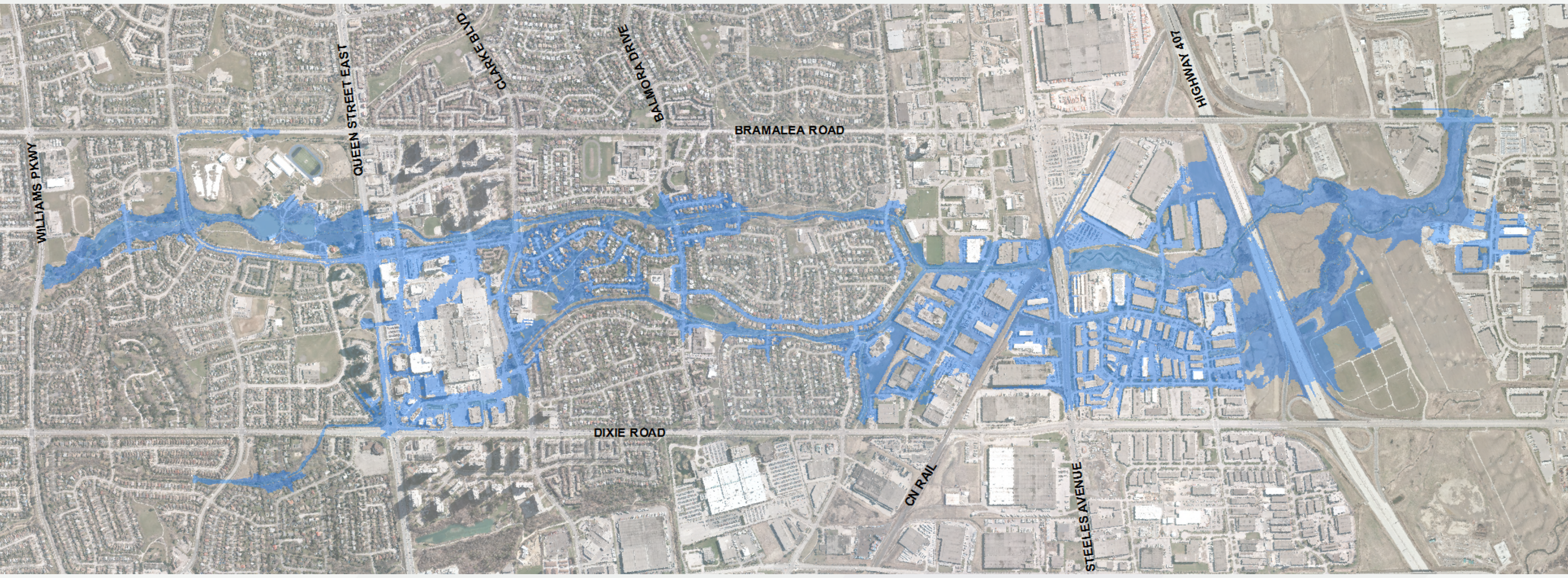

MMM GROUP

Prepared for: Toronto and Region Conservation Authority

SPRING CREEK FLOODPLAIN UPDATE STUDY

FINAL REPORT

3814513-000 | October 2015

MMM GROUP

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1.0 INTRODUCTION

1.1 Study Need

The TRCA is in the process of updating floodline mapping for watercourses within the Etobicoke Creek watershed, including Spring Creek. While the standard one-dimensional (1D) HEC-RAS modelling program is adequate for most of the watershed, the flood regime through the study areas, particularly upstream and through the Avondale Special Policy Area (SPA) in Brampton are quite complex and warrant a 2D modelling approach. Specifically, Spring Creek overtops its banks at multiple locations throughout the study area and either reenters the creek further downstream or flows overland to the Dixie Tributary to the west. This causes spills and overland flooding through developed areas.

The objective of this study is to develop an integrated 1D/2D MIKE FLOOD hydraulic model of Spring Creek based on current LiDAR mapping and to map flooding conditions within the study area for selected flood events. 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 illustrates the study area in the context of the broader watershed.

A portion of the study area was modelled in advance of the current study due to a pending development project in the near vicinity of the Peel Region Police Headquarters building. The first phase involved updating only the upstream portion of the current Spring Creek 2D hydraulic model (north of Clark Blvd.) in order to get a relatively quick turnaround on the updated modelling results for development site. The Phase I project was finished in August 2014 by DHI using the MIKE FLOOD software for coupled 1D and 2D flood modelling. Phase II of the project involves extending the updated area to include the entire area of the existing Spring Creek 2D hydraulic model.

1.2 Existing Special Policy Area

Special Policy Areas (SPAs) represent existing flood prone development and are intended to strike a balance between flood protection and maintaining the economic viability of the community. As such, development is allowed within an SPA subject to a number of constraints related to flood protection and safe access / egress. The existing Avondale SPA is identified on Exhibit 1.

1.3 Etobicoke Creek Hydrology Update

In 2013 the Etobicoke Creek Hydrology Update was completed by MMM Group. 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. The results of the hydrology update were used as input to the current study. Further details on the hydrology data used for the modelling are provided in Section 4.1.

1.4 Study Scope

The ultimate purpose of this project is to develop updated flood hazard mapping for Spring Creek and the Dixie Tributary from Williams Parkway to Bramalea Road, and provide a modelling tool that will aid in assessing the flood risk in the SPAs and adjacent flood prone areas as well as the hydraulic impacts of development applications.

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 – compilation of structure inventory
- Section 3.0 – preparation of updated base mapping
- Section 4.0 – development of MIKE 11 1D model
- Section 5.0 – development of MIKE 21 2D model and integrated 1D/2D MIKE FLOOD floodplain model
- Section 6.0 – discussion of modelling results
- Section 7.0 – characterization of flood risk within the study area
- Section 8.0 – floodplain definition and mapping within the study area
- Section 9.0 – summarization of conclusions and recommendations

1.5 Study Team

The Study Team included MMM Group Limited (MMM) as the project lead, with the Danish Hydraulics Institute (DHI) responsible for development of the MIKE FLOOD model.

2.0 STRUCTURE INVENTORY

An inventory of all channel crossing structures within the study area was completed in January and February 2015. Each structure was observed as part of a site visit. In addition to generic observations, the height and span of each structure were measured. The inverts at the upstream and downstream limits of structures were measured using portable GPS (vertical accuracy <=0.2 m). Structure Inventory Sheets including numerous photographs were developed for each crossing and are provided in Appendix A.

2.1 Structure Data Comparison

The structure inventory was completed to ensure the as-built drawings provided were current and complete and/or that the data in the existing HEC-RAS model was accurate (particularly where as-built drawings were not available). A detailed comparison of the structure parameters available in a) the existing HEC-RAS model, b) the as-built drawings, and c) the structure inventory program, was completed and compiled.

This comprehensive data comparison indicated that while many of the as-built drawings received were out of date, the large majority of the structures in the existing HEC-RAS model were representative of the field measurements.

3.0 BASE MAPPING AND DATA

The LiDAR data for the Spring Creek 2D Modelling study was collected and produced by Airborne Imaging, a Clean Harbors Company in November 2012. The data was collected on two flight missions carried out on November 27 and 28 of 2012.

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 square metre. 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 (root-mean-square error). 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.

To create the contour data TRCA staff used the surface as a raster grid provided by MMM which 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 from which the contours would be generated. The contours were generated using the Spatial Analyst tool in ESRI ArcMap in 1 m intervals. Spot elevations were 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.

3.1 Topographic Data Processing

A significant amount of data preparation was completed on the provided LiDAR topographic data. Data preparation tasks, discussed in more detail below, included:

- Building layer overlay
- Data gap filling
- Interpolation of ground surface under parking garage at Bramalea City Centre
- Development of underpasses and overpasses

The LiDAR received from the TRCA for use in this project included numerous data gaps where data points had been removed to develop the bare earth surface. Before applying this topographic data to the model, all data gaps needed to be filled. The first step in this process was to overlay the building footprint polygons. Building areas were assigned a 'land value' elevation. 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.

The vast majority of the remaining gaps were small, and thus assumed to be backyard structures (decks, sheds, etc.) or trees. These gaps were filled through interpolation based on the surrounding data using the surface interpolation tool provided in the MIKE software. Additionally, small gaps at the edges of buildings were filled using this tool with the option to ignore 'land values' activated.

There are a few cases where additional judgement and analysis were required to fill data gaps or to adjust the data to represent the existing overland flow paths. The first of these are the large parking structures at the Bramalea City Centre. These structures are open, permitting water to flow through them and therefore the standard interpolation method noted above was not appropriate for these parking structures. The ground surface under these parking structures was recreated using interpolation tools in AutoCAD Civil3D.

Other areas that required special consideration were bridges and overpasses within the study area. These had been removed (by others) during the bare earth surface generation. Sixteen (16) bridges over Spring Creek and its tributaries and four (4) underpasses and overpasses within the study area were recreated using interpolation methods in AutoCAD Civil3D. These areas could not be interpolated using the MIKE surface interpolation tools due to the variation in surrounding elevations.

The following bridges over Spring Creek and its tributaries were recreated to determine deck elevations for the 1D riverine model:

- Williams Pkwy East at Spring Creek
- Chinguacousy Park Access Road 1
- Chinguacousy Park Access Road 2
- Queen Street East at Spring Creek
- Kensington Road at Spring Creek
- Knightsbridge Road at Spring Creek
- Algonquin Boulevard at Spring Creek
- Avondale Boulevard at Spring Creek
- Birchbank Road Dixie Trib
- Birchbank Park at Unknown Trib.
- Orenda Road at Spring Creek
- Alfred Kuehne Blvd. at Spring Creek
- Highway 407 at Spring Creek
- Bramalea Road at Spring Creek
- Dixie Road at Unknown Trib
- Drew Road at Unknown Trib

The following grade separation structures were interpolated to allow flow to pass under the structure:

- Queen Street East at Bramalea City Centre Drive
- Steeles Avenue East at Railway
- Highway 407 at Bramalea Road
- Highway 407 at Dixie Road

3.2 Surface Roughness Data Development

A spatially distributed surface of Manning's roughness values was created to reflect the different surface materials and vegetation, as shown in Figure 3.1. The Manning's roughness map was constructed based on the standard Manning's n polygon layer for the study area provided by

TRCA. Table 3.1 summarizes the standard TRCA Manning's n values that were used in the MIKE 21 model as well as the colour coding used for plotting purposes in Figure 3.1.

Table 3.1: Standard TRCA Manning's n Values

Surface	Manning's n – TRCA (1)	Manning's M (2)	Colour Code
Paved Surface	0.025	40	Blue
Urban Pervious	0.050	20	Green
Natural Areas	0.080	12.5	Red
Buildings	--	<2.5 (3)	White

Notes:
1) TRCA values were used for MIKE FLOOD modelling
2) M = 1/n
3) Set sufficiently high such that flow is zero

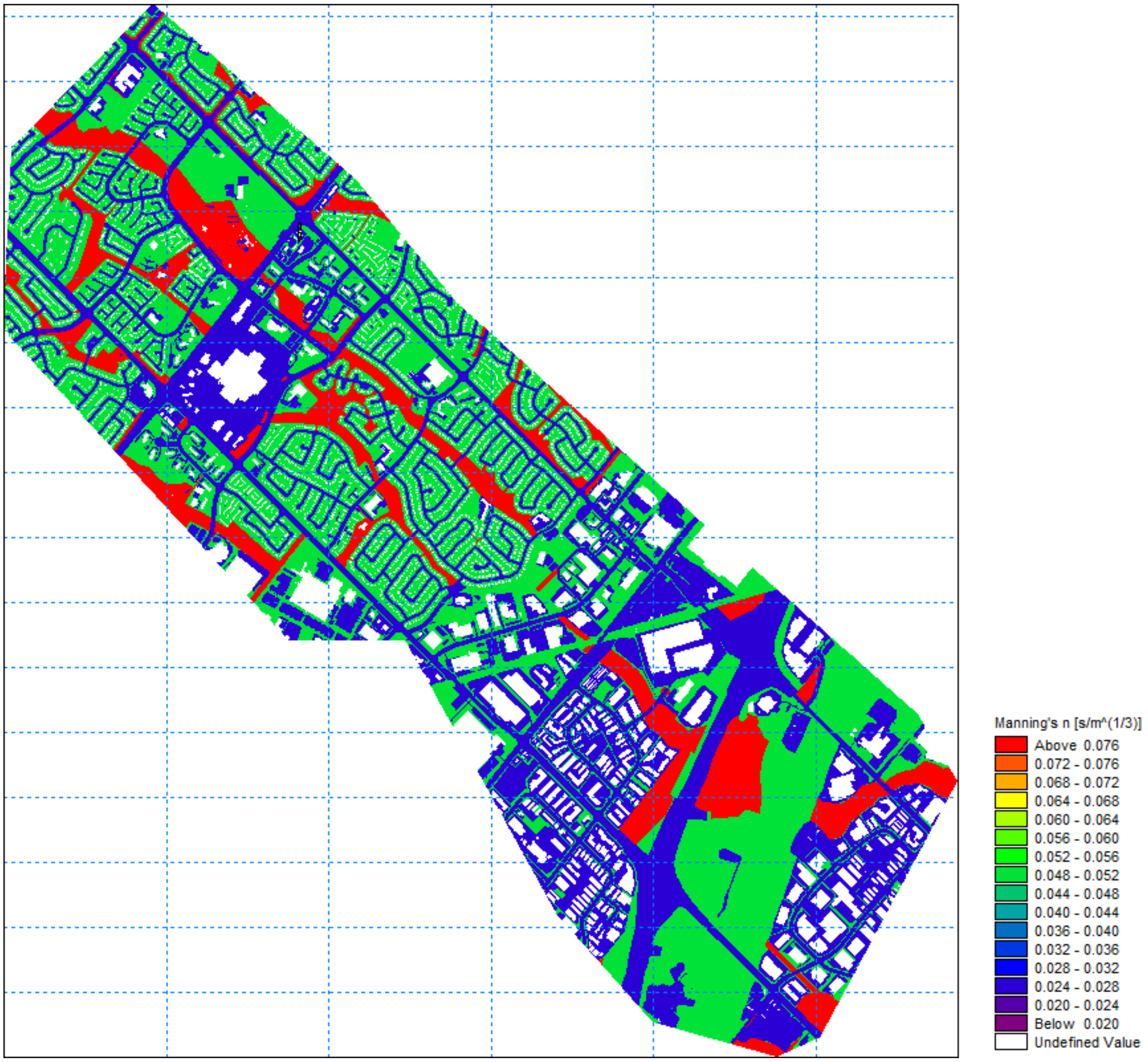


Figure 3.1: Map of Manning's n Values used in the MIKE 21 Model

4.0 1-DIMENSIONAL CHANNEL MODELLING

As previously noted, Spring Creek overtops its banks at several locations. The majority of the flow that spills from the creek travels overland and then back into the channel upstream of Highway 407.

The spill routes are dominantly two-dimensional (2D) in nature and cannot be accurately modelled using a traditional one-dimensional (1D) model such as HEC-RAS. For this reason a 1D/2D integrated hydraulic model (MIKE FLOOD) was used to model the overall flood regime. Application of MIKE FLOOD is a two-step process and includes the development of a 1D model (MIKE 11) of Spring Creek, and a 2D model (MIKE 21) of the overland topography, which are then combined to create the integrated MIKE FLOOD model. This section of the report documents the development of the MIKE 11 model for Spring Creek. Section 5.0 addresses the development of the 2D MIKE 21 model and the integrated MIKE FLOOD model.

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

- Completion of a field review of crossing structures on Spring Creek and its tributaries in the study area. These structure details were used in conjunction with available as-built drawings to confirm and revise the data from the existing HEC-RAS model.
- Cross-section development from LiDAR with supplemental sections from survey and HEC-RAS where necessary.
  - Surveyed cross-sections provided by TRCA were used for the structures on Unknown Trib and Unknown Trib 2.
  - HEC-RAS cross-sections were used for the ponds in Chinguacousy Park as the water in the ponds is too deep to be effectively represented by LiDAR data.
- Compilation of modelling results and comparison to existing HEC-RAS modelling results.

The 1D MIKE 11 model developed for the Phase I Spring Creek project was extended up to Williams Parkway (HEC-RAS station 23.52) in the north and to downstream of Bramalea Road (HEC-RAS station 20.10) in the south. The Dixie Tributary was extended to Lascelles Boulevard (HEC-RAS station 22.84) in the north and downstream to the confluence with Spring Creek. In addition, two small unnamed tributaries were added – the first one flowing into Spring Creek below Highway 407 (called Unknown Trib), and the second one flowing into the Dixie Tributary at Birchbank Public School (called Unknown Trib 2). Figure 4.1 shows the study area and the watercourses modelled in this study.

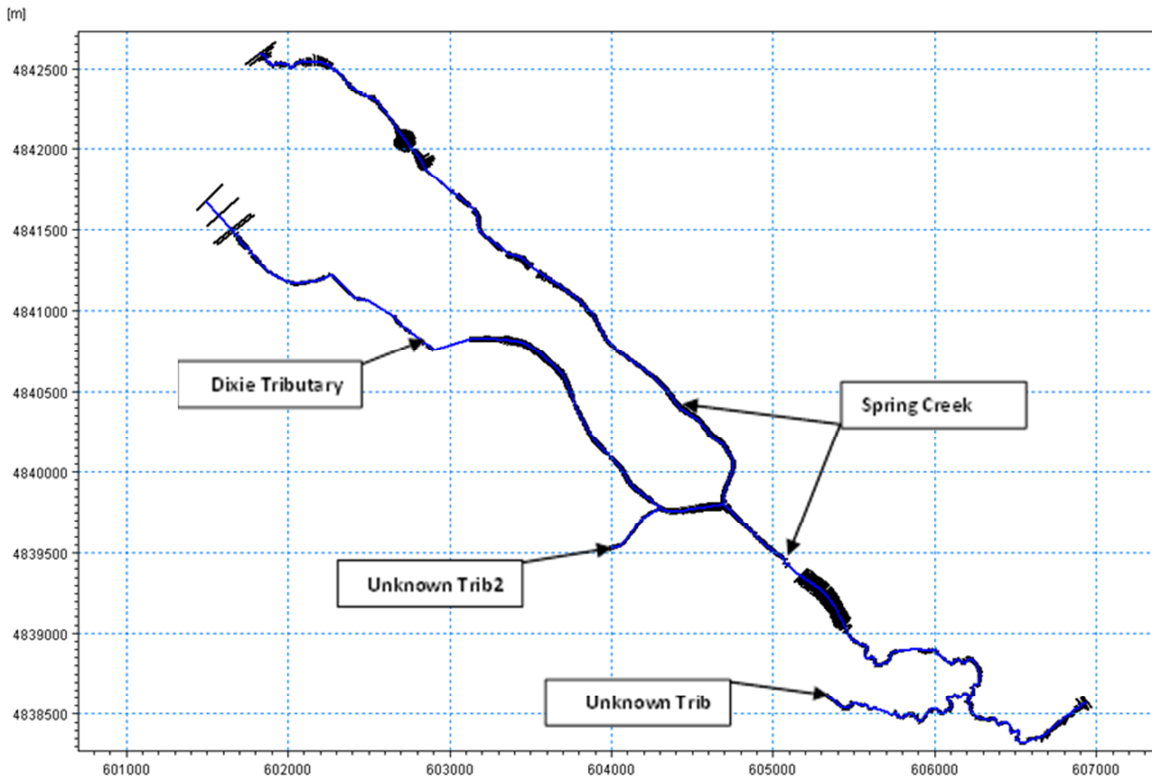


Figure 4.1: MIKE 11 Model Setup

4.1 Boundary Conditions

The next step in developing the MIKE 11 model was to define the boundary inflows at the upstream end of the model, tailwater elevation at the downstream end of the model, as well as the additional inflows to the channels throughout the study area.

4.1.1 Flow Inputs

The inflows were obtained from the 2013 Etobicoke Creek Hydrology Update model results for the flood events of interest at the corresponding flow nodes. Exhibit 2 illustrates the location of the hydrologic input flow nodes from the Hydrology Update which were used to complete this floodplain study. In discussions with the TRCA it was determined that steady state simulations were desired for all modelled storm events. As MIKE FLOOD cannot inherently run steady state simulations, quasi-steady state simulations were completed.

Table 4.1 summarizes peak flows at key locations for the various design storms. The distributed source boundary condition items disperse the specified inflow evenly along a number of cross-sections. This method provides an improvement in model stability as compared to large point sources introduced sporadically throughout the model.

Table 4.1: Summary of Peak Flows for Spring 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	Regional Storm
Dixie Trib 1234	Inflow Node 9.04	8.248	11.386	13.488	16.166	18.197	20.258	26.927	32.157
Dixie Trib 1234 – 2283	Distributed Source 445	1.673	2.272	2.681	3.197	3.580	3.964	5.239	5.647
Dixie Trib 2283 – 2737	Distributed Source 121	4.501	6.000	7.02	8.309	9.268	10.231	13.432	14.682
Dixie Trib 2737 – 4178	Distributed Source 136	2.442	3.284	3.859	4.587	5.129	5.674	7.496	8.270
Spring Creek 1743.17	Distributed Source 7.09	6.473	10.013	15.414	21.096	23.758	26.439	101.873	155.067
Spring Creek 1743.17 – 3519	Distributed Source 110	2.654	3.602	4.254	5.083	5.703	6.326	8.409	9.515
Spring Creek 3519 – 4843	Distributed Source 721	1.292	1.781	2.119	2.55	2.873	3.198	4.284	4.872
Spring Creek 4843 – 6099	Distributed Source 150	2.490	3.273	3.801	4.465	4.957	5.449	7.079	7.338
Spring Creek 6099 – 6731	Distributed Source 175	2.472	3.276	3.822	4.512	5.024	5.539	7.248	7.719
Spring Creek 6731 - 7722	Distributed Source 702, 171, 128	7.329	9.832	11.541	13.706	15.319	16.94	22.359	25.116
Spring Creek 7722 - 8552	Distributed Source 179	0.970	1.372	1.657	2.027	2.308	2.593	3.566	4.51
Unknown Trib 0.00	Inflow Node 10.02	4.674	6.240	7.307	8.655	9.658	10.665	14.058	15.204
Unknown Trib 2 0.00	Inflow Node 9.18	22.239	30.274	35.898	43.481	49.404	54.980	85.411	101.562

Notes:

1) *Peak Flow for future conditions. Source Etobicoke Creek Hydrology Update, MMM Group, 2013; based on 12-hour AES storm*

Quasi-steady state simulations were developed based on the peak flows from the hydrology study. The hydrographs are shown in Figure 4.2. The quasi-steady state hydrographs include a gradual startup period spread over one (1) hour to achieve stability. The peak flow was then held for nine (9) hours to achieve steady state throughout the study area.

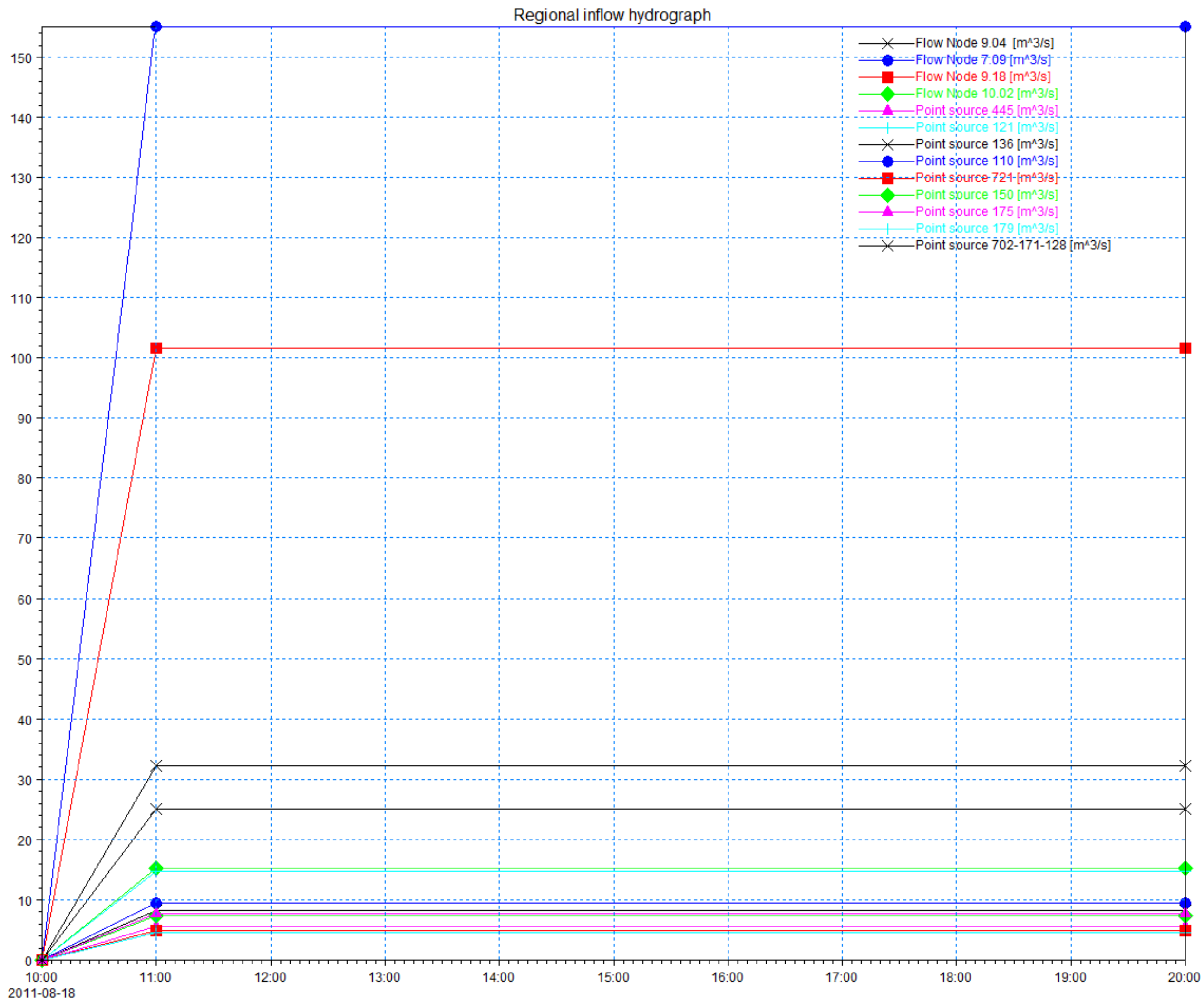


Figure 4.2: Quasi-Steady Regional Storm Input Hydrographs

4.1.2 Tailwater Condition

The downstream water level boundary condition was extracted from HEC-RAS results at a location downstream where the channel characteristics are represented by a 1D flow regime. The existing HEC-RAS model was updated with flows from the 2013 Etobicoke Creek Hydrology Update. The water levels at station 20.10 downstream of the Bramalea Road crossing for the various storm events were transferred to the MIKE 11 model for use as tailwater conditions.

