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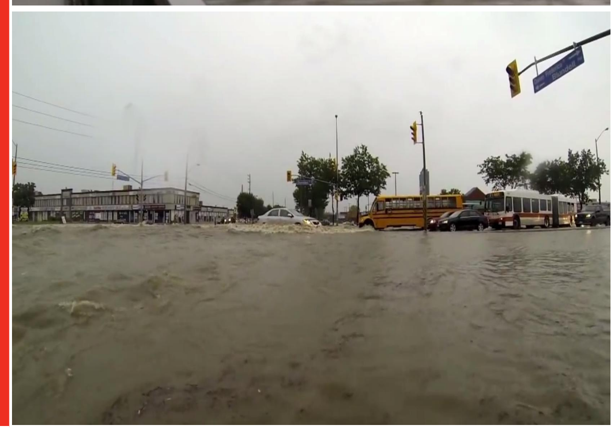

Floodplain Mapping in Applewood and Dundas / Dixie Special Policy Area

Little Etobicoke Creek

MMM GROUP

January 2015 | 1412606-000

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1.0 INTRODUCTION

1.1 Study Need

The TRCA is in the process of updating floodline mapping for watercourses within Etobicoke Creek, including Little Etobicoke Creek. While the standard one-dimensional (1D) HEC-RAS program is adequate for most of the watershed, the flood regime through the Dixie and Dundas Special Policy Area (SPA) and Applewood SPA in Mississauga are quite complex and warrant a 2D modelling approach. Specifically, Little Etobicoke Creek overtops its banks at multiple locations through the study area. The spills generally flow in a southerly direction across Dundas Street. It should be noted that the ultimate destination of the spill flow is not clear at this time, and will be assessed through subsequent study.

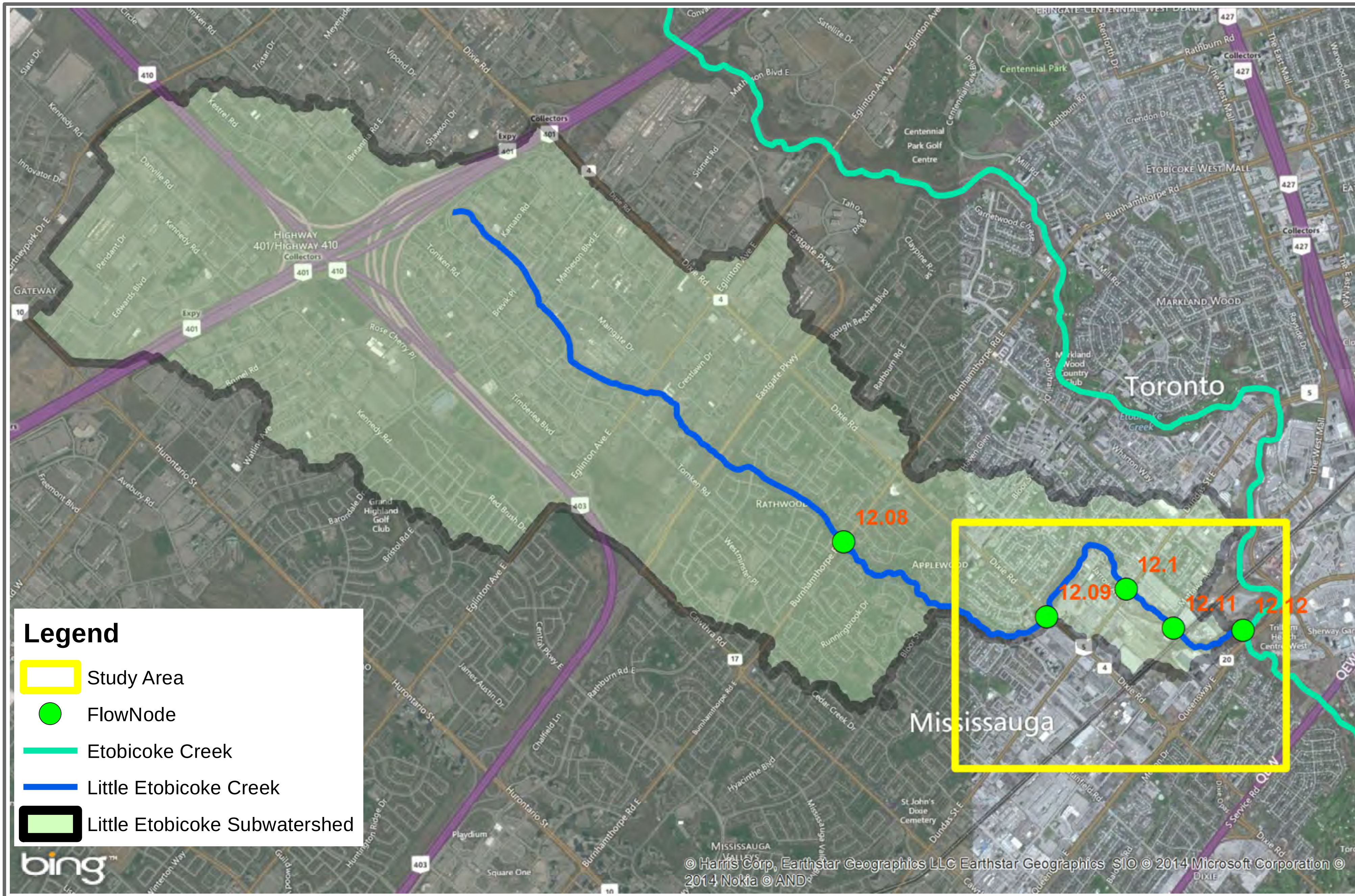
The objective of this study is to develop a 2D hydraulic model of Little Etobicoke Creek to map flooding conditions within the Dixie / Dundas SPA and Applewood SPA for selected flood events, and to use the model to complete a preliminary evaluation of flood mitigation alternatives. Results from the study will provide input to private business sectors and landowners for preparing development proposals, such as flood proofing and mitigation plans for these areas. The updated flood constraint mapping will provide guidance to local, regional and provincial government agencies as well as private sectors in managing and planning existing and future developments. Exhibit 1.1 illustrates the study area in the context of the broader watershed including conservation authority boundaries.

1.2 Existing SPAs and Flood Mitigation Works

Special Policy Areas represent existing flood prone development, and are intended to strike a balance between flood protection and maintaining the economic viability of community. As such, development is allowed within an SPA subject to a number of constraints related to both flood protection and safe access / egress.

The limits of the Dixie / Dundas SPA and the Applewood SPA are illustrated in Exhibit 1.2, along with the limits of the Regulatory floodplain as defined in 2011.

Document Name: ex1.1-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA - Study Area



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LITTLE ETOBICOKE CREEK STUDY AREA

FLOODPLAIN MAPPING FOR
THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

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1:42,000
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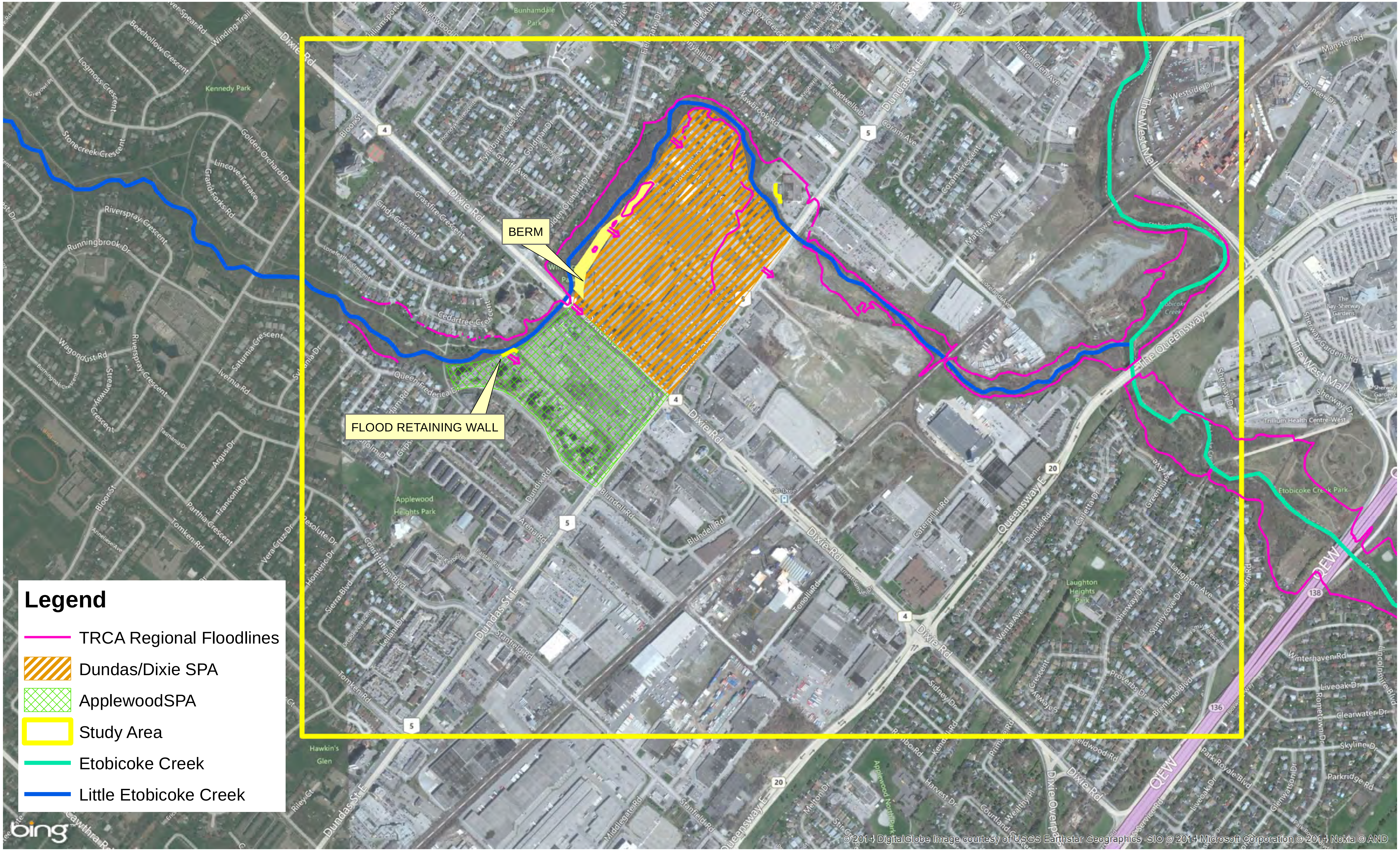
Date: November-03-2014
Project No: 1412606
Exhibit No: 1.1

Document Name: ex1.2-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA - Floodlines and SPA Limits



MMM GROUP

SPECIAL POLICY AREAS AND REMEDIAL WORKS

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

0 120 240 360 m

1:10,000

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Date: August-08-14

Project No: 1412606

Exhibit No. 1.2

As part of managing flood risk in the SPAs, the TRCA completed the following studies between 1988 and 1990 to identify appropriate flood mitigation measures:

a) *A Preliminary Engineering Study for Flood and Erosion Control – Little Etobicoke Creek* (Cumming *Cockburn Limited, October 1988).* The study provided an inventory of erosion and flooding problems and an assessment of hazardous conditions. The report included a long-term program to alleviate flooding and erosion problems.

b) *Environmental Study Report for Flood and Erosion Control, Little Etobicoke Creek, Dixie / Dundas Area (Cumming Cockburn Limited, April 1989).* The study recommended the implementation of a structure mitigative scheme that would improve flood proofing protection for the Dixie and Dundas area.

c) *Little Etobicoke Creek Channelization, Dundas Street to Brick Warehouse (Cumming Cockburn Limited, September 1990).* The study provided recommendations to complete the erosion and flood proofing protection work for the reach, between Dundas Street and upstream of the Brick property.

As illustrated on Exhibit 1.2, the remedial works have since been constructed for Little Etobicoke Creek, including:

a) Construction of earth berms upstream and downstream of Dixie Road (see Photo 3.5 on Page 11)

b) Construction of a concrete flood wall located upstream of Dixie Road, immediately adjacent to the first pedestrian bridge. (Photo 3.6)

c) Lowering the channel invert by one metre at upstream of Dixie Road to relieve flooding problems along Queen Frederica Drive and the shopping mall just upstream of Dixie Road

d) Construction of armourstone protection along the creek for a distance of 500 metres on both sides of Dixie Road and approximately 200 metres upstream of Dundas Street

1.3 Flood of July 8, 2013

On July 8, 2013 the Etobicoke Creek was subject to its largest flood on-record. As described later in this report, the return period of the event in the vicinity of the Dixie Road crossing of the Little Etobicoke Creek was comparable to the 350-year peak flow calculated as part of the 2013 Etobicoke Creek Hydrology Update (MMM Group, 2013).

Given the magnitude and timing of this event, it was used to help verify the accuracy of the flood risk calculated as part of this floodplain mapping study. Details are provided in Section 5.0.

1.4 Etobicoke Creek Hydrology Update

In 2013 the Etobicoke Creek Hydrology Update (MMM Group) was completed. The update was completed to reflect current watershed conditions, to update the calibration based on more recent flow and rainfall data, and to reflect ongoing and future stormwater management practices. Exhibit 1.1 illustrates the limits of the Little Etobicoke Creek watershed and the location of the flow nodes used to complete this floodplain study. Table 1.1 summarizes peak flows at key locations for the various design storms.

Table 1.1: Summary of Peak Flows for Little Etobicoke Creek

Flow Location		Peak Flow Rate[1] (m^3/s)							
Location	Node	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	350-yr	Reg. Storm
Bloor St.	12.08	42.9	55.4	63.9	75.6	84.5	93.68	141.4	193.6
Dixie Rd.	12.09	41.8	54.5	62.9	74.5	83.3	92.40	140.6	191.9
Dundas St.	12.10	42.9	56.5	65.5	77.6	86.8	96.3	146.60	201.8
Queensway	12.12	44.7	58.7	68.3	80.9	90.4	100.2	152.26	209.5
Notes: 1)		*Peak Flow for future conditions. Source Etobicoke Creek Hydrology Update, MMM Group, 2013; based on 12-hour AES storm*							

1.5 Study Scope

The ultimate purpose of this project is to develop updated flood hazard mapping for Little Etobicoke Creek through the Dundas / Dixie and Applewood SPAs, and provide a modelling tool that will aid in assessing the hydraulic impacts of development applications, as well as alternatives to reducing flood risk in the SPAs and adjacent flood prone lands.

Generally the scope encompasses four broad tasks: update base mapping, develop 1D and 2D hydraulic models to estimate flood elevations, complete a preliminary assessment of alternatives to reduce flood risk, and prepare updated flood hazard mapping. The content of each report section is listed as follows:

- Section 2.0 – preparation of updated base mapping developed using LiDAR
- Section 3.0 –development of HEC-RAS and Mike11 1D models for Little Etobicoke Creek, incorporating the updated base mapping, surveyed creek cross-sections, and the most recent flows as presented in the Etobicoke Creek Hydrology Update
- Section 4.0 –development of 2D overland MIKE FLOOD model for Little Etobicoke Creek
- Section 5.0 – validation of MIKE FLOOD using the flood event of July 8, 2014
- Section 6.0 –application of MIKE FLOOD to generate flood elevations and flow patterns for the Regional Storm and design storms with return periods ranging from 2-years to 100-years

- Section 7.0 – summary of updated flood hazard mapping
- Section 8.0 – preliminary assessment of remedial options to reduce food risk in the two SPAs

1.6 Study Team

The Study Team included MMM Group as the project lead, with the Danish Hydraulics Institute (DHI) responsible for development of the MIKE FLOOD model. Valdor Engineering Inc. was also retained to complete a Peer Review of the model on behalf of the TRCA

2.0 BASE MAPPING AND SURVEY

The LIDAR data for the Dixie Dundas 2D Modelling study was collected and produced by Airborne Imaging, a Clean Harbors Company, in November of 2012. The data was collected on two flight missions carried out on November 27 and 28 of 2012. The limits of the LiDAR survey are illustrated on Exhibit 2.1

The LiDAR data was acquired at an altitude of 800 m Above Ground Level with a laser pulse rate set at 300,000 Hz, resulting in a data set with a total point density greater than 11 points per sq. m. The total density is based on two overlapping flight line swaths flown in opposing directions to provide redundancy and to ensure there are no data holes or slivers. The following details the flight parameters:

- Flight Height: 800 m AGL
- Speed: 140 knots
- Flightline Spacing: 350 m
- Single Pass Swath width: 700 m
- Overlap: 50%
- Scan Angle or FOV: 50%
- Scan Frequency: 47Hz
- Scan Pulse Rate: 300kHz
- 11 points per square metre with overlap

The accuracy required for this project was 10 cm RMSE. The results of the ground truthing showed an RMSE of just less than 5 cm. The accuracy at the 2-sigma confidence level (95% of the time) is twice the RMS value. Therefore, the data shows that vertical accuracy is within 10 cm 95% of the time, which exceeds TRCA's current mapping specification.

The planimetric data was acquired from the City of Mississauga. The data for the study area of Dixie Rd. and Dundas St. is based on 2011 imagery.

To create the contour data TRCA Staff used the surface as a raster grid provided by MMM that included the original LiDAR data set with the Smart Centre survey (located in the SE portion of the study area) included. The buildings were removed in order to provide a bare earth surface in which the contours would be generated. The contours were generated using the Spatial Analyst tool in ESRI ArcMap in 1 m intervals. Spot elevations will be generated along the bridge decks, overpasses and areas where the contour spacing is large, using a full resolution terrain created from the full LiDAR dataset.

Document Name: ex2.1-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA - Limit of LiDar Mapping

MMM GROUP

LIMIT OF LIDAR MAPPING

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

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Date: November-03-2014
Project No: 1412606
Exhibit No: 2.1

3.0 ETOBICOKE CREEK 1D MODELLING

As previously noted, Little Etobicoke Creek overtops its banks at several locations starting upstream of Dixie Road and continuing downstream to Dundas Street. The primary spill location is upstream of Dixie Road at Queen Frederica Drive, with secondary spill locations just downstream of Dixie Road. The majority of the flow that spills from the creek generally flows overland in a southerly direction to Dundas Street before dividing among multiple routes. The spill routes are dominantly two dimensional (2D) in nature cannot be accurately modelling using a traditional one dimensional (1D) model such as HEC-RAS. It is for this reason that a 2D hydraulic model (MIKE FLOOD) was used to model the overall flood regime.

Application of MIKE FLOOD is a two-step process, including the development of a 1D model (MIKE 11) of Little Etobicoke Creek, and integration of MIKE 11 with the 2D MIKE 21 overland flow model to create the integrate MIKE FLOOD model. This section of the report documents the development of the MIKE 11 model for Little Etobicoke Creek. Section 4.0 addresses the development of the 2D MIKE 21 and the MIKE FLOOD models.

Development of the 1D MIKE 11 model included the following key steps.

- Completion of a field survey of Little Etobicoke Creek to augment the LiDAR survey in areas where LiDAR is ineffective (creek bathometry, structure opening details, key hydraulic constraints)
- MIKE 11 model development including conversion of the existing HEC-RAS model
- Compilation of modelling results and comparison to existing HEC-RAS modeling results
- Peer Review of the completed MIKE 11 modelling

3.1 Cross-Section Survey

A field survey was completed of Little Etobicoke Creek from downstream of Dundas Street to the upstream side of the two foot bridges located upstream of Dixie Road. The survey also included details of the berm and flood wall that were constructed as part of previous remedial works to reduce the frequency of flooding in the Dundas / Dixie SPA and the Applewood SPA.

As illustrated in Exhibit 3.1 the field survey included a total of 18 cross-section coincident with the original cross-sections that were used in the development of the existing HEC-RAS model. The survey also included 6 additional sections at the two pedestrian bridges upstream of Dixie Road which were not included in the original hydraulic model.

The survey for each cross-section included the left and right top of bank, a minimum of five data points within the watercourse, and additional bridge, opening dimensions, and the road / path profile across the top of the structure. Photo 3.1 to Photo 3.4 (Page 11) illustrate the four structures looking downstream.

The field survey also included sufficient points to clearly define the top of wall and top of berm given the critical importance of these features in defining the depth at which Little Etobicoke Creek spills from its riparian zone southerly towards the Dundas / Dixie SPA and the Applewood SPA. Photo 3.5 and Photo 3.6 illustrate these features. The elevation of the top of the wall is approximately 125.0 metres, while the elevation of the top of the berm is a minimum of 122.7 metres, although it is variable along its length.

3.2 Model Development including HEC-RAS Conversion

The MIKE 11 model was developed by conversion of the existing HEC-RAS model from the confluence with Etobicoke Creek (Section 8.01) upstream to Bloor Street (Section 8.25), and then comparing the results between the two models to ensure consistency. The process of converting the model and verifying the results is presented in the following sections.

To automate the conversion from HEC-RAS to MIKE 11, DHI's RAS2MIKE 11 conversion tool was used. This tool automatically converts the HEC-RAS river network, cross-sections and Manning's roughness values into a MIKE 11 readable format. Figure 3.1 shows the comparison of the HEC-RAS and MIKE 11 networks in planview, while Figure 3.2 shows a comparison of a selected HEC-RAS cross-section and the corresponding MIKE 11 cross section.

