Harbourfront (Piers 6, 7 and 8)

Stormwater Management Report

City of Hamilton

Prepared for:

City of Hamilton

Prepared by:

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1.0 INTRODUCTION AND SCOPE

The City of Hamilton is currently proposing to develop the Pier 6, 7 and 8 areas along Hamilton Harbour to a primarily residential land use. Currently, the western portion of the Pier 7 area has been developed for recreational purposes, including a large outdoor rink, the Hamilton Waterfront Trust Centre, and a surrounding promenade. The balance of the area has been used historically for various marine activities. The City of Hamilton has retained S. Llewellyn & Associates (SLA) to undertake a functional servicing, grading, and stormwater management design for the study area. In addition, the City of Hamilton has also retained Amec Foster Wheeler Environment & Infrastructure (Amec Foster Wheeler) to provide input and support services to the development of the stormwater management plan for these lands.

Amec Foster Wheeler's scope of work has been multi-faceted, and has generally included the following:

- Additional review of background information and previous studies for the subject lands;
- Consideration of external drainage areas (beyond the Pier 6, 7 and 8 area) which may influence overland flow and drainage for the subject lands;
- An assessment of stormwater management alternatives (both quantity and quality) for the subject lands and development of a preferred plan; and
- Completion of integrated hydrologic/hydraulic modelling to analyze the expected performance of the proposed drainage system [both minor (sewer) and major (roadway) components].

Throughout the study, Amec Foster Wheeler has co-ordinated the assessment with the City of Hamilton and SLA to ensure a consistent vision for the subject lands. Several meetings between parties has occurred to this end. This report reflects the summary of these efforts and the overall stormwater management analyses and recommendations for the study area.

2.0 BACKGROUND REVIEW

2.1 Mapping and Drawing Data

The following information and data have been reviewed in the preparation of this report:

Mapping and Base Data

- 2014 Aerial Photography (from First Base Solutions)
- Current (2017) and historic aerial photography (2004-2017) of the study area and surrounding area (as available from First Base Solutions as well as from Google Earth Pro ™)
- Hamilton Conservation Authority Regulated Areas Map Tool (Online).
- 1 m Elevation Contours (2010 - City of Hamilton).
- Topographic Survey Data for Pier 7 and 8 area (as included with AutoCAD drawings from S. Llewellyn & Associates)

Design Drawings

- Plan and Profile Drawings
  - Guise Street (Bay Street to Catharine Street)
  - Dock Service Road (Catherine Street to Ferguson Street)
  - John Street (Burlington Street to Guise Street)
  - James Street (Macaulay Street to Guise Street)
  - Brock Street (John Street to Mary Street)
  - Burlington Street (Bay Street to Ferguson Avenue)
  - Catharine Street (Macauley Street to Guise Street)
  - Hughson Street (Wood Street to Guise Street)
  - Ferguson Street (Burlington Street to Dock Service Road)
  - MacNab Street (Picton Street to Guise Street)
  - Mary Street (Burlington Street to Brock Street)
  - Wood Street (MacNab Street to Ferguson Avenue)
- Pier 7 Shoreline Improvements & Transient Docks (Dillon Consulting, June 2015)
- Functional Servicing and Grading Drawings by S. Llewellyn & Associates
  - Grading Plan, Servicing Plan and Storm Drainage Area Plan (April 2016)
  - Grading Plan, Servicing Plan and Storm Drainage Area Plan (May 2017)
  - First Submission Drawing Set (October 2017)

Relevant findings from the above-noted information are referenced as required in subsequent sections of this Stormwater Management Report.

2.2 Summary of Available Reporting

West Harbourfront Development Study – Conceptual Servicing Plan (Philips Planning + Engineering Limited, October 1995).

- Limited information for the Pier 6, 7, 8 area
- Concept plan indicates small diameter storm sewers (< 600 mm), draining west along Guise Street to a potential Stormwater Quality Facility at the end of James Street.
- Separated sanitary sewers shown also draining west on Guise Street.

West Harbour "Setting Sail" Secondary Plan (City of Hamilton, June 2012)

- Key document which outlines the goals and direction for development in the study area; a number of key principles related to SWM planning are noted
- Section A.6.3.2 (Planning Principles)
  - *Employ "best practice" techniques for stormwater management to minimize reliance on the existing combined sewer system*
  - *Encourage water conservation*
  - *Maintain or enhance existing aquatic and shoreline habitats;*
  - *Remove, replace or seal potentially harmful subsurface materials, as per statutory policies and guidelines*
  - *It is important to… relocate heavy industrial uses and clean-up contaminated sites*
- Section A.6.3.4.1 (General)
  - *New development and redevelopment shall be encouraged to incorporate rooftop terraces, greenwalls, rooftop gardens and/or other green technologies to improve micro-climatic conditions, energy efficiency, air quality and for stormwater management.*
- Section A.6.3.4.3 (Water Quality)
  - *Development shall contribute to the improvement of water quality in Hamilton Harbour.*
  - *Stormwater shall be managed using a suite of lot, conveyance and end-of-pipe solutions. Rainwater shall be considered a resource rather than a waste product.*

