Duffins Creek
Floodplain Mapping Update

Toronto and Region Conservation Authority
101 Exchange Avenue, Vaughan, Ontario, L4K 5R6

December 18, 2020

Technical Report

Duffins Creek Floodplain Mapping Update
Contract #1002970
Final Report

Project # TPB198077

Prepared for:

Toronto and Region Conservation Authority
101 Exchange Avenue, Vaughan, Ontario, Canada L4K 5R6

Prepared by:

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December 18, 2020

Wood Project TPB198077

Toronto and Region Conservation Authority
101 Exchange Avenue,
Vaughan, Ontario, L4K 5R6

Attn: Christina Bright, M.A.Sc., P.Eng.
Flood Risk Management Engineering Services

Dear Christina:

RE: Final Technical Report
Duffins Creek Floodplain Mapping Update
Contract #10020970

Wood Environment & Infrastructure Solutions, a division of Wood Canada Limited (Wood), is pleased to provide the Toronto and Region Conservation Authority (TRCA) with this final technical report for the above noted project.

We appreciate the opportunity of providing TRCA with our services and trust this submission is fully satisfactory. If you have any questions with regard to this information, please do not hesitate to contact the undersigned.

Yours truly,

Wood Environment & Infrastructure Solutions,
a Division of Wood Canada Limited

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Michael Todd
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EXECUTIVE SUMMARY

Wood Environment & Infrastructure Solutions, a Division of Wood Canada Limited (Wood) was retained by the Toronto and Region Conservation Authority (TRCA) in June 2019 to update floodplain maps for selected areas of Duffins Creek and its associated tributaries, within the Town of Ajax, City of Markham, City of Pickering, Town of Uxbridge, and the Town of Whitchurch-Stouffville.

The previously available floodplain maps for Duffins Creek consists of a compilation of various mapping bases and models which have been periodically updated (dating between approximately 2004 and 2017). Since the last comprehensive floodplain mapping update for the study area, a substantial amount of development has occurred within the watershed, including some channel and corridor realignments, and the construction of additional hydraulic structures.

Recognizing this, TRCA obtained more current topographic data (2015 LiDAR, with selected updates using 2019 LiDAR as noted in subsequent sections). Flows are primarily sourced from the previously completed Duffins Creek Hydrology Study Update and Addendum (2013).

The update of floodplain maps for the Duffins Creek study area has focused on the following key tasks:

- Background Review and Site Reconnaissance

  Various datasets and other information have been provided by TRCA through the course of the project. This information has been reviewed and used in the development of the floodline mapping as deemed relevant. This information included basemap/planimetric data, existing hydraulic modelling for the subject watercourses, topographic surveys, as-built drawings, existing reports, aerial imagery and flow data.

  Pre-screening and site reconnaissance of the three hundred and seven (307) long-listed watercourse crossings (road, rail pedestrian, etc.) initially identified from a review using Google Earth Pro™ as being located along Duffins Creek and its tributaries within the study area was completed. From this reconnaissance, two hundred and twenty (221) crossings have been identified for inclusion in the hydraulic model as they have been deemed to be of hydraulic significance. Placeholders for an additional four (4) structures have been incorporated into the model as well.

- HEC-RAS Model Development

  The objective of the hydraulic analysis has been the computation of water surface elevations resulting from the 2-year through 100-year design events and Regional Storm (Hurricane Hazel) flows. The computed water surface elevations are used in conjunction with the LiDAR data to delineate the limits of the floodplain on topographic mapping sheets. Please note that

the assessment of the 350-year design events was not included in the scope as per TRCA direction, as this event was not simulated in the original hydrology study. The US Army Corps of Engineers (USACE) HEC-RAS one-dimensional backwater model has been utilized for this analysis.

The collection and processing of data, computational procedures and analysis of computed profiles completed for this study are compliant with Environment Canada, MNRF and TRCA guidelines, software use guidance provided by the US Army Corps of Engineers, Public Safety Canada, and other industry standard hydraulic modelling practices.

A sensitivity analysis of parameters (Manning's Roughness, Peak Discharge, and Starting Water Surface Elevation) included in the new hydraulic model has been completed. It has been concluded from this analysis that there was no need to alter the parameterization of the hydraulic model for the present study.

- Flood Risk Characterization and Screening

Upon receipt of TRCA approval for the new hydraulic model, preparation of the floodplain delineations for the required suite of flow scenarios required for this assignment has been completed in collaboration with TRCA. The flow scenarios have been the Regional Storm and, the 2, 5, 10, 25, 50, and 100-year design storms.

The delineation of the Regulatory floodline has been completed in compliance with MNRF procedures, whereby the greater of the 100-year, or Regional (Hurricane Hazel) Flood inundation limits has been used to establish the Regulatory floodline. The 100-year and Regional Flood inundation limits have been subjected to a greater level of scrutiny for accuracy commensurate with an engineering flood delineation approach.

Flood inundation limits for the 2, 5, 10, 25, 50, and 100-year design storm flow scenarios have not been subjected to the same "clean-up" effort as the engineered flood delineations as these flood zones are to be used for flood risk screening and characterization only.

A structure overtopping assessment has been completed with regard to the watercourse crossings included in the new hydraulic model. The following conveyance capacity limitations have been identified from the hydraulic model results:

Flow Scenario	# of crossings having conveyance capacity for the noted flow scenario without overtopping
2-year	211
5-year	207
10-year	202
25-year	193
50-year	187
100-year	181
350-year	n/a
Regional Flood	85

The results indicate that eighty five (85) structures, of the two hundred and twenty-one (221) structures modelled, have sufficient capacity to convey the Regional Flood without overtopping.

An assessment of spill locations and paths has been completed following the MNRF's Technical Guide River & Stream Systems: Flooding Hazard Limit (2002) (ref. Section 4.13 of the guidelines) which defines a spill as occurring when flood levels overtop the banks of a watercourse and spill overland away from the watercourse channel. In this context, thirteen (13) spill areas have been identified within the study area for this project listed as follows:

- Spill Area 1 is located along Stouffivlle Creek (Reach 1) near Park Drive in the Town of Whitchurch-Stouffville. Any potential spill appears to be generally to the south and towards existing residential areas. This spill is a concern as it may impact the local recreational centre and downstream residential areas. Any future assessment should also consider grading changes due to the recent expansion of the site which may affect the spill pathway(s).

- Spill Areas 3 and 4 are located along Whitevale Creek (Reach 2 and Tributary A2, respectively) directly upstream of Highway 407 to the west of Whites Road in the City of Pickering. The spill pathway appears to be westerly towards West Duffins Creek. The spill is a concern given the width and also potential impacts to a 400 series Highway and warrants further assessment.

- Spill Area 5 is located along West Duffins Creek (Tributary A2) parallel to Sideline 26 in the City of Picking. The spill is westerly towards the adjacent tributary (B1). Given the magnitude of the spill and that the branches confluence approximately 500 m to the south, this location is not considered a primary spill of interest.

- Spill Area 6 is located along Mitchell Creek (Tributary C2) immediately upstream of the CNR tracks near Sideline 20 and 9th Concession in the City of Pickering. The spill would be southerly towards the adjacent watercourse (Michell Creek Tributary D1). The area is rural in nature and given that the two tributaries approximately 400 m downstream this location is not considered a primary spill of interest.

- Spill Area 7 is located along East Duffins Creek (Tributary C1) directly downstream of Westney Road North, north of Highway 407 in the City of Pickering. Spill is southerly towards a depression north of Highway 407. Given the small flow and rural nature of the study area, this location is not considered a primary spill of interest.

- Spill Area 8 is located along Brougham Creek (Tributary A1) near Highway 7, west of Paddock Road. The spill pathway appears to be easterly towards East Duffins Creek, however, has the potential to impact the Pickering Museum Village Site as well as the roadways along the spill pathway, and as such warrants further assessment.

- Spill Area 9 is located along Ganatsekiagon Creek (Reach 1) just upstream of a private structure (former rail line) to the north of Taunton Road in the City of Pickering. The spill would likely be split between return flow towards the structure and potential spill to the south towards Taunton Road and then ultimately east back to the same watercourse. Although the spill does not have the potential to directly impact area properties there is the potential for some impact to Taunton Road (an arterial roadway) and thus may warrant further review.

- Spill Area 10 is located downstream of Spill Area 9 along Ganatsekiagon Creek (Reach 1), south of Taunton Road and upstream of the CNR tracks, within the City of Pickering. Spill would tend to accumulate in a low point directly west, and likely return to the main branch. Given the preceding, this location is not considered a primary spill of interest.

- Spill Area 11 is located along Millers Creek (Reach 1) along the right overbank at Taunton Road West (west of the CNR) in the Town of Ajax. The spill has the potential to impact a recently constructed residential development. Given this, and the complex hydraulics (three sequential hydraulic structure crossings in close proximity to one another), a more detailed hydraulic assessment is likely warranted.

- Spill Areas 12 and 13 are located directly in series along Millers Creek (Reach 1) at Highway 401 in the Town of Ajax. The crossing is complex (multiple different opening sizes along its length) and was modelled separately by TRCA using a PCSWMM model to confirm appropriate geometry for HEC-RAS and also internal boundary condition water levels. The spill in this case is expected to be westerly towards the main branch of Duffins Creek. Given the magnitude of the likely spill and the impact to a 400-series highway, further hydraulic assessments is considered warranted.

All graphical representations of the new hydraulic model computations have been prepared and submitted to TRCA in accordance with the requirements for this study. The finalization of the study geomatic deliverables has been completed in collaboration with TRCA.

A number of recommendations have been advanced as outcomes of the foregoing assessment, as outlined below:

1. Given their potential to impact a broad area and/or transfer of flow to another watercourse, the following spill areas should be further assessed: 1, 3, 4, 8, 9, 11, 12 and 13. Further assessment should include quantification of the spill flow to determine if it exceeds MNRF's 10% peak flow threshold and enhanced modelling to better delineate floodplains and to better understand flood risk associated with those properties in the spill zones.

2. While this floodplain mapping update assessment has been based on best available data at the time of the project, some aspects of the modelling have been developed based on limited information. Further, obtaining information, with particular reference to watercourse crossing structures, has required significant effort and, depending on the source organization, significant expense. It is therefore recommended the TRCA develop an in-house data store for watercourse crossing structures and maintain on-going liaison with local municipalities and other organizations (e.g. railways, MTO, 407ETR, etc.) to maintain this database.

3. Where new data becomes available for watercourse re-alignments or hydraulic structures, updates to the model should be undertaken. Hydraulic crossing structures presently included in the Duffins Creek hydraulic model, TRCA should assess whether remodelling of the structure with the new data would result in a significant change in computed water surface elevations and resultant floodplain limits.

4. The implications of climate change influenced rainfall on peak flow estimation for Duffins Creek, and other watersheds in their jurisdiction, should be investigated to better understand the potential for expansion of the 100-year flood inundation limits (and those associated with other return period based events) and generally increased flooding in the future.

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1.0 Introduction

Wood Environment & Infrastructure, a Division of Wood Canada Limited (Wood), was retained by the Toronto and Region Conservation Authority (TRCA) in June 2019 to update floodplain maps for the defined reaches of the Duffins Creek and its associated tributaries within the Regions of Durham and York, located east of Toronto. The Duffins Creek watershed has its headwaters in the Towns of Uxbridge and Whitchurch-Stouffville and its outlet at Lake Ontario in the Town of Ajax.

The study area for the current project includes areas within the Town of Ajax, City of Markham, City of Pickering, Town of Uxbridge, and the Town of Whitchurch-Stouffville (ref. Figure 1-1). The specific limits of the current study are presented in Figure 1-2.

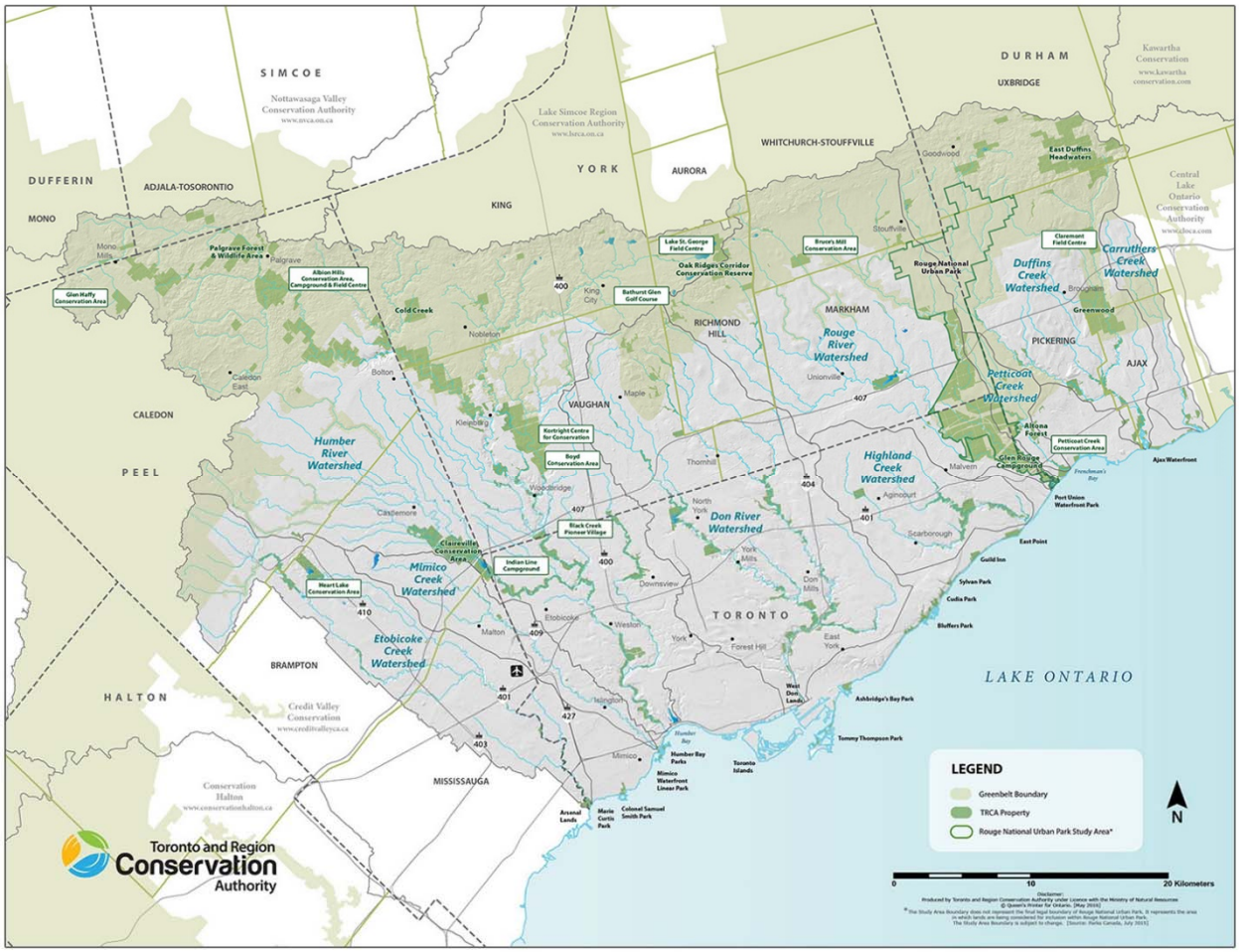

Figure 1-1 Duffins Creek Watershed - Regional Context

(Image Source: TRCA Watershed Map)

The existing floodplain maps for the study area (Figure 1-2) consists of a compilation of various mapping bases and models, which have been modified and revised throughout the years by MMM Group Limited (MMM, 2004), Greck and Associates Limited (Greck, 2005), R.J. Burnside & Associates Limited (RJB, 2007, 2008 and 2014), GHD Group (GHD, 2017) and, Valdor Engineering Inc. (Valdor, 2018). Since the last comprehensive update, a substantial amount of development has occurred within the watershed which included channel and corridor realignments and the construction of a number of new watercourse crossings, all of which is not reflected in the current base mapping.

Floodplain maps for the Seaton lands were updated in 2017 by GHD. However, the topographic data utilized for this area was based on DEM developed from 2002 base mapping which was augmented by 2011 topographic data acquired from First Base Solutions. It is expected that recently acquired LiDAR information (2015) will provide a greater degree of accuracy within these areas. The Pickering Ajax Special Policy Area (SPA) was updated as part of the Pickering Ajax SPA 2D Modeling and Dyke Assessment Study by Valdor in 2018 and does not need to be updated as part of this study.

The intent of this project is to complete a comprehensive floodplain mapping update within the Duffins Creek watershed. The floodplain mapping update has been based on the latest version of the HEC-RAS engine (i.e. version 5.0.7), new topographic information as developed using TRCA's 2015 LiDAR data (with selected application of more current 2019 LiDAR data as required), and application of flow data as developed through the 2012 Duffins Creek Hydrology Study Update and 2013 Duffins Creek Hydrology Update Addendum by Aquafor Beech Ltd).

This report summarizes the development of a new hydraulic (HEC-RAS) model and floodplain mapping defining various annual exceedance probability (AEP) flood risk for watercourse reaches within the study area, as illustrated in Figure 1-2.

1.1 Overview of the Duffins Creek Watershed

The Duffins Creek watershed spans 283 km^2 of land and water in the Regions of Durham and York, Cities of Pickering and Markham, and the Towns of Uxbridge, Ajax and Whitchurch Stouffville. The watershed includes all the lands that drain to the Duffins Creek and its tributaries, including the two major branches, the West and East Duffins Creeks, starting in the Oak Ridges Moraine and flowing south to the Lower Main Duffins prior to discharging into Lake Ontario.

Both major branches have a number of contributing tributaries; the West Duffins Creek receives drainage from the Stouffville, Reesor, Major, Whitevale and Wixon Creeks, and the East Duffins Creek receives drainage from the Mitchell, Spring, Brougham, Urfe and Ganatsekiagon Creeks. In the lower portion of the watershed, downstream of the confluence between the West and East branches, Millers Creek is a tributary to the Lower Main Branch prior to outlet at Lake Ontario.

Based upon the Duffins Creek Watershed Report Card (TRCA, 2018), the land use within the Duffins Creek watershed today is approximately 40% rural, 18% urban, and 42% natural cover, which is the highest proportion of natural cover within TRCA jurisdiction. The natural cover is distributed throughout the Duffins Creek watershed, with both the headwaters and central of the watershed

exhibiting the most natural cover. Over 70% of the population in the Duffins Creek watershed is within 300 m of natural cover which is greater than 1 ha in size.

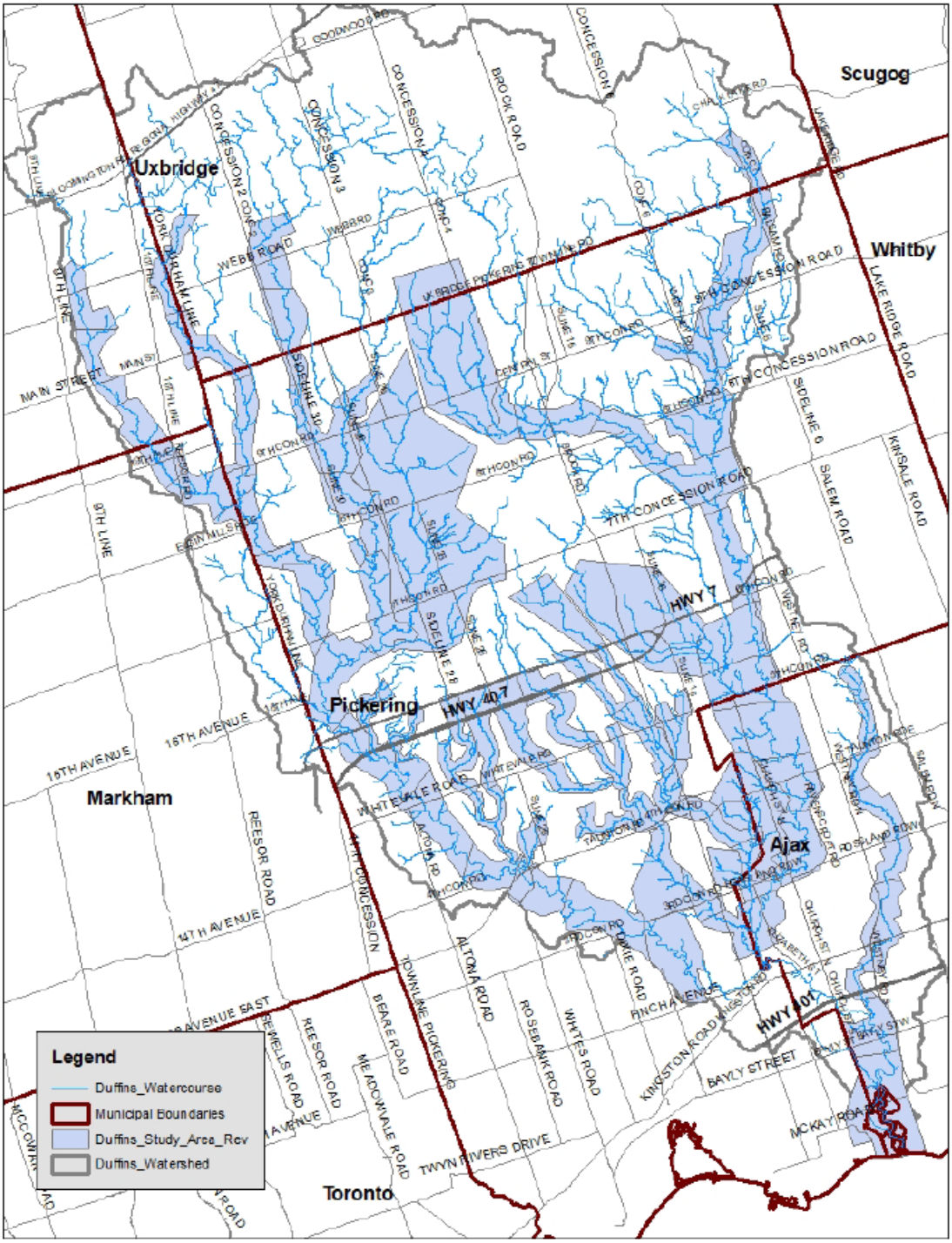

Figure 1-2 Duffins Creek Floodplain Mapping Update Project – Study Area

(Source: TRCA)

1.2 Work Scope and Report Structure

This study has been focused on the development of new floodplain mapping for select reaches of the Duffins Creek and tributaries. The key tasks comprising this study are outlined below:

- **Task 1 - Background Review and Inventory**
  - Task 1A Hydraulic Structure Identification and Background Data Review
  - Task 1B Preparation of a Digital Elevation Model (DEM) using TRCA LiDAR data
  - Task 1C Site reconnaissance of all of the structures within scope of the assignment
  - Task 1D Development of a HEC-RAS steady-state flow table
  - Task 1E Development of a HEC-RAS boundary conditions
  - Task 1F Collection of watercourse crossing as-built information
- **Task 2 – HEC-RAS Model Development**
  - Task 2A Development of the new HEC-RAS hydraulic model
  - Task 2B Determination of watercourse crossings model coding data source(s)
  - Task 2C Field survey of watercourse crossings
- **Task 3 - Spill Identification and Floodplain Mapping**
  - Task 3A Floodline Mapping and Identification of Spills
  - Task 3B Development of a suite of graphical representations of information computed with the HEC-RAS model
  - Task 3C Quality Assurance/Quality Control
- **Task 4 - Preparation of a Draft Technical Report Summarizing All Technical Work**
- **Task 5 - Preparation of Final Deliverables**

The following report sections have also been structured to follow the key tasks.

2.0 Background Review and Inventory (Task 1)

2.1 Task 1A: Hydraulic Structure Identification and Background Data Review

2.1.1 Task 1A.1: Hydraulic Structure Identification

As noted in the Terms of Reference, TRCA identified approximately 255 stream crossings within the study area limits, which included approx. 41 pedestrian/trail crossings. Of these identified stream crossings, approx. 160 of the crossings have been modeled previously.

Wood, at the outset of the project, developed a database of hydraulic structures crossing any of the watercourses, and other in watercourse phenomena relevant to hydraulic modelling, included in the study scope, as defined in the RFP, based upon visual interpretation of features using Google Earth Pro™. This review was based on the study boundary figure provided with the RFP. This initial review identified a long-list total of 307 crossings. An initial screening of this long list was undertaken in conjunction with TRCA, which identified crossings which were either not apparent (not on the watercourse/removed at some point in time, or not constructed yet – future crossing) or immediately identified as not hydraulically significant (golf cart or pedestrian bridges). Further review was undertaken through field verification (refer to Section 2.3) to confirm information and whether or not the structure warranted inclusion. In addition, the final structures to be included were affected by minor revisions to the reaches included in the final modelling and floodplain mapping effort, which included some changes from the reaches indicated in Figure 1-2. Through this process, a final list of 221 structures was determined, and a further 4 placeholder cross-sections for future structure coding. The following is noted:

- A number of the structures identified included grade changes, on-line ponds, spillways and other on-line structures. These were identified to prompt discussion in regard to whether or not these features should be included in the new hydraulic model.
- A number of features were identified that could not be specifically recognized as watercourse crossings. It was clear from the Google Earth Pro© review that something was in or over a study watercourse, but the exact nature of the feature could not be determined.
- Of the 307 structures identified, a preliminary review of their hydraulic significance (including location relative to final selected study reaches) was conducted with TRCA, which concluded that 225 structures (221 directly incorporated and 4 placeholder locations) should be included in the new hydraulic model.

Table 2-1 Review of Hydraulic Structure Significance

Hydraulically Significant or Relevant?	Number of Structures
Yes (included)	221
Yes (future inclusion)	4
No	82

Of the 82 hydraulic structures ultimately not included in the modelling, structures were not included because:

- The hydraulic structure was out of scope (beyond the final agreed upon limits of hydraulic modelling and floodplain mapping) – 53 hydraulic structures;
- The hydraulic structure was not significant (pedestrian or golf cart bridges which would have little if any effect on floodplain elevations or extents) – 22 hydraulic structures; or
- The hydraulic structure was not present (future planned crossing or crossing has been removed since previous modelling or mapping) – 7 hydraulic structures.

This summary is presented graphically in Figure 2-1.

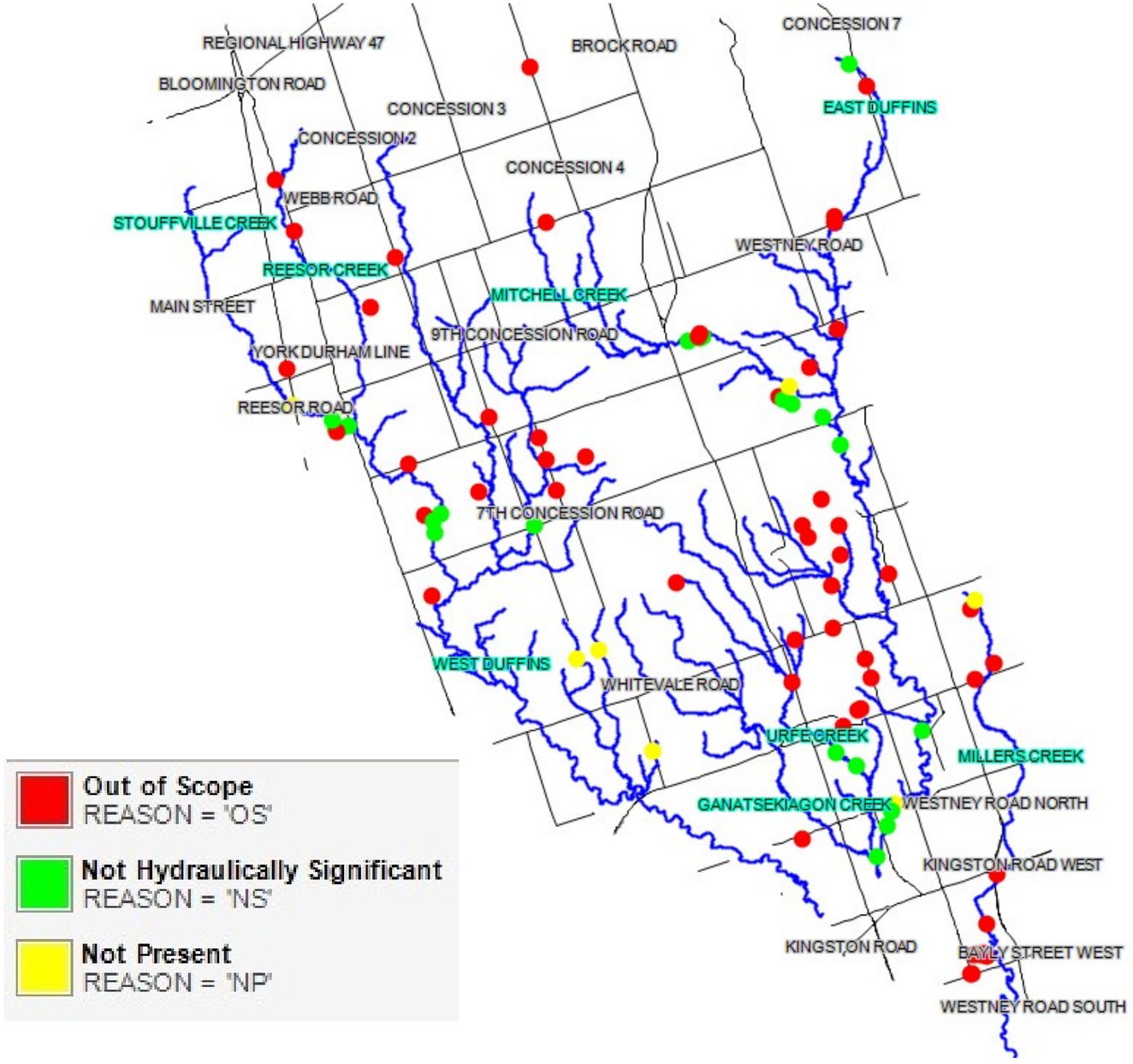

Figure 2-1 Hydraulic Structures not Included in HEC-RAS Modelling

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2.1.2 Task 1A.2: Background Data Review

Various datasets and other information were provided by TRCA at the beginning, and through the course, of this project. This information was reviewed and used in the development of the floodline mapping as deemed relevant. The various datasets and other information included:

- Various basemap data in shapefile format, including: municipal boundaries, contours, building footprints, roadway and railway, crossing locations, land uses, watercourse centerlines, current floodplain limits, Duffins Creek Hydrology flow nodes, and study area boundaries.
- Existing HEC-RAS models for various sections of Duffins Creek were provided in catchment specific models and the Seaton Lands models, which contained information for the following components of Duffins Creek:
  - Brougham Creek
  - East Duffins Creek
  - Ganatsekiagon Creek
  - Lower Duffins Creek
  - Mitchell Creek
  - Reesor Creek
  - Stouffville Creek
  - West Duffins Creek
  - Wixon Creek
- Construction and/or as-built drawings of structures from TRCA, the relevant municipalities, Metrolinx, 407ETR, Canadian Pacific Railway (CPR), and the Ontario Ministry of Transportation (MTO),
- Background documentation, including:
  - Seaton Lands Floodline Mapping Study Update, December 2017, including associated HEC-RAS model
  - Stouffville Dam Downstream Flood Remediation Study, June 2019, including the associated survey of the reservoir outlet structure
  - Standard Manning's Roughness Coefficients for TRCA Watershed Hydraulic Modelling document
  - Hydraulic Structure Inventory Sheet template document
- Various other digital data, including:
  - LiDAR data in 1-m ESRI Grid format, having vertical datum CGVD 1928 with the Southern Ontario Adjustment of 1978
  - 15 cm Orthographic Aerial Imagery (2015)
  - Topographic surveys of the watercourse in select locations where available
  - Peak Flows in Microsoft™ Excel file format & associated shapefile for locations
  - Lake Ontario water levels
  - Water level boundaries extracted from the Pickering Ajax SPA 2D Modeling Study

2.2 Task 1B: Preparation of a Digital Elevation Model

The 1-m ESRI Grid format LiDAR data (2015) provided by the TRCA was used to develop a Digital Elevation Model (DEM) for use in the study. The DEM defined the base topography for the HEC-RAS model, was used to generate cross-section geometry data (i.e. station/elevation pairings) and supported floodplain delineation. In addition to the primary use of the 2015 LiDAR data, more current 2019 LiDAR data was used in selected locations where recent changes in channel geometry due to development or other changes were apparent, and where the 2015 LiDAR data would not reasonably represent current topography. The areas for which 2019 LiDAR data has been utilized are demonstrated in Figure 2-2.

