary Natural Channel Design of Red Hill Creek, Vol. 1 of 2"*, Prepared for The City of Hamilton, May 2002

WRIS, *"A Stream Network Inventory, Fluvial Geomorphologic Assessment, Impact Assessment, And Preliminary Natural Channel Design of Red Hill Creek, Vol. 2 of 2"*, Prepared for The City of Hamilton, May 2002

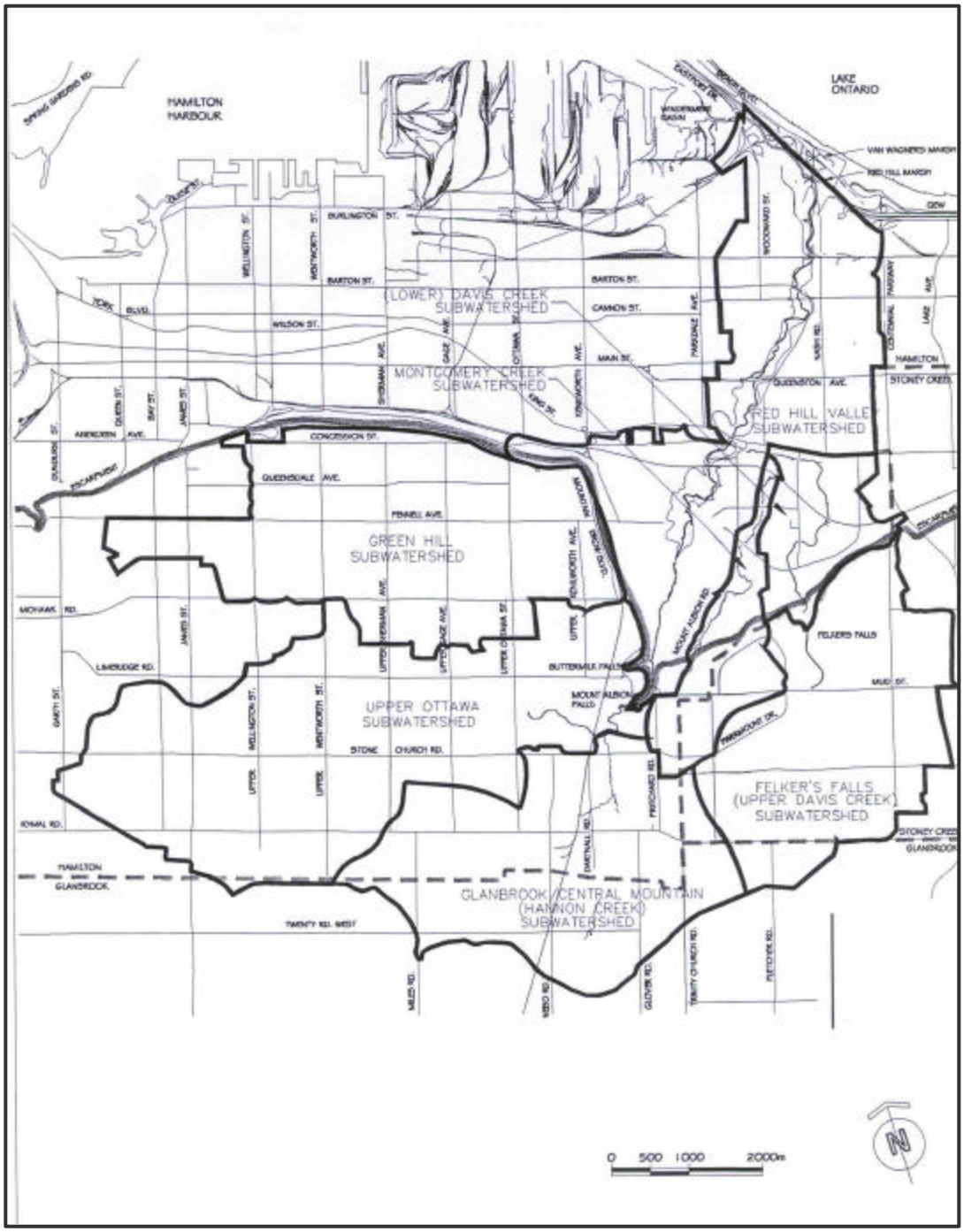

Figure 1—Red Hill Watershed and Subwatershed Location Plan

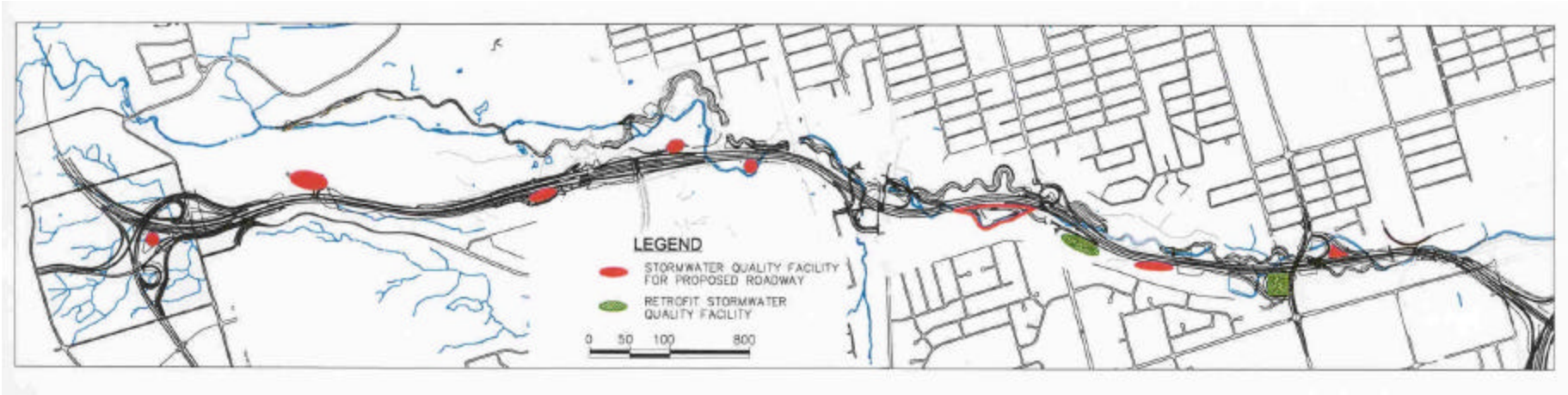

Figure 2—Stormwater Quality Control Facilities for North-South Transportation Corridor

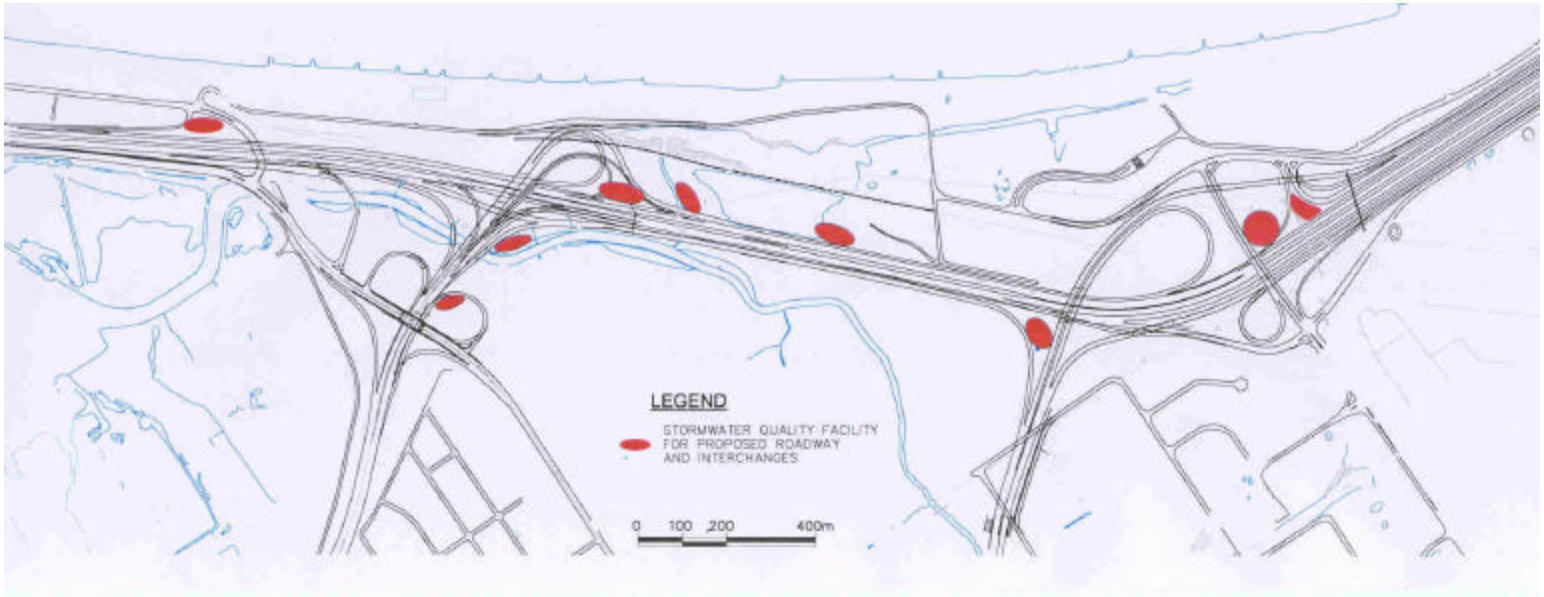

Figure 3—Stormwater Quality Control Facilities for Interchanges