4.2 Channel Cross-Sections

The cross-sections for the MIKE 11 model were predominantly cut from the LiDAR data at approximately 10 m intervals. It is recognized that LiDAR does not penetrate the water surface and thus the inverts of these sections represent the water surface at the time of data collection.

However, discussions with TRCA indicated that the LiDAR was collected during a low flow period. Additionally, due to the nature of the channel within the study area (concrete-lined trapezoid) and the urbanized catchment (i.e., flashy with very little low flow) it was decided that cross-sections developed strictly from the LiDAR was acceptable.

The upstream section of the Dixie Tributary extended beyond the coverage of the LiDAR data. The existing HEC-RAS cross-sections 22.84, 22.83, 22.82 and 22.81 were used to define the channel geometry for this section.

The two online ponds in Chinguacousy Park (on Spring Creek just upstream of Queen Street) were included in the model based on the cross-sections developed from the pond bathymetry in the existing HEC-RAS model. The HEC-RAS cross-sections were used because the water in the ponds is too deep to be effectively represented by LiDAR data.

In addition to the LiDAR data, TRCA provided surveyed cross-sections for select locations on Dixie Tributary and the Unknown Trib 2. Comparisons were carried out between the cross-sections cut from LiDAR and the surveyed cross-sections. Although there is some variance between the LiDAR and surveyed cross-sections it is very minor and the difference in conveyance capacity is insignificant. This comparison analysis validates the use of the LiDAR data for channel cross-section geometry for this study. A comparison of the surveyed and LiDAR cross-sections is provided in Appendix B.

The completed MIKE 11 model included over 1,190 cross-sections with an average spacing of 11 m. Table 4.2 provides a breakdown of reach lengths and cross-section quantities by reach. Each cross-section was cut from the LiDAR and no interpolated cross-sections were used.

Table 4.2: Cross-Section Spacing Summary

Branch Name	Total Length (m)	Number of Cross-Sections (-)	Average Section Spacing (m)
Dixie Tributary	4112	325	12.7
Spring Creek	7884	720	10.9
Unknown Trib	1190	105	11.3
Unknown Trib 2	399	41	9.7

4.2.1 Channel Roughness

The channel roughness for the MIKE 11 model was defined using high and low Flow zones to describe the transverse distribution of values along the cross-section. This approach splits the cross-section into 3 zones between the left and right bank of the channel:

1. Left high flow
2. Low flow
3. Right high flow

Each of these zones is assigned a uniform Manning's n value as appropriate. The distribution of Manning's n used in the MIKE 11 model was based on the existing HEC-RAS model. Table 4.3 provides a summary of the Manning's n values assigned throughout the 1D model.

Table 4.3: Channel Roughness Summary

Branch name	Start Chainage (m)	End Chainage (m)	Manning's n		
			Left High Flow ($s/m^{1/3}$)	Low Flow ($s/m^{1/3}$)	Right High Flow ($s/m^{1/3}$)
Dixie Tributary	1234.00	1744.00	0.08	0.035	0.08
	1753.48	2153.47	0.05	0.035	0.05
	2163.47	4137.00	0.05	0.013	0.05
	4147.00	5346.16	0.08	0.013	0.08
Spring Creek	1743.17	2499	0.05	0.013	0.05
	2549.00	2821.37	0.05	0.013	0.05
	2831.37	3111.37	0.05	0.018	0.05
	3129.00	6327.31	0.05	0.013	0.05
	6345.88	6345.88	0.08	0.08	0.08
	6364.44	6631.42	0.05	0.035	0.05
	6737.86	7187.89	0.08	0.013	0.08
	7198.00	7758.61	0.035	0.035	0.035
	7843.25	9627.00	0.08	0.035	0.08
Unknown Trib	0	1189.95	0.035	0.035	0.035
Unknown Trib 2	0	398.96	0.05	0.013	0.05

4.3 Structure Modelling

Upon completion of the MIKE 11 cross-sections definition the bridge and culvert structures were incorporated into the 1D model. Table 4.4 summarizes the type and location of the structures within the study area. A number of pedestrian bridges within the study area were inventoried in the initial stages of the project; however, pedestrian crossings are not typically included in hydraulic models for floodplain delineation. It was confirmed with the TRCA that the pedestrian bridges would not be included in this study.

Special considerations were taken at a number of crossing locations which would not be adequately represented by the typical MIKE 11 bridge or culvert structure. Further discussion of the structure types is provided in Section 4.3.1 below.

As seen from the tables, some structures were represented in the model using a classic bridge structure description, while other structures were represented using a combined culvert and weir. If a structure was represented as bridge in the existing HEC-RAS model, then a bridge structure was also used in the MIKE 11 model. The exception to this is when the soffit of the bridge is not a horizontal shape or is an irregular shape (the MIKE 11 bridge structure only accepts a horizontal flat soffit and bridge deck). In these cases a culvert structure was used for the underflow and a weir was used to represent the top of the bridge deck.

Table 4.4: Structure Summary

Location		Modelled Structure Type
Structure Name	Reach	
EC 17-14R HILLDALE CRESCENT	Spring Creek	Culvert + Weir
EC 17-13R CENTRAL PARK DRIVE	Spring Creek	Culvert + Weir
EC 17-5R CHINGACOUSY PARK	Spring Creek	Bridge + Weir
EC 17-4R CHINGACOUSY PARK	Spring Creek	Bridge + Weir
EC 17-3R QUEEN STREET	Spring Creek	Culvert + Weir
EC 17-2R KENSINGTON ROAD	Spring Creek	Culvert + Weir
EC 17-1R KNIGHTSBRIDGE ROAD	Spring Creek	Culvert + Weir
EC 16-8R CLARK BOULEVARD	Spring Creek	Culvert + Weir
EC 16-3R BALMORAL DRIVE	Spring Creek	Culvert + Weir
EC 16-2R ALGONQUIN BOULEVARD	Spring Creek	Culvert + Weir
EC 16-1R AVONDALE BOULEVARD	Spring Creek	Culvert + Weir
EC 15-5R ORENDA ROAD	Spring Creek	Culvert + Weir
EC 15-4RR CNR	Spring Creek	Culvert + Weir
EC 15-3R STEELES AVE. EAST	Spring Creek	Culvert
EC 15-2R ALFRED KUEHNE BLVD	Spring Creek	Culvert + Weir
EC 15-1R HWY 407	Spring Creek	Bridge
EC 14-2R BRAMALEA ROAD	Spring Creek	Culvert + Weir
LAKEHURT STREET	Dixie Tributary	Culvert + Weir
HOWDEN BLVD	Dixie Tributary	Culvert + Weir
HAZELWOOD DRIVE	Dixie Tributary	Culvert + Weir
DIXIE ROAD	Dixie Tributary	Culvert + Weir
QUEEN STREET	Dixie Tributary	Culvert
BRAMALEA CC NORTH ACCESS ROAD	Dixie Tributary	Culvert + Weir
BRAMALEA CITY CENTER PARKING LOT ACCESS	Dixie Tributary	Culvert
BRAMALEA CC SOUTH ACCESS ROAD	Dixie Tributary	Culvert + Weir
CLARK BLVD.	Dixie Tributary	Culvert
BALMORAL DRIVE	Dixie Tributary	Culvert + Weir
EC 16-5R BRENTWOOD DRIVE	Dixie Tributary	Culvert + Weir
EC 16-4R BIRCHBANK ROAD	Dixie Tributary	Culvert + Weir
BIRCHBANK (near Birchbank P.S.)	Unknown Trib. 2	Culvert + Weir
HWY 407 CULVERT	Unknown Trib.	Culvert

4.3.1 Culvert Overflow Methodology

A typical channel crossing in MIKE 11 (as in HEC-RAS) consists of a bridge or culvert opening and an overflow weir. However, as seen in Table 4.4 above, there are a handful of structures that do not follow this typical protocol.

In the cases of the Highway 407 and Steeles Avenue crossings, the top of roads were very high and as such the overflow weir was omitted for model simplicity.

In the cases of the Queen Street, Bramalea City Centre parking access and Clark Boulevard crossings, it was decided to model the overflow at these locations using the MIKE 21 portion of MIKE FLOOD instead of using the typical MIKE 11 weir. The 1D/2D model integration nature of MIKE FLOOD models offer the ability to represent culvert overflow into the 2D portion of the model instead of representing this as a weir in the 1D portion. This is particularly useful in the case of long culverts where the overland flow path at the upstream end of the culvert is not directly connected to the downstream end of the culvert. In the case of a particularly long culvert, the 1D channel is discontinued such that the topography overlying the buried section of the culvert is explicitly represented in the 2D model. This is depicted in Figure 4.3 below.

A typical culvert and weir are represented in the 1D model and thus are not visible within the 2D surface.

A long culvert is represented in the 1D model, but the overflows are represented by the 2D portion of the integrated model.

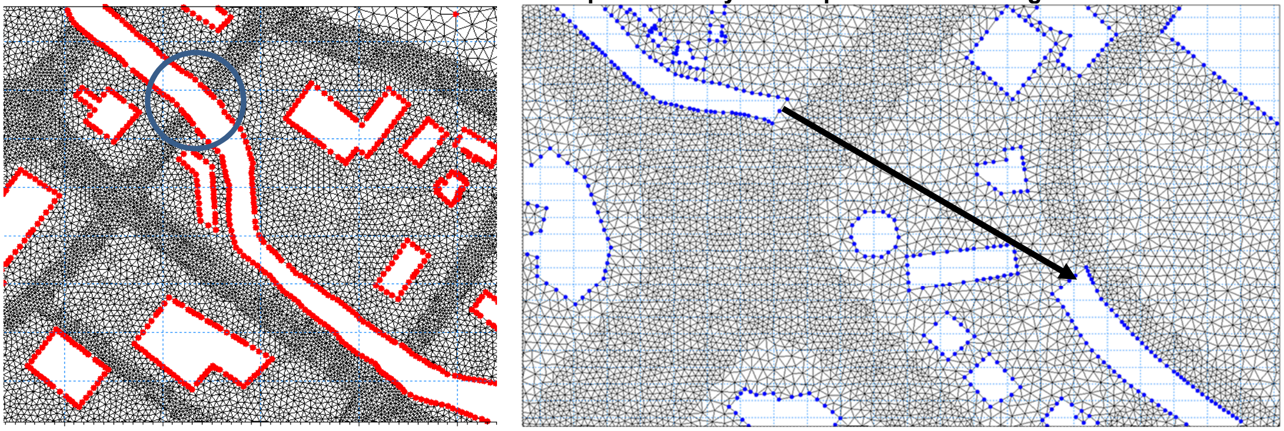


Figure 4.3: 1D vs 2D Culvert Overflow

4.3.2 Bent Culverts

Two culverts on Dixie Tributary near Bramalea City Centre have significant bends that impact the hydraulic characteristics of the culvert. The Queen Street culvert (4.3 m x 1.9 m, 3.23 m equivalent diameter) has a 26 degree bend (10 m bend radius) and the Clark Boulevard culvert (4.27 m x 1.83 m, 3.15 m equivalent diameter) has an 81 degree bend (33 m radius) followed by a 44 degree bend (10.5 m radius).

The structure editor in MIKE 11 includes a field in which the head loss factor due to bends can be entered. This bend loss coefficient is incorporated into the MIKE 11 pre-processing step for developing the internal Q-h relations of the free-flow relationship of the culvert. MIKE 11 uses the common head loss equation (Eq. 4.1) to calculate head loss due to bends.

The required input to MIKE 11 is the bend loss coefficients for each culvert, which were determined from the chart depicted in Figure 4.4. This is the standard method for calculating losses in bends in closed conduits; therefore, it is suitable for regulation purposes. Moreover, the original Spring Creek HEC-RAS model did not include bend losses through these structures and as such, our approach is conservative.

The bend loss and equivalent diameter (based on box culvert area) calculations are provided in Appendix C.

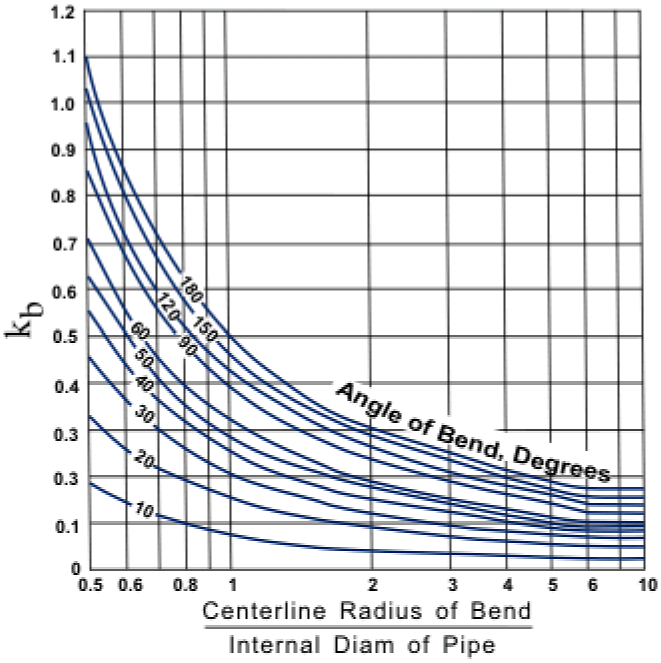


Figure 4.4: Culvert Bend Coefficient Chart (Source: Babcock & Wilcox Co., 1978)

The resulting bend coefficient for the Queen Street culvert was 0.15 and the resulting coefficient for the Clark Boulevard culvert was 0.30. These values were entered into the MIKE 11 model for the appropriate culverts.

The bend head losses (though not needed for input to MIKE 11) were calculated for the Queen Street culvert through use of the common head loss equation, where k is the head loss coefficient.

$$h = k\frac{v^2}{2g} \qquad \text{(Eq. 4.1)}$$

Due to the multiple bends in the Clark Boulevard culvert, the following equation was used to calculate the bend losses in the Clark Boulevard culvert. This assumes that the velocity throughout the culvert is constant and therefore the k values for the bends can simply be added together to determine the composite k value.

$$h_{total} = (k_1 + k_2)\frac{v^2}{2g} \quad \text{(Eq. 4.2)}$$

Additionally, the culvert crossing Clark Boulevard and Cloverdale Drive on the main branch of Spring Creek has a bend in it. However, this bend is considered insignificant and has not been included in the model.

5.0 2-DIMENSIONAL FLOODPLAIN MODELLING

Once the 1D MIKE 11 model was developed the remaining steps to construct the integrated 1D/2D MIKE FLOOD hydraulic model consisted of the following:

1. Trim the cross-sections within the 1D MIKE 11 model
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.

5.1 Trim the 1D MIKE 11 Model

Developing 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 Spring Creek and its tributaries. Trimming cross-sections is completed by indicating the desired cross-section limits through the use of markers in MIKE 11. The cross-sections were trimmed to represent only the main channelized flows as shown in Figure 5.1. This is required for the channelized flow to be represented in MIKE 11 while the overbank flows are represented by the MIKE 21 2D overland flow model. The ends of the trimmed cross-sections are then linked to the 2D surface during a later task.

It should be noted that the cross-sections at the inflow boundary (i.e., the uppermost cross-sections) of Spring Creek 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 (see Figure 4.1). In this manner, the upstream boundary condition inflows enter the model domain as 1D flow and then gradually transition to coupled 1D/2D flow. This enhances model stability, particularly during very high flow events.

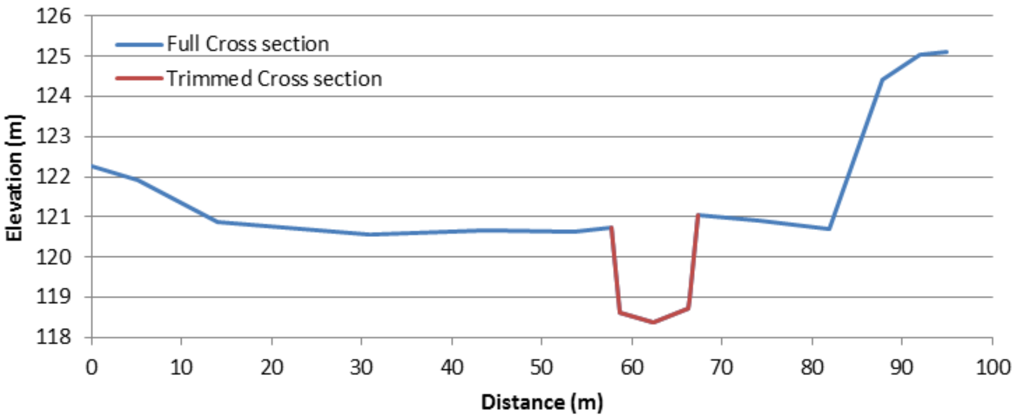


Figure 5.1 Example of a full cross-section and a trimmed cross-section

Typically the cross-sections were trimmed to include only the low flow channel. The one exception is between Steeles Avenue and Alfred Kuehne Boulevard. This section of Spring Creek has recently been reconstructed and includes a meandering low flow channel within a defined valley, refer to Figure 5.2. As a result of these recent works, the defined valley is characterized by a 1D flow regime and does not pose a risk to surrounding property or infrastructure. In this reach the 1D cross-sections were trimmed to the top of the defined valley and the 2D model represents only flow which spills beyond the valley limits.

Figure 5.2: Reconstructed Reach between Steeles Ave. and Alfred Kuehne Blvd.

5.2 Construct 2D MIKE 21 Overland Flow Model

A flexible mesh surface model was selected for this project. The 2D surface of the study area is approximately 8 km^2 and therefore the flexible mesh option, as opposed to rigid grid, was an important component to the project success. An accurate representation of the topography within the study area is critical in order to generate an accurate and reliable assessment of overland flooding. If the model mesh is too coarse it will not be able to pick up the topographic features that influence the direction of overland flow and the extent of flooding. A high resolution mesh size was needed in areas of distinct topographic features to capture these small changes in topography. However, due to the size of the study area a high resolution rigid grid mesh over the entire area would not be feasible in terms of modelling time or file size. Through the use of a flexible mesh the resolution was refined to different scales throughout the model domain such that the streets and other key areas were represented with a finer mesh resolution to ensure they are properly accounted for in terms of their influence on overland flooding.

The maximum mesh area throughout most of the model domain is 25 m^2, while the maximum mesh size through significant roadways is 10 m^2. Furthermore, the mesh over the berm between Clark Boulevard and Cloverdale Drive was generated with a maximum area of 4 m^2. Figure 5.3 depicts an example of the various mesh sizes used in this study.

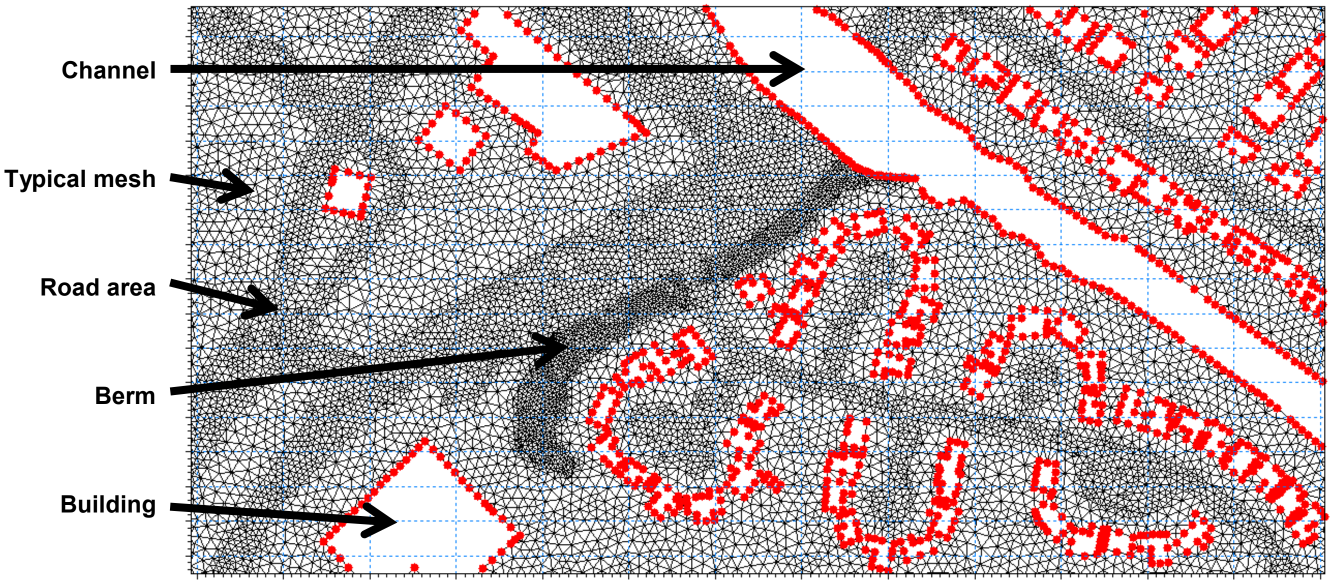


Figure 5.3: Mesh Representation Diagram

As shown in Figure 5.3, the area occupied by the main channels is not included in the 2D model mesh. The channelized flows in Spring Creek, Dixie Tributary, Unknown Trib and Unknown Trib 2 are represented by the 1D MIKE 11 model. By leaving this area empty on the 2D surface it becomes an inactive area of the 2D model. This avoids double-counting the channel flow in both the 1D model and the 2D model. As discussed in Section 4.3 the 1D portion of the model was set up to include the transfer of overflow at crossing structures (in most cases). As such, the topography at roadway crossings is not represented in the 2D model mesh. Figure 5.4 graphically indicates the areas modelled in 1D MIKE 11 and those modelled in 2D MIKE 21. The 1D area is bounded by the solid orange lines.

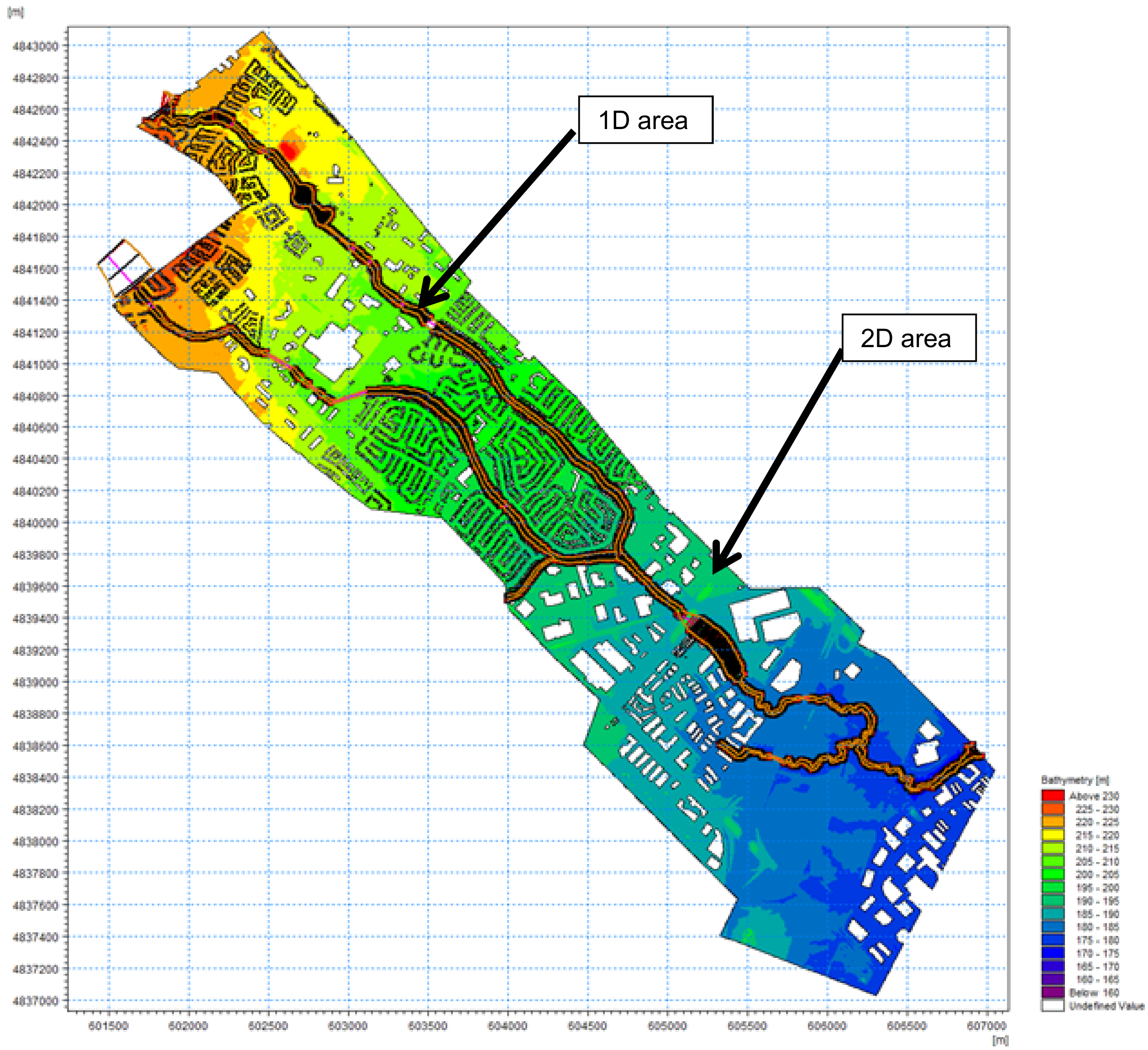


Figure 5.4: MIKE 11 and MIKE 21 Model Areas

In order to develop the topography for the 2D model area multiple steps were required. A raster file of the topography in the native MIKE 21 grid file format (.dfs2) with 0.5 m grid spacing was developed. This file was then edited to represent buildings as flow obstructions (refer to Section 3.1). Furthermore, the 2D grid cells that intersect with the MIKE 11 cross-sections were removed. This step was done to avoid double accounting of flows in both the MIKE 11 model and the MIKE 21 model, similar to the trimming of the 1D cross-section (refer to Section 5.1).

The topographic data from the raster file was then transferred to the completed mesh design. The topographic data was interpolated to the mesh nodes using the value from the nearest data point. This method of assigning the topographic elevations was chosen because the LiDAR data points are more closely spaced than the mesh nodes.