Piers 5-8 Sewage Pumping Facilities (Dillon Consulting, May 2014)

- Class EA which reviewed sewage pumping facilities with respect to infrastructure needs in light of the "Setting Sail" Secondary Plan
- Preferred solution involved the construction of two (2) new sanitary pumping stations:
  - First to service Pier 8 (replacing an existing station which has several deficiencies and would provide additional capacity for future area developments)
  - Second to be located on Pier 6 and would service Piers 5 to 7.
- New forcemain noted to be required to discharge to Burlington Street trunk sewer at Ferguson Avenue.
- Class EA notes that a single pumping station at Pier 8 is possible (eliminate Pier 6 station) however existing infrastructure may conflict with gravity sewer routing.

Sustainable Stormwater Management Alternatives for the Redevelopment of Piers 7 & 8 (McMaster University, August 2015)

- Study prepared by a Masters student
- Based on a life cycle costing basis; concluded LID practices (bioretention, green roofs, soil retention cells, bioswales) would be more suitable than conventional SWM techniques
- Acknowledgement that site constraints to be considered in detailed design

Piers 5 to 8 Environmental Site Assessment Summary (Dillon, February 2016)

- Site is built on approximately 1-2 m of fill at Guise Street, thickening northwards towards harbour where up to 8 m of fill is present.
- Much of the fill is considered to be contaminated, including one location where free heating oil was discovered and will require remediation.
- Fill material has high hydraulic conductivity (up to 10^{-5} m/s) but is underlain by more fine grained silts, clays, and clay till materials.
- High groundwater noted, approximately 1-2 m below surface on average. Hydraulic gradient is to the north towards the harbour.

Pier 8 Wave Overtopping Analysis (Shoreplan, March 2016)

- Existing harbour perimeter is steel sheet piles with paving, graded to flow back to harbour
- Top of wall elevations range from 76.05 m to 76.67 m
- Overtopping of the site perimeter walls is to be expected under existing conditions, for 100-year storm event; rates vary between 35 L/s (west wall) to 80 L/s (north wall) to 145 L/s (east wall)
- 100-year wave heights are highest for north wall (1.25 m), notably lower for the west and east walls (0.80 m on average).
- Recommends construction of a secondary wall set back approximately 6 m from the existing wall, of between 0.5 and 0.6 m in height.

Functional Servicing Report, Piers 7 & 8 (S. Llewellyn & Associates Limited, April 2016).

- Preliminary Proposed functional servicing (storm, sanitary and water) and grading plan for the Pier 6, 7, and 8 lands
- Preliminary Proposed Quantity control to reduce peak discharge by 20-30% (based on City input)- use of a SWM block (greenway - enhanced grassed swale) to achieve this (0.56 ha) (subsequently revised)
- Preliminary Proposed Enhanced swales to provide some filtration and increase infiltration (subsequently revised). Other infiltration based LID BMPs are noted as not recommended (given contaminated soils, groundwater depth, and other considerations).
- Storm sewer sizing using the Rational Method but noted need for dual drainage modeling

Pier 7 and 8 Urban Design Study (Brook McIlroy, April 2016)

- Generation of a concept plan for the Pier 7 and 8 area, including layout of buildings, roadways and paths
- Key feature included the “greenway” (stormwater garden and pedestrian walkway)
- The “greenway” was considered an essential component of the general park design; a “community anchor” and major east-west route for pedestrian traffic
- The greenway should include “a combination of rain garden, bio-swales and dry ponds”

DRAFT Geotechnical Investigation – West Harbour Pumping Station (Terraprobe Inc., November 2016)

- Prepared in support of proposed sanitary sewers and pumping stations for Pier 8
- Groundwater identified at depths of between 1 to 3 m below grade.
- Concerns noted with respect to potential settlement, given the lack of engineered soils and the presence of large depths of fill material.

Stormwater Management Brief - Pier 7 & 8 Development (S. Llewellyn & Associates Limited, October 2017).

- Prepared to summarize proposed stormwater measures for the development; to be read in conjunction with the current report by Amec Foster Wheeler.
- Provides calculations on oil/grit separator sizing as well as storm sewer design sheets.

3.0 OPPORTUNITIES AND CONSTRAINTS

In order to develop a stormwater management plan for the proposed lands, a review of potential opportunities and constraints is considered warranted, and is outlined herein.