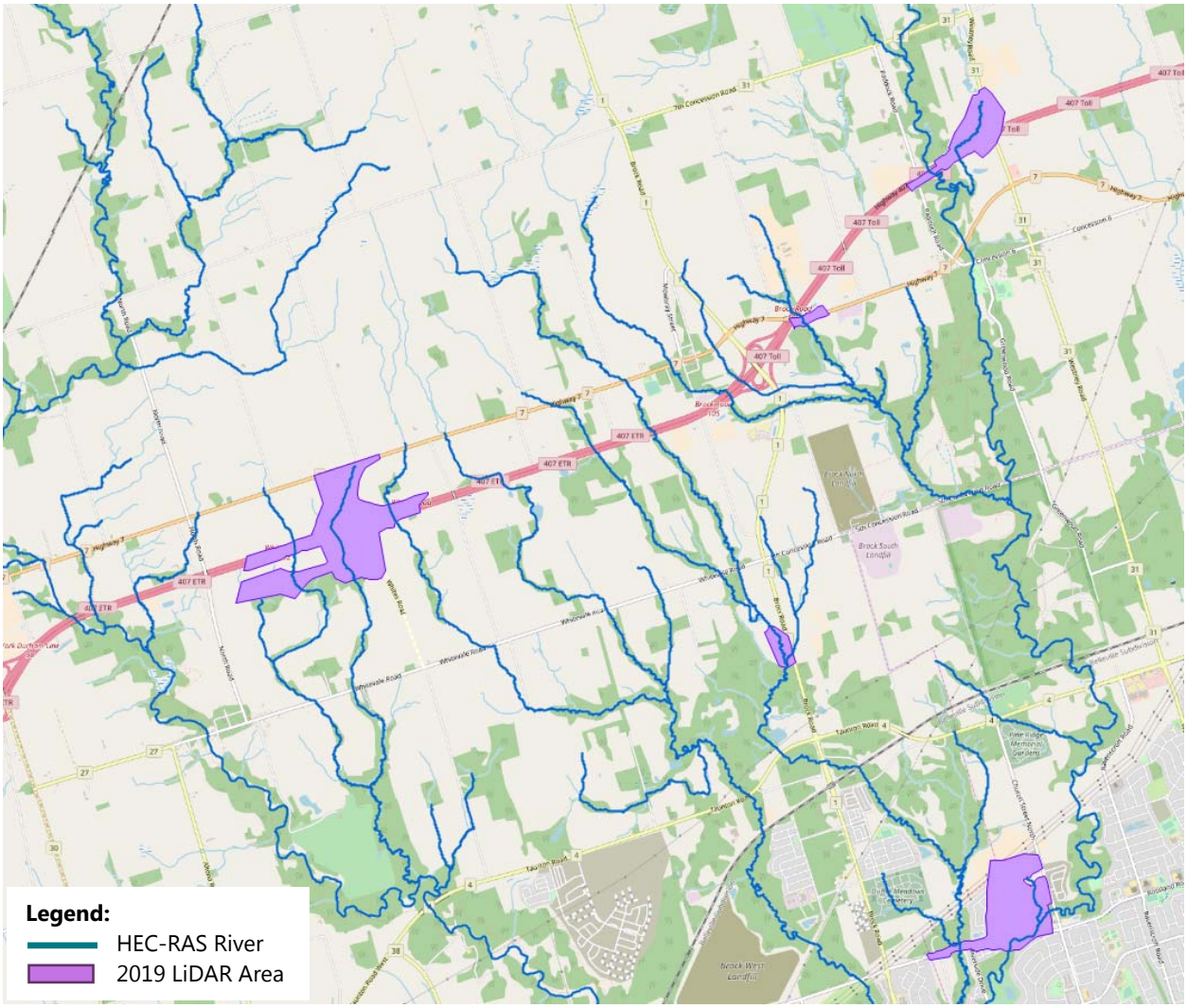

Figure 2-2 2019 LiDAR Mapping Areas

2.3 Task 1C: Watercourse Crossings Reconnaissance

As noted from Task 1A.1, a total of three hundred and seven (307) watercourse crossings (road, rail, pedestrian, etc.) were identified, from a review using Google Earth Pro™, as being located along the Duffins Creek and tributaries within the study area.

Of this total, two hundred and twenty-five (225) crossings were identified for inclusion in the hydraulic model as they were deemed to be of hydraulic significance. Each of the structures identified for inclusion in the HEC-RAS model was subject to reconnaissance as noted in Task 1C, where the reconnaissance effort could be completed safely. An information summary for these structures is provided in Table 2-4, which includes an identification of the data type used to complete the structure coding in the hydraulic model.

The remaining 82 crossings (ref. Table 2-1) were either not deemed to be of hydraulic significance, were identified as being out of scope of the study, or a structure could not be identified in the field and were therefore not included in the hydraulic model.

Summary information for all watercourse crossings within the study area that were included in the site reconnaissance program is provided in Appendix A.

2.4 Task 1D: HEC-RAS Steady-State Flow Table Development

A HEC-RAS steady flow data table was developed and refined during the study. The flow data, provided by the TRCA, was obtained from the 2012 Duffins Creek Hydrology Update and 2013 Duffins Creek Hydrology Update Addendum (Aquafor Beech Ltd). The 2 year through 100-year storm event peak flow data assigned in the steady flow table were based on an Existing Conditions model scenario, which includes existing SWM facilities within the Duffins Creek Watershed. The Regional Storm event peak flow data assigned in the steady flow table is understood to exclude any impacts from existing SWM facilities, as per Provincial Policy.

The following flow processing information provides context for the development of the steady flow data:

- TRCA initially provided a suite of 190 flow nodes to be reviewed as possible flow change locations.
- The flow nodes were initially filtered to ensure that all Regional Flood flows were increasing as the model progressed downstream (i.e. remove any decreasing flow nodes, likely due to routing in the hydrology model). Flow nodes which had consistent flows (i.e. 0% change) which are assumed to be routing nodes with no additional contributing catchments, were also removed where applicable given that they were unnecessary.
    - TRCA then completed a review of the filtered flows and requested that all 190 flow nodes provided be maintained and included within the steady flow data, despite slight decreases in peak flow (likely due to hydrologic routing).

- Appropriate HEC-RAS cross-sections for flow change locations were then determined; the flows have been conservatively been defined in the HEC-RAS model at the upstream extent of a reach as is standard practice. Additionally, flow changes within the four (4) cross-sections associated with a hydraulic structure have been avoided when possible.

Based on the final flows incorporated in the model, the change in flows moving downstream have been reviewed to denote any increases exceeding 10% (ref. Table 2-2). Decreases exceeding 10% (due to routing effects as noted previously) have not been considered. An illustration of the locations of the corresponding flow nodes used for development of the HEC-RAS steady flow data table has been provided in Appendix E.

The majority of the flow change exceedances have been identified to be related to small contributing catchments and flows which result in a large differences (%) but minimal increases in absolute flow. Nonetheless, it is recommended that TRCA review the hydrologic modelling in these areas to assess the possibility for additional flow nodes to reduce the number of flow exceedances (> 10%) and update the hydraulic modelling as needed.

Table 2-2: List of Flow Nodes with Flow Change Increases Exceeding 10%

River and Reach	Flow Node ID / Associated Flow (m^3/s)				Difference (%)
	Upstream		Downstream		
Brougham Creek - Reach 4	JN112	12.97	JN111	18.43	42%
Brougham Creek - Reach 4	JN111	18.43	JN65	21.18	15%
Brougham Trib D - Trib D1	JN110	4.10	JN69	4.89	19%
E Duffins Trib E - East E1	JN102	6.92	JN9	8.97	30%
E Duffins Trib F - East F1	JN103	1.12	JN71	2.14	91%
Ganatsekiagon B - Trib B1	JN93	7.91	JN94	16.43	108%
Ganatsekiagon B - Trib B1	JN94	16.43	3403	27.02	64%
Ganatsekiagon Ck - Reach 4	JN96	6.96	JN95	17.87	157%
Ganatsekiagon Ck - Reach 4	JN95	17.87	JN59	21.04	18%
Ganatsekiagon Ck - Reach 1	JN92	54.12	JN91	67.18	24%
Ganatsekiagon Ck - Reach 1	JN91	67.18	3304	74.87	11%
Millers Creek - Reach 1	JN72	12.89	5603	28.80	123%
Millers Creek - Reach 1	5603	28.80	JN73	39.27	36%
Millers Creek - Reach 1	JN73	39.27	JN74	49.90	27%
Millers Creek - Reach 1	JN74	49.90	5512	56.77	14%
Millers Creek - Reach 1	5512	56.77	JN75	73.19	29%
Millers Creek - Reach 1	JN75	73.19	JN76	93.52	28%
Millers Creek - Reach 1	JN76	93.52	JN77	128.49	37%
Mitchell Creek - Reach 4	JN105	12.29	JN104	16.47	34%
Mitchell Creek - Reach 4	JN104	16.47	JN23	23.58	43%
Mitchell Creek - Reach 2	111	80.36	JN108	97.50	21%
Reesor Creek - Reach 3	2207	37.96	JN87	43.88	16%
Reesor Creek - Reach 3	2006	48.07	101	60.47	26%
Stouffville Ck - Reach 1	1700	29.60	JN90	39.56	34%
Stouffville Ck - Reach 1	JN90	39.56	JN89	51.14	29%
Stouffville Ck - Reach 1	100	62.64	1402	76.16	22%
Urfe Creek - Reach 6	JN97	10.64	3903	13.39	26%
Urfe Creek - Reach 4	JN99	46.61	3702	51.55	11%
Urfe Trib E - Trib E1	JN98	11.41	3803	20.04	76%
W Duffins Trib H - West H1	JN80	1.26	JN81	5.13	307%
W Duffins Trib H - West H1	JN81	5.13	JN36	5.98	17%
West Duffins - Reach 12	JN83	71.34	103	109.54	54%
Whitevale Creek - Reach 2	JN79	11.30	3103	18.40	63%

2.5 Task 1E: HEC-RAS Boundary Conditions Development

2.5.1 Lake Ontario Boundary Condition

As documented in the Great Lakes Technical Guide Part 3 Flooding Hazard (Ontario, 2001):

> *"Determining the relevant flooding hazard limit at the junction of a lake and river or stream is based on an evaluation of which flooding hazard limit governs the site, namely the flooding hazard limit for large inland lakes or the flooding hazard limit for river and stream systems. In other words, the decision on which limit applies is based on which factors most influence the level of the flood risk or hazard at a given location.*
>
> *Determining which flooding hazard limit applies is based on the same principles outlined in the Technical Guide for River and Stream Systems (MNR 1996) and are as follows:*
>
> *Rivers flowing into large inland lakes require an analysis of the respective river and lake flood levels. Where the high water conditions at the junction are generated by two independent flood events, the flooding hazard limit should be based on the higher of:*
>
> *i. mean annual lake level and the river and stream systems flooding hazard limit as shown in Figure 4.12, Section A-A';*
> *or*
> *ii. large inland lakes flooding hazard limit as shown in Figure 4.12, Section B-B'.*

Figure 4.12 from the Great Lakes Technical Guide is replicated as Figure 2-3 in this report.

The aforementioned guidance is consistent with guidance provided in the *Technical Guidelines for Flood Hazard Mapping* (EWRG, 2017).

As noted previously, the downstream limit of the new hydraulic model is Lake Ontario. The surface area of Lake Ontario is about 19,000 square kilometres[1]. Given the size of Lake Ontario, it can be reasonably concluded that a flood event impacting Lake Ontario and one impacting the Duffins Creek Watershed would be independent events.

The Lake Ontario monthly mean water level based on recorded water surface elevations over the period 1918 to 2017, referred to International Great Lakes Datum 1985 (IGLD 1985), is 74.76 m[2].

[1] Source: https://www.thecanadianencyclopedia.ca/en/article/lake-ontario
[2] Source: Fisheries and Oceans Canada via URL http://www.tides.gc.ca/C&A/network_means-eng.html

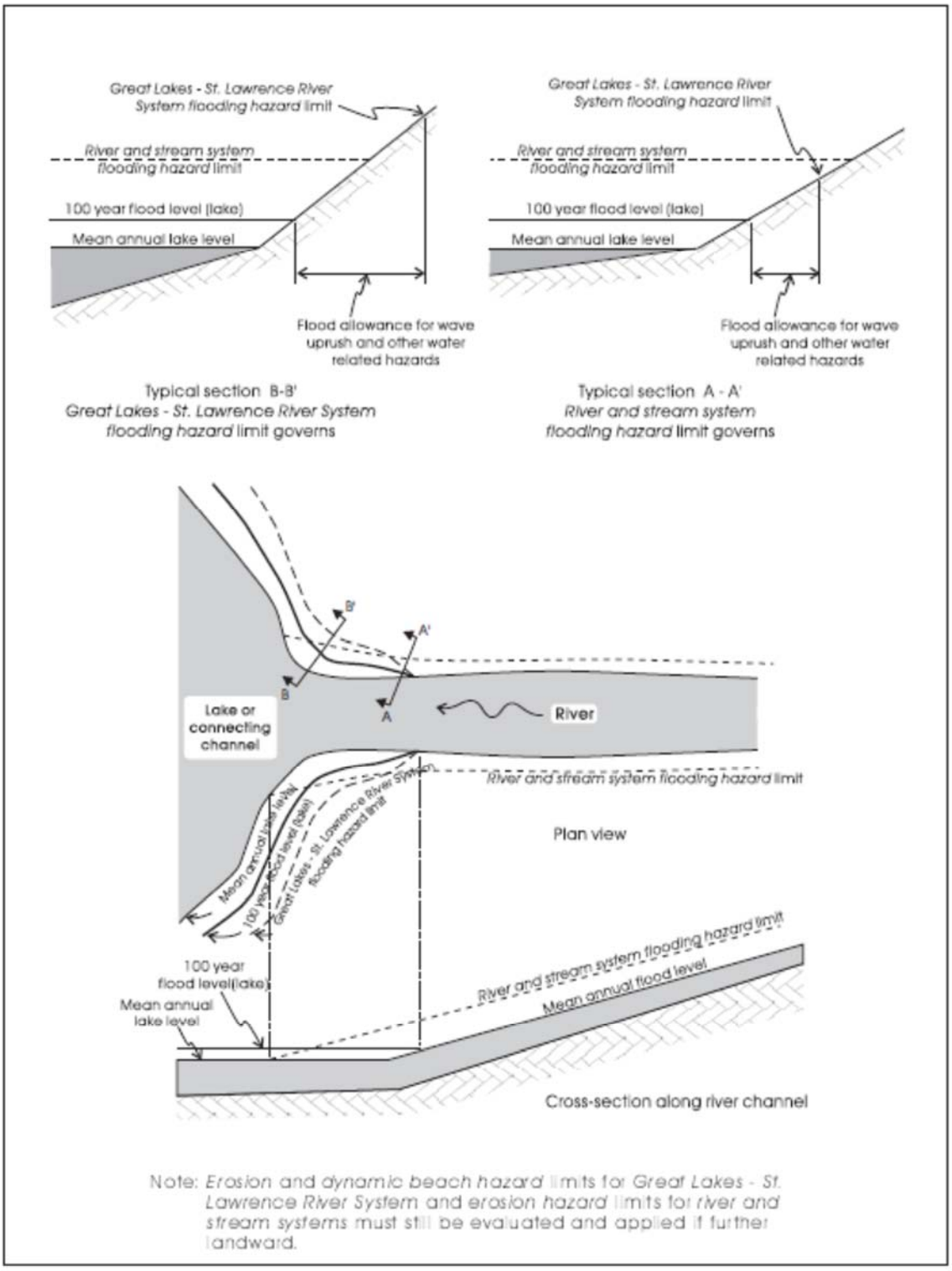

Figure 2-3 Flooding Hazard Limits at Junction of River and Lake

(Source: Figure 4.12, Great Lakes Technical Guide Part 3 Flooding Hazard (Ontario, 2001))

However, in late May 2017, the Lake Ontario water surface elevation was recorded as 75.88 m. This Lake Ontario water level has been the highest on record since reliable records began in 1918 (Baird, 2019; ECCC, 2017). Locally, this exceeded the documented Ministry of Natural Resources and Forestry's 1 in 100-year instantaneous lake level.

A review of the Lake Ontario return period water surface elevations developed by the Ontario Ministry of Natural Resources (now the Ministry of Natural Resources and Forestry) in 1989 was a component of the recently completed Toronto Islands Flood Characterization and Risk Assessment Project, completed by W.F. Baird & Associates Coastal Engineers Limited (Baird) for the TRCA. These return period water surface elevations were updated using the last 57 years of measured Lake Ontario water levels (1962 - 2018), and the analysis indicates that the 100-year return period static (monthly) Lake Ontario water level should be increased by approximately 0.2 m. The Baird study recommended that the 100-year Lake Ontario Water level be increased from 75.74 m to 76.05 m, referencing the International Great Lakes Datum of 1985 (IGLD85). TRCA has based their LiDAR on the vertical datum as established by the Geodetic Survey of Canada CGVD[3] 1928-1978 Ontario Adjusted Version (CGVD 1928:1978). The conversion of 76.05 m IGLD85 to CGVD 1928:1978 yields an elevation of 75.966 m (-0.084 m conversion factor).

TRCA, through discussions on the water surface elevation information presented as a component of the Toronto Islands Flood Characterization and Risk Assessment Project, decided to adopt a conservative approach in regards to the 100-year Lake Ontario water surface elevation defined for regulatory purposes. As such, TRCA directed, for the present Duffins Creek study, to use the 100-year Lake Ontario water level as the starting water surface elevation for hydraulic model boundary condition definition for all reaches draining to Lake Ontario. Therefore, for this study the most up-to-date definition of the 100-year Lake Ontario water level (i.e. 75.966 m CGVD 1928:1978) has been used as the Lake Ontario boundary conditions for the section of Duffins Creek discharging to Lake Ontario.

2.5.2 Pickering Ajax Special Policy Area (SPA) Boundary Condition

For the East Duffins and West Duffins watercourses, the boundary conditions have been provided directly by TRCA, and are the water levels based on the 2D modeling results from the Pickering Ajax Special Policy Area (SPA) Modeling study. These results are presented in Table 2-3.

Table 2-3: Water Level Boundary Conditions for the East and West Duffins Branches

Watercourse	Water Level Boundary Condition from Pickering Ajax SPA 2D Modeling Study (m)							
	Regional	350yr	100yr	50yr	25yr	10yr	5yr	2yr
West Duffins	90.91	90.10	89.40	89.35	89.22	89.02	88.86	88.61
East Duffins	85.30	83.65	82.90	82.74	82.55	82.32	82.08	81.64

[3] Canadian Geodetic Vertical Datum

2.6 Task 1F: Collection of Watercourse Crossing As-Built Information

As noted previously, construction and/or as-built drawings of structures were obtained from the various structure owners, including the TRCA, the relevant municipalities, Metrolinx, 407ETR, Canadian Pacific Railway (CPR), and the Ontario Ministry of Transportation (MTO). This information was used to inform HEC-RAS model development specific to bridges, culverts and inline structures.

2.7 Task 2B: Determination of Watercourse Crossings Model Coding Data Source(s)

This task, completed following Tasks 1C and 1F (watercourse crossing inventory and collection of as-built water crossing information, respectively), made the determination, based on site reconnaissance, whether or not the as-built, and other available information (existing HEC-RAS models, and aerial photography), was considered to be a good representation of the structure to support coding in HEC-RAS.

A structure information summary is provided as Table 2-4, which includes an identification of the primary and secondary data used to complete the structure coding for the hydraulic model.

Summary information for watercourse crossings located within the study area and which could be safely accessed by the field reconnaissance team is provided in Appendix A as structured Watercourse Crossing Data Sheets formatted to TRCA's standard template.

2.8 Task 2C: Field Survey of Watercourse Crossings

The potential for field topographic survey was contemplated at the outset of the project if information gaps were identified that would preclude coding of watercourse crossings in the new hydraulic model. Following completion of the preceding Tasks 1A, 1B, and 1E (ref. Sections 2.1, 2.2 and 2.5 respectively), the available existing information sources, namely:

- the previous HEC-RAS models;
- the available construction and/or as-built drawings/data; and/or;
- information measured as a component of the field reconnaissance; and,
- aerial imagery

were deemed to be sufficient to code majority of the required watercourse crossings in HEC-RAS. No additional topographic field survey was considered warranted to support the current study as part of initial data gathering. During the updated floodline delineation, TRCA found discrepancies with previous floodlines which warranted additional field investigation and topographic survey of structures, on an as needed basis. The three (3) structures coded using survey completed by TRCA or others (MTO) have been denoted in the structure information summary.

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Table 2-4: Summary of Watercourse Crossings Included in Hydraulic Model

Structure #	Crossing Location/Designation	Included in Previous TRCA HEC-RAS Model?	New HEC-RAS Model								
			Structure Type (HEC-RAS)	HEC-RAS Watercourse Designation	HEC-RAS Section	How Coded?[1]					
						Skew Angle	Field Recon	Available Drawings	Aerial Imagery	LiDAR / DEM	Previous HEC-RAS Dataset
duf_001	Sideline 32	N	Culvert	W Duffins Trib E / West E1	388.89						
duf_002	North Rd	Y	Culvert	W Duffins Trib C / West C1	1897.27						
duf_003	Sideline 34	N	Culvert	W Duffins Trib F / West F1	549.14						
duf_004	Sideline 24	N	Culvert	W Duffins Trib H / West H1	3861.96						
duf_005	Sideline20	N	Culvert	Urfe Creek / Reach 6	3327.09	30					
duf_006	Sideline 22	N	Culvert	Urfe Trib E / Trib E1	3729.21						
duf_007	Sideline 8	N	Culvert	E Duffins Trib I / East I1	496.83						
duf_008	Sideline32	Y	Bridge	West Duffins / Reach 9	519.05						
duf_009	Sideline20	Y	Culvert	Ganatsekiagon Ck / Reach 1	1792.69	10					
duf_010	Sideline 34	N	Culvert	W Duffins Trib G / West G1	220.86	45					
duf_011	Sideline 34	Y	Bridge	Reesor Creek / Reach 1	4541.21						
duf_012	Sideline 32	Y	Culvert	W Duffins Trib D / West D2	861.43						
duf_013	North Rd	N	Culvert	W Duffins Trib H / West H1	238.06						
duf_014	Harwood Ave N	Y	Culvert	Millers Creek / Reach 1	8335.39	25					
duf_015	Sideline 22	N	Culvert	Urfe Creek / Reach 6	5562.12						
duf_016	Williamson Dr W	Y	Bridge	Millers Creek / Reach 1	6905.96						
duf_017	Sideline 20	N	-	Mitchell Trib C / Trib C2	-	-	Placeholder Cross-Sections in Model for Future Structure Coding				
duf_018	Sideline20	Y	Bridge	Mitchell Trib B / Trib B1	1324.12						
duf_019	Sideline 22	Y	Culvert	Ganatsekiagon A / Trib A1	1292.12						
duf_020	Westney Rd	N	Culvert	E Duffins Trib F / East F1	155.18						
duf_022	Burkholder St	Y	Culvert	Stouffville Ck / Reach 1	6109.34						
duf_023	Millard Street	Y	Culvert	Stouffville Ck / Reach 1	7200.93						
duf_024	Somerville St	Y	Culvert	Stouffville Ck / Reach 1	6233.7	45					
duf_025	Market St	Y	Culvert	Stouffville Ck / Reach 1	6299.1	45					
duf_026	North Rd.	Y	Bridge	W Duffins Trib I / West I1	111.13						
duf_027	Sideline20	Y	Bridge	Mitchell Creek / Reach 3	1418.14						
duf_028	Hoover Park Dr	Y	Culvert	Stouffville Ck / Reach 1	5524.9						
duf_029	Sideline 34	N	Culvert	Reesor Trib A / Trib A1	278.32						
duf_030	Sideline12	Y	Bridge	Mitchell Creek / Reach 1	487.39	20					
duf_031	Haskell Ave	Y	Culvert	Millers Creek / Reach 1	7990.86						
duf_032	Sideline 12	Y	Culvert	E Duffins Trib E / East E1	1324.35						
duf_033	Sullivan Dr	Y	Culvert	Millers Creek / Reach 1	4461.05						
duf_034	Jackwin Dr.	Y	Culvert	Millers Creek / Reach 1	950.52						
duf_035	Rotherglen Rd S	Y	Bridge	Millers Creek / Reach 1	1635.08						

Structure #	Crossing Location/Designation	Included in Previous TRCA HEC-RAS Model?	New HEC-RAS Model								
			Structure Type (HEC-RAS)	HEC-RAS Watercourse Designation	HEC-RAS Section	How Coded?[1]					
						Skew Angle	Field Recon	Available Drawings	Aerial Imagery	LiDAR / DEM	Previous HEC-RAS Dataset
duf_036	Magil Dr	Y	Culvert	Millers Creek / Reach 1	3768.1						
duf_037	Carwin Crescent	Y	Culvert	Millers Creek / Reach 1	1209.93						
duf_038	Sideline 24	N	Culvert	W Duffins Trib K / West K1	1421.8						
duf_039	Sideline 24	N	Culvert	W Duffins Trib L / West L1	1126.76						
duf_040	North Rd	Y	Bridge	W Duffins Trib C / West C1	1757.48						
duf_042	Church St N	N	Culvert	E Duffins Trib B / East B1	1082.43						
duf_043	Whitevale Rd	Y	Culvert	Ganatsekiagon C / Trib C1	928.72						
duf_044	Whitevale Rd./5th Concession	Y	Culvert	Urfe Trib D / Trib D1	595.84						
duf_045	Sideline16	N	Culvert	Brougham Trib E / Trib E1	210.98						
duf_046	7th Concession	N	Culvert	E Duffins Trib D / East D1	297.13						
duf_047	8th Concession Rd	N	Culvert	E Duffins Trib F / East F1	706.36						
duf_048	Whitevale Rd	Y	Culvert	Urfe Trib C / Trib C2	765.71						
duf_049	7th Concession	N	Culvert	W Duffins Trib H / West H1	3406.67	>45					
duf_050	Whitevale Rd	Y	Bridge	East Duffins / Reach 4	226.83	45					
duf_051	Rossland Rd	Y	Bridge	Urfe Creek / Reach 2	1371.48						
duf_052	Whitevale Road	Y	Culvert	Brougham Creek / Reach 1	542.35						
duf_053	Whitevale Rd	Y	Culvert	Ganatsekiagon Ck / Reach 4	1220.5						
duf_054	9th Concession	Y	Culvert	Reesor Creek / Reach 3	1285.33						
duf_055	Sideline 26	N	Culvert	W Duffins Trib H / West H1	2848.77						
duf_056	York Durham Line	Y	Bridge	Stouffville Ck / Reach 1	153.85						
duf_057	8th Concession Rd	Y	Bridge	East Duffins / Reach 10	646.1						
duf_058	8th Concession	Y	Culvert	West Duffins / Reach 12	1474.54	>45					
duf_059	19th Ave	Y	Bridge	Stouffville Ck / Reach 1	3404.65	45					
duf_060	Reesor Rd	Y	Bridge	Stouffville Ck / Reach 1	2333.39	25					
duf_061	Church St N	Y	Bridge	East Duffins / Reach 2	189.37						
duf_062	Uxbridge Pickering Townline	Y	Bridge	West Duffins / Reach 13	3848.1						
duf_063	Sideline30	Y	Culvert	West Duffins / Reach 13	2665.61	>45					
duf_064	7th Concession/North Rd	Y	Bridge	West Duffins / Reach 11	676.68	>45					
duf_065	9th Concession Rd	Y	Culvert	East Duffins / Reach 13	1162.14						
duf_066	Forestream Trail	Y	Bridge	West Duffins / Reach 1	6834.34						
duf_067	Taunton Road	N	Bridge	West Duffins / Reach 1	7236.42						
duf_068	Webb Rd	Y	Bridge	West Duffins / Reach 13	6548.72						
duf_069	Brock Rd	Y	Culvert	Urfe Trib C / Trib C1	115.55	40					
duf_070	Whitevale Rd	Y	Culvert	Ganatsekiagon B / Trib B1	2443.67						
duf_070b	Driveway near Whitevale Rd	N	Culvert	Ganatsekiagon B / Trib B1	2643.24						

Structure #	Crossing Location/Designation	Included in Previous TRCA HEC-RAS Model?	New HEC-RAS Model								
			Structure Type (HEC-RAS)	HEC-RAS Watercourse Designation	HEC-RAS Section	How Coded?[1]					
						Skew Angle	Field Recon	Available Drawings	Aerial Imagery	LiDAR / DEM	Previous HEC-RAS Dataset
duf_071	Sideline 28	N	Culvert	Wixon Trib A / Trib A1	155.07	>45					
duf_072	Whitevale	Y	Bridge	West Duffins / Reach 3	4453.88						
duf_073	Bethesda Side Rd	Y	Culvert	Stouffville Ck / Reach 2	1520.29						
duf_074	Bayly St	Y	Bridge	Lower Duffins / Reach 1	4216.42						
duf_075	9th Concession	Y	Bridge	West Duffins / Reach 13	1402.35						
duf_076	Balsam Rd	Y	Bridge	East Duffins / Reach 14	910.18						
duf_077	Uxbridge Pickering Townline	N	Culvert	Mitchell Creek / Reach 4	4971.94						
duf_078	Brock Rd	Y	Bridge	Ganatsekiagon Ck / Reach 1	1032.24						
duf_079	Whitevale Rd	Y	Culvert	Urfe Creek / Reach 6	543.49						
duf_080	Sideline26	Y	Culvert	Wixon Creek / Reach 2	1238.47						
duf_081	7th Concession	Y	Culvert	East Duffins / Reach 14	2984.37						
duf_082	Sideline30	Y	Bridge	West Duffins / Reach 13	1641.21						
duf_083	Brock Rd	N	Culvert	Brougham Creek / Reach 4	2369.73						
duf_084	Taunton Rd W	N	Culvert	E Duffins Trib B / East B1	1005.19	25					
duf_085	8th Concession Rd	Y	Bridge	Reesor Creek / Reach 1	4845.25						
duf_086	Sideline 28	N	Culvert	W Duffins Trib H / West H1	1282.38	45					
duf_087	Taunton Rd E	Y	Culvert	Millers Creek / Reach 1	8394.16	20					
duf_088	Sideline 16	N	Culvert	Brougham Creek / Reach 4	1023.65						
duf_089	9th Concession	N	Culvert	Mitchell Creek / Reach 4	2204.3						
duf_090	Whitevale Road	Y	Bridge	Whitevale Trib A / Trib A1	1303.26						
duf_091	Westney Rd	Y	Culvert	E Duffins Trib H / East H1	1191.63						
duf_092	Sideline28	Y	Bridge	Wixon Creek / Reach 1	1938.7	>45					
duf_093	9th Concession	Y	Culvert	Wixon Creek / Reach 1	1558.86	25					
duf_094	8th Concession	N	Bridge	W Duffins Trib I / West I3	1397.56						
duf_095	Whitevale Rd	Y	Culvert	Urfe Trib E / Trib E1	772.44						
duf_096	7th Concession	Y	Bridge	East Duffins / Reach 6	232.53						
duf_097	7th concession/sdl28	N	Culvert	W Duffins Trib I / West I1	1754.61						
duf_098	Taunton Rd	Y	Bridge	Urfe Creek / Reach 4	2788.84						
duf_099	Brock Rd	Y	Culvert	Urfe Creek / Reach 4	2259.4						
duf_100	William Jackson Dr	Y	Bridge	Urfe Creek / Reach 4	1665.66						
duf_101	Riverside Dr	Y	Bridge	East Duffins / Reach 1	585.01						
duf_102	Taunton Rd	N	Culvert	Urfe Trib B / Trib B1	1606.17						
duf_103	6 Concession rd	Y	Bridge	East Duffins / Reach 4	3046.77	30					
duf_104	York Durham Line	Y	Bridge	Reesor Creek / Reach 3	8630.69						
duf_105	York Durham Line	Y	Culvert	Reesor Creek / Reach 3	5748.21						