5.3 2D Model Boundary Conditions

The boundaries of 2D model area were initially closed except for where Spring Creek flows out of the model domain at the downstream limit. However, preliminary runs of the model indicated that flooding from the Regional design storm event reaches the outer edge of the model domain in several locations. With a closed boundary condition at these locations, the water will begin to pool at the edge and may begin flowing along the edge of the boundary and into locations that would not otherwise be flooded. In order to avoid this condition a Q-h rating curve boundary condition was defined in the locations where overland flooding was anticipated to reach the edge of the 2D model domain. These locations include the Steeles Avenue underpass and along the entire southeastern edge of the model domain (see Figure 5.5).

The Q-h boundaries were defined such that any water reaching the edge of the model would be immediately removed from the model so as to not cause artificial ponding at the edge. In both cases the slope of the topography at the edge of the model domain is generally leading out of the model so it was considered reasonable to allow the water to leave the model and prevent unrealistic pooling along the edge of the domain.

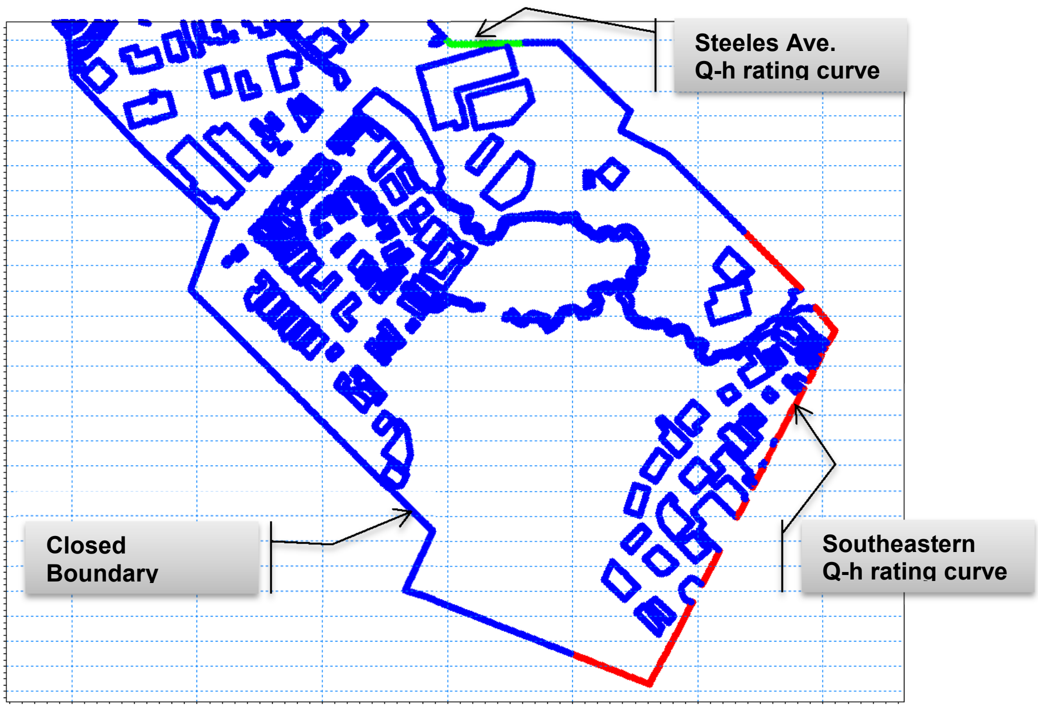


Figure 5.5: 2D Model Boundary Conditions Locations

The methodology of incorporating the tailwater condition rating curve extracted from HEC-RAS (as described in Section 4.1.2) in combination with the 2D domain Q-h rating curve at the southeastern extent is the most accurate representation of the overland flow conditions at the downstream boundary. That is, the tailwater condition of the creek system is controlled by the rating curve in the 1D network, and the rating curve along the southeastern 2D domain boundary allows free flow out of the system without limiting outflow rates. This allows the results over the entire study area, including the downstream area, to be utilized with high confidence.

The modelling completed for this study does not capture the full extents of the flooding from Spring Creek. As a result, the flood maps indicate spills out of the study area. In order to fully define the extents of the flooding from Spring Creek, the model boundaries would need to be extended. The intent of this project was to define flooding conditions within the Avondale SPA and Peel Centre site, not to track the full extent of spills, and therefore the extents of the modelled area is deemed appropriate for this study. However, it is recommended that any future modelling work should be conducted with an expanded study area to fully define the extents of flooding.

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

To enable the exchange of flows between the 1D MIKE 11 model and the 2D MIKE 21 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[1]:

- A standard link describing the coupling at the upstream or downstream end of the 1D MIKE 11 model to the 2D MIKE 21 model (see Figure 5.6).
- A lateral link describing the coupling along the left bank and/or right bank of the channel to the 2D model (see Figure 5.7).
- A structure link describing the coupling between a 1D structure element (e.g. culvert) to the 2D model (see Figure 5.8).

[1] As defined in the MIKE FLOOD 1D/2D Modelling User Manual:

- Standard Link: The link is the connection between the end of a MIKE 11 branch and a series of MIKE 21 cells or element faces
- Lateral Link: The link is the connection between one MIKE 11 river reach (within one branch) and a series of MIKE 21 cells/elements
- Structure Link: The connection between the end of a MIKE 11 branch and a series of MIKE 21 cells (same as standard link). However low links are required for each structure link – one for each end of the structure. These link pairs should link adjacent cells in the grid.

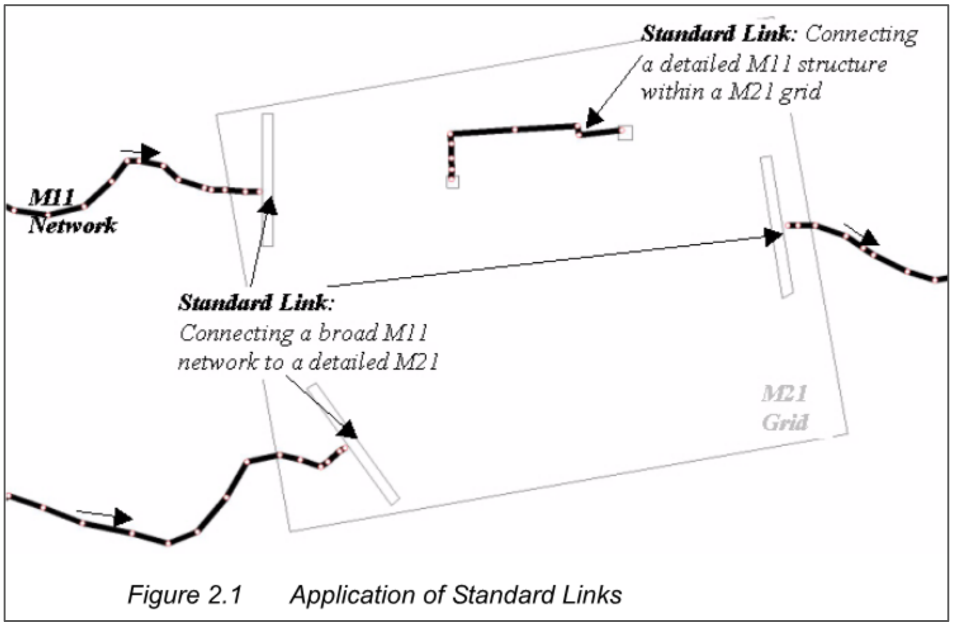


Figure 5.6: Standard Link
(Source: MIKE FLOOD User Manual)

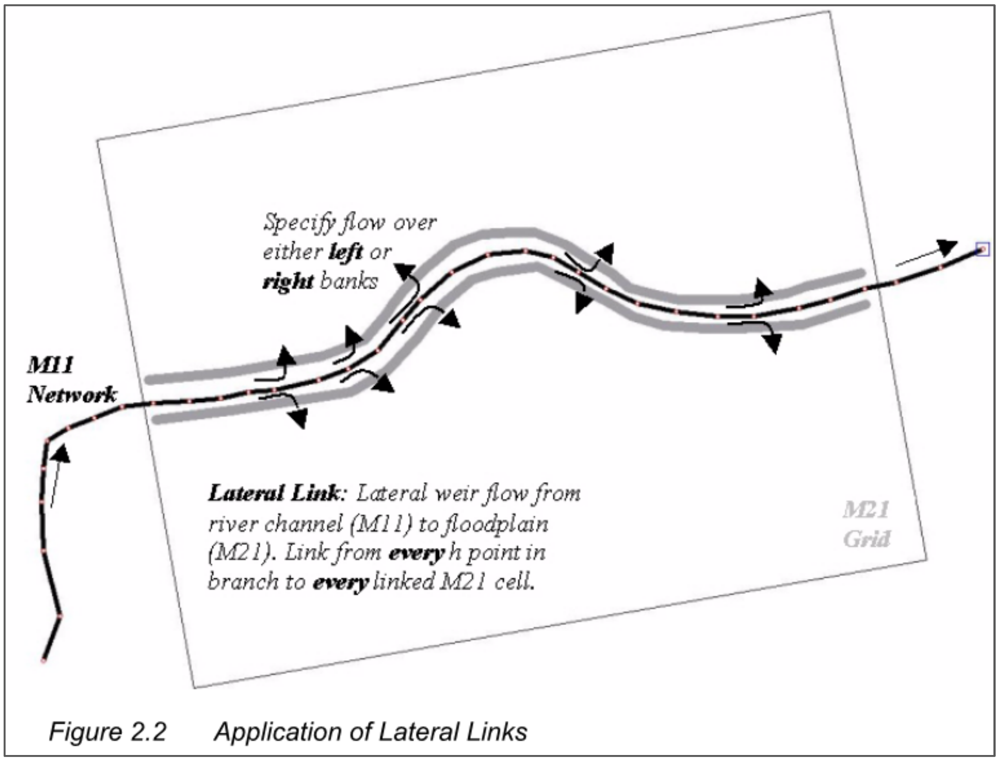


Figure 5.7: Lateral Link
(Source: MIKE FLOOD User Manual)

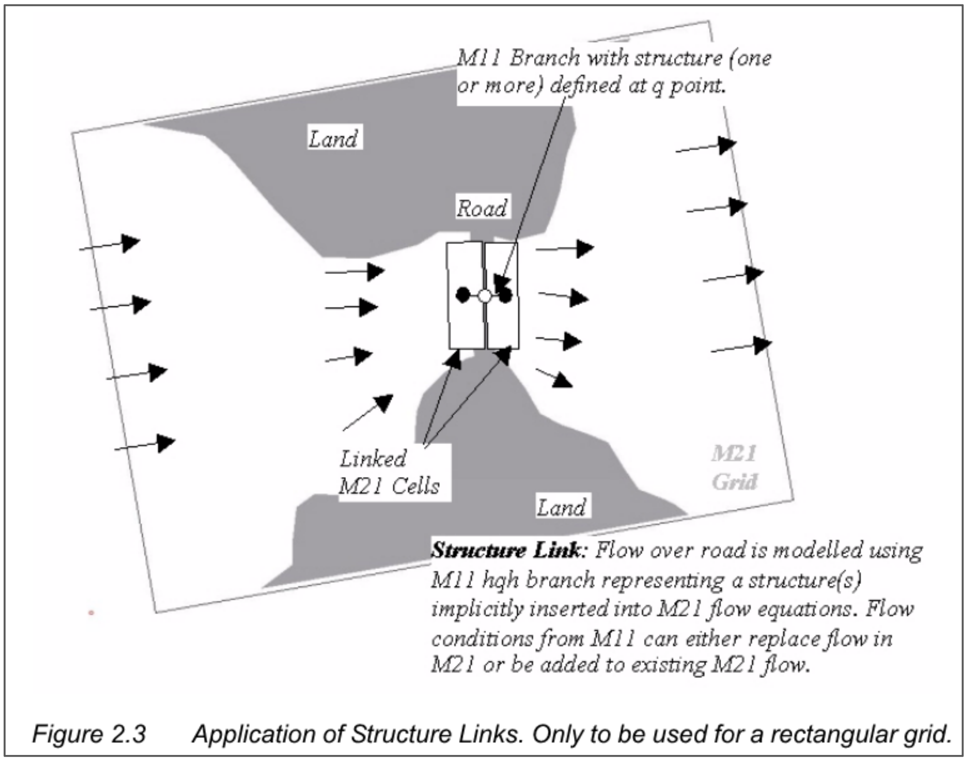


Figure 2.3 Application of Structure Links. Only to be used for a rectangular grid.

Figure 5.8: Structure Link
(Source: MIKE FLOOD User Manual)

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 mesh elements of the 2D MIKE 21 model, as depicted in Figure 5.9. Lateral link couplings allow a dynamic exchange of overbank flows between the 1D and 2D models. The linked mesh elements 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.

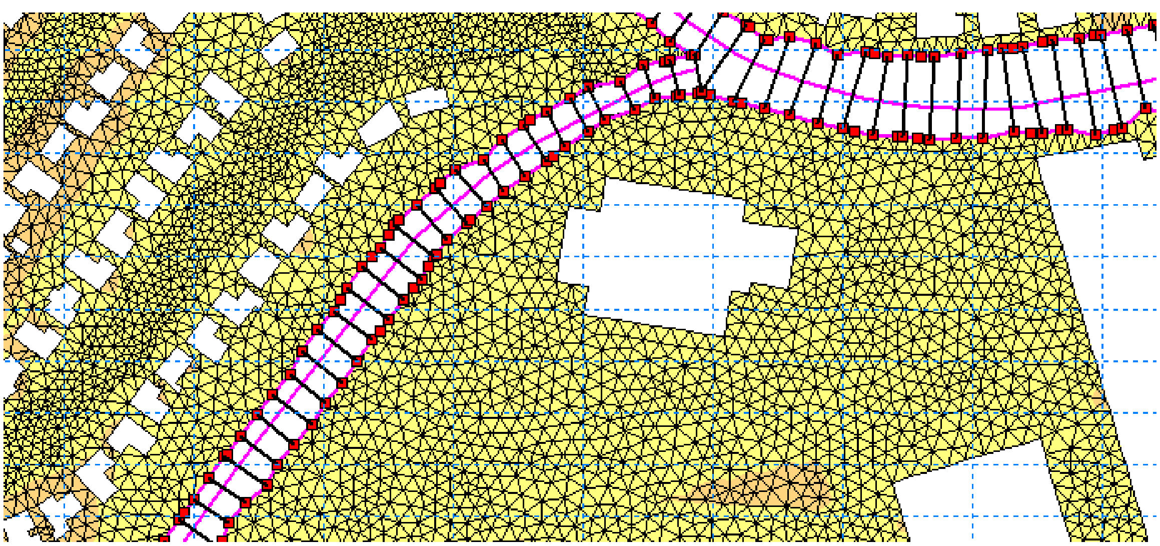


Figure 5.9: Lateral Links for Coupling MIKE FLOOD Model

6.0 INTEGRATED MODEL RESULTS

Once the final version of the coupled 1D/2D MIKE FLOOD model was completed it was run for each of the design storm events including the 2, 5, 10, 25, 50, 100, 350 Year and Regional storms using the quasi-steady state approach discussed above (refer to Section 4.1.1). The maximum flood extents and associated depths and velocities for each design storm scenario were extracted from the last time step of each of the dynamic result files.

Exhibits 3 through 10 illustrate the calculated flood depths for each of the modelled storm events. It should be noted that the flood depth mapping provided in the exhibits is based on the bare earth surface. Therefore, the flow depths provided in the channel are relative to the channel invert, not the bridge deck at crossings. The list of flood depth maps is summarized as follows:

- Exhibit 3: 2-Year Storm Flood Depths (1:20,000)
- Exhibit 4: 5-Year Storm Flood Depths (1:20,000)
- Exhibit 5: 10-Year Storm Flood Depths (1:20,000)
- Exhibit 6: 25-Year Storm Flood Depths (1:20,000)
- Exhibit 7: 50-Year Storm Flood Depths (1:20,000)
- Exhibit 8: 100-Year Storm Flood Depths (1:20,000)
- Exhibit 9: 350-Year Storm Flood Depths (1:20,000)
- Exhibit 10: Regional Storm Flood Depths (1:20,000)

The calculated surface flow velocities were also mapped from the model output. Exhibits 11 through 13 illustrate the calculated surface flow velocities of the major storm events. The list of floodplain velocity maps is summarized as follows:

- Exhibit 11: 100-Year Storm Velocities (1:20,000)
- Exhibit 12: 350-Year Storm Velocities (1:20,000)
- Exhibit 13: Regional Storm Velocities (1:20,000)

Post processing was completed on the model output to determine the resultant $depth \times velocity$ for the floodplain within the study area for the major storm events. The list of floodplain depth-velocity product maps is summarized as follows:

- Exhibit 14: 100-Year Storm Depth x Velocity (1:20,000)
- Exhibit 15: 350-Year Storm Depth x Velocity (1:20,000)
- Exhibit 16: Regional Storm Depth x Velocity (1:20,000)

6.1 Spill Frequencies

Spill from Spring Creek and its tributaries occurs at varying frequencies throughout the study area. Table 6.1 provides a summary of the spills occurring at each of modelled storm events as indicated on the exhibits presented above. The flood depth maps which graphically indicate the spills at each return period frequency are also summarized below.

Table 6.1: Spill Summaries

Return Period Frequency	Spill Description	Exhibit
2 year	North of Steeles Avenue flow is contained within the channel with the exception of some minor flow in rear yards along Aloma Crescent. South of Steeles Avenue flow has spilled from the low flow channel but is generally confined within the valley corridor.	Exhibit 3
5 year	Spill has begun to occur near Bramalea City Centre and Clark Boulevard. There is ponding in Chinguacousy Park downstream of the SWM ponds. The industrial area between Orenda Road and the CNR has become inundated.	Exhibit 4
10 year	There is now spill in the parking area at Bramalea City Centre along Steeles Avenue and in the parking lot adjacent to the CNR south of Steeles Avenue.	Exhibit 5
25 year	Inundation throughout the industrial area east of Dixie Road between Steeles Avenue and Highway 407 has occurred.	Exhibit 6
50 year	Unknown Trib 2 has started spilling and the flooding in the southern industrial areas is increasing.	Exhibit 7
100 year	The Queen Street is overtopped at Dixie Tributary. There is flooding at Clark Boulevard Public School as well as along Balmoral Drive, Avondale Boulevard, Addington Crescent, Appleby Drive, and along a large stretch of Orenda Road.	Exhibit 8
350 year	The neighbourhood between Clark Boulevard and Balmoral Dive is inundated, as is Birchbank Road. Flooding in the south has become severe.	Exhibit 9
Regional Storm	Bramalea City Centre is completely surrounded. All other flooding locations have increased in severity.	Exhibit 10

6.2 Flood Depths

During the Regional Storm event the maximum depth in the floodplain (i.e., not within the channel) reaches approximately 6.24 m upstream of Steeles Avenue (refer to Exhibit 10); this is the worst case location. Table 6.2 compares the flood depth at select locations for various storm events.

Table 6.2: Flood Depths at Select Locations

Location	Regional Flood Depth (m)	100 year Flood Depth (m)	10 year Flood Depth (m)
Upstream of Bramalea Road	4.78	3.26	2.42
Upstream of Highway 407	5.25	3.57	2.34
Upstream of Steeles Avenue	6.24	5.53	5.16
Bramalea City Centre	3.81	2.71	2.51

7.0 FLOOD RISK CHARACTERIZATION

Characterization of flood risk typically considers depth, velocity, and the depth-velocity product. The following criteria were used to define the upper limits of safe access:

- Maximum Depth: 0.8 m
- Maximum Velocity: 1.7 m/s
- Maximum Depth-Velocity product: 0.37 m^2/s

The MIKE FLOOD model results were assessed against the above criteria to define high and low risk areas, as illustrated in Exhibit 17. The flood risk characterization is discussed in more detail under a separate cover titled *Floodplain Characterization Report, MMM Group Limited (October 2015)*.

8.0 REGIONAL FLOODLINE MAPPING

Contour mapping based on the current LiDAR topography was developed and provided by TRCA for development of the Regional Floodline. TRCA reviewed the MIKE FLOOD results for the Regional design storm event and provided guidelines for the delineation of the Regional Floodline. Exhibit 18 illustrates the Regional Floodline associated with the spill generated by the Regional Event. The spill continues easterly along the railway and southerly beyond Tranmere Drive. These two locations are indicated as spills on the provided mapping.

9.0 CONCLUSIONS AND RECOMMENDATIONS

The Spring Creek Floodplain Update study included the development of a 2D MIKE FLOOD hydraulic model to map flooding conditions within the Spring Creek watershed. A 1D/2D integrated modelling approach was used due to the complex flood regime in the study area, including multiple locations in which Spring Creek overtops its banks and reenters the creek further downstream or into the adjacent Dixie Tributary to the west. This modelling approach also allowed for characterizing flood conditions in the overbank areas, such as flow velocity, direction, and depth. This is not feasible using traditional 1D modelling methods, such as HEC-RAS.

Simulations were undertaken for a number of design storm events, ranging from the 2-Year to the Regional storm event. The results were used to generate flood constraint mapping which will provide guidance to local, regional and provincial government agencies as well as private sectors for managing and planning existing and future developments in the context of flood protection.

As discussed in Section 5.3, the extent of the 2D model area used in this study does not capture all anticipated spill areas, as it was more centralized on the Avondale SPA and Peel Centre site. It is recommended that any future modelling work include an extended 2D model area to fully define the extents of flooding.

Respectfully submitted:

MMM Group Limited

Prepared by:

______________________________ ______________________________

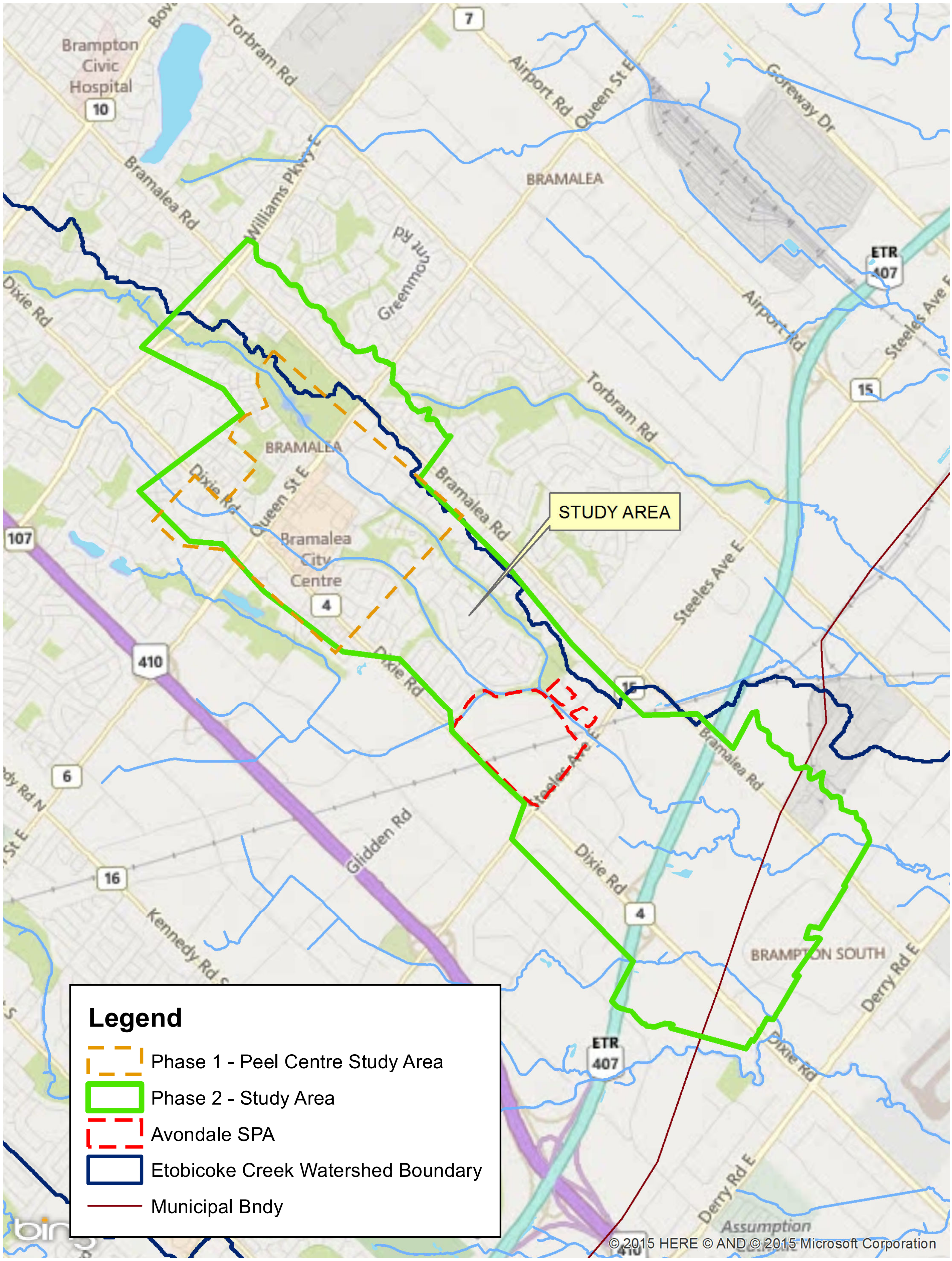
Kelly Molnar, P.Eng. | Jeff Schroeder, C.E.T.

Reviewed by:

____

Mark Hartley, B.Sc., M.Sc., P.Eng.

