

APPENDIX C: TECHNICAL SUPPORTING DOCUMENTS

APPENDIX C-7: STORMWATER REPORT

PART 1/1



Metrolinx

Hamilton Light Rail Transit Environmental Assessment Report Stormwater Management

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Revision History

Revision #	Date	Revised By:	Revision Description
0	29/06/2016	PW	DRAFT for Review by City of Hamilton
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2	07/12/2016	FY	Revised based on comments received from the City
3	27/02/2017	FY	Revised based on comments received from SDG & Metrolinx

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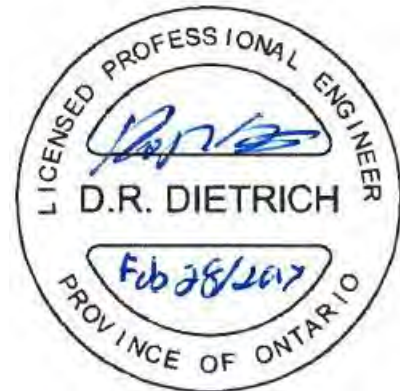


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1. Introduction and Background Information

1.1 Introduction

Metrolinx has partnered with the City of Hamilton to deliver the Hamilton LRT (Ha LRT) project. Recognized as a priority Next Wave project within the regional transportation plan, the Hamilton LRT is part of the Government of Ontario's investment in new transportation within the Greater Toronto Hamilton Area (GTHA). Upon completion, the Hamilton LRT will provide fast, reliable and convenient transportation options with linkages to local and regional subways, buses and GO Transit lines.

AECOM has been awarded the Technical Advisory Services contract for the project. As the Technical Advisor (TA), AECOM will execute the scope of work outlined in Appendix B of RFP-2015-PM-015 inclusive of all staging and associated schedules. The AECOM project team will work closely with Metrolinx and Infrastructure Ontario to prepare the following submissions:

1. Reference Concept Design (RCD) to 10% design level;
2. Project Specific Output Specification (PSOS); and
3. Technical Sections of associated Project Agreement (PA)/Request for Proposal (RFP) schedules.

These documents will form part of a DBFOM (Design, Build, Finance, Operate and Maintain) procurement strategy for construction and future maintenance of the LRT. AECOM will also support Metrolinx through the construction phases of the project, which may include additional enabling works to facilitate schedule benefits.

The Hamilton LRT (Ha LRT) project will be carried out in the following four (4) phases, inclusive of functional requirements throughout all phases:

Phase 1: Design and Planning

Phase 2: Procurement

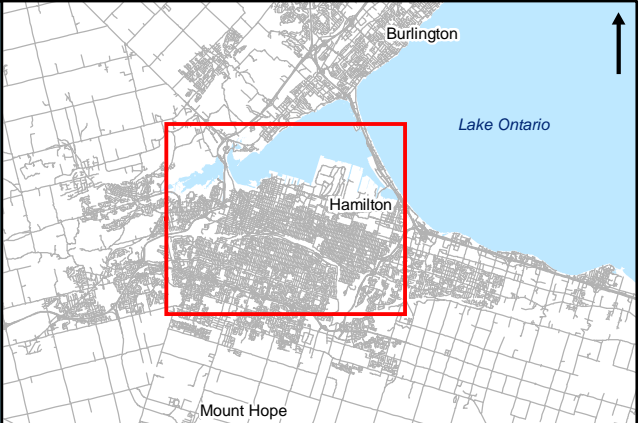
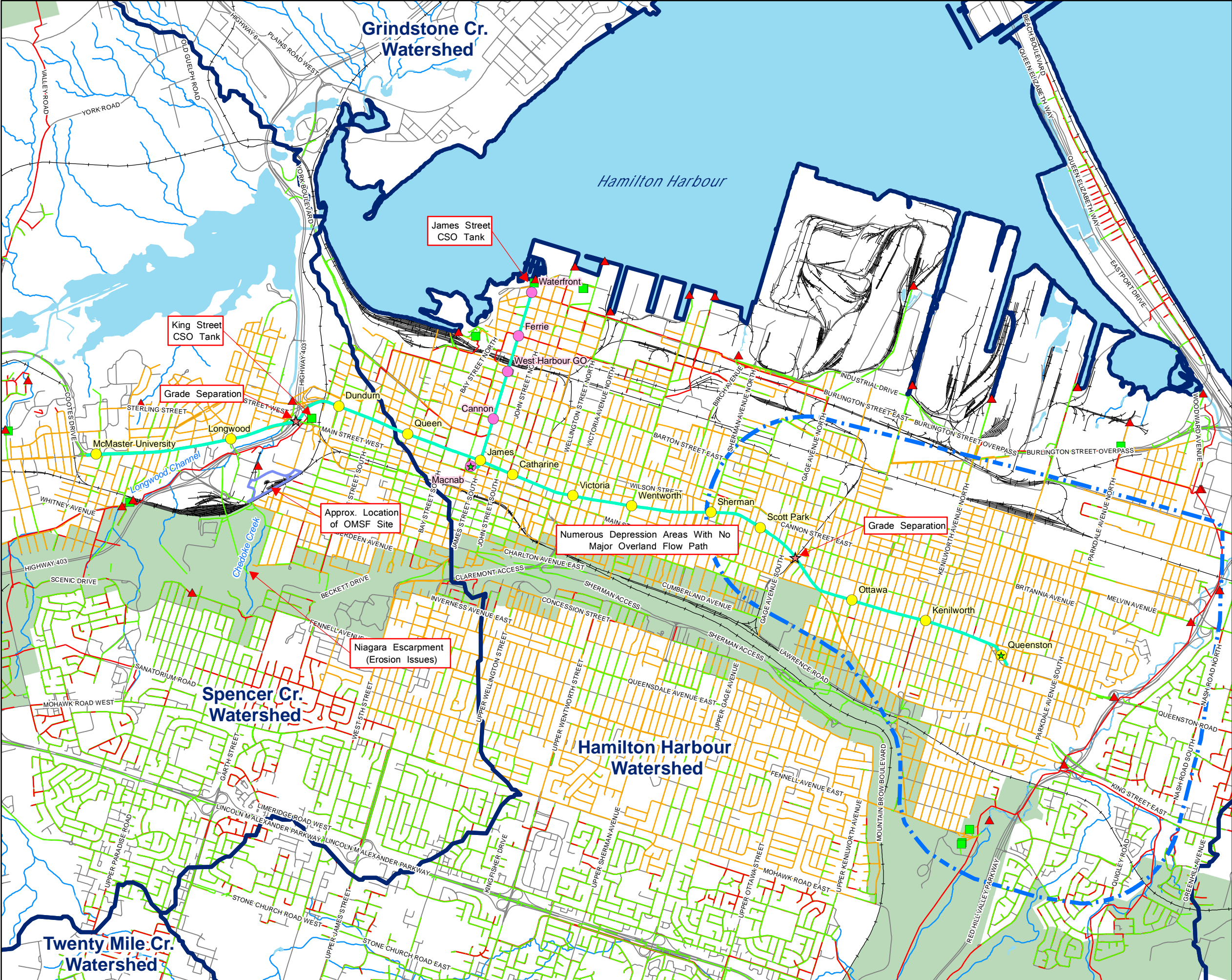
Phase 3: Implementation/Construction Phase