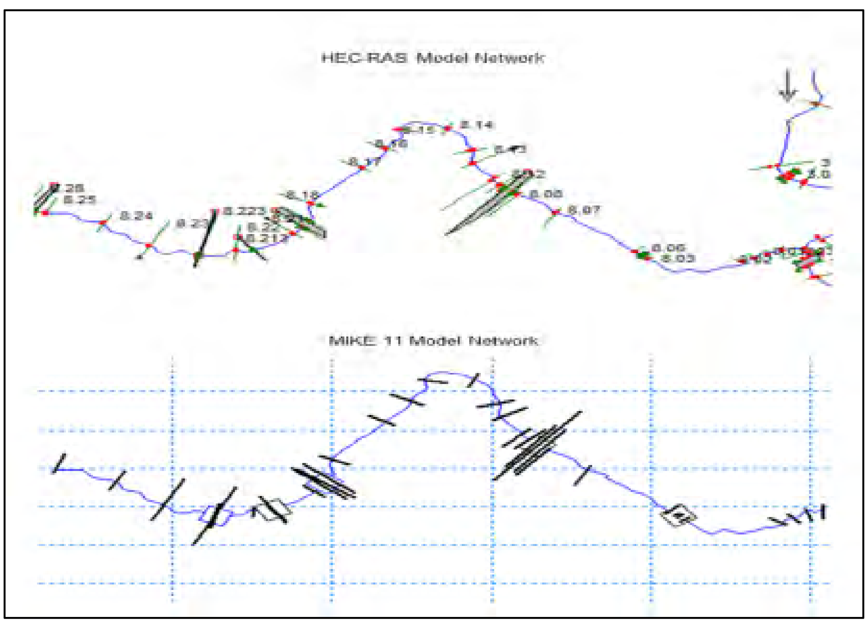


Figure 3.1: HEC-RAS vs. MIKE 11 - Comparison of Model Networks

Photo 3.1 - Dundas Street Culvert

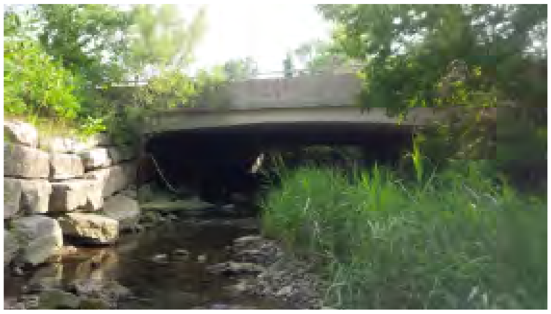


Photo 3.2 - Dixie Road Bridge

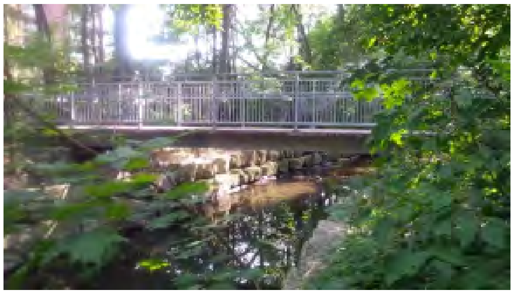


Photo 3.3 – Downstream Pedestrian Bridge

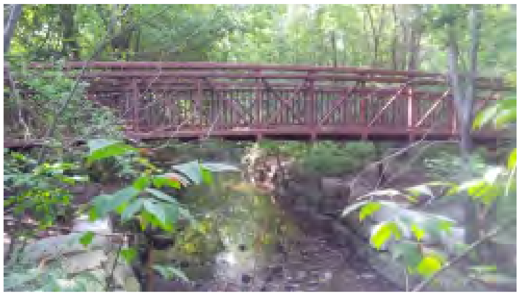


Photo 3.4 – Upstream Pedestrian Bridge

Photo 3.5 – Berm downstream of Dixie Road

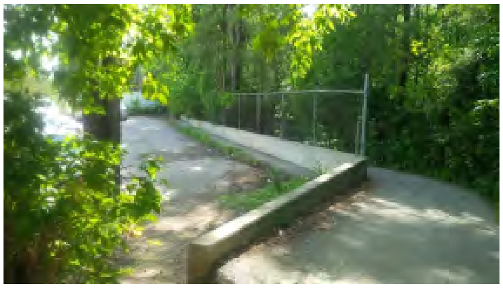
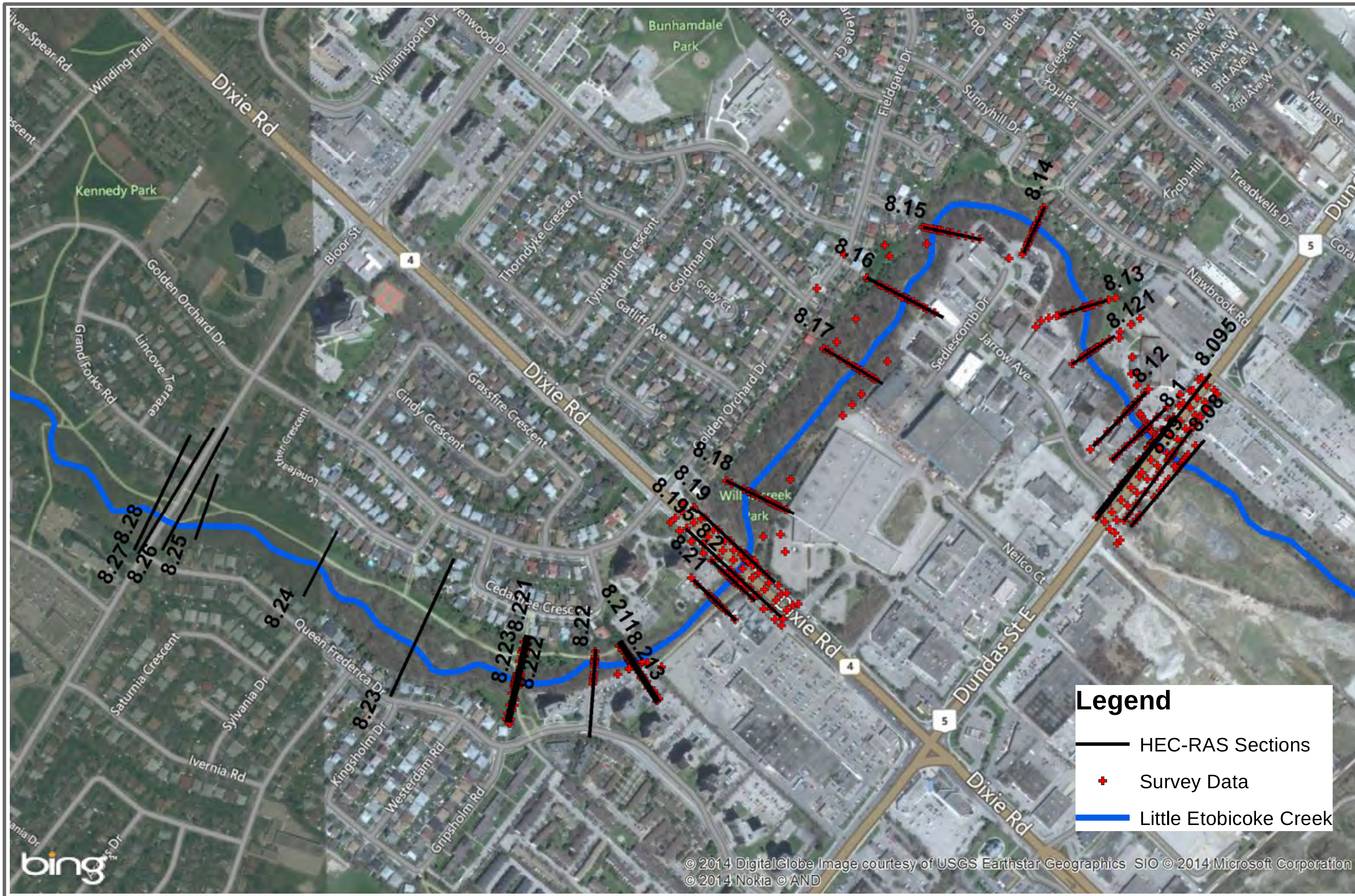


Photo 3.6 – Flood Wall at Downstream Ped. Bridge

Document Name: ex3.1-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA - Cross-Section Survey



MMM GROUP

CROSS-SECTION SURVEY

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

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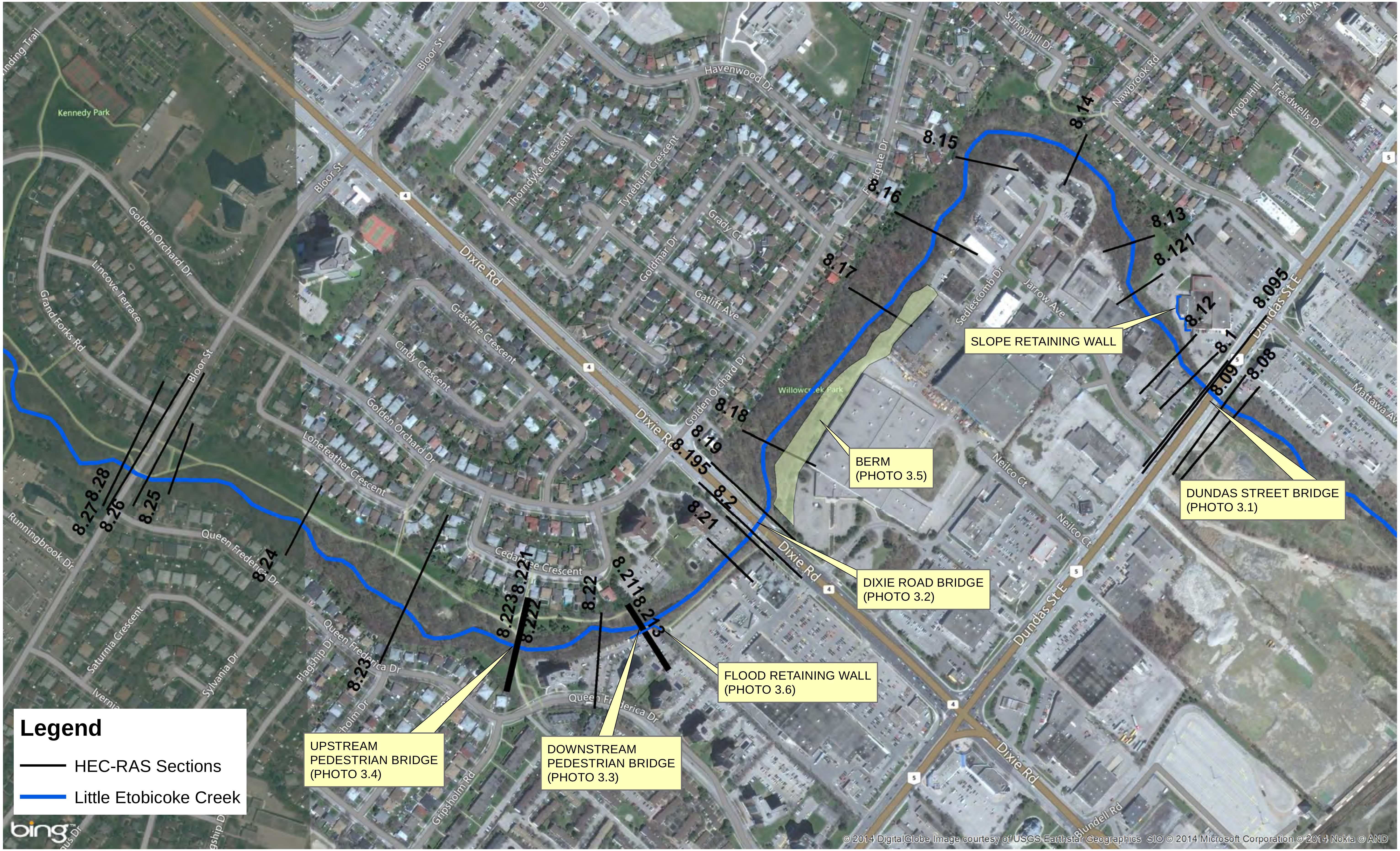
Date: November-03-2014
Project No: 1412606
Exhibit No: 3.1



Document Name: ex3.2-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA - HEC-RAS Cross Sections and Key Features

MMM GROUP

HEC-RAS CROSS SECTIONS AND KEY FEATURES

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

0 60 120 180 m

1:5,000

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Date: November-03-2014

Project No: 1412606

Exhibit No. 3.2

Although the conversion tool automates the conversion of the river topology, cross-section geometry and roughness values, the resulting MIKE 11 model still requires some additional editing to complete the model setup. For example, MIKE 11 and HEC-RAS use opposite river stationing conventions where, in HEC-RAS, river station 0.0 is usually defined at the downstream end of the model domain, while in MIKE 11, a chainage of 0.0 is usually defined at the upstream end of the model domain.

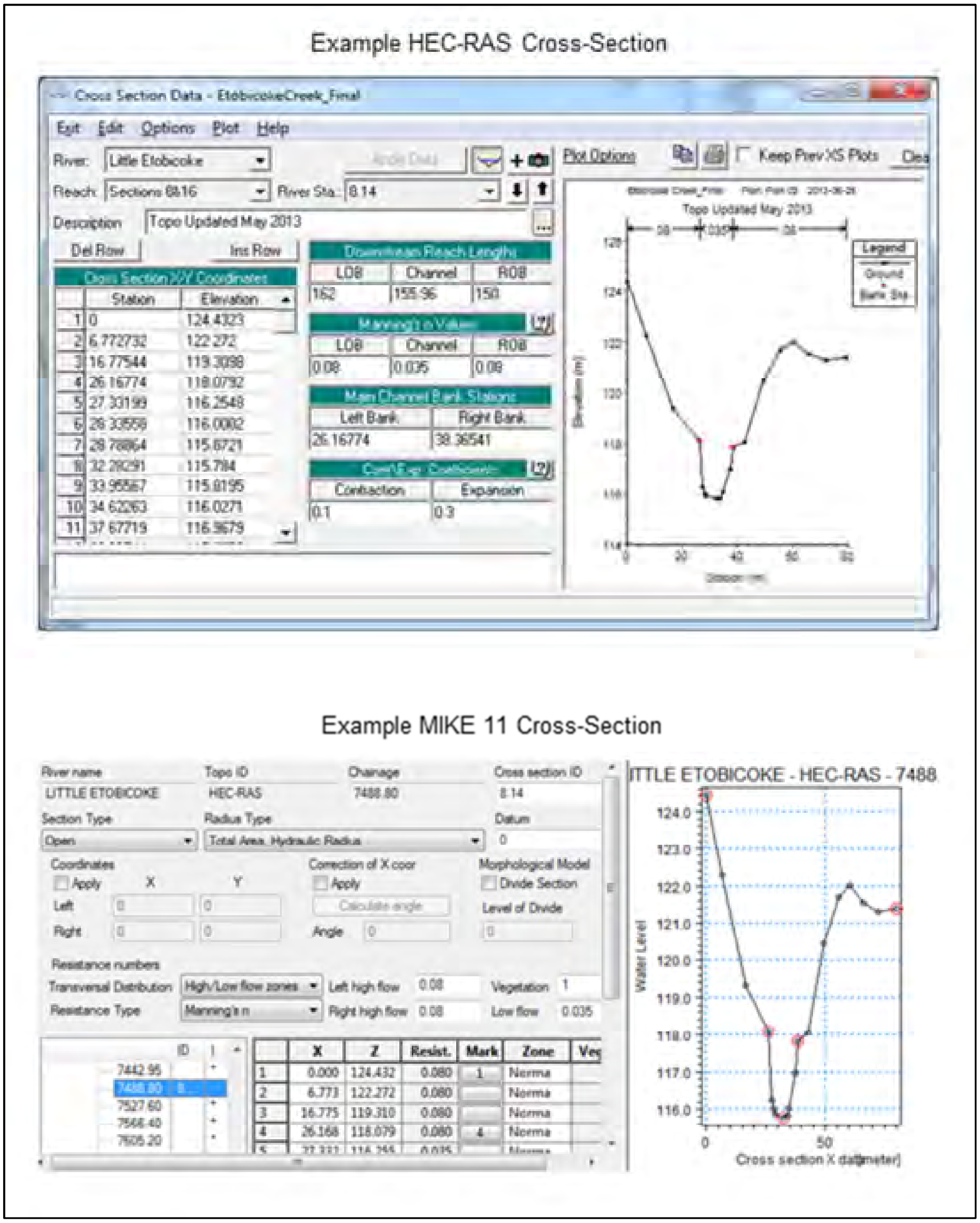


Figure 3.2: HEC-RAS vs. MIKE 11 - Comparison of Cross-Section Geometry

The conversion of the river network preserves the river alignment and adjusts the river stationing according to the MIKE 11 convention. In addition, MIKE 11 and HEC-RAS do not use all of the same structure formulations so the RAS2MIKE11 conversion tool does not convert structures. As a result, all structures from the HEC-RAS model were manually inserted into the MIKE 11 model based on structure geometries and settings defined in the HEC-RAS model. In total, 5 bridges were converted from the HEC-RAS model and included in the MIKE 11 model. The converted bridges and their locations are presented in Table 3.1. In all cases the HEC-RAS model was first updated to reflect the field survey completed of each structure (Section 3.1).

Table 3.1: RAS vs. MIKE 11 – Comparison of Bridge Locations

Bridge Name	HEC-RAS Station	MIKE 11 Chainage
Pedestrian Bridge 1	8.2215	6229.9
Pedestrian Bridge 2	8.2115	6425.2
EC 3-3R Dixie Road	8.195	6643.9
EC 3-2R Dundas Street W	8.095	7900.89
EC 3-1RR CPR	8.045	8495.5

The next step in converting the HEC-RAS model to MIKE 11 was to define the boundary inflows at the upstream end of the model, and tailwater elevation at the downstream end of the model. The upstream inflow was obtained from the 2013 Etobicoke Creek Hydrology Update model results for the flood events of interest at the flow node corresponding to the upstream boundary of the MIKE 11 model. The downstream water level boundary conditions were taken from the HEC-RAS model results (updated with flows from the 2013 Etobicoke Creek Hydrology Update) at the confluence of Little Etobicoke Creek and Etobicoke Creek.

3.3 Modelling Results and Comparison to HEC-RAS

The next step was to compare the MIKE 11 and HEC-RAS models to ensure that they are consistent in terms of estimating flood elevations. It is important to note that the results will never be identical as each model has its own assumptions and modelling algorithms. A flow of 147 m^3/s and a starting water surface elevation of 104.5 metres at the confluence with Etobicoke Creek were selected for comparison purposes. They represent the 100-year conditions calculated from the 2011 mapping update. A comparison of the resulting water levels along the channel profile is presented in Figure 3.3 and Table 3.2.

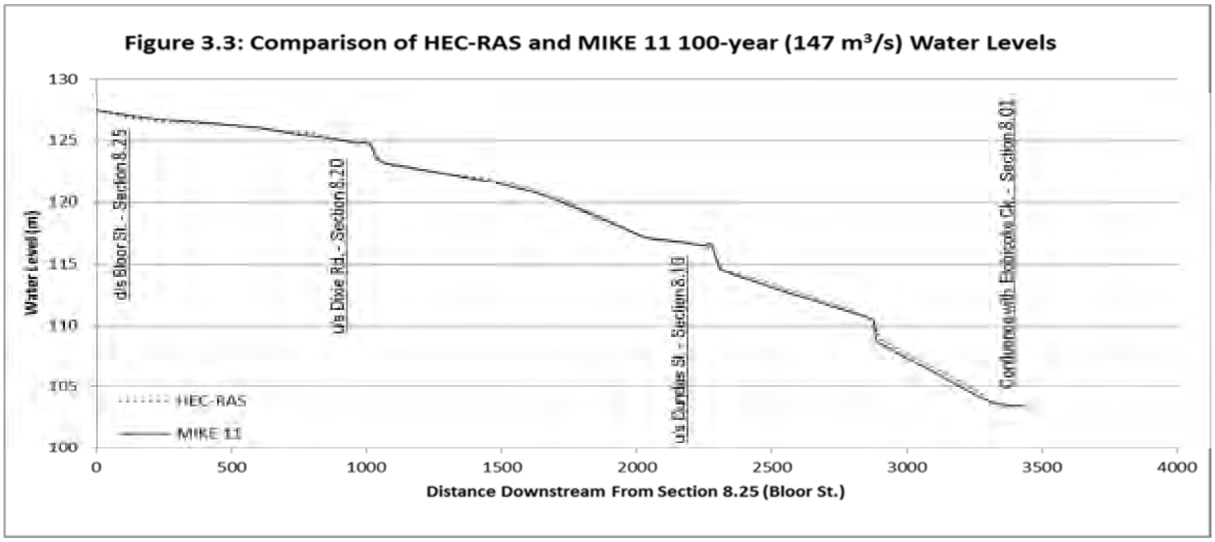


Figure 3.3: Comparison of HEC-RAS and MIKE 11 100-year (147 m^3/s) Water Levels

Table 3.2: Comparison of Water Surface Elevations calculated with MIKE 11 and HEC-RAS

Cross-Section		Comparison of Water Surface Elevations (m)		
Section No.	Location	HEC-RAS	MIKE 11	Difference
8.04	d/s of CPR Bridge	109.92	108.73	-0.44
8.05	u/ of CPR Bridge	110.01	110.45	1.19
8.08	d/s Dundas St.	114.41	114.34	0.07
8.10	u/s Dundas St.	116.48	116.62	-0.14
8.14	mid point between Dundas/Dixie	118.78	118.66	0.12
8.19	d/s Dixie Rd.	123.35	123.36	-0.01
8.20	u/s Dixie Road	124.95	124.77	0.18
8.22	Queen Frederica	125.69	125.52	0.17
8.24	u/s of Ped Bridge	126.60	126.79	-0.19
8.25	d/s of Bloor St.	127.41	127.46	-0.05

The comparison shows a very good match between the HEC-RAS model and the MIKE 11 model for the 147 m^3/s flow rate, with the lone exception of the tail-water at CPR Bridge (i.e. HEC-RAS station 8.04). At this location, MIKE 11 water level is approximately 1.19 m lower than HEC-RAS water level. This difference was attributed to the different equations that are solved for a HEC-RAS steady-state model versus a MIKE 11 fully-hydrodynamic model. The difference quickly converges moving upstream, and has no bearing on model results through the SPA areas.

3.4 Initial Peer Review

The development of the MIKE 11 model was submitted to Valdor Engineering Inc. in order to complete a Peer Review of the model development. Appendix A includes the original Valdor comments along with the response prepared by MMM Group and DHI. All comments raised through the Peer Review were addressed, with model changes completed as necessary.

4.0 2-DIMENSION MODELLING OF SPECIAL POLICY AREAS

Once the 1D MIKE 11 model was constructed and verified the remaining steps to construct the integrated 1D - 2D MIKE FLOOD hydraulic model consisted of the following:

1. Trim the 1D MIKE 11 mode
2. Construct a 2D MIKE 21 overland flow model
3. Couple the 1D MIKE 11 and 2D MIKE 21 models

Development of each of these three components is described in detail in the following sections.