EXHIBITS



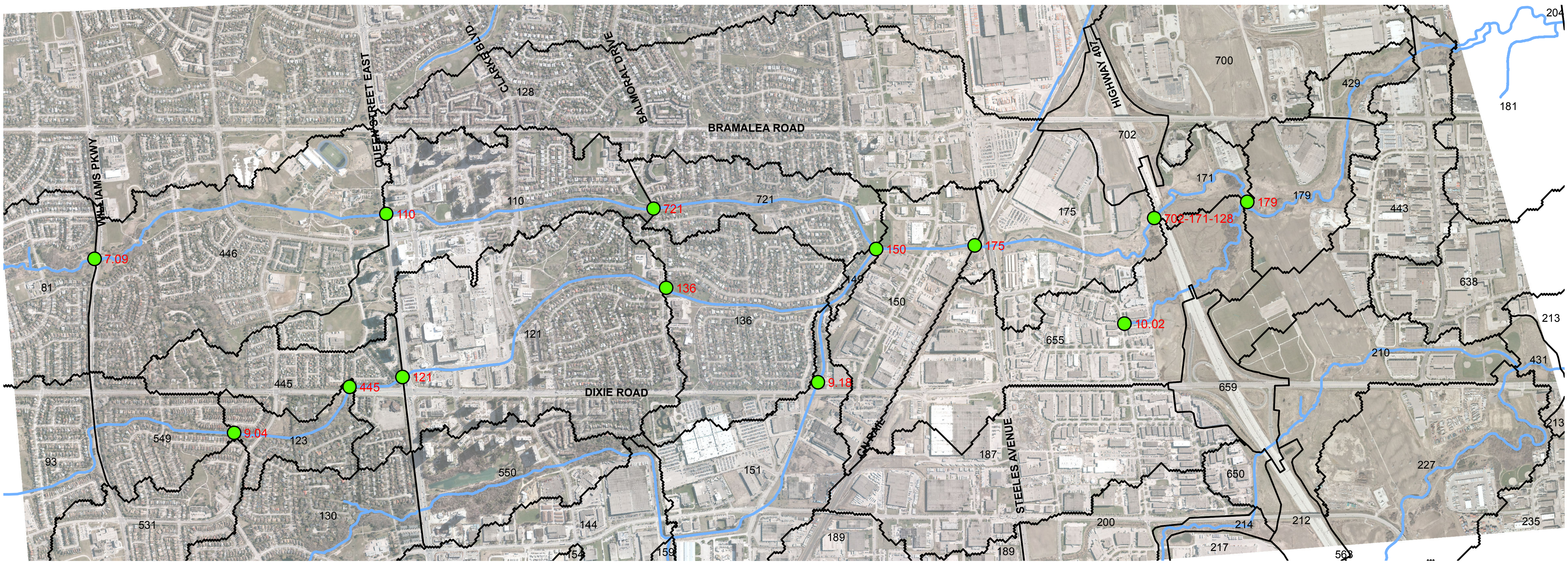
STUDY AREA
SPRING CREEK FLOODPLAIN UPDATE

MMM GROUP

0 210 420 630 m
1:40,000
N

Date: October-16-2015
Project No: 3814513
Exhibit No: 1

Document Path: L:\Projects\2014\3814513-Spring Creek 2D Update\Maps\3814513-Study Area.mxd



CATCHMENT AREAS AND FLOW NODE LOCATIONS
SPRING CREEK FLOODPLAIN UPDATE

MMM GROUP

0 240 480 720 m
1:20,000

Date: October-27-2015
Project No:3814513
Exhibit No. 2

Document Path: L:\Projects\2014\3814513-Spring Creek 2D Update\Maps\Task 1-Main Report\3814513-MIKE Results_2yr Storm Flood Depths.mxd

MMM GROUP

2-YEAR STORM FLOOD DEPTHS
SPRING CREEK FLOODPLAIN UPDATE

0 240 480 720 m

1:20,000

N

Date: October-27-2015

Project No:3814513

Exhibit No. 3

Document Path: L:\Projects\2014\3814513-Spring Creek 2D Update\Maps\Task 1-Main Report\3814513-MIKE Results_5yr Storm Flood Depths.mxd

MMM GROUP

5-YEAR STORM FLOOD DEPTHS
SPRING CREEK FLOODPLAIN UPDATE

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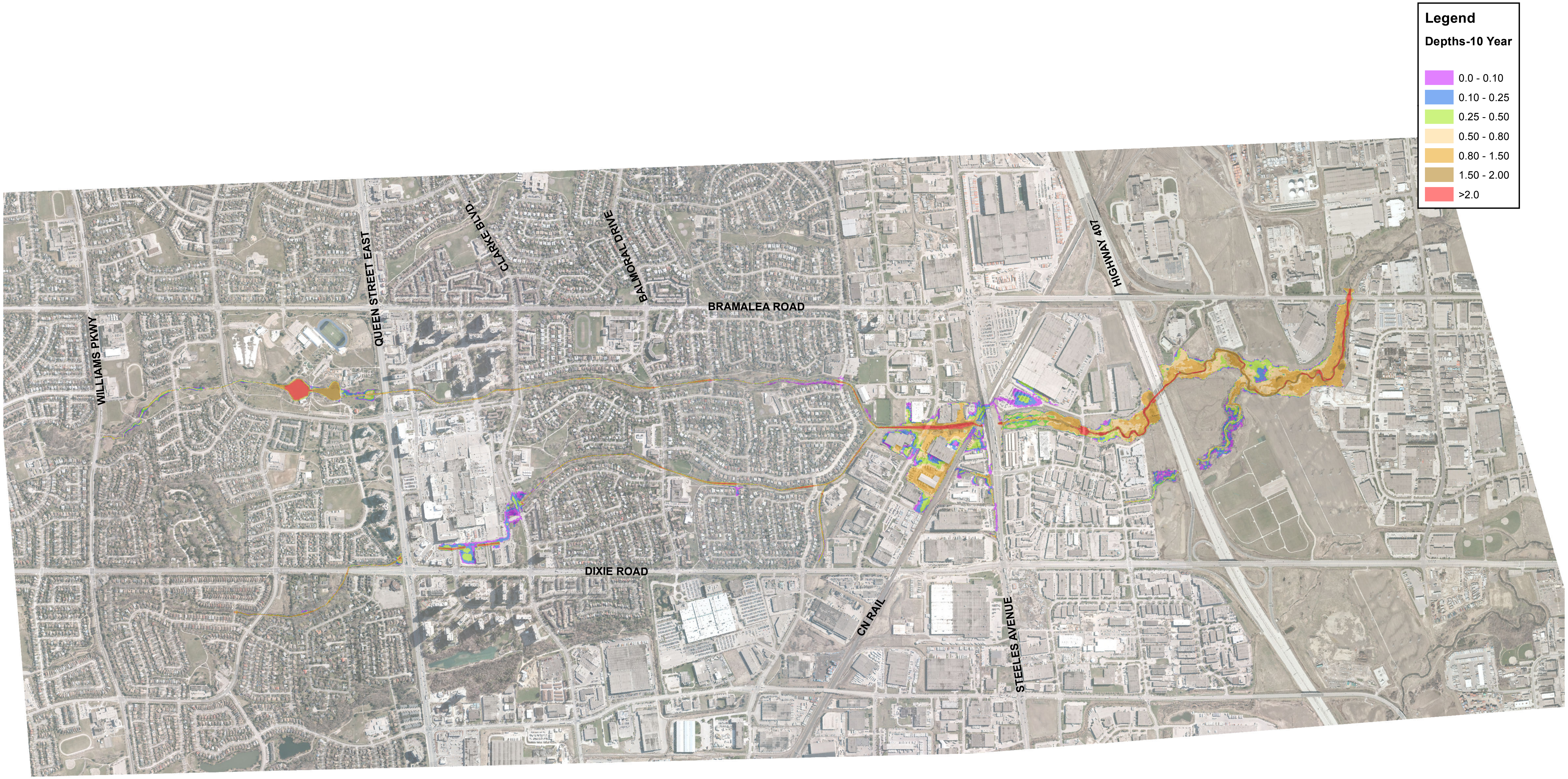
1:20,000

N

Date: October-27-2015
Project No:3814513
Exhibit No. 4



10-YEAR STORM FLOOD DEPTHS
SPRING CREEK FLOODPLAIN UPDATE

MMM GROUP

Date: October-27-2015

Project No:3814513

Exhibit No. 5

Document Path: L:\Projects\2014\3814513-Spring Creek 2D Update\Maps\Task 1-Main Report\3814513-MIKE Results_10yr Storm Flood Depths.mxd

Document Path: L:\Projects\2014\3814513-Spring Creek 2D Update\Maps\Task 1-Main Report\3814513-MIKE Results_25yr Storm Flood Depths.mxd

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25-YEAR STORM FLOOD DEPTHS
SPRING CREEK FLOODPLAIN UPDATE

0 240 480 720 m

1:20,000

N

Date: October-27-2015

Project No:3814513

Exhibit No. 6

Document Path: L:\Projects\2014\3814513-Spring Creek 2D Update\Maps\Task 1-Main Report\3814513-MIKE Results_50yr Storm Flood Depths.mxd

MMM GROUP

50-YEAR STORM FLOOD DEPTHS
SPRING CREEK FLOODPLAIN UPDATE

0 240 480 720 m

1:20,000

N

Date: October-27-2015

Project No:3814513

Exhibit No. 7

Document Path: L:\Projects\2014\3814513-Spring Creek 2D Update\Maps\Task 1-Main Report\3814513-MIKE Results_100yr Storm Flood Depths.mxd

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100-YEAR STORM FLOOD DEPTHS
SPRING CREEK FLOODPLAIN UPDATE

0 240 480 720 m

1:20,000

N

Date: October-27-2015

Project No:3814513

Exhibit No. 8

Legend

Depths-350 Year

- 0.0 - 0.10
- 0.10 - 0.25
- 0.25 - 0.50
- 0.50 - 0.80
- 0.80 - 1.50
- 1.50 - 2.00
- >2.0

Document Path: L:\Projects\2014\3814513-Spring Creek 2D Update\Maps\Task 1-Main Report\3814513-MIKE Results_350yr Storm Flood Depths.mxd

MMM GROUP

350-YEAR STORM FLOOD DEPTHS
SPRING CREEK FLOODPLAIN UPDATE

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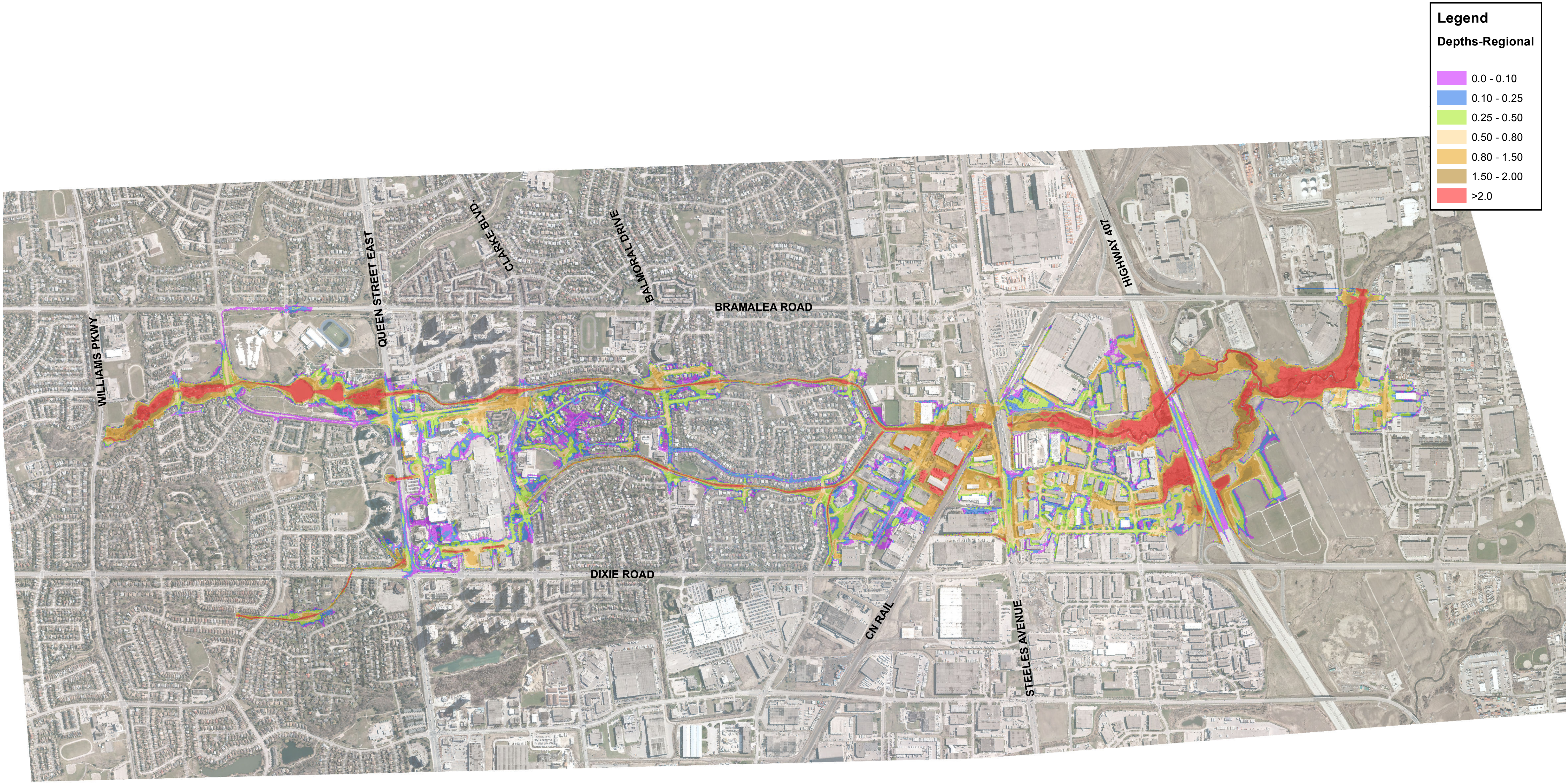
1:20,000

N

Date: October-27-2015

Project No:3814513

Exhibit No. 9



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REGIONAL STORM FLOOD DEPTHS
SPRING CREEK FLOODPLAIN UPDATE

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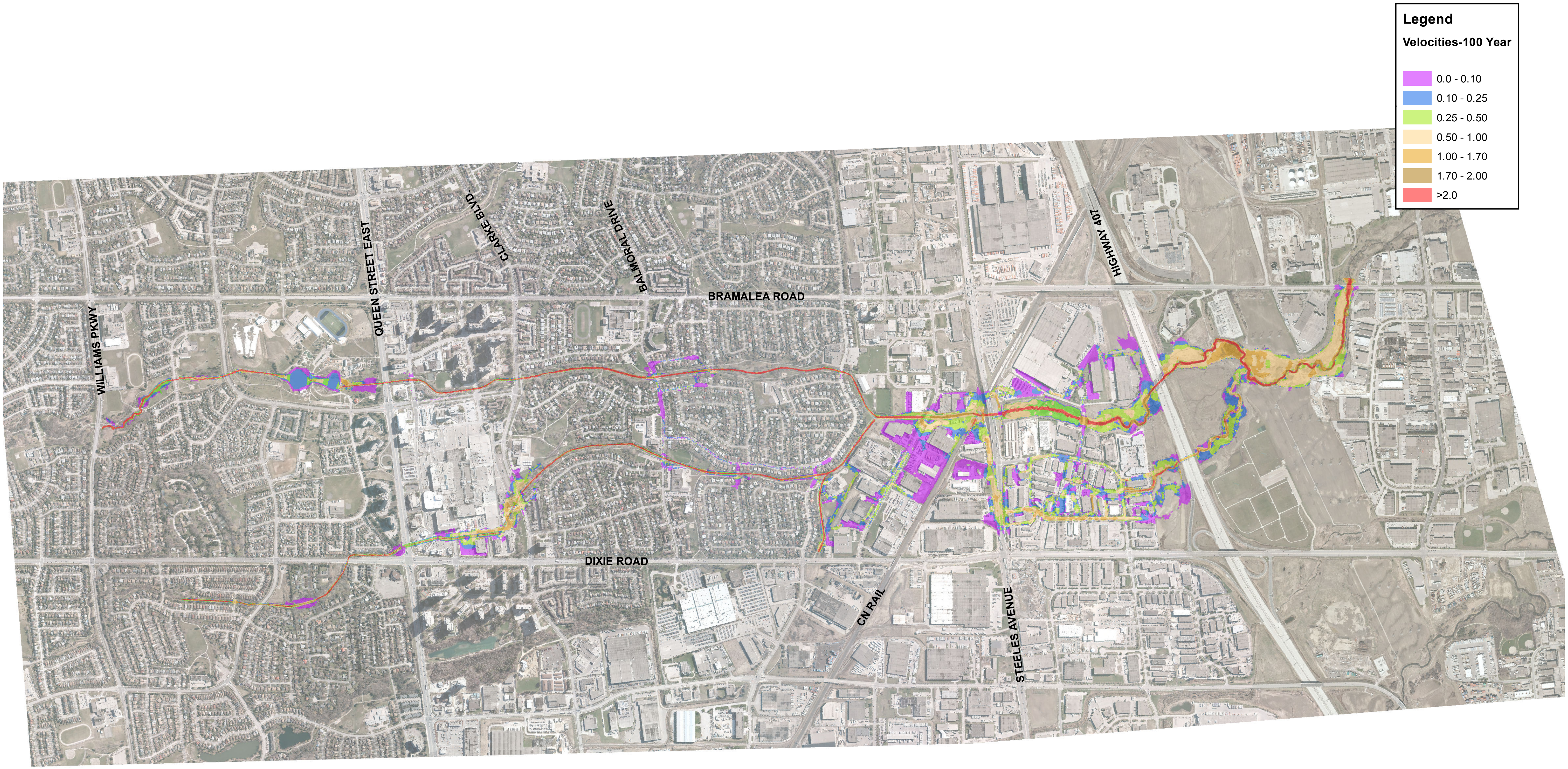
1:20,000

N

Date: October-27-2015
Project No:3814513
Exhibit No. 10



Document Path: L:\Projects\2014\3814513-Spring Creek 2D Update\Maps\Task 1-Main Report\3814513-MIKE Results_100yr Storm Velocities.mxd

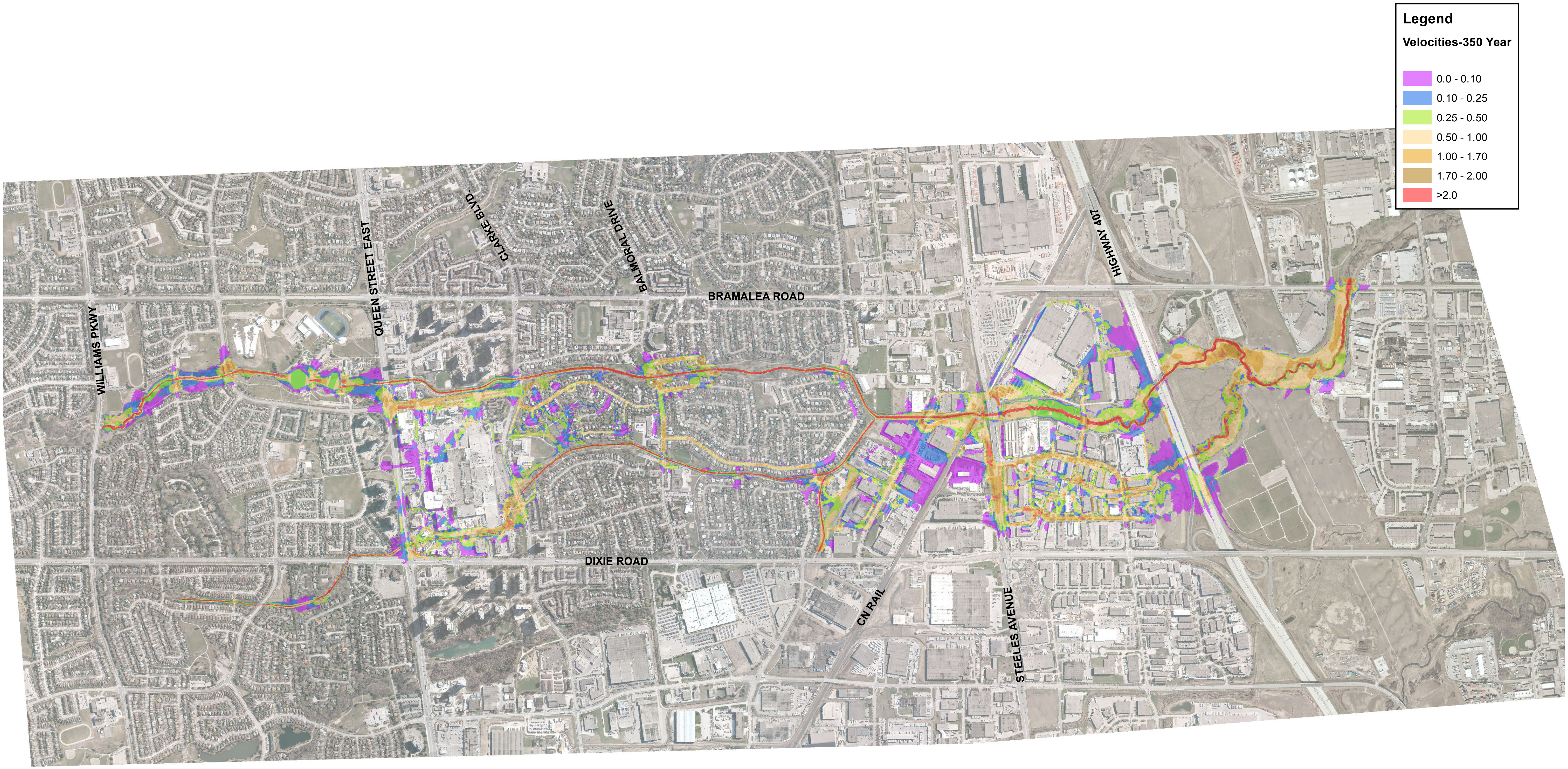
MMM GROUP

100-YEAR STORM VELOCITIES
SPRING CREEK FLOODPLAIN UPDATE

0 240 480 720 m
1:20,000

N

Date: October-27-2015
Project No:3814513
Exhibit No. 11



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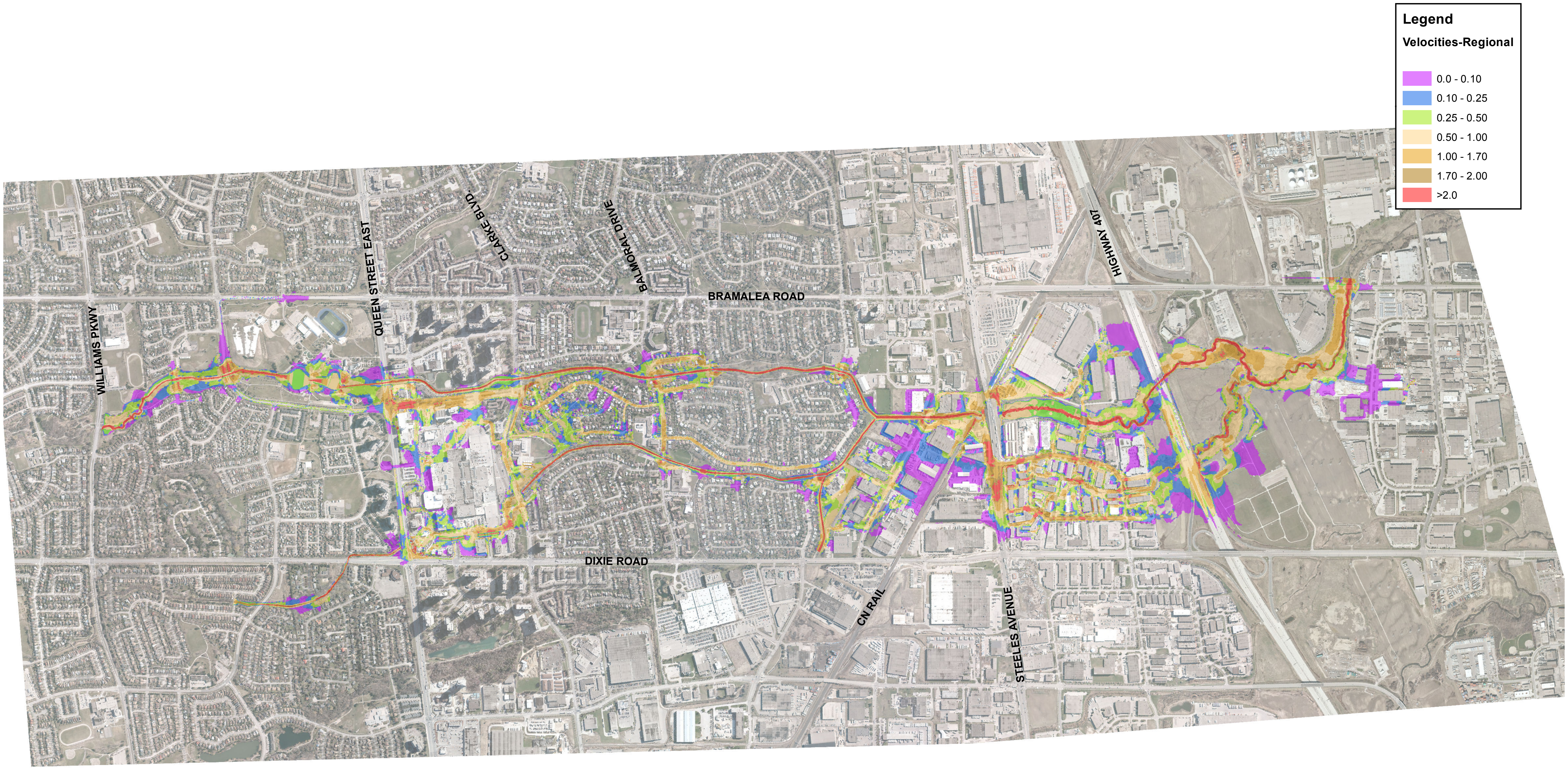
350-YEAR STORM VELOCITIES
SPRING CREEK FLOODPLAIN UPDATE