Phase 4: Operations

Key Features of the Hamilton LRT include (See Figure 1 below):

- 13 kms of new light rail transit from McMaster University through downtown Hamilton to Queenston Circle.
- Transit Connections (Hamilton GO Centre, Hamilton Street Railway bus network).
- Operations Maintenance and Service Facility (OMSF).
- Traction Power Substation (TPSS).

Figure 1 shows the Hamilton LRT study area.



Legend

- ★ Terminal Location
- ★ Grade Separation Location
- A-Line Connection Proposed Stop
- B-Line LRT Proposed Stop
- ▲ Outlet
- CSO Tank/OGS
- Proposed LRT
- Roads
- Rail
- Watercourse
- Contours (5m)

Sewer

- Combined
- Sanitary
- Storm

- Proposed OMSF Boundary
- Watershed Boundary
- Area of Known Basement and Overland Flooding Issues
- Escarpment Area
- Waterbody

0 1.5 3
Kilometers

Hamilton LRT

Study Area (Drainage)

December 2016	1:40,000	Datum: NAD 83 Zone 17 Source: ONB, LIO, City of Hamilton
P#: 60494276	V#:	

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Figure 1

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Drainage and stormwater management (SWM) is an essential component of any good design. This document provides an overview of relevant criteria and background information as well as a conceptual assessment of issues and opportunities with respect to drainage and stormwater management. This document is intended to provide sufficient detail to accomplish the following:

- To confirm design criteria requirements with City of Hamilton;
- To determine the impacts on the municipal storm and combined sewer system, as well as the receiving watercourses as a result of increased imperviousness from changes in land use;
- To determine whether the proposed conditions will negatively impact water surface elevations at watercourse crossings within the study area;
- To identify critical sections that require storage or flood mitigation; and
- To demonstrate the feasibility of integrating the SWM design considerations with the overall design, and other utilities along the LRT Right-of-way (ROW).

1.2 Background Information Sources

The following background information is to be reviewed to prepare the RCD:

- Relevant design standards, guidelines:
 - Design Criteria Manual (DCM) for LRT Projects, Metrolinx (May, 2012)
 - City of Hamilton Storm Drainage Policy, Philips Engineering (May, 2004)
 - Erosion and Sediments Control Guidelines for Urban Construction (Greater Golden Horseshoe Area Conservation Authorities, December 2006)
 - Integrated Water and Wastewater Master Plan for the Lake Based Systems Class EA Project file – Phase 1 & 2, KMK (November, 2006)
 - City of Hamilton's Comprehensive development guidelines and financial policies (2016)
 - Ontario Ministry of the Environment and Climate Change (MOECC) Stormwater Management Planning and Design (SWMP) Manual (MOE, 2003)
 - Ontario Ministry of Transportation Highway Drainage Design Standards (MTO, 2008)
 - Ontario Ministry of Transportation Drainage Management Manual (MTO, 1997)
 - Canadian Highway Bridge Design Code
- Hydraulic models, and floodplain maps from Hamilton Conservation Authority (HCA) for Longwood Channel and Chedoke
- MTO - Drainage and Stormwater Management Report, Improvement of the Longwood Drainage Channel and Upper Cascades Outfall along Highway 403 in Hamilton, AECOM (March, 2016)
- Mike Urban Hydrologic/Hydraulic Model of Combined sewer areas (City of Hamilton)
- Hamilton Intensity Duration Frequency (IDF) Assessment Draft Report, Cole Engineering (April, 2014)
- Integrated Subwatershed Study of Lower Spencer Creek (HCA, 2013)

2. Existing Conditions

2.1 Existing Road Drainage

In terms of surface drainage, the Hamilton corridor receives storm runoff primarily from urban municipal drainage areas. The areas contributing to the road corridor are serviced by a combined sewer system within the road corridor representing the principle storm conveyance feature for overland flow. The conveyance function is provided via the existing combined sewer network discharging to multiple storm combined sewer overflows (CSOs), as well as overland flow along the road discharging to various watercourses and the Hamilton Harbour as described below.

