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INNOVATIVE STORMWATER SOURCE CONTROL POLICY FOR INDUSTRIAL, COMMERCIAL AND INSTITUTIONAL LAND USES

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Submitted to:
City of Hamilton
Hamilton, Ontario

Submitted by:
AMEC Environment & Infrastructure
a division of AMEC Americas Limited
3215 North Service Road
Burlington, ON L7N 3G2

Tel: 905-335-2353
Fax: 905-335-1414

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TABLE OF CONTENTS

Section **Page No.**

1. INTRODUCTION 1
1.1 Description of City of Hamilton 1
1.2 Evolution of Stormwater Management Practices 2
1.2.1 Technical and Functional Criteria 2
1.2.2 Source Control Criteria and Guidelines Within Ontario 3
1.2.3 City of Hamilton Storm Drainage Policies and Guidelines 4
1.3 Innovative Source Control Concept 4

2. CITY OF HAMILTON STORMWATER MANAGEMENT POLICY 5
2.1 Storm Drainage Policy 5
2.1.1 Goals and Objectives 5
2.1.2 Legislative Framework and Planning Process 5
2.1.3 Current Policy Regarding Source Controls 6
2.2 Innovative Stormwater Source Control Policy 7
2.2.1 Relation to Stormwater Drainage Policy 7
2.2.2 Goals and Objectives 7
2.3 Other Policies 8

3. FUNCTIONAL BENEFITS OF INNOVATIVE SOURCE CONTROL PRACTICES 9

4. PREFERRED SOURCE CONTROL PRACTICES WITHIN CITY OF HAMILTON 10

5. DESIGN CRITERIA AND GUIDELINES 12
5.1 Design Criteria 12
5.2 Design Guidelines 17

6. PLANNING PROCESS 18
6.1 Stormwater Management Planning Process 18
6.2 Stormwater Management Planning Principles 19
6.2.1 Practices in Public Spaces 19
6.2.2 Practices on Private Properties 20

7. METHODS FOR EVALUATING REQUIREMENTS AND EFFECTIVENESS 21
7.1 Analytical Methods 21
7.2 Monitoring 21

8. ECONOMIC CONSIDERATIONS 22
8.1 Construction Cost Estimates 22
8.2 Operation and Maintenance Cost Estimates 22
8.3 Potential Development Charge Credits 22

9. REQUIREMENTS FOR REVIEW OF ENGINEERING SUBMISSIONS 23
9.1 Submission Requirements at Planning Stage 23
9.2 Submission Requirements at Detailed Design Stage 24

Draft

List of Tables

Table 4.1 Preferred Stormwater Source Control Practices Within the City of Hamilton for Industrial, Commercial, and Institutional Land Uses
Table 4.2 Stormwater Management Function Provided by Preferred Stormwater Source Control Practice
Table 5.1 Summary of Criteria for the Planning and Design of Stormwater Source Controls for IC&I Land Uses

List of Appendices

Appendix A - Assessment of Using LID for Infiltrating Urban Runoff (Farrell/Scheckenberger, November 2009)

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1. INTRODUCTION

The City of Hamilton (ref. Figure 1), has established this Innovative Stormwater Source Control Policy for use in the planning and design process specifically related to Industrial, Commercial, and Institutional land uses.