4.1 Trim the 1D MIKE 11 Model

As noted, the MIKE 11 model that was developed and verified (as described in the previous sections) was a direct conversion of the existing HEC-RAS model. As a result, it was modelling flow in both the main channel of the Little Etobicoke Creek and the overbank areas adjacent to the creek. Development of the 1D MIKE 11 model for coupling with the 2D MIKE 21 overland flow model involves trimming the cross-sections of the MIKE 11 model such that they represent only the main channelized flows in Little Etobicoke Creek (see Figure 4.1). This allows the 1D channelized flow to be calculated by MIKE 11 while the overbank flows are calculated by the 2D MIKE 21 overland flow model.

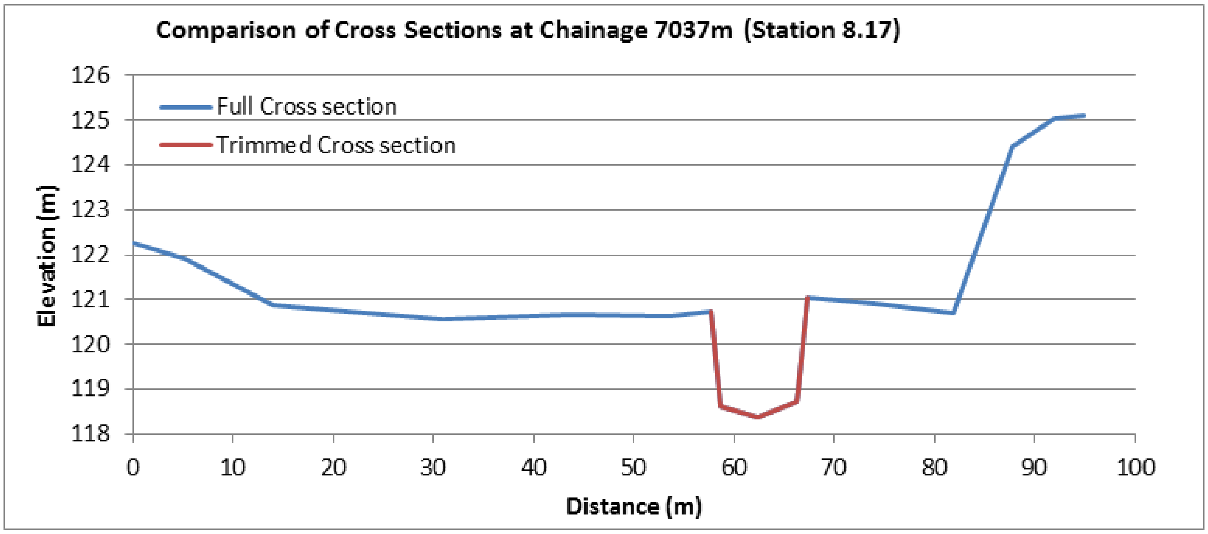


Figure 4.1 Comparison of a full cross section and a trimmed cross section

The spacing of cross-sections in the converted MIKE 11 model is approximately 100 m. Considering the grid size of the 2D model (2 m) and the potential increased accuracy of representing locations of bank overtopping in the 2D model, a more resolved spacing between cross-sections was required. Initially, the original cross-sections were trimmed up to the top of the banks on either side of the channel, and then additional cross-sections were interpolated between these cross-sections using a maximum 50 m distance. Cross-sections were interpolated along the reach from the upstream pedestrian bridge (HEC-RAS Section 8.24 and MIKE FLOOD chainage 6232.9) to the CPR Bridge (HEC-RAS Section 8.05 and MIKE FLOOD Chainage 8493.5) since this is where the overbank flows are most likely to occur.

No interpolated cross-sections were added downstream of the CPR bridge since flood waters are mostly confined in the channel. The only exception is at the inflow boundary where cross-sections were maintained across the full width of the channel and overbank area and then gradually reduced to the trimmed width representing only the main channel. This was done to allow inflows from the channel to enter the model domain as 1D flow and then gradually transition to coupled 1D - 2D flow to ensure stability of the model, particularly during very high flow events.

4.2 Construct 2D MIKE 21 Overland Flow Model

The data requirements for a 2D overland flood model include:

- High-resolution topography to describe the direction of flow
- Surface roughness to describe the resistance to flow from different surfaces and vegetation
- Boundary conditions to describe how flow enters or leaves the model across the outer edges of the model domain
- Sources and sinks to describe how flow enters or leaves the model domain from within the model domain

For this project it was decided to use the Single Grid version of MIKE 21 to solve for the overland flow. This version of the model uses a uniform, finite difference grid throughout the model domain. The Single Grid version of MIKE 21 was chosen over the Flexible Mesh version for several reasons:

- it is easier and faster to set up the 2D model
- it is easier and faster to couple it to a MIKE 11 model
- the solution is generally much faster
- similar accuracy will be achieved by the single grid version provided that the grid size is sufficiently small

When constructing a MIKE 21 Single Grid model, the first things that need to be decided are the extent of the model area and the size of the grid spacing. The extent of the 2D model area was identified in the scope of work provided by TRCA and is shown in Figure 4.2 (also see Exhibit 2.1 for more detail). Typically, the boundary of the model domain is selected based on topographic ridges or hydraulic controls where overland flow is not likely to pass. However, in this case the boundary was also chosen based on both the availability of high-resolution LiDAR topographic data.

In order to decide the appropriate grid spacing it is important to consider the setting and level of detail required for the model. In this case, the study area is characterized by a mixture of commercial and residential land use, and in several there are developed areas where gaps between buildings are very narrow - in some cases smaller than the 2 m. Considering the need to balance the accuracy of model versus being able to achieve a reasonable model runtime, a 2 m grid spacing was chosen for the 2D models.

In order to develop the topography for the 2D model area multiple steps were required. Initially, MMM Group provided a raster file of the topography in the native MIKE 21 grid file format (.dfs2) with 2 m grid spacing. This file was then edited to represent buildings as flow obstructions. This was achieved by extruding the building footprints and setting the grid cell elevation to a ‘land value’. Although it is counter-intuitive for inland flooding applications, a ’land value’ in MIKE 21 is equivalent to a threshold elevation above which all cells are considered inactive (i.e all cells with an elevation greater than or equal to the land value will be considered as inactive during the simulation). Setting these grid cells to a ‘land value’ ensures that the extruded grid cells act as buildings and obstruct overland flow. Finally, the last step was to remove the 2D grid cells that intersect with the MIKE11 cross-sections. This step was done to avoid double accounting of flows in both the MIKE 11 model and the MIKE 21 model.

The boundaries of 2D model area were initially closed except for where the Little Etobicoke Creek flows out of the model domain near the downstream confluence with Etobicoke Creek, and two water level boundaries were defined as internal water level boundaries in MIKE 21 (see Figure 4.2). Water levels on Etobicoke Creek upstream and downstream of the confluence were obtained from the HEC-RAS model results at station 3.01 and station 1.23 for each of the flood conditions being considered, and then these water surface elevations were defined as the water level boundaries in the MIKE 21 model.

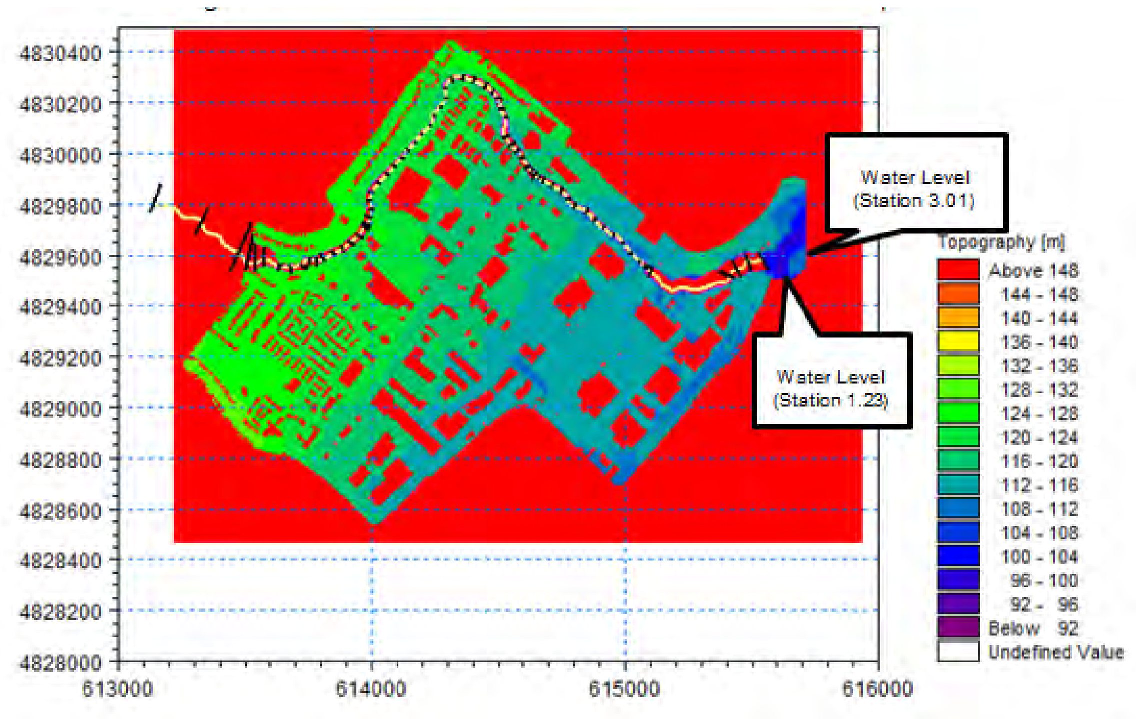


Figure 4.2: Map of topography in study area with extruded buildings (2 m grid resolution)

A spatially distributed map of Manning's roughness values was created to reflect the different surface materials and vegetation (see Figure 4.3) The Manning's roughness map was constructed based on a standard Manning's n polygon layer for the study area provided by TRCA. Table 4.1 summarizes the standards TRCA Manning's n values that were used in the MIKE 21 model as well as the color coding used for plotting purposes in Figure 4.3.

Table 4.1: Standard TRCA Manning's n Values

Surface	Manning's n - TRCA1	Manning's M2	Colour Code
Paved Surface	0.025	40	Red
Urban Pervious	0.050	20	Green
Natural Areas	0.080	12.5	Blue
Buildings	--	<2.5[3]	Purple
Notes: 1) TRCA values were used for MIKE FLOOD modelling 2) M = 1/n 3) Set sufficiently high such that flow is zero			

Figure 4.3: Map of Manning's M values in study area (2 m grid resolution)

4.3 Couple the 1D MIKE 11 Model and the 2D MIKE 21 Model

In order to enable the exchange of flows between the 1D MIKE11 model and the 2D MIKE21 model these two models need to be coupled together using MIKE FLOOD. MIKE FLOOD provides three options to couple the MIKE 11 and MIKE 21 models together;

- a standard link describing the coupling at the upstream or downstream end of the 1D MIKE 11 model to the 2D MIKE 21 model
- a lateral link; describing the coupling along the left bank and right bank of the channel to the 2D model
- a structure link describing the coupling between a 1D structure element (e.g. culvert) to the 2D model

For the Little Etobicoke Creek MIKE FLOOD model, a standard link was used to describe the discharge of flows from the downstream boundary of the 1D MIKE 11 model into the 2D MIKE 21 model at the confluence of Little Etobicoke Creek and Etobicoke Creek (see Figure 4.4). The grid cells in the 2D model directly downstream of the 1D model boundary were identified and selected for coupling based on the width of the cross-section at the Little Etobicoke Creek outlet. These 'standard link' grid cells allow outflow from the 1D MIKE11 model to be evenly distributed into the MIKE 21 model across the connected grid cells.

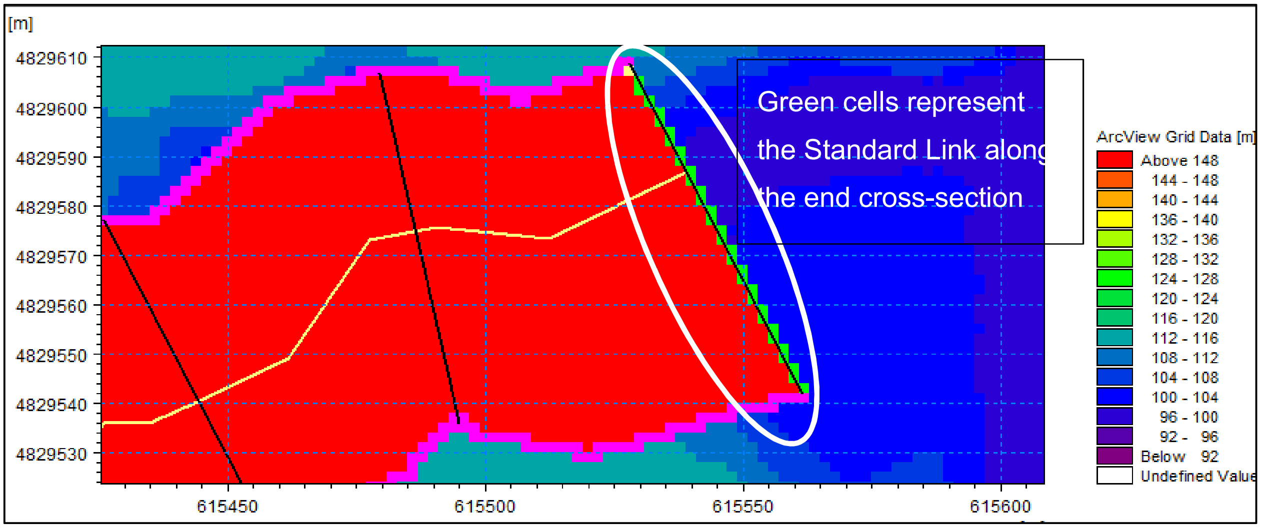


Figure 4.4: Standard link connecting the downstream boundary of the 1D channel for Little Etobicoke Creek with the 2D water body representing the confluence with Etobicoke Creek

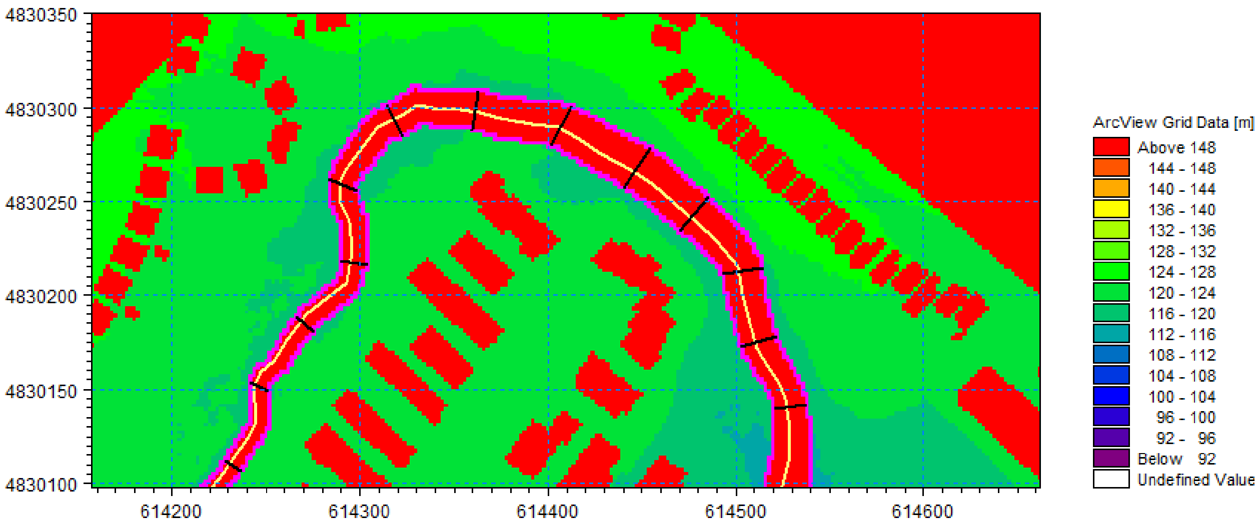


Figure 4.5: Left bank and right bank lateral links used in coupled MIKE FLOOD model

Along the edge of the river banks, lateral links were used to connect the top of banks in the 1D MIKE 11 model with the corresponding grid cells of the 2D MIKE 21 model (see Figure 4.5). Lateral link couplings allow a dynamic exchange of overbank flows between the 1D and 2D models. The linked cells in the 2D model are treated as weir structures where the crest elevation of the weir structure controls the exchange of flows along the top of bank.

In order to test the performance and evaluate the results of the coupled MIKE FLOOD model it was decided to run the model for a 6-hr simulated period with constant inflow of 147m^3/s (flow used in comparing HEC-RAS to MIKE11, and comparable to the 350-year event). The evaluation was used to determine whether the flooding would reach the outer edges of the model domain. Figure 4.6 shows the calculated flood extent and flood depth after the 6-hr simulation period. The results clearly show that flood water has reached the outer boundary of the predefined model extents and is essentially piling up along the closed boundary.

Following this model run it became clear that the flooding from the major flood events was going to reach the outer edges of the 2D model domain. This represented a problem because there were no boundary conditions defined along these boundaries, In this case the water will simply build up along the edge of the domain and eventually flow laterally along the boundary, or it will back up and spill into areas that should otherwise be unaffected.

In order to avoid this problem, the options were to either expand the lateral extents of the study area, or define a boundary condition that will allow overland flow to leave the model when it encounters the outer edge of the domain.

In the absence of reliable, high-resolution topographic data for the downstream, off-site area, it was decided to define the area outside of the 2D model domain as a constant water level that is effectively below ground level. This allows overland flow that comes into contact with the edge of the 2D model domain to leave the model without any resistance (i.e. it essentially ‘pours’ off the edge of the model). Although this is not completely representative of the flows and water levels along the boundary, the SPAs under consideration in this study are far enough away from the affected model boundaries that it will not have any material influence on the results in the near vicinity of the SPAs.

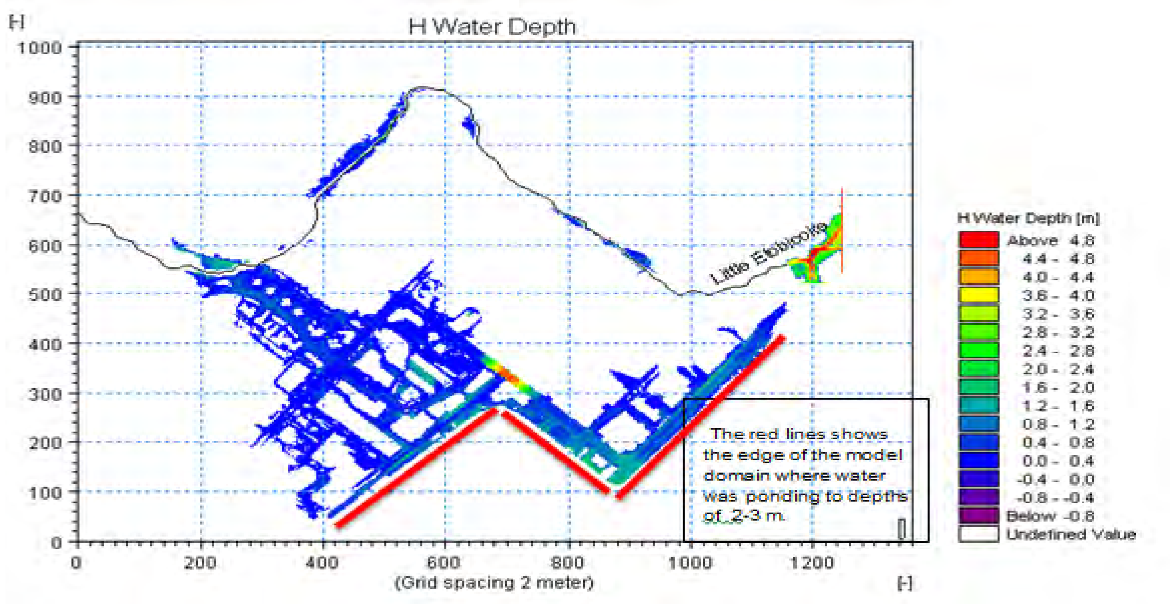


Figure 4.6: Calculated flood extent and flood depth after 6 hour simulation

4.4 Final Peer Review

The development of the MIKE 21 and MIKE FLOOD models were submitted to Valdor Engineering Inc. in order to complete a Peer Review of the model development. Appendix B includes a letter prepared by MMM Group that includes both the comments received from Valdor Engineering Inc. and the response prepared by DHI and MMM Group. All comments raised through the Peer Review were addressed, with model changes completed as necessary.

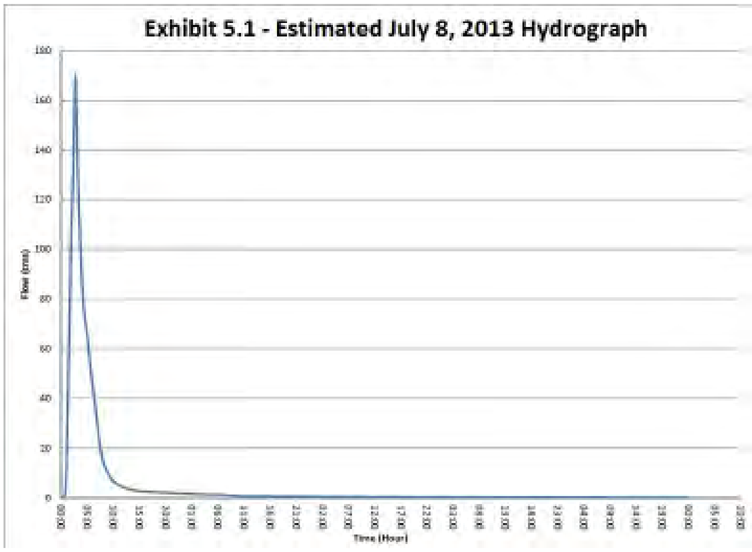
5.0 MODEL VALIDATION

5.1 Observed Data - July 8 2013

The flood of July 8, 2013 was used to validate the MIKE FLOOD model. Validation included three steps: development of the July 8, 2013 hydrograph for the study area, modelling of the hydrograph using MIKE FLOOD to provide an estimate of anticipated water depths, and comparison of the modelled water depths to observed data.