3.1 Opportunities

i. **Potential to provide improved quantity/quality control for off-site areas**. Currently, off-site areas draining towards the study area are largely collected by existing combined sewers and directed to CSO tanks (James Street and Eastwood Park). Minor flows would be directed to the Woodward WWTP (thus receiving treatment), however major flows (including CSO spills) would be directed uncontrolled towards Hamilton Harbour. As part of the proposed re-development, there is the potential to better manage and control these external flows, including separating and treating storm flows before discharge to the harbour.

ii. **Potential to reduce loading to existing CSO tanks**. In combination with #1, planning for, and incorporating, a combined sewer strategy for upstream areas (as well as the site itself) would allow for a reduction in excess storm flows to CSO tanks, and thus a potential reduction in the frequency and magnitude of deleterious CSO discharges to the harbour.

iii. **Potential to provide enhanced water quality treatment for existing lands**. The existing study area currently receives no stormwater quality treatment (with the potential exception of any treatment for the Discovery Centre area, if in place). As such, the proposed re-development will allow for the provision of enhanced water quality treatment for this entire area.

iv. **Potential to remediate contaminated soils and lands**. As per the background review, much of the study area site is built on fill material, much of which is considered contaminated. As part of the re-development, the City will have the opportunity to remediate these lands, consistent with the direction in “Setting Sail” (ref. Section 2.1).

v. **Potential to implement newer SWM technologies (filtration)**. As part of the SWM strategy with respect to water quality, newer end-of-pipe SWM technologies which incorporate filtration (i.e. Imbrium Systems Jellyfish™, Filterra™, sand filters) can potentially be considered for use to achieve a greater degree of water quality treatment (including nutrient and phosphorous removal) than traditional oil/grit separators.

vi. **Potential to provide clean water to the harbour to improve circulation**. City staff has noted that some areas of the harbour suffer from poor water circulation, which can lead to water quality concerns. As part of the proposed re-development, there is an opportunity to separate “clean” sources of runoff (rooftops, grassed areas) and direct this water strategically to improve water circulation and offer dilution in problematic areas of the harbour.

vii. **Potential to incorporate advanced water recycling approaches [LID/BMPs (green roofs, cisterns, soil cells), greywater recycling (separated internal plumbing systems)]**. As part of the re-development, there is an opportunity to implement innovative water management approaches. LID BMPs could be considered to propose water re-use (i.e. cisterns and soil cells for vegetation watering), which would also benefit overall stormwater quality and quantity management. Greywater recycling could also be considered to minimize impacts to water and sanitary sewer system (including CSO tank) demand; notwithstanding, there are no direct benefits to SWM.

3.2 Constraints

i. **Elevated groundwater levels**. Previous studies have noted elevated groundwater levels (up to 1 m below surface) through the study area (ref. Section 2.2). Elevated groundwater levels limit the feasibility of infiltration based techniques (i.e. LID BMPs), but could also impact upon servicing strategies (i.e. infiltration into underground services, buoyancy considerations).

ii. **Contaminated soils**. Previous studies have noted that the study area consists primarily of fill material, much of which is considered to be contaminated. These areas will therefore require remediation under proposed conditions, and may limit the feasibility of infiltration-based SWM techniques (i.e. LID BMPs).

iii. **Flat site grading under existing conditions**. The majority of the site area is noted to be flat under existing conditions. This may impact upon overland flow grading (i.e. to ensure suitable grade to direct surface flows to suitable outlets), as well as ensuring consistent ground cover for underground utilities.

iv. **Wave uprush and lake level impacts to site and site services**. Wave uprush impacts must be taken into account as part of the grading design for the site, to minimize flood potential for development. Likewise, expected long-term variation in lake levels must also be considered. High lake levels in particular could impact the function and design of stormwater outfalls.

v. **Limited surface availability for SWM**. The proposed re-development is expected to include higher density residential and mixed uses, given the high value of the land. As such, there is a limited amount of available space for more traditional open SWM facilities.

vi. **Limited efficacy of oil/grit separators for larger drainage areas**. Typically, oil/grit separators are employed for smaller site developments (i.e. < 2 ha). Although larger units are available from manufacturers, they tend to become more space consumptive and costly. There is also concern (typically from regulatory agencies) that these units are not as effective for larger drainage areas. Multiple units would potentially be required to service the currently proposed development area.

4.0 STORMWATER MANAGEMENT STRATEGY

The opportunities and constraints presented in Section 3 have been considered in conjunction with the previous background review in order to develop an overall SWM strategy. The strategy is summarized further in this section. Detailed calculations for the stormwater management strategy components are outlined in subsequent sections.