Structure #	Crossing Location/Designation	Included in Previous TRCA HEC-RAS Model?	New HEC-RAS Model								
			Structure Type (HEC-RAS)	HEC-RAS Watercourse Designation	HEC-RAS Section	How Coded?[1]					
						Skew Angle	Field Recon	Available Drawings	Aerial Imagery	LiDAR / DEM	Previous HEC-RAS Dataset
duf_106	Main St	Y	Culvert	Stouffville Ck / Reach 1	6415.95						
duf_107	9th Concession	N	Culvert	W Duffins Trib I / West I6	840.99						
duf_108	7th Concession Rd	Y	Bridge	Reesor Creek / Reach 1	870.08	45					
duf_109	8th Concession	N	Culvert	E Duffins Trib G / East G1	771.21						
duf_110	Brock Rd	Y	Culvert	Mitchell Creek / Reach 2	3002.78						
duf_111	Whitevale Rd.	Y	Culvert	Whitevale Creek / Reach 2	1294.92						
duf_112	Taunton Rd W	Y	Bridge	East Duffins / Reach 3	962.03						
duf_113	Rossland Rd W	Y	Culvert	Millers Creek / Reach 1	5172.93						
duf_114	3rd Concession	Y	Culvert	Ganatsekiagon Ck / Reach 1	1760.16	45					
duf_115	9th Concession	N	Culvert	Mitchell Trib C / Trib C1	1392.66						
duf_116	Taunton Rd	Y	Culvert	Ganatsekiagon Ck / Reach 1	4993.58						
duf_117	Rossland Rd W	Y	Bridge	East Duffins / Reach 1	1765.41						
duf_118	8th Concession	Y	Culvert	E Duffins Trib E / East E1	1985.06						
duf_119	Farm Access Rd	N	-	W Duffins Trib K / West K1	-	-	Placeholder Cross-Sections in Model for Future Structure Coding				
duf_121	Uxbridge Pickering Townline	Y	Culvert	Reesor Creek / Reach 3	4110.11						
duf_122	9th concession	N	Culvert	W Duffins Trib M / West M1	1569.04						
duf_123	Kingston Rd W	Y	Culvert	Millers Creek / Reach 1	2615.15	45	TRCA Survey				
duf_124	Westney Rd S	Y	Bridge	Millers Creek / Reach 1	1852.92	30					
duf_125	HWY407 WB/EB	Y	Culvert	Whitevale Trib A / Trib A2	1668.92						
duf_126	HWY7	N	Culvert	Whitevale Trib A / Trib A2	2273.55						
duf_127	HWY7	N	Culvert	W Duffins Trib C / West C1	2137.51						
duf_128	HWY407 WB/EB	Y	Culvert	Ganatsekiagon Ck / Reach 4	3650.46						
duf_129	HWY7	N	Culvert	Ganatsekiagon Ck / Reach 4	4486.05						
duf_131	HWY7	N	Culvert	Brougham Trib D / Trib D1	1547.18						
duf_132	HWY407 WB/EB, On ramp	N	Culvert	Brougham Trib D / Trib D1	1119.81						
duf_133	HWY407 WB/EB	Y	Bridge	Urfe Creek / Reach 6	2516.69	10					
duf_134	HWY7	N	Culvert	Urfe Creek / Reach 6	3158.24						
duf_135	HWY407 WB/EB	Y	Culvert	W Duffins Trib C / West C1	733.5						
duf_136	HWY7	N	Bridge	Brougham Trib C / Trib C2	1071.71						
duf_137	HWY7	N	Culvert	Urfe Trib E / Trib E1	3406.49	>45					
duf_138	HWY7	Y	Culvert	W Duffins Trib D / West D1	835.18	45					
duf_139	HWY7	Y	Bridge	East Duffins / Reach 4	3270.5						
duf_140	HWY7	Y	Bridge	West Duffins / Reach 6	482.14						
duf_141	HWY7	N	Culvert	Brougham Creek / Reach 4	2743.46						
duf_142	HWY407 WB/EB, On ramp & off ramp	N	Bridge	Brougham Creek / Reach 4	1931.14						

Structure #	Crossing Location/Designation	Included in Previous TRCA HEC-RAS Model?	New HEC-RAS Model								
			Structure Type (HEC-RAS)	HEC-RAS Watercourse Designation	HEC-RAS Section	How Coded?[1]					
						Skew Angle	Field Recon	Available Drawings	Aerial Imagery	LiDAR / DEM	Previous HEC-RAS Dataset
duf_143	HWY7	N	Culvert	Ganatsekiagon B / Trib B1	5138.08	25					
duf_144	HWY407 WB/EB	Y	Culvert	Ganatsekiagon B / Trib B1	4340.65						
duf_145	HWY407 WB/EB	N	Bridge	West Duffins / Reach 5	419.29	>45					
duf_146	HWY407 WB/EB	Y	Culvert	Urfe Trib E / Trib E1	2736.72	10					
duf_147	HWY407 WB/EB	Y	Culvert	Whitevale Creek / Reach 2	3035.77						
duf_148	HWY401	N	Culvert	Millers Creek / Reach 1	806.36		MTO Survey				
duf_149	HWY407 WB/EB	Y	Bridge	W Duffins Trib D / West D1	213.58						
duf_150	West of Chapman Dr	N	Bridge	Millers Creek / Reach 1	2835.5						
duf_151	East of Westney Rd N	N	Bridge	Millers Creek / Reach 1	3165.5						
duf_152	Entrance to NcLean Community Centre	Y	Culvert	Millers Creek / Reach 1	3602.63						
duf_153	Sulivan Dr	N	Bridge	Millers Creek / Reach 1	4259.89						
duf_154	East of Keeble Crescent	N	Bridge	Millers Creek / Reach 1	4841.84						
duf_155	East of Armitage Crescent	Y	Bridge	Millers Creek / Reach 1	5631.41						
duf_156	North of Westacott Crescent	Y	Bridge	Millers Creek / Reach 1	6402.5						
duf_157	East of Curtis Gate	Y	Bridge	Millers Creek / Reach 1	7331.32						
duf_158	West of Mackeller Court	Y	Bridge	Millers Creek / Reach 1	7630.39						
duf_159	West of Feint Dr	Y	Bridge	Millers Creek / Reach 1	8148						
duf_160	CPR	Y	Mult Open	Millers Creek / Reach 1	8466.9						
duf_161	CPR	N	Culvert	E Duffins Trib B / East B1	1326.03						
duf_162	CPR	Y	Bridge	Urfe Creek / Reach 4	1834.43						
duf_163	CPR	Y	Bridge	East Duffins / Reach 3	1487.76						
duf_164	Greenwood Conservation Area	Y	Bridge	East Duffins / Reach 3	3043.14						
duf_165	CPR	N	Bridge	Mitchell Trib D / Trib D1	572.88						
duf_166	CPR	N	Culvert	Mitchell Trib C / Trib C2	781.25						
duf_167	East of Sideline 12	Y	Bridge	Mitchell Creek / Reach 1	363.62	10					
duf_168	East of Sideline 12	Y	Bridge	East Duffins / Reach 6	808.53						
duf_169	East of Sideline 12	Y	Culvert	E Duffins Trib E / East E1	534.64						
duf_170	CPR	Y	Culvert	E Duffins Trib K / East K1	584.39						
duf_171	CPR	Y	Culvert	East Duffins / Reach 14	593.77						
duf_172	New Development	N	Culvert	E Duffins Trib A / East A1	312.97						
duf_173	CPR	Y	Bridge	West Duffins / Reach 1	3873.56						
duf_174	North of Whitevale Rd	N	Inl Struct	West Duffins / Reach 3	5390.16						
duf_175	CPR	N	Bridge	Major Creek / Reach 1	764.76						
duf_176	CPR	Y	Bridge	Reesor Creek / Reach 1	714.86						
duf_177	CPR	Y	Bridge	West Duffins / Reach 12	632.17	>45					

Structure #	Crossing Location/Designation	Included in Previous TRCA HEC-RAS Model?	New HEC-RAS Model								
			Structure Type (HEC-RAS)	HEC-RAS Watercourse Designation	HEC-RAS Section	How Coded?[1]					
						Skew Angle	Field Recon	Available Drawings	Aerial Imagery	LiDAR / DEM	Previous HEC-RAS Dataset
duf_178	CPR	N	Culvert	W Duffins Trib O / West O1	262.63						
duf_179	CPR	N	Bridge	W Duffins Trib I / West I3	2076.94						
duf_180	East of James Ratcliff Ave	N	Bridge	Stouffville Ck / Reach 1	4857.38						
duf_181	East of James Ratcliff Ave	N	Bridge	Stouffville Ck / Reach 1	5276.34						
duf_182	Park Dr	N	Mult Open	Stouffville Ck / Reach 1	5924.75						
duf_183	Park Dr (same location as duf_182)	N	Mult Open	Stouffville Ck / Reach 1							
duf_184	CPR	Y	Culvert	Stouffville Ck / Reach 1	7093.51	42					
duf_185	Stouffville Reservoir	Y	Culvert	Stouffville Ck / Reach 1	7256.85		TRCA Survey				
duf_186	CPR	N	Culvert	Stouffville A / Trib A1	450.94	45					
duf_187	Realigned Brock Rd	N	Culvert	Brougham Trib D / Trib D1	2005.8	25					
duf_188	Realigned Brock Rd	N	Culvert	Brougham Trib D / Trib D1	744.39						
duf_189	HWY407 WB/EB	N	Bridge	Brougham Trib C / Trib C2	1158.37						
duf_191	HWY407	N	Culvert	E Duffins Trib C / East C1	667.34						
duf_192	HWY407 Off ramp	N	Culvert	Brougham Trib D / Trib D1	978.33						
duf_193	Realigned Brock Rd	N	Bridge	Brougham Creek / Reach 4	1139.61						
duf_195	HWY407 WB/EB	N	Bridge	East Duffins / Reach 5	717.65						
duf_196	Sideline 26	Y	Culvert	W Duffins Trib A / West A2	530.84						
duf_197	North of Taunton Rd	Y	Culvert	Ganatsekiagon Ck / Reach 1	5193.26						
duf_198	North of Taunton Rd	Y	Bridge	Urfe Creek / Reach 4	2854.63						
duf_199	CPR	Y	Culvert	Ganatsekiagon Ck / Reach 1	4516.55	10					
duf_200	Sideline 24	Y	Culvert	Ganatsekiagon B / Trib B1	1662.07						
duf_201	South of 5th Concession Rd	N	-	Millers Creek / Reach 1	-	-	Placeholder Cross-Sections in Model for Future Structure Coding				
duf_202	Cemetery Rd	N	Culvert	Urfe Trib A / Trib A1	689.1						
duf_203	Cemetery Rd	N	Culvert	Urfe Trib A / Trib A1	1160.31						
duf_204	Cemetery Rd	N	Culvert	Urfe Trib A / Trib A1	1246.96						
duf_205	East of Sideline 16	N	Culvert	Brougham Creek / Reach 2	484.81						
duf_206	Dutchmaster Nurseries	N	Culvert	Brougham Trib C / Trib C3	857.69						
duf_207	Dutchmaster Nurseries	N	Culvert	Brougham Trib C / Trib C3	540.58						
duf_208	Dutchmaster Nurseries	N	Culvert	Brougham Trib C / Trib C3	350.68						
duf_209	Dutchmaster Nurseries	N	Culvert	Brougham Trib C / Trib C3	262.47						
duf_210	Dutchmaster Nurseries	N	Culvert	Brougham Trib C / Trib C3	181.79						
duf_211	East of 7th Concession	Y	Culvert	East Duffins / Reach 14	2545.08						
duf_212	West of Sideline 32	N	Bridge	West Duffins / Reach 9	208.18						
duf_213	East of Sideline 30	Y	Bridge	West Duffins / Reach 13	3383.82	>45					
duf_214	East of 2nd Concession	N	Bridge	West Duffins / Reach 13	5093.22	25					

Structure #	Crossing Location/Designation	Included in Previous TRCA HEC-RAS Model?	New HEC-RAS Model								
			Structure Type (HEC-RAS)	HEC-RAS Watercourse Designation	HEC-RAS Section	How Coded?[1]					
						Skew Angle	Field Recon	Available Drawings	Aerial Imagery	LiDAR / DEM	Previous HEC-RAS Dataset
duf_215	East of 2nd Concession	N	Bridge	West Duffins / Reach 13	4644.87						
duf_216	Glen Cedars G.C.	N	Culvert	Reesor Creek / Reach 1	1487.62						
duf_217	East of Sideline 28	Y	Culvert	Urfe Trib C / Trib C1	116.05						
duf_218	East of Paddock Rd	Y	Bridge	East Duffins / Reach 4	3702.91						
duf_219	East of Paddock Rd	Y	Culvert	East Duffins / Reach 5	980.45						
duf_220	East of Paddock Rd	N	Inl Struct	East Duffins / Reach 5	1022.44						
duf_221	East of Paddock Rd	N	Culvert	East Duffins / Reach 5	1110.34						
duf_222	Uxbridge Pickering Townline	Y	Culvert	East Duffins / Reach 14	1758.99						
duf_223	East of Sideline 28	N	Culvert	Wixon Trib A / Trib A1	44.3						
duf_224	CPR	N	Culvert	Mitchell Creek / Reach 4	2294.67	45					
duf_225	CPR	N	Culvert	W Duffins Trib L / West L1	380.96						
duf_226	East of Sideline 16	N	Culvert	Brougham Trib C / Trib C2	1285.86						
duf_227	East of 7th Concession	N	Culvert	East Duffins / Reach 14	2622.43						
duf_228	Sideline 26	N	-	W Duffins Trib A / West A2	-	-	Placeholder Cross-Sections in Model for Future Structure Coding				
duf_229	HWY407 Off Ramp to Whites Road	N	Bridge	Whitevale Creek / Reach 2	2886.64						
duf_230	Whites Road Extension	N	Culvert	Whitevale Creek / Reach 2	3441.95						
duf_231	York Durham Line	N	Culvert	Major Creek / Reach 1	898.51						

Notes:

(1) Within the "How Coded" column, the colour coding (see legend to right) indicates how the available information was used to support structure coding in the HEC-RAS model.

	Primary Data Source
	Secondary Data Source
	Tertiary Data Source

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3.0 Hydraulic Model Development (Task 2)

The collection and processing of data, computational procedures and analysis of computed profiles completed for this study are compliant with the following criteria and guidelines:

- Hydrologic Engineering Center User's Manual and Training Documents (USACE, 2010),
- Hydrologic and Hydraulic Procedures for Floodplain Delineation (Environment Canada, 1976,
- MNR Technical Guide Flooding Hazard Limit (MNR, 2002) and,
- Standard Manning's Roughness Coefficients for TRCA Watershed Hydraulic Modelling

The objective of the hydraulic analysis was the computation of water surface elevations resulting from the 2 year through 100-year[4], and Regional Storm (Hurricane Hazel) flow estimates. The computed water surface elevations for the simulated events are then used in conjunction with the LiDAR data (ref. Section 2.3) to delineate the limits of the floodplain on topographic mapping sheets. To determine the water surface profile for a given flood condition, a backwater analysis is generally necessary. The US Army Corps of Engineers (USACE) HEC-RAS one-dimensional backwater model was utilized for this analysis.

The following sections describe the development of the HEC-RAS hydraulic model, as well as the details associated with the results of the hydraulic simulation of various flood events.

3.1 HEC-RAS Software

HEC-RAS (USACE, 2002), the successor to HEC-2, is a hydraulic modelling computer program developed by the USACE to simulate water surface profiles for steady and gradually varied flow in open channel watercourses. The computational procedures used by HEC-2 and HEC-RAS to model steady state flow are generally similar and are based on solving the one-dimensional energy equation. The HEC-RAS computational software estimates water surface elevation and related output along a channel reach under sub-critical, supercritical or mixed flow regimes. The program is capable of modelling complicated networks with multiple reaches and tributaries. Flow through culverts, bridges, weirs and gated spillways can also be accommodated. Levees, blocked obstructions and ineffective flow areas can also be modelled, as can ice jam and debris flow conditions.

In simple terms, the model uses surface water flow rates to predict water surface elevations. These elevations can then be transferred to a DEM or topographic map to identify the limits of flood-prone areas.

[4] Please note that the assessment of the 350-year design storm event was removed from the scope of this study by TRCA.

HEC-RAS requires a terrain model with three-dimensional attributes (x, y, and z) for the area of interest. The terrain model commonly used in hydrologic modelling is a DEM. HEC-GeoRAS is a pre- and post-processing program developed co-operatively by the Hydrologic Engineering Center (HEC) of the USACE and Environmental Systems Research Institute Inc. (ESRI) to:

- extract geometric data from a DEM for input into HEC-RAS, and;
- use output from the hydraulic model and generate a water surface elevation DEM that can be superimposed on the terrain DEM to identify flood-prone areas.

The HEC-GeoRAS 10.4.0.1 for ArcGIS 10.4 and HEC-RAS 5.0.7 were used to complete the one dimensional hydraulic modelling component of this project. HEC-RAS 5.0.7 represents the most up-to-date version of the software at the time the project was initiated.

The software package GeoHEC-RAS, produced by CivilGEO Inc., is another pre- and post-processing interface that can be used to support development of HEC-RAS models and visualization of HEC-RAS computations and results.

HEC-RAS is an approved model for floodplain calculations in Ontario and was identified as the preferred modelling platform in the Terms of Reference for this project.

3.2 Task 2A – HEC-RAS Model Development

3.2.1 Cross-Sections

Hydraulic sections were located in accordance with HEC-RAS modelling guidelines (USACE, 2010). Cross-section data was abstracted from the DEM developed for this project, as outlined in Section 2 of this report, and below.

The locations of the sections are illustrated on the floodplain maps (ref. Appendix E). The study scope for the Duffins FPMU has included the modelling of fifteen (15) separate watercourses, contributing to the three (3) major systems as the focus for the current study (East, West, Lower Duffins Creek), all of which are compiled into a single HEC-RAS dataset. The watercourses have been referenced as:

- Brougham Creek
- East Duffins Creek
- Ganatsekiagon Creek
- Lower Duffins Creek
- Main Duffins
- Major Creek
- Millers Creek
- Mitchell Creek
- Reesor Creek
- Spring Creek
- Stouffville Creek
- Urfe Creek
- West Duffins Creek
- Whitevale Creek
- Wixon Creek

As outlined in Section 2.5, for the East Duffins and West Duffins watercourses, the start of the model commences upstream of the Pickering Ajax SPA Modeling study, north of Finch Avenue in the vicinity of Brock Road. The Lower Duffins watercourse begins at the outlet to Lake Ontario, continuing upstream to north of Taunton Road East.

The LiDAR DEM developed for this project provides topographic information in a 1 m x 1 m grid to a vertical positional accuracy of 0.1 m ±. Since the entire study area was captured in the LiDAR survey, cross-sections extending out past the floodplain extents were cut directly from the LiDAR without the need for supplementary field survey.

With respect to the low flow channel, Wood reviewed the field measurements from the hydraulic structure inventory and flagged reaches which indicated consistent depth readings over 0.3 m (considered to be a reasonable threshold where a low flow channel correction would be warranted). Based on this approach, reaches where a correction could be considered were identified, along with the average corresponding low flow channel depth. It was also assumed that if a correction was applied for a reach, it would be applied for the next downstream reach as well for consistency.

A total of 32 reaches were subsequently identified for low flow channel corrections, with channel depths of between 0.3 and 0.4 m. These reaches are presented in Figure 3.1 (adjusted reaches are indicated in red). As would logically be expected, corrected reaches typically reflect the main branches of the subject watercourses.

TRCA subsequently developed a modified DEM with integrated low flow channel definition based on the preceding areas of correction. The hydraulic sections established by Wood, based on the above waterline DEM, were then re-cut using the low flow channel DEM to augment the hydraulic sections with below waterline information.

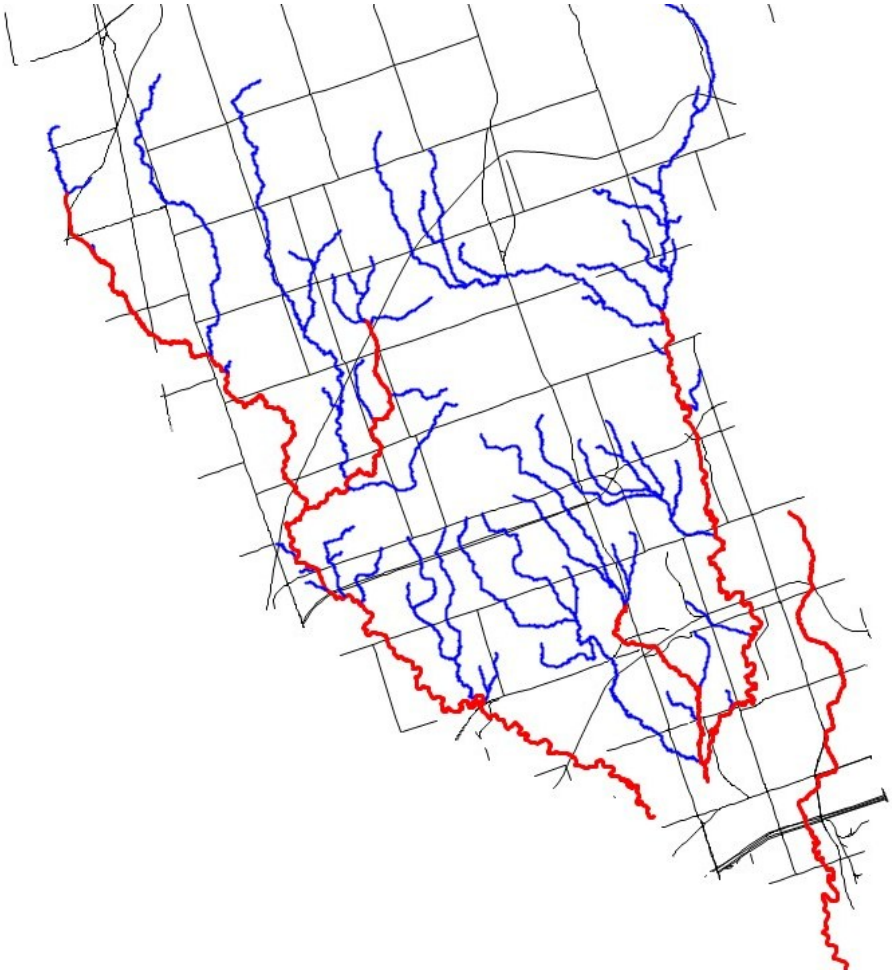

Figure 3-1 Duffins Creek Low Flow Channel Adjustments

An overview of the completed hydraulic model for of the study area is as follows:

- Overall study reach length of approximately 246 km
- 5,676 hydraulic sections across 119 reaches
- Average inter-section reach length of about 52.4 m
- 5,413 sections, or about 95%, have inter-section reach length less than 100 m
- 3,881 sections, or about 68%, have inter-section reach length less than 50 m
- 1,650 sections, or about 29%, have inter-section reach length less than 25 m

Please note also, that all modelling has been completed using a Subcritical flow regime in HEC-RAS.

3.2.2 Hydraulic Structures

Watercourse Crossings / Bridges

A bridge on a skew refers to a condition when a bridge opening is not perpendicular to the direction of flow or, similarly, when a pier is not aligned with the flow. The HEC-RAS User's Manual indicates that skew angle (θ) is defined as the angle between the flow path as water goes through the bridge opening and the line perpendicular to the cross sections bounding the bridge as shown in the image below.

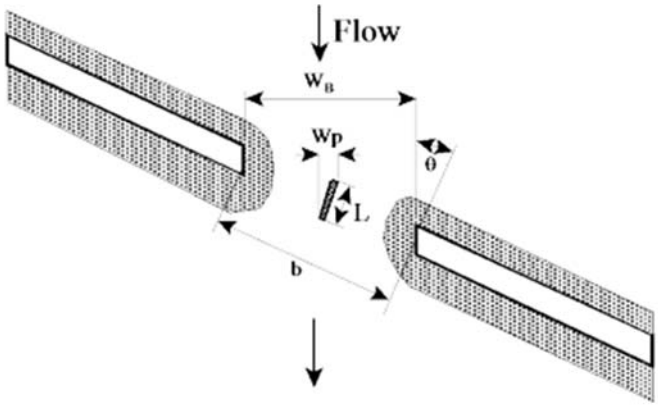

Figure 3-2 Example of Bridge on a Skew

(Image Source: https://engineerpaige.com/2019/04/skew-angle-for-bridges-in-hec-ras/)

As noted previously (ref. Section 2.5), a total of three hundred and seven (307) watercourse crossings were initially identified along the Duffins Creek and tributaries within the study area. Of these, two hundred and twenty-one (221) crossings were included in the new Duffins Creek hydraulic model, with placeholders for four (4) additional crossings to be added in a subsequent effort, and eighty-two (82) crossings which were not included in the modelling.

A skew angle assessment was completed using Google Earth Pro™ for all crossings included in the new HEC-RAS model. This information is summarized in Table 2-4. Where crossings were deemed to have a skew angle greater than 30°, a skew angle was defined in the hydraulic model up to a maximum of 45°, which is the highest allowable skew in HEC-RAS.

Summary information for all watercourse crossings within the study area is provided in Appendix A as structured Watercourse Crossing Data Sheets formatted to TRCA's standard template.

Dams and Weirs

Two (2) in-line structures have been included in the updated HEC-RAS model, both of which are on-line weir structures and were identified / measured during field inventory and confirmed with LiDAR data. One of the in-line structures is a 19.8 m wide x 2.1 m high concrete weir, located on

West Duffins Creek – Reach 3 (duf_174) in the vicinity of the Seaton Hiking Trail. The other in-line structure consists of five (5) openings (1 m x 3.1 m) located on East Duffins Creek – Reach 5 (duf_220) east of Paddock Road, north of the 407.

In addition to in-line structures, the HEC-RAS model includes the Stouffville Dam (duf_185) which has been coded as a culvert with an internal rating curve (boundary condition) based upon data available from previous reporting for the dam. The internal rating curve for the Stouffville Dam has been sourced from the Stouffville Dam Downstream Flood Remediation Study (Stantec, June 2019) and is presented in Table 3-1.

Table 3-1: HEC-RAS Internal Rating Curve for Stouffville Dam (duf_185)

Profile	REG	100Y	50Y	25Y	10Y	5Y	2Y
Known WS (m)	274.109	273.116	273.324	273.233	273.191	273.359	273.288

3.2.3 Lateral Structures

No lateral structures (i.e., side weirs and similar) are located along the study reaches for this project.

3.2.4 Energy Loss Coefficients

Energy loss coefficients are used in the HEC-RAS program to calculate changes in the water surface elevation between sections. The coefficients include Manning roughness coefficients, expansion and contraction coefficients, and weir and pressure coefficients for road / rail crossings. These coefficients were estimated based on published information, field reconnaissance and engineering judgment.

Expansion and Contraction Coefficients

Expansion and contraction coefficients for normal channel cross-sections were set at 0.1 and 0.3, respectively, and 0.3 and 0.5 for cross-sections at hydraulic structures and for locations where there is a rapid change in cross-section, respectively. These ratios are used by HEC-RAS in the computation of energy losses due to flow contraction and expansion between adjacent cross-sections. The noted values are consistent with those recommended in the HEC-RAS Technical Reference Manual.

It should also be noted, with regard to bridge coding, that coefficients of 0.3 and 0.5 (expansion and contraction respectively) have been applied to the two (2) cross-sections upstream of a structure, and the one (1) cross-section immediately downstream of a structure. This application of expansion and contraction coefficients reflects the anticipated rapid changes occurring at these cross-sections. This manner of coding was based on direction from TRCA.

Roughness Coefficients

Initial estimation of Manning roughness coefficients was based on land use, field observations, review of aerial imagery (available via Google Maps™ and TRCA), engineering judgment, previous modelling experience, and comparison of reach characteristics with the "Roughness Characteristics of Natural Channels" (Barnes, 1967). Images available via Google Streetview™ were also helpful in this regard.

Final Manning's 'n' values were aligned with TRCA's "Standard Manning's Roughness Coefficients for TRCA Watershed Hydraulic Modelling" guide (ref. Appendix B).

Roughness coefficients used for the hydraulic model were in the range 0.035 to 0.080[5] for channels and 0.025 to 0.080 for overbank areas. Channels through the study area range from clean, gravel bottom to large boulders with debris (represented by the low and high range of roughness co-efficient). For the overbank areas the lower range represented grassed areas clear of significant vegetation and the upper range represented forested overbank areas. Some urban areas (i.e., asphalt or concrete) are also included in the overbank areas in select locations.

Weir Flow Coefficients

The HEC-RAS weir coefficients for watercourse crossings (i.e. bridge/culvert) in the range 1.4 to 1.7 were adopted for the initial development of the new model where no previous HEC-RAS dataset coding was available for a structure. If a structure was defined in a previous HEC-RAS dataset, the weir coefficient from that previous dataset was adopted for the new hydraulic model where it was deemed to be appropriate. As a component of TRCA's model review, TRCA staff directed that weir coefficients be updated to 1.44 for typical bridges, and 1.7 for elevated deck/embankments, and structures with concrete parapet walls.

3.2.5 Starting Water Surface Elevations

As Lake Ontario represents the downstream boundary defined in the new HEC-RAS model, and consistent with the floodplain mapping requirements outline presented in Section 2.5, the starting water surface elevation defined in the HEC-RAS model for the Lower Duffins Creek reach and used for all model design events is the most up-to-date definition of the 100-year Lake Ontario water level (i.e. 75.966 m CGVD 1928:1978).