5.2 Validation Hydrograph – July 8 2013

Based on recorded rainfall records, the TRCA completed an analysis to estimate a rainfall hyetograph for Etobicoke Creek, and then applied the hyetograph to the 2013 Hydrologic Model in order to generate runoff hydrograph for Little Etobicoke Creek for the study area. Appendix C includes the analysis completed by the TRCA. The hydrograph is presented in Exhibit 5.1, and represents the flow at Node 8.11 (CPR downstream of Dundas Street)



5.3 Comparison of 2D Model Calculated to Observed Flood Elevations

The July 8, 2013 storm was simulated using MIKE FLOOD. The results are illustrated in Exhibit 5.2. The next step was to review posted YouTube videos, estimate the water depth from the videos, and then compare these to the simulated depths illustrated on Exhibit 5.2. Although the water depths can be estimated with reasonable accuracy, some caution is warranted in that there is no way of knowing whether the video was taken at the maximum flow and depth.

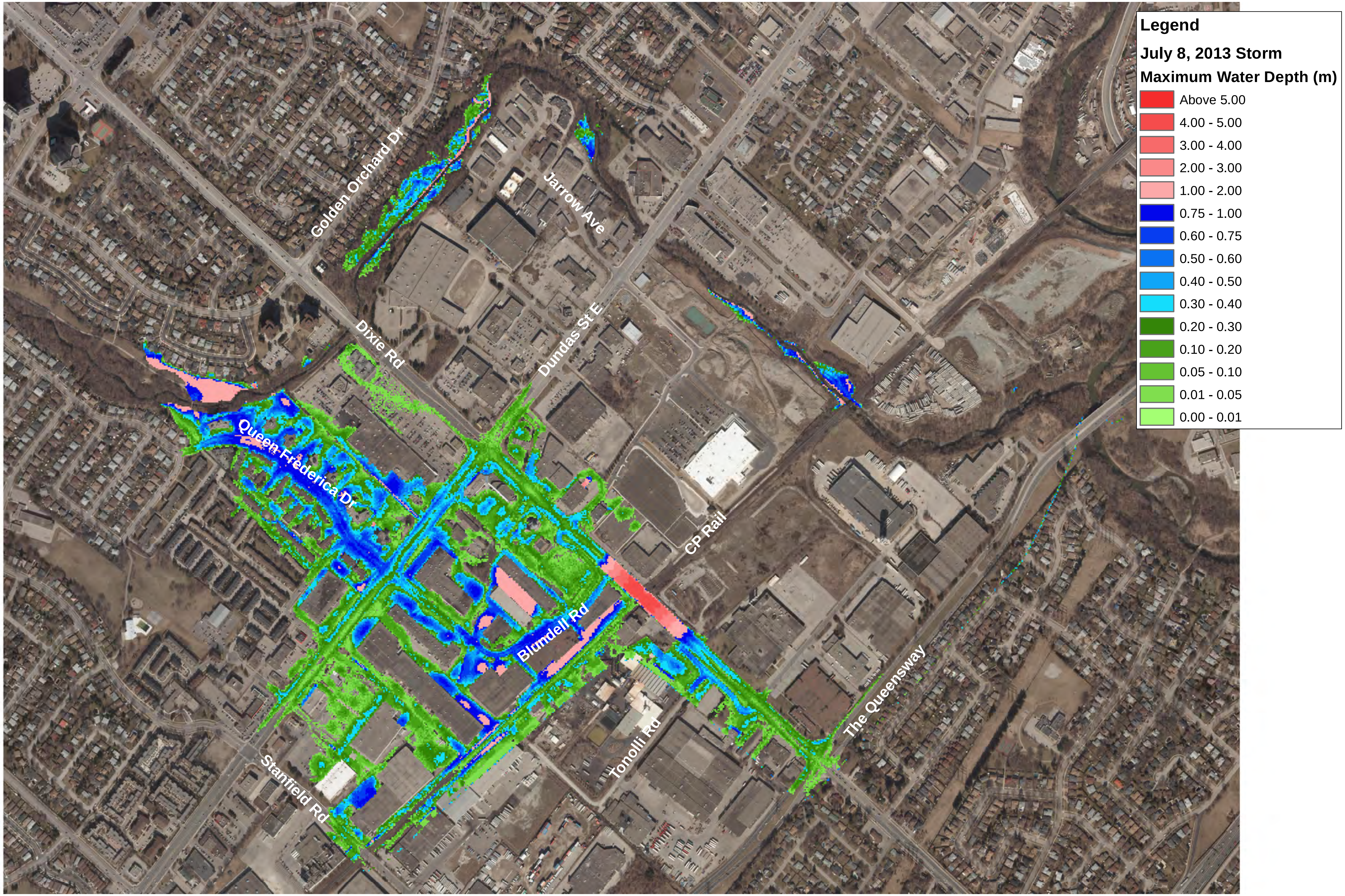
From the videos, five points of interest were selected. The locations, the observed water depth, and the simulated water depth are all illustrated in Exhibit 5.3 and summarized in Table 5.1. As illustrated, for first five points the results between modelled and observed estimated depths are very similar; all within 0.1 metres. However at the CPR underpass on Dixie Road south of Dundas Street the observed depth is substantially less than the calculated depth. This is likely due to the fact that the model did not include the extent of drainage that would have occurred through the Dixie Road storm sewer (i.e. the impact of catch basins and storm sewers conveying flow through the system). During the course of the event the accumulated runoff that would have discharged through the storms sewer would likely have been substantial.

In conclusion, there is a strong correlation between observed estimation and calculated water depths, and it can be concluded that the simulation is representative of the actual flood event.

Table 5.1: Comparison of Observed and Measured Water Depths for Storm of July 8, 2014

Location	Observed Depth (m)	Calculated Depth (m)	Difference (m)
1 - Queen Frederica Dr.	0.3	0.4	-0.10
2 - Queen Frederica Dr. east of Cripsholm Rd.	0.7	0.7	0.00
3 - Dundas St. west of Dixie Road	0.6	0.5	0.10
4 - Dundas St. west of Dixie Road	0.5	0.5	0.00
5 - Dundas St. west of Dixie Road	0.2	0.25	-0.05
6 - Dixie Road at CPR underpass (see note 1)	1.2	4.3	-3.10
Note 1: Model didn't include drainage associated with storm sewer			

The final step was to assess the fraction of water that spilled at Queen Frederica Drive versus the fraction that continued along the Little Etobicoke Creek Corridor. The modelling results show that approximately half the flow spilled and never returned to Little Etobicoke Creek. The remainder would have spilled southerly, although the exact extent of the spill is beyond the limits of the MIKE FLOOD model.



MMM GROUP

ESTIMATED JULY 8, 2013 FLOOD DEPTH MAP (WITH BERM AND WALL)

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

0 90 180 270 m

1:8,000

N

Date: August-12-14

Project No: 1412606

Exhibit No. 5.2

Document Name: ex5.2-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA-Estimated July 8,2013 Flood Depth Map (with berm and wall)

MMM GROUP

ESTIMATED JULY 8, 2013 FLOOD DEPTH VIDEO VERIFICATION

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

0 120 240 360 m

1:10,000

N

Date: August-12-14

Project No: 1412606

Exhibit No. 5.3

Document Name: ex5.3-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA-July 8 Flood Depth Video Verification

6.0 MODELLING SCENARIOS

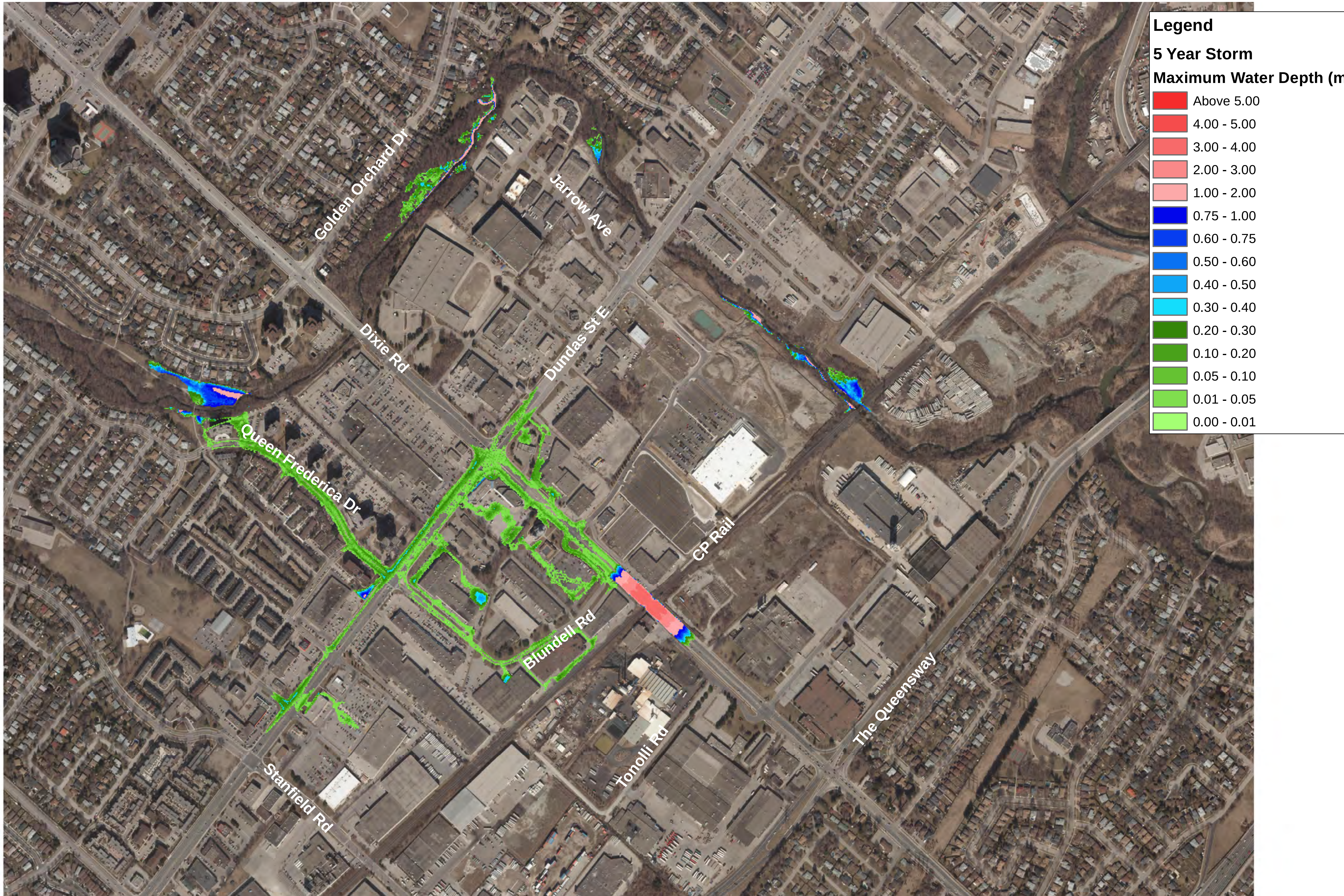
The next step was to simulate the various design storms, from the 5-year event through to the Regional Storm event. The elevations for all events the 5-year to 100-year are based on the existing flood control works (as identified in Section 1.2) being in place, while the elevations for the Regional Storm exclude the impact of the existing flood control works. The 350-year flood elevations are provided for both cases. The wall and berm were excluded for the Regional Storm in accordance with Ministry of Natural Resources (MNR) requirements that flood hazards be calculated based on the exclusion of flood control works such as the wall and berm that are in place for Little Etobicoke Creek. This is because they are not considered as permanent flood control structures (Section B4.1.2, Technical Guide – River and Stream Systems: Flood Hazard Limit, Ontario Ministry of Natural Resources, 2002).

6.1 Modelling Results

The simulations were based on a steady state flow scenario where the inflow to the system is held constant at the peak flow for a period of 6 hours in order to achieve a near steady-state flow condition throughout the entire study area. In this case, since the flow is steady, the timing of the loading from the subcatchments is not an important consideration. Therefore, it was decided to use a single inflow at the upstream end of the study area. As with the unsteady hydrograph conditions, the inflows for each flood event were obtained from the Etobicoke Creek Hydrology Update Study. In order to be conservative, the inflow for each flood event was chosen from Node 12.12 located at the downstream end of the study area (see Exhibit 1.1). For small flood events (e.g. 5-year to 50-year), a constant flow was assigned, while for larger events the inflow was gradually increased to the peak value in order to maintain numerical stability of the model solution (i.e. avoid 'shocking' the system) and then the peak flow remained constant for 6 hours.

Exhibits 6.1 to 6.7 illustrate the calculated flood depth for each of the modeled scenarios. The list of exhibits is summarized as follows:

- Exhibit 6.1: 5-year with berm and wall in place
- Exhibit 6.2: 25-year with berm and wall in place
- Exhibit 6.3: 50-year with berm and wall in place
- Exhibit 6.4: 100-year with berm and wall in place
- Exhibit 6.5: 350-year with berm and wall in place
- Exhibit 6.6: 350-year without berm and wall in place
- Exhibit 6.7: Regional Storm without berm and wall in place



MMM GROUP

5-YEAR FLOOD DEPTH MAP (WITH BERM AND WALL)

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

0 90 180 270 m

1:8,000

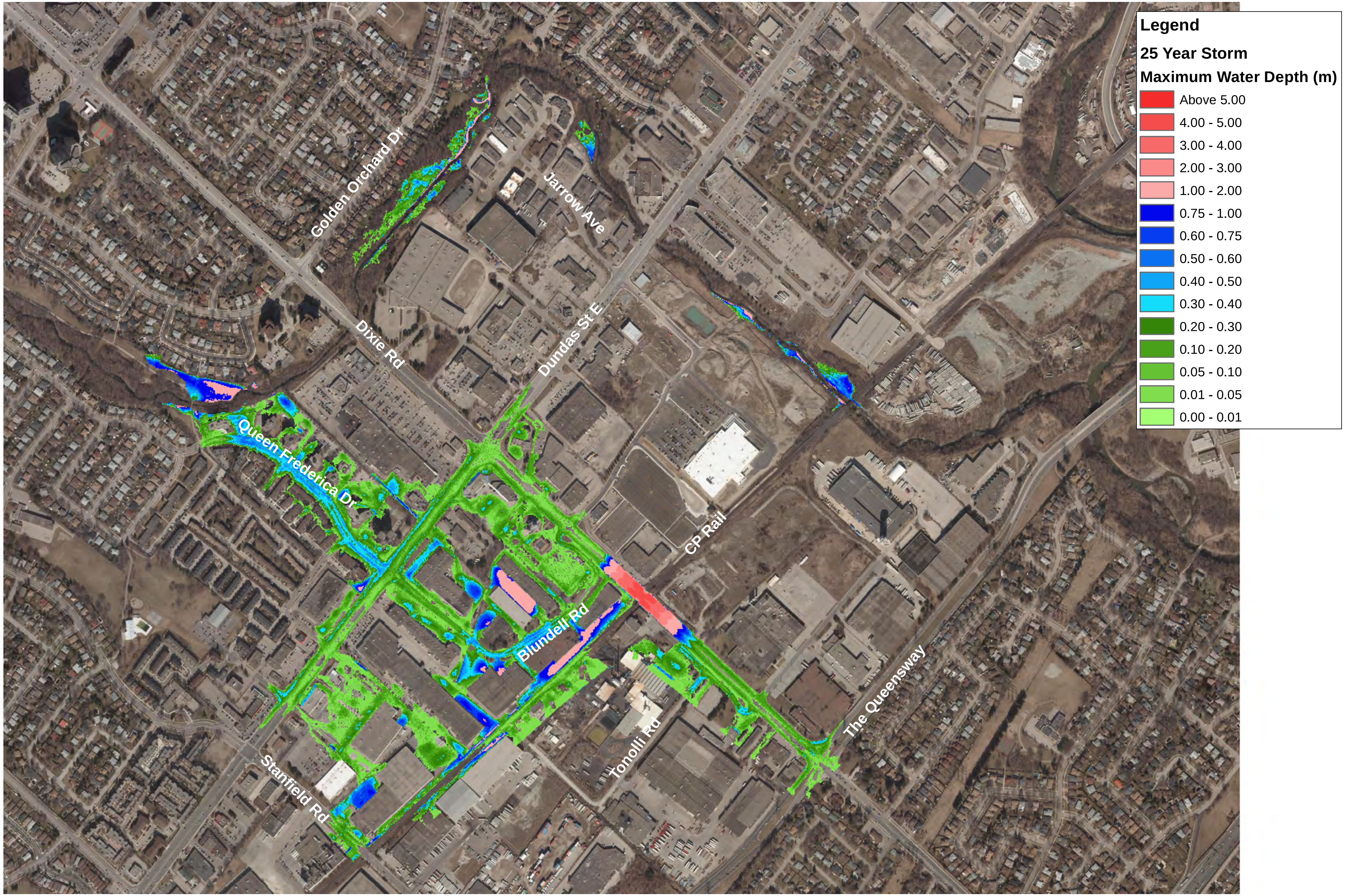
N

Date: August-12-14

Project No: 1412606

Exhibit No. 6.3

Document Name: ex6.3-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA-50-year Flood Depth



MMM GROUP

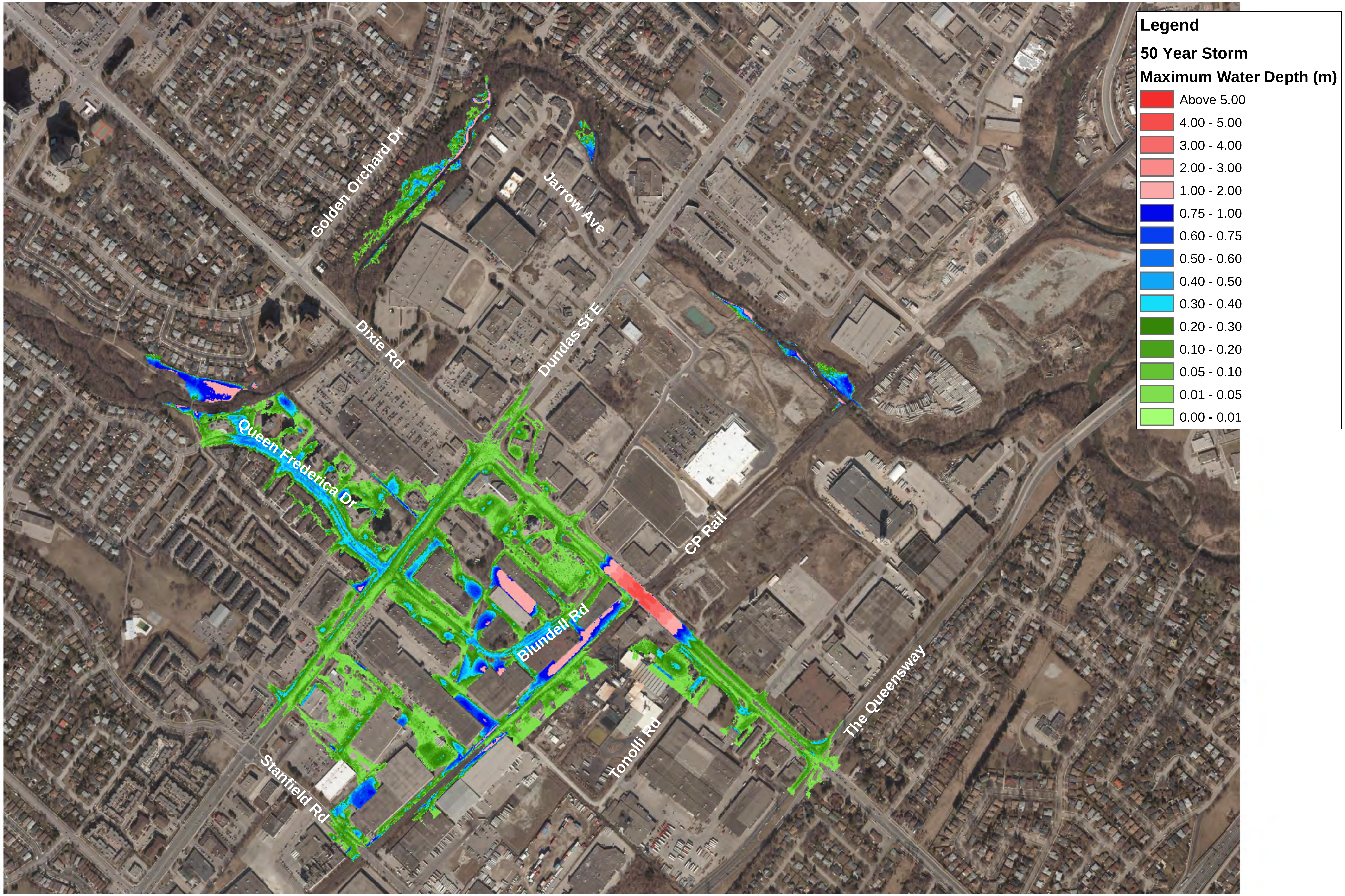
25-YEAR FLOOD DEPTH MAP (WITH BERM AND WALL)