The proposed Ha LRT alignment (approximately 13 km) is located within the Spencer Creek and Hamilton Harbour Watersheds. Both watersheds fall under the jurisdiction of the Hamilton Conservation Authority (HCA). Spencer Creek Watershed's overall drainage pattern is from west to east, with the watershed eventually draining north into Hamilton Harbour, while the Hamilton Harbour watershed drains from south to north. As a result, there are large external drainage areas contributing flows to the proposed corridor from the east (Spencer Creek Watershed) and south with external areas on the north side mostly draining away from the proposed corridor.

2.2 Known Flooding Issues

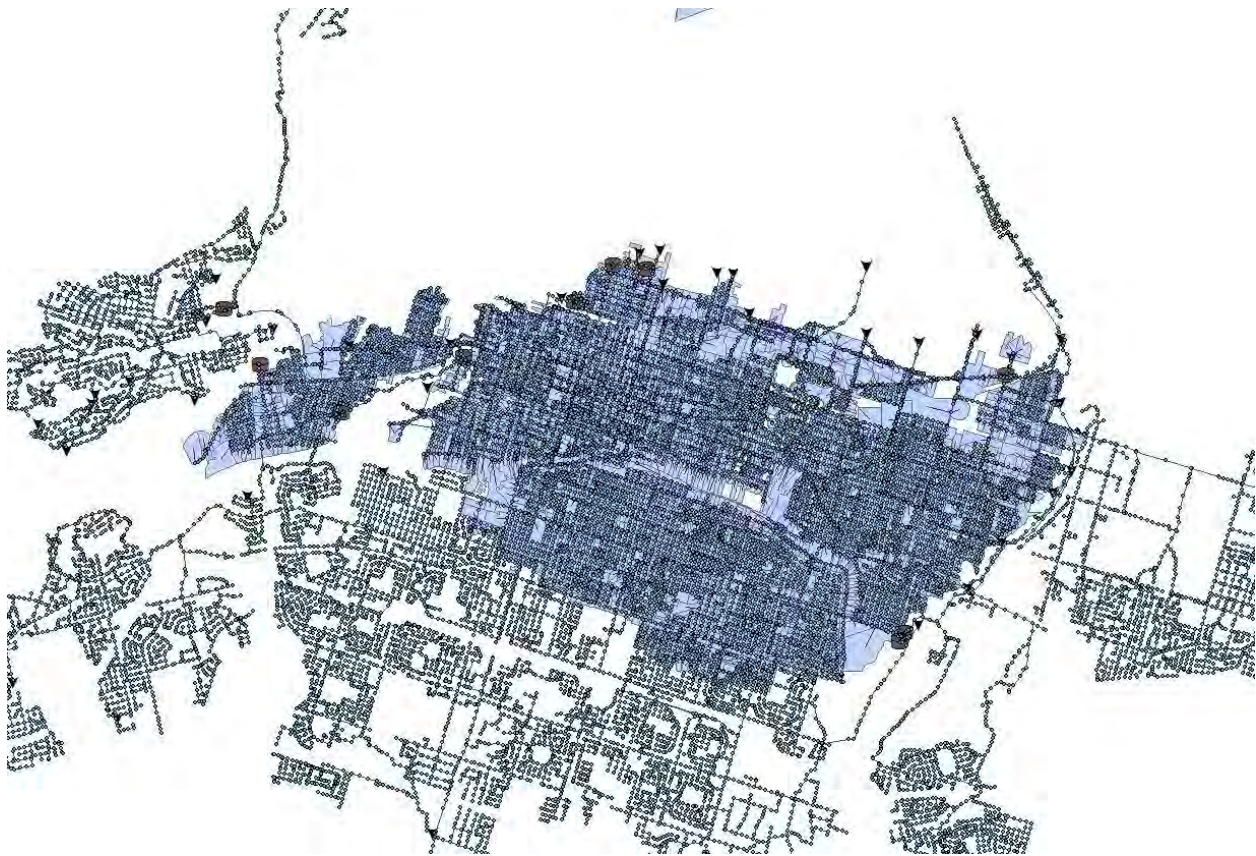
There are known flooding issues within and adjacent to the proposed Ha LRT alignment. The City of Hamilton has recently awarded a Flooding and Drainage Master Servicing Study for the combined sewer area to improve the City's sewer system and overland drainage routes to prevent flooding. The proposed Ha LRT alignment is located entirely within the Study Area.

From information provided in the City of Hamilton Request for Proposal (C11-46-15 - Flooding and Drainage Master Servicing Study): *"In the last decade the City has experienced a number of storms severe enough to cause basement flooding due to sewer backup—in some cases affecting thousands of residents. The City has been proactive in addressing this issue and developing resilience to severe storms via area specific flooding studies, resulting capital works and outreach programs. Lot level initiatives include a popular grant program: the Protective Plumbing Program (3P) which provides financial assistance and guidance to residential property owners for the installation of backwater valves, sump pits and pumps, private drainage system assessment and closed circuit television (CCTV) inspection, and disconnection of downspouts. The vast majority of capital projects are linear works (storm relief sewers) designed to increase the level of service in flood prone neighbourhoods to parity with adjoining neighbourhoods. Although these neighbourhood scale works provide parity in service, there is a need and desire to develop feasible flooding solutions that would provide widespread relief at a higher level of service."*

2.3 City of Hamilton All-Pipes MIKE URBAN Model

The City has developed an all-pipes hydrologic / hydraulic model using the MIKE URBAN DHI software program (See **Figure 2**) that the City will use to confirm proposed sewer relocations do not have adverse downstream effects (combined sewer catchments shaded).