As outlined in Section 2.5, for the East Duffins and West Duffins watercourses, the starting water surface elevations have been provided directly by TRCA, which are the water levels based on the 2D modeling results from the Pickering Ajax SPA Modeling study.

The internal boundary condition applied for Millers Creek is discussed further in Section 3.4.

[5] Please note that a Manning's 'n' value of 0.08 was assigned in small tributaries that were identified as dry and/or overgrown, and where other TRCA standard Manning's 'n' were not deemed to be an appropriate representation.

3.2.6 Ineffective Flow Areas

The "Ineffective Flow Area" command has been used to represent watercourse crossing embankments and backwater areas. This dataset coding has been completed following the guidance provided in the HEC-RAS User's Manual, and the HEC-RAS Hydraulic Reference Manual. At the direction of TRCA, all ineffective flow areas have been set to "non-permanent" as part of the model development.

3.2.7 Blocked Obstructions

The "Blocked Obstruction" command has been used to represent buildings within the floodplain. In addition, buildings which are immediately adjacent to cross-sections, but not necessarily bounded by cross-sections have been represented in the adjacent cross sections.

3.2.8 Hydraulic Model Calibration/Validation

Calibration and validation of the newly developed hydraulic model was not a requirement for this study.

3.3 HEC-RAS Model Development – TRCA Input

TRCA was also actively involved in the development of the new HEC-RAS model for the study area. This effort was focused as part of the model QA/QC and TRCA's input has been specific to areas where there have been recent changes, require updated 2019 DEM or other considerations.

TRCA's efforts as part of general model QA/QC for floodline delineation included minor edits, such as the following:

- Addition of cross-sections to resolve critical depth occurrences and/or close the floodline.
- Adding/removing ineffective flow areas and/or levees for floodplain storage areas.
- Contraction/expansion coefficients updated for abrupt changes in cross-section valley geometry.
- Updating channel and/or floodplain manning's n to the correct locations.
- Cross-section extensions to ensure sections are contained and the floodlines are fully closed.
- Updating bridge methodology for both low and high flow events based upon updated results due to model edits.
- Minor adjustments to watercourse centreline alignment.

More substantial edits to structures were also completed by TRCA based upon supplemental field investigation to confirm the sizing and/or elevations of select watercourse crossings, some of which included the need for topographic survey. The three (3) structures for which field survey was completed is summarized in Table 2-4 and have been updated in the hydraulic model to reflect the survey data, respectively.

Several reaches were also extended further upstream by TRCA, in order to match the extent of existing engineered floodlines and include these areas in the current update. In some cases, these reach extensions may have required additional flow nodes and/or shifting flow change locations, which would have also been completed by TRCA as part of their edits.

The reaches which have been extended through TRCA's edits are as follows:

- Brougham Trib A – Trib A1
- Major Creek – Reach 1
- Millers Creek – Reach 1
- Mitchell Trib A – Trib A1
- Reesor Creek – Reach 3
- Reesor Trib A – Trib A1
- Stouffville A – Trib A1
- Wixon Trib A – Trib A1

The reach extension along Major Creek resulted in an additional structure being added (duf_231), which is one of the structures for which additional TRCA field visits were completed. As part of floodline delineation, an additional structure on Ganatsekiagon Creek (duf_070b) was added to improve the floodline accuracy, bringing the modelled structures total to two hundred and twenty-one (221).

3.4 PCSWMM Model Development

3.4.1 PCSWMM Professional

Hydrologic and hydraulic modelling of the duf_148 crossing (Miller's Creek at Highway 401) has been completed by TRCA using Personal Computer Storm Water Management Model (PCSWMM) 2013 Professional (version 5.1.011). PCSWMM can simulate the runoff response from rainfall inputs and routes the resulting unsteady state flows (i.e. time varying hydrographs) through a specified system of hydraulic conduits (i.e. storm sewers, open channels, culverts, etc.) and accounts for attenuation due to backwater in conduits and surface ponding in right-of-ways. For this assessment, the runoff response simulation capacities of the software were not utilized as flows from the Duffins Creek Watershed Hydrology Study Update (Aquafor Beech, 2013) study were used.

The model's analytical engine is SWMM5 (Storm Water Management Model version 5), developed by the U.S. Environmental Protection Agency. The routing component of SWMM5 solves the complete 1-dimensional Saint Venant (shallow water) equations for unsteady flow (continuity and momentum), which allows for full accounting varied flow conditions (backwater, channel storage, flow reversal, pressurized flow, etc.).

The PCSWMM model is considered well-suited to detailed urban drainage investigations and as such has been applied for the current assessment for a single culvert crossing, as described in the section below.

3.4.2 Highway 401 Crossing Structure duf_148 PCSWMM Model

The Highway 401 crossing (structure duf_148) is a component of the HEC-RAS model along Millers Creek (RS. 806.36), located between Church Street South to the west, and Westney Road South to the east. This structure is located upstream of the confluence with Main Duffins Creek south of the Pickering Ajax SPA (not included in the model), which contributes to the downstream reach of Lower Duffins prior to the watershed outlet at Lake Ontario. The location and associated river reaches are shown in Figure 3-7.

Figure 3-3: Highway 401 Crossing Structure (duf_148) Location

The available drawing sets detailing this structure include:

- Highway 401 Bridge Widening, Contract No. 75-07
- GO TRANSIT East Section – Pickering to Whitby Project, Contract No. GGE-311
- GO-ALRT Pickering to Oshawa Section Contract GGE 312
- GO TRANSIT East Section – Pickering to Whitby Project, Contract No. GGE-315 (Highway 401/Westney Road North Interchange)

- Contract No 98-39 MTO (Highway 401, Brock Road to Harwood Avenue)
- Contract No. 2017-2041 Central Region, MTO

Additionally, survey was completed at this structure by MTO (ref. 18M-01021-10 Miller Ck Culvert), which has been used as the primary source of data for the coding and modelling of this structure by TRCA.

Based upon the survey and associated drawings, the structure includes the following elements:

- Two (2) culverts from Inlet to Storm Chamber:
  - 6.13 m width x 2.3 m height concrete culvert
  - 3.1 m diameter CSP
- Three (3) CSP pipes from Storm Chamber to Outlet
  - 4.2 m diameter CSP
  - 3.25 m diameter CSP
  - 1.5 m diameter CSP
- Total length from Inlet to Outlet is estimated as 172 m based upon the profile view of the survey (95 m from Inlet to Storm Chamber, and 77 m from Storm Chamber to outlet).

Given the complex nature of this structure with varying inlets and outlets, the decision was made to complete a separate PCSWMM model to evaluate the hydraulic capacity of this structure and incorporate the hydraulic results into the HEC-RAS model via an internal boundary curve. The PCSWMM model for this structure was developed by TRCA and reviewed by Wood. The inverts for the structure have been sourced from the completed survey, and some assumptions were required for the inverts inside the Storm Chamber.

This structure has been included in the HEC-RAS modelling as a multiple culvert structure, as well as an internal boundary curve applied at the upstream cross-section (RS 884.14) based upon the results of the PCSWMM model for all simulated events, as developed by TRCA. An image of the structure coding in HEC-RAS is presented in Figure 3-8, and the internal boundary curve resulting from the PCSWMM modelling is presented in Table 3-2.

Table 3-2: HEC-RAS Internal Rating Curve for Highway 401 Structure (duf_148)

Profile	REG	100Y	50Y	25Y	10Y	5Y	2Y
Known WS (m)	88.70	83.33	83.14	82.94	82.66	82.39	82.14

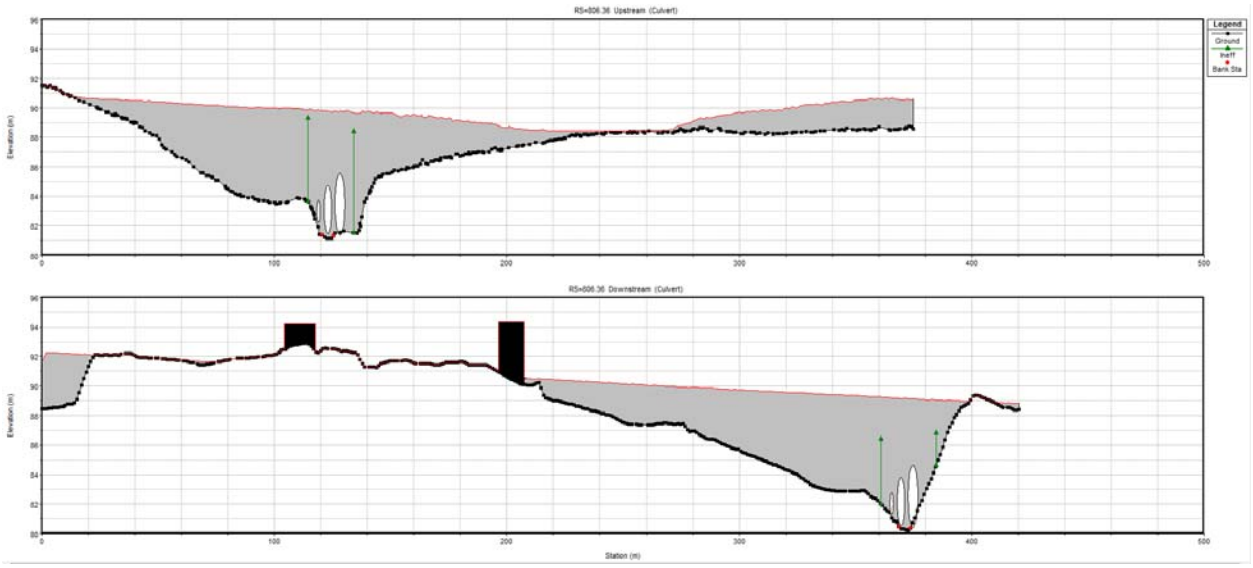

Figure 3-4: Highway 401 Structure (duf_148) HEC-RAS Culvert Coding

3.5 Model Sensitivity and Uncertainty Analysis

The new hydraulic model has been developed based on a review of available data, site reconnaissance of structures, new LiDAR data, and selection of appropriate input data. However, as is the case in all numerical modelling of physical processes, there is the inherent potential for errors or uncertainty to be associated with the selection of input variables which could affect the resulting flood flows. Sensitivity analysis can be useful for a range of purposes, including:

- Testing the robustness of simulation model results in the presence of uncertainty.
- Increasing the understanding of the relationships between input and output variables in simulation models.
- Increasing confidence in simulation model results by identifying model inputs that cause significant uncertainty in the output. Increased attention to these specific model inputs can then be applied to ensure proper definition and/or parameterization.
- Ensuring the model accurately reflects watercourse conditions and responses by identifying errors in the model output as reflected by unexpected relationships between inputs and outputs.

As well, all sensitivity analysis modelling has been completed using a Subcritical flow regime in HEC-RAS.

3.5.1 Manning's Roughness

The Manning's Roughness input parameter of the hydraulic model defines the relative roughness of the main channel and floodplain areas. A higher Manning's Roughness coefficient will, generally, increase flooding levels and reduce velocities. The Manning's Roughness definitions at

each cross-section were increased and decreased by 20 percent. The results of the analysis are presented in Table 3-3.

The selection of Manning's Roughness coefficient generally has a limited overall impact. However, significant impacts in localized reaches are demonstrated through this analysis where changes in flow regime occur as a result of roughness variation (i.e. from critical to subcritical or vice-versa). Large changes in water surface can also occur in cross-sections near (typically upstream) critical culvert and bridge locations where flow changes from open surface flow to surcharged or overtopping situations. The analysis has demonstrated that altering of Manning's Roughness coefficient by 20% (positive or negative) results in an average change in computed water surface elevation up to about 3 cm.

Table 3-3: Sensitivity Analysis - Manning's Roughness – Change in Computed Water Surface Elevations

Event	Manning's n + 20%			Manning's n - 20%		
	Average Change in CWSE[1] (m)	Maximum Increase in CWSE (m)	Maximum Decrease in CWSE (m)	Average Change in CWSE (m)	Maximum Increase in CWSE (m)	Maximum Decrease in CWSE (m)
2 year	0.03	0.17	-0.25	-0.03	0.04	-0.23
5 year	0.03	0.29	-0.14	-0.03	0.45	-0.31
10 year	0.03	0.27	-0.27	-0.03	0.20	-0.26
25 year	0.03	0.52	-0.96	-0.03	0.35	-0.44
50 year	0.03	0.66	-1.49	-0.03	0.83	-0.54
100-year	0.03	0.36	-2.22	-0.03	1.54	-0.64
Regional	0.04	0.64	-2.43	-0.03	3.54	-1.09

Notes:
1 CWSE = Computed Water Surface Elevation

A comparative assessment of the occurrence of critical depth at cross-sections was also completed (ref. Table 3-4). The results indicate that variation of Manning's roughness co-efficient has a significant influence on critical depth occurrence across the model. As would be expected, an upward change in this variable tends to decrease the number of sections where critical depth is the resultant computed water surface elevation when compared with the occurrence of critical depth in the base model. Similarly, a downward change in Manning's roughness tends to increase the occurrence of critical depth.

Table 3-4: Sensitivity Analysis - Manning's Roughness – Change in Critical Depth Occurrence

Scenario	Critical Depth Occurrence by Event						
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	Regional
Manning's n -20%	2766	2961	3054	3179	3226	3292	2950
Base Model	1959	2090	2197	2354	2428	2510	2315
Manning's n +20%	1393	1521	1573	1651	1702	1749	1764

Notes:
1 The values presented in this table are the number of computational cross-section in the HEC-RAS model where critical depth is the resultant computed water surface elevation.

3.5.2 Peak Discharge

To determine the impact of the changes in peak flows on the resulting water surface profile, the peak flows for the various flow scenarios were increased and decreased by 10, and 20 percent. Table 3-5 summarizes the changes in water levels for modelled events associated with the varying peak flow conditions.

As for Manning's Roughness, the selection of peak discharge generally has a limited impact on average (<0.2 m). However, significant impacts in localized reaches is demonstrated through this analysis where changes in flow regime occur (i.e. from critical to subcritical or vice-versa). Large changes in water surface can also occur in cross-sections near (typically upstream) critical culvert and bridge locations where flow changes from open surface flow to surcharging or overtopping situations.

A comparative assessment of the occurrence of critical depth at cross-sections was also completed (ref. Table 3-6). The results indicate that variation of flow has a minimal influence on critical depth occurrence across the model.

3.5.3 Starting Water Surface Elevation

The downstream boundary conditions were provided to the study by TRCA for all modelled flood events. The base HEC-RAS model for this study used the most up-to-date definition of the 100-year Lake Ontario water level (i.e. 75.966 m CGVD 1928:1978) as the Lake Ontario boundary condition, and water levels based on the Pickering Ajax SPA 2D Modeling study for all model flow scenarios. For this aspect of the sensitivity analysis, the downstream boundary conditions were increased by 1 m. The results of the analysis are presented in Table 3-7.

The resulting increase in water level is consistent with the incremental increase in the downstream boundary condition of 1.0 m. The maximum increase in water level is 1.16 m, which is associated with the Regional flood event. For the change in the Lake Ontario boundary, the change in WSE

results is primarily within the approximately. 5 km stretch of the Lower Duffins Reach 1, with minor changes occurring within the downstream portion of Millers Creek, less than 200 m from the confluence point. The West Duffins reaches were shown to be relatively insensitive to an increase in starting WSE, with the affected cross-sections being within the downstream portion of West Duffins Reach 1 (less than 500 m).

The East Duffins reaches were shown to have a wider range of WSE changes as a result of the increased boundary condition, seeing as there are three (3) tributaries in close proximity to the Main Duffins Reach 2, which includes the East Duffins, Urfe Creek, and the Ganatsekiagon Creek. During the 2-year event, the WSE changes are limited within the Main Duffins Reach 1 (most downstream). For the 5-year through to Regional events, the WSE changes are exhibited throughout all three (3) tributaries, having a maximum combined reach length of approx. 2.8 km impacted during the Regional event.

Table 3-5: Sensitivity Analysis – Peak Discharge – Change in Computed Water Surface Elevations

Event	Average Change in CWSE[1] (m)	Maximum Increase in CWSE (m)	Maximum Decrease in CWSE (m)	Average Change in CWSE (m)	Maximum Increase in CWSE (m)	Maximum Decrease in CWSE (m)
	Peak Flow - 10%			Peak Flow + 10%		
2 year	-0.024	0.210	-0.620	0.023	0.670	-0.190
5 year	-0.028	0.300	-0.340	0.026	0.330	-0.240
10 year	-0.031	0.270	-0.480	0.029	0.350	-0.370
25 year	-0.034	0.430	-1.000	0.033	0.650	-0.270
50 year	-0.036	0.500	-1.270	0.034	0.720	-1.320
100-year	-0.038	1.480	-0.740	0.036	0.870	-0.430
Regional	-0.073	2.000	-2.700	0.067	1.440	-1.910
	Peak Flow - 20%			Peak Flow + 20%		
2 year	-0.048	0.130	-1.140	0.044	1.390	-0.170
5 year	-0.057	0.180	-0.420	0.051	0.420	-0.180
10 year	-0.064	0.210	-0.430	0.057	0.760	-0.320
25 year	-0.071	0.340	-1.010	0.063	1.560	-0.600
50 year	-0.076	0.880	-1.530	0.066	0.860	-1.280
100-year	-0.079	0.520	-0.970	0.069	1.240	-2.320
Regional	-0.147	2.310	-2.770	0.133	2.260	-2.520

Notes:
1 CWSE = Computed Water Surface Elevation

Table 3-6: Sensitivity Analysis - Peak Discharge – Change in Critical Depth Occurrence

Scenario	Critical Depth Occurrence by Event						
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr	Regional
Peak Flow - 20%	1915	2019	2107	2209	2314	2385	2397
Peak Flow - 10%	1941	2065	2152	2286	2374	2445	2357
Base Model	1959	2090	2197	2354	2428	2510	2315
Peak Flow + 10%	1978	2141	2258	2388	2483	2526	2288
Peak Flow + 20%	1989	2175	2305	2439	2522	2547	2261

Notes:
1 The values presented in this table are the number of computational cross-section in the HEC-RAS model where critical depth is the resultant computed water surface elevation.

Table 3-7: Sensitivity Analysis – Starting Water Level – Summary of Changes in Computed Water Surface Elevations

Event	Starting Water Surface Elevation + 1 m			
	Average Change in CWSE[1] (m)	Maximum Increase in CWSE (m)	Maximum Decrease in CWSE (m)	Maximum Upstream Propagation
				Cross-section[2,3]
2 year	0.425	1.040	-0.060	Lake Ontario – Millers Creek-Reach 1-RS 189.8914 [4] West SPA – West Duffins-Reach 1-RS 474.1478 East SPA – Main Duffins-Reach 2-RS 496.9963
5 year	0.404	1.130	-0.310	Lake Ontario – Lower Duffins-Reach 1-RS 4714.4 West SPA – West Duffins-Reach 1-RS 401.9729 East SPA – East Duffins-Reach 1-RS 177.6161 Ganatsekiagon Ck-Reach 1-RS 466.0594 Urfe Creek-Reach 2-RS 247.6839
10 year	0.407	1.130	-0.270	Lake Ontario – Lower Duffins-Reach 1-RS 4389.907 West SPA – West Duffins-Reach 1-RS 474.1478 East SPA – East Duffins-Reach 1-RS 237.3819 Ganatsekiagon Ck-Reach 1-RS 466.0594 Urfe Creek-Reach 2-RS 247.6839
25 year	0.402	1.000	-0.080	Lake Ontario – Lower Duffins-Reach 1-RS 4389.907 West SPA – West Duffins-Reach 1-RS 401.9729 East SPA – East Duffins-Reach 1-RS 237.3819 Ganatsekiagon Ck-Reach 1-RS 466.0594 Urfe Creek-Reach 2-RS 195.5754
50 year	0.360	1.000	-0.090	Lake Ontario – Millers Creek-Reach 1-RS 150.4365 [4] West SPA – West Duffins-Reach 1-RS 283.1107 East SPA – East Duffins-Reach 1-RS 336.0535 Ganatsekiagon Ck-Reach 1-RS 317.5556 Urfe Creek-Reach 2-RS 195.5754
100-year	0.444	1.000	-0.110	Lake Ontario – Lower Duffins-Reach 1-RS 4247.347 West SPA – West Duffins-Reach 1-RS 283.1107 East SPA – East Duffins-Reach 1-RS 336.0535 Ganatsekiagon Ck-Reach 1-RS 576.043 Urfe Creek-Reach 2-RS 195.5754
Regional	0.703	1.160	-0.330	Lake Ontario – Lower Duffins-Reach 1-RS 2523.536 West SPA – West Duffins-Reach 1-RS 474.1478 East SPA – East Duffins-Reach 1-RS 679.2131 Ganatsekiagon Ck-Reach 1-RS 779.2876 Urfe Creek-Reach 2-RS 730.8303

Notes:
1 Computed Water Surface Elevation over the reach of affected cross-sections
2 Affected cross-sections are summarized based upon the boundary condition zone (Lake Ontario, West SPA or East SPA Modeling Result Boundary)
3 The cross-section number is indicative of the zone of influence of the change in boundary conditions.
4 The results demonstrate that the computed WSE increases on Millers Creek occur only during the 2 year and 50 year events. The results show that a maximum increase of only 0.02 m (impacting 3 XS) and 0.01 m (impacting 2 XS) occurs during the 2 year and 50 year respectively. These results demonstrate a minimal impact on Millers Creek and are likely attributed to oscillations in the model, isolated to the 2 year and 50 year events.

3.5.4 Summary of Hydraulic Model Sensitivity

Average changes in computed water levels resulting from the sensitivity runs were reasonably close to base case results. More significant changes in computed water levels were attributed to changes in flow regime (i.e. from critical to subcritical or vice-versa) or changes in flow conditions around bridges and culverts (i.e. changes from open surface flow to surcharged or overtopping situations).

As noted previously, sensitivity analysis is used to:

- *Increase confidence in simulation model results by identifying model inputs that cause significant uncertainty in the output thereby focusing increased attention towards estimation of these specific model inputs.*

  The sensitivity analysis results associated with river reach roughness and flows did not justify any additional effort towards refining initial model estimates for these parameters.

- *Ensuring the model is accurately reflecting watershed conditions and responses by identifying errors in the model output as reflected by unexpected relationships between inputs and outputs.*

  The sensitivity analysis results did not demonstrate any unexpected relationships or model errors.

The sensitivity analysis results associated with the hydraulic model indicate a general insensitivity to changes in input parameters when viewed as average changes to computed water surface elevations. Some specific locations do experience larger variation in computed water levels but these are associated with changes in the flow regime between sub-critical flow and critical flow (and vice versa) and changes in bridge hydraulics associated with open water to pressure flow situations (and vice versa).

The sensitivity analysis results of the hydraulic models did not suggest a need to alter the parameterization of the hydraulic models for the present study.

4.0 Spill Identification and Floodplain Mapping (Task 3)

4.1 Task 3A - Floodline Mapping and Identification of Spills

4.1.1 HEC-RAS Model Finalization

Upon receipt of TRCA approval for the new hydraulic model, preparation of the floodplain delineations for the required suite of flow scenarios required for this assignment (ref. Task 1D) was completed in collaboration with TRCA. The flow scenarios were the Regional Storm and, the 2, 5, 10, 25, 50, 100 design storms.

The delineation of the Regulatory floodline was completed by TRCA in compliance with MNRF procedures, whereby the greater of the 100-year, or Hurricane Hazel inundation limits has been used to establish the Regulatory floodline. The 100-year and Hurricane Hazel inundation limits were subjected to a greater level of scrutiny for accuracy commensurate with an engineering flood delineation approach.

Flood inundation limits for the other flow scenarios were not subjected to the same "clean-up" effort as the engineered flood delineations as the 2, 5, 10, 25, 50, 100-year design storm flood zones are to be used for flood risk screening and characterization only.

Please also note that:

- In confluence areas floodplain boundaries were subject to manual adjustment to reflect probable spills from one connecting watercourse to another.
- For a number of watercourses, cross-sections were included at a structure which represented the upstream limit of a modelled reach. In some cases, TRCA directed that flood inundation limits only be delineated to the downstream side of the structure.

4.1.2 Structure Overtopping

Table 4-1 summarizes all of the watercourse crossings/structures modelled in the new HEC-RAS model and the associated computed water surface elevations for each of the modelled flow scenarios.

Table 4-2 summarizes the available freeboard and overtopping depths for all watercourse crossings and all modelled flow scenarios.

It is worth noting that Table 4-2 highlights ten (10) crossings that do not have the conveyance capacity to accommodate the 2-year peak flow subject to the crossing. Furthermore, an additional four (4) crossings do not have the conveyance capacity to accommodate the 5-year peak flow subject to the crossing. The number of simulated overtopping structures increases to a maximum of one-hundred and thirty-six (136) during the Regional event.

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Table 4-1: Modelled Structures – Computational Summary

Crossing #	Crossing Location/Designation	Structure Type	HEC-RAS Watercourse Designation	HEC-RAS Section Upstream of Structure	Top of Road / When Weir Flow Begins (m)	Computed Water Surface Elevations (m)							Regulatory
						2 year	5 year	10 year	25 year	50 year	100 year	Regional	
duf_001	Sideline 32	Culvert	W Duffins Trib E / West E1	395.19	192.90	192.26	192.3	192.32	192.35	192.37	192.4	192.98	192.98
duf_002	North Road	Culvert	W Duffins Trib C / West C1	1911.78	210.48	210.52	210.55	210.56	210.57	210.58	210.59	210.82	210.82
duf_003	Sideline 34	Culvert	W Duffins Trib F / West F1	554.58	190.94	190.28	190.37	190.42	190.49	190.54	190.59	191.01	191.01
duf_004	Sideline 24	Culvert	W Duffins Trib H / West H1	3868.79	241.19	240.46	240.55	240.6	240.67	240.72	240.77	241.27	241.27
duf_005	Sideline 20	Culvert	Urfe Creek / Reach 6	3333.85	202.90	202.2	202.24	202.26	202.29	202.3	202.32	202.95	202.95
duf_006	Sideline 22	Culvert	Urfe Trib E / Trib E1	3734.02	212.21	211.02	211.09	211.13	211.18	211.21	211.25	212.43	212.43
duf_007	Sideline 8	Culvert	E Duffins Trib I / East I1	504.13	191.19	189.96	190.09	190.17	190.27	190.36	190.44	191.59	191.59
duf_008	Sideline 32	Bridge	West Duffins / Reach 9	530.63	198.13	196.5	196.81	197.01	197.3	197.48	197.69	198.93	198.93
duf_009	Sideline 20	Bridge	Mitchell Trib B / Trib B1	1800.41	241.32	239.9	240.08	240.19	240.34	240.34	240.57	241.75	241.75
duf_010	Sideline 34	Culvert	W Duffins Trib G / West G1	229.71	184.41	183.33	183.39	183.43	183.47	183.5	183.53	184.46	184.46
duf_011	Sideline 34	Bridge	Reesor Creek / Reach 1	4548.21	225.08	224.12	224.52	224.77	225.06	225.09	225.12	226.43	226.43
duf_012	Sideline 32	Culvert	W Duffins Trib D / West D2	871.38	194.79	194.07	194.23	194.32	194.46	194.57	194.67	195	195
duf_013	North Rd	Culvert	W Duffins Trib H / West H1	246.92	208.56	206.04	206.17	206.25	206.35	206.42	206.49	208.3	208.3
duf_014	Harwood Ave N	Culvert	Millers Creek / Reach 1	8357.46	112.41	110.24	110.45	110.58	110.75	110.88	111.01	112.85	112.85
duf_015	Sideline 22	Culvert	Urfe Creek / Reach 6	5569.17	229.62	229.65	229.67	229.7	229.7	229.71	229.73	229.88	229.88
duf_016	Williamson Dr W	Bridge	Millers Creek / Reach 1	6917.96	107.42	103.92	104.15	104.32	104.5	104.6	104.67	105.71	105.71
duf_018	Sideline 20	Bridge	Mitchell Trib B / Trib B1	1330.51	235.14	234.6	234.82	234.91	235.21	235.24	235.27	235.72	235.72
duf_019	Sideline 22	Culvert	Ganatsekiagon A / Trib A1	1298.32	146.70	145.98	146.11	146.19	146.28	146.35	146.42	146.89	146.89
duf_020	Westney Road	Culvert	E Duffins Trib F / East F1	164.27	172.81	171.76	171.83	171.88	171.94	171.99	172.02	172.86	172.86
duf_022	Burkholder Street	Culvert	Stouffville Ck / Reach 1	6118.36	262.97	262.74	262.98	263.18	263.35	263.39	263.44	263.76	263.76
duf_023	Millard Street	Culvert	Stouffville Ck / Reach 1	7213.03	271.61	269.85	269.98	270.06	270.16	270.24	270.47	271.75	271.75
duf_024	Somerville Street	Culvert	Stouffville Ck / Reach 1	6241.94	264.47	263.7	263.93	264.07	264.23	264.52	264.7	265.18	265.18
duf_025	Market Street	Culvert	Stouffville Ck / Reach 1	6309	264.98	264.05	264.24	264.37	264.52	264.64	264.82	266.06	266.06
duf_026	North Road	Bridge	W Duffins Trib I / West I1	119.21	206.74	203.41	203.56	203.64	203.76	203.85	203.93	205.61	205.61
duf_027	Sideline 20	Bridge	Mitchell Creek / Reach 3	1425.76	232.83	231.55	231.74	231.86	232.03	232.17	232.29	233.35	233.35
duf_028	Hoover Park Drive	Culvert	Stouffville Ck / Reach 1	5543.76	264.01	258.79	258.95	259.16	259.28	259.33	259.4	260.03	260.03
duf_029	Sideline 34	Culvert	Reesor Trib A / Trib A1	285.78	232.59	231.82	232.07	232.31	232.63	232.66	232.67	232.88	232.88
duf_030	Sideline 12	Bridge	Mitchell Creek / Reach 1	494.94	161.22	159.35	159.59	159.77	159.93	160.52	160.62	162.78	162.78
duf_031	Haskell Ave	Culvert	Millers Creek / Reach 1	8006	111.86	107.03	107.16	107.25	107.35	107.41	107.48	108.47	108.47
duf_032	Sideline 12	Culvert	E Duffins Trib E / East E1	1331.75	182.01	180.46	180.54	180.6	180.66	180.71	180.75	181.45	181.45
duf_033	Sullivan Drive	Culvert	Millers Creek / Reach 1	4475.9	99.35	96.34	96.64	96.81	97.06	97.26	97.43	99.51	99.51
duf_034	Jacwin Drive	Culvert	Millers Creek / Reach 1	967.62	86.49	83	83.4	83.72	84.12	84.43	84.76	88.74	88.74
duf_035	Rotherglen Road South	Bridge	Millers Creek / Reach 1	1650.76	88.36	85.99	86.45	86.83	87.63	87.85	88.01	89.72	89.72
duf_036	MaGill drive	Culvert	Millers Creek / Reach 1	3783.55	97.02	93.75	94.05	94.15	94.28	94.42	94.56	97.57	97.57
duf_037	Carwin Crescent	Culvert	Millers Creek / Reach 1	1233.77	87.97	84.07	84.4	84.59	84.8	84.96	85.42	89.32	89.32
duf_038	Sideline 24	Culvert	W Duffins Trib K / West K1	1427.05	241.33	240.35	240.51	240.61	240.74	240.84	240.94	241.57	241.57
duf_039	Sideline 24	Culvert	W Duffins Trib L / West L1	1133.25	240.14	239.8	239.99	240.13	240.16	240.17	240.18	240.29	240.29
duf_040	North Road	Bridge	W Duffins Trib C / West C1	1764.79	208.68	208.64	208.76	208.79	208.83	208.85	208.86	209.24	209.24
duf_042	Church Street N	Culvert	E Duffins Trib B / East B1	1100.82	121.93	117.98	118.07	118.13	118.2	118.26	118.31	120.56	120.56
duf_043	Whitevale Road	Culvert	Ganatsekiagon C / Trib C1	941.3	178.39	174.26	174.37	174.43	174.51	174.57	174.63	177.24	177.24
duf_044	5th Concession Road	Culvert	Urfe Trib D / Trib D1	632.6	156.01	150.98	151.05	151.09	151.14	151.16	151.2	152.12	152.12
duf_045	Sideline 16	Culvert	Spring Trib B / Trib B1	220.9	179.18	177.59	177.7	177.76	177.85	177.91	177.98	179.42	179.42
duf_046	7th Concession Road	Culvert	E Duffins Trib D / East D1	309.63	164.89	164.03	164.1	164.14	164.19	164.22	164.25	164.89	164.89