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

Date: August-12-14

Project No: 1412606

Exhibit No. 6.2



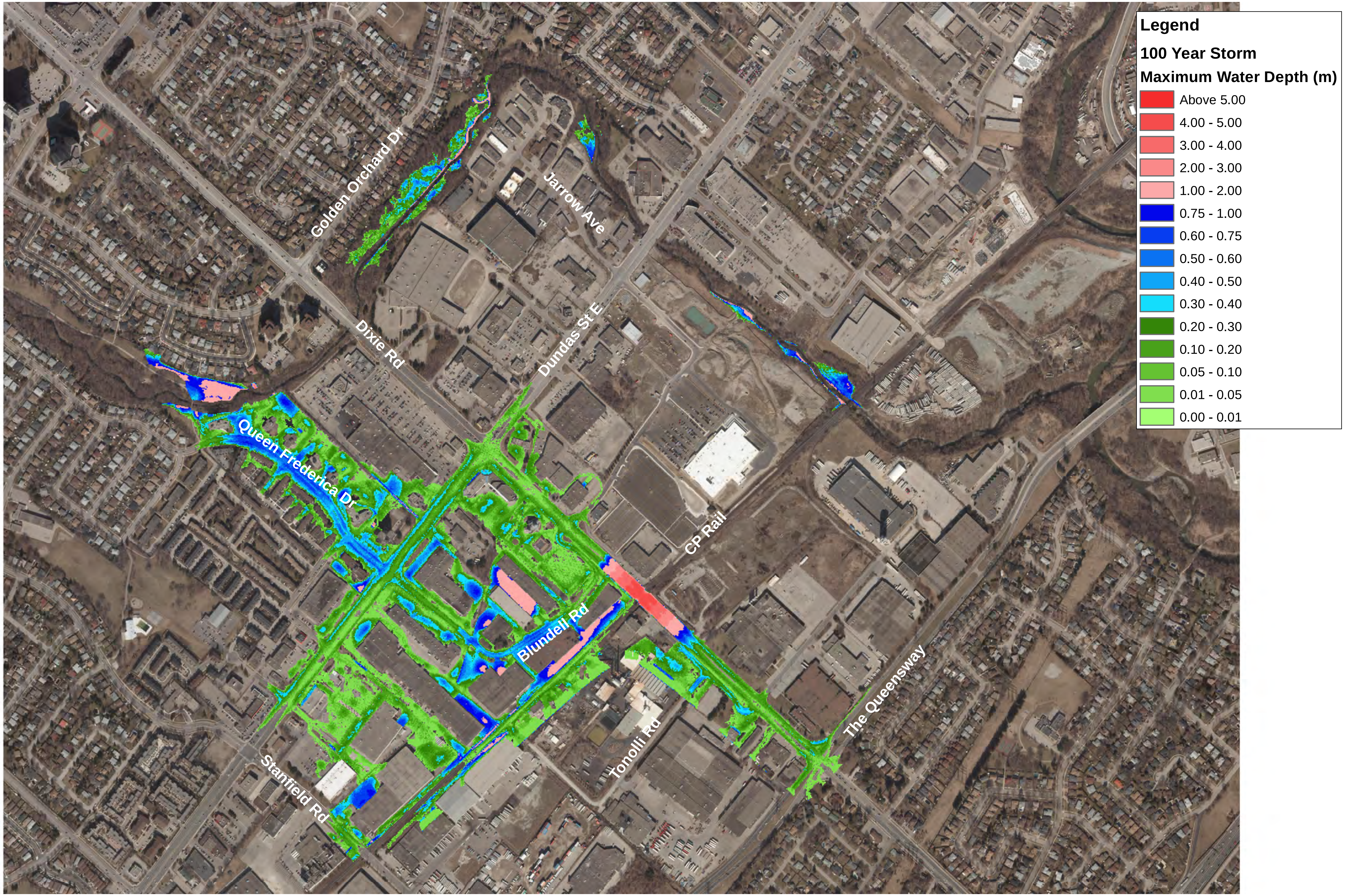
MMM GROUP

50-YEAR FLOOD DEPTH MAP (WITH BERM AND WALL)

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

0 90 180 270 m
1:8,000
N

Date: August-12-14
Project No: 1412606
Exhibit No. 6.1



MMM GROUP

100-YEAR FLOOD DEPTH MAP (WITH BERM AND WALL)

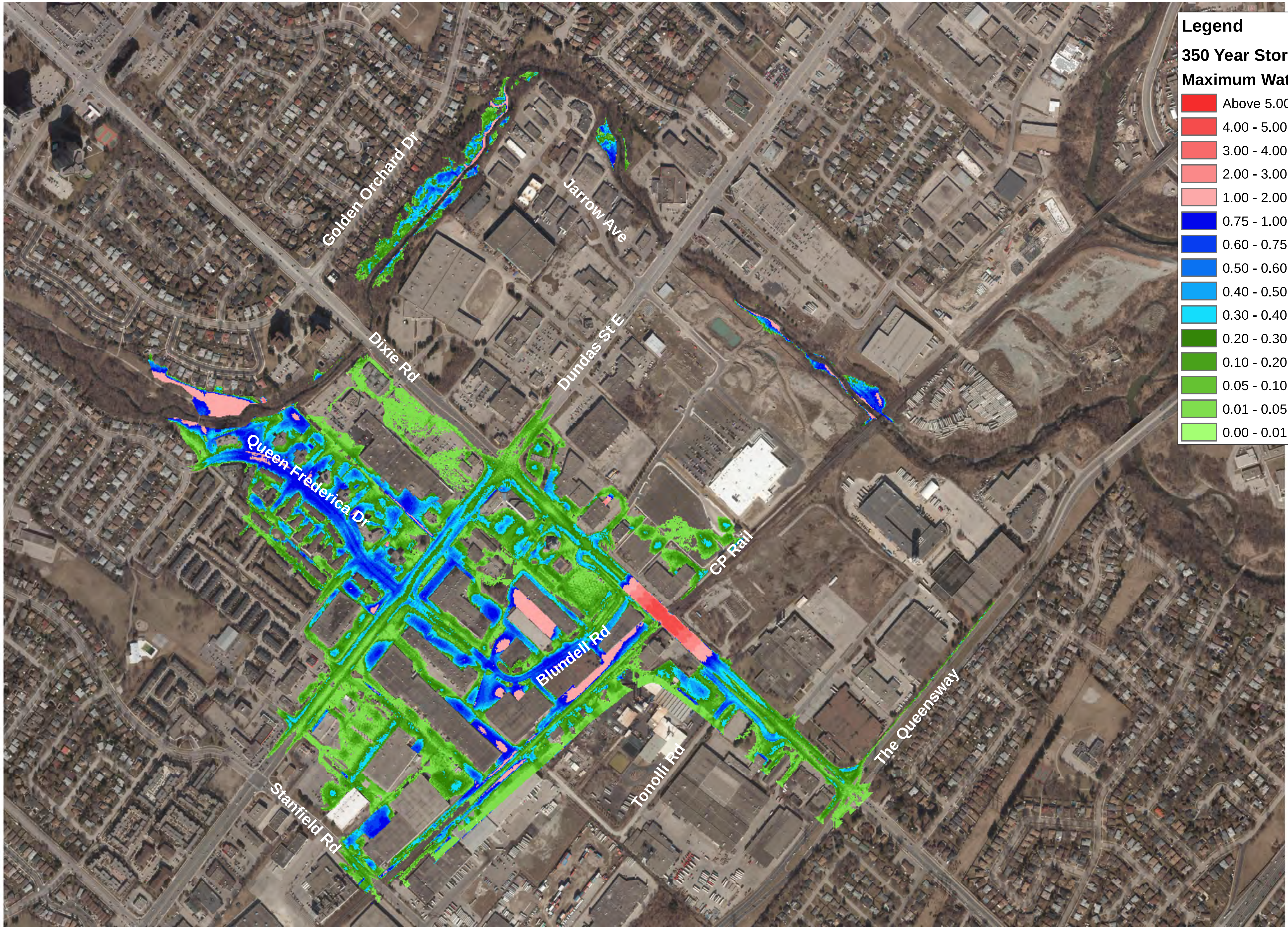
FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

Date: August-12-14

Project No: 1412606

Exhibit No. 6.4

Document Name: ex6.4-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA-100-year Flood Depth



MMM GROUP

350-YEAR FLOOD DEPTH MAP (WITH BERM AND WALL)

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

0 90 180 270 m

1:8,000

N

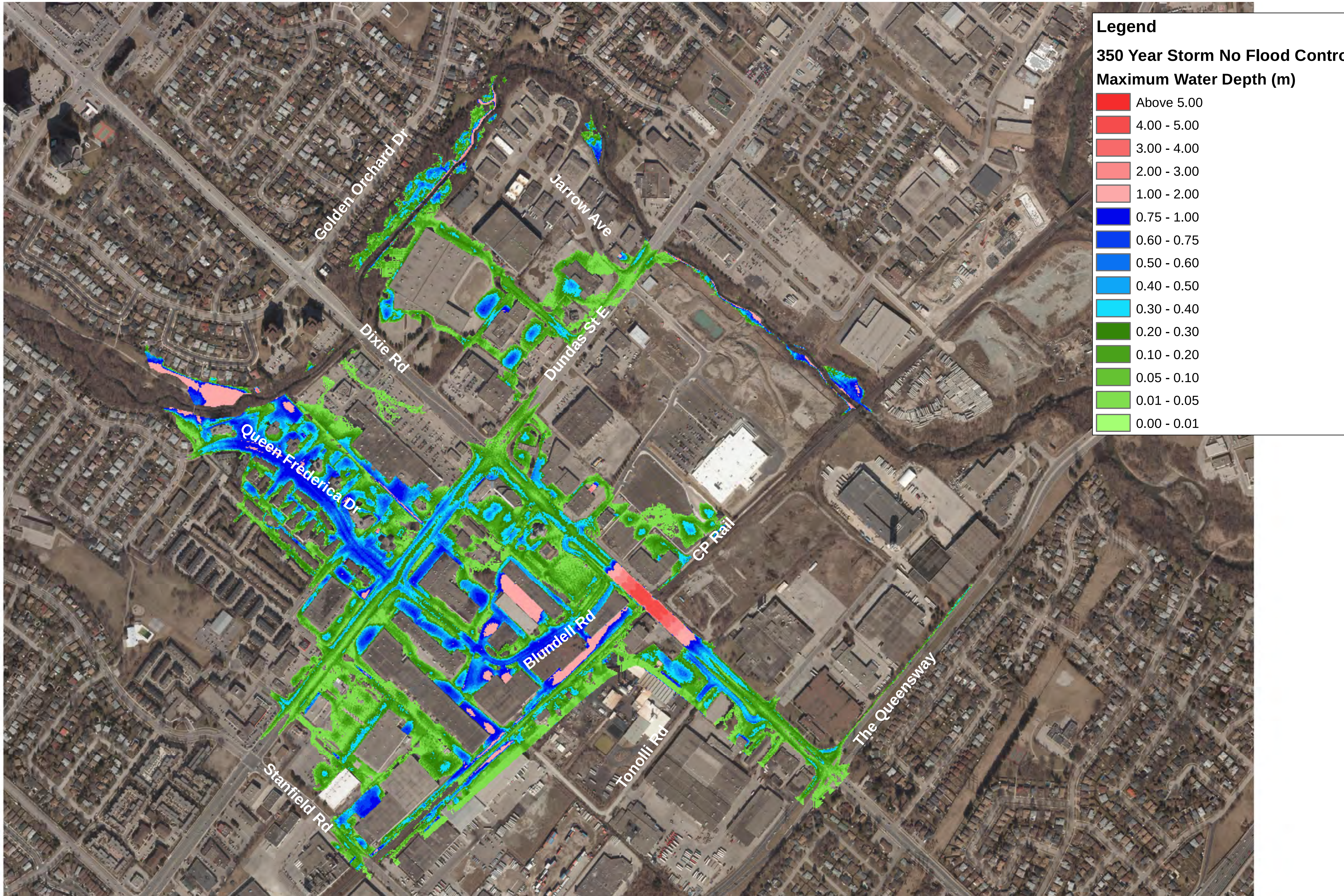
Date: August-12-14

Project No: 1412606

Exhibit No. 6.5

Document Name: ex6.5-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA-350-year Flood Depth (with berm and wall)

Document Name: ex6.6-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA-350-year Flood Depth (without berm and wall)



MMM GROUP

350-YEAR FLOOD DEPTH MAP (WITHOUT BERM AND WALL)

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

0 90 180 270 m

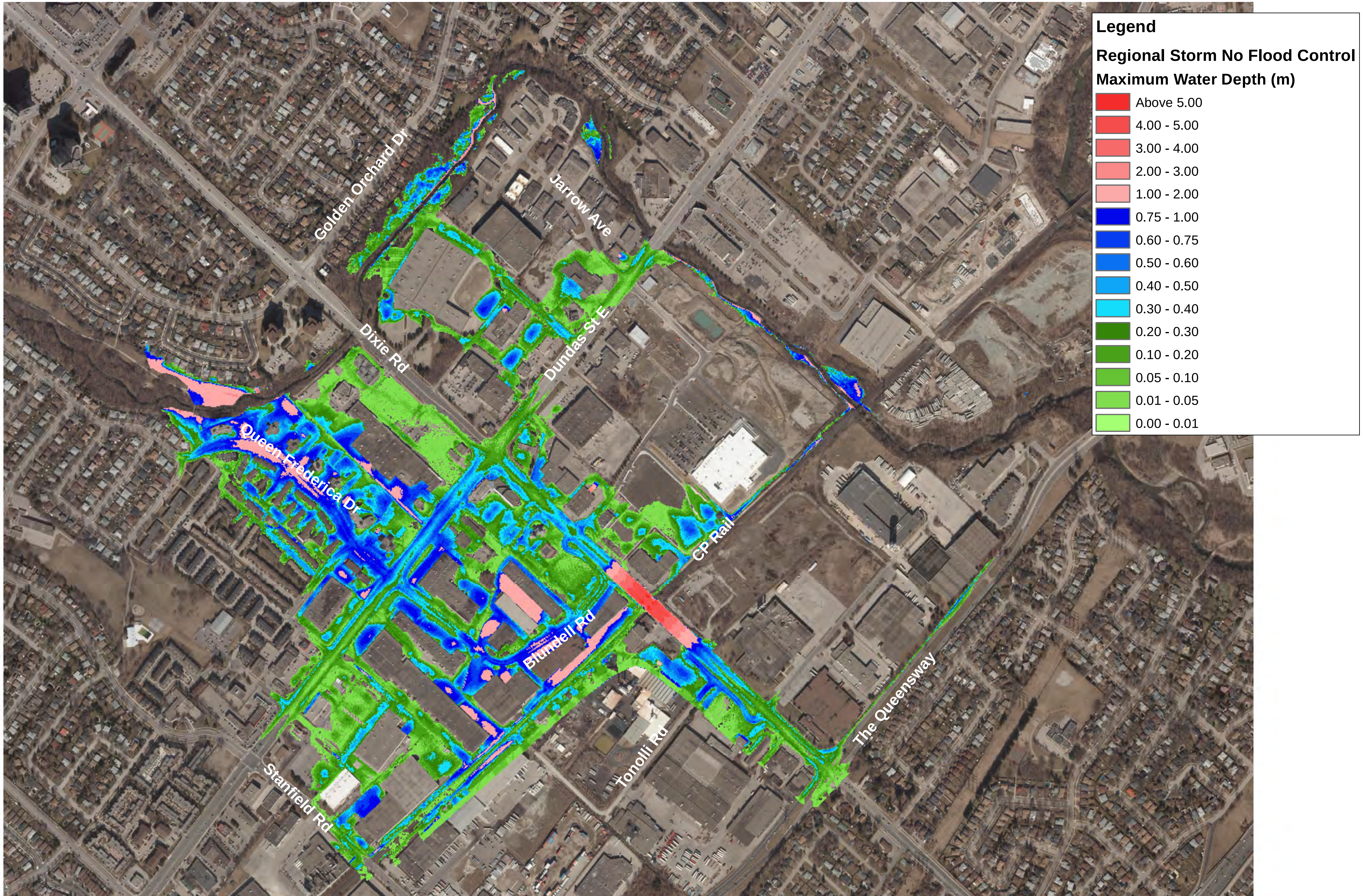
1:8,000

N

Date: August-12-14

Project No: 1412606

Exhibit No. 6.6



Document Name: ex6.7-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA-Regional Flood Depth (without berm and wall)

MMM GROUP

REGIONAL FLOOD DEPTH MAP (WITHOUT BERM AND WALL)

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

0 90 180 270 m

1:8,000

N

Date: August-12-14

Project No: 1412606

Exhibit No. 6.7

6.2 Discussion of Results

Based on the flood mapping presented in Exhibit 6.1 to Exhibit 6.7, one can draw a number of conclusions regarding:

- Frequency of spill from Little Etobicoke Creek to the Applewood and Dundas / Dixie SPAs and the magnitude of the spill
- Spill flow route, depth / elevation of flooding
- Velocity and Depth-Velocity product

6.2.1 Spill Magnitude and Frequency

Spill from Little Etobicoke Creek to Queen Frederica Drive starts to occur during the 5-year event. The spill occurs just downstream of the upstream Pedestrian Bridge, and as such is upstream of the flood wall which is adjacent to the downstream pedestrian bridge. The magnitude of the spill is nominal at approximately 1.0 m^3/s of the total peak flow of 58 m^3/s. For frequent floods such as the 5-year event, the spill flows would likely be intercepted by the municipal storm sewer system or be conveyed along the municipal road network. As such, flooding of this nature would not likely be documented or of concern.

As summarized in Table 6.1 and illustrated in Figure 6.1, the fraction of flow that spills from Little Etobicoke Creek to Queen Frederica Drive increases significantly for higher return events. As a percentage of the total flow it increases from near zero for the 5-year event to 49 percent for the 350-year event with the existing flood wall and flood berm in place.

The calculations were also completed assuming that the flood wall and flood berm were not in place for the 350-year and the Regional Storm events. As illustrated, removal of the wall and berm would only have a nominal impact on the fraction of spill from Little Etobicoke Creek to Queen Frederica Drive; from 49 percent of the total flow to 51 percent of the total flow.

For the Regional Storm event, 62 percent of the total flow spills on to Queen Federica. This means that only about 80 m^3/s remains in Little Etobicoke Creek, which is equivalent to the total peak flow generated by the 25-year event.

Table 6.1: Spill to Queen Frederica

Case	Return Period	Flow Rate (m^3/s)			Spill to Queen Frederica Dr. (%)
		Total flow	At Dixie Road	Spill to Queen Frederica Dr,	
With Berm and Wall	5-year	59	58	1	<2
	25-year	81	65	16	20
	100-year	100	70	30	30
	350-year	152	78	74	49
No Berm and Wall	350-year	152	74	78	51
	Regional St.	210	80	130	62

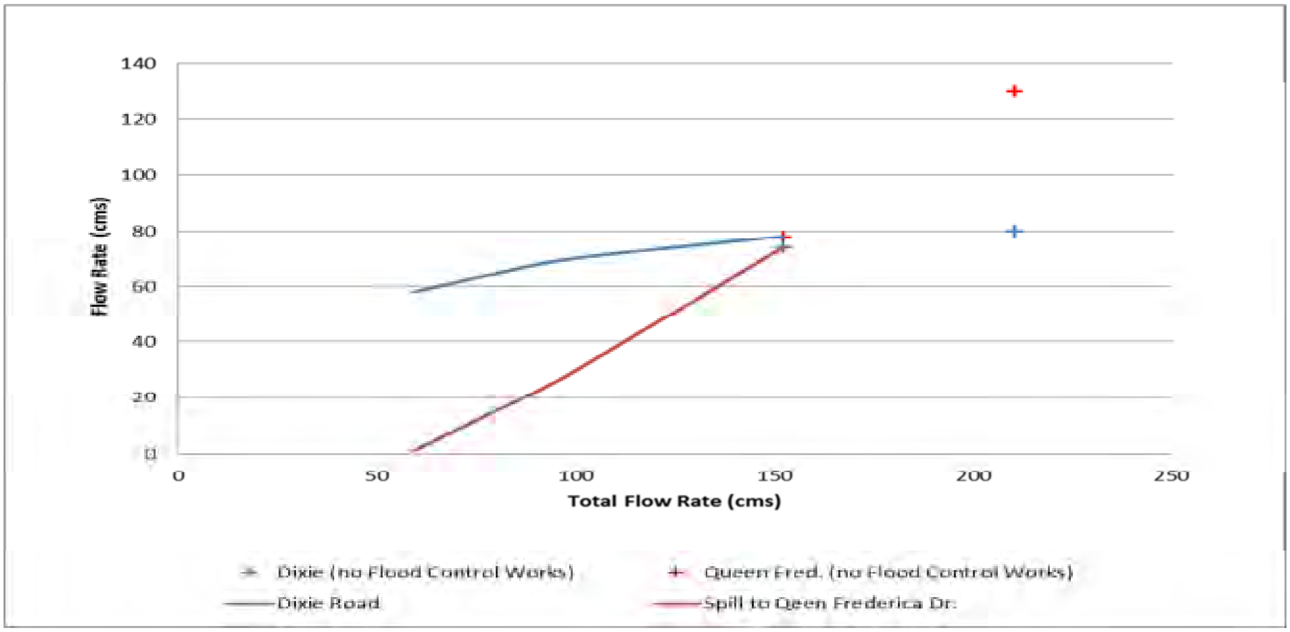


Figure 6.1: Spill Flow from Little Etobicoke Creek to Queen Frederica Drive

Although the spill is predominately upstream of Dixie Road, there is also some spill between Dixie Road and Dundas Street. As per Exhibit 6.1 to Exhibit 6.5, there is no spill for all events up to and including the 350-year event. However, if the berm is removed from the analysis spill occurs for both the 350-year event and the Regional Storm. The spill flow exits the Little Etobicoke Creek floodplain between building openings downstream of Dixie Road, and then flows southeasterly to Dundas Street and thence back to Little Etobicoke Creek.

6.2.2 Flood Flow Routes

The flood flow routes are clearly illustrated on the various maps. The dominate spill route is south on Queen Frederica Drive. At Dundas Street the flow splits as follows:

- The larger fraction continues south across Dundas Street then along Blundell Road towards the CPR, and then southerly on Dixie Road.
- A significant fraction also flows easterly on Dundas Street to Dixie Road, and then south.

- A small fraction flows southwesterly from the intersection of Queen Frederica Drive and Dundas Street.

6.2.3 Flood Depths and Elevations

During the Regional Storm event (Exhibit 6.7), the flood depth in the section of Queen Frederica adjacent to the creek reaches approximately 1.35 metres, gradually decreasing to less than one metre at the intersection of Queen Frederica Drive and Dundas Street. As flow dissipates in both directions from this intersection there is a gradual reduction in flood depths.

The noted exception to the above, is the CPR underpass on Dixie Road south of Dundas Street. As illustrated, the MIKE FLOOD model calculated a maximum flood depth in excess of 4.0 metres. However, as previously discussed, actual flood depths would be considerably less as the existing storm sewer system would have moderated the flood depth to a value substantially less. Given that the storm sewer was not incorporated into the MIKE FLOOD model, there is no way of knowing for sure what the actual depth of flooding would be.

