Waterford River Area Flood Risk Mapping Study

Final Report

153113.00 ● Final Report ● June 2018

Prepared for:

Department of Municipal Affairs and Environment

Prepared by:

CBCL LIMITED

Consulting Engineers

Final Report, Revision 1	Greg Sheppard	06/20/2018	Jennifer Bursey Lindsay Wilcott
Final Report	Greg Sheppard	12/01/2017	Jennifer Bursey Lindsay Wilcott
Draft Final Report	Greg Sheppard	03/31/2017	Jennifer Bursey Lindsay Wilcott
Draft Report	Greg Sheppard	02/27/2017	Jennifer Bursey Lindsay Wilcott
Issue or Revision	***Reviewed By:***	***Date***	***Issued By:***

CBCL LIMITED
Consulting Engineers

REGISTERED PROFESSIONAL ENGINEER
PEG
JENNIFER BURSEY
Jennifer Bursey
SIGNATURE
June 20, 2018
DATE
NEWFOUNDLAND & LABRADOR

153113.00

CBCL LIMITED
Consulting Engineers

187 Kenmount Road
St. John's, Newfoundland
Canada A1B 3P9

Telephone: 709 364 8623
Fax: 709 364 8627
E-mail: info@cbcl.ca
www.cbcl.ca

Solving today's problems with tomorrow in mind

June 20, 2018

Amir Ali Khan, Ph.D, P.Eng
Manager
Water Rights, Investigations, and Modelling Section
Water Resources Management Division
Department of Municipal Affairs and Environment
Government of Newfoundland and Labrador
4th Floor, West Block, Confederation Building
PO Box 8700,
St. John's, NL
A1B 4J6

Dear Mr. Khan:

RE: Flood Risk Mapping Study: Waterford River Area
Final Report

CBCL has completed a flood risk assessment of the Waterford River area for the 1:20 and 1:100 AEP flood events. The analysis includes a complete set of flood zone maps for current and future development conditions within the drainage catchment, as well as climate change considerations including sea level rise. Fully developed and calibrated hydraulic and hydrologic models of the study area using HEC-HMS and HEC-RAS computational software support the flood risk assessment.

It has been a pleasure to work with you and other representatives of the Water Resources Management Division on this important project.

Yours very truly,

CBCL Limited

Greg Sheppard, P. Eng.
Project Manager
Direct: 709-364-8623, Ext. 288
E-Mail: gregs@cbcl.ca

Project No: 153113.00

Canada's Best Managed Companies

Contents

List of Tables

List of Figures

Appendices

CHAPTER 1 INTRODUCTION

1.1 Background

Under the Climate Change Adaptation Initiative, the Government of Newfoundland and Labrador determined that updated flood risk mapping for the Waterford River was required to accurately predict the long-term effects of climate change on the study area. Climate change includes both an increase in precipitation and sea level rise. The previous flood risk study for the Waterford River took place in 1998. At this time, climate change conditions were not incorporated into the inundation boundary delineation.

Historic significant rainfall events in the Waterford River Basin have led to repeated flooding, including damage to hydraulic structures, washouts, and bank erosion. A thorough review of applicable background information for the Waterford River area, including historic flood events, is presented in Chapter 2.

In 2015, the Water Recourses Management Division (WRMD) of the Department of Municipal Affairs and Environment issued a Request for Proposals (RFP) for engineering consulting services related to the development of updated climate change flood risk mapping for the Waterford River. CBCL Limited was awarded the Waterford River Area Food Risk Study in October 2015. The flood risk mapping study will act as a long-term projection of the future flood zone and water surface elevation under anticipated development and climate change conditions within the study area. The purpose of this assessment is to provide maps, which will assist municipalities in all aspects of water resource management, including urban planning, land use zoning, infrastructure design, and policy development.

1.2 Study Area

The study area consists of the Waterford River and major tributaries, including South Brook, Kilbride Brook, Branscombe's Pond, Nevilles Pond, Donovans Tributary, and Bremigens Pond. The Waterford River watershed area totals 66.3 km^2 and extends over three municipalities: the City of St. John's, the City of Mount Pearl, and the Town of Paradise.

The river begins at Bremigens Pond and Brazil Pond within the Eastern tip of the Town of Paradise. From here, the river flows through the City of Mount Pearl and on to the confluence at Donovans

Tributary. The Waterford River continues through the Cities of Mount Pearl and St. John's where it meets up with South Brook and ultimately discharges into St. John's Harbour.

1.3 Scope

The objective of the Waterford River flood risk study is to produce flood risk map deliverables for various development and climate conditions within the watershed. In support of flood risk map production, both hydrologic and hydraulic exercises were required. The watershed's response to pre-defined return period events was measured using the hydrologic model in the form of flood flows. These flows became the major input for the hydraulic model, which measures the river's response to flood flows through flow regulating structures. Finally, the topographic mapping exercise includes overlaying the hydraulic model outputs onto the site-specific terrain.

The linked hydro-fabric was essential in the development of flood risk maps. An extensive survey program was completed on the Waterford River, including determining the topography of the study area through up-to-date Light Detection and Ranging (LiDAR) data and aerial photography. Cross sectional survey data was incorporated into the hydraulic model of the river, complete with bridge and culvert structures.

The flood risk map deliverables are presented by map set in an effort to organize the large volume of data. Each map set includes six figures at a 1:2500 scale preceded by one overview map of the overall river system. Symbols presented on flood risk map figures are consistent with the feature codes expressed on the WRMD Flood Risk Mapping table. The following list outlines all flood risk map packages included in the report along with a description of the data presented:

1. Flood Zone Inundation Boundary Map Set – flood plain and water surface elevation associated with the following conditions:
    - 1:20 and 1:100 AEP for Current Climate, Current Development (CC-CD)
    - 1:20 and 1:100 AEP for Climate Change, Future Development (CLC-FD)

2. Flood Zone Velocity Distribution Map Set – flood zone velocity associated with the following conditions:
    - 1:20 AEP for CC-CD
    - 1:100 AEP for CC-CD
    - 1:20 AEP for CLC-FD
    - 1:100 AEP for CLC-FD

3. Flood Hazard Map Set – flood hazard associated with the following conditions:
    - 1:20 AEP for CC-CD
    - 1:100 AEP for CC-CD
    - 1:20 AEP for CLC-FD
    - 1:100 AEP for CLC-FD

4. Flood Zone Inundation Boundary Comparison Maps – flood plain associated with the following conditions:
    - 1:20 AEP comparison of CC-CD and Climate Change, Current Development (CLC-CD)
    - 1:100 AEP comparison of CC-CD and CLC-CD
    - 1:20 AEP comparison of CC-CD and historical inundation boundary
    - 1:100 AEP comparison of CC-CD and historical inundation boundary

The map packages outlined above are appended to this report and described in depth in the designated report sections.

The purpose of the flood risk mapping deliverables is to assist affected municipalities and government agencies in determining appropriate climate change adaptations. In support of this effort, CBCL Limited has evaluated the application of a flood forecasting service for the municipalities included in the study area. Finally, a hydraulic capacity assessment is presented for hydraulic structures within the study area affected by the 1:20 and 1:100 AEP flood.

CHAPTER 2 INFORMATION REVIEW

2.1 Historical Flooding

WRMD has compiled a flood events inventory. The inventory was searched for floods on the Waterford River and South Brook. Records for St. John's, Mount Pearl and Paradise, and the descriptions of the events and damage were also examined. The following events were determined to have resulted in flooding of the Waterford River:

TABLE 2-1: FLOOD EVENTS ON WATERFORD RIVER AND TRIBUTARIES

Date	Cause	Description of Flooding in Relation to the Waterford River
Oct 12-14, 1934	Rain	Several families in the vicinity of Southside Road and Blackhead Road left their homes.
Jul 27-29, 1946	Rain	Bowring Park swimming pool and several bridges were damaged.
Dec 1-2, 1946	Rain	Bowring Park concrete retaining wall was damaged, a debris jam at Brookfield Road bridge caused the bridge to overtop, Waterford bridge overtopped and water encroached on the Corpus Christi Parish church.
Spring 1948	Unknown	Railway track near Syme's bridge was damaged.
Nov 30, 1951	Rain	Flooding at Waterford bridge.
Oct 6, 1953	Rain	Basement flooding at South Side Road.
Jan 31, 1971	Rain/Snow melt	Flooding at St. Brides College (Littledale), 220 Waterford Bridge Road.
Dec 27, 1977	Rain/Snow melt	Flooding parts of Bowring Park and Squires Avenue.
May 24, 1985	Rain	Flooding of Waterford River banks from Donovans to Kilbride, and South Brook.
Apr 11, 1986	Rain	Flooding at Dunn's Road bridge and Waterford Bridge Road bridge.
Apr 13, 1999	Rain/Snow melt	Flooding of backyards along Waterford Bridge Road.
Apr 29, 1999	Rain	Waterford Bridge Road was inundated near the hydrometric station (02ZM008). The Corpus Christi Parish church building was surrounded by water and its basement was flooded. Two homes near Forest Avenue had basement flooding. A storm manhole on Birch Avenue was surcharging.

Date	Cause	Description of Flooding in Relation to the Waterford River
Sep 19, 2001	Rain (Hurricane Gabrielle)	Waterford River flooded its banks.
Oct 19, 2009	Rain	Several homes near Forest Avenue with flood damage.
Sep 20, 2010	Rain (Hurricane Igor)	Waterford River flooded banks, multiple locations of flooding to buildings, properties and roads.

2.2 Past Flood Studies

A literature review of previous flood studies was conducted to assess the underlying mechanisms of flooding, as well as to identify any areas which experience frequent flooding. Between 1980 and 1985, the Canadian Government and Province of Newfoundland and Labrador completed a series of studies focusing on water quality and quantity in the Waterford River Basin. In 1986, the *Urban Hydrology Study of the Waterford River Basin: Flood Study* was published. In 1988, Fenco Newfoundland Ltd. completed a flood study titled *Waterford River Area - Hydrotechnical Study*, and in 1998, the then Department of Environment and Labour, Water Resources Management Division, completed a flood study titled *Updated Flood Extents for the Waterford River*. The findings of these studies are summarized in the following sections.

2.2.1 Urban Hydrology Study of the Waterford River Basin: Flood Study

The Urban Hydrology Study of the Waterford River Basin (UHS-WRB) was a five year study, which began in 1980 and was mostly completed by 1985. The study was a joint effort between the Government of Canada and the Province of Newfoundland and Labrador. The study focused on the effects of urbanization on both water quality and quantity in the Waterford River Basin. The following topics were studied in detail with respect to the Waterford River basin: Surficial Geology, Geology, Land Use, Surface Water Quality, Storm Runoff Study of Newtown Urban Catchment, Groundwater, Installation and Testing of the Monitoring Well Network, Biological Study, Watershed Modelling Using HYMO, Flood Study, and Streamflow Modelling.

The UHS-WRB: Flood Study was released in 1986. The flows examined were the 1:20 and 1:100 AEP events as developed using the hydrologic model, HYMO. The HEC-2 program was used to simulate the 1:20 and 1:100 AEP flows and develop flood limits. The hydraulic model was limited to three sections of the Waterford River, these include a roughly 330 m reach from the 02ZM008 hydrometric gauge and extending upstream, an approximate 1,120 m reach in Mount Pearl from hydrometric gauge 02ZM010 extending downstream, and a roughly 510 m reach in Donovans Industrial Park upstream from gauge 02ZM011.

The studied reaches showed flooding during the 1:20 and 1:100 AEP events around the Corpus Christi Parish church in the Kilbride reach, with several other buildings in this reach affected as well.

2.2.2 Waterford River Area – Hydrotechnical Study

In June 1988, Fenco Newfoundland Ltd. completed a floodplain mapping study for the then Department of Environment and Lands, which identified the extent of flooding and proposed flood damage reduction strategies for Waterford River between St. John's harbour and Donovans Industrial Park. The study included estimating the 1:20 and 1:100 AEP flows using the modeling software QUALHYMO and statistical techniques, and delineating the resulting floodlines by transposing the water surface elevations determined from the HEC-2 model onto 1:2,500 scale topographic maps.

The flood risk maps identified 20 structures along the Waterford River that would be flooded during a 1:100 AEP event.

2.2.3 Updated Flood Extents for the Waterford River

In 1998, WRMD completed an update of the 1988 Fenco Newfoundland Ltd. study. This update examined the 1:20 and 1:100 AEP flood flows from the 1988 study, completed a statistical analysis of the annual peak instantaneous flows up to 1996, and recommended flood flows used to prepare the updated flood risk maps. The hydraulic model chosen for the study was HEC-RAS and used the cross sections surveyed for the 1988 study. The study found the increased estimates for the 1:20 and 1:100 AEP increased water levels by 15 and 17 cm, respectively, over the 1988 study. The study also found that the width of both the updated 1:20 and 1:100 AEP floodplains increased compared to the 1988 study. The 1:100 AEP floodplain increased only slightly over the 1988 extent, while the 1:20 AEP floodplain increase was more significant.

2.3 Intensity-Duration-Frequency Curves

Intensity-Duration-Frequency (IDF) curves describe rainfall patterns for a particular geographical area. They are created by performing statistical analysis on rainfall data recorded by a rain gauge. The result is a set of curves representing rainfall intensities for a range of storm durations for various return periods, typically the 1:2, 1:5, 1:10, 1:25, 1:50 and 1:100 AEP.

In 2015, Conestoga-Rovers and Associates (CRA) completed a report titled *IDF Curve Updates for Newfoundland and Labrador* for the Office of Climate Change and Energy Efficiency. The IDF curves for the St. John's Airport rain gauge (EC gauge # 8403506) was updated with data recorded at the City of St. John's owned Windsor Lake rain gauge up to and including 2014 data. The last EC update for this gauge included data from 1949-1996. The CRA update included 49 years of precipitation data.

In addition, new IDF curves were created for the Ruby Line rain gauge, which is owned and operated by the City of St. John's. These new IDF curves were created using 16 years of data from 1997 to 2014. The Ruby Line rain gauge is located within the Waterford River drainage basin, suggesting its IDF is more representative of the rainfall experienced in the basin than the St. John's Airport gauge. The report also included future, or climate change, IDF curves for various time frames. These curves are included in Appendix A.

The hydrologic model for this project is simulated with the 1:100 and 1:20 AEP, 6, 12 and 24-hour precipitation events for existing and climate change conditions. Based on the review of IDF updates, it was decided to use the Ruby Line IDF values.

CHAPTER 3 DATA COLLECTION

Several sources of data were required to accurately assemble the hydrologic and hydraulic models. Items included in the data collection process are as follows:

- Aerial photography of the study area collected in May 2016;
- LiDAR data of the study area collected in May 2016;
- Zoning and property mapping provided by the Cities of St. John's and Mount Pearl and the Town of Paradise;
- Future development data provided by the Cities of St. John's and Mount Pearl and the Town of Paradise;
- Soil data;
- Water level measurements provided by the City of St. John's;
- Water level measurements collected by CBCL Limited;
- Flow gauging data provided by Environment Canada (EC);
- Rating curves at EC's flow gauging site provided by EC;
- Precipitation data provided by EC and the City of St. John's;
- Channel cross sections obtained from field investigation;
- Hydrographic chart data; and
- Hydraulic structure details obtained from field investigation.