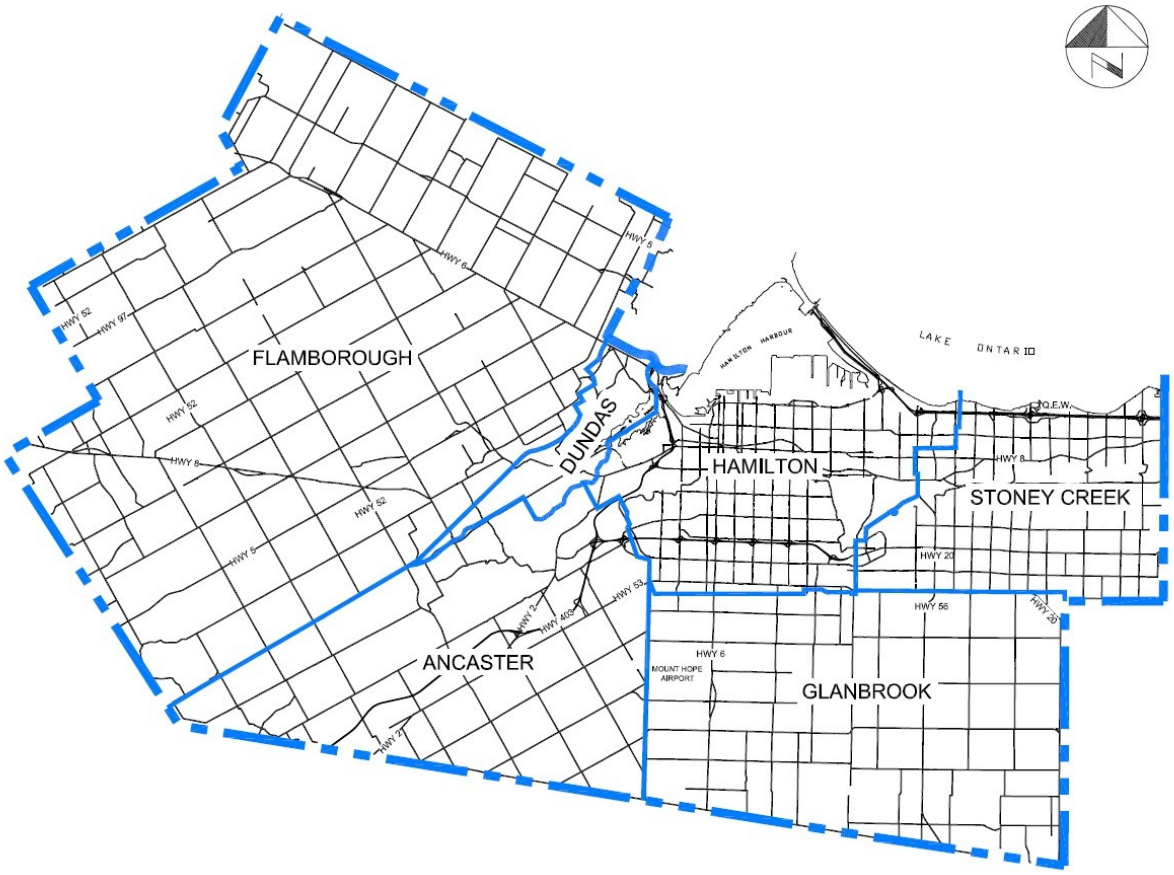

Figure 1

1.1 Description of City of Hamilton

The City of Hamilton is situated at the westerly extent of Lake Ontario. The City spans across 1120 km^2 (+/-), which mostly drains to Hamilton Harbour and Lake Ontario through various watercourses and viaducts.

The City's origins date back to the mid 1700's. Most of the early development within the City was located in Dundas and along the southern shore of Hamilton Harbour. Residential development within the City saw significant growth in the 1970 – 1980 era to those areas of Stoney Creek and Ancaster. Since 1990 to present times, growth has continued in the Hamilton Mountain area, as well the outlying communities. As of 2011, the population of the City of Hamilton was approximately 520,000 (source: Stats Canada, June 2012).

As identified in the companion document, City of Hamilton Storm Drainage Policy (May 2004) the City is rich in natural resources including:

- Cootes Paradise
- Hamilton Harbour
- Niagara Escarpment
- Beverly Swamp
- Eramosa Karst
- Several waterfalls, including: Grindstone, Borer's, Tews, Websters, Sherman, Tiffany, Chedoke, Buttermilk, Albion, Felker's and Devil's Punch Bowl.
- Several Conservation Areas

The 1120 km^2 (+/-) that comprises the City of Hamilton municipal boundary is characterized by urban and rural development and spans across four (4) conservation authorities: Hamilton Conservation Authority, Grand River Conservation Authority, Niagara Conservation Authority, and Conservation Halton.

1.2 Evolution of Stormwater Management Practices

1.2.1 Technical and Functional Criteria

Urbanization is recognized to increase the amount of impervious surfaces within the landscape through the construction of rooftops and paved surfaces (i.e. roads, sidewalks, patios, etc.) compared to non-urban land uses. Hydrologically, this increase in impervious surface is recognized to produce a corresponding increase to both the volume (i.e. amount) and speed (i.e. rate or flow) of runoff compared to the pre-developed (i.e. rural or non-urban) land use condition. In addition, it was similarly recognized that urbanization tended to increase the concentration and mass of certain contaminants and water quality indicators, particularly heavy metals, compared to the pre-developed land use condition.

Original practices related to stormwater management system design focused upon conveyance of the additional runoff resulting from urbanization. The conveyance system typically focused upon subsurface conveyance (i.e. storm sewers or combined sewers) before the 1950's. Following the 1950's, and in the wake of Hurricane Hazel, dedicated stormwater conveyance infrastructure was further emphasized in design.

In the 1970's, it was recognized that flooding continued to occur during formative events, despite the construction of dedicated conveyance infrastructure. Consequently, stormwater management practices were revised to include the construction of stormwater management infrastructure to provide detention storage for flood control. This approach required that under the urban land use condition, peak flows would be controlled to pre-development levels, thereby mitigating any potential increase to flood risk as a result of the urban development. In many instances, these stormwater management flood control and conveyance systems were constructed off-site from development areas, and thus addressed stormwater management requirements for larger drainage areas.