Table 6.2 and Exhibit 6.8 provide a brief summary of flood depths for the 100-year, 350-year and Regional Storm events. Table 6.3 summarized actual flood elevations at four key locations.

Table 6.2: Flood Depths at Key Locations

Case	Return Period	Section 8.22 At Queen Frederica	Queen Frederica at Dundas St	Dixie Rd. at Dundas Street
With Berm and Wall	100-year 350-year	0.80 1.12	0.68 0.82	0.45 0.35
No Berm and Wall	350-year Regional St.	1.06 1.35	0.83 0.92	0.36 0.45

Table 6.3: Flood Elevations at Key Locations

Case	Return Period	Section 8.22 at Creek	Section 8.22 at Queen Frederica	Queen Frederica at Dundas St	Dixie Rd. at Dundas St.
With Berm and Wall	5-year 100-year 350-year	124.68 -- --	123.84 -- --	-- -- --	120.28 -- --

6.2.4 <u>Flood Velocities and Flood Depth-Velocities</u>

Safe access-egress for Special Policy Areas typically considers depth, velocity and the velocity-depth product. Commonly, the following are used to define upper limits of safe access:

- Maximum Depth (emergency vehicles): 0.3 metres
- Maximum Depth (pedestrians): 0.8 metres
- Maximum Velocity (pedestrians): 1.7 m/s
- Maximum Depth-Velocity Product (pedestrians): 0.37 m^2/s

Exhibit 6.9 and Exhibit 6.10 illustrate flood velocities for the 350-year and the Regional Storm events (with flood wall and berm removed), while Exhibit 6.11 and Exhibit 6.12 illustrated the product of depth and velocity.

Document Name: ex6.8-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA-Flood Depth at Key Points of Interest

MMM GROUP

FLOOD DEPTH AT KEY POINTS OF INTEREST

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

0 60 120 180 m

1:5,000

N

Date: August-12-14

Project No: 1412606

Exhibit No. 6.8

MMM GROUP

350-YEAR FLOOD VELOCITY MAP (WITHOUT BERM AND WALL)

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

0 90 180 270 m

1:8,000

N

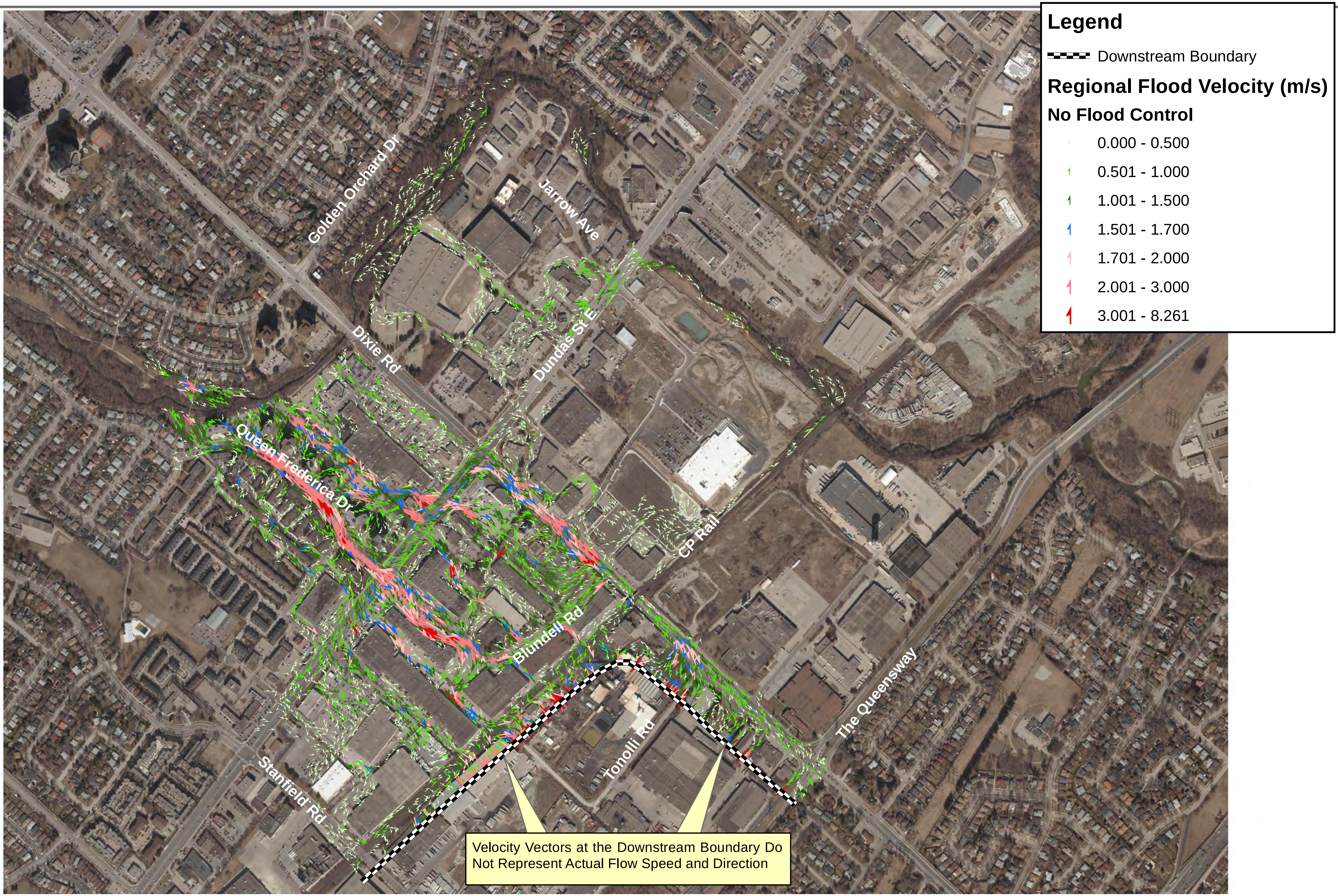
Date: August-28-14

Project No: 1412606

Exhibit No. 6.9

Document Name: ex6.9-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA-350-year Flood Velocity (without berm and wall)

Document Name: ex6.10-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA-Regional Flood Velocity (without berm and wall)



MMM GROUP

REGIONAL FLOOD VELOCITY MAP (WITHOUT BERM AND WALL)

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

0 90 180 270 m

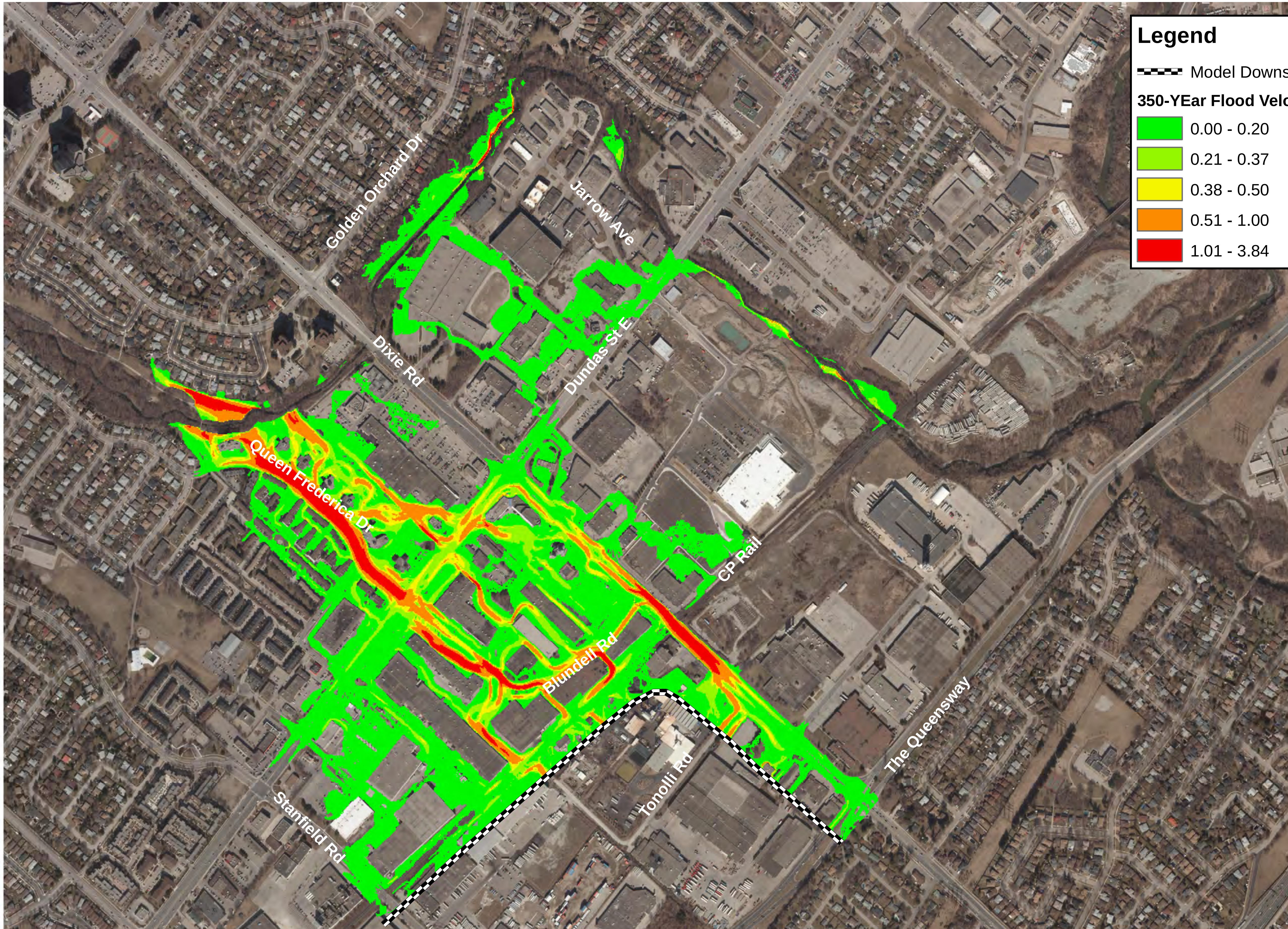
1:8,000

N

Date: August-28-14

Project No: 1412606

Exhibit No. 6.10



MMM GROUP

350-YEAR FLOOD VELOCITY x DEPTH MAP (WITHOUT BERM AND WALL)

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

0 90 180 270 m

1:8,000

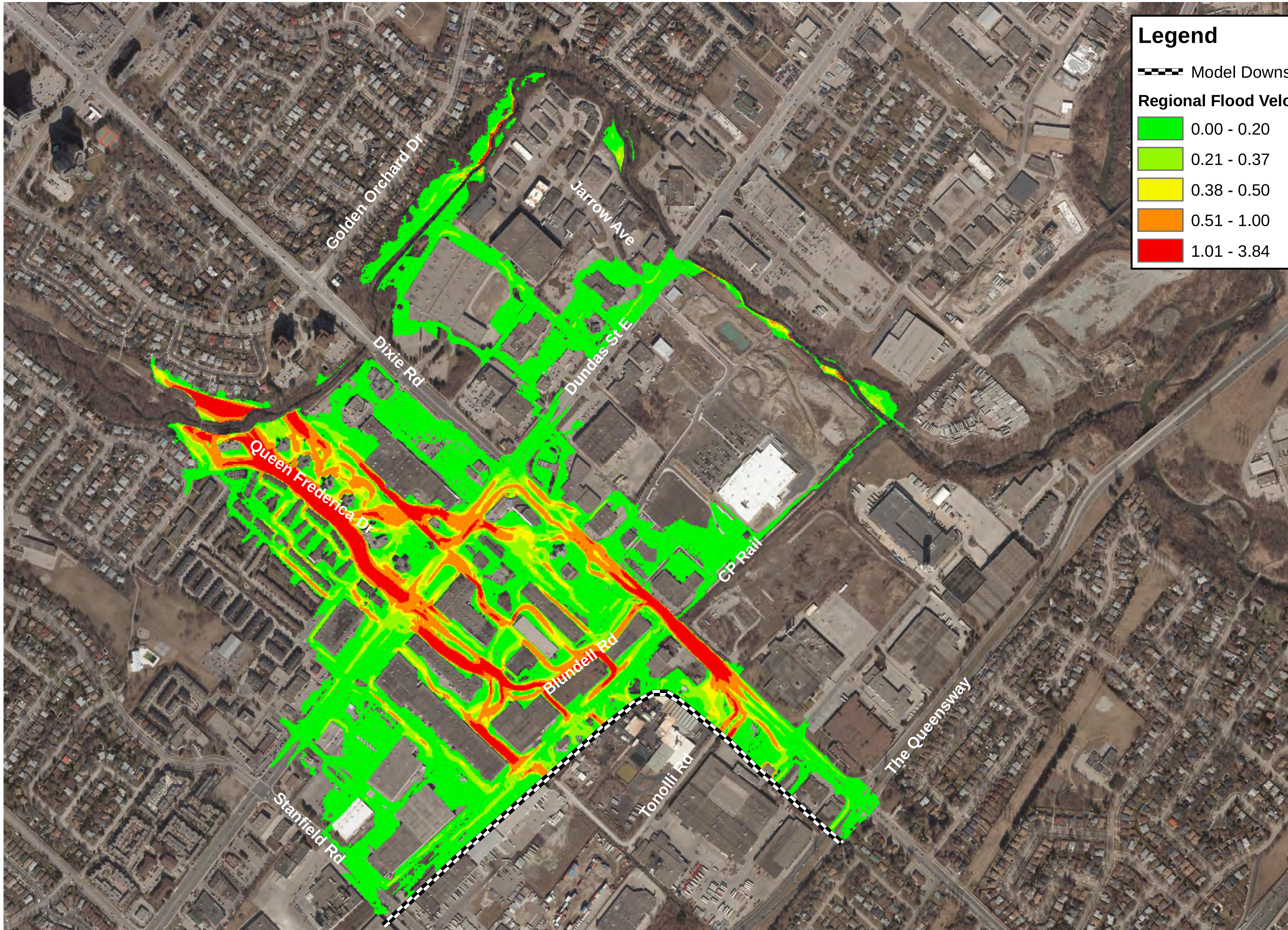
N

Date: August-28-14

Project No: 1412606

Exhibit No. 6.11

Document Name: ex6.11-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA-350-Year Flood VelocityxDepth (without berm and wall)



MMM GROUP

REGIONAL FLOOD VELOCITY x DEPTH MAP (WITHOUT BERM AND WALL)

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

0 90 180 270 m
1:8,000

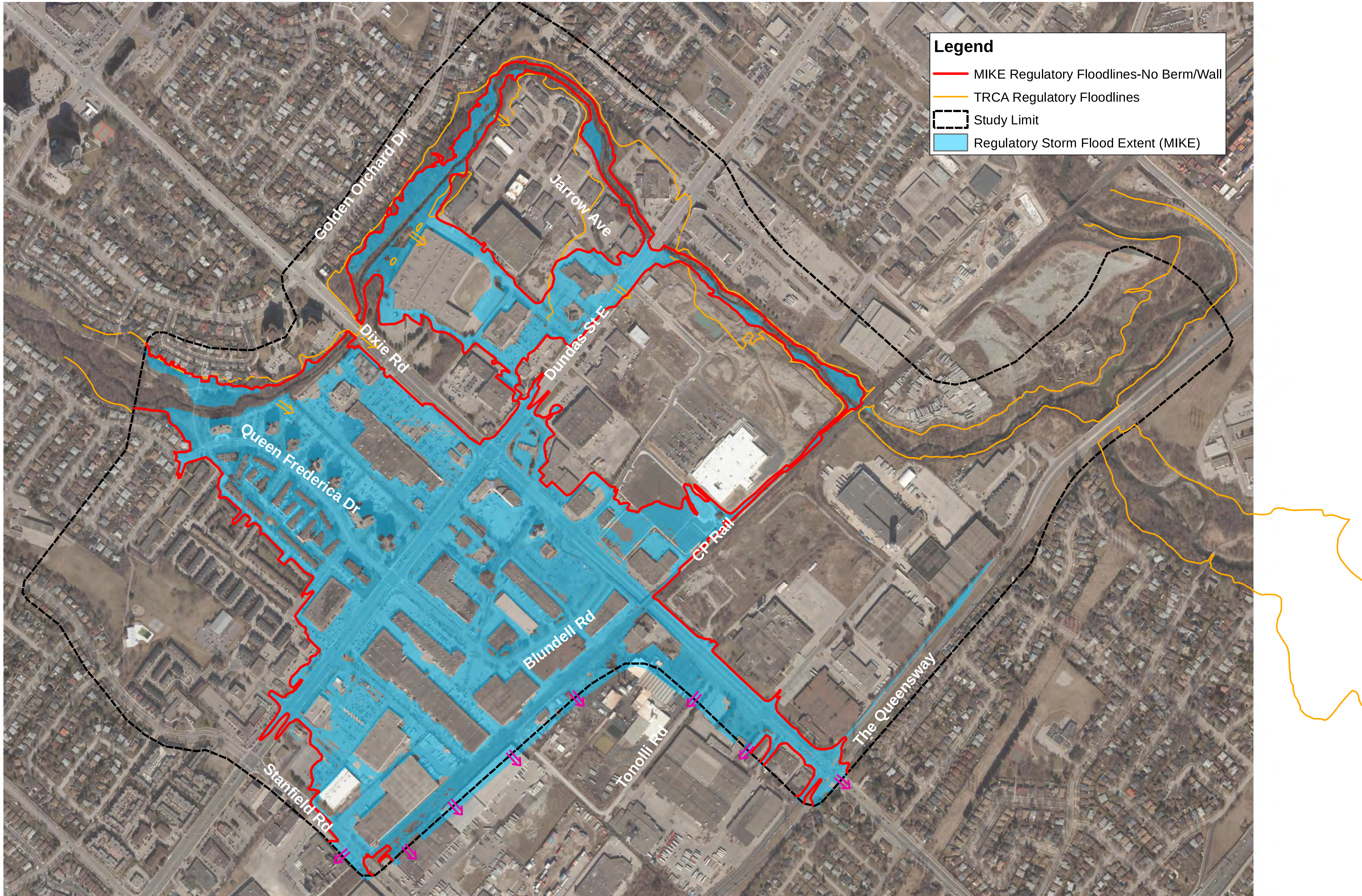
N

Date: August-28-14
Project No: 1412606
Exhibit No. 6.12

Document Name: ex6.12-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA-Regional Flood VelocityxDepth (without berm and wall)

7.0 UPDATED FLOOD HAZARD MAPPING

Exhibit 7.1 illustrates the flood hazard limits associated with the spill generated by the Regulatory Event (no berm or flood wall in place). The spill continues southerly beyond the CPR Rail corridor; however the extent has not been mapped as part of the current study. Exhibit 7.1 also illustrated the existing Regulatory floodlines associated with Little Etobicoke Creek.



Document Name: ex7.1-1412606-Floodplain Mapping for the Applewood and Dundas,Dixie SPA-Reg Floodlines (without berm and wall)

MMM GROUP

REGULATORY FLOODLINES (WITHOUT BERM AND WALL)

FLOODPLAIN MAPPING FOR THE APPLEWOOD AND DUNDAS/DIXIE SPECIAL POLICY AREA

Date: December-16-2014

Project No: 1412606

Exhibit No. 7.1

8.0 PRELIMINARY FLOOD REMEDIATION ASSESSMENT

Given the extent of spill that occurs from Little Etobicoke Creek to Queen Frederica Drive, a number of preliminary alternatives were tested to determine what measures could be implemented to reduce spill and related flood risk. These alteratives will be further investigated as part of a future study. The preliminary alternatives that were investigated included:

- Alternative 1: Remove Two Pedestrian Bridges Upstream of Dixie Road
- Alternative 2: Contain spill west of Dixie Road
- Alternative 3: Contain spill west of Dixie Road and east of Dixie Road to Neilco Court

Alternative 1: Remove Two Pedestrian Bridges Upstream of Dixie Road

The purpose of this alternative was to determine if flow impediment associated with the two pedestrian bridges was a significant factor contributing to the frequency and magnitude of the spill to Queen Frederica Drive.

Figure 8.1 shows the maximum flood extent and flood depth. A comparison of Figure 8.1 to Exhibit 6.7 illustrates that the pedestrian bridges are a minor factor contributing to the spill.

Figure 8.1: Maximum flood extent and flood depth with two pedestrian bridges removed

Alternative 2: Contain spill west of Dixie Road

The purpose of Alternative 2 was to determine the impact of extending a flood wall upstream of Dixie Road such that there would be no spill on to Queen Frederica Drive.

Figure 8.2 illustrates the maximum flood extent and flood depth. As illustrated, this alternatives successfully eliminates the spill at Queen Frederica Drive, however there would a significant spill on to Dixie Road continuing southerly beyond the CPR underpass. There would also be increased flooding within the Dundas-Dixie SPA.

Figure 8.2: Maximum flood extent and flood depth with No Spilling West of Dixie

Alternative 3: Contain spill west of Dixie road and west of Dixie Road to Neilco Court.

This alternative included extending the flood wall identified for Alternative No. 2 further downstream to Neilco Court. The intent was to prevent spill southerly along Dixie Road.

Figure 8.3 illustrates that with this alternative spill is limited to the Dundas / Dixie SPA, with the extent of flooding noticeably reduced from the flooding associated with Alternative No. 2.

Further refinement of this alternative including revisions to the size of the Dundas Street culvert would further contain flows within the floodplain.