3.1 Aerial Photography and Detailed Topographic Data

Aerial photography and LiDAR data were collected by Leading Edge Geomatics Inc. in May 2016. The satellite imagery was used by C-CORE in conducting the land cover classification. The LiDAR data consists of a 1-m grid, and was used in the hydrologic model to determine subbasin area(s) and lag times (basin slope and hydraulic length of the watershed used in the CN lag time calculation are determined from the LiDAR). Further, a digital terrain model (DTM) was developed from the LiDAR data and used in the hydraulic analysis and floodplain mapping. A LiDAR data accuracy report is provided in Appendix B.

3.2 Calibration Data

Meteorological and hydrologic data, including flows and water levels, were obtained for use in this study.

There is one long-term flow gauge in operation on Waterford River. This gauge is located downstream of the confluence of South Brook and Waterford River, and is operated by the Water Survey of Canada under the name Waterford River at Kilbride (EC #02ZM008). The flow gauge has a contributing drainage area of approximately 52.7 km^2 and has been in operation since 1974. There are no operational flow gauges on South Brook or Waterford River (upstream of the confluence). However, the City of St. John's operates four water level monitoring gauges installed at Blackhead Road, Bay Bulls Road and Bowring Park duck pond on the Waterford River, and Green Acre Drive on South Brook. In addition, CBCL Limited installed three level loggers at Walking Trail Bridge near Newdock, Commonwealth Avenue on the Waterford River, and Pearl Town Road on South Brook. Unfortunately, the Pearl Town Road water level was taken out of service during the study, as the bridge it was originally attached to was removed and replaced.

Near real-time stage and flow data for the Water Survey of Canada gauge 02ZM008 is available on both EC's and WRMD's website. This real time data is available in five-minute increments. The EC curve was applied as one source of calibration data for the hydraulic model and can be found in Appendix C.

The use of the above data in the model calibration is discussed further in Chapters 4 and 5.

3.3 Hydraulic Structure Details

Hydraulic structure data was used to develop bridge and culvert geometry within the hydraulic model. These structures represent critical points of energy losses and have a dominant role in generating peak water levels within the model. Data on bridge deck elevation and opening geometry was collected from both field investigation and as-built construction drawings. Collected field information includes photos, elevations, slope, diameter, opening measurements, and other observational notes. Eighty-nine structures (41 bridges and 48 culverts) in total were investigated and assessed for hydraulic capacity; the following table outlines the locations of each structure:

Table 3-1: Hydraulic Structures in Each River Reach

River	Reach	Hydraulic Structure ID	
		Bridge	Culvert
Branscombe's Pond	**Branscombe's Pond**	BP6-7 BP2-3	
Kilbride Brook	**Kilbride Brook**	KB 18-19 KB 13-14 KB 8-9 KB 4-5 68-69	KB 57-58 KB 52-53 KB 47-48 KB 43-44 KB 40-41 KB 36-37 KB 32-33 KB 28-29 KB 23-24

<table>
<tr><th rowspan="2">River</th><th rowspan="2">Reach</th><th colspan="2">Hydraulic Structure ID</th></tr>
<tr><th>Bridge</th><th>Culvert</th></tr>
<tr><td>Nevilles Pond (Brazils Pond)</td><td>Nevilles Pond</td><td></td><td>NP 14-15
NP 10-11
NP 7-8
NP 2-3*</td></tr>
<tr><td>South Brook</td><td>Upper South Brook</td><td>123-124
100-101
96-97
88-89
76-77</td><td>126-127
119-120
116-117
111-112
106-107
92-93
83-84*</td></tr>
<tr><td>South Brook</td><td>Lower South Brook</td><td>65-66
63-64
58-59
47-48</td><td>51-52</td></tr>
<tr><td>Donovans Tributary</td><td>Donovans Tributary</td><td>UR 4-5
UR 2-3</td><td>UR 59-60
UR 52.5B-52.5C
UR 50-51**
UR 47-48**
UR 43-44**
UR 39-40**
UR 36B-36C**
UR 33-34**
UR 29-30
UR 26-27**
UR 23B-23C**
UR 20-21**
UR 14-15**
UR 11A-11B**
UR 10A-10B*</td></tr>
<tr><td>Waterford River</td><td>Upper Waterford</td><td></td><td>268-269
261-262*
259-260*
255-256*
251-252*
247-248*
243-244*</td></tr>
<tr><td>Waterford River</td><td>US of Donovans Tributary</td><td>237-238
231-232</td><td>237-238**
235-236</td></tr>
</table>

River	Reach	Hydraulic Structure ID	
		Bridge	Culvert
Waterford River	**US of Branscombe's Pond**	217-218 212-213 205-206 198-199 192-193 187-188 182-183	228-229 225-226
Waterford River	**US of South Brook**	176-177 158-159 150-151 145-146 141-142 136-137 132-133	170-171
Waterford River	**Lower Waterford**	42-43 37-38 30-31 19-20 12-13 6-7 3-4	

* Indicates twinned culvert (double barrel)
** Indicates tripled culvert (triple barrel)

Hydraulic structure IDs presented in Table 3-1 are consistent with structure labels presented on flood risk map figures. The numbers of surveyed structures for each river reach are summarized in Table 3-2.

TABLE 3-2: SURVEYED HYDRAULIC STRUCTURE INVENTORY FOR EACH RIVER REACH

Reach	# of Hydraulic Structures Surveyed
Waterford River	35
South Brook	17
Nevilles Pond Tributary	4
Donovans Tributary	17
Branscombe's Pond Tributary	2 (+4 upstream of storm sewer)
Kilbride Brook	14

Data sheets for each structure are contained in Appendix D. A detailed description of each surveyed structure as well as the hydraulic structure capacity assessment is discussed in Chapter 5.

3.4 Channel Cross Sections

Cross sections are ground surface elevation field measurements outlining the flood plain, overbank, and stream geometry below the water surface along a linear path. As discussed in section 3.1.1 above, detailed topography of the study area was flown using LiDAR data to establish a DEM. This ground surface data was collected in May when the water surface was potentially high due to spring conditions. Therefore, cross sections are required to understand the stream geometry below the water surface.

In November and December of 2015, two CBCL employees walked Waterford River and South Brook and identified appropriate cross section locations. During the site visits, notes regarding the channel and overbank materials were made and photographs of each cross section were taken. Table 3-3 summarizes the cross sectional field data obtained for each reach.

TABLE 3-3: SURVEYED CROSS SECTION INVENTORY FOR EACH RIVER REACH

Reach	# of Cross Sections Surveyed
Waterford River	180
South Brook	72
Nevilles Pond Tributary	17
Donovans Tributary	70
Branscombe's Pond Tributary	13 (+18 upstream of storm sewer)
Kilbride Brook	63

Cross sections were selected at locations of change in river slope, shape (width), expected changes in discharge (ie. at a confluence with a tributary) or roughness, and at hydraulic structures (such as bridges, culverts and/or levees). The hydraulic model stability requires cross sections at intervals that ensure the change in velocity head is low enough to accurately determine the energy gradient. Energy loss computations for hydraulic structures aim for two upstream and two downstream cross sections.

A total of 433 cross sections were identified for survey. The locations of these cross sections are presented on all flood risk maps. In addition to the Waterford River and South Brook, the following tributaries were surveyed (six reaches in total):

- Donovans Tributary;
- From Branscombe's Pond to Waterford River;
- From Nevilles Pond (also known as Brazils Pond) to Waterford River; and
- Kilbride Brook.

In general, four cross sections were surveyed at each bridge or culvert crossing (two upstream and two downstream). At a few structure locations, it was not possible, for safety reasons, to obtain all four cross sections. For example, at bridge 192-193 on the Waterford River, the velocity was too high for surveyors to safely obtain cross section 194. In this instance, a cross section was interpolated from the LiDAR data. The channel elevations for 194 were compared to the surveyed channel elevations of the bounding cross sections and it was determined appropriate to use only LiDAR information. Cross sections interpolated from the LiDAR data or from nearby channel survey data are identified with an asterisk in the HEC-RAS model (i.e. 194*).

CHAPTER 4 HYDROLOGIC ANALYSIS

4.1 Single Station Flood Frequency Analysis

In accordance with the RFP, the 1:20 and 1:100 AEP flood flows at the EC gauge on Waterford River were estimated by performing a flood frequency analysis. Although there is no defined length of record that should be used to estimate flood flows, the *Regional Flood Frequency Analysis for the Island of Newfoundland* (Version 2014) suggests a period of record exceeding 18 years to sufficiently estimate the 1:100 AEP flood. There are 42 years of annual instantaneous maximum data recorded at the Waterford River at Kilbride (station number 02ZM008) gauge. As such, this gauge can be used to estimate a 1:100 AEP flow.

The annual peak instantaneous flow series for the 02ZM008 is provided in Appendix E. At the time of this study only data from 1974 to 2013 was available on EC's website for the gauge. Therefore, EC was contacted to obtain the peak instantaneous flows for 2014 and 2015. These two data points are included with the data series; however, EC noted that the 2014 and 2015 data is preliminary only and subject to change. In addition, the data series for Waterford River at Kilbride gauge had three missing data points for 1985, 1988 and 1994. The peak flow for these three years was estimated prior to conducting frequency analysis by estimating a peaking factor for the gauge. The peaking factor is calculated by dividing the peak instantaneous flow by the maximum daily flow for each annual pair occurring on the same date, and averaging the results. To estimate the absent peak instantaneous flow, the peaking factor is multiplied by the daily maximum value for that year. These estimated values are also included with the data series contained in Appendix E.

Prior to conducting the frequency analysis, several statistical screening tests were performed on the data. These tests include the following:

- Randomness: variations in the data set are a result of natural causes (i.e. the flow is not regulated);
- Independence: each recorded flow is independent of the other;
- Stationarity: the data series does not display trend with respect to time; and
- Homogeneity: all the data points are derived from a single population.

Plots of the distributions for the flow gauge data and the associated screening tests are included in Appendix E. The results indicate that the data is random and does not display dependence. The data set does display trend at the 5% level of significance, but not at the 1%; that is, the trend of the data is significant, but not highly so. Similarly, the test for homogeneity revealed that there is a significant difference in location at the 5% level of significance, but not so at the 1% level. That is, the location difference is significant, but not highly so.

Several statistical distributions were examined, including Gumbel, Generalized Extreme Value (GEV), Lognormal, 3-Parameter Lognormal and Log Pearson Type III. Appendix E contains the results of the statistical analysis. The most appropriate distribution was selected based on visual goodness-of-fit and statistical test Figure 4-1 illustrates the selected distribution, along with the 95% confidence interval. The resulting AEP flow estimates are listed in Table 4-1.

FIGURE 4-1: WATERFORD RIVER AT KILBRIDE – SINGLE STATION FREQUENCY ANALYSIS

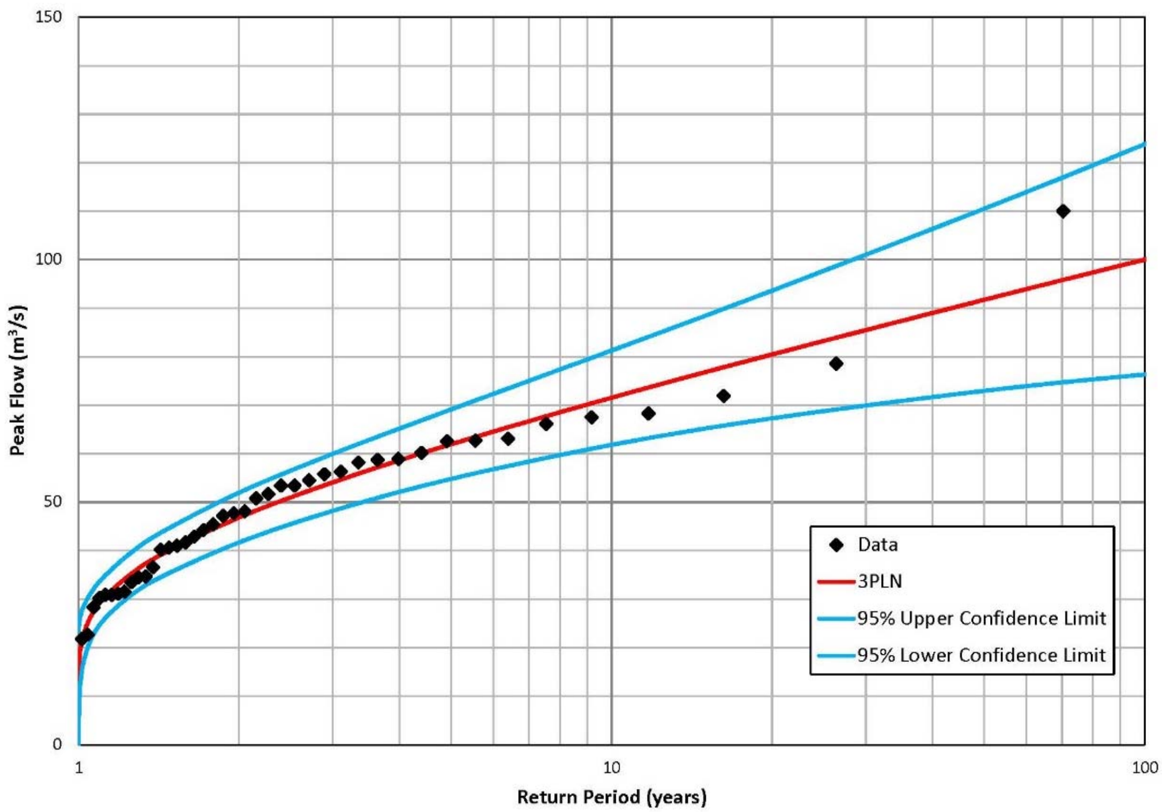


TABLE 4-1: SINGLE STATION FREQUENCY ANALYSIS RESULTS

Station Name	Station Number	Distribution	1:20 AEP Flood Flow (m^3/s)	1:100 AEP Flood Flow (m^3/s)
Waterford River at Kilbride	02ZM008	3PLN	80.5	100.0

4.2 Regional Flood Frequency Analysis

As discussed in the 'Regional Flood Frequency Analysis 2014 Update – User's Guide' the regression equations are not recommended for urbanized areas. Although the Waterford River basin is urbanized, a regional flood frequency analysis was conducted to use as a comparison to the single station frequency analysis and hydrologic model results. Using the equations for the South-East Region and the location of the hydrometric gauge, 02ZM008, as the point of interest, the following flood flow estimates were calculated. The Regional Flood Frequency Analysis spreadsheet outputs are shown in Appendix F. Since only the drainage area (DA) and lake attenuation factor (LAF) are used in the calculations, these were the only parameters estimated.

TABLE 4-2: REGIONAL FLOOD FREQUENCY ANALYSIS RESULTS AT LOCATION OF 02ZM008

South-East Region Equations	RFFA Flood Flow Estimates (m^3/s)	
	1:20 AEP	1:100 AEP
One Parameter Equation	56.2	72.8
Two Parameter Equation	67.7	87.7

4.3 Deterministic Analysis

Hydrologic modeling was carried out using the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) and its geospatial modelling extension (HEC-GeoHMS). HEC-HMS was developed by the US Army Corp of Engineers (USACE) and is specifically geared towards the precipitation-runoff processes of watershed systems. It allows the user to select from a variety of methods to simulate ground infiltration, transformation of surplus precipitation, baseflow, and open channel flow. HEC-GeoHMS is a GIS modeling extension that allows the modeller to extract watershed characteristics, define subbasins and streams, and assemble hydrologic model inputs to be used directly with HEC-HMS.