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In the late 1980's and 1990's there was a broadened focus on quality and erosion control for stormwater management practices and systems designs, in order to mitigate the impacts of storm runoff to the aquatic ecosystems. The stormwater management system design practices continued to include "end-of-pipe" solutions (i.e. providing the requisite stormwater management at the storm sewer outlet to the receiving system). However, the additional requirement to provide stormwater quality control recognized the benefits of a "treatment train" approach whereby stormwater quality enhancements would be provided at all points between the runoff source (i.e. the impermeable surface) and the ultimate receiver (i.e. the receiving watercourse). This approach shifted the focus from providing stormwater quality control solely at the end-of-pipe to providing stormwater quality control at all locations between the source and the receiver, and hence introduced the notion of "source controls". This notion of "source controls" extended beyond technologies and techniques to provide stormwater quality control, and included "source controls" for stormwater quantity controls.

Following the turn of the century (and millennium), stormwater management practices entered the next stage in the evolutionary process. This new focus explored opportunities to mitigate the increased runoff volume generated from the conversion of non-urban land uses to urban land use. A variety of approaches were introduced, which ranged from an interception and retention of stormwater to intercepting and detaining runoff for evaporation to intercepting and infiltrating runoff for groundwater recharge. This new approach toward managing storm runoff recognized that the space provided within the conventionally designed end-of-pipe facility was insufficient to provide any appreciable benefit toward reducing the increased runoff volume. Consequently, this new approach further emphasized the source control strategy for stormwater management system design.

1.2.2 Source Control Criteria and Guidelines Within Ontario

In 1991, the Ontario Ministry of Environment and Energy and Ministry of Natural Resources formally required quality treatment of stormwater and in 1994, the MOE issued the first Stormwater Management Planning and Design Manual. This document provided practitioners with clear guidelines regarding the criteria and standards for the design of stormwater management facilities for stormwater quality control, including the design of source controls to address the new Provincial requirements for stormwater quality control. The Ministry of the Environment's planning and Design Manual was updated most recently in 2003 and it has integrated some of the advancements in stormwater management since the 1994 version.

In 2010, Credit Valley Conservation (CVC) and Toronto Region Conservation Authority (TRCA) developed the LID SWM Planning and Design Guide with funding assistance from MOE. This document has become a key source of information for designers to integrate lot level LID practices into their stormwater management designs, and includes stormwater source control practices which are not currently included within the Provincial Guidelines as established by the Ontario Ministry of the Environment. Although this document has not been developed by any Provincial Ministry, it currently represents the most encompassing document in Southern Ontario for LID source controls and has thus been referenced and applied in areas of the Province which are outside of the CVC and TRCA jurisdiction.

1.2.3 City of Hamilton Storm Drainage Policies and Guidelines

The City of Hamilton current stormwater policy is provided in the Storm Drainage Policy (Philips Engineering Ltd., May 2004). The policy outlines storm drainage policy to be applied within the City of Hamilton, specifically storm drainage requirements to be applied to all new land development, re-development of existing lands, as well as the City of Hamilton Capital Works projects, where appropriate, for storm sewer system extensions and for reconstructions of existing infrastructure. Furthermore, the policy specifies requirements for storm drainage design and reporting at various stages of the land development process and provides reference and context to applicable federal, provincial, and Municipal polices and regulations which much be considered when planning or designing storm drainage systems.

Design criteria for stormwater infrastructure within the City of Hamilton is provided in the City's Criteria and Guidelines for Stormwater Infrastructure Design (Philips Engineering Ltd., September 2007). This document is a companion component to the City of Hamilton Storm Drainage Policy and is generally used by industry practitioners undertaking the detailed design or review of proposed stormwater management infrastructure.

The current stormwater management policies and guidelines for the City of Hamilton have been developed in accordance with the governing Provincial and Federal legislative requirements for the planning and design of stormwater management infrastructure. The policies and criteria were also developed to address the specific requirements and constraints across the City of Hamilton. The current policies and stormwater management guidelines within the City of Hamilton address the requirements to mitigate the increased flood risk and erosion potential resulting from urbanization, as well as the reduced quality of runoff associated with urbanization. This includes the application of source controls to achieve these objectives.

1.3 Innovative Source Control Concept

In general, innovative source controls are those stormwater management strategies and technologies which may be applied at source and which achieve a standard of stormwater management beyond the current Provincial and Federal legislative requirements. Specifically regarding the requirements of the City of Hamilton, these types of source controls would:

- Reduce the peak flow and/or runoff volume from proposed redevelopment areas compared to existing conditions or developments to the same land use condition in a similar hydrologic setting (i.e. similar soil infiltration rates, site slopes, etc.).
- Reduce the peak flow and/or runoff volume from proposed infill or greenfield development areas compared to developments to the same land use condition in a similar hydrologic setting.
- Provide an enhanced reduction to the erosion potential within the receiving watercourse above that which would be required based upon the governing criteria for the subject area.
- Improve the quality of storm runoff beyond that which would be required in accordance with current Provincial standards.