4.1 Off-Site Considerations

a. **Provide safe flow conveyance for overland drainage from off-site areas**. All overland flow routes through the study area should be designed to convey external uncontrolled surface flows (up to 100-year storm event). Overland flow outlets to the harbour should also be explicitly designed, and re-directed from major thoroughfares, to the extent possible. Flow should be diverted to outlets as quickly as possible to reduce internal service impacts; preliminary locations are indicated on the attached sketches. Park/open space areas are preferred. Overland flow outlet routes should be combined with minor system outlets to the extent possible.

b. **Plan for future sewer separation along Guise Street (if feasible)**. Storm sewers through the study area could be sized assuming that storm drainage from Guise Street will be re-directed from the existing combined sewer system into a new separated system, subject to a review of feasibility. Quality controls could also be designed accordingly. These measures are however again subject to a review of feasibility.

c. **Plan for future sewer separation for upstream off-site areas/upsizing (if feasible).** Storm sewer connections for external areas could be upsized to assume a future separation of additional upstream areas (James, John, Hughson, and Catharine Streets). This would require preliminary sewer sizing and grading on Guise Street accordingly. Consideration for further quality control measures would also be required. These measures would again be subject to a review of feasibility.

4.2 On-Site Considerations

a. Grading and Major System

i. **Ensure site grades are set sufficiently high**. Grades should be set to address the wave uprush flood risk; at least 77.25 m based on the 100-year water level of 76.00 m and a 1.25 m wave height at the north face estimated previously by others (ref. Shoreplan, 2016). Clean fill material should also be used for this purpose. Additional fill material would also potentially address concerns related to elevated groundwater levels, and ensure sufficient cover for underground utilities.

ii. **Remove/remediate contaminated on-site soil material**. In conjunction with grading modifications noted previously, any contaminated material on-site should be either be remediated on-site or removed and disposed of in a suitable off-site location.

iii. **Plan suitable overland flow routes**. As noted, as part of *Off-site considerations*, overland flow routes should be explicitly considered as part of the site grading plan, and directed to outlets quickly to reduce internal service impacts. For the site itself, a portion of the open space area at the north limits of the site is proposed for site overland flow conveyance, as is the park feature near the south-west.

b. Quantity Control

i. **No formal quantity controls**. The April 2016 FSR (SLA) included the provision of nominal quantity controls to reduce post-development peak flows by some 20-30%, "following discussions with the City of Hamilton" (SLA). Enhanced grass swale features were proposed to accomplish this objective. Based on subsequent discussions with City staff (April 18, 2017) it was agreed that no quantity control is necessary for the site given the immediate proximity to the harbor. Storm sewers and overland flow conveyance features should be designed based on uncontrolled flows.

ii. **Informal quantity control through other opportunities**. Green roofs, cisterns, and roadway soil cells (i.e. Silva Cell 2™) may provide some degree of informal quantity control, however these features would primarily be incorporated for other benefits (i.e. heat island reduction for green roofs, tree growth and quality pre-treatment for roadway soils cells).

iii. **Limit or avoid infiltration-based approaches.** Given high groundwater levels, concerns about contaminated soils (although remediation has been assumed), lack of adjacent watercourses (maintenance of baseflow), and the lack of a requirement for quantity control, infiltration-based approaches (majority of LID BMPs) are not considered warranted for the proposed development.

iv. **Eliminate the previously proposed SWM block/greenway**. The previous April 2016 FSR included a 0.56 ha SWM block (grassed swales) to achieve quantity control targets and some measure of infiltration. This was consistent with the proposed "greenway" included in the original planning work completed by Brook McIlroy, which promoted a pedestrian thoroughfare in conjunction with LID BMP type measures (bioswales/bioretention/rain garden, etc). Notwithstanding, from a SWM perspective, this is not considered warranted given the lack of a need for infiltration and quantity control. Given the value of land in the proposed development, it is suggested that this land would be better used for development purposes, and other BMPs as noted above be considered across the site. This recommendation was subsequently confirmed in discussions with City staff (April 18, 2017) and SLA and City staff (July 14, 2017).

c. Minor System and Quality Control

i. **Implement a clean water collector system**. A "third pipe" system is proposed to collect "clean" runoff from rooftops and foundation drainage. This collector pipe would then outlet to identified priority locations in the harbour to aid in circulation and dilution. It is assumed that no quality controls would be required for runoff from these areas, given the contributing land use (i.e. roof tops).

ii. **Construct a standard storm sewer system**. Given the proposed clean water collector, a storm sewer system would be required for runoff from roadways and any surface parking areas; sizes may potentially be reduced (optimized) given the separate clean water collector. Requirements for end of pipe water quality treatment should also be reduced by eliminating additional “clean” water areas. The outfalls should be combined with outfalls for the clean water collector system to the extent possible, for long-term operations and maintenance and property access (easements).