Prior to using HEC-GeoHMS to extract watershed characteristics, terrain and basin pre-processing is completed to derive the drainage network. Pre-processing includes determining flow direction, flow accumulation, stream definition and basin delineation. During basin pre-processing, the watershed is divided into sub-basins based on project specific requirements. For instance, the basin was divided at the locations of CBCL installed level loggers and City of St. John's level gauges, and at the location of the EC hydrometric gauge. Flow simulated at the level logger locations for recent rainfalls can be compared to the flows taken from the rating curves created for the level loggers and used as checks, or verification, of the model set up. The flow simulated at the EC gauge location for large historic events is used in the calibration process, discussed later in this section.

Following stream and subbasin delineation, physical characteristics such as stream length and slope, longest flow paths, centroidal flow lengths and basins slopes are extracted from the terrain data using the HEC-GeoHMS extension. It is also used to extract hydrologic parameters such as curve numbers and basin lag time, and to specify the loss, transform, baseflow and river routing methods to be used in the hydrologic model.

4.3.1 Hydrologic Model Inputs

Pertinent information included in the creation of the hydrologic model is discussed below. These HEC-HMS model inputs include:

- Subbasin Areas;
- Loss Method;
- Transform Method; and
- Routing Method.

4.3.1.1 Subbasin Areas

HEC-GeoHMS was used to delineate the watershed area using up-to-date LiDAR data of the study area, flown in May 2016, with a 1m grid. LiDAR data was applied to delineation of sub-basins as well as attributes such as basin slope and hydraulic length of watershed.

The resulting delineation was inspected, particularly the boundary at Petty Harbour-Long Pond (PHLP). Two potential outlets from PHLP were identified from available watercourse shapefiles and aerial imagery: a stream originating at the end of Old Petty Harbour Road flowing toward Kilbride Brook, and a stream originating near the end of Densmores Lane, near the PHLP Water Treatment Plant (WTP) and flowing toward South Brook. These two potential outlets are identified on Figure 4-2.

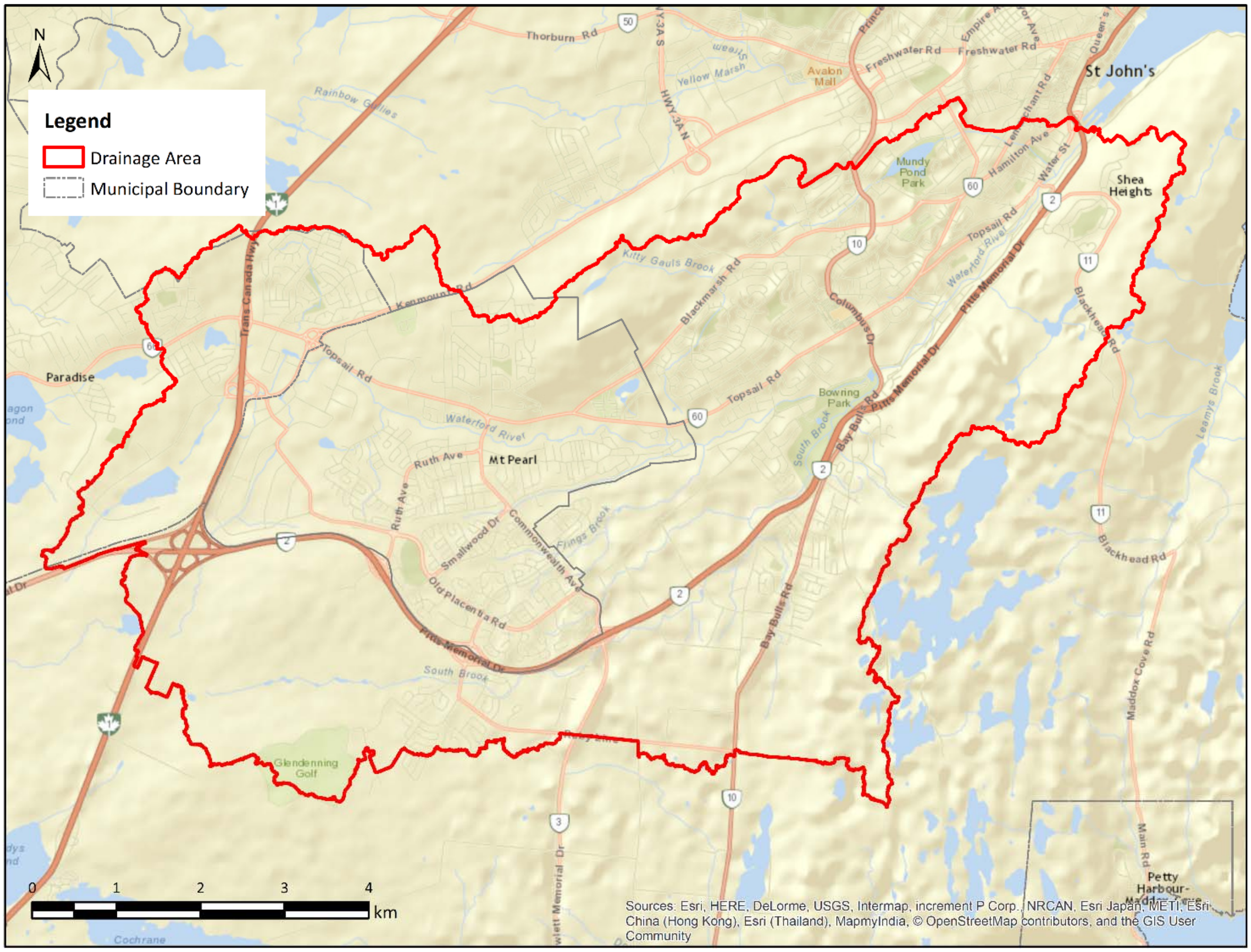
CBCL employees visited the Old Petty Harbour Road site on June 17, 2016, to assess the drainage. The aerial imagery shows a small area of water on the west side of the access road. During the field investigation, it was learned there is no connection between the main pond and this area.

On July 18, 2016, a site visit to the PHLP Water Treatment Plant (WTP) area revealed no connection between PHLP and the small stream running parallel to Densmores Lane. Therefore, PHLP does not contribute to the Waterford River drainage basin. The past flood risk mapping reports prepared for the Waterford River basin also excluded PHLP from the overall drainage area.

Figure 4-3 illustrates the final watershed delineation for the Waterford River. The total area is 66.3 km^2.

FIGURE 4-2: PHLP POTENTIAL CONNECTIONS TO DRAINAGE BASIN

FIGURE 4-3: WATERFORD RIVER DRAINAGE AREA



4.3.1.2 LOSS METHOD

Subbasin elements in HEC-HMS represent ground infiltration, surface runoff and subsurface processes. The infiltration calculations are performed through the selection of a loss method contained in the subbasin. The Soil Conservation Service (SCS) curve number loss method was used for this study, which is a well-established method.

The SCS curve number loss method relates depth of runoff to rainfall, potential maximum soil moisture retention, and initial abstraction through the following equation.

$$Q = \frac{(P - I_a)^2}{P - I_a + S}$$

Where Q = Depth of water retained in the watershed

P = Depth of excess precipitation

I_a = Initial abstraction before ponding begins and

S = potential maximum retention

$$S = \frac{1000}{CN} - 10$$

Where CN = runoff curve number

Runoff curve numbers (CN) are determined through a combination of land use, antecedent runoff condition and soil type. Typical values of CN range between 30 and 100. A large value for CN represents impervious areas.

C-CORE completed land use analysis using high-resolution satellite imagery provided by WRMD. The metadata associated with the imagery implies that the image was clipped from ESRI basemaps on March 30th 2015. The disclaimer on the imagery does not specify the exact satellite that was used to collect data. The following information on basemap imagery source is reflective of ESRI layer property discretion: “The map features 0.3m resolution imagery in the continental United States and 0.6m resolution imagery in parts of Western Europe from Digital Globe. In other parts of the world, 1 meter resolution imagery is available from GeoEye IKONOS, i-cubed Nationwide Prime, Getmapping, AeroGRID, IGN Spain, and IGP Portugal. Additionally, imagery at different resolutions has been contributed by the GIS User Community.”

The land uses were classified in accordance with WRMD’s requirements, and included the following classes:

- Forest;
- Residential;
- Commercial;
- Deforested Areas;
- Barren Land;
- Fields/Pastures/Open Space (ie. Parks, Cemeteries, Golf Courses, Grassed Areas); and
- Swamps/Wetlands/Water Bodies.

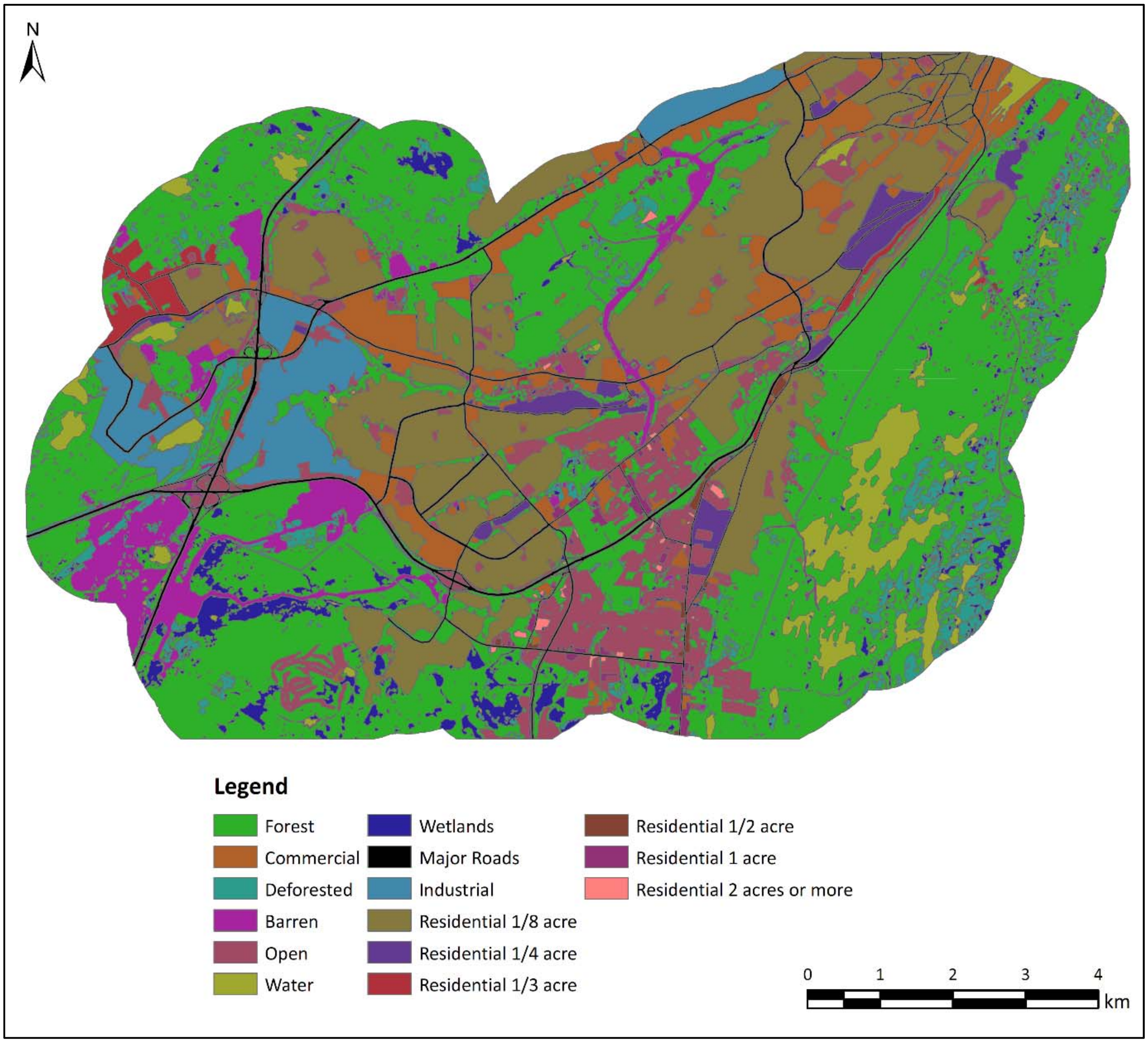
At CBCL’s request, C-CORE included an additional classification called “Road”. This was done to simplify the process of accounting for public roads in areas where both commercial and residential developments exist. C-CORE also added a classification called “Industrial” at CBCL’s request. Appendix G contains C-CORE’s report describing the classification process. The final land classification was presented in raster and shapefile format. Figure 4-4 shows the results of the land classification analysis.

Antecedent runoff conditions (ARC) are used to describe the moisture conditions of soil within the watershed preceding a precipitation event. There are three categories of ARC as described below:

- ARC I – Low moisture
- ARC II – Average moisture
- ARC III – Excessive moisture

ARC III was assumed for the selection of curve numbers for this study.

FIGURE 4-4: LAND CLASSIFICATION ANALYSIS



As mentioned above, curve number selection is also related to soil type. There are four hydrologic soil groups (A, B, C and D), which are characterized by drainage. The United States Department of Agriculture Natural Resources Conservation Services (NRCS) describes the drainage of each soil group as presented in the table below.

TABLE 4-3: HYDROLOGIC SOIL GROUPS DESCRIPTION

Soil Group	Drainage Description
A	Well to excessively drained (high infiltration rates)
B	Moderately well to well drained (moderate infiltration rates)
C	Imperfectly drained (low infiltration rates)
D	Poorly to very poorly drained (very low infiltration rates)

Soil information was obtained from the National Soil Data Base available through Agriculture and Agri-Foods Canada. These soil types were related to the hydrologic soil groups based on drainage. Figure 4-5 illustrates the hydrologic soil groups within the study areas.