2. CITY OF HAMILTON STORMWATER MANAGEMENT POLICY

2.1 Storm Drainage Policy

2.1.1 Goals and Objectives

The goals and objectives of the current City of Hamilton storm drainage policy are:

i) Provide present and future residents of the City of Hamilton with good engineering design that provides a high quality of living environment that protects and enhances natural features and minimizes pollution of water, air and land resources.

ii) Minimize risk of life and property from flooding and erosion.

iii) Encourage the use of stormwater as a resource such that it maintains and/or enhances:

- In-stream Water Quality
- Fisheries and Aquatic Habitat
- Hydrogeologic Function (i.e. baseflow, groundwater quality)
- Natural Channel Forming Processes (stream morphology)
- Terrestrial Linkages and Habitat

iv) Mitigate negative impacts to water resources, which would affect other riparian interests and users.

v) Provide direction for designs of stormwater infrastructure which are easily and effectively maintainable by the City's Public Works Department.

vi) Establish criteria for acceptable service levels for the hydraulic capacity of both the minor and major drainage systems to provide reasonable levels of service for the connected property owners.

2.1.2 Legislative Framework and Planning Process

A detailed discussion of the current Federal, Provincial, Regional, and Municipal policies, guidelines and legislation governing stormwater management and valley systems and watercourses is provided in Section 2 of the City of Hamilton Storm Drainage Policy (Philips Engineering Ltd., May 2004). The main legislative vehicles for the planning and design of source controls and stormwater management infrastructure are:

- The Environmental Assessment Act (Municipal Class Environmental Assessment Process)
- The Planning Act
- The Ontario Water Resources Act (Stormwater Management Planning and Design Manual, MOE, March 2003)
- MOE Exemption Regulation 525-98

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- Infiltration facility is constructed above the water table in order to avoid groundwater interaction; hence, the infiltrated discharge rate for the infiltration facility is calculated as:

$$Q = (i \times A)/3600000 \qquad \text{(Equation 2)}$$

where

Q = infiltrated discharge rate from the infiltration facility (m^3/s)

i = infiltration capacity of the native soil surrounding the infiltration facility (mm/hr)

A = surface area of the granular matrix (m^2)

Based upon a review of available design standards for various infiltration technologies, a depth of 0.4 m was assumed as the appropriate depth of the granular matrix since this was noted to represent the minimum depth of the granular matrix of all the infiltration technologies. As well, a void ratio of 0.3 has been assumed, which is representative of the voids associated with the application of a granular medium.

In many jurisdictions, the storage volume of infiltration facilities is determined based upon a prescribed volume of runoff which is to be captured within the storage matrix and infiltrated into the surrounding soil. This capture volume is typically defined as a depth of water (in mm or inches); hence, the requisite capture volume is the product of this target depth and the size (area) of the contributing drainage area. Recognizing that volume is a prescribed target, Equation 1 can be rearranged to calculate the surface area of the granular matrix based upon the remaining known variables as follows:

$$A = V/(n \times d) \qquad \text{(Equation 3)}$$

When Equation 3 is substituted for A in Equation 2, then the discharge rate from the infiltration facility can be calculated as a function of the target volume and dimensions of the generic infiltration facility (i.e. n and d) as follows:

$$Q = (i \times V)/(n \times d \times 3600000) \qquad \text{(Equation 4)}$$

The foregoing approach toward determining the storage-discharge relationship for the generic infiltration facility, in combination with the modelling technique developed under the Flow Management Study for simulating LID practices at the Subwatershed scale, provides a means for efficiently assessing a broader suite of hydrologic impacts associated with generic LID practices (i.e. water balance, erosion, flood risk) at the Subwatershed Study level. This approach then provides guidance for subsequent studies with respect to specific requirements for LID BMP's in order to meet Subwatershed scale targets and objectives for environmental systems management.

Case Study

In order to demonstrate the function and performance of the proposed approach for simulating LID infiltration functions at the Subwatershed Scale, the methodology described earlier has been applied to a conceptual development area within the Huttonville Creek Subwatershed of the Credit River Watershed (ref. Figure 5). The Huttonville Creek Subwatershed measures some 12.6 km^2, and the conceptual development area measures some 7.0 km^2. Soils within the study area are prominently fractured Halton Till, which exhibits relatively high runoff volume and response, particularly under saturated conditions. In general, these soils exhibit a relatively low infiltration capacity. The land use conditions within the study area are currently predominantly

agricultural, with some isolated areas of forest cover scattered throughout the proposed development area.

Hydrologic analyses for the Huttonville Creek Subwatershed have been completed using the HSP-F hydrologic model which was originally developed for the Credit River Flow Management Study. The original FMS model was refined within the limits of the Subwatershed to include 35 catchments ranging from 5.74 ha to 206.5 ha in size, as well as 29 channel routing elements, and calibrated using local meteorological and flow data. The calibration of the original model included calibration of snow accumulation and melt parameters; the model refinements thus included a validation of the simulated results for snow accumulation and melt within the original parent HSP-F model.