Figure 2 - Snapshot of Hamilton's MIKE URBAN Detailed Wastewater Model



2.4 Watercourse Crossings

There are two water course crossings along the proposed Ha LRT alignment which are described in the following sections.

2.4.1 Chedoke Creek

Chedoke Creek is a tributary of the Longwood Channel, and flows in a south to north direction. The creek is conveyed by a long section of sewer from the Chedoke Golf Course under the CP tracks, under the proposed OMSF site and outlets just south of Hwy 403. (See **Figure 4 – OMSF Site – Existing Conditions**)

2.4.2 Longwood Channel

The Longwood Channel is on City of Hamilton property and is outside of the Highway 403 area, but maintained and owned by MTO. Based on MTO and the City's maintenance records, the Longwood Channel has no history of overtopping. (See **Figure 3 - Longwood Drainage Channel**)

The Longwood Drainage Channel (also known as Longwood Channel) is a trapezoidal open concrete channel that carries the Chedoke Creek along Highway 403 from east of the Toronto, Hamilton and Buffalo (TH&B) Railway easterly approximately 1.6 km to the Main Street West underpass crossing. The existing concrete channel was constructed in 1964. Currently, the channel has several sections subject to deterioration, cracking, vegetation intrusion and possible undermining by erosion. AECOM Canada Ltd. was retained by the Ontario Ministry of Transportation (MTO) to undertake a Class Environmental Assessment and Preliminary Design Study (G.W.P. 2054-14-00) in March 2016 to assess existing hydraulic and structural conditions and develop a preliminary design to mitigate flooding and rehabilitate the channel. Option 1 "Repair / Replacement in kind" was selected as the preferred option for further consideration. The recommended channel improvement works of Option 1 would include slab replacements, outlet structure modifications, and general repairs works such as backfill restoration, filling of scour holes and repairing eroded concrete and erosion gullies on road embankment.

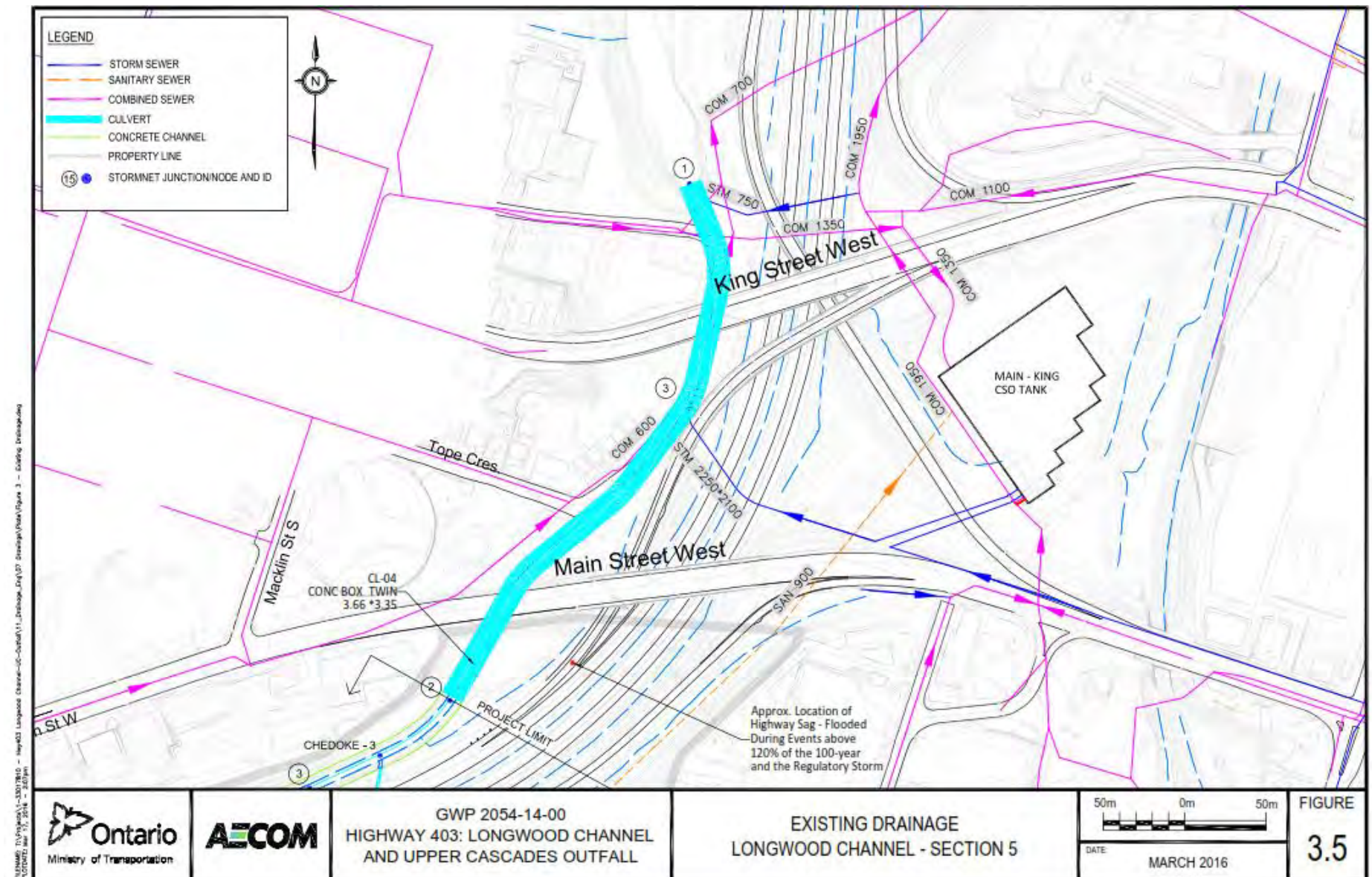


Figure 3 - Longwood Drainage Channel

3. Proposed Conditions

Since the proposed Ha LRT alignment runs entirely through an already urbanized area no additional paved area or increase in imperviousness is required and therefore no specific quantity and quality controls are required. Special considerations will need to be considered at the OMSF site, grade separations and water course crossings as described in the following sections.