Crossing #	Crossing Location/Designation	Structure Type	HEC-RAS Watercourse Designation	HEC-RAS Section Upstream of Structure	Top of Road / When Weir Flow Begins (m)	Computed Water Surface Elevations (m)							Regulatory
						2 year	5 year	10 year	25 year	50 year	100 year	Regional	
duf_047	8th Concession Road	Culvert	E Duffins Trib F / East F1	714.1	186.01	185.38	185.5	185.61	185.98	186.02	186.01	186.1	186.1
duf_048	5th Concession Road	Culvert	Urfe Trib C / Trib C2	782.9	149.44	145.96	146.07	146.13	146.22	146.27	146.34	149.53	149.53
duf_049	Concession Rd 7	Culvert	W Duffins Trib H / West H1	3416.18	238.91	238.21	238.32	238.39	238.5	238.58	238.66	238.99	238.99
duf_050	5th Concession Road	Bridge	East Duffins / Reach 4	243.63	120.43	118.4	118.75	118.95	119.21	119.37	119.52	121.12	121.12
duf_051	Rossland Road West	Bridge	Urfe Creek / Reach 2	1387.18	93.99	89.62	89.78	89.88	90.02	90.09	90.15	91.44	91.44
duf_052	5th Concession Road	Culvert	Brougham Creek / Reach 1	550.13	122.05	121.29	121.68	121.96	122.17	122.23	122.29	122.81	122.81
duf_053	Whitevale Road	Culvert	Ganatsekiagon Ck / Reach 4	1233.15	179.93	175.95	176.12	176.22	176.35	176.45	176.54	180.19	180.19
duf_054	9th Concession Road	Culvert	Reesor Creek / Reach 3	1313.57	248.52	242.32	242.57	242.72	242.9	243.09	243.24	245.72	245.72
duf_055	Sideline 26	Culvert	W Duffins Trib H / West H1	2854.66	232.05	231.46	231.6	231.7	231.83	231.92	232.03	232.2	232.2
duf_056	York Durham Line	Bridge	Stouffville Ck / Reach 1	162.64	234.25	233.44	233.67	233.76	233.92	234.04	234.16	234.85	234.85
duf_057	8th Concession Road	Bridge	East Duffins / Reach 10	652.8	177.54	175.12	175.34	175.47	175.63	175.76	175.89	178.82	178.82
duf_058	Concession Rd 8	Culvert	West Duffins / Reach 12	1484.18	221.47	220.12	220.36	220.53	220.83	220.74	220.8	222.05	222.05
duf_059	19th Avenue	Bridge	Stouffville Ck / Reach 1	3416.26	244.65	243.71	243.87	244	244.09	244.15	244.21	245.2	245.2
duf_060	Reesor Road	Bridge	Stouffville Ck / Reach 1	2339.89	240.66	239.56	239.69	239.75	239.83	239.88	239.92	241.52	241.52
duf_061	Church Street N	Bridge	East Duffins / Reach 2	200.15	100.07	90.36	90.72	90.94	91.18	91.34	91.52	93.28	93.28
duf_062	Uxbridge Pickering Townline	Bridge	West Duffins / Reach 13	3856.02	261.80	260.17	260.38	260.52	260.71	260.85	260.99	262.42	262.42
duf_063	Sideline 30	Culvert	West Duffins / Reach 13	2672.04	251.07	249.84	250	250.13	250.28	250.38	250.49	251.14	251.14
duf_064	Concession Rd 7	Bridge	West Duffins / Reach 11	683.56	207.20	205.72	205.98	206.11	206.32	206.46	206.62	207.95	207.95
duf_065	9th Concession Road	Culvert	East Duffins / Reach 13	1173.63	208.79	204.9	205.11	205.23	205.4	205.51	205.62	207.93	207.93
duf_066	Whites Road	Bridge	West Duffins / Reach 1	6843.32	136.43	132.08	132.47	132.69	133	133.22	133.4	137.12	137.12
duf_067	Taunton Road	Bridge	West Duffins / Reach 1	7251.54	166.70	134.3	134.63	134.82	135.07	135.25	135.4	138.31	138.31
duf_068	Webb Rd	Bridge	West Duffins / Reach 13	6556.29	280.09	277.85	278.05	278.17	278.32	278.46	278.63	279.93	279.93
duf_069	Brock Road	Culvert	Urfe Trib C / Trib C1	129.39	141.06	138.94	139.11	139.21	139.31	139.38	139.44	140.13	140.13
duf_070	Whitevale Road	Culvert	Ganatsekiagon B / Trib B1	2452.11	197.62	196.39	196.52	196.59	196.65	196.69	196.73	197.93	197.93
duf_070b	driveway near Whitevale Road	Culvert	Ganatsekiagon B / Trib B1	2651.7	199.39	199.4	199.42	199.44	199.47	199.47	199.48	199.69	199.69
duf_071	Sideline 28	Culvert	Wixon Trib A / Trib A1	168.44	244.59	242.48	242.59	242.66	242.74	242.8	242.86	243.95	243.95
duf_072	Whitevale Road	Bridge	West Duffins / Reach 3	4463.92	168.80	164.48	164.84	165.09	165.41	165.6	165.77	169.04	169.04
duf_073	Bethessda Sideroad	Culvert	Stouffville Ck / Reach 2	1530.73	283.38	282.1	282.24	282.33	282.44	282.54	282.65	283.74	283.74
duf_074	Bayley Street West	Bridge	Lower Duffins / Reach 1	4228.42	78.90	77.41	77.75	77.9	78.19	78.42	78.14	80.84	80.84
duf_075	9th Concession Road	Bridge	West Duffins / Reach 13	1413.12	238.86	236.19	236.42	236.53	236.65	236.75	236.73	239.16	239.16
duf_076	Balsam Road	Bridge	East Duffins / Reach 14	914.89	248.11	244.94	245.08	245.14	245.24	245.31	245.38	247.18	247.18
duf_077	Uxbridge Pickering Townline	Culvert	Mitchell Creek / Reach 4	4980.88	273.45	272.56	273.04	273.46	273.52	273.55	273.55	273.76	273.76
duf_078	Brock Road	Bridge	Ganatsekiagon Ck / Reach 1	1054.71	93.46	87.29	87.45	87.54	87.66	87.73	87.8	89.17	89.17
duf_079	Whitevale Rd	Culvert	Urfe Creek / Reach 6	555.27	155.82	149.02	149.18	149.27	149.38	149.46	149.53	150.49	150.49
duf_080	Sideline 26	Culvert	Wixon Creek / Reach 2	1247.07	247.92	246.5	246.62	246.69	246.79	246.88	246.85	248.18	248.18
duf_081	Concession Road 7	Culvert	East Duffins / Reach 14	2990.54	284.41	283.21	283.42	283.55	283.73	283.87	284.01	284.88	284.88
duf_082	Sideline 30	Bridge	West Duffins / Reach 13	1651	240.18	238.66	239	239.29	239.37	239.9	240.36	240.18	240.36
duf_083	Brock Road	Culvert	Brougham Creek / Reach 4	2384.57	193.14	190.7	190.9	191.02	191.17	191.28	191.39	193.37	193.37
duf_084	Taunton Road W	Culvert	E Duffins Trib B / East B1	1031.37	122.66	116.76	116.84	116.89	116.95	116.99	117.03	118.26	118.26
duf_085	8th Concession Road	Bridge	Reesor Creek / Reach 1	4853.7	227.71	225.26	225.49	225.62	225.77	225.87	225.98	228.32	228.32
duf_086	Sideline 28	Culvert	W Duffins Trib H / West H1	1293.81	219.00	217.68	217.75	217.82	217.9	217.95	218.01	219.12	219.12
duf_087	Taunton Road E	Culvert	Millers Creek / Reach 1	8425.29	112.15	110.61	110.78	110.88	111.05	111.19	111.38	112.88	112.88
duf_088	Sideline 16	Culvert	Brougham Creek / Reach 4	1038.52	164.98	158.96	159.15	159.27	159.43	159.54	159.65	161.86	161.86
duf_089	9th Concession Rd	Culvert	Mitchell Creek / Reach 4	2213.97	247.51	246.67	246.83	246.95	247.11	247.24	247.37	247.76	247.76
duf_090	Whitevale Road	Bridge	Whitevale Trib A / Trib A1	1310.03	195.08	193.88	194.08	194.32	194.42	194.55	194.76	195.41	195.41

Crossing #	Crossing Location/Designation	Structure Type	HEC-RAS Watercourse Designation	HEC-RAS Section Upstream of Structure	Top of Road / When Weir Flow Begins (m)	Computed Water Surface Elevations (m)							Regulatory
						2 year	5 year	10 year	25 year	50 year	100 year	Regional	
duf_091	Westney Road	Culvert	E Duffins Trib H / East H1	1200.48	198.86	195.91	196.12	196.26	196.47	196.61	196.75	199.29	199.29
duf_092	Sideline 28	Bridge	Wixon Creek / Reach 1	1948.71	239.53	238.36	238.53	238.62	238.67	238.69	238.72	239.69	239.69
duf_093	9th Concession Road	Culvert	Wixon Creek / Reach 1	1569.84	236.87	234.46	234.57	234.64	234.72	234.78	234.85	236.11	236.11
duf_094	8th Concession Road	Bridge	W Duffins Trib I / West I3	1404.66	233.01	230.87	231	231.09	231.24	231.32	231.41	232.9	232.9
duf_095	Whitevail Road	Culvert	Urfe Trib E / Trib E1	782.98	156.24	151.77	151.91	152	152.11	152.18	152.26	154.02	154.02
duf_096	7th Concession Road	Bridge	East Duffins / Reach 6	241.84	155.26	150.59	150.89	151.08	151.36	151.56	151.8	155.26	155.26
duf_097	7th Concession Road	Culvert	W Duffins Trib I / West I1	1776.7	214.68	212.11	212.25	212.35	212.46	212.54	212.59	213.65	213.65
duf_098	Taunton Road	Bridge	Urfe Creek / Reach 4	2807.69	138.56	133.13	133.25	133.32	133.42	133.46	133.56	135.41	135.41
duf_099	Brock Road	Culvert	Urfe Creek / Reach 4	2296.75	131.39	127.63	127.78	127.86	127.97	128.04	128.12	129.8	129.8
duf_100	William Jackson Dr	Bridge	Urfe Creek / Reach 4	1682.85	125.86	118.94	119.28	119.4	119.44	119.57	119.7	126.31	126.31
duf_101	Riverside Drive	Bridge	East Duffins / Reach 1	592.61	84.91	84.04	84.37	84.55	84.77	84.99	85.12	85.89	85.89
duf_102	Taunton Road W	Culvert	Urfe Trib B / Trib B1	1625.37	121.31	117.24	117.43	117.55	117.7	117.8	117.9	121.54	121.54
duf_103	6th Concession Road	Bridge	East Duffins / Reach 4	3057.81	136.20	132.06	132.34	132.49	132.71	132.86	133.01	136.3	136.3
duf_104	York Durham Line	Bridge	Reesor Creek / Reach 3	8637.34	295.13	294.06	294.26	294.39	294.56	294.7	294.98	295.61	295.61
duf_105	York Duham Line	Culvert	Reesor Creek / Reach 3	5757.95	274.73	274.38	274.71	274.83	274.89	274.92	274.94	275.26	275.26
duf_106	Main Street	Culvert	Stouffville Ck / Reach 1	6431.38	266.70	264.8	264.98	265.1	265.23	265.34	265.49	267.55	267.55
duf_107	9th Concession Road	Culvert	W Duffins Trib I / West I6	846.86	247.17	246.85	247.01	247.11	247.19	247.2	247.22	247.32	247.32
duf_108	7th Concession Road	Bridge	Reesor Creek / Reach 1	879.33	201.71	198.84	199.09	199.23	199.38	199.49	199.62	202.29	202.29
duf_109	8th Concession Road	Culvert	E Duffins Trib G / East G1	777.21	186.20	182.55	182.66	182.74	182.84	182.92	182.99	185.36	185.36
duf_110	Brock Road	Culvert	Mitchell Creek / Reach 2	3024.02	229.47	220.43	220.65	220.77	220.91	221.03	221.11	223.04	223.04
duf_111	Whitevale Road	Culvert	Whitevale Creek / Reach 2	1304.62	197.33	195.71	195.92	196.02	196.15	196.25	196.34	197.7	197.7
duf_112	Taunton Road West	Bridge	East Duffins / Reach 3	981.81	109.13	103.99	104.4	104.61	104.89	105.06	105.22	107.37	107.37
duf_113	Rossland Rd W	Culvert	Millers Creek / Reach 1	5199.67	101.64	98.44	98.71	98.84	99.03	99.24	99.41	101.33	101.33
duf_114	3rd Concession Rd	Culvert	Ganatsekiagon Ck / Reach 1	1795.59	110.50	97.7	97.89	98.01	98.13	98.23	98.32	110.9	110.9
duf_115	9th Concession Rd	Culvert	Mitchell Trib C / Trib C1	1399.2	246.40	245.06	245.18	245.26	245.35	245.42	245.49	246.55	246.55
duf_116	Taunton Road	Culvert	Ganatsekiagon Ck / Reach 1	5023.11	130.70	124.11	124.36	124.51	124.69	124.81	124.94	133.09	133.09
duf_117	Rossland Road W	Bridge	East Duffins / Reach 1	1783.42	95.77	89.28	89.59	89.77	90.01	90.17	90.32	92.33	92.33
duf_118	8th Concession Road	Culvert	E Duffins Trib E / East E1	1992.32	197.20	194.74	194.88	194.96	195.08	195.16	195.23	197.18	197.18
duf_121	Uxbridge Pickering Townline Road	Culvert	Reesor Creek / Reach 3	4120.23	263.81	262.47	262.53	262.56	262.6	262.63	262.67	263.87	263.87
duf_122	9th Concession Road	Culvert	W Duffins Trib M / West M1	1577.1	242.94	242.31	242.41	242.48	242.56	242.62	242.68	242.99	242.99
duf_123	Kingston Road West	Culvert	Millers Creek / Reach 1	2649.87	92.05	89.9	90.07	90.16	90.3	90.57	90.74	92.27	92.27
duf_124	Westney Road South	Bridge	Millers Creek / Reach 1	1870.6	90.41	86.64	87.06	87.4	88	88.24	88.43	90.14	90.14
duf_125	Highway 407	Culvert	Whitevale Trib A / Trib A2	1718.86	216.38	214.52	214.58	214.62	214.67	214.7	214.74	215.92	215.92
duf_126	HWY 7	Culvert	Whitevale Trib A / Trib A2	2285.71	221.82	220.81	220.9	220.97	221.05	221.11	221.17	222	222
duf_127	HWY 7	Culvert	W Duffins Trib C / West C1	2148.1	212.83	212.1	212.35	212.53	212.82	212.82	212.82	213.07	213.07
duf_128	Hwy 407	Culvert	Ganatsekiagon Ck / Reach 4	3696.65	211.56	209.47	209.5	209.53	209.56	209.58	209.6	210.3	210.3
duf_129	Hwy 7	Culvert	Ganatsekiagon Ck / Reach 4	4500.97	223.06	220.95	221.08	221.17	221.36	221.52	221.72	223.05	223.05
duf_131	HWY 7	Culvert	Spring Creek / Reach 2	1563.93	194.06	191.04	191.1	191.13	191.16	191.19	191.22	191.77	191.77
duf_132	HWY 407	Culvert	Spring Creek / Reach 2	1175.6	185.02	183.15	183.2	183.23	183.26	183.29	183.32	183.84	183.84
duf_133	Highway 407	Bridge	Urfe Creek / Reach 6	2544.55	196.75	190.11	190.23	190.3	190.39	190.46	190.52	191.36	191.36
duf_134	Highway 7	Culvert	Urfe Creek / Reach 6	3170.56	200.97	198.72	198.83	198.89	198.98	199.04	199.11	200.75	200.75
duf_135	HWY 407	Culvert	W Duffins Trib C / West C1	776.87	189.81	187.6	187.64	187.67	187.71	187.73	187.75	188.67	188.67
duf_136	Highway 7	Bridge	Spring Trib A / Trib A1	1088.57	179.00	160.15	160.25	160.31	160.37	160.42	160.46	161.03	161.03
duf_137	Highway 7	Culvert	Urfe Trib E / Trib E1	3430.1	205.42	204.39	204.52	204.64	204.75	204.83	204.92	205.63	205.63
duf_138	HWY 7	Culvert	W Duffins Trib D / West D1	851.51	187.94	185.31	185.45	185.53	185.64	185.71	185.79	187.94	187.94

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						2 year	5 year	10 year	25 year	50 year	100 year	Regional	
duf_139	Hwy 7	Bridge	East Duffins / Reach 4	3290.8	142.93	133.49	133.84	134.02	134.26	134.42	134.58	137.25	137.25
duf_140	HWY 7	Bridge	West Duffins / Reach 6	495.81	184.10	179.31	179.69	179.9	180.17	180.37	180.61	182.96	182.96
duf_141	HWY 7	Culvert	Brougham Creek / Reach 4	2758.02	198.60	196.18	196.28	196.33	196.41	196.46	196.52	198.55	198.55
duf_142	HWY 407	Bridge	Brougham Creek / Reach 4	1983.19	188.33	184.28	184.37	184.42	184.49	184.54	184.58	185.16	185.16
duf_143	Highway 7	Culvert	Ganatsekiagon B / Trib B1	5150.03	224.18	221.7	221.86	221.95	222.08	222.21	222.37	224.35	224.35
duf_144	Highway 407	Culvert	Ganatsekiagon B / Trib B1	4395.14	221.78	219.47	219.53	219.56	219.61	219.64	219.66	220.41	220.41
duf_145	Highway 407	Bridge	West Duffins / Reach 5	450.78	186.68	177.47	177.76	177.9	178.09	178.2	178.33	180.31	180.31
duf_146	Highway 407	Culvert	Urfe Trib E / Trib E1	2786.07	199.86	192.16	192.21	192.23	192.26	192.28	192.3	193.31	193.31
duf_147	HWY 407	Culvert	Whitevale Creek / Reach 2	3086.73	218.19	216.39	216.48	216.54	216.55	216.59	216.58	218.56	218.56
duf_148	HWY 401 & CNR	Culvert	Millers Creek / Reach 1	884.14	88.83	82.14	82.39	82.66	82.94	83.14	83.33	88.7	88.7
duf_149	HWY 407	Bridge	W Duffins Trib D / West D1	251.86	186.23	179.38	179.44	179.48	179.54	179.57	179.59	180.08	180.08
duf_150	Trail (Ped Bridge)	Bridge	Millers Creek / Reach 1	2838.63	91.72	90.46	90.78	90.94	91.14	91.31	91.46	93.18	93.18
duf_151	Trail (Ped Bridge)	Bridge	Millers Creek / Reach 1	3169.13	93.03	91.34	91.68	91.84	92.07	92.26	92.4	94.07	94.07
duf_152	Driveway off of Magill Drive	Culvert	Millers Creek / Reach 1	3615.15	97.90	92.98	93.42	93.67	94.02	94.29	94.51	96.64	96.64
duf_153	Trail (Ped Bridge)	Bridge	Millers Creek / Reach 1	4264.59	98.70	95.69	95.98	96.14	96.38	96.55	96.69	98.18	98.18
duf_154	Trail (Ped Bridge)	Bridge	Millers Creek / Reach 1	4846.7	100.38	97.46	97.72	97.87	98.08	98.26	98.41	100.1	100.1
duf_155	Trail (ped bridge)	Bridge	Millers Creek / Reach 1	5634.51	100.60	100.27	100.43	100.71	100.72	100.73	101.08	101.77	101.77
duf_156	Trail (ped bridge)	Bridge	Millers Creek / Reach 1	6405.4	102.72	102.78	102.98	103.02	103.13	103.16	103.19	103.59	103.59
duf_157	Trail (ped bridge)	Bridge	Millers Creek / Reach 1	7335.58	105.27	105.04	105.17	105.24	105.35	105.51	105.68	106.25	106.25
duf_158	Trail (ped bridge)	Bridge	Millers Creek / Reach 1	7633.99	106.34	106.05	106.22	106.37	106.48	106.55	106.4	106.99	106.99
duf_159	Trail (ped bridge)	Bridge	Millers Creek / Reach 1	8151.6	109.65	108.92	109.02	109.07	109.15	109.2	109.25	110.29	110.29
duf_160	CPR Railway	Mult Open	Millers Creek / Reach 1	8483.47	119.89	111.39	111.47	111.63	112.07	112.23	112.39	113.79	113.79
duf_161	Railway	Culvert	E Duffins Trib B / East B1	1339.58	126.71	120.11	120.17	120.22	120.27	120.32	120.36	121.28	121.28
duf_162	Railway	Bridge	Urfe Creek / Reach 4	1850.45	131.73	121.62	121.86	122.01	122.21	122.38	122.53	128.57	128.57
duf_163	Railway	Bridge	East Duffins / Reach 3	1509.05	122.02	106.53	106.91	107.12	107.39	107.54	107.71	110.37	110.37
duf_164	Pedestrian Bridge	Bridge	East Duffins / Reach 3	3048.06	111.65	111.59	111.88	112.14	112.27	112.35	112.43	113.3	113.3
duf_165	Railway	Bridge	Mitchell Trib D / Trib D1	580.67	251.59	249.37	249.48	249.55	249.65	249.72	249.79	251.12	251.12
duf_166	Railway	Culvert	Mitchell Trib C / Trib C2	789.29	257.03	257.01	257.01	257.01	257.01	257.01	257.01	257.01	257.01
duf_167	Trail	Bridge	Mitchell Creek / Reach 1	372.07	160.45	158.64	159.07	159.35	159.74	160.5	160.58	161.21	161.21
duf_168	Trail	Bridge	East Duffins / Reach 6	817.48	156.91	153.43	153.81	153.89	154.43	154.66	155.27	157.82	157.82
duf_169	Trail	Culvert	E Duffins Trib E / East E1	539.64	170.74	167.85	167.96	168.05	168.15	168.23	168.29	170.86	170.86
duf_170	Railway	Culvert	E Duffins Trib K / East K1	594.83	252.58	242.2	242.32	242.39	242.49	242.56	242.63	245.92	245.92
duf_171	Railway	Culvert	East Duffins / Reach 14	613.24	254.80	240.39	240.52	240.61	240.73	240.82	240.91	242.81	242.81
duf_172	Harrisview Street	Culvert	E Duffins Trib A / East A1	324.13	105.65	103.42	103.45	103.48	103.49	103.51	103.52	103.85	103.85
duf_173	Canadian Pacific Railroad Bridge	Bridge	West Duffins / Reach 1	3903.27	134.80	110.46	110.79	110.98	111.31	111.37	111.47	112.7	112.7
duf_174	Weir	Inl Struct	West Duffins / Reach 3	5403.26	172.05	172.81	173.08	173.25	173.47	173.63	173.79	173.86	173.86
duf_175	Railway	Bridge	Major Creek / Reach 1	772.17	193.74	187.97	188.1	188.17	188.27	188.34	188.41	189.77	189.77
duf_176	Railway	Bridge	Reesor Creek / Reach 1	730.86	206.68	197.77	197.98	198.11	198.25	198.36	198.5	200.65	200.65
duf_177	CPR Railway	Bridge	West Duffins / Reach 12	642.06	223.28	216.94	217.19	217.32	217.51	217.66	217.84	221.16	221.16
duf_178	CPR Railway	Culvert	W Duffins Trib O / West O1	275.36	221.06	219.44	221.1	221.12	221.11	221.12	221.12	221.18	221.18
duf_179	Railway	Bridge	W Duffins Trib I / West I3	2083.25	236.86	234.17	234.31	234.39	234.49	234.56	234.63	236.04	236.04
duf_180	Trail	Bridge	Stouffville Ck / Reach 1	4861.85	253.36	252.67	252.78	252.88	252.99	253.07	253.17	254.03	254.03
duf_181	Trail	Bridge	Stouffville Ck / Reach 1	5280.33	258.70	256.78	256.92	256.99	257.04	257.13	257.22	258.33	258.33
duf_183	Park Drive (& duf_182)	Mult Open	Stouffville Ck / Reach 1	5939.41	263.84	261.89	262.03	262.13	262.24	262.29	262.36	263.25	263.25
duf_184	Railway (Metrolinx)	Culvert	Stouffville Ck / Reach 1	7104.26	270.67	269.49	269.57	269.62	269.68	269.87	270.3	270.96	270.96

Crossing #	Crossing Location/Designation	Structure Type	HEC-RAS Watercourse Designation	HEC-RAS Section Upstream of Structure	Top of Road / When Weir Flow Begins (m)	Computed Water Surface Elevations (m)							Regulatory
						2 year	5 year	10 year	25 year	50 year	100 year	Regional	
duf_185	Stouffville Dam	Culvert	Stouffville Ck / Reach 1	7275.21	275.10	273.12	273.19	273.23	273.29	273.32	273.36	274.11	274.11
duf_186	Railway (Metrolinx)	Culvert	Stouffville A / Trib A1	462.19	275.72	274.86	275.06	275.19	275.39	275.6	275.76	275.88	275.88
duf_187	Brock Road	Culvert	Spring Creek / Reach 2	2036.04	205.93	202.61	202.67	202.71	202.76	202.8	202.84	203.58	203.58
duf_188	Brock Road	Culvert	Spring Creek / Reach 2	794.52	186.56	169.18	169.21	169.23	169.26	169.28	169.3	170	170
duf_189	HWY 407	Bridge	Spring Trib A / Trib A1	1204.02	171.16	162.45	162.55	162.6	162.67	162.72	162.77	163.54	163.54
duf_191	Hwy 407	Culvert	E Duffins Trib C / East C1	706.71	151.78	149.84	149.87	149.89	149.92	149.93	149.95	150.3	150.3
duf_192	HWY 407 ramp	Culvert	Spring Creek / Reach 2	1011.8	184.69	178.53	178.56	178.58	178.63	178.67	178.71	179.36	179.36
duf_193	Brock Rd	Bridge	Brougham Creek / Reach 4	1156.21	180.50	162.46	162.59	162.67	162.77	162.83	162.9	163.74	163.74
duf_195	Hwy 407	Bridge	East Duffins / Reach 5	753.49	150.04	141.01	141.26	141.38	141.5	141.6	141.7	142.63	142.63
duf_196	Sideline 26	Mult Open	W Duffins Trib A / West A2	536.83	179.95	178.8	178.9	178.95	179.04	179.17	179.29	179.99	179.99
duf_197	Railway	Culvert	Ganatsekiagon Ck / Reach 1	5214.19	137.83	127.65	127.88	128.02	128.19	128.32	128.45	137.87	137.87
duf_198	Trail	Bridge	Urfe Creek / Reach 4	2866.58	136.85	134.08	134.27	134.39	134.51	134.62	134.72	137.37	137.37
duf_199	Railway	Culvert	Ganatsekiagon Ck / Reach 1	4532.04	132.88	120.63	120.92	121.1	121.34	121.53	121.72	133.09	133.09
duf_200	Sideline 24	Culvert	Ganatsekiagon B / Trib B1	1666.71	187.01	186.27	186.57	186.75	186.98	187.14	187.17	187.68	187.68
duf_202	Driveway	Culvert	Urfe Trib A / Trib A1	695.86	104.45	103.04	103.09	103.12	103.16	103.19	103.22	104.61	104.61
duf_203	Driveway	Culvert	Urfe Trib A / Trib A1	1171.31	119.51	117.03	117.12	117.16	117.22	117.27	117.32	119.64	119.64
duf_204	Driveway	Culvert	Urfe Trib A / Trib A1	1254.11	122.15	119.59	119.71	119.77	119.88	119.98	120.11	122.34	122.34
duf_205	Trail	Culvert	Brougham Creek / Reach 2	495.07	134.40	133.37	133.83	134.2	134.66	134.8	134.88	135.46	135.46
duf_206	Private Drive	Culvert	Spring Trib A / Trib A2	874.84	197.30	197.7	197.71	197.73	197.74	197.75	197.76	197.92	197.92
duf_207	Driveway	Culvert	Spring Trib A / Trib A2	551.67	190.78	189.33	189.41	189.45	189.51	189.55	189.6	190.92	190.92
duf_208	Driveway	Culvert	Spring Trib A / Trib A2	369.25	184.50	183.27	183.33	183.35	183.4	183.42	183.45	184.04	184.04
duf_209	Driveway	Culvert	Spring Trib A / Trib A2	283.54	181.28	179.96	180.03	180.07	180.12	180.16	180.19	180.86	180.86
duf_210	Driveway	Culvert	Spring Trib A / Trib A2	189.43	178.43	175.91	175.95	175.98	176	176.02	176.04	176.36	176.36
duf_211	Driveway	Culvert	East Duffins / Reach 14	2549.33	275.55	274.61	274.96	275.19	275.58	275.66	275.7	276.2	276.2
duf_212	Driveway	Bridge	West Duffins / Reach 9	211.71	195.06	193.19	193.57	193.83	194.17	194.72	194.78	195.06	195.06
duf_213	Driveway	Bridge	West Duffins / Reach 13	3389.07	256.62	256.2	256.39	256.71	256.4	256.39	256.94	257.57	257.57
duf_214	Farm Crossing	Bridge	West Duffins / Reach 13	5098.48	270.14	269.83	270.05	270.2	270.32	270.38	270.37	270.92	270.92
duf_215	Farm Crossing	Bridge	West Duffins / Reach 13	4649.72	267.23	266.92	267.08	267.13	267.3	267.39	267.48	268.1	268.1
duf_216	Golfcourse Crossing	Culvert	Reesor Creek / Reach 1	1492.53	204.79	204.18	204.64	204.51	204.42	204.5	204.97	206.01	206.01
duf_217	Private Roadway	Culvert	Wixon Creek / Reach 2	120.91	241.46	241.46	241.46	241.46	241.46	241.46	241.46	241.7	241.7
duf_218	Private Bridge	Bridge	East Duffins / Reach 4	3706.65	137.25	135.71	135.97	136.11	136.29	136.41	136.54	138.17	138.17
duf_219	Private Crossing	Culvert	East Duffins / Reach 5	985.46	141.84	142.25	142.53	142.67	142.82	142.91	142.99	144.26	144.26
duf_220	Inline Structure East of Paddock Road	Inl Struct	East Duffins / Reach 5	1030.45	144.50	144.91	145.06	145.13	145.23	145.27	145.31	146.01	146.01
duf_221	Private Crossing	Culvert	East Duffins / Reach 5	1117.94	145.38	145.63	145.63	145.41	145.85	145.95	145.96	147.04	147.04
duf_222	Private Driveway	Culvert	East Duffins / Reach 14	1768.98	261.01	259.48	259.59	259.66	259.76	259.83	259.91	261.47	261.47
duf_223	Private Road	Culvert	Wixon Trib A / Trib A1	51.7	240.97	239.99	240.13	240.19	240.29	240.36	240.43	241.2	241.2
duf_224	Railway	Culvert	Mitchell Creek / Reach 4	2297.81	247.65	247.39	247.64	247.64	247.64	247.64	247.66	247.81	247.81
duf_225	Railway	Culvert	W Duffins Trib L / West L1	394.36	238.48	236.93	236.99	237.02	237.06	237.09	237.12	237.7	237.7
duf_226	Private reservoir structure outlet	Culvert	Spring Trib A / Trib A1	1300.37	171.70	166	166.17	166.27	166.41	166.5	166.6	168.84	168.84
duf_227	Pond Structure (East of Concession Road 7)	Culvert	East Duffins / Reach 14	2629.87	279.94	277.4	277.73	278.04	278.67	279.35	279.97	280.31	280.31
duf_229	HWY 407 off ramp	Bridge	Whitevale Creek / Reach 2	2919.05	218.33	214.84	214.96	215.04	215.13	215.2	215.27	218.55	218.55
duf_230	Whites Road Extension	Culvert	Whitevale Creek / Reach 2	3482.2	221.05	219.24	219.33	219.39	219.45	219.5	219.55	221.2	221.2
duf_231	York Durham Line	Culvert	Major Creek / Reach 1	910.24	190.33	188.78	188.92	188.95	189.05	189.11	189.2	190.59	190.59