iii. **Implement roadway soil retention cells**. Soil retention cells (such as Silva Cell 2™, ref. attached) should be implemented as part of the streetscaping design where feasible, along with selected tree plantings (which can suitably withstand winter salt loadings). The cells would receive low flow from roadway catchbasins, which would provide water quantity and quality benefits, while also resulting in more stable, robust tree plantings (which, in addition to aesthetic benefits, would assist with heat island reduction). Given that these cells provide sufficient water for tree growth, it is considered that cisterns (rainwater harvesting) would not be warranted.

iv. **Implement formal end-of-pipe quality controls for storm sewer collection system**. A treatment train approach is suggested. The previously noted soil retention systems would be combined with more traditional end-of-pipe treatment measures (i.e. oil/grit separators), although more recent filtration-based technologies (i.e. Jellyfish™, Filterra™, or sand filters) could also be considered to enhance treatment efficiency, particularly for nutrients (i.e. nitrogen and phosphorous) given that the harbour is part of a recognized RAP. These units may require upsizing in order to account for potential contributions from off-site areas, depending on the City’s preferences.

d. Water recycling and other measures

i. **Consider selective implementation of green roofs**. Green roofs are not considered necessary for SWM, given that quantity control is not required, and that a clean water collector is proposed (thus a greater volume of water would be beneficial for harbour mixing and dilution). Notwithstanding, green roofs would be beneficial for heat island impacts, as well as an overall promotion of LID/BMP techniques for City developments.

ii. **Consider selective greywater recycling systems**. As noted previously, greywater recycling has no direct SWM benefit. Notwithstanding, greywater recycling would have overall benefits in reductions to the sanitary sewer system, as well as reductions in water demands.

5.0 STORMWATER QUALITY

5.1 Overall Treatment Design Approach

The overall stormwater management strategy for the study area was outlined in the preceding section. The proposed stormwater quality treatment strategy, as outlined therein, and identified on the first submission drawing set (SLA, October 2017) consists of three (3) primary components:

- Clean Water Collector Pipes;
- Oil/grit separators; and
- Modular Soil Retention Cells.

Subsequent sections discuss these features in further detail.

5.2 Clean Water Collector

In order to aid circulation of stagnant water within the harbour, a separate clean water collector pipe system has been proposed. The intent of this system would be to collect the largely clean water from rooftop drainage and surrounding landscaped areas, as well as the "greenway" walkways, and direct it to the harbour at key locations. Based on discussions with SLA and City staff (ref. e-mail Kizlan-Senior, October 16, 2017), it is understood that no surface parking areas are planned for any of the block areas. The blocks themselves would therefore consist of buildings, as well as landscaped or pedestrian walkway areas only, which would be expected to have a much lower contaminant loading than areas subject to vehicular traffic. As such, all of the block areas are proposed to be serviced by the clean water collector system, without necessitating additional quality controls. By eliminating quantity controls, a regular flow of clean water would assist circulation and dilution within the harbour. In addition, by separating out these flows from the standard storm sewer system (which will drain the roadway areas), end-of-pipe quality controls can be focused on a more limited area with concentrated contaminants, rather than including dilution from cleaner areas.

5.3 Oil / Grit Separators

End-of-pipe oil/grit separators (OGS) have been proposed to provide "Enhanced' (80% average annual removal of total suspended solids) water quality treatment of the roadway areas. Sizing of the OGS units has been undertaken by SLA; reference is made to "Stormwater Management Brief – Pier 7 & 8 Development" (October 2017).

It is noted however that the outlets of the OGS units have been set either close to, or below, the maximum average annual Lake Ontario water level of 75.33 m (NAD 28 datum). It should be noted that based on the International Great Lakes Datum, this level is 75.10 m. Notwithstanding, water levels may be higher than these average values. Although 2017 was considered to be an atypical year, a maximum water level of 75.8 m +\- was reached in June 2017, which would be notably above the previously noted values.

The proposed OGS invert elevations range from a low of 75.13 m (OGS 2 and 4) to a high of 75.24 m (OGS 3), which would all be below the average annual high level of 75.33 m (NAD 28 datum), but below the IGLD value of 75.10 m. These are also static values which do not account for wave action or storm surge, which could further force water back into the OGS units. If feasible, it is suggested that these units be raised further to avoid backwater impacts. Further dialogue with manufacturers is also recommended to determine what impacts, if any, would result from partially submerged outlets.