3.1 OMSF Site

Under existing conditions the OMSF site drains into two outlet points. First outlet drains the west half of the site and is located in a low lying area west of 606 Aberdeen Avenue. This low area ultimately drains into Chedoke Creek. The second outlet point drains the east half of the site and outlets into a ditch north of the train tracks. Outlet points and overland flow routes are shown on **Figure 4**.

The OMSF site will need to adhere to the Planning Act Development Application(s) process which will include a stormwater management pond. The details of this are further discussed in **Section 4**. Drainage from the developed portion of the OMSF site will be directed to the proposed stormwater management pond. The requirements of the pond will likely include the mitigation of proposed development conditions peak flows to pre-development conditions and Level 1 (Enhanced) quality control for the contributing drainage

For this study, it was anticipated that the pond flows would be directed westerly via storm sewer to the low lying area in the vicinity of chainage 0+614. Flows from the OMSF developed site (stormwater management facility outflows) as well as all flows from the localized area will be captured at the low lying area and diverted across the proposed tracks via a culvert.

A preliminary hydrologic model was set up to determine the existing condition peak flows for the site, as shown on **Figure 4 – OMSF Site – Existing Conditions**.

Existing peak flows were calculated as it is assumed that future development will require stormwater measures to control post development flows to existing condition peak flows. The proposed culvert was sized to convey the anticipated peak flows to this low lying area under the proposed tracks.

To adhere to the Planning Act Development Application(s) process, stormwater quality and quantity controls will need to be designed based on relevant criteria (Ontario Ministry of the Environment Stormwater Management Planning and Design Manual, 2003). Below are the conceptual design calculations for the pond design. The existing site conditions are shown in **Figure 4**.

Assumptions:

- Enhanced (Level 1) Wet pond with 75% Impervious contributing area
 - Quality control – Long term removal of 80% of the suspended solids
- 7.05 ha contributing area
- 4:1 side slopes average (manual calls for 5:1 for 3 m on either side of perm pool, 3:1 elsewhere)
- 3:1 length to width ratio

Based on the above, a pond with 2900 m³ of storage and an overall depth of 2.75 m (1.5 m permanent pool depth and 1.25 m of active storage) should be adequate to meet the requirements.

Based on a top of ground elevation of approximately 95 m at the proposed stormwater management pond and a maximum depth of 3 m, a conservative storm sewer inlet elevation of 92 m was used in the calculations. The low lying area is located approximately 180 m westerly of the proposed stormwater management facility, with a culvert invert elevation of 89 m assumed. Based on these inverts and estimated length, a 1050 mm diameter storm sewer was calculated to be sufficient to convey the stormwater management pond flows to the culvert.

As mentioned above, an invert of 89 m was assumed for the upstream culvert invert. The maximum headwater elevation of 91.7 m was assumed to be just below the proposed top of tracks at this location. The calculations indicate that a 1350 mm diameter CSP pipe, or a 1250 mm diameter concrete pipe are both sufficient to convey the flows under the tracks.

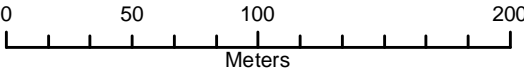
Storm sewer and culvert sizing was carried out using Haestad's FlowMaster hydraulic modelling software. FlowMaster output files are provided in **Appendix A**. Hydrologic modelling output files are also provided in **Appendix B**.



Legend

- Manhole
- ▲ Outlet
- Sewer**
 - Combined
 - Sanitary
 - Storm
- Roads
- Watercourse
- Overland Flow
- ▭ Proposed OMSF Boundary
- ▭ Existing Impervious Area

Total Property Area	7.05 ha
Total Impervious Area	3.54 ha
Precent Impervious	50.24%



Hamilton LRT

OMSF Site -
Existing Conditions

February
2017

1:3,000

Datum: NAD 83 Zone 17
Source: Bing, ONB, LIO,
City of Hamilton

P#: 60494276

V#: 002

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Figure 4

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Map Location: P:\0494276 Hamilton LRT\000-Working\020-282\GIS-Graphics\Design\03_Working\OMSF Site - Existing Conditions 20161205.mxd
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3.3.1 Highway 403 Flyover

The Highway 403 Flyover is intended to link the tracks on Main Street West and King Street West. Since this structure will likely be built on piles it will have little effect on the watercourse (Longwood Channel) hydraulics below. However, appropriate permits will be required as described in **Section 6**.

3.3.2 Gage Avenue Grade Separation

The second grade separation location is at King Street just east of Gage Avenue where the LRT tracks will go under the CPR railway. The new LRT corridor will run along the centre of the road which will be lowered under the existing freight track, while the road lanes on either sides of the LRT track will remain at grade.

This grade separation should be designed with the City's MIKE URBAN model (or similar software) with overland flow routes added as required where the model indicates the water levels would surcharge to the ground surface within the catchment. The design criteria will need to be confirmed with the City, but will typically include:

- Storage of runoff volumes generated from the road catchment to the sag point;
- Pump station or storage / release arrangement that will keep the tracks in an operational condition during all storm events up to and including the regional event;
- Release rate from the sag that matches the existing design for to the downstream receiving sewer; and
- Assessment of tailwater conditions (such as downstream sewer issues or lake levels as presented on **Figure 6**) to confirm any impacts on performance.