0 240 480 720 m
1:20,000

N

Date: October-27-2015
Project No:3814513
Exhibit No. 12



MMM GROUP

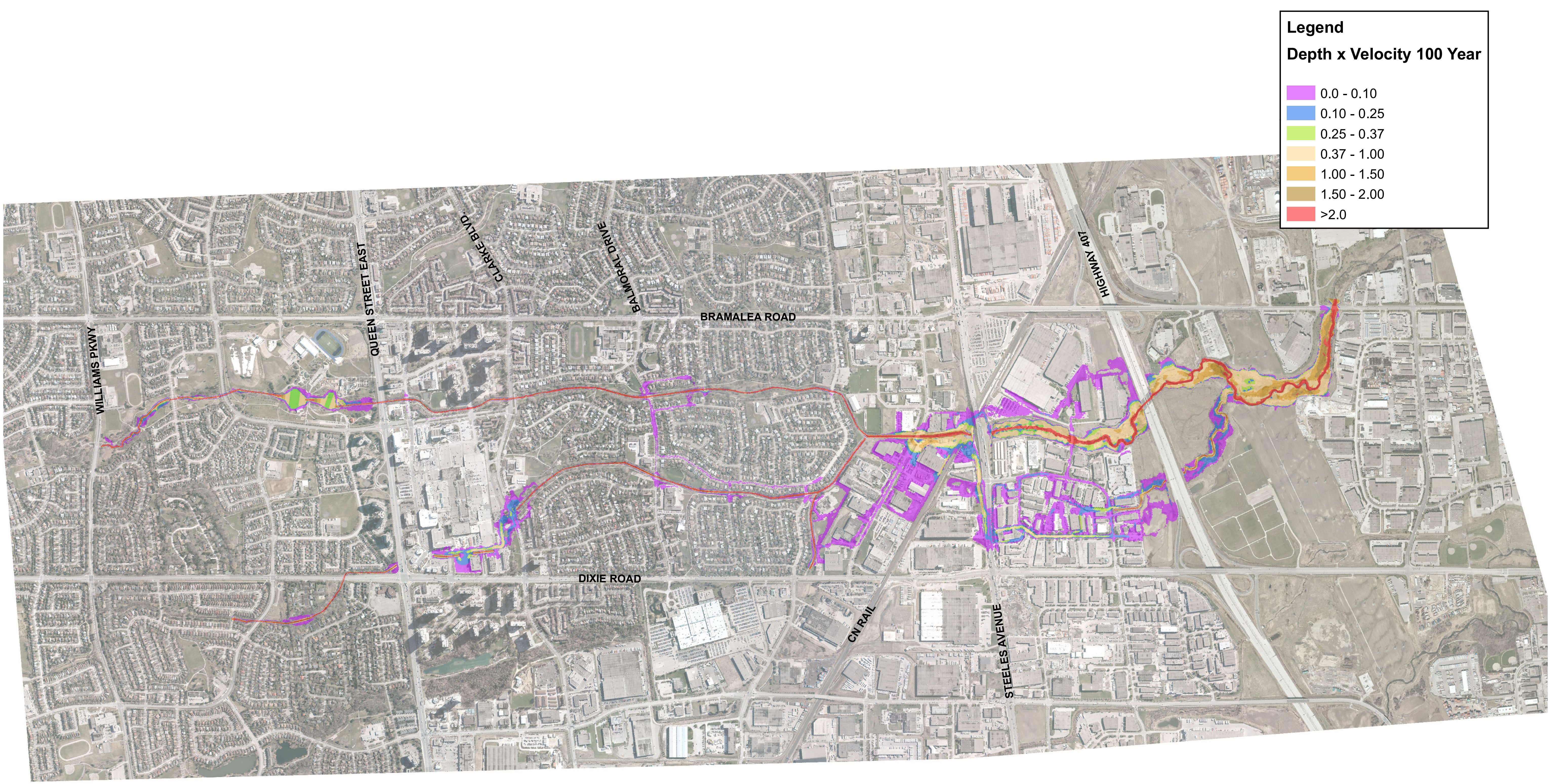
REGIONAL STORM VELOCITIES
SPRING CREEK FLOODPLAIN UPDATE

Date: October-27-2015

Project No:3814513

Exhibit No. 13

Document Path: L:\Projects\2014\3814513-Spring Creek 2D Update\Maps\Task 1-Main Report\3814513-MIKE Results_Regional Storm Velocities.mxd



Document Path: L:\Projects\2014\3814513-Spring Creek 2D Update\Maps\Task 1-Main Report\3814513-MIKE Results_100yr Storm Depth x Velocity.mxd

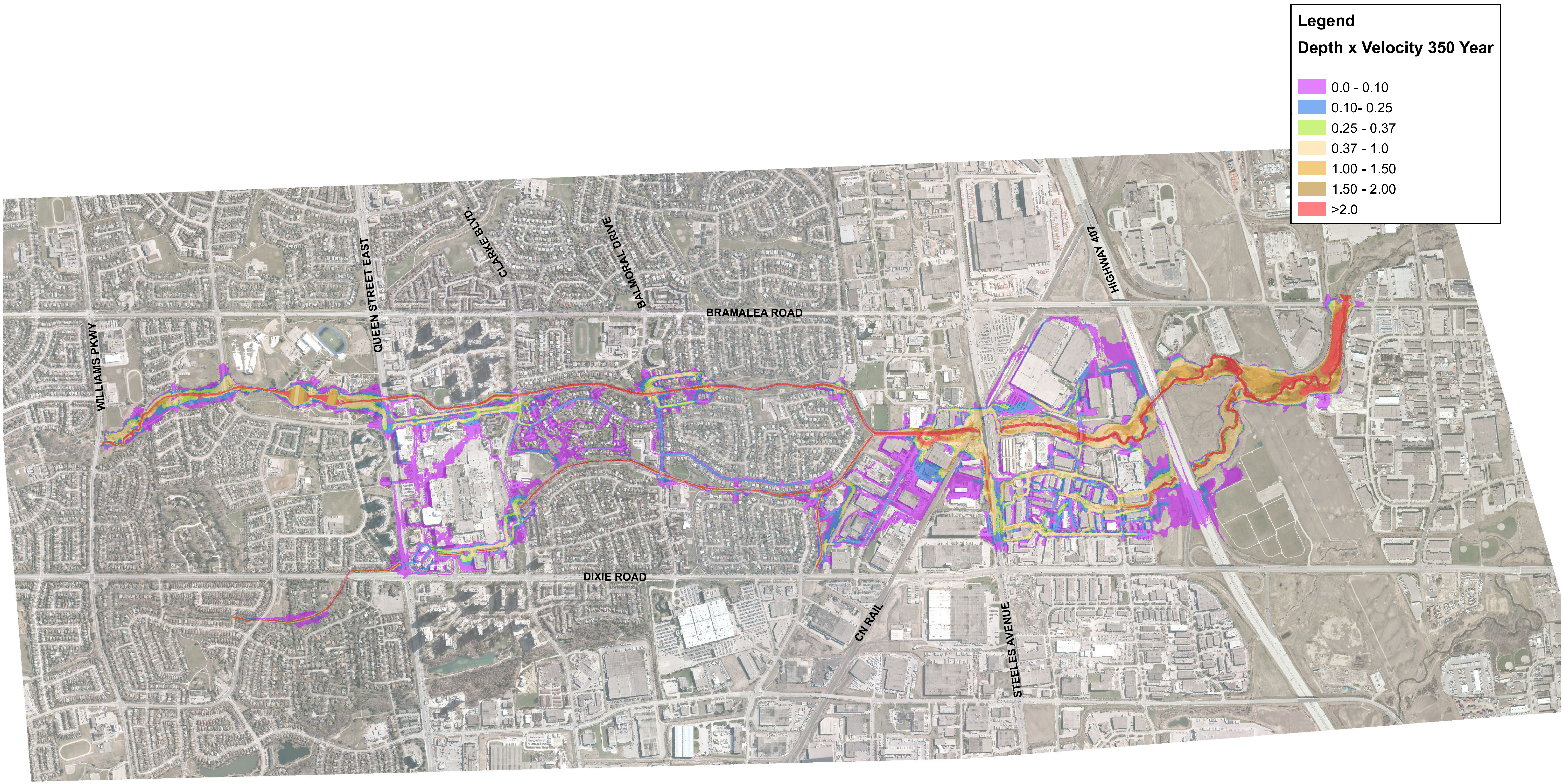
MMM GROUP

100-YEAR STORM DEPTH X VELOCITY
SPRING CREEK FLOODPLAIN UPDATE

Date: October-27-2015

Project No:3814513

Exhibit No. 14



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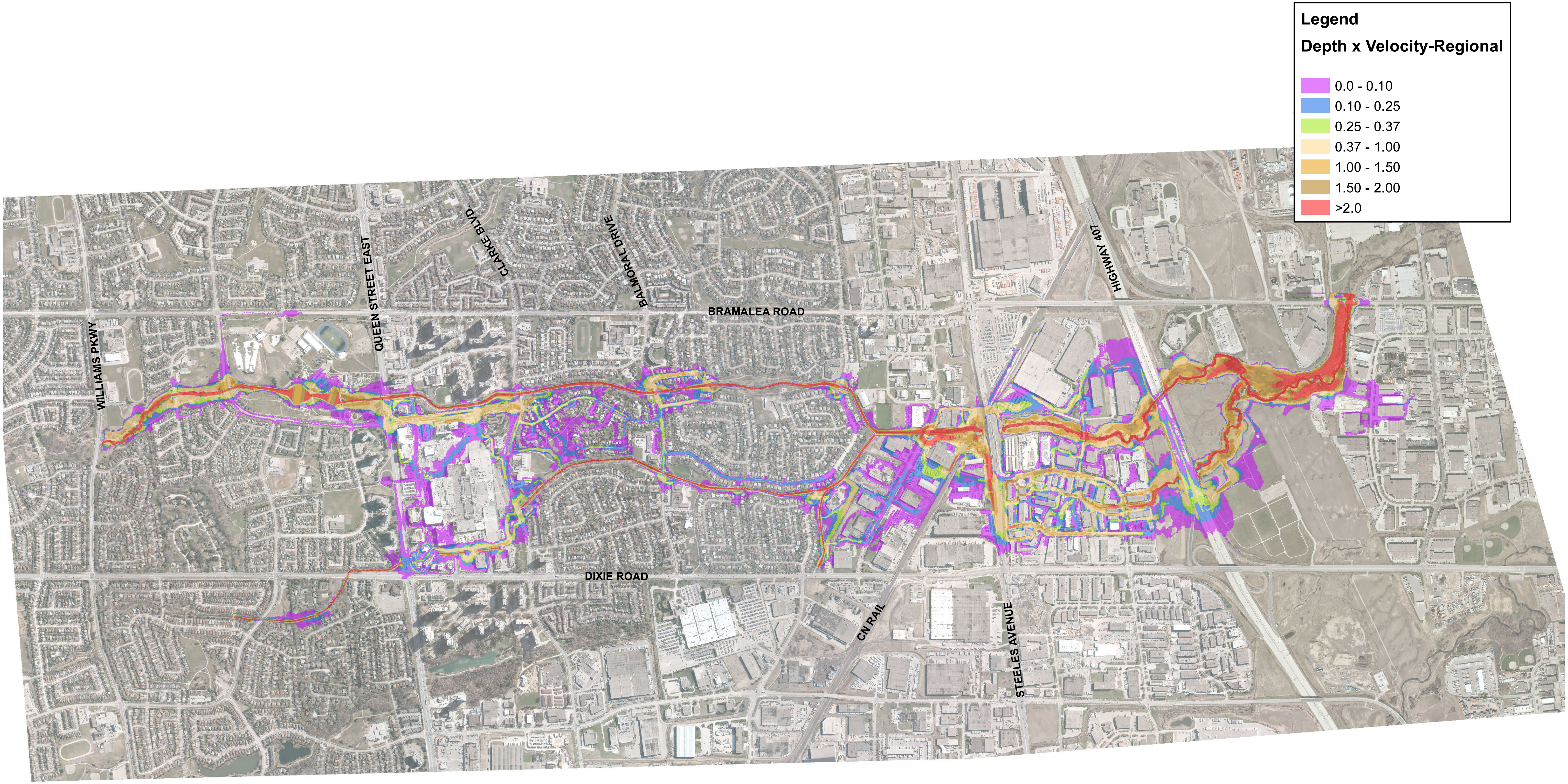
MMM GROUP

350-YEAR STORM DEPTH X VELOCITY
SPRING CREEK FLOODPLAIN UPDATE

0 240 480 720 m
1:20,000

N

Date: October-27-2015
Project No:3814513
Exhibit No. 15



Document Path: L:\Projects\2014\3814513-Spring Creek 2D Update\Maps\Task 1-Main Report\3814513-MIKE Results_Regional Storm Depth x Velocity.mxd

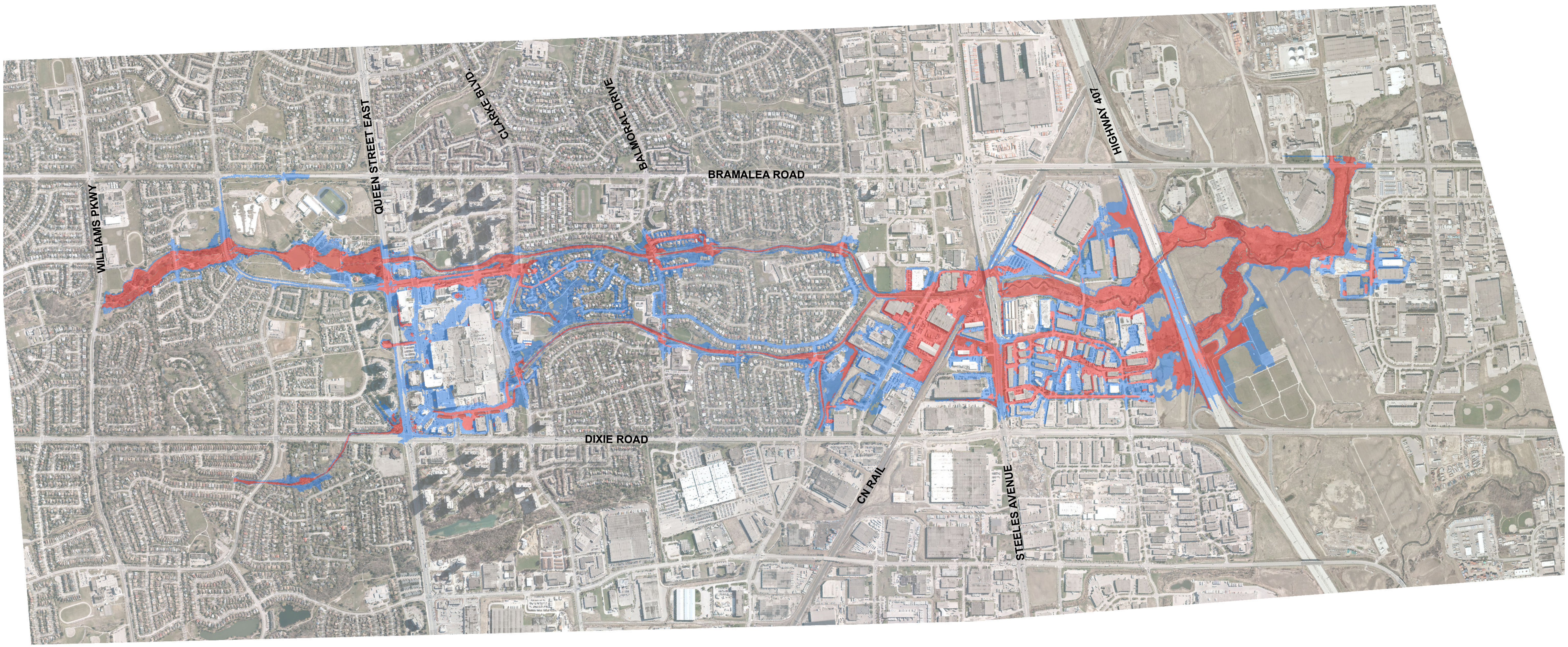
MMM GROUP

REGIONAL STORM DEPTH X VELOCITY
SPRING CREEK FLOODPLAIN UPDATE

0 240 480 720 m
1:20,000

N

Date: October-27-2015
Project No:3814513
Exhibit No. 16

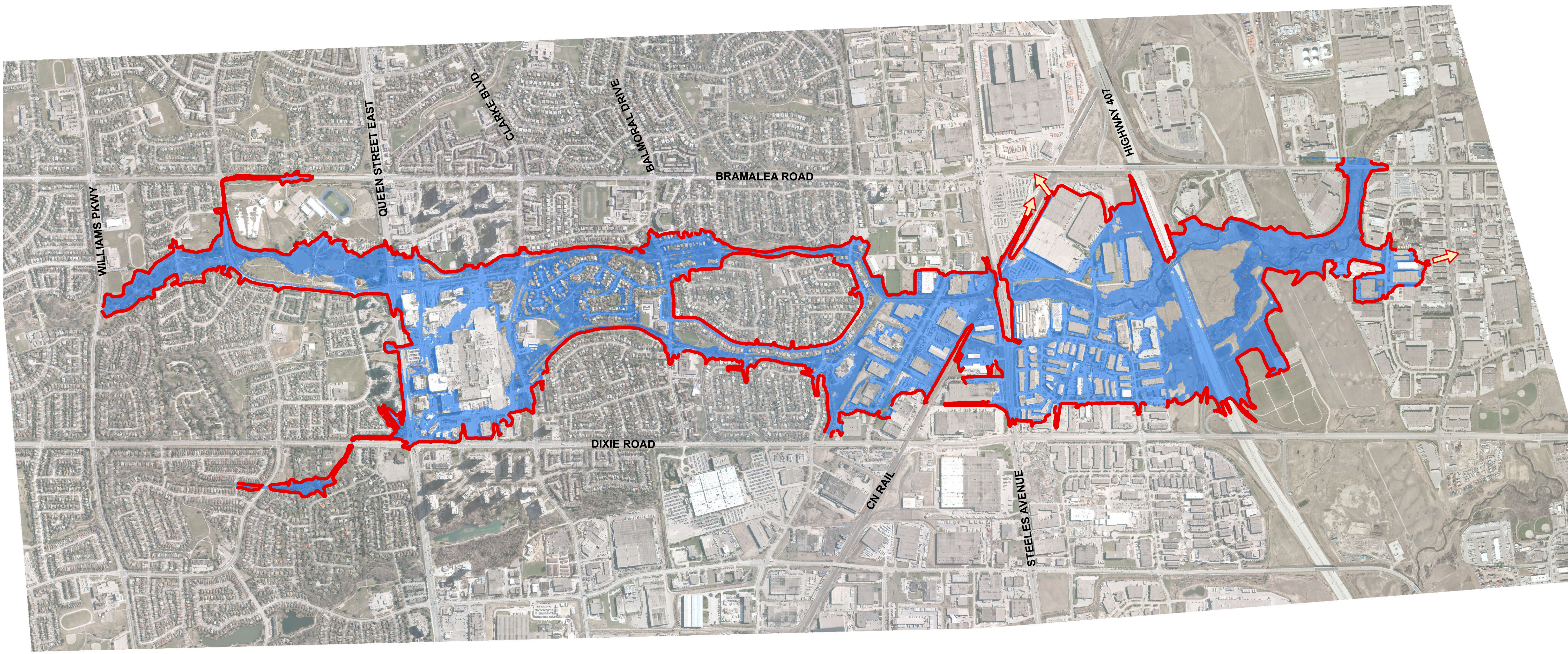


Document Path: L:\Projects\2014\3814513-Spring Creek 2D Update\Maps\Task 1-Main Report\3814513-MIKE Results_Regional Storm Flood Risk Level.mxd

MMM GROUP

REGIONAL STORM FLOOD RISK LEVEL
SPRING CREEK FLOODPLAIN UPDATE

Date: October-27-2015
Project No:3814513
Exhibit No. 17



Document Path: L:\Projects\2014\3814513-Spring Creek 2D Update\Maps\Task 1-Main Report\3814513-Delineated Regional Storm Floodline.mxd

MMM GROUP

REGIONAL STORM FLOODPLAIN
SPRING CREEK FLOODPLAIN UPDATE

0 240 480 720 m
1:20,000

N

Date: October-27-2015
Project No:3814513
Exhibit No. 18

APPENDIX A

Structure Inventory Sheets

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 1

Watershed and Location Information

Date:	21-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Hilldale Crescent

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Bridge
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	Y
Height (m) x Width (m):	2.13 x 5.49
Diameter (m):	
Length (m):	24.99
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (°):	90
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

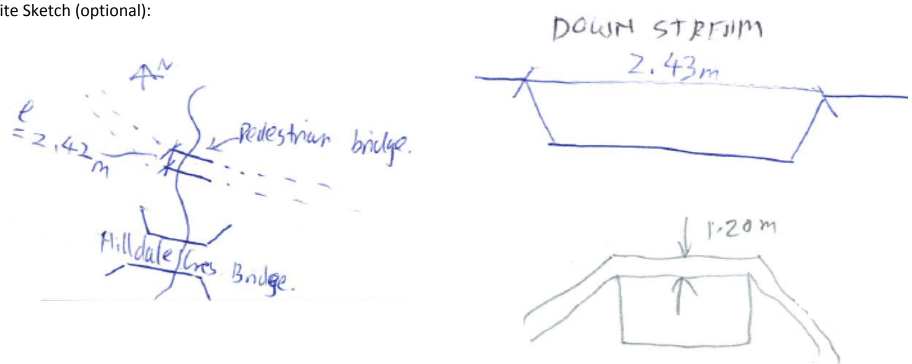
Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 6383-6386, d/s 6387-6398
Upstream, span = 5.45 m, height = 2.07 m, pedestrian crossing
Downstream, obvert to top of retaining wall = 1.20 m, outlet diameter = 0.65 m concrete pipe
Trapezoidal channel, concrete
Erosion under concrete

Site Sketch (optional):



Description of Photograph: Bridge from downstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 2

Watershed and Location Information	
Date:	21-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Central Park Drive

Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	Y
Height (m) x Width (m):	2.13 x 5.49
Diameter (m):	
Length (m):	38.40
Inlet Type (Projecting/Mitered/Headwall):	Projecting
Skew Angle of Crossing (°):	90
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

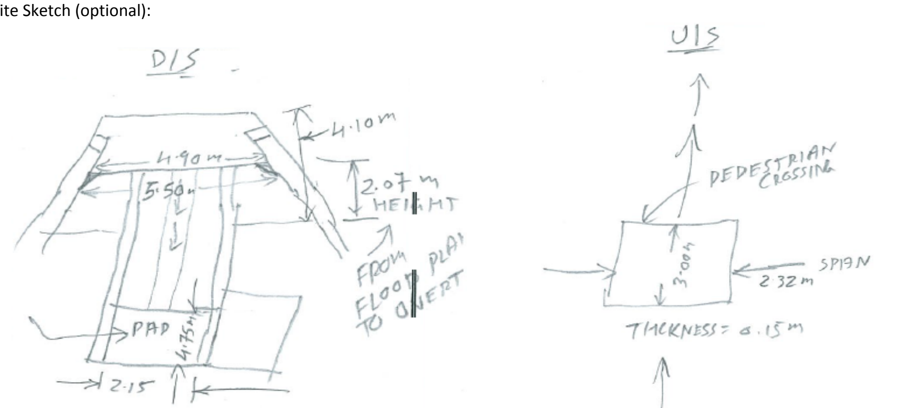
Current Flow Information	
Flow Present (Y/N):	
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 6399-6406, d/s 6407-6413
Upstream has one outlet concrete pipe dia = 0.50 m
Downstream outlet is inside the bridge, hand rail height = 1.10 m

Site Sketch (optional):



Description of Photograph: Bridge from downstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 3

Watershed and Location Information	
Date:	21-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Balmoral Drive East Culvert

Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	
Height (m) x Width (m):	1.98 x 3.96
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (º):	81
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

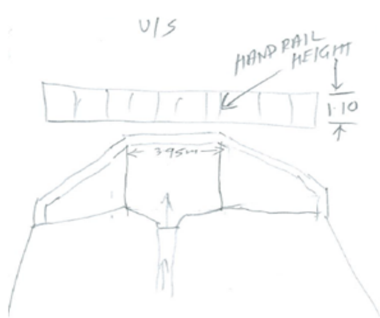
Current Flow Information	
Flow Present (Y/N):	
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 6414-6421, d/s 6422-6427
Upstream span = 3.95 m, thickness = 0.34 m, top of flood span to obvert = 1.42 m, bottom of channel to obvert = 2.15 m
Downstream has two outlets, hand rail height = 1.27 m

Site Sketch (optional):



Description of Photograph:	Bridge from downstream

3814513-000

Stream Crossing Field Inventory Sheet

Point 4

Watershed and Location Information	
Date:	21-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Algonquin Blvd

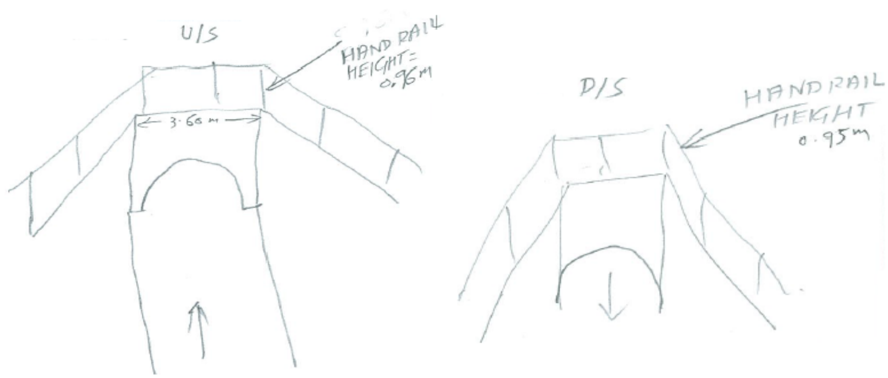
Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Steel
Open Footing (Y/N):	N
Height (m) x Width (m):	2.26 x 3.48
Diameter (m):	
Length (m):	21.34
Inlet Type (Projecting/Mitered/Headwall):	Mitered or Headwall
Skew Angle of Crossing (º):	90
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information	
Flow Present (Y/N):	
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:	Photos: u/s 6428-6436, d/s 6437-6442 Upstream has one outlet Upstream span = 3.60 m, top of headwall to top of culvert = 1.24 m, height of invert to headwall = 3.44 m, obvert to invert = 2.22 m Downstream headwall to top of culvert = 1.35 m, headwall to invert = 3.56 m, obvert to invert = 2.21 m

Site Sketch (optional):



Description of Photograph:	Culvert from upstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 5

Watershed and Location Information	
Date:	21-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Path near Aloma Crescent Public School

Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Bridge
Number of Cells:	1
Material (Concrete/Steel):	Steel
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (º):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

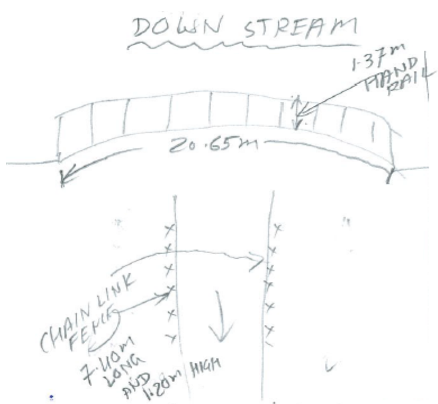
Current Flow Information	
Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 6443-6450, d/s 6451-6456
Upstream, bottom of bridge to invert = 4.00 m
Downstream, bottom of bridge to invert = 4.05 m, thickness of bridge = 0.10 m
One outlet downstream of bridge

Site Sketch (optional):



Description of Photograph: Steel Bridge from upstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 6

Watershed and Location Information	
Date:	21-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Avandale Boulevard