FIGURE 4-5: HYDROLOGIC SOIL GROUP

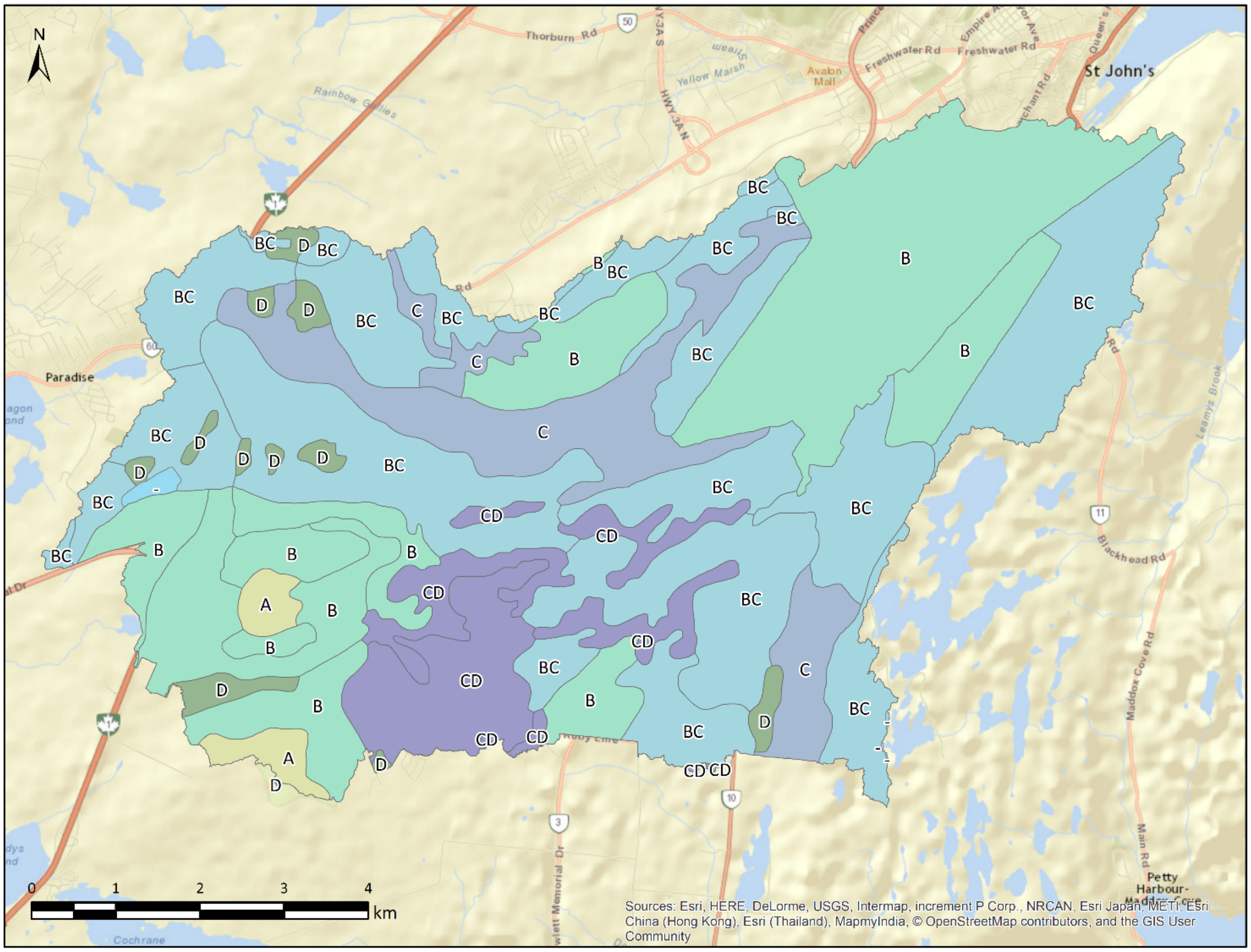


Table 4-4 presents the resulting curve numbers used in the analysis.

TABLE 4-4: CURVE NUMBERS (ARC III)

Land Use Description	Curve Number for Soil Group			
	A	B	C	D
Forest	50	74	85	89
Commercial	96	97	98	98
Deforested	75	87	92	94
Barren	89	94	97	98
Open	59	78	88	91
Water	100	100	100	100
Wetland	100	100	100	100
Major Roads	93	96	97	98
Industrial	92	95	97	98

Land Use Description	Curve Number for Soil Group			
	A	B	C	D
Residential 1/8 Acre	89	94	96	97
Residential 1/4 Acre	78	88	94	96
Residential 1/3 Acre	75	86	92	94
Residential 1/2 Acre	73	85	91	94
Residential 1 Acre	70	84	91	93
Residential 2 Acres or More	66	82	89	92

4.3.1.3 Transform Method

The amount of surface runoff from excess precipitation is calculated using a transform method specified for each subbasin within the model. The SCS unit hydrograph transform method was selected for this study. This method was developed from a large number of recorded observations of rainfall and runoff on small watersheds. It assumes the watershed hydrograph is a single peaked hydrograph. The SCS unit hydrograph method was selected since the study basin is a relatively small area, and the characteristics of the basin and past flood events suggest the river experiences a single peak during a single event.

The SCS unit hydrograph method uses lag time, which is calculated by HEC-GeoHMS using the following equation.

$$T_{lag} = \frac{L^{0.8} * (S+1)^{0.7}}{(735 * Y^{0.5})}$$

Where L = maximum travel length from the most remote part of the basin (m)
Y = average slope of the drainage basin (%)

And

$$S = \left(\frac{1000}{CN} - 10\right)$$

Where CN = Curve Number (described above)

4.3.1.4 Routing Method

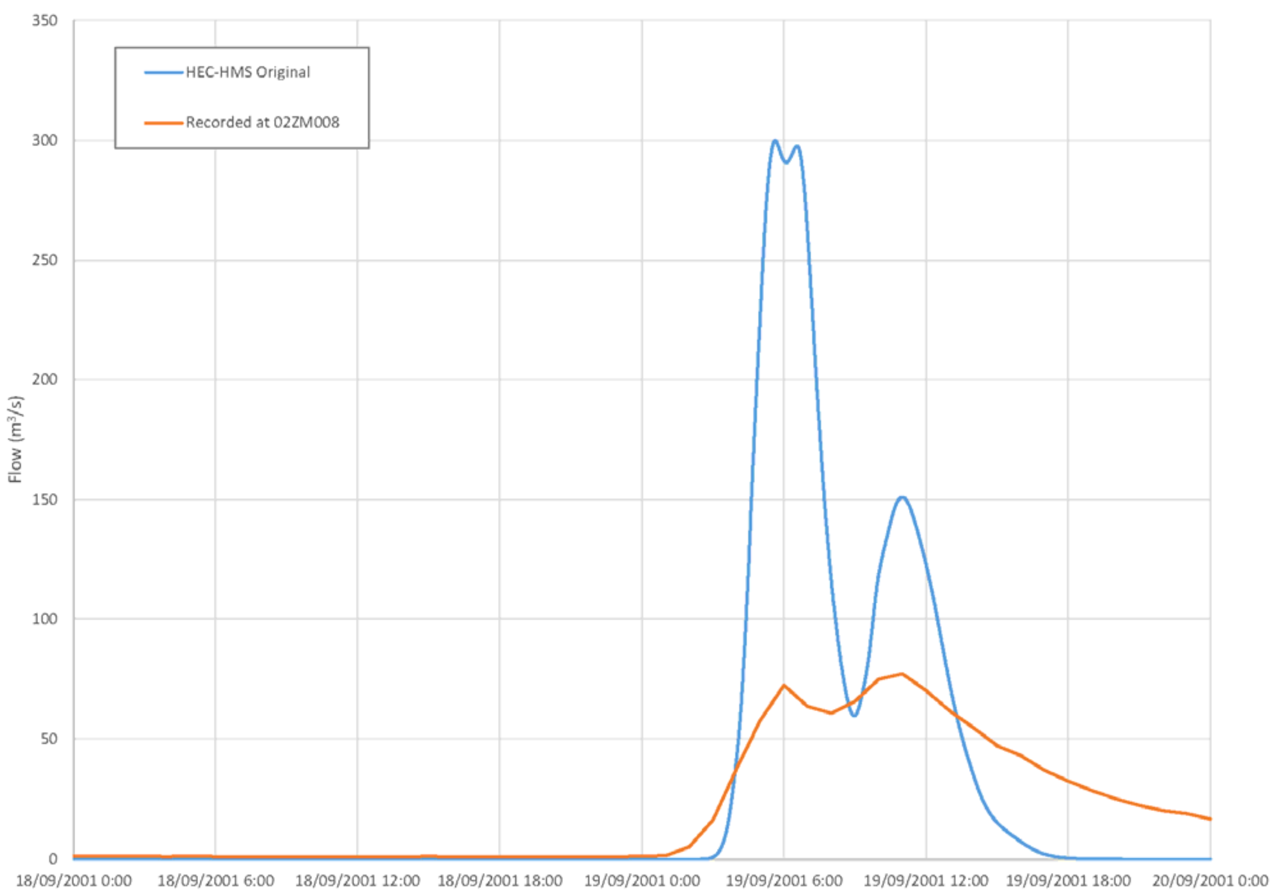
Reach elements are used in HEC-HMS to represent streams, which connect upstream subbasins to downstream subbasins. This channel flow is modeled by selecting one of several routing methods. For this study, the Muskingum-Cunge method was selected. Parameters required for the Muskingum-Cunge method include the channel length, slope, roughness and cross sectional shape. The length and slope of each reach were extracted by HEC-GeoHMS from the pre-processed terrain data. This method allows actual surveyed river sections to be modeled. For reaches that were not surveyed, trapezoidal shapes were approximated based on detailed contours and photographs. Manning's roughness values for the channel and banks were determined from site photos.

4.3.2 Calibration

Calibration of a HEC-HMS model is achieved by simulating a recorded precipitation event and comparing the output hydrograph with measured flows.

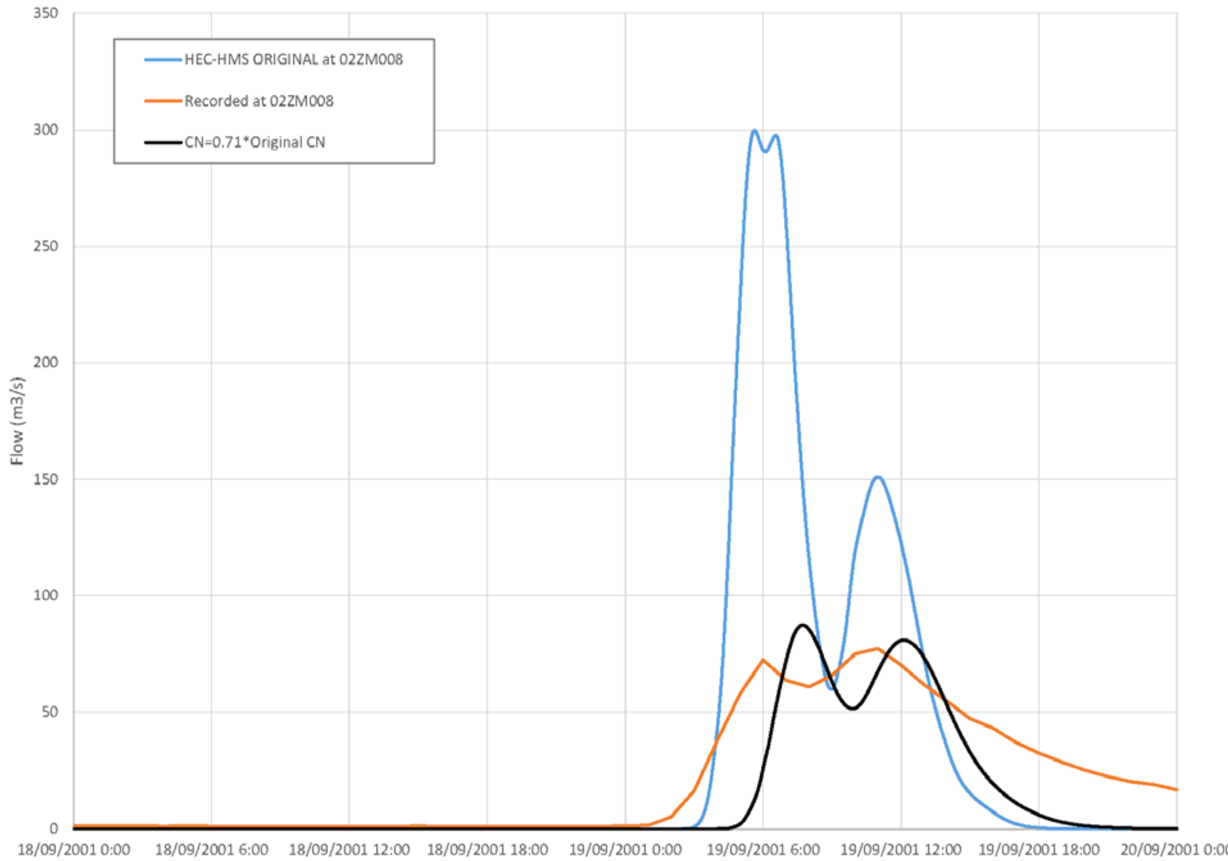
The Waterford River at Kilbride gauge (02ZM008) was used to calibrate the HEC-HMS model. Rainfall data recorded at the Ruby Line rain gauge during Hurricane Gabrielle (September 2001) in 5 minute increments was obtained from the City of St. John's. Hourly flow data recorded at the 02ZM008 gauge was obtained from EC for the same time period. The rain data was simulated in the HEC-HMS model and the model results were compared to the recorded flow data by plotting both hydrographs on the same graph (Figure 4-6).

Figure 4-6: Calibration to Hurricane Gabrielle at O2ZM008



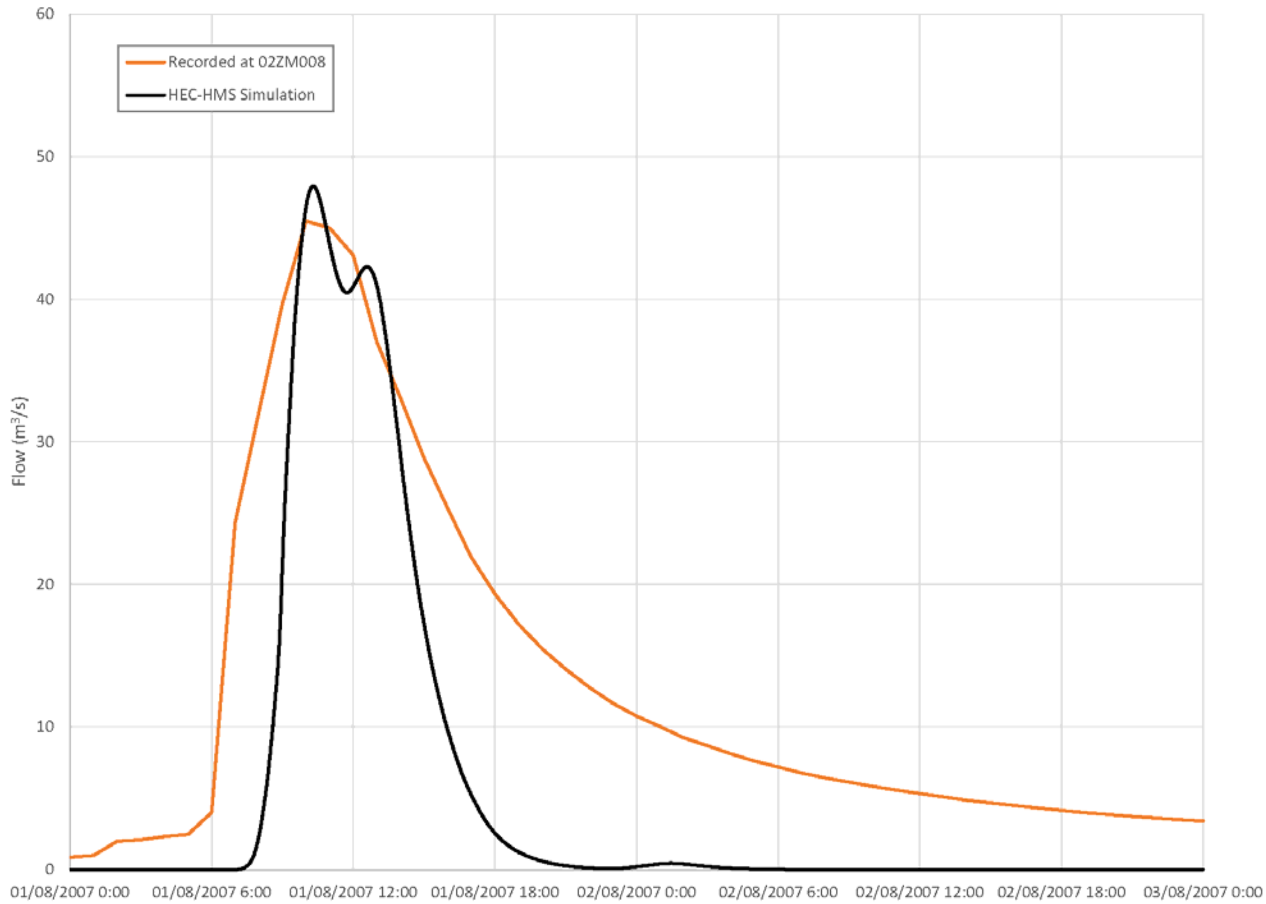
The comparison illustrated that the peak flows simulated by HEC-HMS were higher than the observed gauge flows but the modeled limbs of the hydrograph were much lower than was recorded. Attempts were made to increase the modeled hydrograph limbs by applying a baseflow in the model and running the preceding and following days. However, these efforts did not have a significant impact on the rising and falling hydrograph limbs. The runoff curve numbers were adjusted in an effort to decrease the peak of the model hydrograph to correspond with the recorded peak flow. A decrease of approximately 29% in the subbasin curve numbers, and correspondingly the subbasin lag times, resulted in a simulated peak flow that closely matches the measured peak, as illustrated in Figure 4-7. Since the main objective of the hydrologic models is to determine peak flows for the 1:20 and 1:100 AEP it was decided that by matching the peaks of the simulated and recorded hydrographs the model was considered calibrated.