A preliminary review of the site suggests that the following design components are recommended for this grade separation:

- The sag be isolated from overland flows from the surrounding area;
- The tracks be elevated on the upstream (based on the road slope) side to form a "bump" slightly above the estimated high water level on the road (approximately 0.30 m above gutter elevation) to form a physical barrier to overland flows down into the sag. A similar "bump" should also be implemented on the downstream side to prevent overland backflows into the sag. In both cases the actual bump elevation required will need to be determined based on modelling;
- A barrier wall surround the depressed tracks and extend above the adjacent roadway to prevent overland flows on the roadway from spilling into the sag;
- An interceptor trench (with grate) be installed across the full width of the roadway upstream of the sag to capture overland flows along the roadway and route them to the downstream side of the sag. The use of such a trench would minimize the needed "bump" and barrier wall elevations; and
- Any flows resulting from rainfall onto the depressed rail area be collected and conveyed to a downstream outlet to allow function of the LRT. A direct gravity connection should be avoided to minimize the chance of backwater flows flooding the sag.
- An adequate inlet system be designed to capture the peak flows and run-off volumes within the sag in order to maintain the existing level of service with respect to flooding depths and frequency.
- Release rate from the sag be controlled to the lesser of:
 - the 1:2 Year pre-development flow rate
 - the available residual capacity of the receiving storm sewer.
- The water level in the sag must be maintained at an appropriate level to allow function of the LRT.

3.3.1 Highway 403 Flyover

The Highway 403 Flyover is intended to link the tracks on Main Street West and King Street West. Since this structure will likely be built on piles it will have little effect on the watercourse (Longwood Channel) hydraulics below. However, appropriate permits will be required as described in **Section 6**.

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- A barrier wall surround the depressed tracks and extend above the adjacent roadway to prevent overland flows on the roadway from spilling into the sag;
- An interceptor trench (with grate) be installed across the full width of the roadway upstream of the sag to capture overland flows along the roadway and route them to the downstream side of the sag. The use of such a trench would minimize the needed “bump” and barrier wall elevations; and
- Any flows resulting from rainfall onto the depressed rail area be collected and conveyed to a downstream outlet to allow function of the LRT. A direct gravity connection should be avoided to minimize the chance of backwater flows flooding the sag.
- An adequate inlet system be designed to capture the peak flows and run-off volumes within the sag in order to maintain the existing level of service with respect to flooding depths and frequency.
- Release rate from the sag be controlled to the lesser of:
 - the 1:2 Year pre-development flow rate
 - the available residual capacity of the receiving storm sewer.
- The water level in the sag must be maintained at an appropriate level to allow function of the LRT.

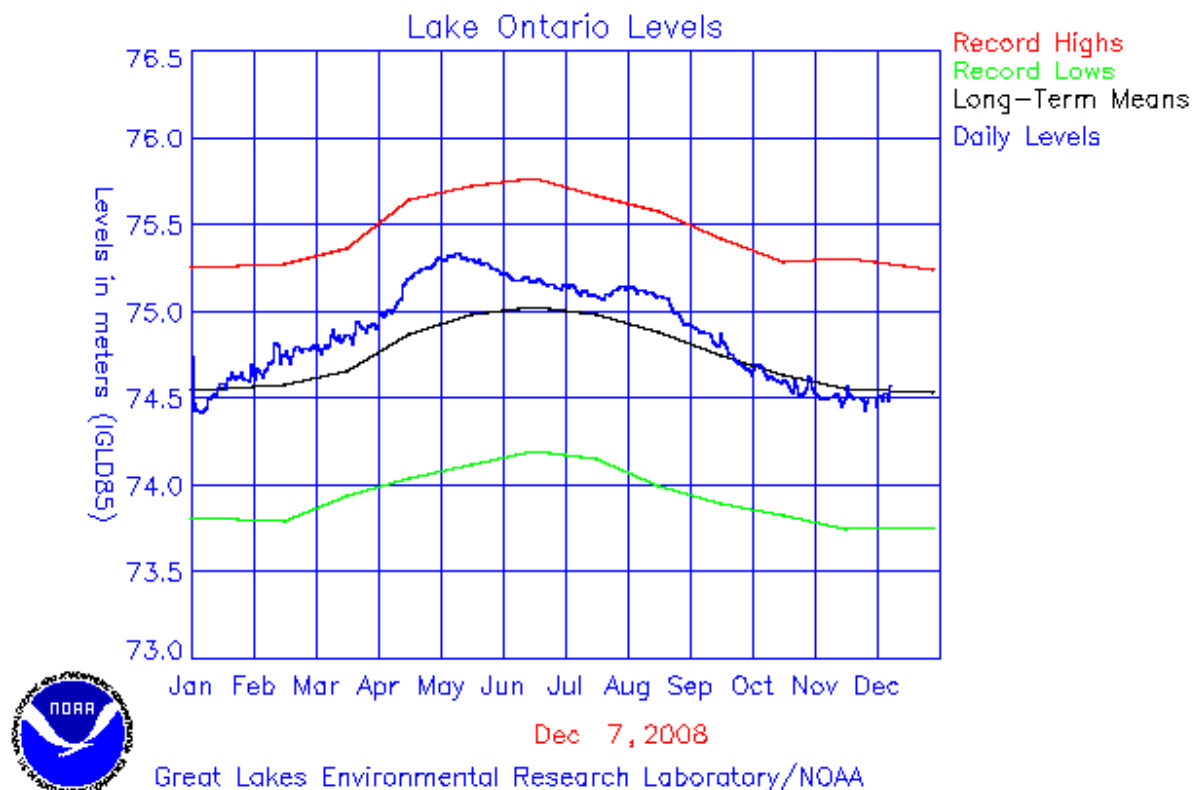


Figure 6 - Lake Ontario Levels

3.4 Watercourse Crossings

At this stage, no structural alterations have been proposed for the crossings at the Longwood Channel or Chedoke Creek. To accommodate the proposed Ha LRT alignment, a grade separation (fly over) will be required across the Longwood Channel. The placement of the piers for this flyover will need to carefully consider the location of various drainage infrastructures such as the King Street CSO tank, numerous large sewers and the Longwood Channel box culvert. However, these piers will likely have little impact on the hydraulic functioning of the watercourse.