In addition to the foregoing, the development of the HSP-F hydrologic model for the study area included the validation and integration of simulated groundwater recharge values with calibrated values obtained using a FEFLOW groundwater model of the study area. The development of the HSP-F hydrologic model thus incorporated a more rigorous calibration process for the simulation of the subsurface regime, and hence represents a more reliable tool for evaluating the associated impacts resulting from proposed changes in land use conditions and the application of various stormwater management processes.

The hydrologic analyses for the study area were completed using a 40 year continuous simulation using hourly precipitation, temperature and dew point data, and daily evaporation, solar radiation and wind movement data. Flow rates to the receiving surface water system were generated at 15 minute timesteps. In addition, the HSP-F model was executed in order to

generate groundwater recharge rates at 15 minute timesteps for the same period of record, for the water balance assessment.

Development of LID Routing Elements

The methodology described in the previous section has been used in order to develop the routing elements to represent the associated infiltration technologies. The infiltration targets were established based upon consultation with the Technical Steering Committee for the project. Initial target rates were established recognizing the limited infiltration capacity of the soils, and primarily predicated upon maintaining the existing water balance to the extent possible; these rates were subsequently modified to account for the anticipated loss of efficiency which would occur over time, as a result of lack of maintenance. Through this consultation, effective capture rates for the given soils conditions ranged from capture volumes of 1 mm/impervious hectare to 4 mm/impervious hectare, depending upon the contributing land use condition. Hence the storage values for the LID routing elements for the respective subcatchments were calculated using the following equation:

$$V_s = \Sigma(V_i \times A_{s,i}) \qquad \text{(Equation 5)}$$

where

V_s = total storage volume available within generic LID infiltration facilities for Subcatchment s (m^3)

V_i = storage volume available within generic LID infiltration facility for Land Use i, as calculated using Equation 1 above and the target rates established by the Technical Steering Committee (m^3/ha)

$A_{s,i}$ = total area of Land Use i within Subcatchment s (ha)

Once the value of V_s was determined for each subcatchment, the corresponding discharge rate for the generic LID facility for the respective subcatchment was calculated using the calibrated infiltration rate for the soils, and Equation 4 above.

The discharge rates for the respective subcatchments were determined using Equation 4, using the storage values calculated as described in the foregoing, and using the calibrated infiltration rates for the subcatchment.

Simulated Water Balance

A water balance assessment was completed for the calibrated HSP-F hydrologic model for existing land use conditions, future land use conditions with conventional end-of-pipe stormwater management, and future land use conditions with LID BMP's. The hydrologic model for future land use conditions with conventional stormwater management was modified in accordance with the methodology described above as follows:

- Model schematic was modified so that the operation sequence for each catchment representing sites of future development corresponded to the schematic provided in Figure 3 (i.e. within the OPN SEQUENCE and NETWORK blocks).

- Storage-discharge relationships for the routing elements representing the LID infiltration systems were incorporated into the model (i.e. within the FTABLES block)

A water balance was calculated for each of the three land use and management scenarios in order to determine the relative effectiveness of LID practices with respect to promoting groundwater recharge and maintaining water balance within the Huttonville Creek Subwatershed. The Water Balance Assessment was completed using the following approach:

- Simulated surface runoff volume for all three scenarios was generated as the sum of the direct surface runoff component and the interflow component for the pervious land segments (i.e. groundwater outflow to the surface water systems was not included as surface runoff).

- Simulated groundwater recharge was generated as a separate simulation for all three land use scenarios.

- Evapotranspiration was calculated for each of the three scenarios using the empirical relationship

  [Total Precipitation] = [Surface Runoff Volume] + [Groundwater Recharge Volume] + [Evapotranspiration Volume]

  and applying an average annual total precipitation of 780 mm based upon the 40 year record.

The results of this assessment are presented graphically in Figure 6.

The results of the water balance assessment, using the methodology described herein, indicate that the application of LID practices would increase the recharge to the groundwater regime compared to conventional stormwater management practices. This is consistent with anticipated results for these systems. The results, however, also indicate that the application of LID practices would result in higher evapotranspiration rates compared to the application of conventional stormwater management practices, and that the majority of the surface runoff which would be captured by the infiltration facilities through the application of LID practices would be lost to evapotranspiration as opposed to infiltrating into the underlying soil. This is considered plausible, given the relatively low infiltration rates associated with the fractured Halton Till, as well as the potential for water to evaporate from the granular matrix within the infiltration facility.

Erosion Assessment

Conventional practice for providing erosion control for future development areas consists of increasing the storage volume and drawdown time for the extended detention storage component of the stormwater management facility, in order to reduce the duration of flows above a pre-determined threshold flow rate within the receiving water course. The threshold flow rate represents the minimum erosive flow rate within at the critical (i.e. most erosion prone) site, and is determined through detailed fluvial geomorphological assessments of the watercourse. This value is used to establish a target unitary discharge rate for erosion control using the following relationship:

$$Q_{unitary} = Q_{erosive}/A \quad \text{(Equation 6)}$$

where

$Q_{unitary}$ = target unitary discharge rate for erosion control ($m^3/s/ha$)

$Q_{erosive}$ = threshold flow rate for erosion at critical site (m^3/s)

A = total drainage area to the critical site for erosion (ha)

The target unitary discharge rate is in turn used to calculate the extended detention discharge rate for the stormwater management facilities, as the product of the target unitary discharge rate for erosion control and the size of the contributing drainage area to the facility. The requisite extended detention storage volume is then determined by iteratively adjusting the volumes for the facilities until the duration of flows above the threshold flow rate at the critical site under the future land use condition with stormwater management, effectively matches the duration for existing conditions (within a reasonable tolerance).