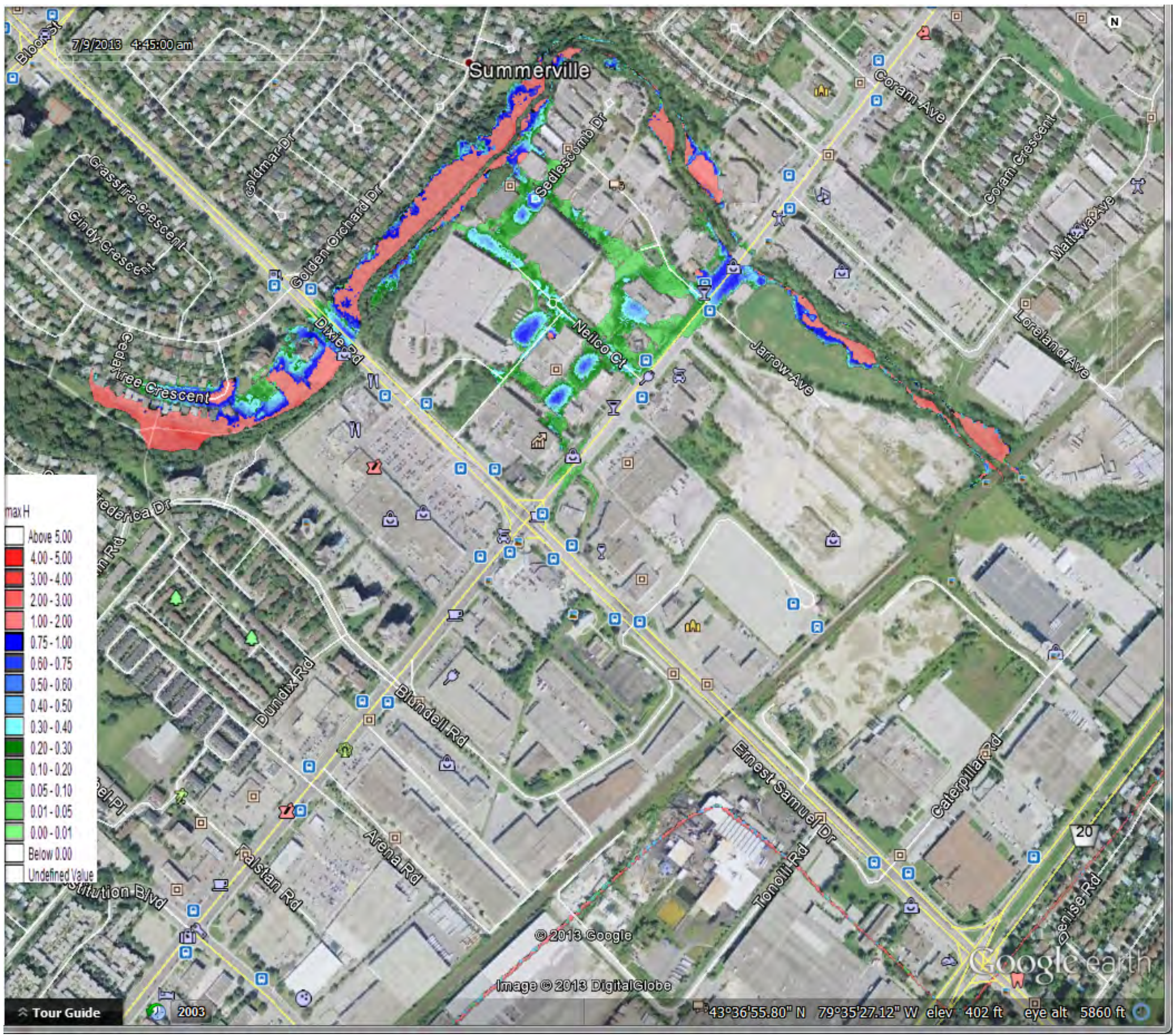


Figure 8.3: Maximum flood extent and flood depth with No Spilling West of Neilco Court

All of which is respectfully submitted

Tim Mereu, P. Eng.

MMM Group Limited

APPENDIX A – INITIAL PEER REVIEW

VALDOR ENGINEERING INC.
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12 September 2013
File: **13117**

Toronto and Region Conservation Authority
5 Shoreham Drive
Toronto, Ontario
M3N 1S4

Attention: **Mr. Jairo Morelli, P.Eng.**
Water Resources Engineering Analyst

Re: **Peer Review of Hydraulic Modeling and Floodplain Mapping for Dixie/Dundas SPA and Applewood SPA**
Comments by Valdor Engineering Inc.

The following documents were provided by the TRCA, DHI and MMM to Valdor for reference during our review:

- *Verification of Mike 11 Model Results, Draft Memo, DHI, 27 August 2013*
- *1-D Mike 11 model for Little Etobicoke Creek*
- *Existing TRCA's HEC-RAS model for Etobicoke Creek*
- *Unsteady HEC-RAS model of Little Etobicoke Creek (HEC-RAS XS 8.25 to 8.01)*
- *Softcopy (pdf) of the TRCA's floodline sheet 3*
- *Pdf map of Etobicoke Creek watershed showing site location*

Based on our review of the above-noted documents and models, we offer the following general and specific comments pertaining to the Mike 11 model setup and comparison with HEC-RAS model results.

General Comments

1. The scope of the DHI memo is limited to a comparison of the HEC-RAS and Mike 11 model results. Please note that additional information including a defined study area and complete supporting calculations will be required when this comparison is incorporated into the final technical report.

2. It is noted that the model runs in Mike 11 and comparisons to HEC-RAS provided in the technical memo are limited to the 100-yr storm. Please note that 2, 5, 10, 25 100, 350-yr return period storms and the Regional storm will ultimately be required for the Mike 11 and coupled 1D/2D model runs.

3. We note that the Mike 11 model was prepared using the existing HEC-RAS cross section data including geo-referencing. Prior to coupling the 1D/2D model, we would suggest that the spatial positioning of the Mike 11 network derived from the HEC-RAS conversion be reviewed and checked with verified available topographic mapping. If

necessary, the network alignment should be adjusted to ensure accurate spatial positioning of the river network in the 2D surface.

Second paragraph of the DHI Memo (draft)

4. It is indicated that the Mike 11 model was created by converting the HEC-RAS model for Little Etobicoke Creek from XS 8.25 to XS 8.01. Typically, the 1D Mike 11 model is extended both u/s and d/s of the 2D flood prone area of interest. Please provide a description in the technical memo whether the proposed Mike 11 extents (from HEC XS 8.25 to 8.01) d/s and u/s will be adequate to avoid any undesirable impacts on the model results (for the core 2D area of interest) related to the Mike 11 boundaries and/or model instabilities close to these end locations.

Mike 11 Model Cross-Sections

5. In Mike 11, the bridge at EC 3-2R Dundas Street W. (at HEC-RAS XS 8.095) was modeled using u/s and d/s cross-sections of the corresponding HEC-RAS bridge location cross section. The cross section (*i.e.* x, z values) used to represent the downstream bridge section does not match with the downstream HEC-RAS section at XS 8.09. Please check and modify, if necessary.

Mike 11 Model Roughness Values

6. The pedestrian bridge at HEC-RAS XS 8.2215 was modeled in Mike 11 (at chainage 6229.9) as a combination of an irregular shaped culvert with roughness of 0.013 and a broad-crested weir for the road deck. Based on a review of the u/s and d/s HEC-RAS cross sections associated with this crossing, the Manning's roughness value seems low. Please justify and/or provide supporting calculations and a description of the channel at the bridge location including any bridge abutments to clarify how the roughness value was derived.

7. The bridge (EC 3-3R Dixie Rd.) at HEC-RAS XS 8.195 was modeled in Mike 11 (at chainage 6643.90) as a combination of an irregular shaped culvert with roughness of 0.013 and a broad-crested weir for the road deck. Based on a review of the u/s and d/s HEC-RAS cross sections associated with this crossing, the Manning's roughness value seems low. Please justify and/or provide supporting calculations and a description of the channel at the bridge location including any bridge abutments to clarify how the roughness value was derived.

8. The two bridges (pedestrian bridge at HEC-RAS XS 8.2115, and EC 3-2R Dundas Street W. at XS 8.095) at chainage 6425.20 and 7910.0 in Mike 11 were modeled taking into account corresponding u/s and d/s HEC-RAS channel sections. A roughness of 0.033 (*i.e.* M =30) was used. Please provide supporting calculations and a description of the channel at the bridge location including any bridge abutments to clarify how the roughness value was derived.

9. A roughness of 0.06 was used at the Mike 11 bridge (EC 3-1RR CPR at HEC-RAS XS 8.045) section at chainage 8499.50. Please justify and/or provide supporting calculations and a description of the channel at the bridge location including any bridge abutments to clarify how the roughness value was derived.

10. The road deck (corresponding to the HEC-RAS bridge at EC 3-3R Dixie Road) represented by the Mike 11 section at chainage 6643.90 has a roughness of 0.08 and 0.001. Please justify and/or provide supporting calculations to clarify how these roughness values were derived.

Unsteady HEC-RAS Model

11. In order to run the unsteady flow HEC-RAS model, a hydrograph was created and used to run an unsteady simulation to create comparable results to that of the unsteady Mike 11 model. Please include in the technical memo some discussion regarding this hydrograph to clarify how it was derived in order to avoid any inappropriate use or reference to this hydrograph in the future.

Mike 11 Model Boundary

12. The water surface elevations and the corresponding different return period flows at HEC-RAS XS 8.01 were used as a Q-h rating curve to establish downstream boundary conditions in the Mike 11 model at the corresponding location. This rating curve was generated by the HEC-RAS steady state simulation. We suggest that a sensitivity analysis should be carried out before finalizing the 1D-2D coupled model to confirm that this boundary condition does not create any unusual or unexpected influences on the flood elevations in the area of interest. A description of the boundary condition data and how the boundary conditions were derived should be provided in the final technical report.

We trust that these comments are of assistance to the TRCA. We would be pleased to further discuss these comments with either the TRCA and/or directly with DHI or MMM. Should you have any comments please do not hesitate to contact the undersigned.

Yours very truly,

VALDOR ENGINEERING INC.

Abdul Baten, M.Sc.
Water Resources / Environmental Analyst

Bill Coffey, M.Sc., P.Eng.
Head of Water Resources

DHI Water & Environment Inc.
336 Eagle Street N, Unit 1A2
Cambridge, ON N3H 1C2
519-650-4545

To: Jairo Morelli

Cc: Patrick Delaney, Tim Mereu

From: Ying Qiao

Date: August 7, 2014

Topic: Responses to Peer Review Comments – Conversion and Comparison of HEC-RAS model and MIKE11 for Dixie Dundas 2D Modeling

Memorandum

In response to Dixie Dundas 2D modeling – Peer Review Comments, DHI prepared this memo to summarize responses to each peer review comment.

Response to General Comment 1 to 3:
1) the technical memo was intended to only cover technical aspects of model conversion and comparison. Final report will not only document defined study area and available information in details but also document model conversion process and comparison results.
2) For model conversion and comparison task, DHI was requested to do model comparison for 100-year event. DHI is aware of that the final 1D/2D coupled model will run for all required flood events.
3) As part of data review, alignment of river network will be checked with available topographic map to make sure it is consistent with the topography.

Response to Comment 4: model boundary selection for 1D/2D coupled model will be discussed in the final report.

Response to Comment 5: the (x,z) at XS 8.09 has been corrected.

Response to Comment 6 to 9: There is no extra document or data available regarding these structures, the only information available for these structures is from the existing HEC-RAS model. DHI does not disagree using 0.035 (i.e. natural channel) for all structures in the study area.

Response to Comment 10: The road deck in MIKE11 is treated as weir, which uses weir coefficient, so it does not use Manning's roughness. In addition, at this location Resistance type was used uniform Manning's n of 0.08 (which is the standard TRCA manning's n for floodplain), so value of 0.001 is not actually used.

Response to Comment 11: converting the existing steady-state HEC-RAS to unsteady-state HEC-RAS is not in the scope of this project. The reason has been explained in the technical memo. For

DHI Water & Environment Inc.
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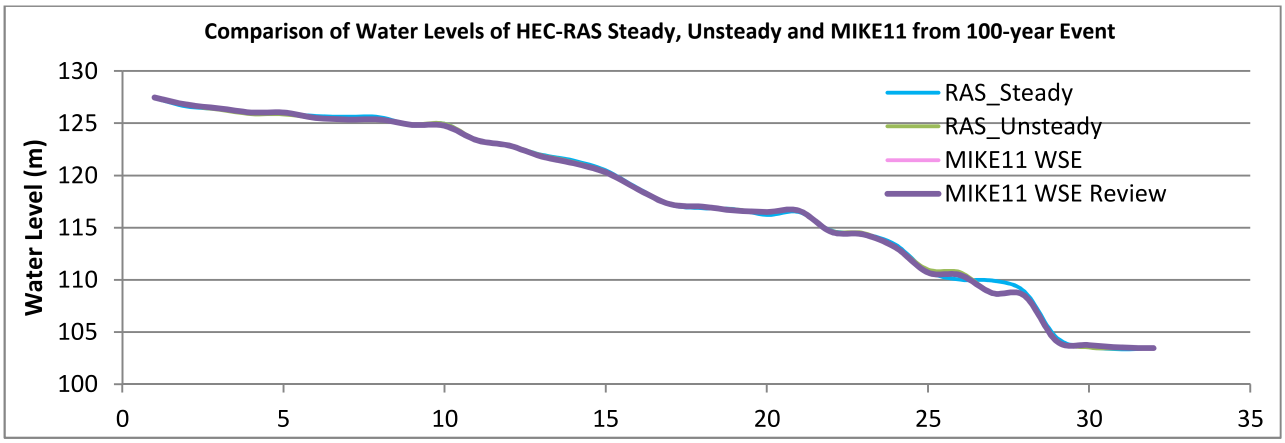
derivation of inflow hydrography, there is no extra information for that. The main interest of this bonus work is to compare maximum water levels from unsteady-state HEC-RAS with MIKE11 model results, so the derivation of inflow hydrography is to preserve the peak flow as 100-year event (i.e. 147.1 m3/s) and to have stable solution.

Response to Comment 12: for 1D/2D coupled model, boundaries will be re-evaluated and discussed with TRCA, and derivation of boundary will be discussed in the final report.

DHI has re-run the MIKE11 model with manning's n change to 0.035 for structures and correction of XS 8.09, and results from the re-run were compared with previous MIKE11 results. In the plot below, the purple line is the latest results with above changes. It can be seen that results are very close to previous MIKE11 results.



APPENDIX B – FINAL PEER REVIEW

MMM Group Limited
100 Commerce Valley Drive West
Thornhill, ON Canada L3T 0A1
t: 905.882.1100 | f: 905.882.0055

www.mmmgrouplimited.com

June 23, 2014

Toronto and Region Conservation Authority
5 Shoreham Drive
Toronto, ON, M3N 1S4

Attention: Nick Lorrain, P. Eng.

Re: Response to Peer Review Comments
<u>Floodplain Mapping – Applewood and Dundas/Dixie SPAs</u>

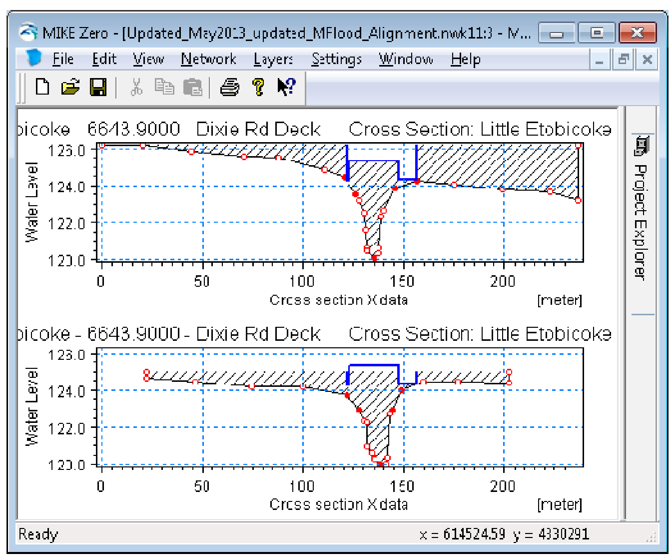
In response to Peer Review comments received from Valdor Engineering Inc. dated April 2, 2014, we provide the following response.

<u>Response to MIKE11 Model Setup Comments 1 to 4</u>:

1) The upstream inflow boundary conditions and downstream water level boundary conditions have been corrected to reflect the future hydrology conditions and the results from the HEC-RAS model using future hydrology conditions.

2) The 350 year event has been included in the analysis. The hydrograph for the 350 year event was derived as part of the Etobicoke Creek Hydrology Update (April 2013). An excerpt from the Report is attached hereto.

3) These high resistances values at the edges of the MIKE 11 cross-sections were an artifact of the original MIKE 11 model that was compared against the original HEC-RAS model. The high resistance values were used to represent the ineffective areas defined in the HEC-RAS model upstream of the bridges. These values have been corrected in the MIKE FLOOD model.



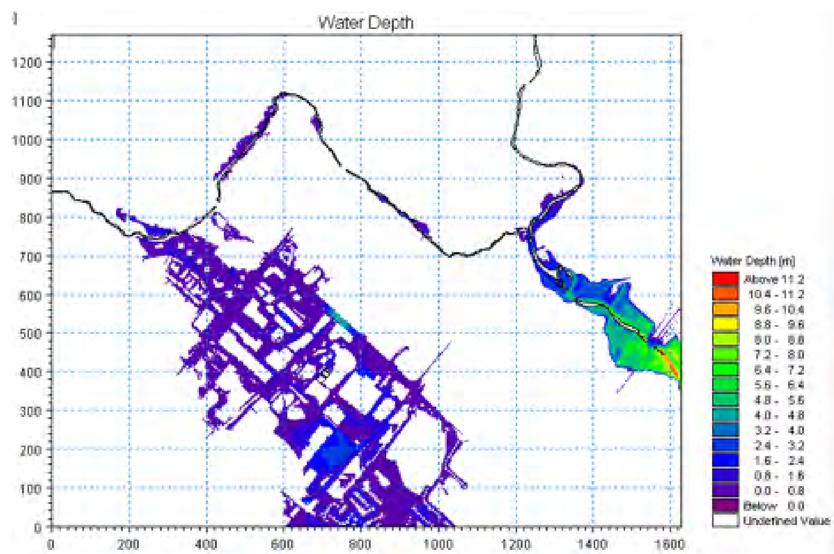
4) The plot function in MIKE 11 is only used for display purpose and does not affect model calculation and results. However, the spatial location has been corrected as shown in the adjacent figure.

Response to MIKE21 Model Setup:

5) The area beyond the study domain is not in the scope of this project so, in the absence of the necessary LiDAR data and additional budget required to include it, using a water level boundary condition is a reasonable choice. The water level boundary condition has been set along the edges of the 2D model domain where preliminary simulations indicate that overland flow will come into contact with the boundary. The water level boundary condition is defined as a pool of water along the edge where the water level of the pool is below the adjacent ground surface elevation inside the model domain. Since the boundary condition water level is below the ground surface the water that comes into contact with the edge (boundary) of the domain will simply be removed from the model domain (ie it will flow into the pool).

   Given the distance of the boundary from the SPA's, the difference in elevation from boundary to the SPA's, and the shallow depth of overland flow along the edges of the model (typically less than 0.15 m), it is hydraulically impractical for there to be any risk of this boundary condition impacting the model results in the near vicinity of the SPA's.

   That being said, as part of the model development process, DHI did evaluate the possibility of extending the model domain further to the southeast using the available 10 m DEM. The southeast extension was considered because it remains within the TRCA boundary. The results of a simulation using the 100 Year Flood Event (see figure below) confirmed that overland flow continues to follow topography streets and generally flows south and west. It also indicates there are no immediate downstream obstructions to overland flow that could impact flooding results within the study area. Given these observations it was determined that no further analysis of potential boundary effects was warranted.



Yours truly,
MMM Group

Tim Mereu, P. Eng.
Vice President, MMM Group
Water Resources and Environmental Services

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18 July 2014
File: **13117**

Toronto and Region Conservation Authority
5 Shoreham Drive
Toronto, Ontario
M3N 1S4

Attention: **Mr. Nick Lorrain**
Senior Project Manager

Re: **Peer Review of Final 2D Hydraulic Model (using Mike Flood) for Dixie/Dundas SPA and Applewood SPA**
Technical Comments by Valdor Engineering Inc.

Valdor completed a peer review of the 2D hydraulic models (using the Mike Flood modeling system) for the above study area and prepared comments dated 02 April 2014. In response to the Valdor peer review comments, MMM/DHI provided their response in a memo dated 27 June 2014 along with a revised copy of the Mike Flood model files provided on 09 July 2014. The following documents and model files in regard to the above hydraulic modeling were provided by the TRCA and MMM to Valdor for a final review:

- *MMM's response (June 27, 2014) to Valdor's peer review comments (dated 02 April, 2014);*
- *Model setup and results files for Existing Conditions with Berm and Wall in place for 100-yr and 350-yr events;*
- *Model setup and results files for Existing Conditions with Berm and Wall Removed for Regional and 350-yr events;*
- *2D dfs2 resistance file for the study area;*
- *Land use map used for Manning's roughness; and,*
- *GIS files for buildings, berms and walls removed.*

Based on our review of the above revised documents and model files provided, we confirm that Valdor's earlier review comments have been satisfactorily addressed and that we have no further comments.

We trust that these comments are of assistance to the TRCA. Should you have any comments or questions please do not hesitate to contact the undersigned.

Yours very truly,

VALDOR ENGINEERING INC.

Abdul Baten, M.Sc.
Water Resources / Environmental Analyst

Bill Coffey, M.Sc., P.Eng.
Head of Water Resources

S:\Projects\2013\13117\Reports\ReviewMikeFlood\13117 - Letter - Valdor Review of Final 2D Hydraulic Model (dated 09Jul2014) - 18 July 2014.doc

APPENDIX C – TRCA Analysis of flood of July 8, 2013

MEMORANDUM

TO:	Nick Lorrain	DATE:	June 18, 2014
FROM:	Dilnesaw Chekol	CFN:	N/A
RE:	Estimated Flows of July 8, 213 within Etobicoke Creek using 2013 Etobicoke Creek Hydrology Model.		
CC:			

Introduction:

In order to have better confidence on the results of the hydrodynamic model of Little Etobicoke Creek through the Dixie-Dundas Area, a comparison of the model results against observed data from the July 8, 2013 event will be completed. Unfortunately, there is no stream gauge station within Little Etobicoke to obtain measured discharge and water level. On July 8, 2014, the Dixie Dundas area received a significant storm event, which produced significant flooding. During the following weeks TRCA staff collected high water marks across TRCA jurisdiction.

Due to the lack of a stream gauge for the area, TRCA staff is assessing the July 8 hydrologic inputs based on the latest hydrology model for the broader Etobicoke Creek watershed which was completed by the MMM Group.in2013.