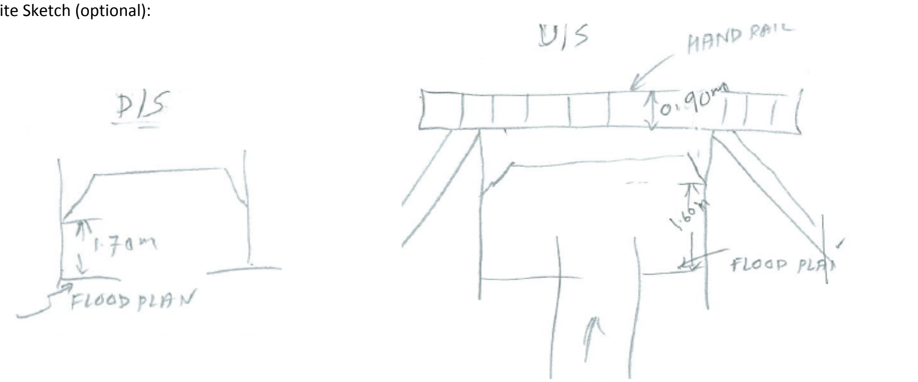
Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	N
Height (m) x Width (m):	2.26 x 3.48
Diameter (m):	
Length (m):	21.34
Inlet Type (Projecting/Mitered/Headwall):	Mitered
Skew Angle of Crossing (°):	90
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information	
Flow Present (Y/N):	
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:	Photos: u/s 6457-6460, d/s 6461-6464 Upstream, top of culvert to invert = 3.16 m, obvert from flood plain = 1.90 m, thickness of culvert = 0.61 m Downstream, top of culvert to invert = 3.35 m, obvert to invert = 2.75 m, flood plain to obvert = 2.01 m, handrail = 0.68 m 4 outlets downstream of bridge

Site Sketch (optional):



Description of Photograph:	Culvert from upstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 7

Watershed and Location Information

Date:	21-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Orenda Road

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	2
Material (Concrete/Steel):	Steel
Open Footing (Y/N):	N
Height (m) x Width (m):	2.26 x 3.48
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

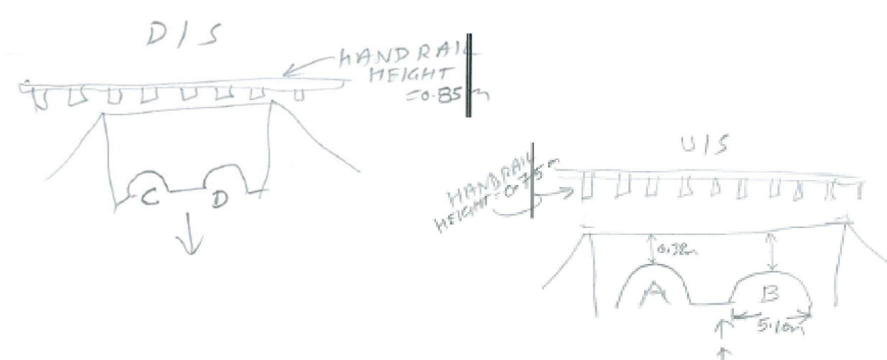
Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 6465-6470, d/s 6471-6474
Unable to measure top of headwall to invert A and B due to thick ice
2 outlets upstream and downstream

Site Sketch (optional):



Description of Photograph: Culvert from upstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 8

Watershed and Location Information

Date:	21-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	CNR

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Bridge
Number of Cells:	1
Material (Concrete/Steel):	CNC
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

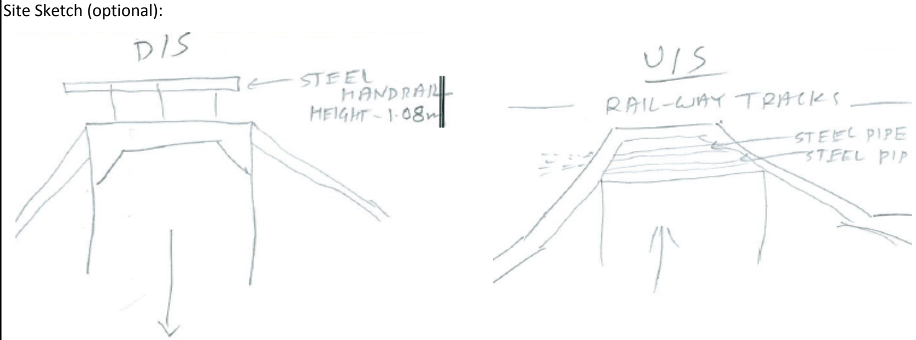
Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 6475-6484, d/s 6485-6492
Upstream, invert to obvert = 3.85 m, span = 4.62 m, wooden handrail is broken
Downstream, 2 outlets, invert to obvert = 4.10 m

Site Sketch (optional):



Description of Photograph: Bridge from downstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 9

Watershed and Location Information	
Date:	
Field Crew:	
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	

Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	
Number of Cells:	
Material (Concrete/Steel):	
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (º):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information	
Flow Present (Y/N):	
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:	Not on map
Site Sketch (optional):	
Description of Photograph:	

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 10

Watershed and Location Information

Date:	21-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Steeles Avenue East

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	N
Height (m) x Width (m):	4.57 x 9.14
Diameter (m):	
Length (m):	9.14
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (°):	90
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

Flow Present (Y/N):	
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Site Sketch (optional):

Description of Photograph:

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 11

Watershed and Location Information

Date:	21-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Alfred Kuehne Boulevard

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	6
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	N
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

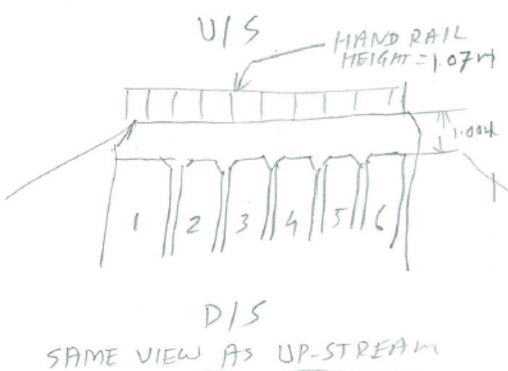
Flow Present (Y/N):	
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 6525-6532, d/s 6533-6539
Upstream, obverty to top of culvert = 1.00 m, span = 26.5 m, invert not available due to thick ice
Downstream, 6 spans, total length = 26.80 m, handrail = 1.08 m, invert not available due to thick ice

Site Sketch (optional):



Description of Photograph: Culvert from downstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 12

Watershed and Location Information	
Date:	
Field Crew:	
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	407

Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	
Number of Cells:	
Material (Concrete/Steel):	
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (º):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information	
Flow Present (Y/N):	
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:	
Site Sketch (optional):	
Description of Photograph:	

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 13

Watershed and Location Information	
Date:	22-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Lakehurst Street

Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Mitered
Skew Angle of Crossing (º):	20, southeast
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

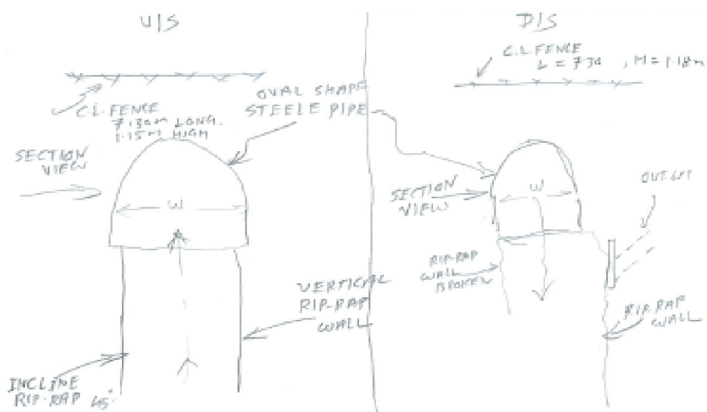
Current Flow Information	
Flow Present (Y/N):	N
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	Thick ice

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 9-12, d/s 13-17
Upstream, top to invert = 2.90 m, width = 4.30 m
Downstream, one outlet, top to invert = 2.90 m, width = 4.30 m

Site Sketch (optional):



Description of Photograph: Culvert from downstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 14

Watershed and Location Information	
Date:	22-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Howden Boulevard

Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Steel
Open Footing (Y/N):	N
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Mitered
Skew Angle of Crossing (º):	53
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

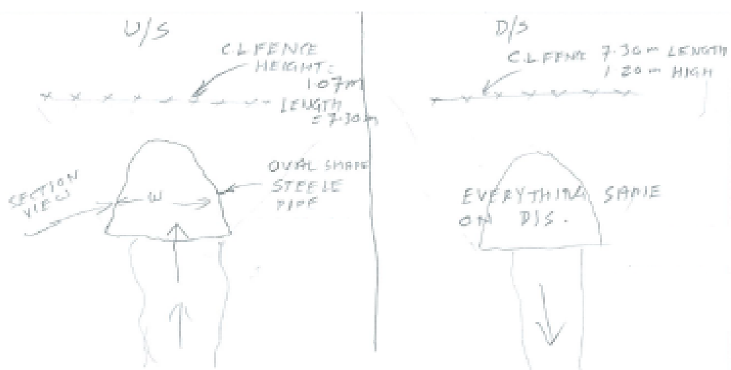
Current Flow Information	
Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 1-4, d/s 5-8
Upstream, top to invert = 2.90 m, width = 4.30 m, depth = 2.90 m
Downstream, top to invert = 2.90 m, width = 4.30 m, depth = 2.90 m

Site Sketch (optional):



Description of Photograph: Culvert from upstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 15

Watershed and Location Information	
Date:	22-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Balmoral Drive West Culvert

Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	Y
Height (m) x Width (m):	1.98 x 3.96
Diameter (m):	
Length (m):	24.99
Inlet Type (Projecting/Mitered/Headwall):	Projecting
Skew Angle of Crossing (°):	65 and 10'
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

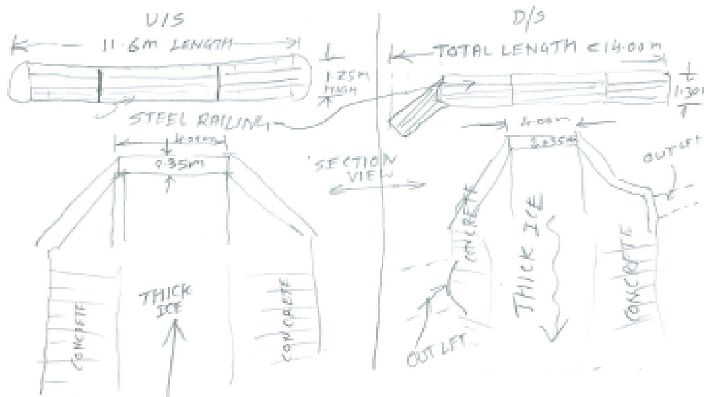
Current Flow Information	
Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 18-21, d/s 22-25
Upstream, invert not available due to thick ice, span = 4.00 m, thickness = 0.35 m
Downstream, invert not available due to thick ice, span = 4.00 m, thickness = 0.35 m

Site Sketch (optional):



Description of Photograph: Culvert from downstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 16

Watershed and Location Information

Date:	22-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Path near Balmoral Drive Senior Public School

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Bridge
Number of Cells:	1
Material (Concrete/Steel):	Steel
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (º):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

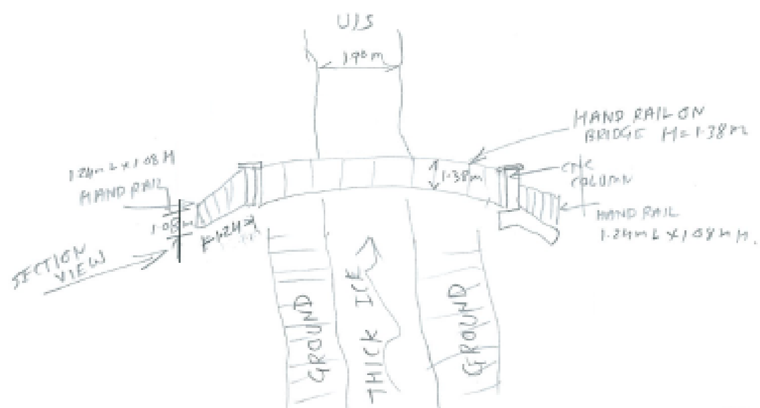
Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 26-28, d/s 29-31
Upstream, width = 3.30 m, length = 23.40 m, top to invert = 3.10 m, channel span = 1.90 m (not visible at upstream due to ice)
Downstream, top to invert = 3.25 m, obvert to top (thickness) = 0.14 m

Site Sketch (optional):



Description of Photograph: Bridge from downstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 17

Watershed and Location Information

Date:	22-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Brentwood Drive

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	N
Height (m) x Width (m):	1.98 x 3.96
Diameter (m):	
Length (m):	18.9
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (º):	94
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

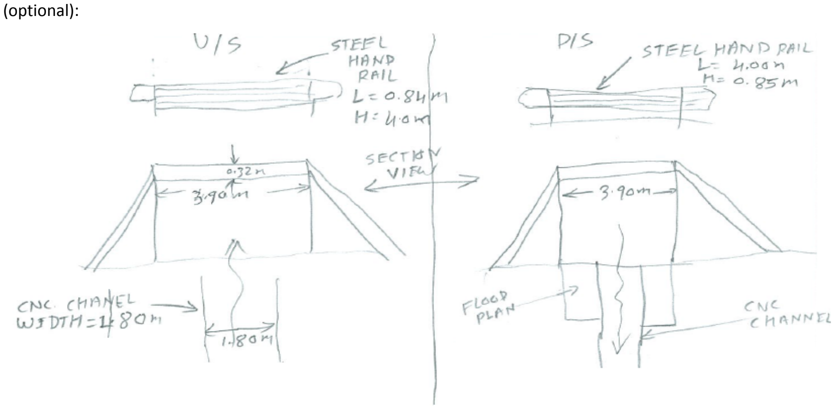
Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 32-34, d/s 35-37
Upstream, obvert to invert = 2.15 m, top to invert = 2.45 m, span = 3.90 m, two outlets under culvert
Downstream, top to invert = 2.80 m, obvert to flood plain = 2.00 m, top width of channel = 1.70m, thickness of culvert = 0.32 m, span = 3.90 m

Site Sketch (optional):



Description of Photograph: Upstream from culvert

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point 18

Watershed and Location Information

Date:	22-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Birchbank Road

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	Y
Height (m) x Width (m):	1.98 x 3.96
Diameter (m):	
Length (m):	18.9
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (º):	90
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

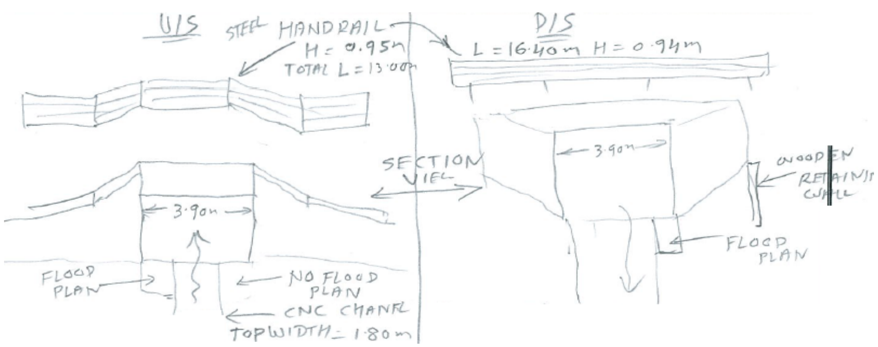
Flow Present (Y/N):	N
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 38-40, d/s 41-43
Upstream, obvert to invert = 2.25 m, top to invert = 3.36 m, obvert to flood plain = 1.75 m, flood plain to top = 2.92 m, one outlet under culvert
Downstream, obvert to invert = 2.25 m, top to invert = 3.34 m, obvert to flood plain = 1.82 m, flood plain to top = 2.97 m, concrete channel full of ice

Site Sketch (optional):



Description of Photograph:	Downstream from culvert

3814513-000

Stream Crossing Field Inventory Sheet

Point 19 and 20

Watershed and Location Information	
Date:	21-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Near CNR, culvert through Steeles Ave

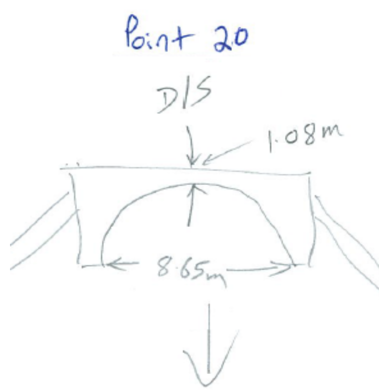
Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information	
Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:	Photos: u/s 6502-6524, d/s 6493-6501 Point 19 Upstream, invert to obvert = 4.60 m, obvert to top = 0.94 m Point 20 Downstream, invert not available due to thick ice, 2 outlets

Site Sketch (optional):



Description of Photograph:	Culvert from Downstream

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Stream Crossing Field Inventory Sheet

Point A1

Watershed and Location Information

Date:	23-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Chinguacousy Park Near Central Park

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Pedestrian Bridge
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

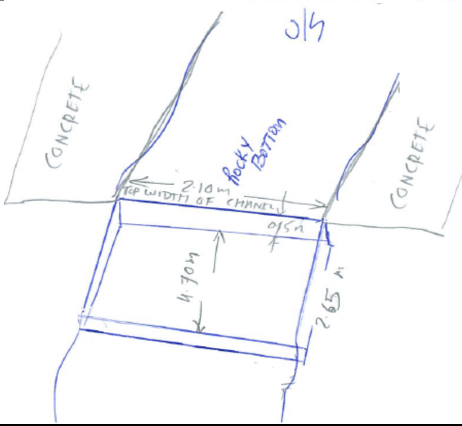
Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 44, d/s 45
Upstream, invert to top = 0.62 m, thickness of slab = 0.15 m
Downstream, invert to obvert = 0.42 m, thickness of slab = 0.15 m, channel not visible due to ice

Site Sketch (optional):



Description of Photograph: Bridge from upstream

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3814513-000

Stream Crossing Field Inventory Sheet

Point A2

Watershed and Location Information

Date:	23-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Chinguacousy Park Between Lakes

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Bridge
Number of Cells:	1
Material (Concrete/Steel):	Wood
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

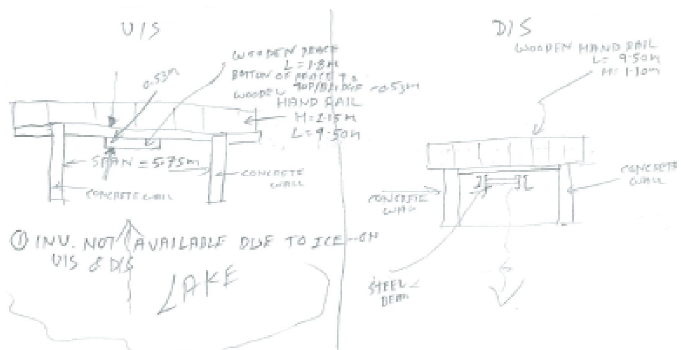
Current Flow Information

Flow Present (Y/N):	N
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

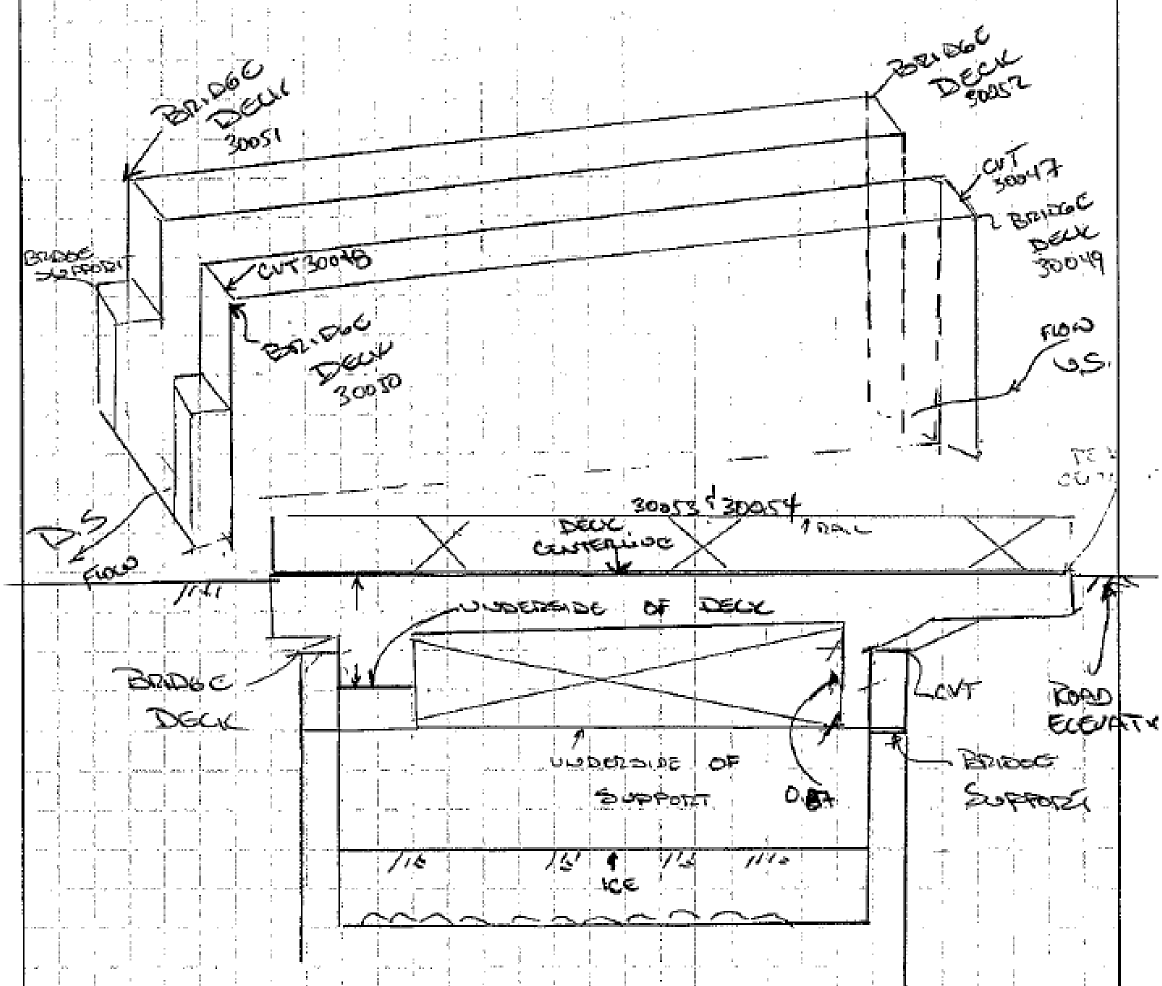
Additional Field Notes:	Photos: u/s 46-48, d/s 49-51 Upstream, two visible outlets, invert not available due to thick ice, width = 13.30 m, thickness = 0.23 m Downstream, invert not available due to thick ice, span = 5.65 m, bottom of steel beam to top, 0.60 m, thickness = 0.32 m

Site Sketch (optional):



Description of Photograph:	Bridge from Downstream

POINT "A2"



LOT / BLK ______	Weather SUN/CLOUD	Job No.	(M) FT.
CON / PLAN ______			
GEO. TWP ______	Instrument GPS 1200	Crew BR JK	22 01 15 (day mo yr)	Page 1
MUNICIPALITY ______			

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Stream Crossing Field Inventory Sheet

Point A3

Watershed and Location Information

Date:	23-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Chinguacousy Park South of Water

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Bridge
Number of Cells:	1
Material (Concrete/Steel):	Wood
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

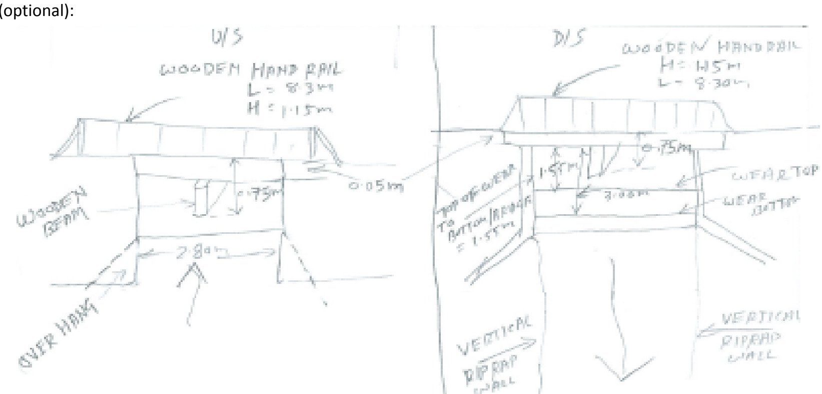
Flow Present (Y/N):	
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

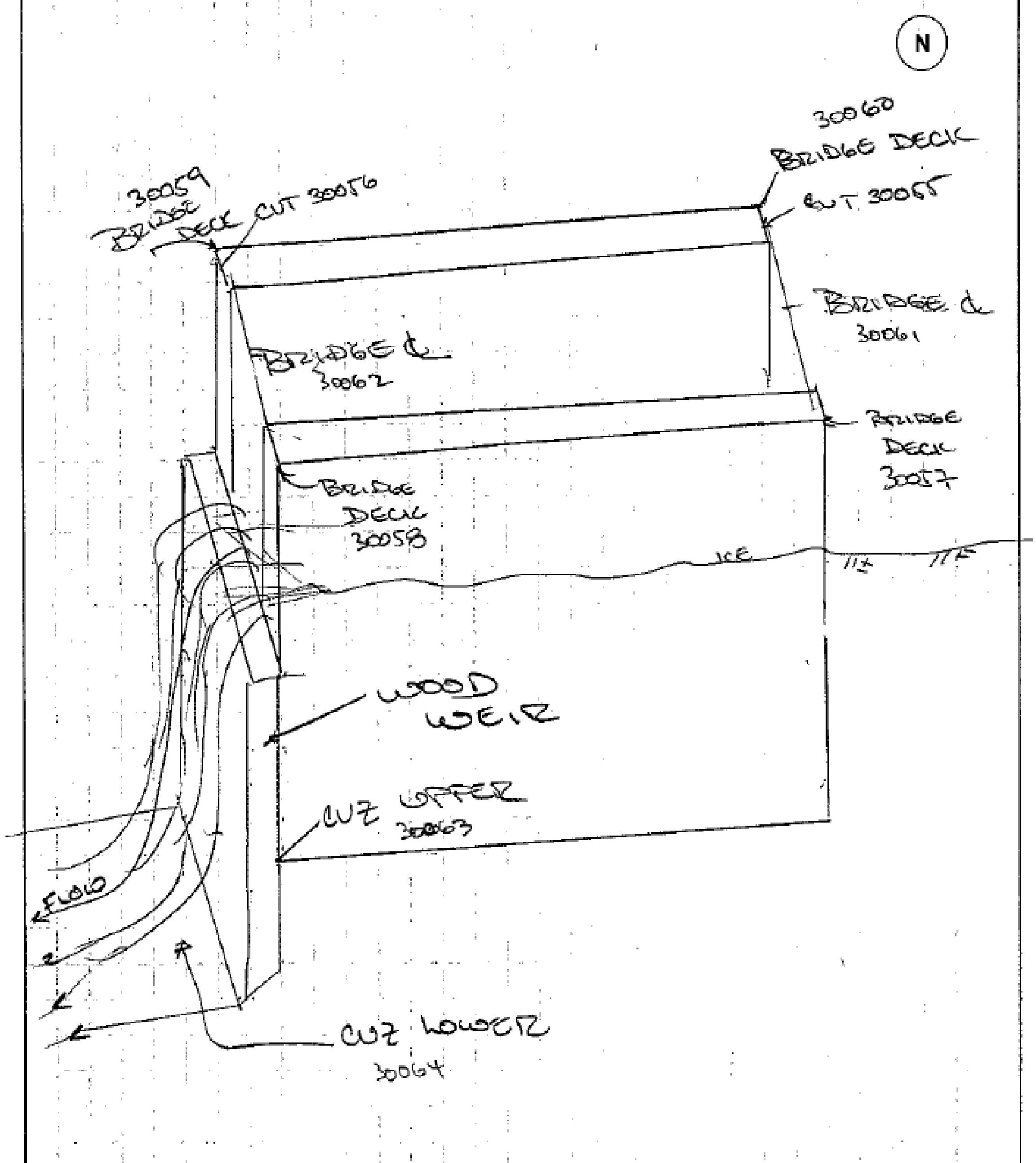
Photos: u/s 52-54, d/s 55-58
Upstream, frozen, top to obvert = 0.05 m, span = 2.80 m, wooden beam to top = 0.75 m
Downstream, one outlet, water flowing, invert to bottom = 4.00 m, span = 2.90 m, wooden beam to top = 0.75 m
Bridge width = 4.00 m