The above approach toward determining erosion control requirements within end-of-pipe facilities has been applied for the conceptual development area in order to determine whether or not LID infiltration practices within the subject study area may afford efficiencies (i.e. reductions) to end-of-pipe facility requirements for erosion control. The results of this assessment have indicated that, through the application of LID infiltration practices within the upstream conceptual development area, erosion control requirements within the end-of-pipe facility for that area could be reduced by as much as 36 %.

Summary

The foregoing has outlined an approach whereby LID BMP's which promote infiltration for future development areas can be incorporated into conventional Subwatershed-scale modelling in order to evaluate the long-term effectiveness of these practices at a larger scale in order to provide direction related to maintaining the water balance within the study area, as well as determining efficiencies for the sizing of end-of-pipe facilities. The methodology utilizes a conceptual routing element to determine the storage-discharge relationship for the conceptual infiltration facilities within the contributing catchment, and applies the infiltration capacity of the native soils to determine the effective discharge from the facility, based upon a generic configuration of the conceptual infiltration facility.

The approach has been applied to a Case Study which utilized the HSP-F hydrologic model and long-term continuous simulation methodology. The approach was further tailored to the HSP-F methodology, by utilizing the opportunities to link the infiltration discharge from the conceptual routing element to the lower storage zone within the pervious land segment of the contributing drainage area, as a lateral input to the lower zone, which thereby accounts for the increased antecedent moisture conditions within the pervious land segment which may result from the application of the LID practices. The approach affords a more efficient means of evaluating the hydrologic benefits of applying LID practices at discrete timesteps and for longer simulation periods, compared to other approaches which have been applied, and also affords the opportunity to assess potential reductions to end-of-pipe facility requirements to address Subwatershed-scale targets.

Future research and development of this approach includes validation against other tools and techniques which may also applied at the Subwatershed scale, as well as assessments in other jurisdictions with soil conditions exhibiting higher infiltration capacities. Further research includes testing the application of this approach for establishing LID application requirements to satisfy Subwatershed-scale hydrologic targets (i.e. water balance and erosion control).

References

Ontario Ministry of the Environment (MOE), March 2003. Stormwater Management Planning and Design Manual.

Credit Valley Conservation (CVC), Toronto and Region Conservation Authority (TRCA), October 2009. Low Impact Development Stormwater Management Manuarl (Draft).

The City of Calgary Water Resources, November 2007. Stormwater Source Control Practices Handbook.

Farrell, A., Perdikaris, J., Scheckenberger, R., 2008. An Evaluation of Stormwater Managmenet Practices to Provide Flod Protection for Watershed-Based Targets, Conceptual Modeling of Urban Water Systems, Monograph 17, pp 81 – 108.

Farrell, A., Scheckenberger, R., Guther, R., 2001. A Case In Suppor of Continuous Modeling for Stormwaer Managemen System Design, Models and Applications to Urban Water Systems, Monograph 9, pp. 113 – 130.

City of Toronto, January 2003. City of Toronto Wet Weather Flow Management Master Plan.

Philips Engineering Ltd., September 2007. Credit River Flow Management Study.

Pitt, R. E., Chen, S., Clark, S., Lantrip, J., 2005. Soil Structure Effects Associated with Urbanization and the benefits of Soil Amendments, Proceedings EWRI ASCE 2005, pp 1 – 12.

Tables

TABLE 1: Summary of common LID BMP's

TABLE 2: Summary of conventional modelling techniques

TABLE 3: Summary of simulation techniques applied for Credit River Flow Management Study for watershed-scale assessment of LID practices