FIGURE 4-7: CALIBRATION TO HURRICANE GABRIELLE AT 02ZM008 (WITH SIMULATED HYDROGRAPH)



A second rain event was also modeled to assess the calibrated HEC-HMS model. The rainfall data for August 2007 (tropical storm Chantal) was obtained from the City of St. John's Ruby Line rain gauge. EC provided the hourly flow data for 02ZM008 during the event. The rain data was simulated in the calibrated model and the resulting hydrograph was compared to the observed flow at gauge 02ZM008. As illustrated in Figure 4-8 the simulated peak flow is very similar to the observed, indicating the model is well calibrated.

FIGURE 4-8: CHECK OF CALIBRATION TO TROPICAL STORM CHANTAL



4.3.3 Rainfall Input

HEC-HMS requires a rainfall hyetograph (time-series precipitation data) as input to simulate the rainfall to runoff process. Hyetographs representing the 1:20 and 1:100 AEP precipitation amounts, as determined from the IDF update, were entered in HEC-HMS to estimate the corresponding 1:20 and 1:100 AEP flood flows.

The alternating block method was used to estimate a synthetic hyetograph shape. This method incorporates the precipitation for various durations for a particular return period rainfall event into a single hyetograph. The maximum incremental precipitation is placed at the centre of the storm and the remaining incremental precipitation values are arranged in descending order alternating right and left of the centre. The hyetographs created for the 1:20 and 1:100 AEP return periods include the precipitation amounts for the 15 and 30-minute, and 1, 2, 6, 12 and 24-hour duration. Figures 4-9 and 4-10 illustrate the 1:20 and 1:100 AEP hyetographs.

FIGURE 4-9: 1:100 AEP HYETOGRAPH

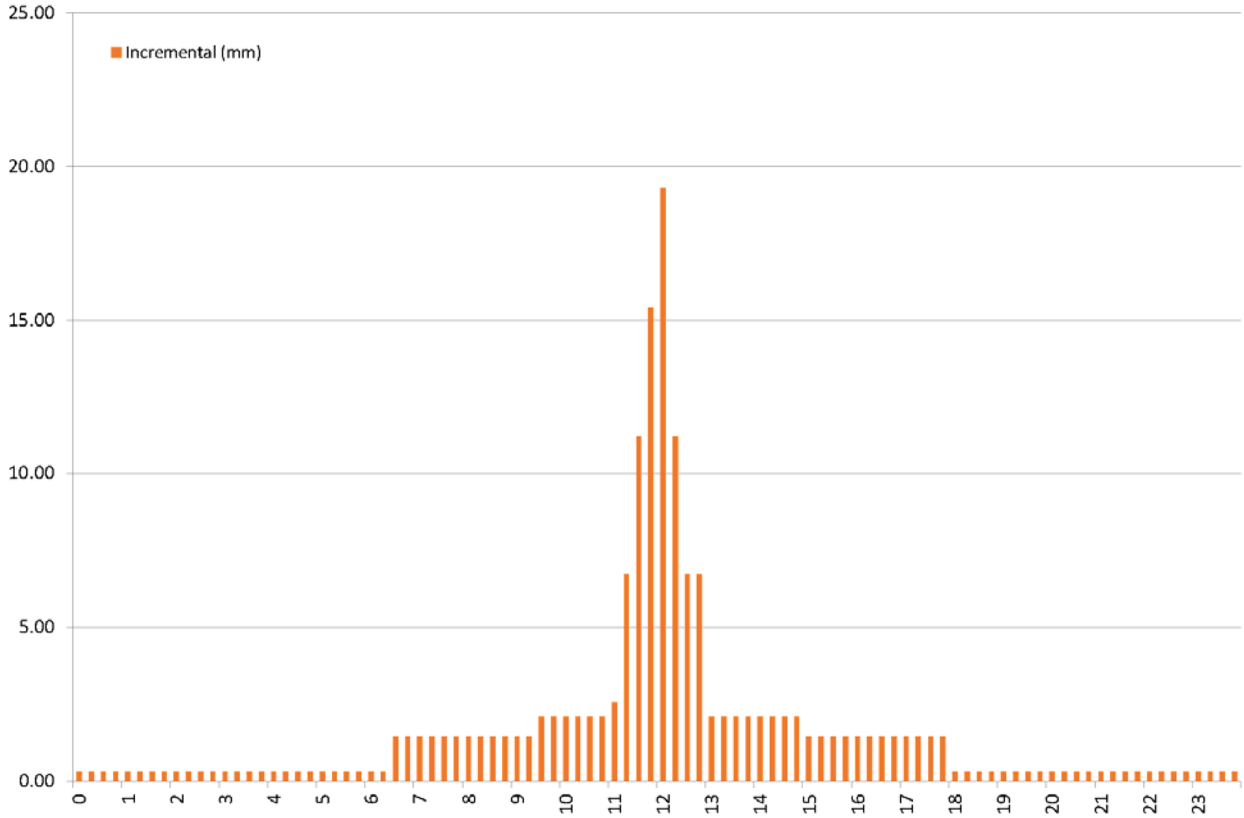
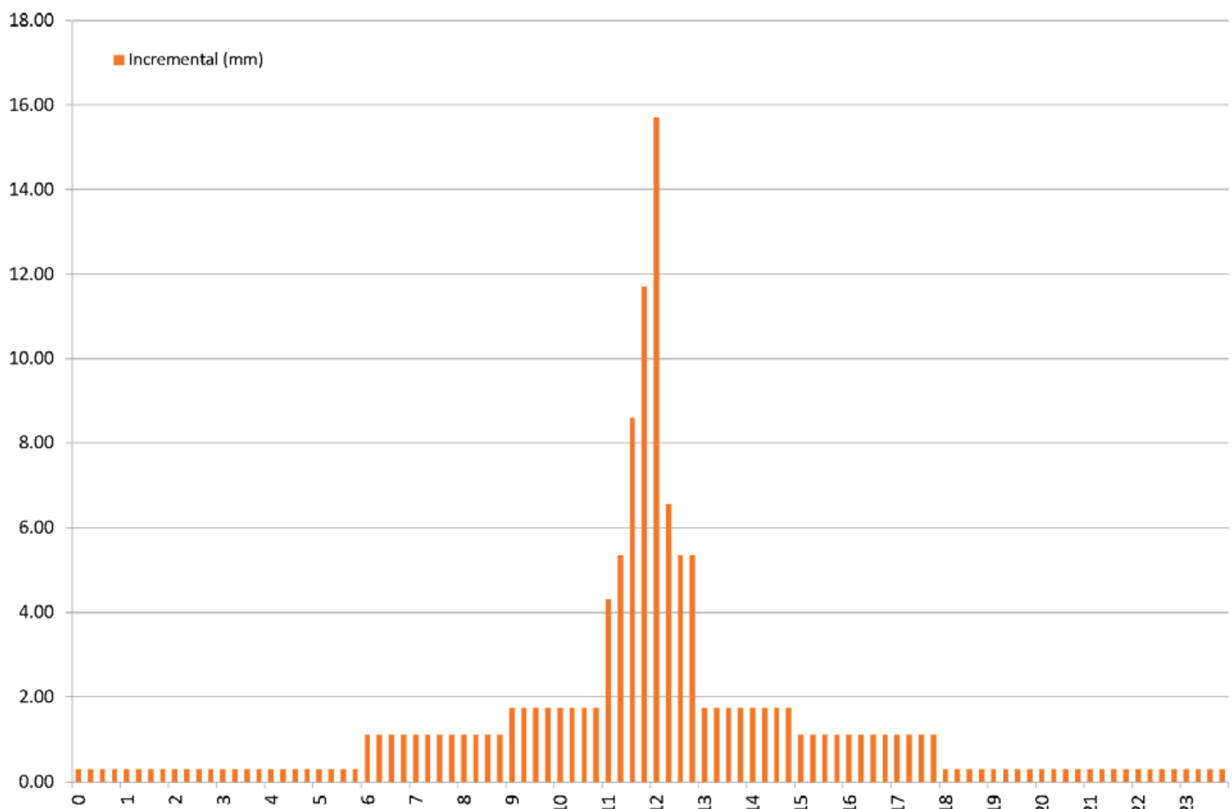


FIGURE 4-10: 1:20 AEP HYETOGRAPH



4.3.4 Effects of Planned Development

One of the main benefits of estimating flood flows using a deterministic method is that site-specific watershed characteristics are used to predict flood flows. Therefore, planned changes within the basin can also be simulated to determine the impacts those changes may have on flood flows. For example, an area of planned development can be modeled in HEC-HMS by altering the curve number (and consequently lag time) for that area, and the pre- and post-development flows can be compared. This process has been used in recent flood risk mapping studies completed for WRMD.

When modeling fully developed conditions for this study, the stormwater detention policies enforced by the three municipalities contributing to runoff in the drainage basin must be considered.

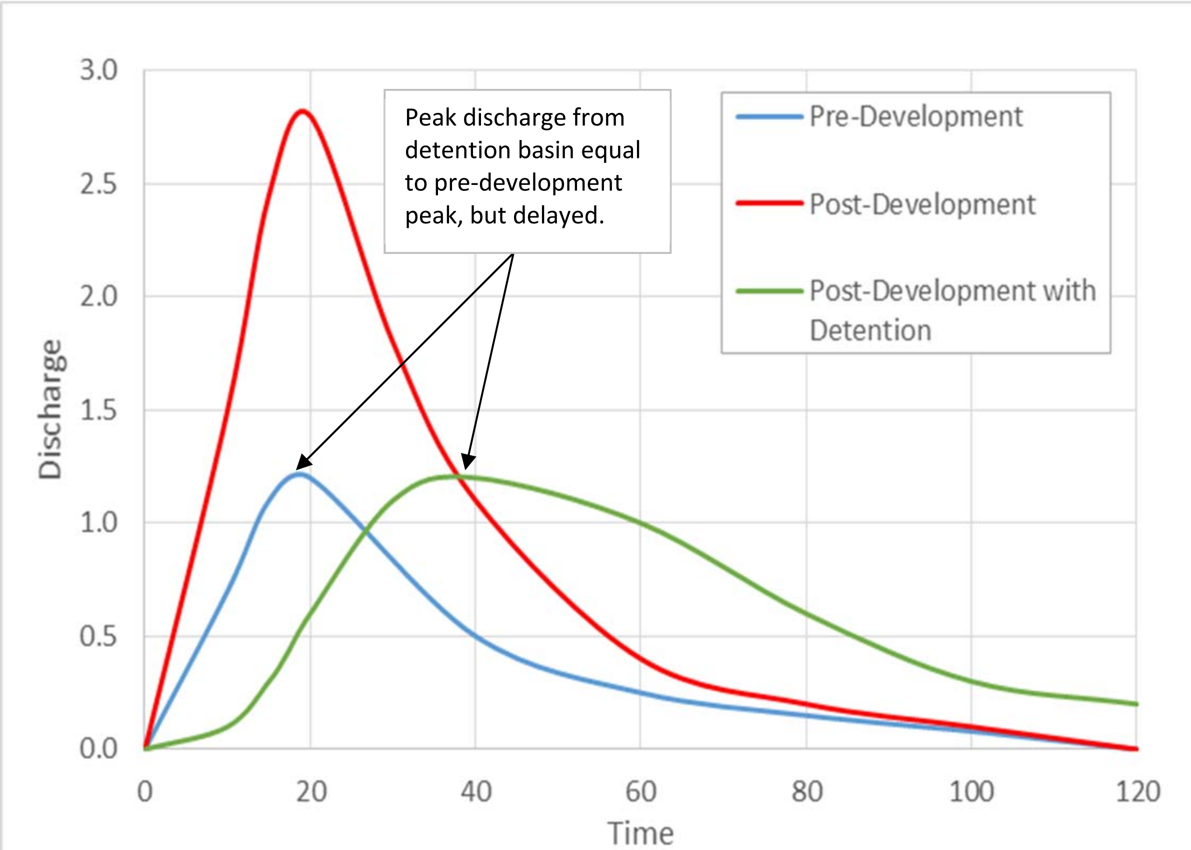
The Cities of Mount Pearl and St. John's have stormwater detention policies, whereas the Town of Paradise currently does not. The Town of Paradise is currently conducting a stormwater management plan; one of the requirements of the request for proposals (RFP) was to investigate, and comment on, the need for a stormwater detention policy.

There are many differences between the detention policies for Mount Pearl and St. John's. Mount Pearl requires the 1:100 AEP event be released at the pre-development rate, for the storm duration, which results in the largest storage volume, from the time of concentration up to the 12-hour storm. St. John's requires that the post-development runoff for each of the 1:25, 1:50 and 1:100 AEP events for the 1, 2, 6, 12 and 24 hour durations be limited to the pre-development rates. There are also differences in the IDFs referenced in the two policies. Mount Pearl indicates that the rainfall intensity be obtained from the most up-to-date data available from EC for the St. John's area; it does not specify if the Ruby Line or St. John's Airport/Windsor Lake IDF is to be used. St. John's provides the hyetographs in its detention policy, which are based on the upper 95% confidence limit of its own IDF update, which used data from the St. John's Airport and Windsor Lake gauges up to and including 2001.

It is noteworthy that the three municipalities, along with the Rotary Club of Waterford Valley, commenced the Waterford River Watershed Study in October 2016. Some of the objectives of the study are to examine stormwater management technologies and to present specific watershed management policies for the Waterford River basin with the intent that the three municipalities adopt one common management policy for the basin.

Future developments within Mount Pearl and St. John's will have detention basins. The outlet hydrograph from a detention basin is such that the peak post-development flow is "flattened" to match the peak pre-development flow and, therefore, is delayed and stretched over a longer time period compared to the pre-development hydrograph (an illustration of this is presented in Figure 4-11). The delayed hydrograph peak may in fact increase the peak of the downstream subbasin(s) if the timing of the delayed peak coincides with the downstream subbasin peak. Therefore, keeping the curve numbers of future developable land the same as the current CNs is not technically representative of future developed conditions, since the peak of the hydrograph will not be delayed and stretched, as it would be if a detention basin were modeled. Without modeling future developable lands with detention basins, the effect of detention on the main tributaries cannot be simulated. This analysis would require detention basin design for each parcel of land available for development. Such an analysis is outside the scope of this study.