Objective:

To estimate flows that were generated during the July 8 storms using the approved 2013 Etobicoke Hydrology model.

Materials and Methods:

Input: Rainfall

There are six rain gauges within and surrounding Etobicoke Creek watershed (see Table 1 and Figure 1). Time interval of measurement for five of the gauges is 5 minutes, but the gauge at

Pearson International Airport is 60 minutes. Due to this course temporal resolution, important characteristics of the storm that was responsible for the observed peak flows were not captured. Martin Grove station was used instead of the Pearson International Airport gauge due to its proximity to the study area and the availability of 5 min rainfall information.

As the measurements of the July 8 storm show, the storm was not uniformly distributed across the watershed (see Figure 1 and 2), as such it was necessary to define sub-catchments that are represented by each rain gauge stations. In order to create areas of influence around each rain gauge stations, the Thiessen Polygons method was selected. Thiessen Polygon is a widely used approach to define storm distributions across watersheds for the purpose of hydrologic modeling. TRCA's GIS staff applied Thiessen Polygon in a GIS environment to assign a representative rainfall distribution for each sub-catchment (see Figure 1).

Hydrology Model:

As referenced above, the hydrology model utilized for this analysis was the 2013 Etobicoke Creek Hydrology model. The existing condition scenario was used for the assessment as it includes all existing stormwater management ponds. In addition the existing condition scenario model run utilizes AMC II conditions, which based on weather records is consistent and representative of watershed soil conditions prior to the July 8 event.

	Station Name	Owned and Operated by	Measurement time interval
1	ETOBICOKE @ QEW (HY025)	TRCA	5 min
2	HEART LAKE CA (HY033)	TRCA	5 min
3	MISSISSAUGA WORKS YARD (HY046)	TRCA	5 min
4	SUE GRANGE FARM (HY061)	TRCA	5 min
5	EC – Pearson Int'l Airport (6158731)	Environment Canada	60 min
6	Martin Grove	City of Toronto	5 min

Table 1: Rain-gauge used to estimation of flows

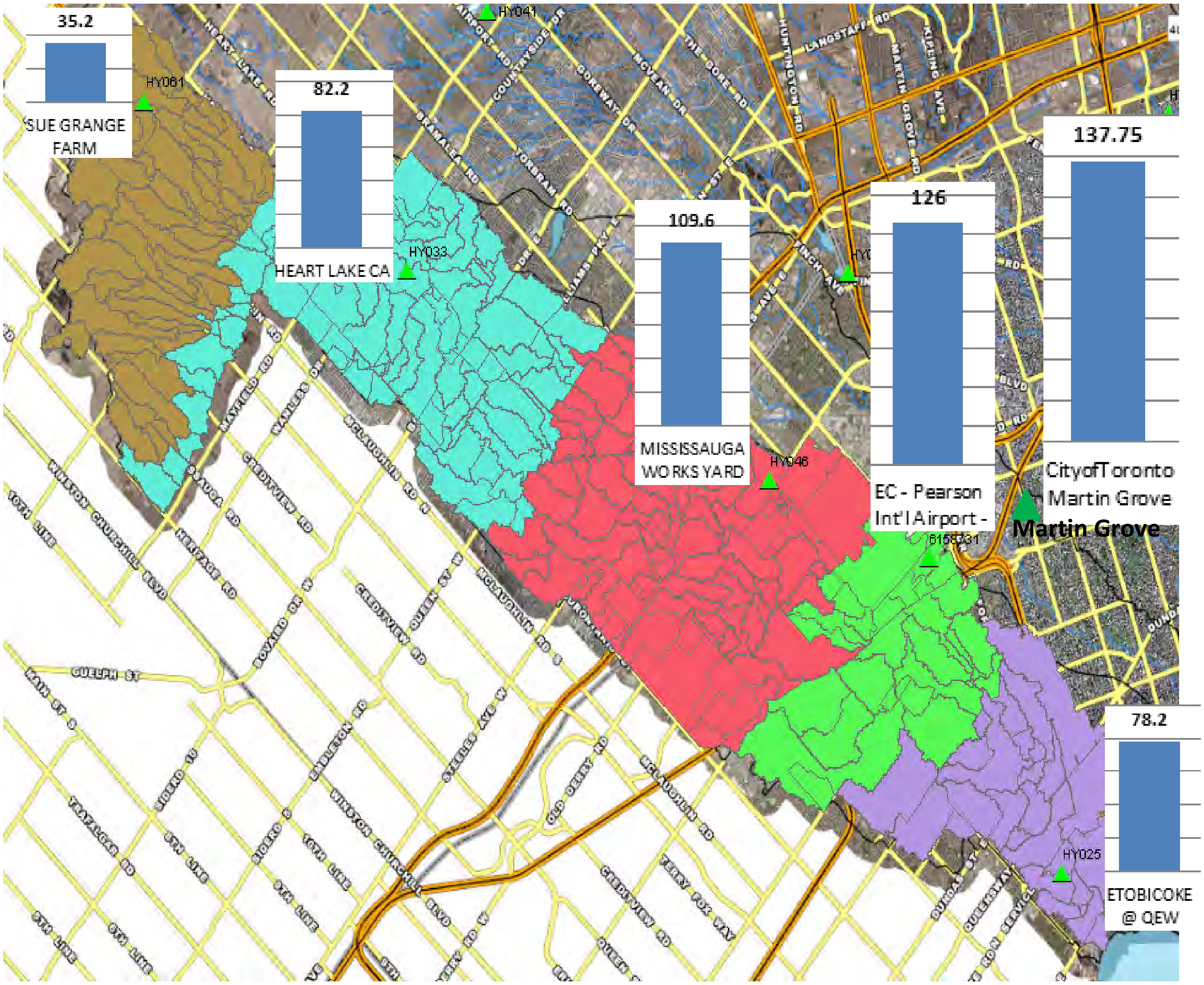

Figure 1: Sub-catchments of Etobicoke Creek influenced by Rain gauge based on Thiessen Polygon Method and total rainfall amount of July 8 storm at each rain gauge.

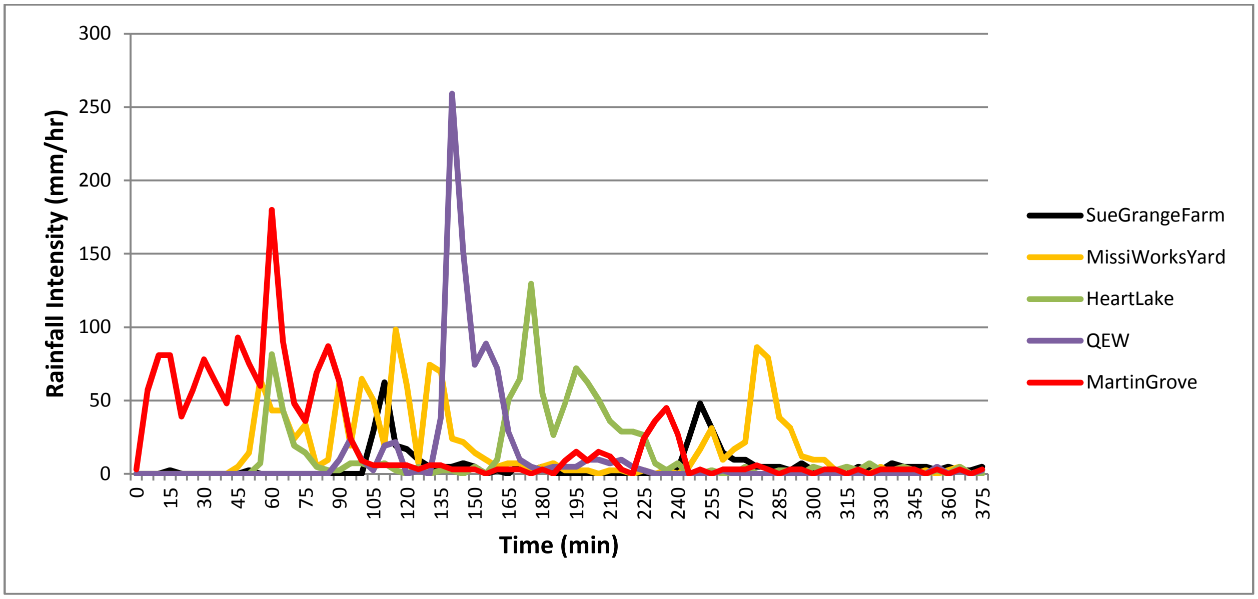

Figure 2: Rainfall Intensity

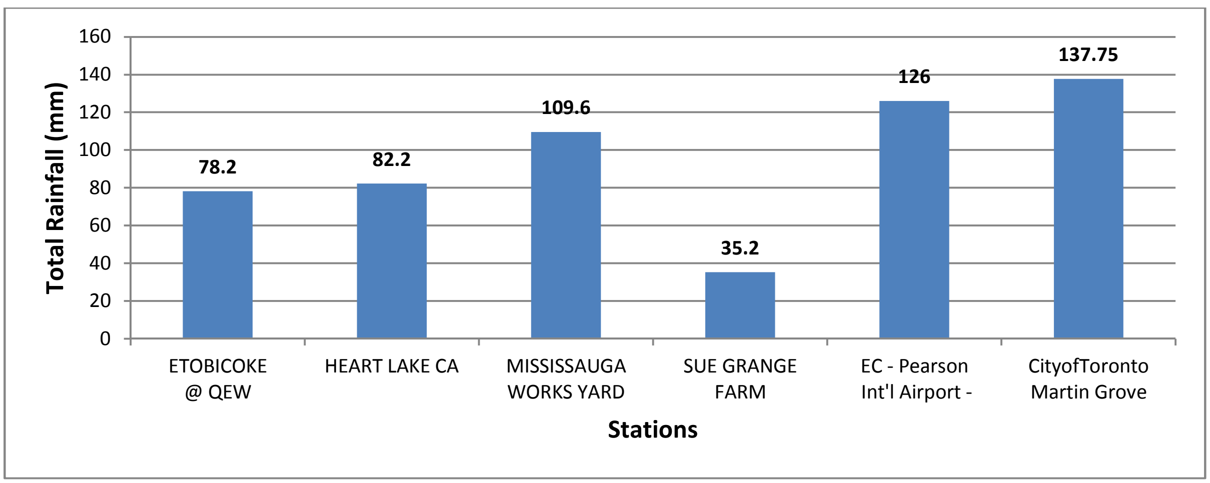

Figure 3: Total Rainfall Amount

Results:

Flows generated from the analysis for different flow nodes and sub-catchments shown on Figure 4 are shown in Table 2, Figure 4 through 9.

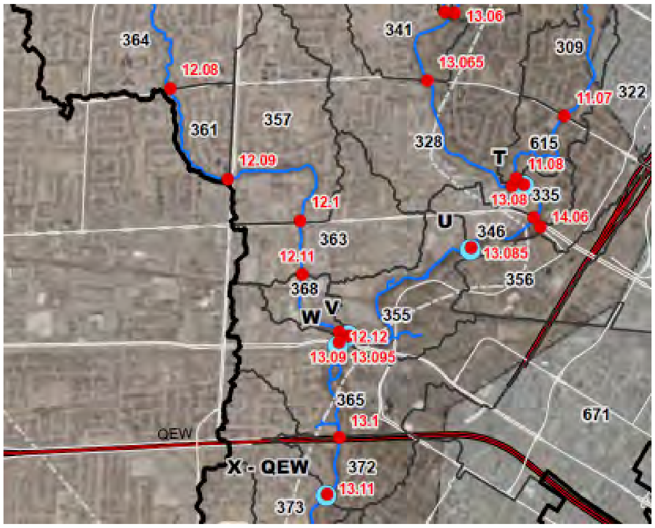

Figure 4: Locations of Flow Nodes and Sub-catchments.

	Peak Flows (cms)								
	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	350-Yr	July 8	Regional
Node 12.09	42.4	55.2	63.7	75.5	84.4	93.6	141.9	130.0	194.0
Node 12.1	43.4	57.1	66.2	78.5	87.8	97.3	147.6	145.4	192.5
Node 12.11	45.2	59.3	68.8	81.5	91.2	101.2	152.4	164.5	202.3
Node 12.12	45.2	59.3	69.0	81.7	91.3	101.1	153.0	170.3	208.3
Sub-361	0.9	1.3	1.5	1.8	2.1	2.3	3.2	3.9	3.8
Sub-357	4.2	5.6	6.5	7.8	8.7	9.6	12.7	20.2	7.1
Sub-363	3.9	5.2	6.0	7.1	7.9	8.7	11.3	20.1	5.7
Sub-368	1.0	1.4	1.6	1.9	2.1	2.3	3.1	6.2	3.3

Table 2: Comparisons of peak flows of July 8 and the Regional storms

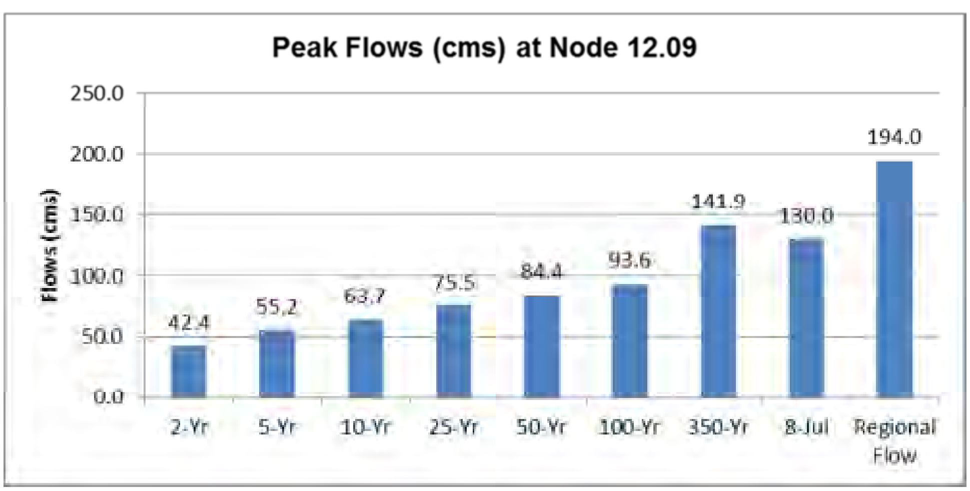

Figure 5: Comparisons of peak flows of 2-100 year, July 8 and the Regional storms at Flow Node 12.09

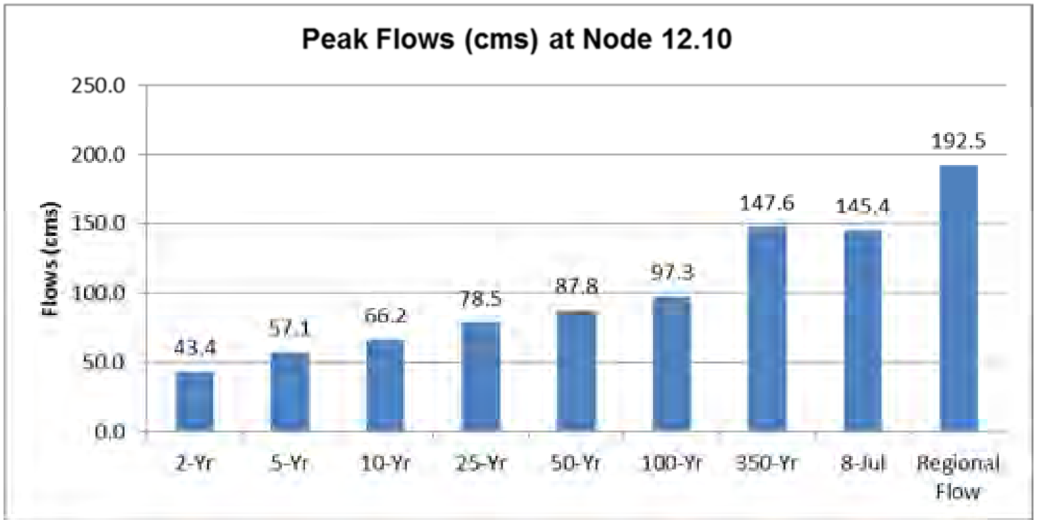

Figure 6: Comparisons of peak flows of 2-100 year, July 8 and the Regional storms at Flow Node 12.10

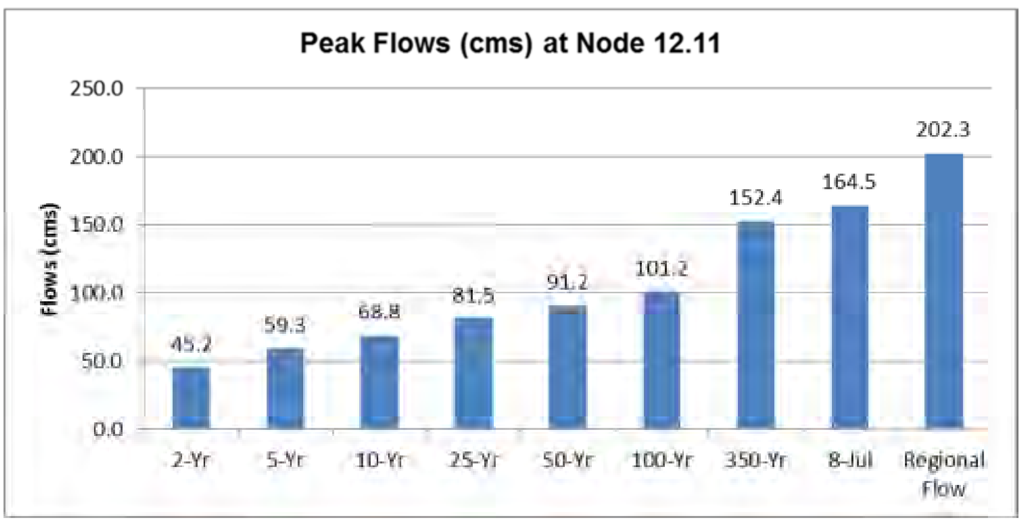

Figure 7: Comparisons of peak flows of 2-100 year, July 8 and the Regional storms at Flow Node 12.11

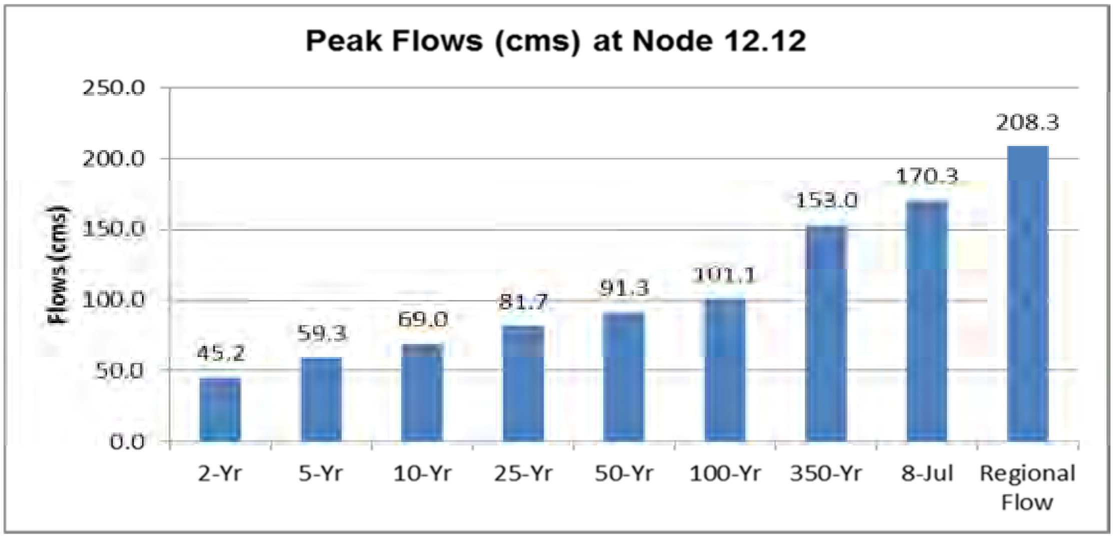

Figure 8: Comparisons of peak flows of 2-100 year, July 8 and the Regional storms at Flow Node 12.12

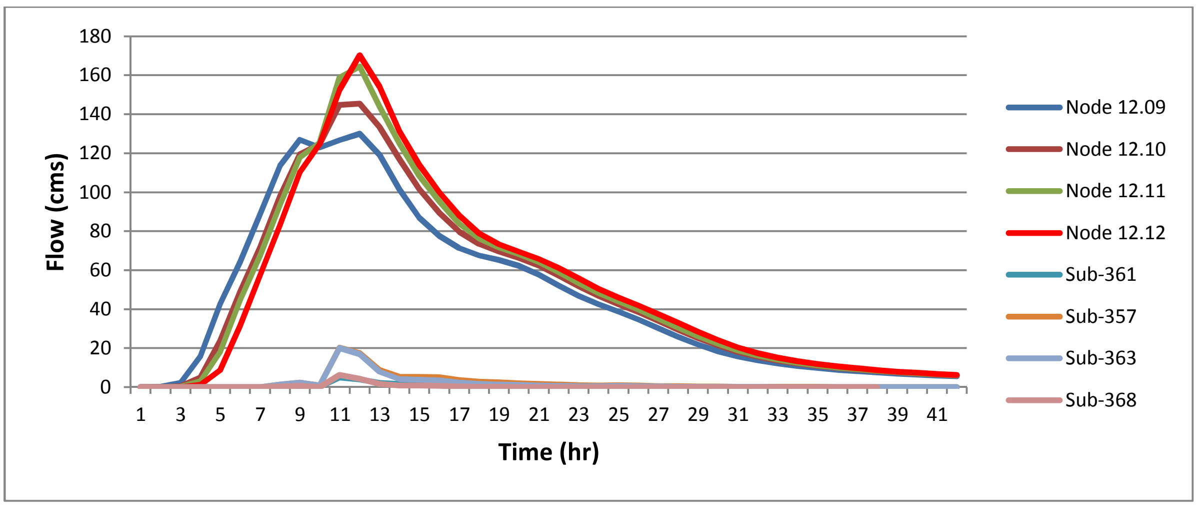

Figure 9: Hydrographs of July 8 storms at different flow nodes.

<u>Conclusion and Recommendation</u>:

Based on the assessment completed in this exercise, we are comfortable enough to use the flows for the purposes of the 2D model comparisons.