Figures

FIGURE 1: Conceptual application of LID BMP's on residential lot

FIGURE 2: Modelling schematic for conventional lot-level assessment of LID

FIGURE 3: Modelling schematic for subcatchment-scale assessment of LID

FIGURE 4: Design concept for generic LID infiltration facility

FIGURE 5: Case Study Area Location Plan

FIGURE 6: Summary of water balance for Huttonville Creek subwatershed

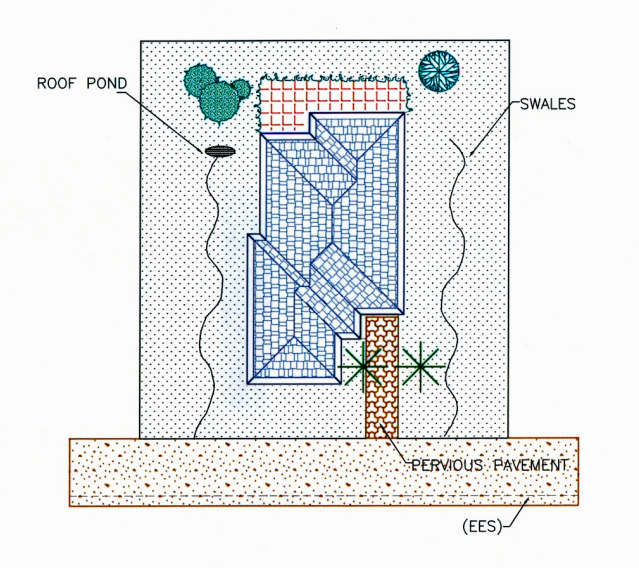