Site Sketch (optional):



Description of Photograph: Bridge from downstream

POINT "A3"



LOT / BLK	Weather	Job No.		M / FT.
CON / PLAN	SUN/CLOUD			
GEO. TWP	Instrument	Crew		Page
MUNICIPALITY	GPS 1200	BR JK	20 01 15 day mo yr	1

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Stream Crossing Field Inventory Sheet

Point A4

Watershed and Location Information

Date:	23-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Chinguacousy Park

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Bridge
Number of Cells:	1
Material (Concrete/Steel):	Wood
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 59-61, d/s 62-63
Bridge width = 1.80 m, span = 5.15 m, thickness = 0.05 m
Upstream, invert to obvert = 1.60 m
Downstream, invert to obvert = 1.60 m
2 Outlets

Site Sketch (optional):

Description of Photograph: Bridge from downstream

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Stream Crossing Field Inventory Sheet

Point A5

Watershed and Location Information	
Date:	23-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Chinguacousy Park, Near Queen St East

Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Bridge
Number of Cells:	
Material (Concrete/Steel):	Wood
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (º):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

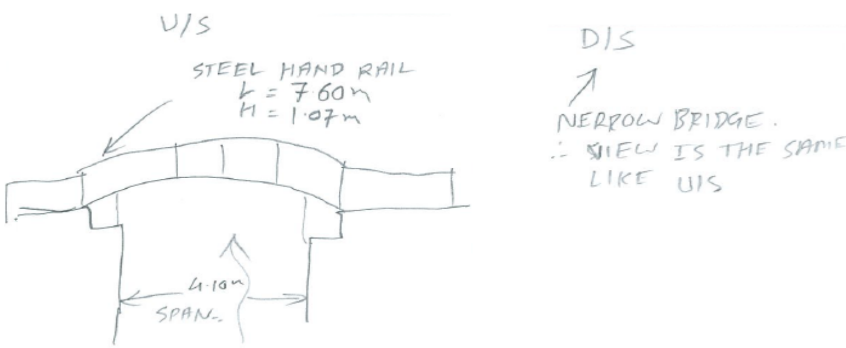
Current Flow Information	
Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 73-75, d/s 70-72
Bridge width = 1.83 m, span = 4.10 m, thickness = 0.09 m
Upstream, invert to obvert = 1.15 m
Downstream, invert to obvert = 1.32 m

Site Sketch (optional):



Description of Photograph: Bridge from upstream

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Stream Crossing Field Inventory Sheet

Point A6

Watershed and Location Information	
Date:	23-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	North side of Queen St East, East Culvert

Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Bridge
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	
Height (m) x Width (m):	7.62 m
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (º):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

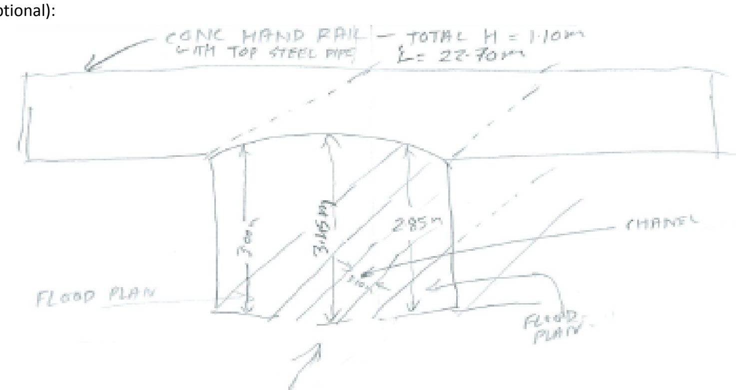
Current Flow Information	
Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 67-69
Bridge span = 7.56 m
Flood plain to obvert, west site = 2.85 m, invert to obvert = 3.45 m
Channel top width = 3.10 m, depth in middle of bridge = 0.70 m, bottom width = 2.00 m

Site Sketch (optional):



Description of Photograph: Bridge from upstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A7

Watershed and Location Information

Date:	23-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	South side of Queen St East, Same location as A6

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Bridge
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	Y
Height (m) x Width (m):	7.62 m
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

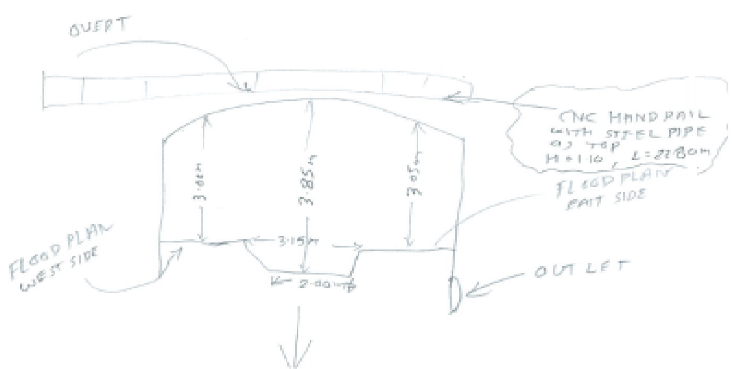
Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: d/s 64-66
Total length of A5 and A6 = 35.20 m (ie under side of Queen St, bridge N to S)
Bridge span = 7.55 m
2 Outlets

Site Sketch (optional):



Description of Photograph:	Bridge from downstream

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Stream Crossing Field Inventory Sheet

Point A8

Watershed and Location Information

Date:	26-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Kensington Road

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	2
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	Frozen, Thick Ice

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 76-78, d/s 79-81
A, (1) flood plain to obvert = 2.27 m, (2) flood plain to obvert = 2.10 m, span = 3.75 m, invert to obvert = 2.65 m, top to invert = 2.95 m
B, span = 3.75 m
C, span = 3.85 m, top to invert = 2.82 m, invert to obvert = 2.50 m
D, span = 3.85 m, unable to measure invert due to ice
No flood plan visible

Site Sketch (optional):

Description of Photograph:	Culvert from downstream

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Stream Crossing Field Inventory Sheet

Point A9

Watershed and Location Information

Date:	26-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Park North of Central Park Dr and Knightsbridge Rd

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Bridge
Number of Cells:	1
Material (Concrete/Steel):	Wood
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

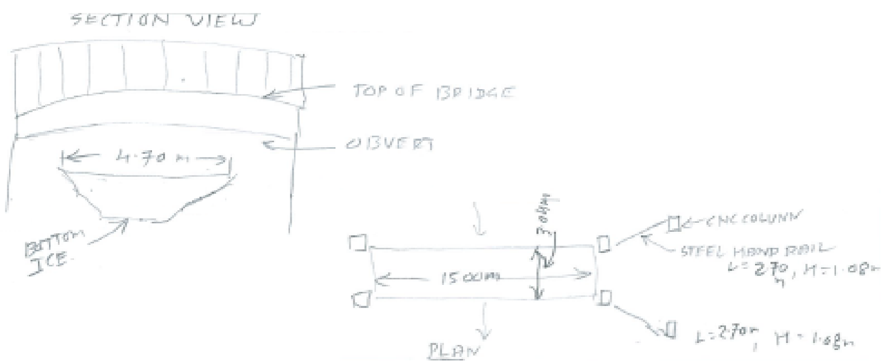
Current Flow Information

Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	Frozen, Thick Ice

Site Photograph and Additional Field Notes

Additional Field Notes:	Photos: u/s 82-83, d/s 84-85 Upstream, top to invert = 2.81 m, top to obvert = 0.31 m Downstream, top to invert = 2.96 m

Site Sketch (optional):



Description of Photograph:	Bridge from downstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A10

Watershed and Location Information

Date:	26-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Knightsbridge Rd

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	2
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	
Height (m) x Width (m):	2.51 x 3.81
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (°):	90
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

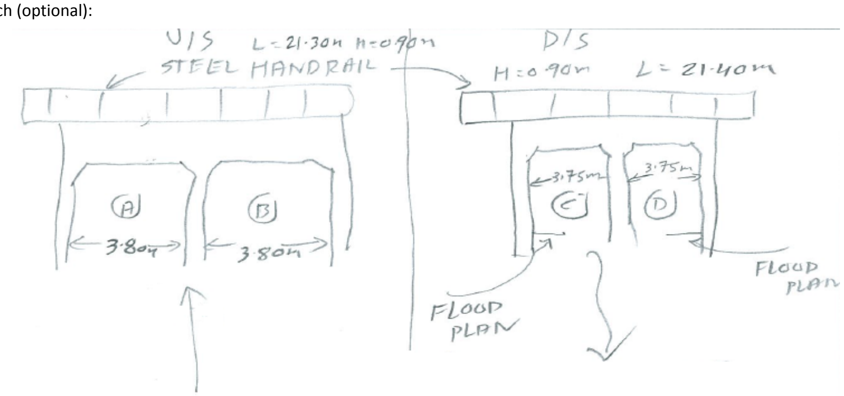
Current Flow Information

Flow Present (Y/N):	N
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:	Photos: u/s 86-88, d/s 89-91 Upstream, unable to measure invert due to ice A and B, top to obvert = 0.80 m Downstream, one outlet C and D, top to obvert = 0.80 m, flood plain to top = 3.00 m

Site Sketch (optional):



Description of Photograph: Culvert from downstream

3814513-000

Stream Crossing Field Inventory Sheet

Point A11

Watershed and Location Information

Date:	26-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Clark Boulevard East Culvert

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	2
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	Y
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

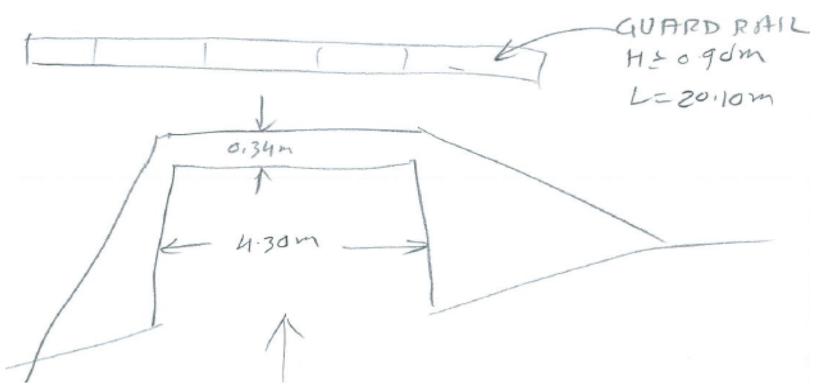
Current Flow Information

Flow Present (Y/N):	N
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:	Photos: 92-94 Frozen ice, unable to measure invert Span = 4.30 m, top to obvert = 0.34 m 2 Outlets

Site Sketch (optional):



Description of Photograph:	Concrete culvert

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A12

Watershed and Location Information	
Date:	26-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Clark Boulevard East Culvert, same location as A11

Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	Y
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (º):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information	
Flow Present (Y/N):	N
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Site Sketch (optional):

Description of Photograph:

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A13

Watershed and Location Information	
Date:	26-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Cloverdale Drive

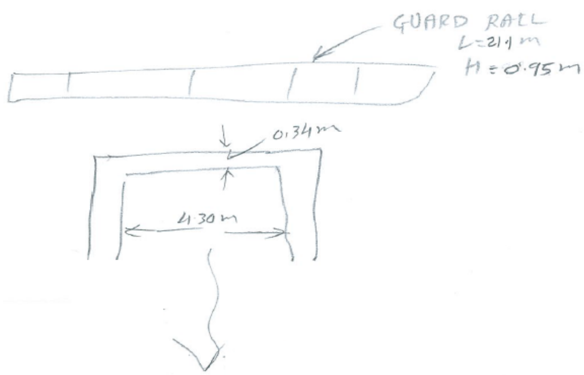
Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information	
Flow Present (Y/N):	N
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:	Photos: u/s 95-97 Span = 4.30 m, top to obvert = 0.34 m, invert not available due to thick ice

Site Sketch (optional):



Description of Photograph:	Culvert from upstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A14

Watershed and Location Information	
Date:	26-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Crawley Park

Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Bridge
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (º):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

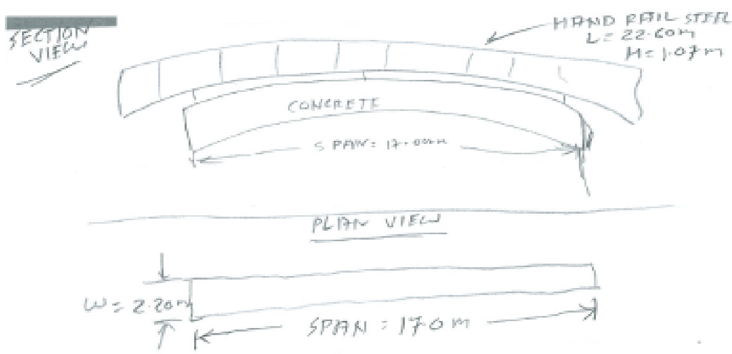
Current Flow Information	
Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 98-100, d/s 101-103
Upstream, invert to obvert = 2.85 m, invert to top = 3.57 m
Downstream, invert to obvert = 2.90 m, invert to top = 3/57 m
Creek is full of thick ice

Site Sketch (optional):



Description of Photograph: Bridge from downstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A15

Watershed and Location Information

Date:	27-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Hazelwood Drive

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	Y
Height (m) x Width (m):	1.83 x 3.66
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (°):	90
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

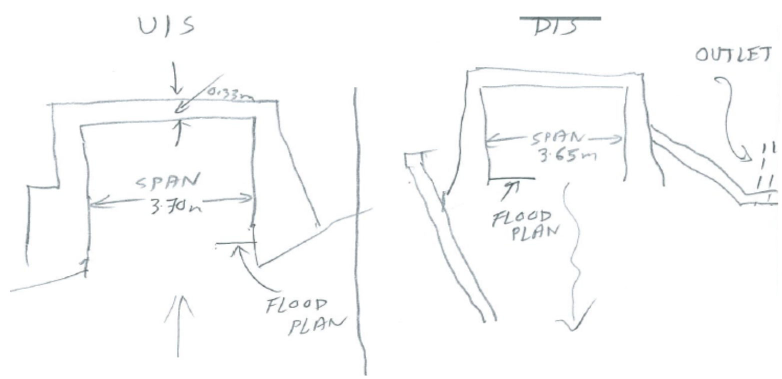
Current Flow Information

Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	Creek is frozen

Site Photograph and Additional Field Notes

Additional Field Notes:	Photos: u/s 112-114, d/s 115-117 Upstream, flood plain to obvert = 1.65 m, flood plain to top = 1.98 m, invert not available due to ice Downstream, one outlet, flood plain to obvert = 1.70 m, flood plain to top = 2.00 m, invert not available due to ice

Site Sketch (optional):



Description of Photograph:	Culvert from upstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A16

Watershed and Location Information

Date:	27-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Dixie Rd

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Steel
Open Footing (Y/N):	N
Height (m) x Width (m):	2.55 x 3.90
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (°):	20, southwest
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

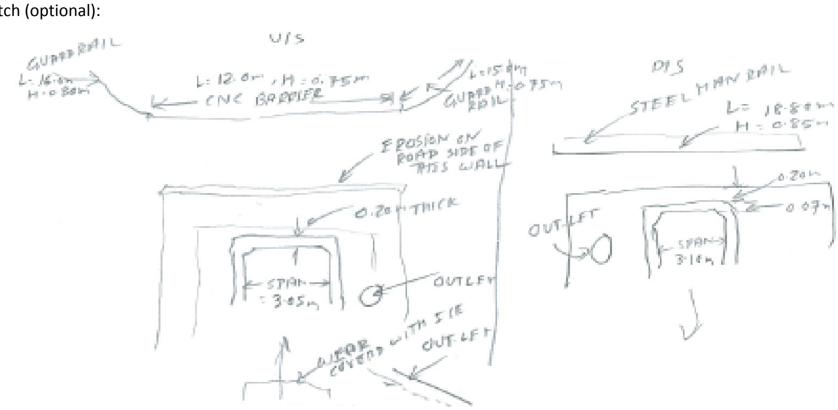
Flow Present (Y/N):	
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	Creek is frozen

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 118-120, d/s 121-123
Upstream, 2 outlets, invert not available due to ice
Downstream, obvert to top = 0.27 m, invert not available due to ice

Site Sketch (optional):



Description of Photograph: Culvert from downstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A17

Watershed and Location Information

Date:	27-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	North of Dixie Road and Queen St East

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Bridge
Number of Cells:	
Material (Concrete/Steel):	Wood and Steel
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

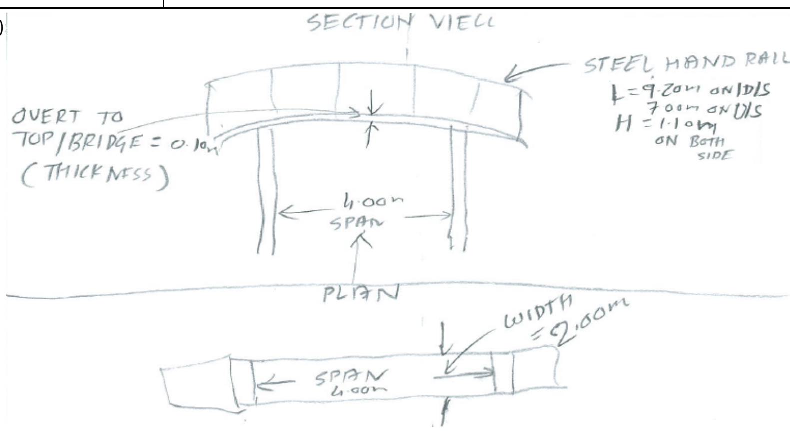
Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 124-126, d/s 127-129
Upstream, invert to obvert = 2.10 m, invert to top = 2.20 m
Downstream, one outlet, invert not available due to ice

Site Sketch (optional):



Description of Photograph: Bridge from downstream

3814513-000

Stream Crossing Field Inventory Sheet

Point A18

Watershed and Location Information	
Date:	27-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Queen Street East West Culvert

Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	No
Height (m) x Width (m):	1.83 x 4.26
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (º):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

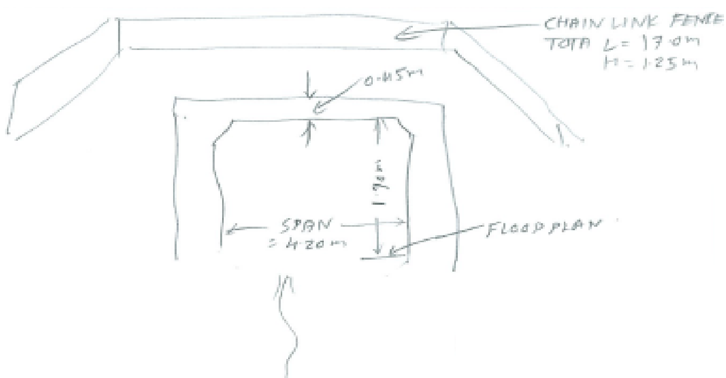
Current Flow Information	
Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Upstream only
Photos: u/s 130-132
flood plain to obvert = 1.90 m
3 outlets inside culvert

Site Sketch (optional):



Description of Photograph: Culvert from upstream

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A19

Watershed and Location Information

Date:	27-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Queen Street East West Culvert, same location as A18

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	No
Height (m) x Width (m):	1.83 x 4.26
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

Flow Present (Y/N):	Y
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Site Sketch (optional):

Description of Photograph:

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A20

Watershed and Location Information	
Date:	26-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Lisa Street

Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	No
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (º):	90
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

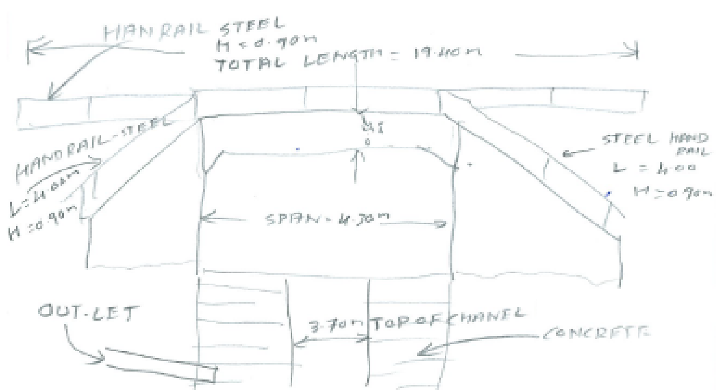
Current Flow Information	
Flow Present (Y/N):	N
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: 104-105
obvert to invert = 1.85 m, top to obvert = 0.55 m
bottom of the channel unvailable due to ice

Site Sketch (optional):



Description of Photograph: Concrete culvert

MMM GROUP   3814513-000

Stream Crossing Field Inventory Sheet

Point A21

Watershed and Location Information	
Date:	26-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Lisa Street

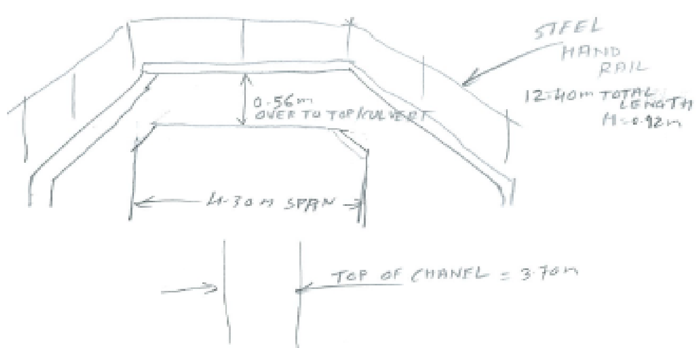
Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	No
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (°):	90
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information	
Flow Present (Y/N):	N
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:	Photos: 106-108 obvert to top = 0.56 m invert and bottom of the channel unvailable due to ice

Site Sketch (optional):



Description of Photograph:	Concrete Culvert

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A22

Watershed and Location Information

Date:	26-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Home Outfitters off of Dixie Road Peel Centre Drive

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	No
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (º):	90
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

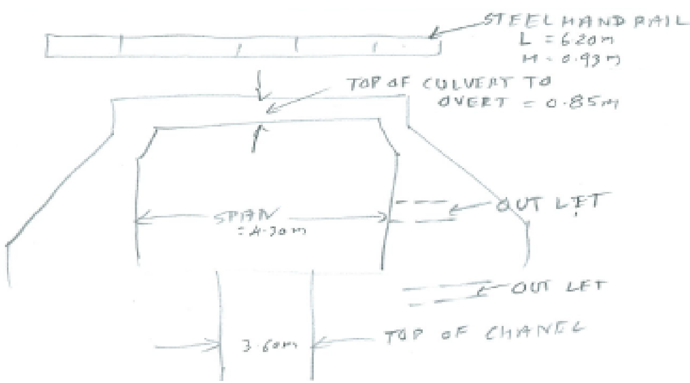
Current Flow Information

Flow Present (Y/N):	
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:	Photos: 109-111 2 Outlets invert and bottom of the channel unvailable due to ice

Site Sketch (optional):



Description of Photograph:	Concrete Culvert

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A23

Watershed and Location Information

Date:	26-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Home Outfitters off of Dixie Road Peel Centre Drive

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	No
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (°):	90
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

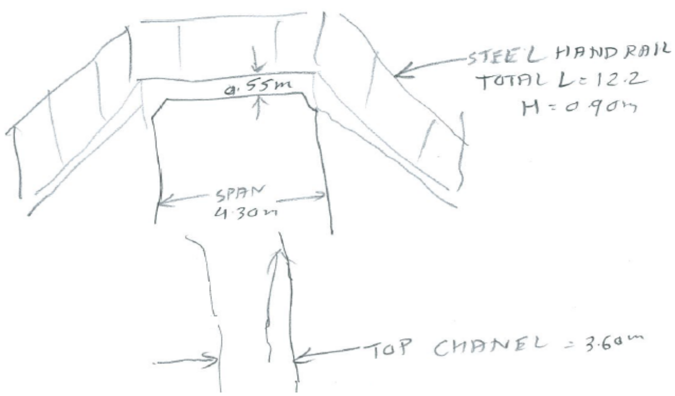
Flow Present (Y/N):	N
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: 133-135
invert and bottom of the channel unavailable due to ice

Site Sketch (optional):



Description of Photograph: Concrete culvert

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A24

Watershed and Location Information

Date:	27-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Beer Store on Peel Centre Drive

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	No
Height (m) x Width (m):	1.83 x 4.27
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (°):	90
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