5.4 Soil Retention Cells

In addition to the preceding measures, it has been recommended that soil retention cells be implemented along roadway areas where feasible. The most commonly known system is Silva Cell^{TM}, by Deeproot. Silva Cells are modular premanufactured frames and decks which can be installed beneath hard surfaced areas to provide structural support. These units allow for relatively uncompacted soil to be placed which encourages more rapid growth of trees and tree roots. In addition to encouraging the growth of trees in highly urbanized areas, these units can also provide a stormwater management benefit by re-directing low flows from catchbasins into the Silva Cells with a perforated pipe. The stormwater is then stored in the soil void space and used by tree roots. The combination of infiltration and biological action also helps to reduce and treat stormwater contaminants, which helps reduce loadings to the downstream end-of-pipe OGS units, and ultimately to Hamilton Harbour.

The locations of the Silva Cell units are to be determined as part of subsequent detailed design works by the site engineer, in consultation with the City of Hamilton and the landscape architect. Engineering direction will be key to ensure that the relevant stormwater components (i.e. catchbasin bypasses and overflows) are incorporated into the final design.

6.0 HYDROLOGIC / HYDRAULIC MODELLING

6.1 General Criteria and Approach

Grading and servicing plans under proposed conditions have been developed by S. Llewellyn & Associates (SLA). Reference should be made to the most current drawing set (Pier 7 & Pier 8, Draft Plan No. 25T201605, Issued for First Submission, September 2017).

The current analyses (hydrologic/hydraulic modelling) have verified the storm sewer sizing completed by SLA (which were completed using Rational Method calculations included in Appendix A of the Stormwater Management Brief, October 2017), as well as overland flow drainage and conveyance capacity, which also accounts for drainage from off-site (external areas). Analyses have been completed for proposed conditions only. Given that no quantity controls are proposed for the site, there has been no need to simulate existing conditions (as there are no "post to pre" peak flow control targets being employed).

Based on discussions with SLA and the City of Hamilton (ref. September 29, 2017 e-mail Kizlan-Senior), it is understood that further storm sewer upgrades (to accommodate future upstream sewer separations) would be expected to add significant additional cost to the project, given the required pipe sizing and depth of cover constraints. Ultimately, storm sewers for the site have been sized for the local drainage contributions only. Overland flow contributions from external areas have however been included within the modelling, as part of the current assessment.

PCSWMM has been employed for the current assessment. PCSWMM is a graphical user interface and pre-processor for the well-known US EPA-SWMM model. It is a combined hydrologic/hydraulic model which is capable of assessing complex hydraulic conditions, including dual drainage (minor/major system) and surcharge and reverse flow. PCSWMM has been employed successfully for several projects within the City of Hamilton, and is a logical choice for the current assessment.

Design criteria for the minor (storm sewer) and major (overland flow/roadway) systems have followed current City of Hamilton Criteria (ref. City of Hamilton Comprehensive Development Guidelines and Financial Policies Manual, 2017). Based on these guidelines, the following apply for design of new development drainage infrastructure:

- Storm Sewers – 1 in 5 year storm event
  - Unsurcharged standard (85% of pipe capacity)
- Roadway Conveyance – 1 in 100 year storm event
  - Urban Arterial/Emergency Routes – 0 mm depth above road crown
  - Local/Rural Arterial Collector – 150 mm depth above road crown

The clean water collector sewer system has been assumed to be designed to the same standard as roadway storm sewers (i.e. the 1 in 5 year storm event).

It has been assumed that all the roadways within the subject development would be classified as local roadways, thus the second criteria (150 mm above roadway crown, or 230 mm above the gutter based on a 4 m lane roadway with a 2% crossfall) would apply.

6.2 Hydrologic Model Setup

In order to evaluate flow responses to different storm events, it has been necessary to conduct hydrologic modelling, to develop storm response hydrographs and associated peak flows.

Drainage area boundaries for external areas have been developed based on the topographic mapping and a review of roadway plan and profile drawings provided by the City of Hamilton.

The results of this analysis are presented in Drawing 1. As evident, approximately 14.3 ha of overland drainage from upstream areas would be expected to be directed towards the Pier 6, 7, and 8 area (including 0.5 ha +\- of street drainage along Guise Street and the Dock Service Road). These areas are currently serviced by the City's combined sewer system, but would be expected to experience surface (overland) flow during more formative storm events.

The land use types for external drainage areas have been interpreted based on a review of current aerial photography. Impervious coverage for external drainage areas was then estimated using the City of Hamilton's standard impervious coverage by land use ratios (ref. City of Hamilton Comprehensive Development Guidelines and Financial Policies Manual, 2017) using an area weighting approach. Resulting estimated impervious coverage has been estimated at between 60 and 70% for these drainage areas.