FIGURE 4-11: EXAMPLE OF PRE- AND POST-DEVELOPMENT HYDROGRAPHS



Through consultations with WRMD, it was determined that fully developed conditions for this study should be modeled in the following manner:

- CNs within the boundaries of Paradise and the drainage basin were changed to reflect future land use.
- CNs within Mount Pearl and the boundaries of St. John's and the drainage basin remained the same as current CNs.

The current land classification map, prepared by C-CORE, revealed areas near Bremigens Pond and Neil's Pond Ridge as the remaining undeveloped land within the Town's boundary and the study watershed area. The Paradise Municipal Plan draft report (including future land use map) is currently under review by the Town. CBCL spoke with one of Paradise's Planners who advised of expected changes to the areas of interest in the draft future land use map. The expected land uses for these areas include the following:

- OSR – Open Space Recreation;
- PU – Public Use;
- CG – Commercial General;
- RHD – Residential High Density; and

- PMDC – Planned Mixed Development Commercial (mix of CG and RHD).

The area identified as OSR was assumed to be forested, and was confirmed with the Town Planner. Since there is no way of knowing the portion of PMDC area which will be commercial and the portion that will be residential, it was assumed the entire PMDC area will be commercial. This assumption is conservative, since the curve number for commercial is greater than that for residential.

Areas identified as open space or rural in the draft future land use map are assumed to remain the same as current land classifications.

The curve numbers for these areas were changed in the HEC-HMS model to reflect future development. The 1:20 and 1:100 AEP hyetographs were then simulated in the model. Table 4-5 summarizes the peak flows for the 1:20 and 1:100 AEPs for current and fully developed conditions. Peak flows are given at the location of the hydrometric gauge, 02ZM008 and at the outlet to the St. John's harbour.

TABLE 4-5: 1:20 AND 1:100 AEP FLOW ESTIMATES FOR CURRENT AND FULLY DEVELOPED CONDITIONS

Development	Flow at 02ZM008 (m^3/s)		Flow at Outlet to Harbour (m^3/s)	
	1:20	1:100	1:20	1:100
CC-CD	80.2	118.0	91.6	136.4
CC-FD (Current Climate, Future Development)	84.8	121.8	98.9	144.0

4.4 Climate Change IDF

The CRA IDF study produced estimates of future IDF curves that reflect the anticipated effects of climate change on precipitation amounts. Future IDF curves were projected for the 2011-2040, 2041-2070 and 2071-2100 time horizons. For the current study, the 2071-2100 IDF projections were used to assess the impacts of climate change on flooding. The future IDF curves for the Ruby Line station for the 1:20 and 1:100 AEPs were used to produce synthetic hyetographs using the alternating block method. These hyetographs were simulated in both the current development, and fully developed HEC-HMS models. Table 4-6 contains the peak flows for the 1:20 and 1:100 AEPs for current development and fully developed conditions, for climate change precipitation. Peak flows are given at the location of the hydrometric gauge, 02ZM008 and at the outlet to the St. John's harbour.

TABLE 4-6: 1:20 AND 1:100 AEP FLOWS ESTIMATED USING THE HYDROLOGIC MODEL FOR CLIMATE CHANGE CONDITIONS

Development Condition	Flow at Location of 02ZM008 (m^3/s)		Flow at Location of Outlet (m^3/s)	
	1:20	1:100	1:20	1:100
CLC-CD	107.0	164.1	122.6	192.0
CLC-FD	111.6	167.7	131.2	201.2

A comparison of flood flow estimates for current development conditions for current climate and climate change conditions is included in Table 4-7. It is shown that the flow estimates corresponding to climate change precipitation are between 33 and 41% larger than the flow estimates for current climate conditions.

TABLE 4-7: COMPARISON OF FLOOD FLOW ESTIMATES FOR CURRENT AND CLIMATE CHANGE CONDITIONS FOR CURRENT DEVELOPMENT CONDITIONS

Location	Return Period	CC-CD	CLC-FD	% Flow Increase
02ZM008	1:20	80.2	107.0	33
	1:100	118.0	164.1	39
Outlet	1:20	91.6	122.6	34
	1:100	136.4	192.0	41

CHAPTER 5 HYDRAULIC ANALYSIS

The purpose of the hydraulic analysis is to translate the 1:20 and 1:100 AEP flood flows, estimated during the hydrologic analysis, into a flood zone (water surface level). The resulting water surface elevation has an associated depth and velocity profile for each flood flow and development condition (current and future). The velocity and depth results are both considered in the development of the flood hazard maps based on the Royal Haskoning flood hazard matrix. In summary, the following results are presented on the flood risk maps:

- Water Surface Elevation;
- Depth;
- Flow;
- Velocity, and
- Inundation Boundary.

Hydraulic modeling was carried out using the Hydrologic Engineering Center's River Analysis System (HEC-RAS) and its geospatial modelling extension (HEC-GeoRAS). HEC-RAS provides open channel solutions for one- and two-dimensional steady and unsteady flow hydraulics.

5.1 Hydraulic Modeling Technique

The RFP suggests that HEC-RAS 5.0 2D function be considered for producing the flood velocity profiles. The use of a 2D model (or a combined 1D-2D model) in HEC-RAS requires running an unsteady flow simulation. A 1D model can be run for both steady and unsteady flows. Hence, when selecting an appropriate model technique, we must consider two modeling options: 1D vs. 2D, and steady vs. unsteady flow. The following paragraphs describe the selection of an appropriate hydraulic modeling technique for this study.

5.1.1 1D vs. 2D Modeling

The *HEC-RAS River Analysis System 2D Modeling User's Manual* Version 5.0, February 2016, Chapter 6: Steady vs. Unsteady Flow and 1D vs. 2D Modeling was used in the selection of a suitable hydraulic modeling technique. This reference notes that 2D modeling may give better results than 1D modeling for the following situations:

- A levee or dam breach;
- Bays and estuaries;

- Highly braided rivers;
- Alluvial fans;
- Modeling flow around abrupt bends;
- Very wide and flat floodplains in which the flow in the overbanks travels in multiple directions, and
- When detailed velocities around an object are required (ie. bridge piers).

None of these scenarios apply to the current study.

The above-noted reference also lists situations where 1D models produce results that are as good as, or better than, 2D modeling, including:

- Rivers and floodplains in which the main flow path is in the direction of the river flow path;
- Steep streams that are highly driven by gravity;
- Systems that contain many structures (i.e. bridges, culverts, weirs, dams, etc.) that affect the flow and stage in the river. Bridges cannot currently be modeled in the 2D domain using the HEC-RAS bridge modeller;
- Larger systems (100+ miles), where the run time is long, as there are computational time limits for the 2D model; and
- Areas where there is a lack of detailed terrain data.

The first three items listed above apply to the current study.

5.1.2 Steady vs. Unsteady State Modeling

In comparing steady and unsteady flow, the above-noted reference suggests that unsteady flow should be used in the following instances:

- Where there is tidal influence for the area of interest;
- When the event is very dynamic with respect to time;
- If flow reversal occurs;
- Dynamic events (ie. dam breaks), and
- Flat systems, where gravity may not be the driving force of flow.

Although there is tidal influence, it is only a relatively short portion of the lower reach of the river that will be affected by the tide. The above list suggests that there is no additional benefit of preforming an unsteady flow simulation for the current study.

In addition, the peak flows to be modeled have been produced by a well-calibrated hydrologic model (which are also comparable to the peak flows determined by statistical analysis of the long term flow gauge). Therefore, there is confidence in the peak flows simulated in the hydraulic model.

With respect to the simulation of velocity, steady flow analysis in HEC-RAS can be used to compute the flow (and hence velocity) in the overbanks and channel by dividing the section into a number of subsections (up to 45 subsections). Therefore, a detailed distribution of velocity can be visualized across each section.

Since the floodplain along the Waterford River and its tributaries is generally not flat (as evident from the topography and previous studies), the flow and velocity in the floodplain is expected to follow the path of the main river; it is not expected to spread out in multiple directions. Therefore, the potential benefit of modeling the floodplain in 2D will likely not be realized.

Based on the preceding discussion, and through consultation with WRMD, it was concluded that a 1D steady flow analysis of the Waterford River and its tributaries is appropriate.

5.1.3 1D Steady Flow Modeling

The basic steady flow computational procedure follows the solution of a one-dimensional energy equation through an iterative procedure (standard step method). Energy losses attributed to channel roughness are estimated by Manning's equation and contraction and expansion losses are estimated as a function of the rate of change in velocity head. HEC-RAS computations account for energy losses associated with common channel obstructions (ie. bridges, culverts, and weirs) and facilitates horizontal and vertical variations in channel roughness at each river cross section. HEC-GeoRAS facilitates efficient model construction as well as floodplain mapping, through GIS.

5.2 Model Development

HEC-RAS model development requires the following geometry elements:

- Stream Centerlines – Digitized polyline representing the river reach network
- Cross Section – Locations where the model computes results across the river section
- Bank Lines – Represent the right and left bank lines across each cross section
- Junctions – Mark confluence, start and stop points on the river

These model geometry elements make up the HDF5 file format that is displayed in RAS Mapper. The development of these elements is discussed below.

5.2.1 River Reaches

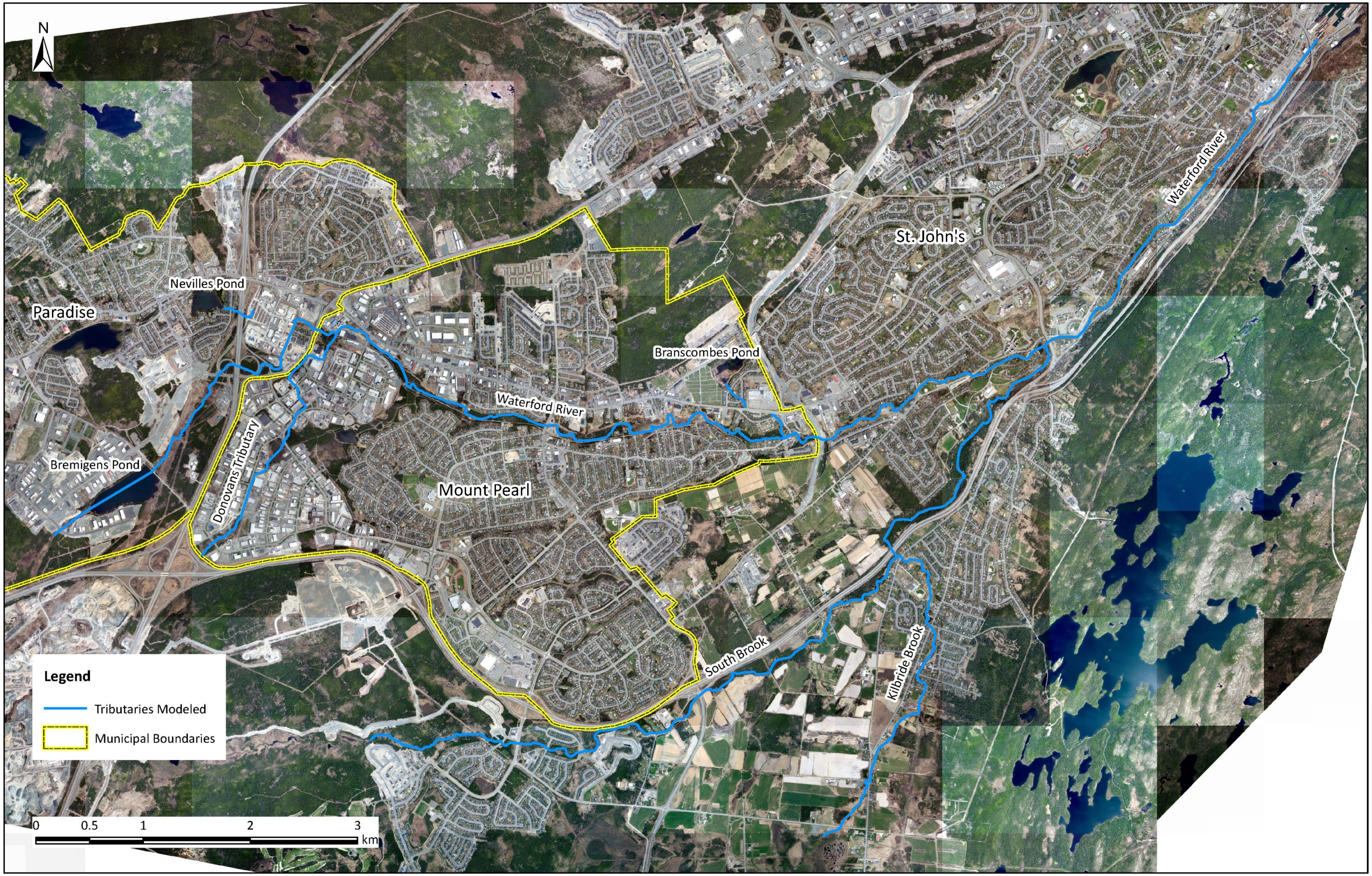
The major tributary to the Waterford River is South Brook; it accounts for approximately 33% of the total Waterford River basin area. South Brook joins the Waterford River at the confluence just downstream of the Bowring Park duck pond. Environment Canada operates the hydrometric gauge, 02ZM008, slightly downstream of this confluence.

In addition to South Brook, there are several other smaller tributaries that empty into the Waterford River. CBCL consulted with staff at Paradise, Mount Pearl and St. John's, as well as WRMD, to develop a list of tributaries for which flood risk maps are produced. These tributaries include the following:

- Waterford River;
- South Brook;
- Tributary from Nevilles Pond (also known as Brazils Pond) to Waterford River;
- Donovans Tributary;
- Tributary from Branscombe's Pond to Waterford River; and
- Kilbride Brook.

These tributaries are identified on Figure 5-1. Branscombe's Pond tributary is shown as a broken line, because the stream enters the storm sewer system at the intersection of Topsail Road and the west entrance to Mount Pearl Square and exists at the south side of Topsail Road, between Dunns Road and Greenwood Crescent. HEC-RAS is an open channel flow model, and although it has the ability to simulate flow through culverts and bridges, it is not capable of modeling flow through piped networks. Therefore, the section of piped storm sewer is not included in the hydraulic model. The Nevilles Pond tributary is also shown as a broken line through St. Anne's Industrial Park. However, from field visits, it appears that the stream is carried through one continuous culvert spanning the industrial park; therefore, the entire reach is modeled in HEC-RAS for the Nevilles Pond tributary.

FIGURE 5-1: TRIBUTARIES MODELED



5.2.2 Cross Sections and Structures

Hydraulic calculations are performed at cross sections and hydraulic structures. The geometry of the cross section (river section) is based on station-elevation data. Manning's roughness coefficients are then set for the left overbank, main channel, and right overbank. A field survey program was completed across the river system and is discussed in great detail in Chapter 3. Each surveyed cross section includes channel elevations below the water level. This elevation data was combined with the LiDAR data in HEC-GeoRAS to assemble cross section "cut-lines" for import into HEC-RAS.

Additional data was required to effectively model the hydraulic structures (bridge, weir, and culvert). Structures are identified based on their bounding cross sections. Table 5-1 below summarizes the surveyed cross sections and structures in each river reach.

TABLE 5-1: SUMMARY OF FIELD SURVEY

Reach	# of Cross Sections Surveyed	# of Hydraulic Structures Surveyed
Waterford River	180	35
South Brook	72	17
Nevilles Pond Tributary	17	4
Donovans Tributary	70	17
Branscombe's Pond Tributary	13 (+18 upstream of storm sewer)	2 (+4 upstream of storm sewer)
Kilbride Brook	63	14
Total	**433**	**93**

Interpolated cross sections are required when the change in velocity head between the surveyed cross sections is too large and triggers a computational error warning. Cross sections can be sampled from the LiDAR data in HEC-GeoRAS to assemble cross section cut lines for import to the HEC-RAS model. In total, there are 433 surveyed cross sections and 664 interpolated cross sections in the current model geometry.