Table 4-2: Modelled Bridges – Overtopping Crossings

Crossing #	Crossing Location/Designation	Structure Type	HEC-RAS Watercourse Designation	Top of Road / When Weir Flow Begins (m)	HEC-RAS Section Upstream of Structure	Difference between CWSE and Top of Road Elevation (m)						
						2 year	5 year	10 year	25 year	50 year	100 year	Regional
duf_001	Sideline 32	Culvert	W Duffins Trib E / West E1	192.90	395.19	-0.64	-0.60	-0.58	-0.55	-0.53	-0.50	0.08
duf_002	North Road	Culvert	W Duffins Trib C / West C1	210.48	1911.78	0.04	0.07	0.08	0.09	0.10	0.11	0.34
duf_003	Sideline 34	Culvert	W Duffins Trib F / West F1	190.94	554.58	-0.66	-0.57	-0.52	-0.45	-0.40	-0.35	0.07
duf_004	Sideline 24	Culvert	W Duffins Trib H / West H1	241.19	3868.79	-0.73	-0.64	-0.59	-0.52	-0.47	-0.42	0.08
duf_005	Sideline 20	Culvert	Urfe Creek / Reach 6	202.90	3333.85	-0.70	-0.66	-0.64	-0.61	-0.60	-0.58	0.05
duf_006	Sideline 22	Culvert	Urfe Trib E / Trib E1	212.21	3734.02	-1.19	-1.12	-1.08	-1.03	-1.00	-0.96	0.22
duf_007	Sideline 8	Culvert	E Duffins Trib I / East I1	191.19	504.13	-1.23	-1.10	-1.02	-0.92	-0.83	-0.75	0.40
duf_008	Sideline 32	Bridge	West Duffins / Reach 9	198.13	530.63	-1.63	-1.32	-1.12	-0.83	-0.65	-0.44	0.80
duf_009	Sideline 20	Bridge	Mitchell Trib B / Trib B1	241.32	1800.41	-1.42	-1.24	-1.13	-0.98	-0.98	-0.75	0.43
duf_010	Sideline 34	Culvert	W Duffins Trib G / West G1	184.41	229.71	-1.08	-1.02	-0.98	-0.94	-0.91	-0.88	0.05
duf_011	Sideline 34	Bridge	Reesor Creek / Reach 1	225.08	4548.21	-0.96	-0.56	-0.31	-0.02	0.01	0.04	1.35
duf_012	Sideline 32	Culvert	W Duffins Trib D / West D2	194.79	871.38	-0.72	-0.56	-0.47	-0.33	-0.22	-0.12	0.21
duf_013	North Rd	Culvert	W Duffins Trib H / West H1	208.56	246.92	-2.52	-2.39	-2.31	-2.21	-2.14	-2.07	-0.26
duf_014	Harwood Ave N	Culvert	Millers Creek / Reach 1	112.41	8357.46	-2.17	-1.96	-1.83	-1.66	-1.53	-1.40	0.44
duf_015	Sideline 22	Culvert	Urfe Creek / Reach 6	229.62	5569.17	0.03	0.05	0.08	0.08	0.09	0.11	0.26
duf_016	Williamson Dr W	Bridge	Millers Creek / Reach 1	107.42	6917.96	-3.50	-3.27	-3.10	-2.92	-2.82	-2.75	-1.71
duf_018	Sideline 20	Bridge	Mitchell Trib B / Trib B1	235.14	1330.51	-0.54	-0.32	-0.23	0.07	0.10	0.13	0.58
duf_019	Sideline 22	Culvert	Ganatsekiagon A / Trib A1	146.70	1298.32	-0.72	-0.59	-0.51	-0.42	-0.35	-0.28	0.19
duf_020	Westney Road	Culvert	E Duffins Trib F / East F1	172.81	164.27	-1.05	-0.98	-0.93	-0.87	-0.82	-0.79	0.05
duf_022	Burkholder Street	Culvert	Stouffville Ck / Reach 1	262.97	6118.36	-0.23	0.01	0.21	0.38	0.42	0.47	0.79
duf_023	Millard Street	Culvert	Stouffville Ck / Reach 1	271.61	7213.03	-1.76	-1.63	-1.55	-1.45	-1.37	-1.14	0.14
duf_024	Somerville Street	Culvert	Stouffville Ck / Reach 1	264.47	6241.94	-0.77	-0.54	-0.40	-0.24	0.05	0.23	0.71
duf_025	Market Street	Culvert	Stouffville Ck / Reach 1	264.98	6309.00	-0.93	-0.74	-0.61	-0.46	-0.34	-0.16	1.08
duf_026	North Road	Bridge	W Duffins Trib I / West I1	206.74	119.21	-3.33	-3.18	-3.10	-2.98	-2.89	-2.81	-1.13
duf_027	Sideline 20	Bridge	Mitchell Creek / Reach 3	232.83	1425.76	-1.28	-1.09	-0.97	-0.80	-0.66	-0.54	0.52
duf_028	Hoover Park Drive	Culvert	Stouffville Ck / Reach 1	264.01	5543.76	-5.22	-5.06	-4.85	-4.73	-4.68	-4.61	-3.98
duf_029	Sideline 34	Culvert	Reesor Trib A / Trib A1	232.59	285.78	-0.77	-0.52	-0.28	0.04	0.07	0.08	0.29
duf_030	Sideline 12	Bridge	Mitchell Creek / Reach 1	161.22	494.94	-1.87	-1.63	-1.45	-1.29	-0.70	-0.60	1.56
duf_031	Haskell Ave	Culvert	Millers Creek / Reach 1	111.86	8006.00	-4.83	-4.70	-4.61	-4.51	-4.45	-4.38	-3.39
duf_032	Sideline 12	Culvert	E Duffins Trib E / East E1	182.01	1331.75	-1.55	-1.47	-1.41	-1.35	-1.30	-1.26	-0.56
duf_033	Sullivan Drive	Culvert	Millers Creek / Reach 1	99.35	4475.90	-3.01	-2.71	-2.54	-2.29	-2.09	-1.92	0.16
duf_034	Jacwin Drive	Culvert	Millers Creek / Reach 1	86.49	967.62	-3.49	-3.09	-2.77	-2.37	-2.06	-1.73	2.25
duf_035	Rotherglen Road South	Bridge	Millers Creek / Reach 1	88.36	1650.76	-2.37	-1.91	-1.53	-0.73	-0.51	-0.35	1.36
duf_036	MaGill drive	Culvert	Millers Creek / Reach 1	97.02	3783.55	-3.27	-2.97	-2.87	-2.74	-2.60	-2.46	0.55
duf_037	Carwin Crescent	Culvert	Millers Creek / Reach 1	87.97	1233.77	-3.90	-3.57	-3.38	-3.17	-3.01	-2.55	1.35
duf_038	Sideline 24	Culvert	W Duffins Trib K / West K1	241.33	1427.05	-0.98	-0.82	-0.72	-0.59	-0.49	-0.39	0.24
duf_039	Sideline 24	Culvert	W Duffins Trib L / West L1	240.14	1133.25	-0.34	-0.15	-0.01	0.02	0.03	0.04	0.15

Crossing #	Crossing Location/Designation	Structure Type	HEC-RAS Watercourse Designation	Top of Road / When Weir Flow Begins (m)	HEC-RAS Section Upstream of Structure	Difference between CWSE and Top of Road Elevation (m)						
						2 year	5 year	10 year	25 year	50 year	100 year	Regional
duf_040	North Road	Bridge	W Duffins Trib C / West C1	208.68	1764.79	-0.04	0.08	0.11	0.15	0.17	0.18	0.56
duf_042	Church Street N	Culvert	E Duffins Trib B / East B1	121.93	1100.82	-3.95	-3.86	-3.80	-3.73	-3.67	-3.62	-1.37
duf_043	Whitevale Road	Culvert	Ganatsekiagon C / Trib C1	178.39	941.30	-4.13	-4.02	-3.96	-3.88	-3.82	-3.76	-1.15
duf_044	5th Concession Road	Culvert	Urfe Trib D / Trib D1	156.01	632.60	-5.03	-4.96	-4.92	-4.87	-4.85	-4.81	-3.89
duf_045	Sideline 16	Culvert	Spring Trib B / Trib B1	179.18	220.90	-1.59	-1.48	-1.42	-1.33	-1.27	-1.20	0.24
duf_046	7th Concession Road	Culvert	E Duffins Trib D / East D1	164.89	309.63	-0.86	-0.79	-0.75	-0.70	-0.67	-0.64	0.00
duf_047	8th Concession Road	Culvert	E Duffins Trib F / East F1	186.01	714.10	-0.63	-0.51	-0.40	-0.03	0.01	0.00	0.09
duf_048	5th Concession Road	Culvert	Urfe Trib C / Trib C2	149.44	782.90	-3.48	-3.37	-3.31	-3.22	-3.17	-3.10	0.09
duf_049	Concession Rd 7	Culvert	W Duffins Trib H / West H1	238.91	3416.18	-0.70	-0.59	-0.52	-0.41	-0.33	-0.25	0.08
duf_050	5th Concession Road	Bridge	East Duffins / Reach 4	120.43	243.63	-2.03	-1.68	-1.48	-1.22	-1.06	-0.91	0.69
duf_051	Rossland Road West	Bridge	Urfe Creek / Reach 2	93.99	1387.18	-4.37	-4.21	-4.11	-3.97	-3.90	-3.84	-2.55
duf_052	5th Concession Road	Culvert	Brougham Creek / Reach 1	122.05	550.13	-0.76	-0.37	-0.09	0.12	0.18	0.24	0.76
duf_053	Whitevale Road	Culvert	Ganatsekiagon Ck / Reach 4	179.93	1233.15	-3.98	-3.81	-3.71	-3.58	-3.48	-3.39	0.26
duf_054	9th Concession Road	Culvert	Reesor Creek / Reach 3	248.52	1313.57	-6.20	-5.95	-5.80	-5.62	-5.43	-5.28	-2.80
duf_055	Sideline 26	Culvert	W Duffins Trib H / West H1	232.05	2854.66	-0.59	-0.45	-0.35	-0.22	-0.13	-0.02	0.15
duf_056	York Durham Line	Bridge	Stouffville Ck / Reach 1	234.25	162.64	-0.81	-0.58	-0.49	-0.33	-0.21	-0.09	0.60
duf_057	8th Concession Road	Bridge	East Duffins / Reach 10	177.54	652.80	-2.42	-2.20	-2.07	-1.91	-1.78	-1.65	1.28
duf_058	Concession Rd 8	Culvert	West Duffins / Reach 12	221.47	1484.18	-1.35	-1.11	-0.94	-0.64	-0.73	-0.67	0.58
duf_059	19th Avenue	Bridge	Stouffville Ck / Reach 1	244.65	3416.26	-0.94	-0.78	-0.65	-0.56	-0.50	-0.44	0.55
duf_060	Reesor Road	Bridge	Stouffville Ck / Reach 1	240.66	2339.89	-1.10	-0.97	-0.91	-0.83	-0.78	-0.74	0.86
duf_061	Church Street N	Bridge	East Duffins / Reach 2	100.07	200.15	-9.71	-9.35	-9.13	-8.89	-8.73	-8.55	-6.79
duf_062	Uxbridge Pickering Townline	Bridge	West Duffins / Reach 13	261.80	3856.02	-1.63	-1.42	-1.28	-1.09	-0.95	-0.81	0.62
duf_063	Sideline 30	Culvert	West Duffins / Reach 13	251.07	2672.04	-1.23	-1.07	-0.94	-0.79	-0.69	-0.58	0.07
duf_064	Concession Rd 7	Bridge	West Duffins / Reach 11	207.20	683.56	-1.48	-1.22	-1.09	-0.88	-0.74	-0.58	0.75
duf_065	9th Concession Road	Culvert	East Duffins / Reach 13	208.79	1173.63	-3.89	-3.68	-3.56	-3.39	-3.28	-3.17	-0.86
duf_066	Whites Road	Bridge	West Duffins / Reach 1	136.43	6843.32	-4.35	-3.96	-3.74	-3.43	-3.21	-3.03	0.69
duf_067	Taunton Road	Bridge	West Duffins / Reach 1	166.70	7251.54	-32.40	-32.07	-31.88	-31.63	-31.45	-31.30	-28.39
duf_068	Webb Rd	Bridge	West Duffins / Reach 13	280.09	6556.29	-2.24	-2.04	-1.92	-1.77	-1.63	-1.46	-0.16
duf_069	Brock Road	Culvert	Urfe Trib C / Trib C1	141.06	129.39	-2.12	-1.95	-1.85	-1.75	-1.68	-1.62	-0.93
duf_070	Whitevale Road	Culvert	Ganatsekiagon B / Trib B1	197.62	2452.11	-1.23	-1.10	-1.03	-0.97	-0.93	-0.89	0.31
duf_070b	driveway near Whitevale Road	Culvert	Ganatsekiagon B / Trib B1	199.39	2651.70	0.01	0.03	0.05	0.08	0.08	0.09	0.30
duf_071	Sideline 28	Culvert	Wixon Trib A / Trib A1	244.59	168.44	-2.11	-2.00	-1.93	-1.85	-1.79	-1.73	-0.64
duf_072	Whitevale Road	Bridge	West Duffins / Reach 3	168.80	4463.92	-4.32	-3.96	-3.71	-3.39	-3.20	-3.03	0.24
duf_073	Bethessda Sideroad	Culvert	Stouffville Ck / Reach 2	283.38	1530.73	-1.28	-1.14	-1.05	-0.94	-0.84	-0.73	0.36
duf_074	Bayley Street West	Bridge	Lower Duffins / Reach 1	78.90	4228.42	-1.49	-1.15	-1.00	-0.71	-0.48	-0.76	1.94
duf_075	9th Concession Road	Bridge	West Duffins / Reach 13	238.86	1413.12	-2.67	-2.44	-2.33	-2.21	-2.11	-2.13	0.30
duf_076	Balsam Road	Bridge	East Duffins / Reach 14	248.11	914.89	-3.17	-3.03	-2.97	-2.87	-2.80	-2.73	-0.93
duf_077	Uxbridge Pickering Townline	Culvert	Mitchell Creek / Reach 4	273.45	4980.88	-0.89	-0.41	0.01	0.07	0.10	0.10	0.31

Crossing #	Crossing Location/Designation	Structure Type	HEC-RAS Watercourse Designation	Top of Road / When Weir Flow Begins (m)	HEC-RAS Section Upstream of Structure	Difference between CWSE and Top of Road Elevation (m)						
						2 year	5 year	10 year	25 year	50 year	100 year	Regional
duf_078	Brock Road	Bridge	Ganatsekiagon Ck / Reach 1	93.46	1054.71	-6.17	-6.01	-5.92	-5.80	-5.73	-5.66	-4.29
duf_079	Whitevale Rd	Culvert	Urfe Creek / Reach 6	155.82	555.27	-6.80	-6.64	-6.55	-6.44	-6.36	-6.29	-5.33
duf_080	Sideline 26	Culvert	Wixon Creek / Reach 2	247.92	1247.07	-1.42	-1.30	-1.23	-1.13	-1.04	-1.07	0.26
duf_081	Concession Road 7	Culvert	East Duffins / Reach 14	284.41	2990.54	-1.20	-0.99	-0.86	-0.68	-0.54	-0.40	0.47
duf_082	Sideline 30	Bridge	West Duffins / Reach 13	240.18	1651.00	-1.52	-1.18	-0.89	-0.81	-0.28	0.18	0.00
duf_083	Brock Road	Culvert	Brougham Creek / Reach 4	193.14	2384.57	-2.44	-2.24	-2.12	-1.97	-1.86	-1.75	0.23
duf_084	Taunton Road W	Culvert	E Duffins Trib B / East B1	122.66	1031.37	-5.90	-5.82	-5.77	-5.71	-5.67	-5.63	-4.40
duf_085	8th Concession Road	Bridge	Reesor Creek / Reach 1	227.71	4853.70	-2.45	-2.22	-2.09	-1.94	-1.84	-1.73	0.61
duf_086	Sideline 28	Culvert	W Duffins Trib H / West H1	219.00	1293.81	-1.32	-1.25	-1.18	-1.10	-1.05	-0.99	0.12
duf_087	Taunton Road E	Culvert	Millers Creek / Reach 1	112.15	8425.29	-1.54	-1.37	-1.27	-1.10	-0.96	-0.77	0.73
duf_088	Sideline 16	Culvert	Brougham Creek / Reach 4	164.98	1038.52	-6.02	-5.83	-5.71	-5.55	-5.44	-5.33	-3.12
duf_089	9th Concession Rd	Culvert	Mitchell Creek / Reach 4	247.51	2213.97	-0.84	-0.68	-0.56	-0.40	-0.27	-0.14	0.25
duf_090	Whitevale Road	Bridge	Whitevale Trib A / Trib A1	195.08	1310.03	-1.20	-1.00	-0.76	-0.66	-0.53	-0.32	0.33
duf_091	Westney Road	Culvert	E Duffins Trib H / East H1	198.86	1200.48	-2.95	-2.74	-2.60	-2.39	-2.25	-2.11	0.43
duf_092	Sideline 28	Bridge	Wixon Creek / Reach 1	239.53	1948.71	-1.17	-1.00	-0.91	-0.86	-0.84	-0.81	0.16
duf_093	9th Concession Road	Culvert	Wixon Creek / Reach 1	236.87	1569.84	-2.41	-2.30	-2.23	-2.15	-2.09	-2.02	-0.76
duf_094	8th Concession Road	Bridge	W Duffins Trib I / West I3	233.01	1404.66	-2.14	-2.01	-1.92	-1.77	-1.69	-1.60	-0.11
duf_095	Whitevail Road	Culvert	Urfe Trib E / Trib E1	156.24	782.98	-4.47	-4.33	-4.24	-4.13	-4.06	-3.98	-2.22
duf_096	7th Concession Road	Bridge	East Duffins / Reach 6	155.26	241.84	-4.67	-4.37	-4.18	-3.90	-3.70	-3.46	0.00
duf_097	7th Concession Road	Culvert	W Duffins Trib I / West I1	214.68	1776.70	-2.57	-2.43	-2.33	-2.22	-2.14	-2.09	-1.03
duf_098	Taunton Road	Bridge	Urfe Creek / Reach 4	138.56	2807.69	-5.43	-5.31	-5.24	-5.14	-5.10	-5.00	-3.15
duf_099	Brock Road	Culvert	Urfe Creek / Reach 4	131.39	2296.75	-3.76	-3.61	-3.53	-3.42	-3.35	-3.27	-1.59
duf_100	William Jackson Dr	Bridge	Urfe Creek / Reach 4	125.86	1682.85	-6.92	-6.58	-6.46	-6.42	-6.29	-6.16	0.45
duf_101	Riverside Drive	Bridge	East Duffins / Reach 1	84.91	592.61	-0.87	-0.54	-0.36	-0.14	0.08	0.21	0.98
duf_102	Taunton Road W	Culvert	Urfe Trib B / Trib B1	121.31	1625.37	-4.07	-3.88	-3.76	-3.61	-3.51	-3.41	0.23
duf_103	6th Concession Road	Bridge	East Duffins / Reach 4	136.20	3057.81	-4.14	-3.86	-3.71	-3.49	-3.34	-3.19	0.10
duf_104	York Durham Line	Bridge	Reesor Creek / Reach 3	295.13	8637.34	-1.07	-0.87	-0.74	-0.57	-0.43	-0.15	0.48
duf_105	York Duham Line	Culvert	Reesor Creek / Reach 3	274.73	5757.95	-0.35	-0.02	0.10	0.16	0.19	0.21	0.53
duf_106	Main Street	Culvert	Stouffville Ck / Reach 1	266.70	6431.38	-1.90	-1.72	-1.60	-1.47	-1.36	-1.21	0.85
duf_107	9th Concession Road	Culvert	W Duffins Trib I / West I6	247.17	846.86	-0.32	-0.16	-0.06	0.02	0.03	0.05	0.15
duf_108	7th Concession Road	Bridge	Reesor Creek / Reach 1	201.71	879.33	-2.87	-2.62	-2.48	-2.33	-2.22	-2.09	0.58
duf_109	8th Concession Road	Culvert	E Duffins Trib G / East G1	186.20	777.21	-3.65	-3.54	-3.46	-3.36	-3.28	-3.21	-0.84
duf_110	Brock Road	Culvert	Mitchell Creek / Reach 2	229.47	3024.02	-9.04	-8.82	-8.70	-8.56	-8.44	-8.36	-6.43
duf_111	Whitevale Road	Culvert	Whitevale Creek / Reach 2	197.33	1304.62	-1.62	-1.41	-1.31	-1.18	-1.08	-0.99	0.37
duf_112	Taunton Road West	Bridge	East Duffins / Reach 3	109.13	981.81	-5.14	-4.73	-4.52	-4.24	-4.07	-3.91	-1.76
duf_113	Rossland Rd W	Culvert	Millers Creek / Reach 1	101.64	5199.67	-3.20	-2.93	-2.80	-2.61	-2.40	-2.23	-0.31
duf_114	3rd Concession Rd	Culvert	Ganatsekiagon Ck / Reach 1	110.50	1795.59	-12.80	-12.61	-12.49	-12.37	-12.27	-12.18	0.40
duf_115	9th Concession Rd	Culvert	Mitchell Trib C / Trib C1	246.40	1399.20	-1.34	-1.22	-1.14	-1.05	-0.98	-0.91	0.15

Crossing #	Crossing Location/Designation	Structure Type	HEC-RAS Watercourse Designation	Top of Road / When Weir Flow Begins (m)	HEC-RAS Section Upstream of Structure	Difference between CWSE and Top of Road Elevation (m)						
						2 year	5 year	10 year	25 year	50 year	100 year	Regional
duf_116	Taunton Road	Culvert	Ganatsekiagon Ck / Reach 1	130.70	5023.11	-6.59	-6.34	-6.19	-6.01	-5.89	-5.76	2.39
duf_117	Rossland Road W	Bridge	East Duffins / Reach 1	95.77	1783.42	-6.49	-6.18	-6.00	-5.76	-5.60	-5.45	-3.44
duf_118	8th Concession Road	Culvert	E Duffins Trib E / East E1	197.20	1992.32	-2.46	-2.32	-2.24	-2.12	-2.04	-1.97	-0.02
duf_121	Uxbridge Pickering Townline Road	Culvert	Reesor Creek / Reach 3	263.81	4120.23	-1.34	-1.28	-1.25	-1.21	-1.18	-1.14	0.06
duf_122	9th Concession Road	Culvert	W Duffins Trib M / West M1	242.94	1577.10	-0.63	-0.53	-0.46	-0.38	-0.32	-0.26	0.05
duf_123	Kingston Road West	Culvert	Millers Creek / Reach 1	92.05	2649.87	-2.15	-1.98	-1.89	-1.75	-1.48	-1.31	0.22
duf_124	Westney Road South	Bridge	Millers Creek / Reach 1	90.41	1870.60	-3.77	-3.35	-3.01	-2.41	-2.17	-1.98	-0.27
duf_125	Highway 407	Culvert	Whitevale Trib A / Trib A2	216.38	1718.86	-1.86	-1.80	-1.76	-1.71	-1.68	-1.64	-0.46
duf_126	HWY 7	Culvert	Whitevale Trib A / Trib A2	221.82	2285.71	-1.01	-0.92	-0.85	-0.77	-0.71	-0.65	0.18
duf_127	HWY 7	Culvert	W Duffins Trib C / West C1	212.83	2148.10	-0.73	-0.48	-0.30	-0.01	-0.01	-0.01	0.24
duf_128	Hwy 407	Culvert	Ganatsekiagon Ck / Reach 4	211.56	3696.65	-2.09	-2.06	-2.03	-2.00	-1.98	-1.96	-1.26
duf_129	Hwy 7	Culvert	Ganatsekiagon Ck / Reach 4	223.06	4500.97	-2.11	-1.98	-1.89	-1.70	-1.54	-1.34	-0.01
duf_131	HWY 7	Culvert	Spring Creek / Reach 2	194.06	1563.93	-3.02	-2.96	-2.93	-2.90	-2.87	-2.84	-2.29
duf_132	HWY 407	Culvert	Spring Creek / Reach 2	185.02	1175.60	-1.87	-1.82	-1.79	-1.76	-1.73	-1.70	-1.18
duf_133	Highway 407	Bridge	Urfe Creek / Reach 6	196.75	2544.55	-6.64	-6.52	-6.45	-6.36	-6.29	-6.23	-5.39
duf_134	Highway 7	Culvert	Urfe Creek / Reach 6	200.97	3170.56	-2.25	-2.14	-2.08	-1.99	-1.93	-1.86	-0.22
duf_135	HWY 407	Culvert	W Duffins Trib C / West C1	189.81	776.87	-2.21	-2.17	-2.14	-2.10	-2.08	-2.06	-1.14
duf_136	Highway 7	Bridge	Spring Trib A / Trib A1	179.00	1088.57	-18.85	-18.75	-18.69	-18.63	-18.58	-18.54	-17.97
duf_137	Highway 7	Culvert	Urfe Trib E / Trib E1	205.42	3430.10	-1.03	-0.90	-0.78	-0.67	-0.59	-0.50	0.21
duf_138	HWY 7	Culvert	W Duffins Trib D / West D1	187.94	851.51	-2.63	-2.49	-2.41	-2.30	-2.23	-2.15	0.00
duf_139	Hwy 7	Bridge	East Duffins / Reach 4	142.93	3290.80	-9.44	-9.09	-8.91	-8.67	-8.51	-8.35	-5.68
duf_140	HWY 7	Bridge	West Duffins / Reach 6	184.10	495.81	-4.79	-4.41	-4.20	-3.93	-3.73	-3.49	-1.14
duf_141	HWY 7	Culvert	Brougham Creek / Reach 4	198.60	2758.02	-2.42	-2.32	-2.27	-2.19	-2.14	-2.08	-0.05
duf_142	HWY 407	Bridge	Brougham Creek / Reach 4	188.33	1983.19	-4.05	-3.96	-3.91	-3.84	-3.79	-3.75	-3.17
duf_143	Highway 7	Culvert	Ganatsekiagon B / Trib B1	224.18	5150.03	-2.48	-2.32	-2.23	-2.10	-1.97	-1.81	0.17
duf_144	Highway 407	Culvert	Ganatsekiagon B / Trib B1	221.78	4395.14	-2.31	-2.25	-2.22	-2.17	-2.14	-2.12	-1.37
duf_145	407	Bridge	West Duffins / Reach 5	186.68	450.78	-9.21	-8.92	-8.78	-8.59	-8.48	-8.35	-6.37
duf_146	Highway 407	Culvert	Urfe Trib E / Trib E1	199.86	2786.07	-7.70	-7.65	-7.63	-7.60	-7.58	-7.56	-6.55
duf_147	HWY 407	Culvert	Whitevale Creek / Reach 2	218.19	3086.73	-1.80	-1.71	-1.65	-1.64	-1.60	-1.61	0.37
duf_148	HWY 401 & CNR	Culvert	Millers Creek / Reach 1	88.83	884.14	-6.69	-6.44	-6.17	-5.89	-5.69	-5.50	-0.13
duf_149	HWY 407	Bridge	W Duffins Trib D / West D1	186.23	251.86	-6.85	-6.79	-6.75	-6.69	-6.66	-6.64	-6.15
duf_150	Trail (Ped Bridge)	Bridge	Millers Creek / Reach 1	91.72	2838.63	-1.26	-0.94	-0.78	-0.58	-0.41	-0.26	1.46
duf_151	Trail (Ped Bridge)	Bridge	Millers Creek / Reach 1	93.03	3169.13	-1.69	-1.35	-1.19	-0.96	-0.77	-0.63	1.04
duf_152	Driveway off of Magill Drive	Culvert	Millers Creek / Reach 1	97.90	3615.15	-4.92	-4.48	-4.23	-3.88	-3.61	-3.39	-1.26
duf_153	Trail (Ped Bridge)	Bridge	Millers Creek / Reach 1	98.70	4264.59	-3.01	-2.72	-2.56	-2.32	-2.15	-2.01	-0.52
duf_154	Trail (Ped Bridge)	Bridge	Millers Creek / Reach 1	100.38	4846.70	-2.92	-2.66	-2.51	-2.30	-2.12	-1.97	-0.28
duf_155	Trail (ped bridge)	Bridge	Millers Creek / Reach 1	100.60	5634.51	-0.33	-0.17	0.11	0.12	0.13	0.48	1.17
duf_156	Trail (ped bridge)	Bridge	Millers Creek / Reach 1	102.72	6405.40	0.06	0.26	0.30	0.41	0.44	0.47	0.87