Drainage boundaries for the development site itself have been based on the work completed by S. Llewellyn & Associates (SLA, ref. Pier 7 & 8 Drawing Set, First Submission, September 2017). Impervious coverage for these areas has been based on the Rational Method Coefficients applied by SLA for these drainage areas. Coefficients have been converted to an impervious coverage by interpolating between coefficients of 0.20 (0% imperviousness) and 0.90 (100% imperviousness). Resulting imperviousness for the development lands generally averages approximately 70% +\-.

In addition to imperviousness, in order to determine appropriate infiltration parameters for the remaining pervious land segment, a characterization of on-site soils is required. There is no information on the site (or upstream area) from Ontario Soils Mapping, as the entire area is classified as "urban". Geotechnical investigations have been completed for the development site itself, which note primarily fill materials. Given the lack of detailed soil information, to be consistent with previous assessments completed for the City of Hamilton, an SCS Classification of "C" for area soils has been assumed. Infiltration modelling has applied the SCS Curve Number method, with an assumed Curve Number of 74 for pervious areas (consistent with grassed areas in good condition). A depression storage value of 5 mm has also been assumed for pervious areas.

Other hydrologic parameters, such as length and slope, have generally been directly measured from the available mapping and grading information. Subcatchment length is a key parameter within PCSWMM, as it is used to represent sheet flow/overland flow, and accounts for the expected degree of attenuation (i.e. is a surrogate for time of concentration or time to peak used in unit hydrograph methodologies).

Other hydrologic parameters have used standard values employed for assessments within the City of Hamilton, including Manning's Roughness Coefficients of 0.013 and 0.2 for the impervious and pervious land segments respectively, and a depression storage of 1 mm for the impervious land segment.

6.3 Hydraulic Model Setup

It is expected that not all of the external contributing drainage area would result in overland flow towards the development site, specifically via Guise Street and the three (3) access points near Hughson Street, John Street, and Catharine Street. As noted, these areas are serviced by combined sewer system which would collect minor flows. Further, the grading/profile along Guise Street is such that the majority of the overland flows would be expected to discharge away from the three (3) roadway access points. Notwithstanding, in order to represent the potential overland flow contribution and account for conveyance by the minor system, the first section of the minor (combined sewer) system has been included in the modelling to represent the available conveyance capacity. Overflows would then be directed to the major system and routed based on the conveyance capacity and grading of the major system conduits within the modelling. Note that sanitary flows have not been included for the combined sewers. While these flows would reduce the available conveyance capacity within the sewer, it has been assumed that they would be minor relative to storm flows (particularly for a 5 or 100 year storm event). The calculation of external sanitary flows is also considered to be beyond the scope of the current assessment.

For the development site, the storm sewer and clean water collector layouts and grading details provided by SLA have been inputted directly into the PCSWMM model. The major (overland flow) system has been developed using the dual drainage creator within PCSWMM, and representative transects of roadway cross-sections.

Exit losses for all storm sewers have been incorporated into the modelling based on the angle at which the storm sewers connect at maintenance holes. Exit losses range from 0.15 (straight run) to 1.0 (90 degree bend), and are consistent with the direction from U.S. Department of Transportation's Federal Highway Administration Urban Drainage Design Manual (Hydraulic Engineering Circular No. 22, Third Edition).

In all cases, inlets (catchbasins) have been modeled using a “two-stage” orifice system. A first orifice is used to represent the surface catchbasin grate, based on an estimated 0.125 m^2 per catchbasin grate being represented (as per OPSD details). This orifice is linked to a junction node which represents the catchbasin structure. A second orifice (representing the catchbasin lead) then links the catchbasin to the storm sewer. The second orifice is sized based on the number and size of catchbasin leads being represented, and converted to an equivalent rectangular opening which preserves the height (i.e. 0.25 m or 0.3 m), at an assumed invert elevation of 1.5 m below surface. This approach results in a more accurate representation of inlet capacity, as well as allowing for potential backwater from surcharged storm sewers to return to surface.

Outfalls have been implemented at all discharge points to the harbour. A fixed water surface elevation of 75.33 m has been employed at all outfalls, which represents the long-term average maximum annual water surface elevation in Lake Ontario.

6.4 Rainfall and Design Storms

As part of the modelling process, rainfall input is required. For previous applications of PCSWMM to urban drainage assessments within the City of Hamilton, two design storm distributions have typically been considered: the 6-Hour Chicago and the 24-hour SCS Type-II. Given the highly urbanized/impervious nature of the drainage area being assessed, it is considered that the 6-Hour Chicago distribution is a more appropriate choice of distribution, and has been applied for this assessment. Rainfall data are as per the most recent intensity-duration-frequency (IDF) dataset (2004 IDF Update for Mount Hope (Airport) gauge). Both the 5 and the 100 year storm events have been simulated, in order to assess conformance with City criteria (as per Section 6.1).