Each surveyed cross section includes channel elevations below the water level as well as elevation points in the channel overbanks. Interpolated cross sections are averages below the water surface between two surveyed cross sections. The digital terrain model values (LiDAR data) are assigned to the overbanks at 1m spacing and therefore the only true interpolated data is beneath the water surface.

Table 5-2 lists all of these surveyed hydraulic structures with a description of each. Hydraulic structure data sheets, including photos and a description of each structure, are provided in Appendix D.

Table 5-2: Hydraulic Structures Located on Main River Reaches

Reach	Structure ID/ Hydraulic Structure Data Sheet	Description
Waterford River	3-4	Pedestrian Bridge Near Newdock/Southside Road
	6-7	Waterford River Walk T'Railway Pedestrian Bridge
	12-13	Blackhead Road Bridge
	19-20	Symes Bridge Road Bridge
	30-31	Waterford Lane Bridge
	37-38	Bay Bulls Road Bridge
	42-43	Columbus Drive Bridge
	271-272	Bowring Park Duck Pond Pedestrian Bridge (x2), Spillway and Fish Ladder
	132_B-133	Bowring Park Duck Pond Pedestrian Bridge
	136-137	Bowring Park Pedestrian Bridge
	141-142	Bowring Park Pedestrian Bridge
	145-146	Bowring Park Pedestrian Bridge Near Waterford Bridge Road and Cowan Ave. Intersection
	150-151	Waterford Bridge Road Bridge
	158-159	Brookfield Road Bridge
	170-171	Team Gushue Highway Extension Culvert
	176-177	Dunn's Road Bridge
	182-183	T'Railway Pedestrian Bridge Near Avery Place
	187-188	T'Railway Pedestrian Bridge Near Valleyview Ave.
	192-193	T'Railway Pedestrian Bridge Near Valleyview Ave.
	198-199	T'Railway Pedestrian Bridge Near Forest Ave.
	205-206	T'Railway Pedestrian Bridge Near Forsey Place
	212-213	Commonwealth Ave. Bridge
	217-218	T'Railway Pedestrian Bridge Near Roosevelt Ave.
	225-226	Corisande Drive Culvert
	228_B-229_A	T'Railway Culvert Near Country Ribbon
	231-232	T'Railway Bridge Near Kenmount Road
	235-236	Kenmount Road Culvert
	237-238	T'Railway Bridge Near Wynnford Dr.
	237-238	T'Railway Culvert Near Wynnford Dr.
	243-244	Highway Maintenance Depot Culverts
	247-248	On Ramp to Outer Ring Road East from Kenmount Road Culvert
	251-252	Outer Ring Road Off Ramp to Kenmount Road Culvert
	255-256	Outer Ring Road Culvert
	259-260	On Ramp to Outer Ring Road West from Kenmount Road Culvert
	261-262	Kenmount Road Culvert

Reach	Structure ID/ Hydraulic Structure Data Sheet	Description
	265_C-266	Bremigens Pond Earth Dam and Concrete Spillway
	268-269	Bremigens Blvd. Culvert
South Brook	47-48	Bowring Park Railway Bridge
	51-52	South Brook Trail Culvert
	58-59	South Brook Trail near Beacon Hill Cres. Bridge
	63-64	Pitts Memorial Dr. East Bridge
	65-66	Pitts Memorial Dr. West Bridge
	76-77	Pearltown Road Bridge
	83-84	Robert E. Howlett Memorial Dr. Culvert
	84_A-84_B	Concrete Weir
	88-89	No. 78 Heavy Tree Road Private Driveway Bridge
	92-93	Heavy Tree Road Culvert
	96-97	No. 59 Heavy Tree Road Private Driveway Bridge
	100-101	No. 55 Heavy Tree Road Private Driveway Bridge
	106-107	Green Acre Dr. Culvert
	111-112	Sprucedale Dr. Culvert
	116-117	Southlands Blvd. Culvert
	119-120	Pedestrian Bridge Near Great Southern Dr.
	123-124	Pedestrian Bridge Near Treetop Dr.
	126-127	Treetop Dr. Culvert
Nevilles Pond Tributary	NP2-NP3	St. Anne's Cres. Culvert
	NP7-NP8	Private Drive Culverts Near Outer Ring Road West
	NP10-NP11	Outer Ring Road Culvert
	NP14-NP15	Hollyberry Dr. Culvert
Donovans Tributary	UR2-UR3	T'Railway Bridge Near Kenmount Road
	UR4-UR5	Walkway Bridge
	UR10_A-UR10_B	No. 3 Glencoe Dr. Parking Lot Culvert
	UR11_A-UR11_B	No. 3 Glencoe Dr. Parking Lot Culvert
	UR14-UR15	No. 3 Glencoe Dr. Culvert
	UR20-UR21	No. 26 Glencoe Dr. Culvert
	UR23_B-UR23_C	Donovans Tributary Culvert
	UR26-UR27	Intersection Of Bruce St. and Clyde Ave. Culvert
	UR29-UR30	No. 65 Clyde Ave. Driveway Culvert
	UR33-UR34	Sagona Ave. Culvert
	UR36_B-UR36_C	Rear Of No. 103 Clyde Ave. Culvert
	UR39-UR40	No. 117 Clyde Ave. Driveway Culvert
	UR43-UR44	No. 119 Clyde Ave. Driveway Culvert
	UR47-UR48	No. 119 Clyde Ave. Driveway Culvert
	UR50-UR51	No. 127 Clyde Ave. Driveway Culvert
	UR52.5_B-UR52.5_C	No. 46 Dundee Ave. Driveway Culvert

Reach	Structure ID/ Hydraulic Structure Data Sheet	Description
	UR59-UR60	Glencoe Dr. Culvert
Branscombe's Pond Tributary	BP2-BP3	Pedestrian Bridge Near Dunn's Road
	BP6-BP7	Pedestrian Bridge Near Greenwood Cres.
	BP14-BP15	Harlequin Cres. Culvert
	BP18-BP19	Goldeneye Pl Playground Pedestrian Bridge
	BP22-BP23	Goldeneye Pl. Culvert
	BP26-BP27	Branscombe's Pond Walking Trail Pedestrian Bridge
Kilbride Brook	68-69	Old Bay Bulls Road Bridge
	KB4-KB5	Bay Bulls Road Near Griffin's Lane Bridge
	KB8-KB9	Pedestrian Bridge Near Cape Pine St.
	KB13-KB14	Connollys Lane Bridge
	KB18-KB19	Valleyview Road Bridge
	KB23-KB24	No. 307 Bay Bulls Road Driveway Culvert
	KB28-KB29	No. 355 Bay Bulls Road Driveway Culvert
	KB32-KB33	No. 367 Bay Bulls Road Driveway Culvert
	KB36-KB37	No. 381 Bay Bulls Road Driveway Culvert
	KB40-KB41	No. 381 Bay Bulls Road Driveway Culvert
	KB43-KB44	Bay Bulls Road Culvert
	KB47-KB48	Lundrigan Road Culvert
	KB52-KB53	No. 448 Bay Bulls Road Driveway Culvert
	KB57-KB58	Ruby Line Culvert

5.2.3 Manning's Roughness Coefficient

Energy losses at each cross section are calculated by HEC-RAS using Manning's roughness coefficients (Manning's n) for the channel and overbanks. During the field investigations, photos and notes were taken to aid with selecting appropriate Manning's n values. Literature values for Manning's n for channels and flood plains are listed in Table 5-3[1].

TABLE 5-3: LITERATURE VALUES FOR MANNING'S N

Natural Streams	Minimum	Normal	Maximum
Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.035
Same as above but more stones and weeds	0.030	0.035	0.040
Clean, winding, some pools and shoals	0.033	0.040	0.045
Same as above but some weeds and stones	0.035	0.045	0.050
Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
Very weedy reaches, deep pools, or floodways with heavy stands of timber and underbrush	0.075	0.100	0.150
Floodplains	**Minimum**	**Normal**	**Maximum**
Short grass	0.025	0.030	0.035
Tall grass	0.030	0.035	0.050
Scattered brush, heavy weeds	0.035	0.050	0.070
Light brush and trees, in summer	0.040	0.060	0.080
Medium to dense brush, in summer	0.070	0.100	0.160

5.2.4 Contraction and Expansion Coefficient

Energy losses due to changes between two cross sections are calculated using contraction and expansion coefficients in HEC-RAS. Where there are minor, or gradual, changes between cross sections, typical values of contraction and expansion coefficients are 0.1 and 0.3, respectively. At a bridge or culvert, the change in effective cross section areas is generally abrupt and the contraction and expansion coefficients are 0.3 and 0.5, respectively.

5.2.5 Boundary Conditions

Steady flow analysis requires upstream and downstream boundary conditions to establish starting water levels at each reach end. The starting water levels are used to begin calculations. The normal depth boundary condition was selected for all upstream reach ends. Normal depth is calculated by HEC-RAS based on slope entered by the modeller. The slope entered is approximated as the average slope of the channel at the upstream cross section.

At the mouth of the Waterford River, the water levels are influenced by the ocean. To model the boundary conditions at the mouth of the river, a tide estimate for high high water large tide (HHWLT) was obtained for St. John's from the Canadian Hydrographic Service (CHS) nautical chart 4846: Motion Bay to Cape St. Francis. The HHWLT elevation is 0.7 m (geodetic). For the current climate model scenarios, 0.7 m was added to an approximation of the normal depth in order to establish the boundary condition.

[1] Chow, V.T. 1959. *Open Channel Hydraulics.* McGraw-Hill, New York.

The boundary condition for the climate change model scenarios must also consider sea level rise. *Past and Future Sea-Level Change In Newfoundland and Labrador: Guidelines for Policy and Planning (2010)* was referenced to obtain a storm surge depth of 1.00 m. For the climate change model scenarios, 1.70 m (0.7+1.00) was added to the normal depth estimate to obtain a boundary condition.

During the hydraulic model sensitivity analysis, larger downstream water levels were examined to determine the effects on the Waterford River water surface elevation. This analysis is discussed further in Section 5.4.

5.3 Hydraulic Model Calibration

Calibration of the HEC-RAS model is achieved by simulating a recorded flow value and comparing the output water levels to measured water levels. Although water level data was collected at three locations by CBCL during the duration of the study, captured events were too low to be suitable for model calibration.

The City of St. John's, however, has six water level gauges throughout the Waterford River basin. The City provided a list of dates for which these gauges were active. The earliest gauge data dated back to 2007, however only two gauges were active during that year: Bowring Park Duck Pond (corresponding cross section 133), and Bay Bulls Road near Griffin's Lane (corresponding cross section KB5). Since the hydrologic model was calibrated to tropical storm Chantal (August 2007), it was decided to calibrate the HEC-RAS model to the same event.

The peak flows were extracted from the HEC-HMS model and entered in the HEC-RAS model. The simulated water surface elevations at cross sections 133 and KB5 were compared to the recorded peak elevations for the corresponding storm. Adjustments were made to the Manning's n values to match the simulated water levels to the measured water levels within an acceptable tolerance. All adjustments fall within the limits of the literature values for Manning's n. These calibrated model results are presented in Table 5-4 below.

TABLE 5-4: TROPICAL STORM CHANTAL CALIBRATION DATA

Location	Recorded WS El (m)	Simulated WS El (m)	Calibrated WS El (m)
Bowring Park Duck Pond (x-sect 133)	34.9	35.11	0.21
Bay Bulls Road near Griffin's Lane (x-sect KB5)	101.2	101.25	0.05
Bay Bulls Road near Corpus Christi (x-sect 38)*	32.18	32.24	0.06

* Anecdotal data (see explanation).

Although water level was not recorded at the Bay Bulls Road (near Corpus Christi) gauge during tropical storm Chantal, some anecdotal water levels were compared. To do this, the water level modeled at cross section 38 (location of Bay Bulls Road gauge) for the peak flow simulated (50 m^3/s from calibrated HEC-HMS model) was compared to the water level recorded at Bay Bulls Road gauge during a different event when the flow also reached approximately 50 m^3/s. Since the Bay Bulls Road gauge is relatively close to the Environment Canada hydrometric gauge (approximately 265 m downstream), the flow measured at 02ZM008 was assumed to be the same at cross section 38. The hourly flow data during Hurricane Igor at 02ZM008 was examined to determine the time when the measured flow was close to 50 m^3/s, which occurred between 10:00 (Q=31.2 m^3/s) and 11:00 AM (Q=54.1 m^3/s) on September 21, 2010. Assuming a linear increase in flow during that hour the flow would have been approximately 48.4 m^3/s at 10:45 AM, which is similar to the 50 m^3/s experienced at the Bay Bulls Road gauge during tropical storm Chantal. At 10:45 AM during Hurricane Igor the water surface elevation recorded at the Bay Bulls Road gauge was 32.18 m. This is comparable to the water surface elevation of 32.24 m produced by the HEC-RAS model during Tropical Storm Chantal.

Since the simulated water surface elevations are similar to the measured elevations (maximum difference of 21 cm), no adjustments were made to the HEC-RAS model and it is considered calibrated.

Although most of the water level gauges were in operation during Hurricane Igor (with the exception of the Green Acre Drive gauge), this event was not selected to calibrate the HEC-RAS model. At the onset of the project, the Manager of Development - Engineering with the City of St. John's informed CBCL that the data recorded at Ruby Line rain gauge during Hurricane Igor was likely less than actually observed as a result of high winds blowing rain out of the gauge. Therefore, simulating the rainfall recorded during Hurricane Igor in the calibrated hydrologic model would not produce flows similar to that recorded at 02ZM008.

5.4 Sensitivity Analysis

Hydraulic model sensitivity analyses were conducted on selected model parameters to assess the impact of changing these parameters on model results. The hydrologic parameters selected for sensitivity analysis include curve number and Manning's roughness values. The 1:100 AEP event for the existing development conditions was selected as a benchmark to evaluate the sensitivity of the flow to the variation of each parameter. Sensitivity analysis for the parameters was limited to ± 10%, 20% and 30%. The flow simulated at the location of hydrometric gauge 02ZM008 for each parameter change was used for this comparison. Table 5-6 summarizes the percent change in peak flows.

TABLE 5-6: VARIATIONS IN PEAK FLOW AS A RESULT OF ADJUSTING HYDROLOGIC PARAMETERS

Variation	Curve Number	Manning's n
-30%	-79.2%	+0.3%
-20%	-62.6%	+0.2%
-10%	-36.5%	+0.2%
+10%	+46.2%	-0.2%
+20%	+104.2%	-0.5%
+30%	+173.7%	-1.0%

The results indicate that the hydrologic model is most sensitive to changing the curve number. Decreasing the curve number by 10% decreased peak flow at the location of the hydrometric gauge 02ZM008 by 36.5% (compared to the base case). Reducing the calibrated CNs by 20% and 30% results in CNs that are outside the range of CNs for the current land uses and soil types. The effects of these reductions are included in Figure 5-2 on the following page.

Changing the Manning's n values has little impact on the resulting flows; an increase of 30% in Manning's n decreases the flow by only 1%. Figure 5-3 presents the hydrologic models sensitivity to changing Manning's n.