4. Erosion and Sediment Controls during Construction

An erosion and sediment control plan is required to satisfy the criteria of “Erosion and Sediments Control Guidelines for Urban Construction” (Greater Golden Horseshoe Area Conservation Authorities, December 2006). The following control measures are recommended to be implemented during the construction:

- Erosion protection be provided around all storm manholes, sanitary manholes and catch basins;
- Erosion control structures should be monitored regularly with sediment being removed when accumulations reach a maximum of 1/3 of the height of the silt fence;
- All erosion control structures should remain in place until all disturbed ground surfaces have been re-stabilized either by paving or restoration of vegetative ground cover;
- The contractor must remove sediments from the municipal roadway and sidewalks at the end of each work day;
- A single construction entrance be utilized with a “mud mat” installed to minimize the amount of sediment transported off the site on construction vehicles tires;
- All disturbed areas not scheduled for construction within 30 days be stabilized and seeded immediately;
- Inspections be completed weekly and after an event greater than 13 mm, and submitted regularly to the City and the HCA;
- Slopes greater than 5:1 be stabilized using geogrid or an erosion control blanket, and seeded or sodded as soon as possible; and
- During construction, slopes should be maintained with a dense cover of grass.

5. Environmental Permits

At a minimum, the following permits will be required; however, additional permits may be required as a result of changes in Provincial or Federal legislation:

- A permit under Ontario Regulation 166/06 “Regulation of Development, Interference with Wetlands and Alterations to Shorelines and Watercourses” will have to be secured from the Hamilton Conservation Authority for any alteration/modification work along the watercourse crossings.
- Any proposed works that are likely to alter or damage fish habitat must be reviewed and authorized by the Department of Fisheries and Oceans (DFO).
- Endangered Species Act permit or authorization from the Ministry of Natural Resources and Forestry.
- An Environmental Compliance Approval (ECA) from MOECC will be required for all new sewers, stormwater management facilities and storm outlets.
- A MOECC Permit To Take Water (PTTW) may be required if the construction requires any temporary dewatering.

6. Conclusions and Recommendations

On the basis of above analysis, the following conclusions and recommendations can be drawn:

- The proposed 13 km long Ha LRT alignment from McMaster University to the Queenston Traffic Circle is located within the Spencer Creek and Hamilton Harbor Watersheds.
- Since this route is entirely located within an already urbanized area, no additional paved area or increase in imperviousness is required and therefore no specific quantity and quality controls are required.
- The proposed vertical profile for the Ha LRT will closely follow the existing road/ground surface (except at the two grade separation locations), and therefore no alteration of the major overland flows paths are anticipated.
- There are two grade separation locations:
 - Highway 403 flyover: This grade separation will not require any specific design with respect to drainage, but will need to account for existing infrastructure.
- King Street east of Gage Avenue: An adequate inlet system be designed to capture the peak flows and run-off volumes within the sag in order to maintain the existing level of service with respect to flooding depths and frequency.
- The existing combined and storm sewers will continue to discharge to the current watercourses and trunk sewer systems thereby maintaining the existing general flow direction and pattern.
- There are significant existing flooding issues along alignment which the City is currently addressing with a flooding masterplan. Ongoing coordination between these two projects is required/recommended.
- Sewers along the alignment within the exclusion zone will need to be relocated. Most of these sewers do not meet current design standards. Replacement sewers are to be “like for like”, i.e. maintain the existing hydraulic capacity.
- The existing watercourse crossings will not be affected by the proposed design therefore no significant changes are anticipated in the upstream/downstream flood elevations due to the construction of Ha LRT. However, additional hydraulic investigations may be required for permitting requirements.
- A separate SWM study will need to be undertaken to prepare the detailed stormwater management required for the OMSF Site.

Appendix A

FlowMaster Output Files

Culvert Calculator Report

Storm sewer

Comments: Assumed upstream and downstream inverts, headwater elevation, and estimated pipe length of 180m

Solve For: Section Size

Culvert Summary			
Allowable HW Elevation	93.00 m	Headwater Depth/Height	1.41
Computed Headwater Elev.	92.50 m	Discharge	2.2000 m ³ /s
Inlet Control HW Elev.	92.50 m	Tailwater Elevation	89.00 m
Outlet Control HW Elev.	92.49 m	Control Type	Inlet Control
Grades			
Upstream Invert	91.00 m	Downstream Invert	89.00 m
Length	180.00 m	Constructed Slope	0.011111 m/m
Hydraulic Profile			
Profile	S2	Depth, Downstream	0.68 m
Slope Type	Steep	Normal Depth	0.68 m
Flow Regime	Supercritical	Critical Depth	0.84 m
Velocity Downstream	3.67 m/s	Critical Slope	0.006440 m/m
Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.07 m
Section Size	1050 mm	Rise	1.07 m
Number Sections	1		
Outlet Control Properties			
Outlet Control HW Elev.	92.49 m	Upstream Velocity Head	0.43 m
Ke	0.50	Entrance Loss	0.22 m
Inlet Control Properties			
Inlet Control HW Elev.	92.50 m	Flow Control	Submerged
Inlet Type	Square edge w/headwall	Area Full	0.9 m ²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report