6.5 Modelling Results

The resulting proposed conditions modelling has been executed for both the 6-hour Chicago distribution for the 5-year and 100-year return periods as noted previously. The results of these simulations are discussed in the following sections.

6.5.1 5-Year Storm Event

Simulated peak flows for the 5-year storm event at outfalls (reference Drawing 1) are presented in Table 6.1.

Table 6.1. Simulated 5-Year Event (6-Hour Chicago) Peak Flows (m^3/s) at Outfalls

Outfall	Location	Drainage Area (ha)	Discharge Type	OGS Reference	Peak Flow (m^3/s)
1	Block 7	1.09	Clean Water Collector	NA	0.35
2	Street C	1.11	Storm Sewer	OGS2	0.26
	Street C	2.54	Clean Water Collector	NA	0.54
3	Street E	0.70	Storm Sewer	OGS1	0.17
4	Street B	0.26	Storm Sewer	OGS3	0.06
5	Catherine Street	1.46	Clean Water Collector	NA	0.33
6	Catherine Street	1.51	Storm Sewer	OGS4	0.34

Note: [1] Does not include Block 9 (Pier 6) since no storm sewer services or exact outfalls yet proposed for this area.

Based on the simulated results, none of the proposed sewers (storm sewers or clean water collectors) would be expected to be surcharged, consistent with the Rational Method design completed by SLA.

As would be expected for the 5-year storm event, simulated overland flow depths are also nominal. The largest overland flow depth simulated is 0.07 m relative to the gutter at the Street ‘C’ sag point (Outfall 2), which would be below the roadway crown.

6.5.2 100-Year Storm Event

Simulated peak flows for the 100-year storm event at outfalls are presented in Table 6.2.

Table 6.2. Simulated 5-Year Event (6-Hour Chicago) Peak Flows (m^3/s) at Outfalls

Outfall	Location	Drainage Area (ha)	Discharge Type	OGS Reference	Peak Flow (m^3/s)
1	Block 7	1.09	Clean Water Collector	NA	0.67
2	Street C	1.11	Storm Sewer	OGS2	0.52
	Street C	2.54	Clean Water Collector	NA	1.03
3	Street E	0.70	Storm Sewer	OGS1	0.30
4	Street B	0.26	Storm Sewer	OGS3	0.12
5	Catherine Street	1.46	Clean Water Collector	NA	0.61
6	Catherine Street	1.51	Storm Sewer	OGS4	0.60

Note: [1] Does not include Block 9 (Pier 6) since no storm sewer services or exact outfalls yet proposed for this area.

Based on the simulated results, almost all of the pipes (storm sewers and clean water collectors) would be surcharged to varying degrees for the 100 year storm event. This is to be expected given the magnitude of the storm event. None of the simulated surcharging is however extensive enough to be above the ground surface. Notwithstanding, foundation drain connections under proposed conditions should carefully consider the hydraulic condition of the receiving sewer system under more formative events

With respect to overland flow, simulated 100-year overland flows are contained within the roadway limits and do not overtop (i.e. towards the pier promenade or the harbour at sag points). A simulated maximum depth of 0.12 m is indicated at the Street ‘C’ sag point, which would be approximately 40 mm above the roadway crown, and thus still within acceptable City limits for a local roadway. Simulated depths at other roadway sag points are less than at this location, and typically below the roadway crown.

In general, simulated overland flow contributions from external (upstream) areas are generally less than was initially expected. A 100-year peak flow of 0.11 m^3/s is indicated along Discovery Drive from upstream areas, which is safely conveyed by the proposed drainage systems within the study area.

7.0 SUMMARY AND CONCLUSIONS

A stormwater management strategy has been developed for the proposed Harbourfront development, and assessed using hydrologic/hydraulic modelling tools (PCSWMM). To summarize, the strategy will involve:

- A separated clean water collector pipe system for “clean” areas – rooftops and walkways within the development blocks. This piping system will outlet directly to the harbour and provide benefits to water circulation.
- A conventional storm sewer system for roadway areas, which will also include:
  - End-of-pipe oil/grit separators (OGSs) at outfalls, and
  - Selected installation of soil retention units (Silva CellsTM) which will benefit both tree growth and stormwater treatment.

Based on the this assessment, all proposed pipes will remain unsurcharged for the 5-year storm event, and will not flood (surcharge to surface) for the 100-year storm event. Overland flow for the 100-year event will be contained within the proposed roadway right-of-ways, and simulated depths will remain within acceptable City standards (i.e. less than 150 mm above the roadway crown). Upstream areas which drain towards the proposed site appear to have a minimal impact to the development lands.

We trust the foregoing to be satisfactory. Please do not hesitate to contact our office should you wish to discuss further.

Yours truly,

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