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						2 year	5 year	10 year	25 year	50 year	100 year	Regional
duf_157	Trail (ped bridge)	Bridge	Millers Creek / Reach 1	105.27	7335.58	-0.23	-0.10	-0.03	0.08	0.24	0.41	0.98
duf_158	Trail (ped bridge)	Bridge	Millers Creek / Reach 1	106.34	7633.99	-0.29	-0.12	0.03	0.14	0.21	0.06	0.65
duf_159	Trail (ped bridge)	Bridge	Millers Creek / Reach 1	109.65	8151.60	-0.73	-0.63	-0.58	-0.50	-0.45	-0.40	0.64
duf_160	CPR Railway	Mult Open	Millers Creek / Reach 1	119.89	8483.47	-8.50	-8.42	-8.26	-7.82	-7.66	-7.50	-6.10
duf_161	Railway	Culvert	E Duffins Trib B / East B1	126.71	1339.58	-6.60	-6.54	-6.49	-6.44	-6.39	-6.35	-5.43
duf_162	Railway	Bridge	Urfe Creek / Reach 4	131.73	1850.45	-10.11	-9.87	-9.72	-9.52	-9.35	-9.20	-3.16
duf_163	Railway	Bridge	East Duffins / Reach 3	122.02	1509.05	-15.49	-15.11	-14.90	-14.63	-14.48	-14.31	-11.65
duf_164	Pedestrian Bridge	Bridge	East Duffins / Reach 3	111.65	3048.06	-0.06	0.23	0.49	0.62	0.70	0.78	1.65
duf_165	Railway	Bridge	Mitchell Trib D / Trib D1	251.59	580.67	-2.22	-2.11	-2.04	-1.94	-1.87	-1.80	-0.47
duf_166	Railway	Culvert	Mitchell Trib C / Trib C2	257.03	789.29	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
duf_167	Trail	Bridge	Mitchell Creek / Reach 1	160.45	372.07	-1.81	-1.38	-1.10	-0.71	0.05	0.13	0.76
duf_168	Trail	Bridge	East Duffins / Reach 6	156.91	817.48	-3.48	-3.10	-3.02	-2.48	-2.25	-1.64	0.91
duf_169	Trail	Culvert	E Duffins Trib E / East E1	170.74	539.64	-2.89	-2.78	-2.69	-2.59	-2.51	-2.45	0.12
duf_170	Railway	Culvert	E Duffins Trib K / East K1	252.58	594.83	-10.38	-10.26	-10.19	-10.09	-10.02	-9.95	-6.66
duf_171	Railway	Culvert	East Duffins / Reach 14	254.80	613.24	-14.41	-14.28	-14.19	-14.07	-13.98	-13.89	-11.99
duf_172	Harrisview Street	Culvert	E Duffins Trib A / East A1	105.65	324.13	-2.23	-2.20	-2.17	-2.16	-2.14	-2.13	-1.80
duf_173	Canadian Pacific Railroad Bridge	Bridge	West Duffins / Reach 1	134.80	3903.27	-24.34	-24.01	-23.82	-23.49	-23.43	-23.33	-22.10
duf_174	Weir	Inl Struct	West Duffins / Reach 3	172.05	5403.26	0.76	1.03	1.20	1.42	1.58	1.74	1.81
duf_175	Railway	Bridge	Major Creek / Reach 1	193.74	772.17	-5.77	-5.64	-5.57	-5.47	-5.40	-5.33	-3.97
duf_176	Railway	Bridge	Reesor Creek / Reach 1	206.68	730.86	-8.91	-8.70	-8.57	-8.43	-8.32	-8.18	-6.03
duf_177	CPR Railway	Bridge	West Duffins / Reach 12	223.28	642.06	-6.34	-6.09	-5.96	-5.77	-5.62	-5.44	-2.12
duf_178	CPR Railway	Culvert	W Duffins Trib O / West O1	221.06	275.36	-1.62	0.04	0.06	0.05	0.06	0.06	0.12
duf_179	Railway	Bridge	W Duffins Trib I / West I3	236.86	2083.25	-2.69	-2.55	-2.47	-2.37	-2.30	-2.23	-0.82
duf_180	Trail	Bridge	Stouffville Ck / Reach 1	253.36	4861.85	-0.69	-0.58	-0.48	-0.37	-0.29	-0.19	0.67
duf_181	Trail	Bridge	Stouffville Ck / Reach 1	258.70	5280.33	-1.92	-1.78	-1.71	-1.66	-1.57	-1.48	-0.37
duf_183	Park Drive	Mult Open	Stouffville Ck / Reach 1	263.84	5939.41	-1.95	-1.81	-1.71	-1.60	-1.55	-1.48	-0.59
duf_184	Railway (Metrolinx)	Culvert	Stouffville Ck / Reach 1	270.67	7104.26	-1.18	-1.10	-1.05	-0.99	-0.80	-0.37	0.29
duf_185	Stouffville Dam	Culvert	Stouffville Ck / Reach 1	275.10	7275.21	-1.98	-1.91	-1.87	-1.81	-1.78	-1.74	-0.99
duf_186	Railway (Metrolinx)	Culvert	Stouffville A / Trib A1	275.72	462.19	-0.86	-0.66	-0.53	-0.33	-0.12	0.04	0.16
duf_187	Brock Road	Culvert	Spring Creek / Reach 2	205.93	2036.04	-3.32	-3.26	-3.22	-3.17	-3.13	-3.09	-2.35
duf_188	Brock Road	Culvert	Spring Creek / Reach 2	186.56	794.52	-17.38	-17.35	-17.33	-17.30	-17.28	-17.26	-16.56
duf_189	HWY 407	Bridge	Spring Trib A / Trib A1	171.16	1204.02	-8.71	-8.61	-8.56	-8.49	-8.44	-8.39	-7.62
duf_191	Hwy 407	Culvert	E Duffins Trib C / East C1	151.78	706.71	-1.94	-1.91	-1.89	-1.86	-1.85	-1.83	-1.48
duf_192	HWY 407 ramp	Culvert	Spring Creek / Reach 2	184.69	1011.80	-6.16	-6.13	-6.11	-6.06	-6.02	-5.98	-5.33
duf_193	Brock Rd	Bridge	Brougham Creek / Reach 4	180.50	1156.21	-18.04	-17.91	-17.83	-17.73	-17.67	-17.60	-16.76
duf_195	Hwy 407	Bridge	East Duffins / Reach 5	150.04	753.49	-9.03	-8.78	-8.66	-8.54	-8.44	-8.34	-7.41
duf_196	Sideline 26	Mult Open	W Duffins Trib A / West A2	179.95	536.83	-1.15	-1.05	-1.00	-0.91	-0.78	-0.66	0.04
duf_197	Railway	Culvert	Ganatsekiagon Ck / Reach 1	137.83	5214.19	-10.18	-9.95	-9.81	-9.64	-9.51	-9.38	0.04

Crossing #	Crossing Location/Designation	Structure Type	HEC-RAS Watercourse Designation	Top of Road / When Weir Flow Begins (m)	HEC-RAS Section Upstream of Structure	Difference between CWSE and Top of Road Elevation (m)						
						2 year	5 year	10 year	25 year	50 year	100 year	Regional
duf_198	Trail	Bridge	Urfe Creek / Reach 4	136.85	2866.58	-2.77	-2.58	-2.46	-2.34	-2.23	-2.13	0.52
duf_199	Railway	Culvert	Ganatsekiagon Ck / Reach 1	132.88	4532.04	-12.25	-11.96	-11.78	-11.54	-11.35	-11.16	0.21
duf_200	Sideline 24	Culvert	Ganatsekiagon B / Trib B1	187.01	1666.71	-0.74	-0.44	-0.26	-0.03	0.13	0.16	0.67
duf_202	Driveway	Culvert	Urfe Trib A / Trib A1	104.45	695.86	-1.41	-1.36	-1.33	-1.29	-1.26	-1.23	0.16
duf_203	Driveway	Culvert	Urfe Trib A / Trib A1	119.51	1171.31	-2.48	-2.39	-2.35	-2.29	-2.24	-2.19	0.13
duf_204	Driveway	Culvert	Urfe Trib A / Trib A1	122.15	1254.11	-2.56	-2.44	-2.38	-2.27	-2.17	-2.04	0.19
duf_205	Trail	Culvert	Brougham Creek / Reach 2	134.40	495.07	-1.03	-0.57	-0.20	0.26	0.40	0.48	1.06
duf_206	Private Drive	Culvert	Spring Trib A / Trib A2	197.30	874.84	0.40	0.41	0.43	0.44	0.45	0.46	0.62
duf_207	Driveway	Culvert	Spring Trib A / Trib A2	190.78	551.67	-1.45	-1.37	-1.33	-1.27	-1.23	-1.18	0.14
duf_208	Driveway	Culvert	Spring Trib A / Trib A2	184.50	369.25	-1.23	-1.17	-1.15	-1.10	-1.08	-1.05	-0.46
duf_209	Driveway	Culvert	Spring Trib A / Trib A2	181.28	283.54	-1.32	-1.25	-1.21	-1.16	-1.12	-1.09	-0.42
duf_210	Driveway	Culvert	Spring Trib A / Trib A2	178.43	189.43	-2.52	-2.48	-2.45	-2.43	-2.41	-2.39	-2.07
duf_211	Driveway	Culvert	East Duffins / Reach 14	275.55	2549.33	-0.94	-0.59	-0.36	0.03	0.11	0.15	0.65
duf_212	Driveway	Bridge	West Duffins / Reach 9	195.06	211.71	-1.87	-1.49	-1.23	-0.89	-0.34	-0.28	0.00
duf_213	Driveway	Bridge	West Duffins / Reach 13	256.62	3389.07	-0.42	-0.23	0.09	-0.22	-0.23	0.32	0.95
duf_214	Farm Crossing	Bridge	West Duffins / Reach 13	270.14	5098.48	-0.31	-0.09	0.06	0.18	0.24	0.23	0.78
duf_215	Farm Crossing	Bridge	West Duffins / Reach 13	267.23	4649.72	-0.31	-0.15	-0.10	0.07	0.16	0.25	0.87
duf_216	Golfcourse Crossing	Culvert	Reesor Creek / Reach 1	204.79	1492.53	-0.61	-0.15	-0.28	-0.37	-0.29	0.18	1.22
duf_217	Private Roadway	Culvert	Wixon Creek / Reach 2	241.46	120.91	0.00	0.00	0.00	0.00	0.00	0.00	0.24
duf_218	Private Bridge	Bridge	East Duffins / Reach 4	137.25	3706.65	-1.54	-1.28	-1.14	-0.96	-0.84	-0.71	0.92
duf_219	Private Crossing	Culvert	East Duffins / Reach 5	141.84	985.46	0.41	0.69	0.83	0.98	1.07	1.15	2.42
duf_220	Inline Structure East of Paddock Road	Inl Struct	East Duffins / Reach 5	144.50	1030.45	0.41	0.56	0.63	0.73	0.77	0.81	1.51
duf_221	Private Crossing	Culvert	East Duffins / Reach 5	145.38	1117.94	0.25	0.25	0.03	0.47	0.57	0.58	1.66
duf_222	Private Driveway	Culvert	East Duffins / Reach 14	261.01	1768.98	-1.53	-1.42	-1.35	-1.25	-1.18	-1.10	0.46
duf_223	Private Road	Culvert	Wixon Trib A / Trib A1	240.97	51.70	-0.98	-0.84	-0.78	-0.68	-0.61	-0.54	0.23
duf_224	Railway	Culvert	Mitchell Creek / Reach 4	247.65	2297.81	-0.26	-0.01	-0.01	-0.01	-0.01	0.01	0.16
duf_225	Railway	Culvert	W Duffins Trib L / West L1	238.48	394.36	-1.55	-1.49	-1.46	-1.42	-1.39	-1.36	-0.78
duf_226	Private reservoir structure outlet	Culvert	Spring Trib A / Trib A1	171.70	1300.37	-5.70	-5.53	-5.43	-5.29	-5.20	-5.10	-2.86
duf_227	Pond Structure (East of Concession Road 7)	Culvert	East Duffins / Reach 14	279.94	2629.87	-2.54	-2.21	-1.90	-1.27	-0.59	0.03	0.37
duf_229	HWY 407 off ramp	Bridge	Whitevale Creek / Reach 2	218.33	2919.05	-3.49	-3.37	-3.29	-3.20	-3.13	-3.06	0.22
duf_230	Whites Road Extension	Culvert	Whitevale Creek / Reach 2	221.05	3482.20	-1.81	-1.72	-1.66	-1.60	-1.55	-1.50	0.15
duf_231	York Durham Line	Culvert	Major Creek / Reach 1	190.33	910.24	-1.55	-1.41	-1.38	-1.28	-1.22	-1.13	0.26

- Structure not overtopped
- Structure overtopped

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4.2 Floodplain Mapping Process

Following the completion of hydraulic modelling (Section 3), floodplain mapping extents were generated by TRCA. Floodlines were generated by TRCA using RASMapper within HEC-RAS as well as GeoHECRAS. The two sets of floodlines were compared. In notable areas of discrepancies, a more conservative and reasonable approach was followed. Manual GIS quality checks were performed by TRCA with special attention paid to areas where infilling was required to remedy topographic highs that artificially cut off sections of floodlines that would otherwise be connected or vice-versa where floodlines had to be clipped to account for true topographic highs. This "clean-up" was only applied to the Regulatory Floodlines and not the flood inundation limits for the other design storms which have been generated for use in flood risk screening and characterization only.

GIS layers of the generated floodplain extents for the Regulatory Event (Regional Storm Event typically) were provided by TRCA to Wood for review; the floodplain extents were also reviewed internally by TRCA staff. Key areas of concern included:

- Floodline exceeds cross-section extents
- Gaps in the floodline
- Irregularly shaped floodline extents
- Correct rendering of floodline at hydraulic structures (i.e. whether or not deck is overtopped)
- Floodplain "islands" (high points within the flood inundated area)
- Floodplain extent excessively close to watercourse centreline
- Connectivity between adjacent floodplain areas
- Potential or confirmed spill areas

After the proceeding areas of concern were addressed to the satisfaction of both TRCA and Wood, TRCA proceeded with the preparation of formal floodplain mapping sheets (refer to Appendix E). A total of eight (8) 36"x48" (Arch E) mapping sheets were prepared by TRCA (1:10,000 scale) to cover the study area limits, including Professional Engineering Stamping by Wood.

4.3 Task 3B – Identification of Potential Spills and Spill Paths

The MNRF's Technical Guide River & Stream Systems: Flooding Hazard Limit (2002) (ref. Section 4.13 of the guidelines) defines a spill as occurring when flood levels overtop the banks of a watercourse and spill overland away from the watercourse channel. Frequently, this spill will move into another watershed or join the originating watercourse at a distance downstream. Further, the guidelines describe that:

> *"The effect of spills moving into another watershed should be assessed to determine the potential flood risks. Alternative measures should be investigated to prevent the spill moving into the adjacent watershed. If the amount of spill is relatively small, less than 10% of the peak flow, the floodplain mapping for the watercourse should be based on the original flow, without any deduction for the spill. For larger spills, allowance for the reduced flow should only be made where the review of alternatives proves that the spill cannot be prevented, either because there are no feasible alternatives or the costs, when compared to the potential benefits, are too high. Where the spill re-joins the watercourse further downstream, the route of the spill should be examined to determine the potential harmful effects of overland flow. No reduction should be made for the spill in the downstream floodplain computations."*

For the current study, thirteen (13) potential spill areas have been identified as an outcome of the finalization of the delineations of the flood inundation limits. Potential Spill areas are summarized in Table 4-3. Details regarding these locations are described in greater detail in the following sections.

The deliverable from the assessment of possible spill locations has been to identify to TRCA areas of legitimate spill only. Modelling of any spill path is beyond the identified study scope of work. As well, spill paths illustrated in figures in this report should only be considered approximate having been determined only by visual interpretation of available topographic information.

Table 4-3: Identified Potential Spill Areas for Duffins Creek

Spill ID	HEC-RAS Watercourse	HEC-RAS XS	Structure ID	Location Description
1	Stouffville Creek Reach 1	5993.63	Duf_182 Duf_183	Park Drive, Whitchurch-Stouffville
2	West Duffins Creek Reach C1	2155.95	Duf_127	Highway 7 at North Road, Pickering
3	Whitevale Creek Reach 2	3086.73	Duf_147 Duf_229	Highway 407 West of Sideline 26 and Whites Road, Pickering
4	Whitevale Creek Trib A2	1718.86	Duf_125	Highway 407 West of Sideline 26 and Whites Road, Pickering
5	West Duffins Creek Trib A2	780.23	Duf_041	Sideline 26, Pickering
6	Mitchell Creek Trib C2	812.79	Duf_166	CNR (Sideline 20 and 9th Concession Road), Pickering
7	East Duffins Creek Trib C1	1349.05	N/A	Westney Road North of Highway 407, Pickering
8	Brougham Creek Trib A1	2151.34	N/A	Highway 7 West of Paddock Road, Pickering
9	Ganatsekiagon Creek Reach 1	5228.94	Duf_197	Private Structure Upstream of Taunton Road, Pickering
10	Ganatsekiagon Creek Reach 1	4532.04	Duf_199	CNR South of Taunton Road, Pickering
11	Millers Creek Reach 1	8425.29	Duf_087	Taunton Road West, West of CNR, Ajax
12 and 13	Millers Creek Reach 1	884.14	Duf_148	Highway 401, Ajax

4.3.1 Spill Area 1

Spill Area 1 is located along Stouffville Creek Reach 1, in the vicinity of Park Drive in the Town of Whitchurch Stouffville. The spill occurs just upstream of Park Drive and west of Franklin Avenue, at the rear of the Whitchurch-Stouffville Leisure Centre. The spill area is presented in Figure 4-1.

Based on available historical aerial photography (i.e. Google Earth™), the Leisure Centre was expanded and reconstructed/re-graded in approximately 2017. Given the vintage of the LiDAR data applied for the current study in this area (2015), the topographic contours for the subject area site may not reflect final grading changes in this area. Current aerial photography however indicates a small, elongated stormwater management pond in this area, which appears to drain easterly towards Stouffville Creek. As such, the topographic contours suggest that this volume would have to be first filled by spill from the creek. If the volume of spill combined with local site drainage was sufficiently large, it does appear that any excess volume would likely spill southerly via a low point between the basketball court and the skate park area, towards Hoover Park Drive, and then ultimately continue south on Reeves Way Boulevard.

The spill width in this location is approximately 65 m; the full Regional Storm Flow in the main branch at this location is 51.14 m^3/s. Given the width of the spill and the proximity to residential areas, this spill likely warrants further investigation, using more current topographic data (2019).

Figure 4-1 Duffins Creek Spill Area 1 (Park Drive): Stouffville Creek, Reach 1 (XS 5993.63)

4.3.2 Spill Area 2

Spill Area 2 is located along West Duffins Creek Reach C1, upstream of Highway 7 in the City of Pickering, at North Road. The spill occurs along the east overbank upstream of Highway 7, close to North Road. The spill is presented in Figure 4-2.

Based on the topographic data for this area, it appears that the spill would likely overtop North Road, and then continue westerly along the north ditch of Highway 7. The ditch flow would likely continue westerly towards West Duffins Creek Reach D1, approximately 1 km to the west.

The spill width in this location is approximately 14 m; the full Regional Storm Flow in the main branch at this location is 16.94 m^3/s. Given the rural nature of the spill and the minor associated spill width, this spill is not considered to be a primary spill of interest.

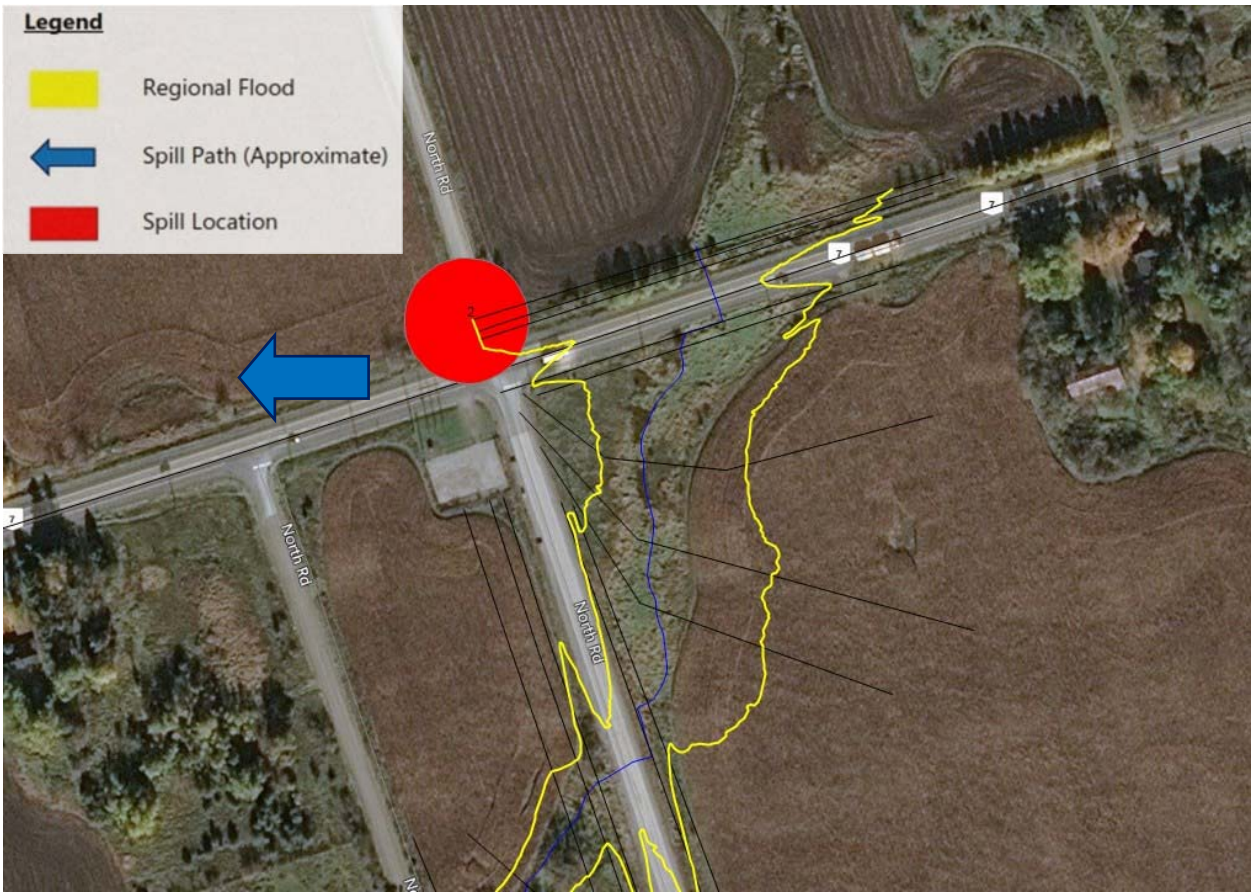

Figure 4-2 Duffins Creek Spill Area 2 (Highway 7): W Duffins Trib C, Reach West C1 (XS 2155.95)

4.3.3 Spill Areas 3 and 4

Spill areas 3 and 4 are located directly adjacent to one another, along Highway 407, west of Whites Road in the City of Pickering. Spill area 3 is located on Whitevale Creek Reach 2, while Spill area 4 is located on Whitevale Creek Trib A2. The spill area is presented in Figure 4-3.

The topography in the area slopes consistently westerly, as such it is expected that spill area 3 would drain westerly and combine with spill area 4, and continue westerly from that point towards West Duffins Tributary C1 and ultimately the main branch of West Duffins Creek (Reach 4).

The spill width at Area 3 is approximately 176 m; and the full Regional Storm Flow in the main branch at this location is 11.3 m^3/s. The spill width at Area 4 is approximately 79 m; and the full Regional Storm Flow in the main branch at this location is 8.43 m^3/s. Given the extents of the spills indicated and the nature of the roadway (400 series highway), this spill likely warrants further assessment.

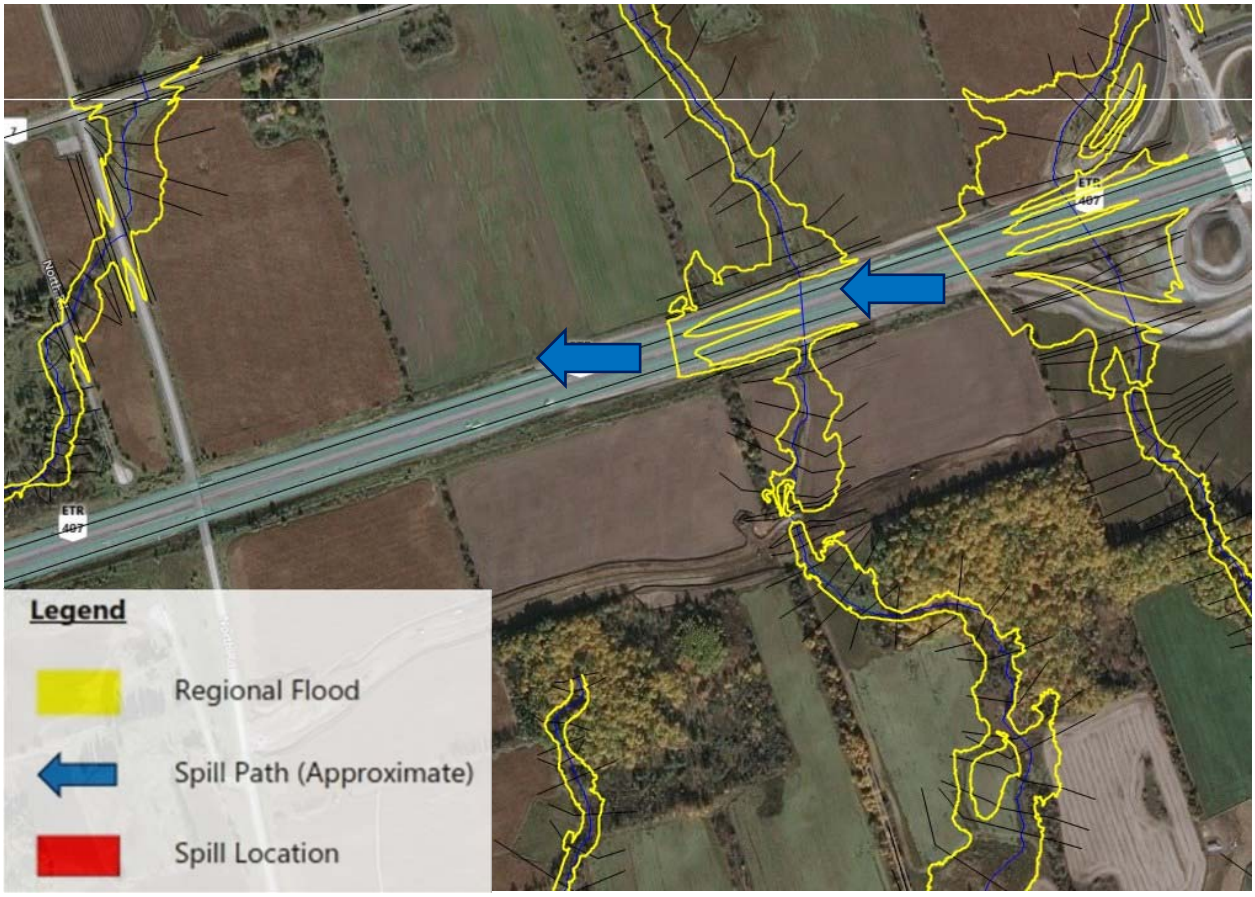

Figure 4-3 Duffins Creek Spill Areas 3 and 4 (Highway 407): Whitevale Creek, Reach 2 (XS 3086.73) and Whitevale Creek Trib A, Reach Trib A2 (XS 1718.86)

4.3.4 Spill Area 5

Spill area 5 is located along the right overbank of West Duffins Creek Tributary A2, parallel to Sideline 26 in the City of Pickering. The spill area is presented in Figure 4-4.

Based on the topography in this area it is expected that any spill would flow westerly towards the adjacent tributary (West Duffins Tributary B1), approximately 170 m to the west. The two branches ultimately confluence approximately 500 m to the south, to the north of Taunton Road.

The spill width in this location is approximately 36 m; the full Regional Storm Flow in the main branch at this location is 7.36 m^3/s. Given the rural nature of the spill and the minor associated spill flow, this spill is not considered to be a primary spill of interest.

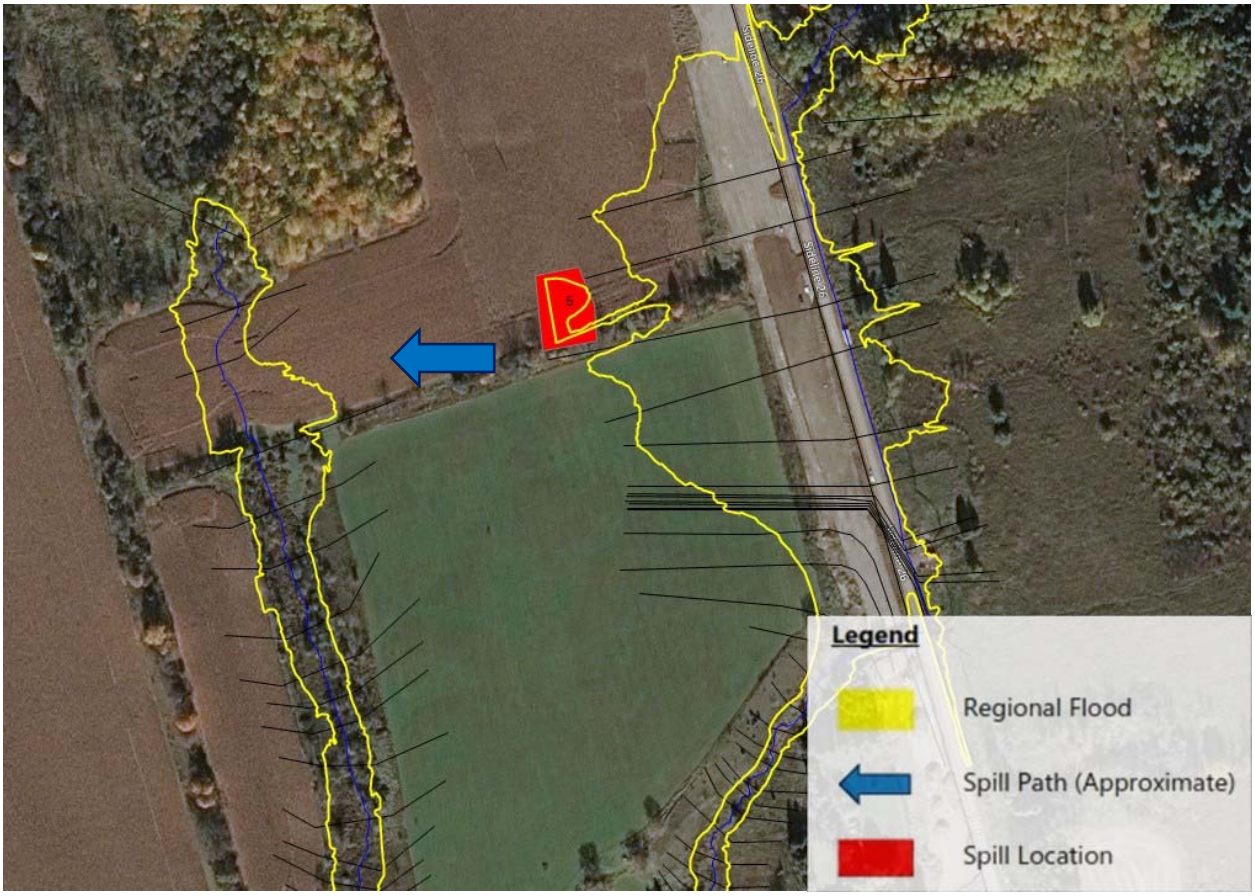

Figure 4-4 Duffins Creek Spill Area 5 (Sideline 26): W Duffins Trib A, Reach West A2 (XS 780.23)

4.3.5 Spill Area 6

Spill area 6 is located along Mitchell Creek Tributary C2, immediately upstream of the CNR tracks near Sideline 20 and 9th Concession in the City of Pickering. The spill area is presented in Figure 4-5.