OMSF - 1 - SINGLE CULVERT - CSP

Solve For: Section Size

Culvert Summary			
Allowable HW Elevation	91.70 m	Headwater Depth/Height	1.75
Computed Headwater Elev.	91.50 m	Discharge	4.3500 m³/s
Inlet Control HW Elev.	91.41 m	Tailwater Elevation	89.00 m
Outlet Control HW Elev.	91.50 m	Control Type	Outlet Control
Grades			
Upstream Invert	89.10 m	Downstream Invert	89.00 m
Length	20.00 m	Constructed Slope	0.005000 m/m
Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	1.11 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	1.11 m
Velocity Downstream	3.40 m/s	Critical Slope	0.021391 m/m
Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.37 m
Section Size	1350 mm	Rise	1.37 m
Number Sections	1		
Outlet Control Properties			
Outlet Control HW Elev.	91.50 m	Upstream Velocity Head	0.44 m
Ke	0.90	Entrance Loss	0.40 m
Inlet Control Properties			
Inlet Control HW Elev.	91.41 m	Flow Control	Submerged
Inlet Type	Projecting	Area Full	1.5 m²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Calculator Report

OMSF - 1 - SINGLE CULVERT - CONCRETE

Solve For: Section Size

Culvert Summary			
Allowable HW Elevation	91.70 m	Headwater Depth/Height	1.98
Computed Headwater Elev.	91.58 m	Discharge	4.3500 m³/s
Inlet Control HW Elev.	91.58 m	Tailwater Elevation	89.00 m
Outlet Control HW Elev.	91.34 m	Control Type	Inlet Control
Grades			
Upstream Invert	89.10 m	Downstream Invert	89.00 m
Length	20.00 m	Constructed Slope	0.005000 m/m
Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	1.11 m
Slope Type	Mild	Normal Depth	N/A m
Flow Regime	Subcritical	Critical Depth	1.11 m
Velocity Downstream	3.78 m/s	Critical Slope	0.008931 m/m
Section			
Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	1.25 m
Section Size	1250 mm	Rise	1.25 m
Number Sections	1		
Outlet Control Properties			
Outlet Control HW Elev.	91.34 m	Upstream Velocity Head	0.64 m
Ke	0.50	Entrance Loss	0.32 m
Inlet Control Properties			
Inlet Control HW Elev.	91.58 m	Flow Control	Submerged
Inlet Type	Square edge w/headwall	Area Full	1.2 m²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Appendix B

Hydrologic Modelling Output Files

 NOTE: The summary statistics displayed in this report are
 based on results found at every computational time step,
 not just on results from each reporting time step.

Analysis Options

Flow Units CMS

Process Models:

Rainfall/Runoff YES
 RDII NO
 Snowmelt NO
 Groundwater NO
 Flow Routing NO
 Water Quality NO

Infiltration Method HORTON

Starting Date AUG-11-2016 00:00:00

Ending Date AUG-13-2016 00:00:00

Antecedent Dry Days 0.0

Report Time Step 00:01:00

Wet Time Step 00:05:00

Dry Time Step 00:05:00

Element Count

Number of rain gages 2

Number of subcatchments ... 2

Number of nodes 2

Number of links 0

Number of pollutants 0

Number of land uses 0

Raingage Summary

Name	Data Source	Data Type	Recording Interval
100-Year	100-Year	INTENSITY	5 min.
5-Year	5-Year	INTENSITY	5 min.

Subcatchment Summary

Name	Area	Width	%Imperv	%Slope	Rain Gage	Outlet
S1	6.76	500.00	40.00	1.0000	100-Year	J16

S2 7.24 500.00 25.00 1.0000 100-Year OF1

Node Summary

Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
J16	OUTFALL	85.00	0.00	0.0	
OF1	OUTFALL	85.00	0.00	0.0	

	Volume hectare-m	Depth mm
Runoff Quantity Continuity		
Total Precipitation	1.720	122.891
Evaporation Loss	0.000	0.000
Infiltration Loss	0.130	9.296
Surface Runoff	1.593	113.798
Final Surface Storage	0.000	0.012
Continuity Error (%)	-0.175	

	Volume hectare-m	Volume 10^6 ltr
Flow Routing Continuity		
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	1.593	15.929
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	0.000	0.000
External Outflow	1.593	15.929
Internal Outflow	0.000	0.000
Evaporation Loss	0.000	0.000
Exfiltration Loss	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.000	0.000
Continuity Error (%)	0.000	

Subcatchment Runoff Summary

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
S1	122.89	0.00	0.00	8.16	114.95	7.77	2.35	0.935
S2	122.89	0.00	0.00	10.35	112.72	8.16	2.19	0.917

Analysis begun on: Thu Oct 13 10:40:43 2016
Analysis ended on: Thu Oct 13 10:40:44 2016
Total elapsed time: 00:00:01

About AECOM

AECOM (NYSE: ACM) is built to deliver a better world. We design, build, finance and operate infrastructure assets for governments, businesses and organizations in more than 150 countries.

As a fully integrated firm, we connect knowledge and experience across our global network of experts to help clients solve their most complex challenges.

From high-performance buildings and infrastructure, to resilient communities and environments, to stable and secure nations, our work is transformative, differentiated and vital. A Fortune 500 firm, AECOM companies had revenue of approximately US\$19 billion during the 12 months ended June 30, 2015.

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