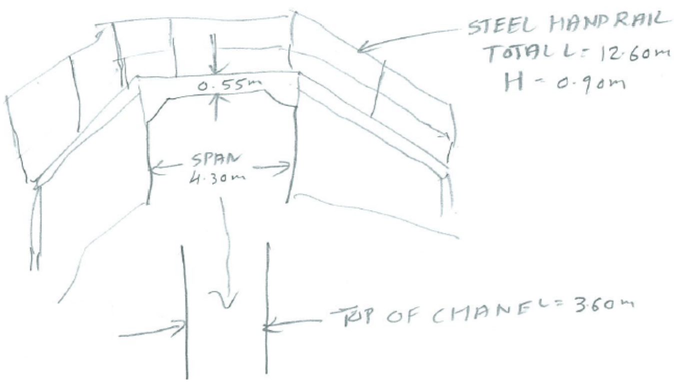
Flow Present (Y/N):	N
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: 136-138
invert and bottom of the channel unvailable due to ice

Site Sketch (optional):



Description of Photograph: Concrete Culvert

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A25

Watershed and Location Information

Date:	27-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Clark Boulevard West Culvert

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	1
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	Y
Height (m) x Width (m):	1.83 x 3.35
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	Headwall
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

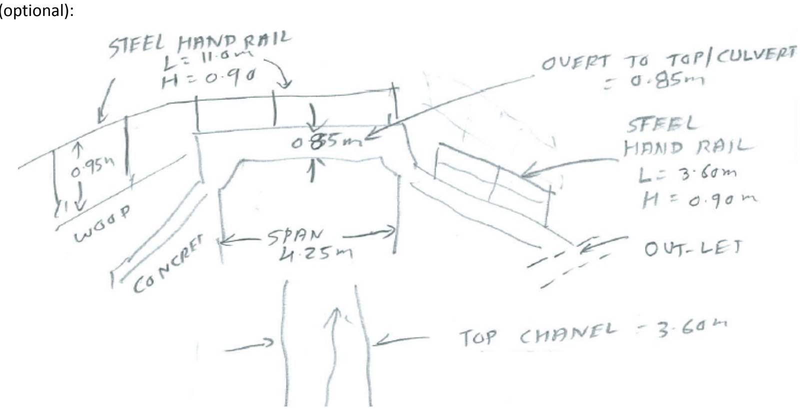
Current Flow Information

Flow Present (Y/N):	N
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:	Photos: 139-141 invert and bottom of the channel unvailable due to ice one outlet

Site Sketch (optional):



Description of Photograph:	Concrete Culvert

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A26

Watershed and Location Information

Date:	27-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	Clark Park

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (º):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

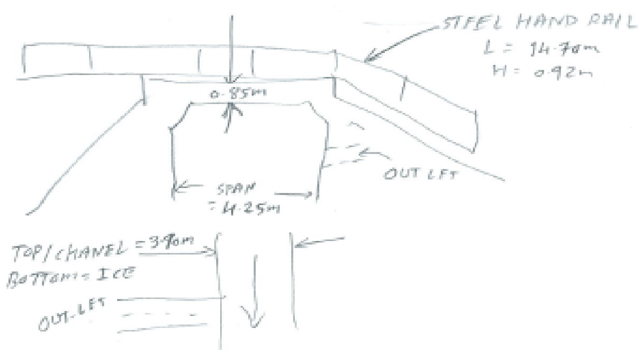
Flow Present (Y/N):	N
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: 142-144
obvert to top = 0.85 m
invert and bottom of the channel unvailable due to ice
one outlet inside culvert and one outlet outside culvert

Site Sketch (optional):



Description of Photograph: Concrete culvert

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A27

Watershed and Location Information	
Date:	27-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	

Structure Configuration and Dimensions	
Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

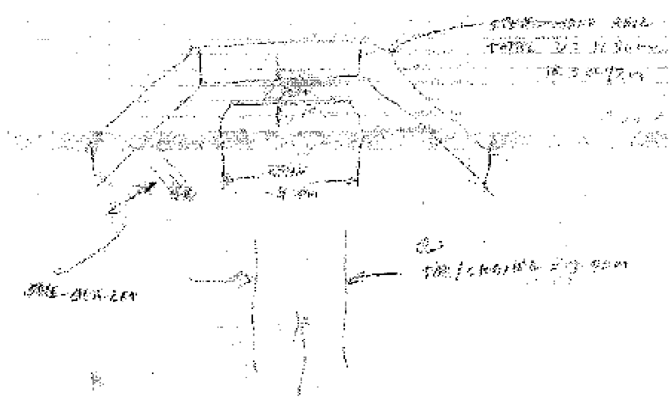
Current Flow Information	
Flow Present (Y/N):	
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: 145-147
obvert to top = 0.55 m
invert and bottom of the channel unvailable due to ice
one outlet

Site Sketch (optional):



Description of Photograph:	Concrete culvert

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A28

Watershed and Location Information

Date:	27-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Culvert
Number of Cells:	
Material (Concrete/Steel):	Concrete
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

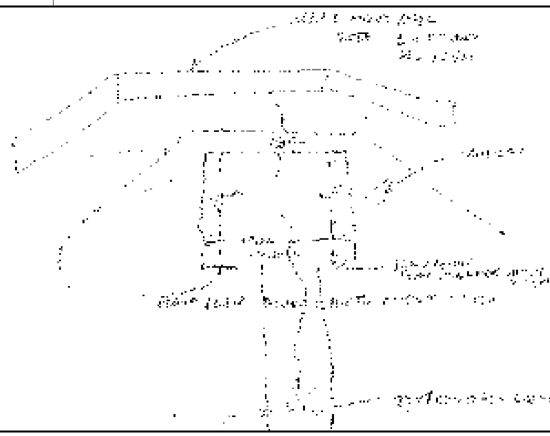
Flow Present (Y/N):	
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:

Photos: u/s 148-150
invert to obvert = 2.00 m, invert to top = 2.35 m, span = 4.25 m
bottom of the channel unvailable due to ice

Site Sketch (optional):



Description of Photograph:	Concrete culvert

MMM GROUP 3814513-000

Stream Crossing Field Inventory Sheet

Point A29

Watershed and Location Information

Date:	27-Jan-15
Field Crew:	BR, JK
Watershed Name:	
Subcatchment Area:	
Tributary Name:	
Flood Plain Map Sheet Number:	
Cross Section Range:	
Municipality:	Brampton
Location (Road Name / Intersection):	

Structure Configuration and Dimensions

Structure Type (Culvert/Bridge):	Bridge
Number of Cells:	
Material (Concrete/Steel):	Steel and Wood
Open Footing (Y/N):	
Height (m) x Width (m):	
Diameter (m):	
Length (m):	24.80
Inlet Type (Projecting/Mitered/Headwall):	
Skew Angle of Crossing (°):	
Height from Obvert to Top of road (m):	
Depth of Siltation (mm):	

Current Flow Information

Flow Present (Y/N):	
Approximate Depth (mm):	
Approximate Velocity (m/s):	
Upstream Erosion (Y/N):	
Downstream Erosion (Y/N):	
Additional Flow Information:	

Site Photograph and Additional Field Notes

Additional Field Notes:	Photos: u/s 151-154, d/s 155-158 upstream, invert to top = 4.50 m downstream, invert to top = 4.55 m, obvert to top = 0.28 m bottom of the channel unvailable due to ice One outlet upstream

Site Sketch (optional):

Description of Photograph:	Bridge from downstream

APPENDIX B

Survey vs. LiDAR Section Comparison

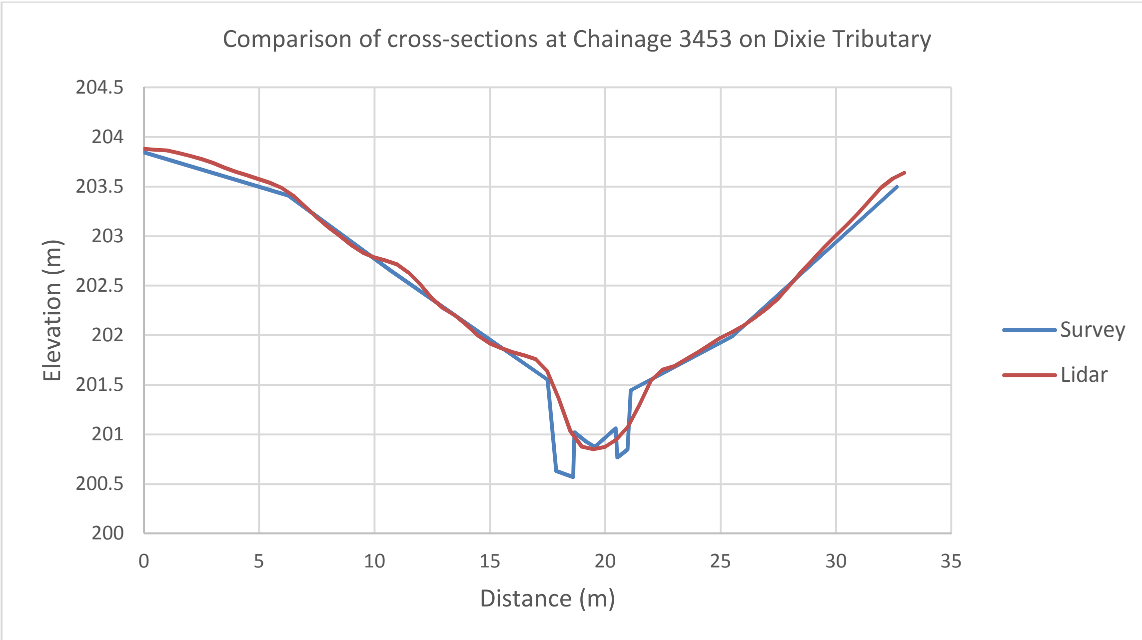


Figure B1: Dixie Tributary cross-section at Chainage 3453 m

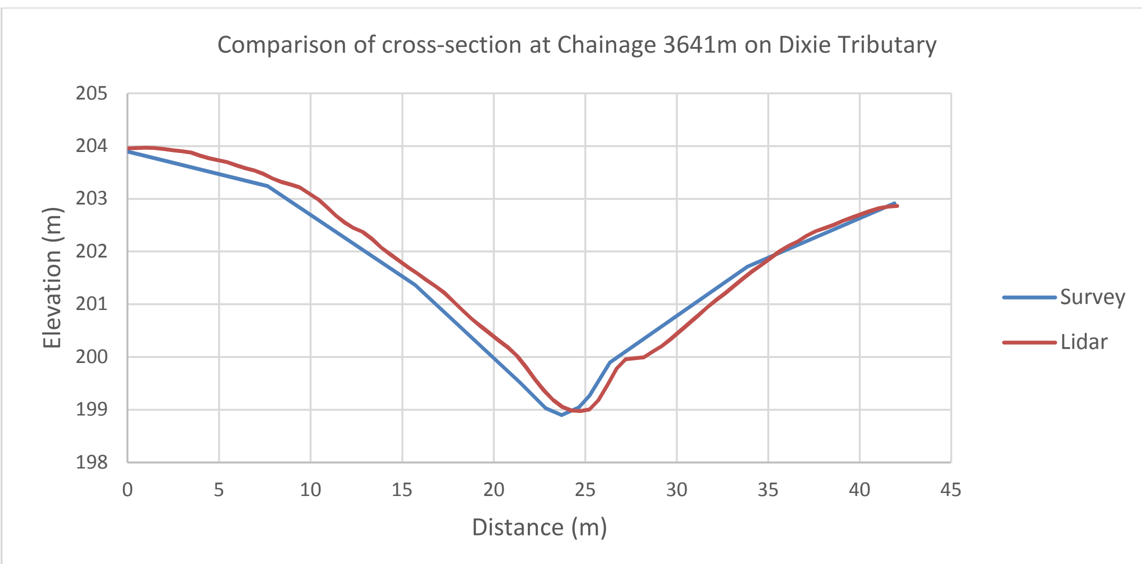


Figure B2: Dixie Tributary cross section at Chainage 3641 m

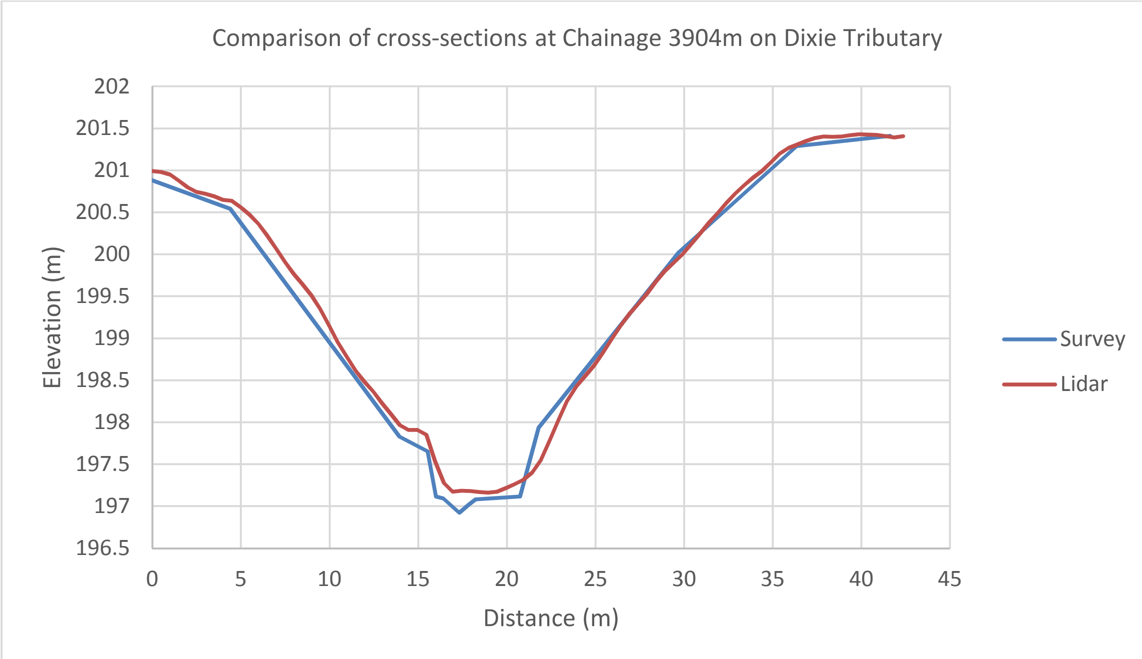


Figure B3: Dixie Tributary cross-section at Chainage 3904 m

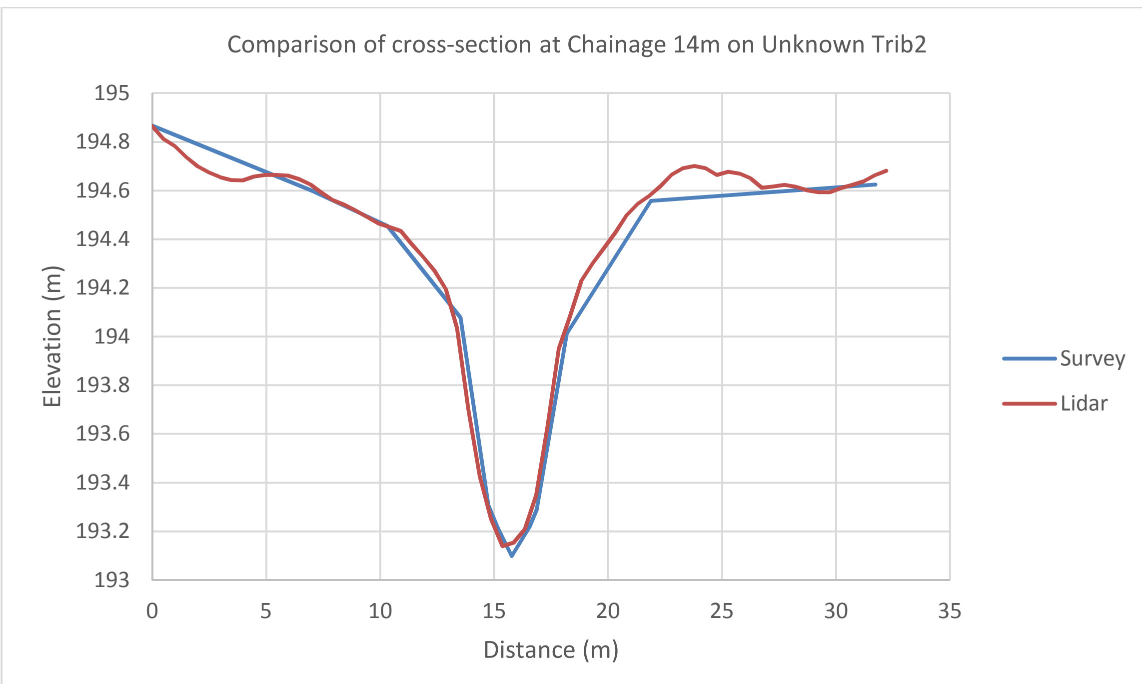


Figure B4: Unknown Trib2 cross-section at Chainage 14 m

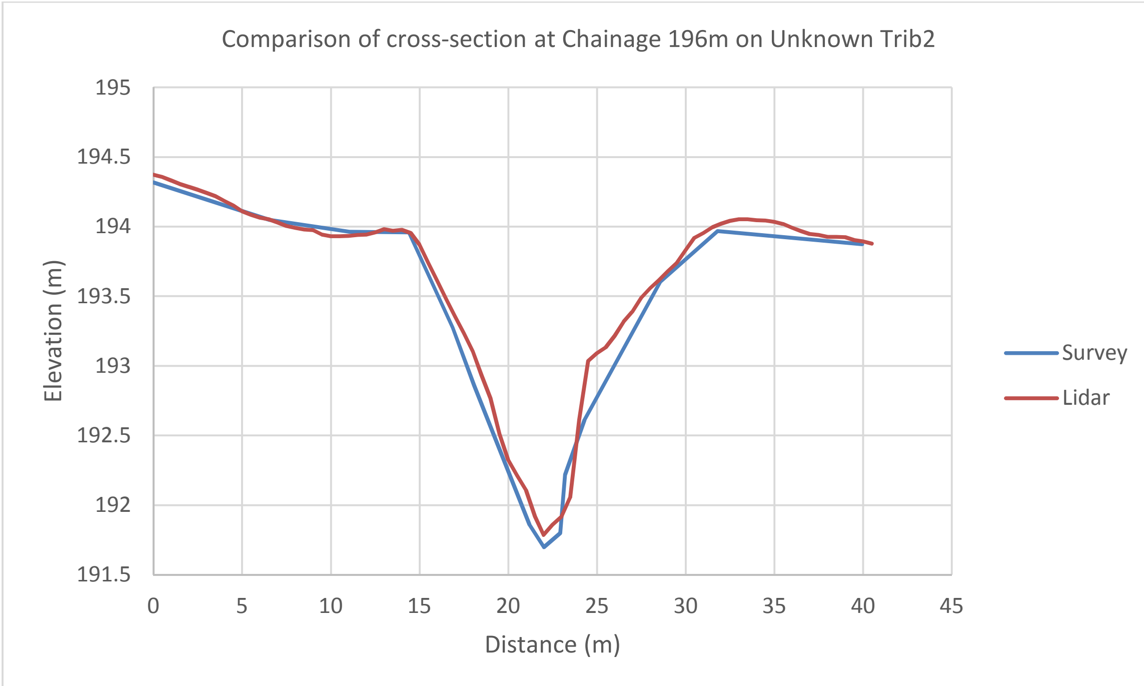


Figure B5: Unknown Trib2 cross-section at Chainage 196 m

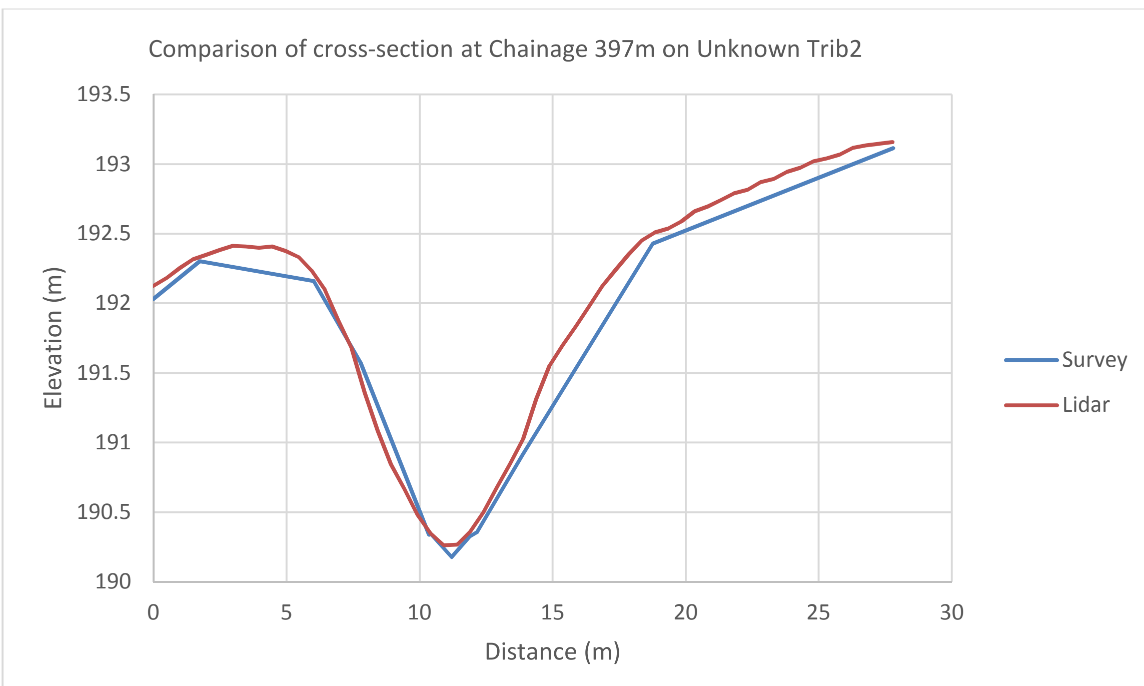


Figure B6: Unknown Trib2 cross-section at Chainage 397 m

APPENDIX C

Culvert Bend Loss and Equivalent Diameter Calculations

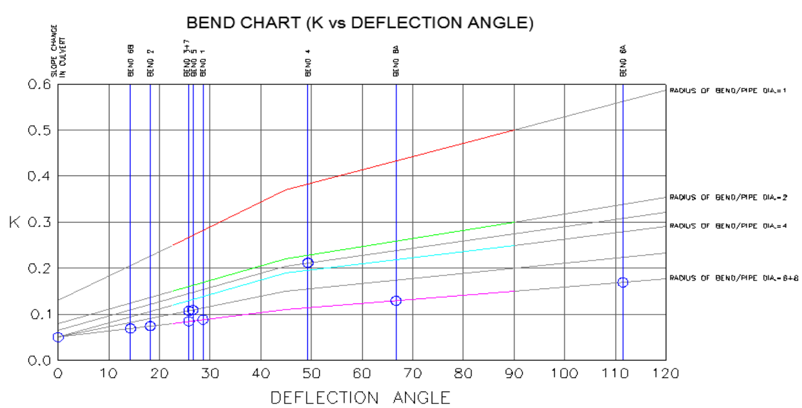
(orange)	Value taken from Opt21, Head Loss Sheet		h_b=k x (V^2/2g)
(yellow)	Automatically Calculated		k=radius of bend/Eq. pipe dia.and deflection angle coefficient
(blue)	K Value taken from Bend Chart		
(cyan)	Automatically Calculated (Added to in Head Loss Calcs for Future Culvert)		

Culvert Characteristics of Clark Blvd Structure						Reg storm		Calculated		
Width	Height	Area	Wetted P.	Hyd. Rad.	Eq. pipe dia.	Flow	Vel.	Eq. Diam.	Eq. Area	
(m)	(m)	(m2)	(m)	(m)	(m)	(m3/s)	(m/s)	(m)		Check
4.27	1.83	7.81	12.20	0.64	3.15	29.75	3.81	3.15	7.81	0.00

Bend Characteristics (Reg Storm)					
Bend	Radius of Bend	Defl. Angle	RadBend/dia.	k	**headloss (h_b)**
	(m)	(deg)	Reg Storm	Reg Storm	(m)
1	33.0	81	10.5	0.12	0.09
2	10.5	44	3.3	0.18	0.13
Total				0.30	0.22

Culvert Characteristics of Queen St Structure						Reg storm		Calculated		
Width	Height	Area	Wetted P.	Hyd. Rad.	Eq. pipe dia.	Flow	Vel.	Eq. Diam.	Eq. Area	
(m)	(m)	(m2)	(m)	(m)	(m)	(m3/s)	(m/s)	(m)		Check
4.30	1.90	8.17	12.40	0.66	3.23	33.84	4.14	3.23	8.17	0.00

Bend Characteristics (Reg Storm)					
Bend	Radius of Bend	Defl. Angle	RadBend/dia.	k	**headloss (h_b)**
	(m)	(deg)	Reg Storm	Reg Storm	(m)
1	10.0	26.4	3.1	0.15	0.13
Total					0.13



d. Bends

(Values of K_L in $h_{L_m} = K_L \frac{V^2}{2g}$, the head loss in excess of that in a straight pipe of equal length)

Radius of bend / Pipe diameter	Deflection angle of bend 90°	45°	22.5°
1	0.50	0.37	0.25
2	0.30	0.22	0.15
4	0.25	0.19	0.12
6	0.15	0.11	0.08
8	0.15	0.11	0.08

Source: Table 11-2-Water Resources Engineering 2nd Edition (Linsley and Franzini)

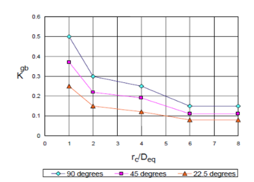


Figure 4.1: Loss Coefficients for Gradual Bends in Conduits Flowing Full (4, 5)

Source:University of Kansas

k coefficients

Radius/Dia	Deflection Angle 90	45	22.5
1	0.50	0.37	0.25
2	0.30	0.22	0.15
4	0.25	0.19	0.12
6	0.15	0.11	0.08
8	0.15	0.11	0.08

Deflection Angle	1	2
90	1,0.5	2,0.3
45	1,0.37	2,0.22
22.5	1,0.25	2,0.15

k vs radius of bend/pipe diameter

Radius/Dia 4	6	8
4,0.25	6,0.15	8,0.15
4,0.19	6,0.11	8,0.11
4,0.12	6,0.08	8,0.08

k coefficients

Defl Angle	Radius/Dia 1	2	4	6	8
90	0.50	0.30	0.25	0.15	0.15
45	0.37	0.22	0.19	0.11	0.11
22.5	0.25	0.15	0.12	0.08	0.08

Defl Angle	1	2
90	90,0.5	90,0.3
45	45,0.37	45,0.22
22.5	22.5,0.25	22.5,0.15

k vs deflection angle

Radius/Dia 4	6	8
90,0.25	90,0.15	90,0.15
45,0.19	45,0.11	45,0.11
22.5,0.12	22.5,0.08	22.5,0.08