Based on the topography in this area, it appears that the spill would continue to drain southerly towards the CNR tracks, and then westerly towards the adjacent watercourse (Mitchell Creek Tributary D1). The two watercourses then recombine/confluence approximately 400 m downstream at 9th Concession Road.

The spill width in this location is approximately 171 m; the full Regional Storm Flow in the main branch at this location is 8.27 m^3/s. Given the rural, undeveloped nature of the spill area, and that any spill flows would ultimately recombine with the main branch flows at the next crossing downstream, the spill is not considered to be a primary spill of interest.

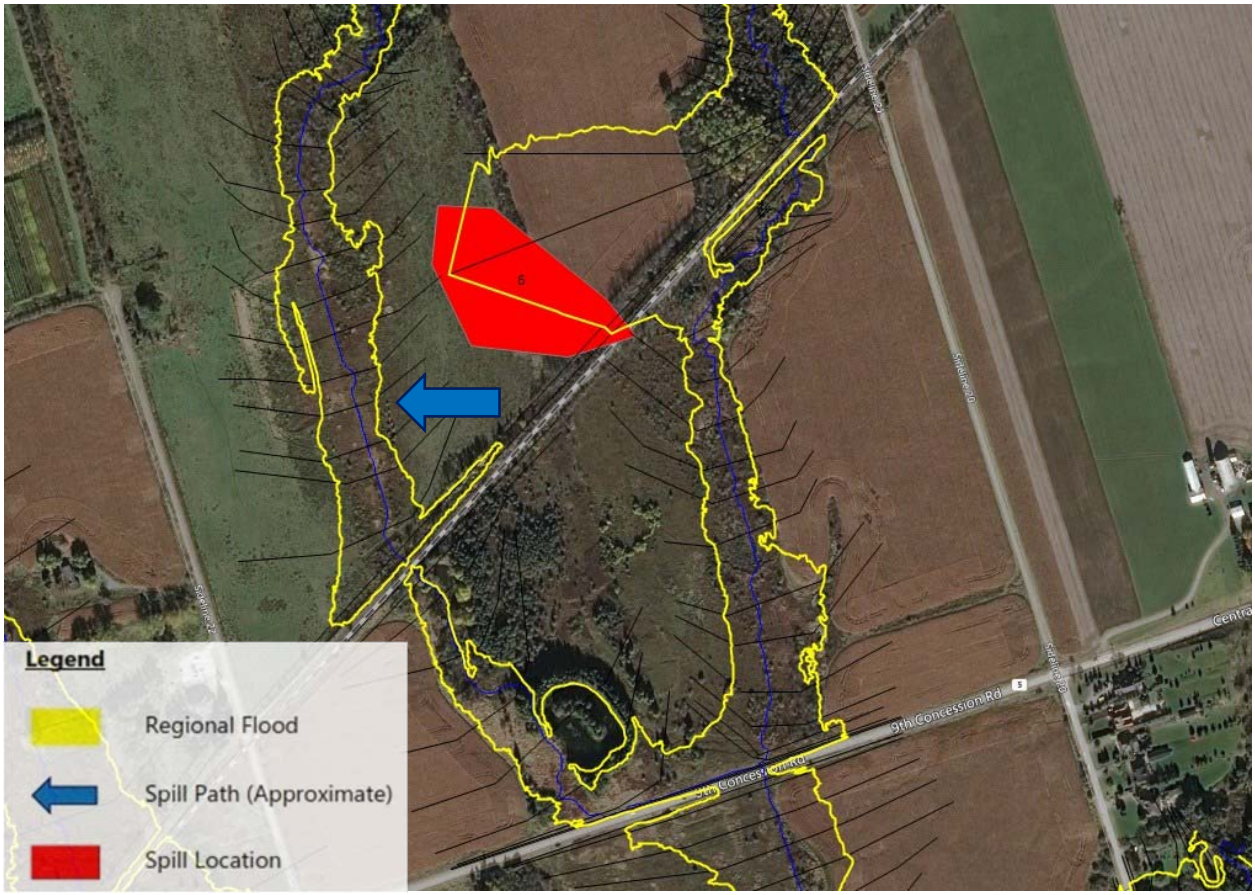

Figure 4-5 Duffins Creek Spill Area 6 (CNR Tracks): Mitchell Trib C, Reach Trib C2 (XS 821.41)

4.3.6 Spill Area 7

Spill Area 7 is located along East Duffins Creek Tributary C1, directly downstream of Westney Road North, north of Highway 407 in the City of Pickering. The spill area is presented in Figure 4-6.

Based on the topographic data in this area, the spill would drain southerly towards an existing low point west of Westney Road and north of Highway 407. Spill volume would need to accumulate to depth of approximately 1 m or greater before being able to spill onto Highway 407.

The spill width in this location is approximately 11 m; the full Regional Storm Flow in the main branch at this location is 3.72 m^3/s. Given the small spill width and peak flow in this case, the rural nature of the study area, and that any spill flow would likely be contained in a low lying area to the south, this spill area is not considered to be a primary spill area of concern.

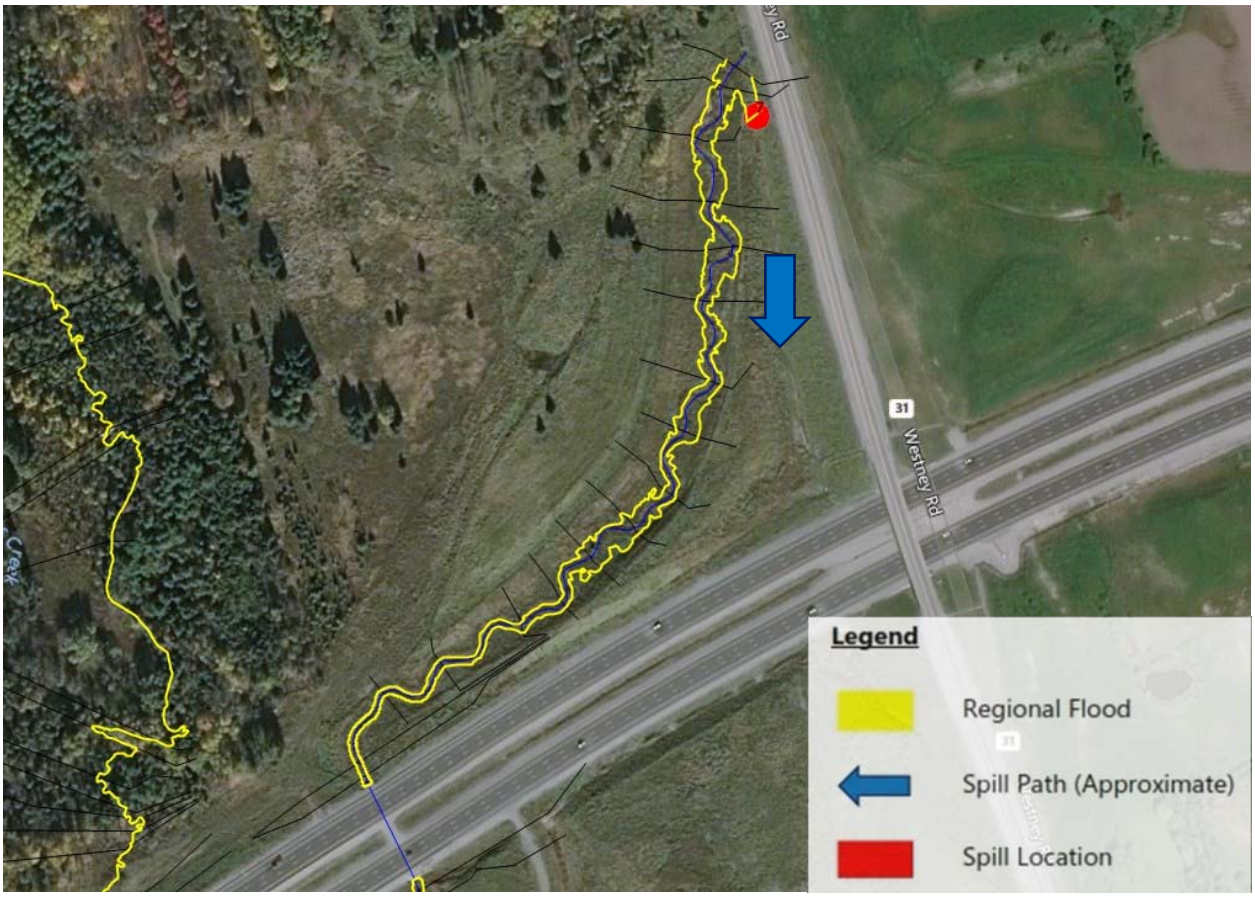

Figure 4-6 Duffins Creek Spill Area 7 (Westney Road): E Duffins Trib C, Reach East C1 (XS 1349.05)

4.3.7 Spill Area 8

Spill Area 8 is located along Brougham Creek Tributary A1, immediately south of Highway 7 and west of Paddock Road in the City of Pickering. The spill area is presented in Figure 4-7.

Based on the topographic data in this area, the spill would drain primarily easterly, along a private road (Pickering Museum Village) towards 6th Concession Road, and ultimately towards East Duffins Creek (Reach 4).

The spill width in this location is approximately 26 m; the full Regional Storm Flow in the main branch at this location is 29.11 m^3/s. Although the spill width is relatively narrow, the Regional Flow in this case is relatively high and would have the potential to impact the museum site and the adjacent roadways. As such, this spill area likely warrants further detailed assessment.

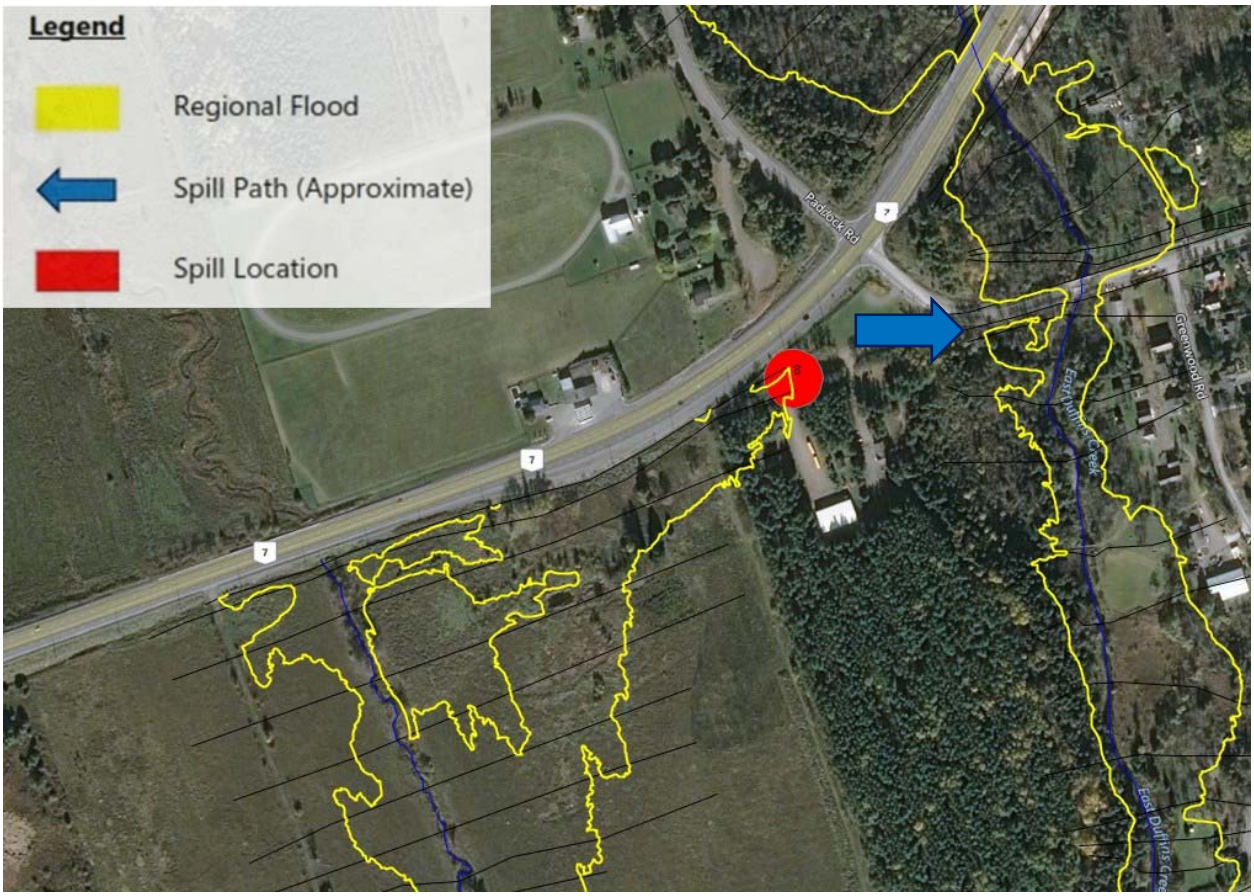

Figure 4-7 Duffins Creek Spill Area 8 (Highway 7): Brougham Trib A, Reach Trib A1 (XS 2159.01)

4.3.8 Spill Area 9

Spill Area 9 is located along Ganatsekiagon Creek Reach 1, just upstream of a private structure (former railway line) to the north of Taunton Road in the City of Pickering. The spill area is presented in Figure 4-8.

Based on the topographic data in this area, it appears that the former railway line acts as a berm to a certain elevation, with a swale/ditch along the north side of the berm, which drains towards the creek. Thus, it would be expected that initial spill flows would initially drain into this swale/ditch and be returned to the watercourse. If ponding elevations are sufficient, spill would ultimately be directed into the north ditch of Taunton Road, and then drain easterly towards the main branch of the creek.

The spill width in this location is approximately 63 m; the full Regional Storm Flow in the main branch at this location is 54.12 m^3/s. Based on the magnitude of flow and the spill width, this spill area may warrant further review to confirm extents, however the spill would not appear to have direct impacts to area properties or major impacts to infrastructure/roadways. To confirm definitively, this spill area likely warrants further detailed assessment.

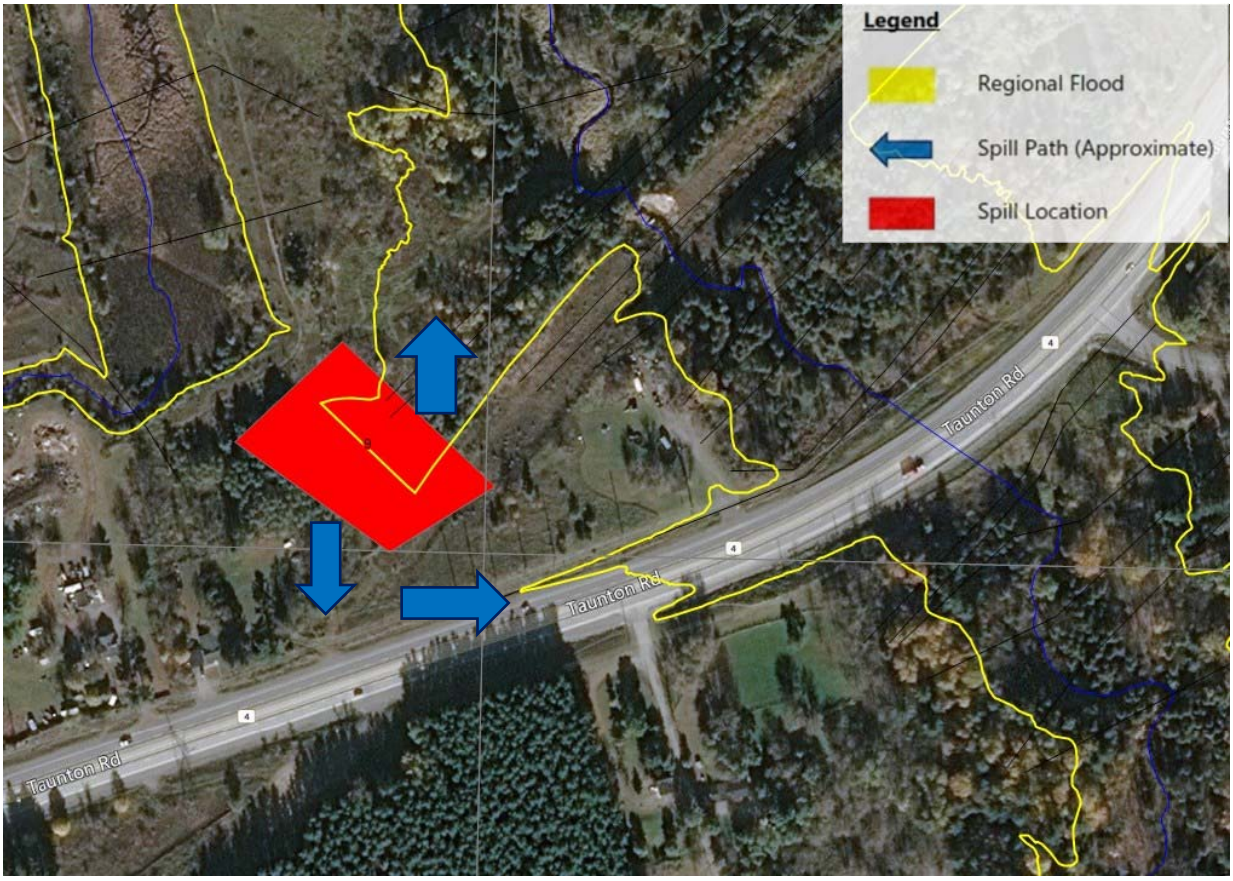

Figure 4-8 Duffins Creek Spill Area 9 (Former Railway Line): Ganatsekiagon Creek, Reach 1 (XS 5228.94)

4.3.9 Spill Area 10

Spill Area 10 is located just downstream of Spill Area 9 along Ganatsekiagon Creek Reach 1, south of Taunton Road and upstream of the CNR tracks, within the City of Pickering. The spill is presented in Figure 4-9.

Based on the topographic data in this area, it appears there is a low point directly west of the spill point to the north of the CNR tracks. As such, any spill in this area would likely accumulate in this area. There is also a swale feature along the railway tracks which would collect spill flow and likely direct it back towards the primary watercourse.

The spill width in this location is approximately 40 m; the full Regional Storm Flow in the main branch at this location is 67.18 m^3/s. Based on the preceding, the spill in this case is not considered to be a primary spill area of concern.

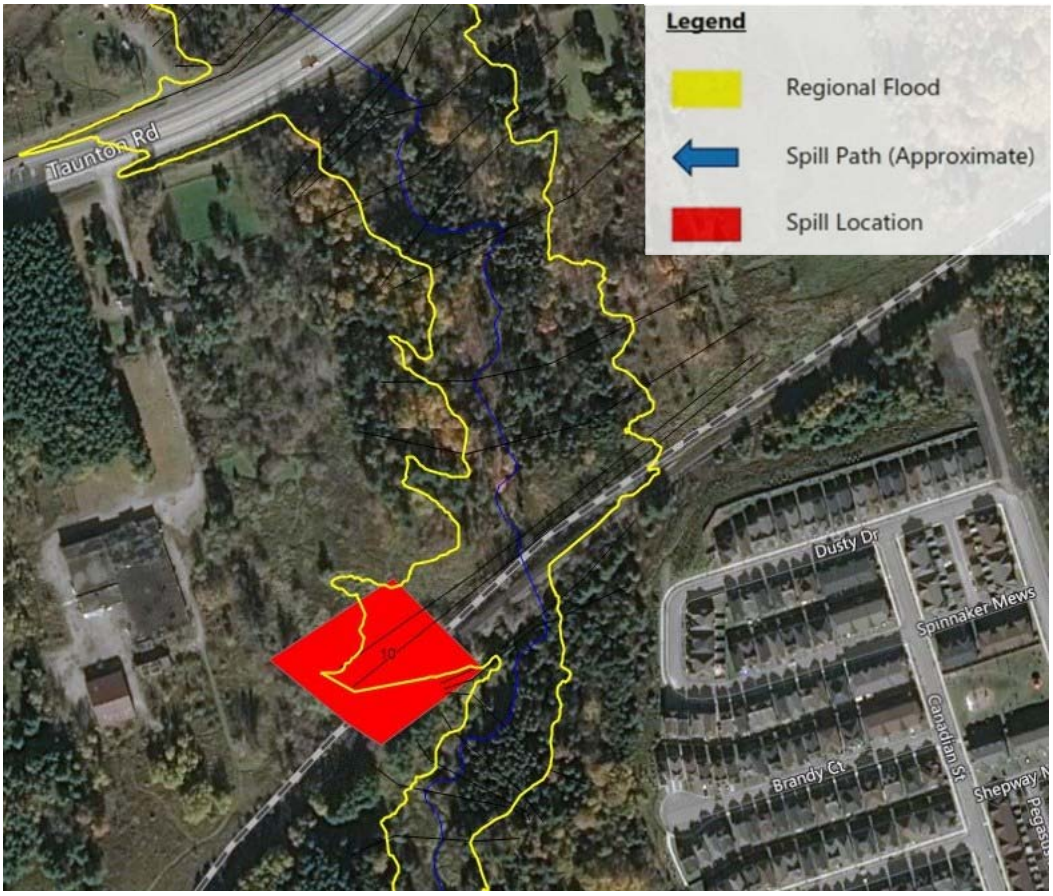

Figure 4-9 Duffins Creek Spill Area 10 (CNR Tracks): Ganatsekiagon Creek, Reach 1 (XS 4542.26)

4.3.10 Spill Area 11

Spill Area 11 is located along Millers Creek Reach 1, along the right overbank at Taunton Road West (west of the CNR) in the Town of Ajax. The spill is presented in Figure 4-10.

Based on the topographic data in this area, surface grades are relatively flat between the spill point (Harwood Avenue) and the smaller unmodelled tributary of Miller Creek to the west, west of Keenlyside Lane (a small infill development constructed in approximately 2017 based on historical aerial photography in Google Earth™). The topographic data in this area (2015 LiDAR based) may not accurately represent current grading, however in general, it appears that any spill in this area may drain through the Keenlyside Lane area towards Millers Creek, potentially posing a safety hazard for the residential area.

The spill width in this location is approximately 18 m; the full Regional Storm Flow in the main branch at this location is 28.8 m^3/s (Regional Flow increases to 39.27 m^3/s at XS 8089.75, at the confluence with the smaller western tributary, approximately 200 m downstream of Harwood Avenue). Based on the preceding, and also the complex hydraulics in this area (sequential crossings of the CNR, Taunton Road West, and Harwood Avenue), a more detailed hydraulic assessment is recommended for this spill area to confirm the potential spill impacts.

Figure 4-10 Duffins Creek Spill Area 11 (Taunton Road West): Millers Creek, Reach 1 (XS 8425.29)

4.3.11 Spill Area 12 and 13

Spill Areas 12 and 13 are both located along Millers Creek Reach 1 at Highway 401 in the Town of Ajax (structure Duf_148). The spill is presented in Figure 4-11.

The hydraulic structure in this location is complex, and changes geometries multiple times over the crossing length. WSP, working for MTO, completed a topographic survey of the structure, which was provided to TRCA and ultimately to Wood. This topographic survey was incorporated into the hydraulic modelling of the structure. TRCA staff subsequent developed a hydraulic model of the crossing in PCSWMM to confirm the most appropriate geometry to incorporate into the HEC-RAS modelling, as well as to define internal boundary condition water levels.

Based on the topographic data in this area, it is expected that any spill would drain along Highway 401 westerly, towards the main branch of Duffins Creek. This section of Duffins Creek was not included in Wood's current scope of work, and is understood to have been assessed through previous study (Pickering Ajax SPA 2D Modeling and Dyke Assessment Study by Valdor Engineering in 2018).

The spill width in this location is approximately 27 m (Spill 12) and 102 m (Spill 13); the full Regional Storm Flow in the main branch at this location is 139.36 m^3/s. Based on the preceding, further detailed hydraulic modelling and assessment of this spill is warranted, given the spill extents and peak flow magnitude, and the potential impacts to a 400-series highway. This would potentially involve an update to the previously noted SPA 2D modelling work.

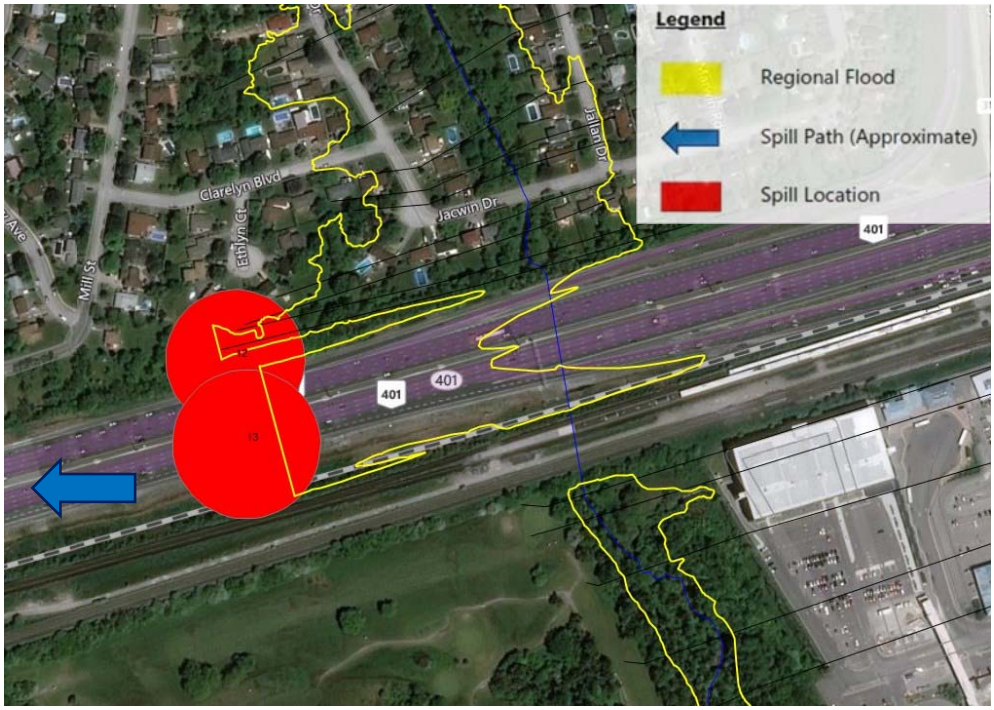

Figure 4-11 Duffins Creek Spill Areas 12 and 13 (Highway 401): Millers Creek, Reach 1 (XS 918.09)

4.3.12 Spills Summary

An assessment of spill locations and paths was completed following the MNRF's Technical Guide River & Stream Systems: Flooding Hazard Limit (2002) (ref. Section 4.13 of the guidelines) which defines a spill as occurring when flood levels overtop the banks of a watercourse and spill overland away from the watercourse channel. In this context, thirteen (13) spill areas have been identified within the study area for this project, as per Table 4-3.

From the analyses it is recommended, given their potential to impact a broad area and/or transfer of flow to another watercourse, that the following spill areas should be further assessed; 1, 3, 4, 8, 9, 11, 12 and 13. Further assessment should include quantification of the spill flow to determine if it exceeds MNRF's 10% threshold and enhanced modelling to better delineate floodplains and to better understand flood risk associated with those properties in the spill zones or along spill pathways.

4.4 Task 3C - Development of Graphical Representations of Model Data

The graphical representations of the new hydraulic model computations, namely:

- water surface elevation;
- water depth;
- velocity rasters;
- cross-sections attributed with the water surface elevations and other relevant data; and,
- polygon features of the flood extents for the Regional Storm and, the 2, 5, 10, 25, 50, 100, 350 year design storms;

have been prepared and submitted to TRCA in accordance with the requirements for this study.

The finalization of the study geomatics deliverables was completed in collaboration with TRCA.

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5.0 Recommendations

A number of recommendations have been advanced as outcomes of the foregoing assessment, as outlined below:

1. Given their potential to impact a broad area and/or transfer of flow to another watercourse, the following spill areas should be further assessed; 1, 3, 4, 8, 9, 11, 12 and 13. Further assessment should include quantification of the spill flow to determine if it exceeds MNRF's 10% peak flow threshold and enhanced modelling to better delineate floodplains and to better understand flood risk associated with those properties in the spill zones or along spill pathways.
2. While the foregoing assessment has been based on best available data at the time of the project, some aspects of the modelling have been developed based on limited information. Further, obtaining information, with particular reference to watercourse crossing structures, has required significant effort and, depending on the source organization, significant expense. It is therefore recommended the TRCA develop an in-house data store for watercourse crossing structures and maintain on-going liaison with local municipalities and other organizations (railways, MTO, 407ETR, etc.) to maintain this database.
3. Where new data becomes available for watercourse re-alignments or new hydraulic structures, the model should be updated. For hydraulic crossing structures presently included in the Duffins Creek hydraulic model, TRCA should assess whether remodelling of the structure with the new data would result in a significant change in computed water surface elevations and resultant floodplain limits.
4. The implications of climate change influenced rainfall on peak flow estimation for Duffins Creek, and other watersheds in their jurisdiction, should be investigated to better understand the potential for expansion of the 100-year flood inundation limits (and those associated with other return period based events) and generally increased flooding in the future.

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6.0 References

Aquafor Beech, (2013). *2012 Duffins Creek Hydrology Update Final Report*, Aquafor Beech Limited, February 11 2013.

Baird (2019). *Toronto Islands Flood Characterization and Risk Assessment Project. Flood Characterization Report,* Baird, 2019. Available via URL https://s3-ca-central-1.amazonaws.com/trcaca/app/uploads/2019/06/13113216/13017.101.R1.Rev0_FloodCharacterization.pdf

ECCC, (2017). *Level News, Great Lakes and St Lawrence River Water Levels*, Environment & Climate Change Canada, Volume 25, Issue 6, June 2017. Available via URL http://www.ec.gc.ca/eau-water/9DAD89EC-798F-4AC8-B15D-ADDAAA180628/LEVELnews_06_2017_e.pdf

EWRG, (2017). Technical Guidelines for Flood Hazard Mapping, Toronto and Region Conservation, Nottawasaga Valley Conservation Authority, Ganaraska Conservation, Grand River Conservation Authority, Credit Valley Conservation, and the Central Lake Ontario Conservation, March 2017. Available via URL https://s3-ca-central-1.amazonaws.com/trcaca/app/uploads/2016/02/17161112/Technical-Guidelines-For-Flood-Hazard-Mapping-March-2017-Final.pdf

Ontario, (2001). Great Lakes – St. Lawrence River System and Large Inland Lakes Technical Guides for flooding, erosion and dynamic beaches in support of Natural Hazards Policies 3.1 of the Provincial Policy Statement (1997) of the Planning Act, published by Trent University, Peterborough, Ontario, Canada, Queen's Printer for Ontario ISBN 0-9688196-1-3, 2001

Stantec, (2019). *Stouffville Dam Downstream Flood Remediation Study*, Stantec Consulting Limited, June 26 2019.

Valdor Engineering, (2018). *Pickering Ajax Special Policy Area (SPA) 2-Dimensional (2D Modelling and Dyke Assessment Study,* Valdor Engineering, 2018.

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