FIGURE 1: Conceptual application of LID BMP's on residential lot

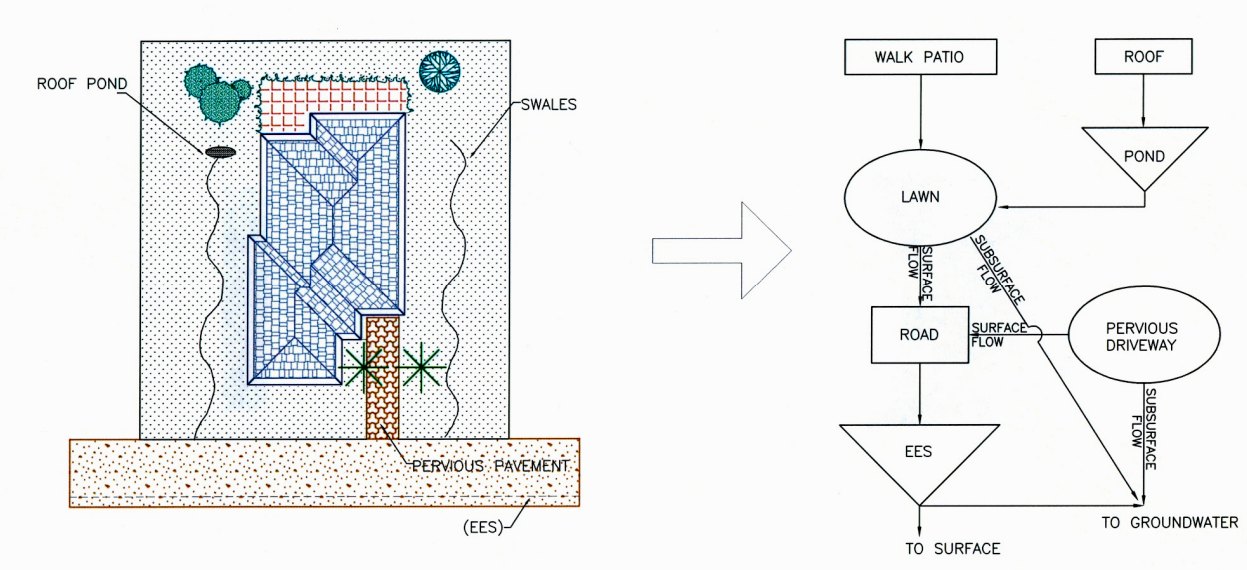

FIGURE 2: Modelling schematic for conventional lot-level assessment of LID

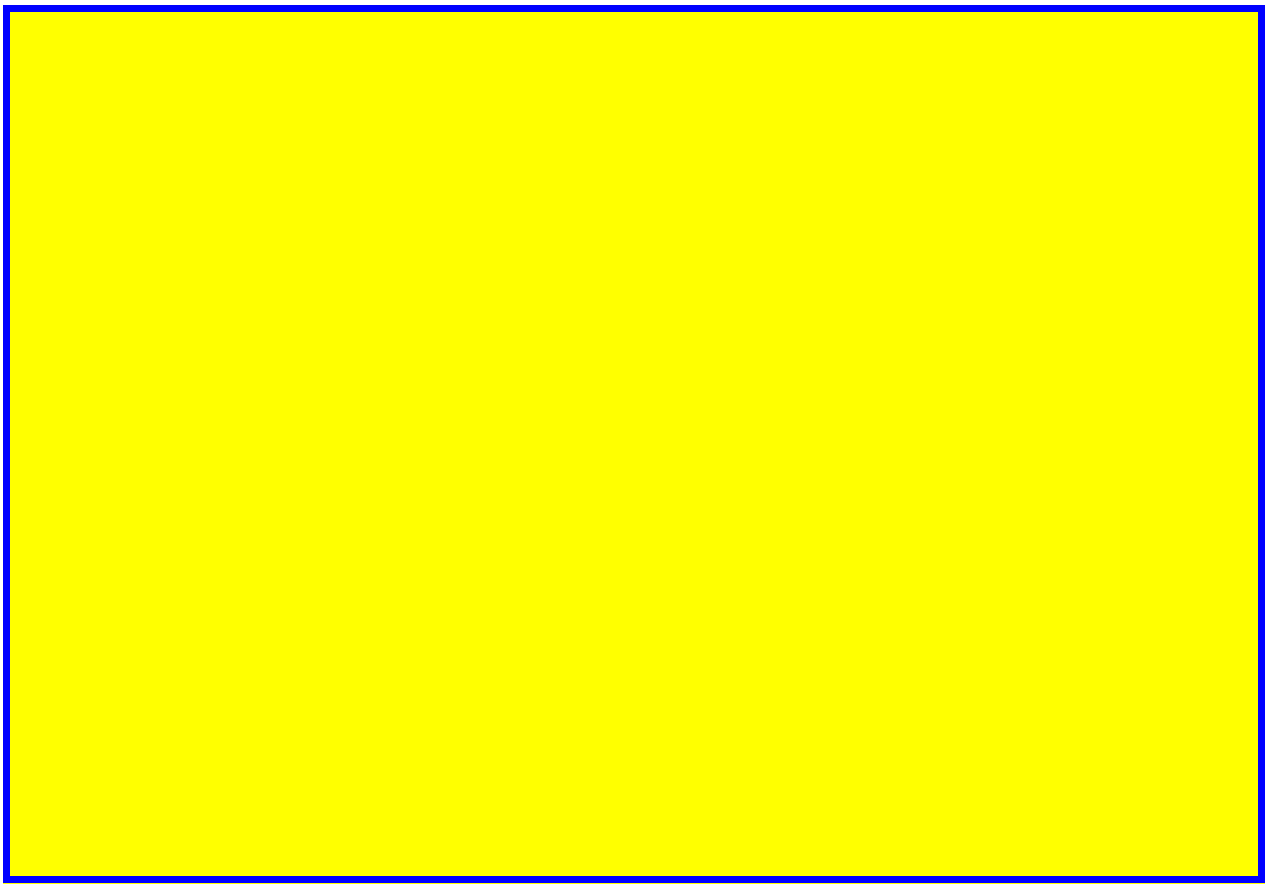

FIGURE 3: Modelling schematic for subcatchment-scale assessment of LID

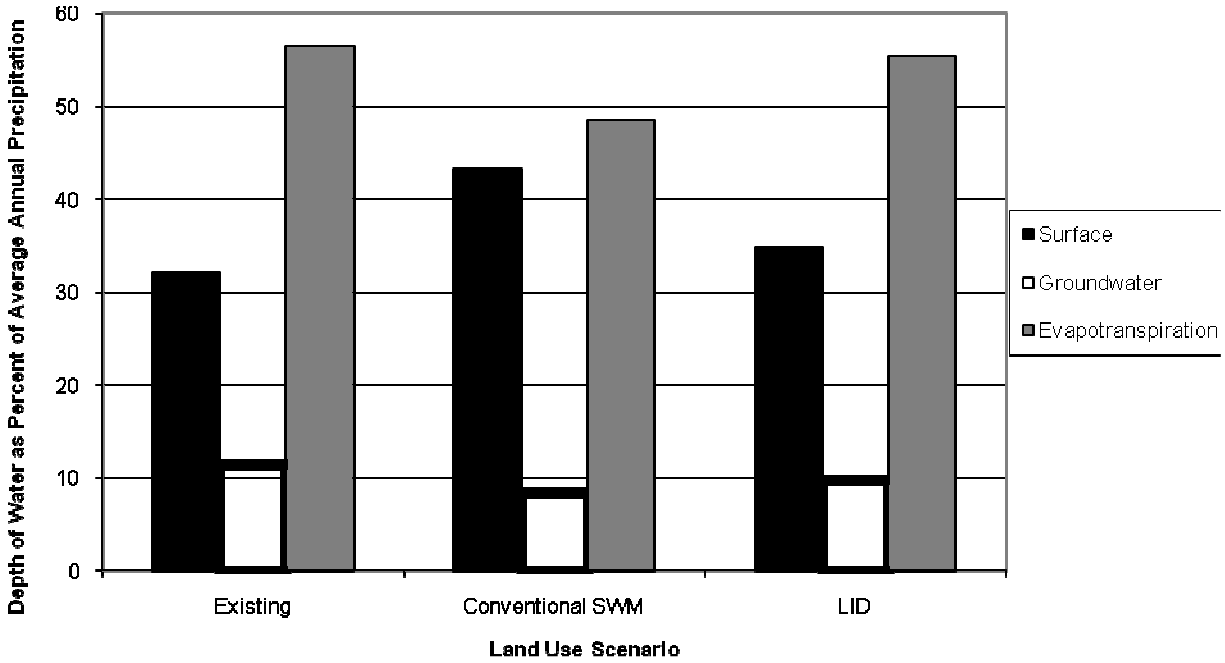

FIGURE 6: Summary of water balance for Huttonville Creek subwatershed

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