FIGURE 5-2: CURVE NUMBER SENSITIVITY ANALYSIS

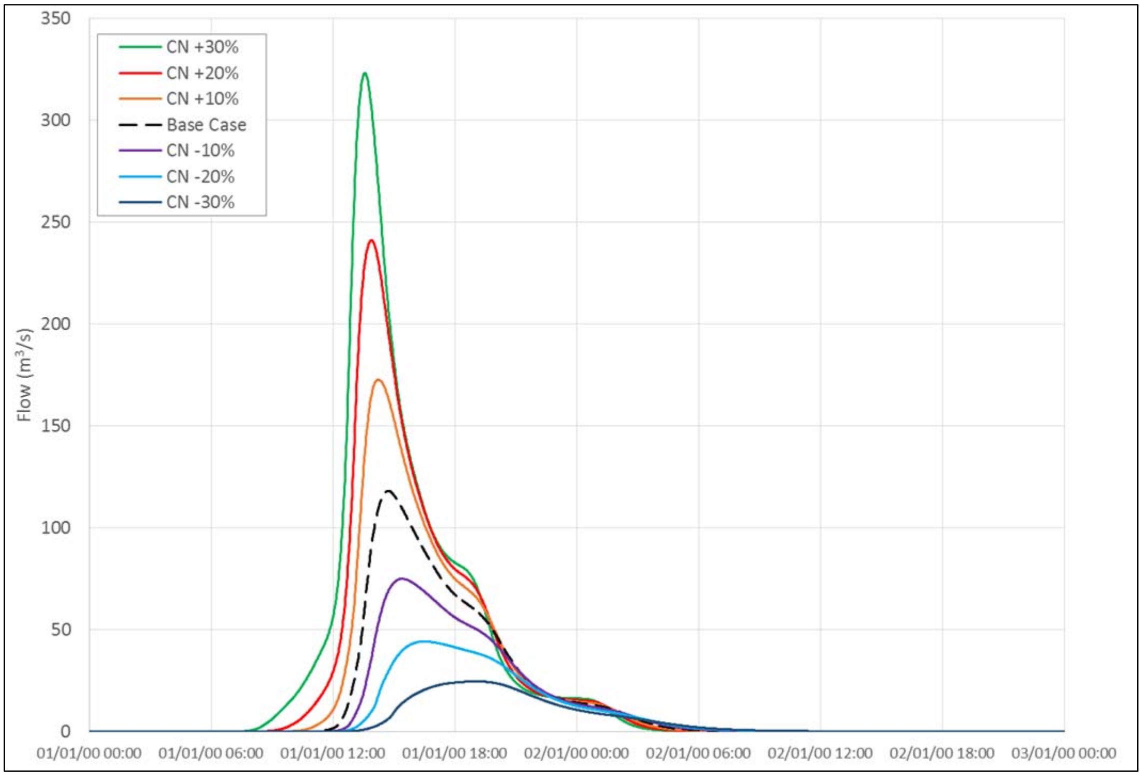
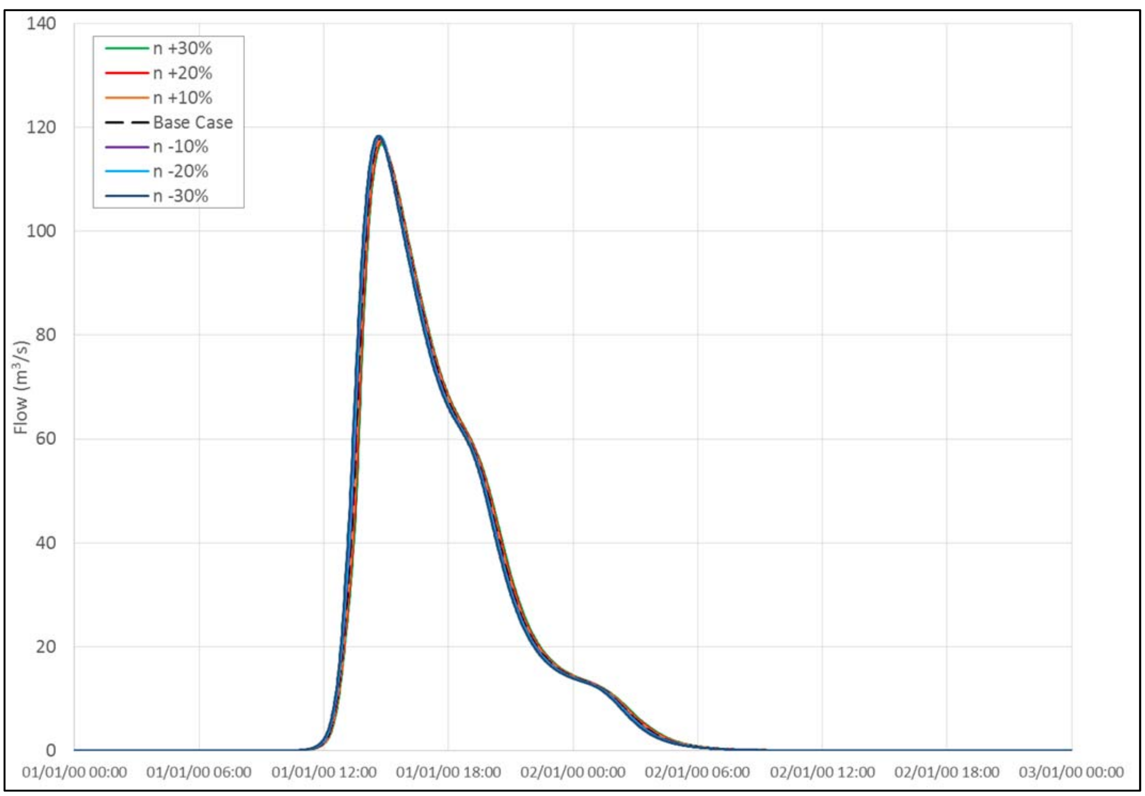


FIGURE 5-3: MANNING'S N SENSITIVITY ANALYSIS



5.5 Simulated Flows

Flood flows for the 1:20 and 1:100 AEP events for current and fully developed conditions were extracted from the HEC-HMS models at various locations along each river reach. A summary of the simulated flow scenarios assessed are described below:

- Current Climate Condition – reflects most recent weather data available for the study area.
- Climate Change Condition – includes both a precipitation increase (climate change IDF) as well as sea level rise predictions.
- Current Development Condition - reflects the existing land cover for the study area.
- Fully Developed Condition – reflects future development predictions within the watershed.

As discussed in Section 4.3.4, the effects of future development on storm water runoff are reflective of storm water management policies for each of the three municipalities in the watershed. Therefore, fully developed conditions were modeled by adjusting CN (66.58) within the Town of Paradise subbasin.

Flood flows, presented in Table 5-7, were input in the hydraulic model to simulated water surface profiles to be used to create flood risk maps. These flows represent current climate conditions. Table 5-8 presents the 1:20 and 1:100 AEP flows for current and fully developed conditions for projected climate change.

TABLE 5-7: SIMULATED FLOOD FLOWS FOR CURRENT CLIMATE CONDITIONS

River	Flow Change Location (X-Section)	CC-CD		CC-FD	
		1:20 (m^3/s)	1:100 (m^3/s)	1:20 (m^3/s)	1:100 (m^3/s)
Waterford River	270	5.7	8.5	7.3	10.4
	239	16.6	24.2	18.4	26.6
	229_B	29.7	43.4	31.5	45.7
	213	34.4	50.4	36.2	52.7
	179	46	67.4	47.9	69.8
	44	56.2	81.6	57.9	83.8
	36	80.5	118.4	82	120.2
	23	84.3	124	85.8	125.9
	13	88.5	130.5	90.1	132.5
South Brook	131	91.7	136.5	93.2	138.5
	103	7.8	12	7.8	12
	67	12.9	19.4	12.9	19.4
Nevilles Pond	NP17	26.5	39.5	26.5	39.5
Donovans Tributary	UR62	6.6	9.6	6.6	9.6
Branscombe's Pond	BP10	5.6	8.4	5.6	8.4
Kilbride Brook	KB60	4.9	7.4	4.9	7.4

TABLE 5-8: SIMULATED FLOOD FLOWS FOR CLIMATE CHANGE CONDITIONS

River	Flow Change Location (X-Section)	CLC-CD		CLC-FD	
		1:20 (m^3/s)	1:100 (m^3/s)	1:20 (m^3/s)	1:100 (m^3/s)
Waterford River	270	7.7	12	9.6	14.6
	239	22.2	34.3	24.5	37.5
	229_B	39.8	61.2	41.9	64.1
	213	46	71.2	48.3	74.3
	179	61.6	95.1	63.9	98.2
	44	74.6	113.9	76.7	116.7
	36	107.4	164.6	109.2	166.9
	23	112.1	172.3	114	174.8
	13	117.8	181.9	119.8	184.6
South Brook	131	122.7	192.2	124.7	195
	103	10.6	17.1	10.6	17.1
	67	17.2	27.5	17.2	27.5
Nevilles Pond	NP17	35.3	56.2	35.3	56.2
Donovans Tributary	UR62	8.8	13.6	8.8	13.6
Branscombe's Pond	BP10	7.6	12	7.6	12
Kilbride Brook	KB60	6.8	10.8	6.8	10.8

The water levels resulting from these flood flows were used in the creation of the flood risk maps presented in the following section.

5.6 Flood Risk Maps

Flood risk maps were determined for the following combinations of climate and development conditions:

- Existing Scenario: CC-CD; and
- Future Scenario: CLC-FD.

In total, 92 flood risk figures are presented, where the 1:20 and 1:100 AEP were both considered. Each map set includes seven figures at a 1:2500 scale with the following river sections represented:

- Summary Overview Map – entire river system
- Waterford River Section 1 (WR-1): Drawing 1, Top Inset Map
- Waterford River Section 2 (WR-2): Drawing 1, Bottom Inset Map
- South Brook Section 1 (SB-1): Drawing 2, Top Inset Map
- South Brook Section 2 (SB-2): Drawing 2, Bottom Inset Map
- South Brook Section 3 (SB-3): Drawing 3, Top Inset Map
- Kilbride Brook Section (KB-1): Drawing 3, Bottom Inset Map
- Waterford River Section 3 (WR-3): Drawing 4, Top Inset Map
- Waterford River Section 4 (WR-4): Drawing 4, Bottom Inset Map
- Waterford River Section 5 (WR-5): Drawing 5, Top Inset Map
- Nevilles Pond Section (NP-1): Drawing 5, Bottom Inset Map
- Waterford River Section 6 (WR-6): Drawing 6, Top Inset Map

- Donovans Tributary Section (UR-1): Drawing 6, Bottom Inset Map

The following sections summarize the information presented on each map. A complete set of overview maps are presented in Appendix H.

Flood Inundation Mapping

Each flood inundation map set represents the flood plain extents for both the 1:20 and 1:100 AEP events for both existing and future conditions. Surveyed cross sections are labeled with the corresponding water surface elevation (WSE).

- Map Set 1: CC-CD 1:20 AEP and 1:100 AEP Inundation Flood Zone
- Map Set 2: CLC-FD 1:20 AEP and 1:100 AEP Inundation Flood Zone

Flood Velocity Mapping

- Map Set 3: CC-CD 1:20 AEP Velocity Maps
- Map Set 4: CC-CD 1:100 AEP Velocity Maps
- Map Set 5: CLC-FD 1:20 AEP Velocity Maps
- Map Set 6: CLC-FD 1:100 AEP Velocity Maps

Flood Hazard Mapping

- Map Set 7: CC-CD 1:20 AEP Flood Hazard Maps
- Map Set 8: CC-CD 1:100 AEP Flood Hazard Maps
- Map Set 9: CLC-FD 1:20 AEP Flood Hazard Maps
- Map Set 10: CLC-FD 1:100 AEP Flood Hazard Maps

Flood Comparison Mapping

Comparison maps include both a historical and a climate change flood inundation boundary. The climate change comparison presents the change in flood plain association with the:

- Map Set 11: 1:20 AEP CC-CD vs. 1:20 AEP CLC-FD
- Map Set 12: 1:100 AEP CC-CD vs. 1:100 AEP CLC-FD

The historical comparison presents the change in flood plain association with the:

- 1998 1:20 AEP vs. 1:20 AEP for CC-CD
- 1998 1:100 AEP vs. 1:100 AEP for CC-CD

The historical flood inundation boundary was determined by referencing the Waterford River Area - Hydrotechnical Study completed by Fenco in 1988.

Table 5-10 outlines the historical water surface elevation against the current conditions for both the 1:20 and 1:100 AEP events.

TABLE 5-10: COMPARISON OF HISTORICAL AND CURRENT DEVELOPMENT WATER SURFACE ELEVATION (WSE)

Historical Cross Section Station	HEC-RAS Cross Section Station	Historical WSE (m)*		WSE (m)	
		1:20 AEP	1:100 AEP	1:20 AEP	1:100 AEP
510	536.28	2.66	3.14	3.12	3.45
745	726.05	3.55	4.00	3.40	3.81
816	838.99	3.71	4.34	3.86	4.42
857	850.44	4.41	4.93	3.82	4.36
Leslie Street Bridge D	12	4.2	4.7	3.82	4.36
Leslie Street Bridge U	13	4.76	5.27	3.99	4.55
928	965.73	4.82	5.25	3.44	3.80
1050	1085.09	6.78	7.25	6.49	6.77
1555	1568.06	13.29	13.73	12.88	13.28
Symes Bridge D	19	13.34	13.75	13.02	13.30
Symes Bridge U	20	13.64	14.28	13.54	13.89
1590	1596.38	13.81	14.51	13.49	13.91
1895	1847.34	14.16	14.50	14.14	14.55
2088	2086.08	15.23	15.60	15.67	15.96
3837	3742.94	33.24	33.96	33.27	34.07
4100	4171.28	35.07	35.60	35.21	34.56
5425	5443.43	56.56	57.77	56.78	57.16
5895	5870.76	59.88	59.96	59.70	59.88
8232	8225.12	102.73	102.95	103.22	103.61
8988	8993.53	104.39	104.43	103.65	103.75
12233	12224.8	135.15	135.37	135.08	135.58

*Source: Figure 7-1 through 7-7 in Waterford River Area - Hydrotechnical Study (Fenco, 1988)

5.7 Hydraulic Capacity Analysis

An assessment of the capacity of structures during various flow conditions was performed using the hydraulic model. The assessment includes the hydraulic structure (culvert) and not the embankment above the culvert supporting the road or walkway. The hydraulic capacity analysis of existing structures (bridge and culvert) was completed for the following conditions:

- 1:20 AEP CC-CD
- 1:100 AEP CC-CD
- 1:20 AEP for CLC-FD
- 1:100 AEP for CLC-FD

Data presented in HEC-RAS detailed structure output tables are defined as follows:

- **Q Total** (m^3/s) – Total flow in cross section.
- **Min. Chl. Elev.** (m) – Minimum channel elevation.
- **W.S. Elev.** (m) – Calculated water surface from energy equation.

- **Crit. W.S.** (m) – Critical water surface elevation. The critical water surface elevation corresponds to the minimum energy of the energy vs. depth curve.
- **E.G. Elev.** (m) – Energy grade line for given water surface elevation.
- **E.G. Slope** (m/m) – Slope of energy grade line at a cross section.
- **Vel. Chnl.** (m/s) – Average velocity of flow in main channel.
- **Flow Area** (m^2) – Total area of cross section active flow.
- **Top Width** (m) – Top width of the wetted cross section.
- **Froude # Chl.** – Froude number for the main channel.

For culverts specifically, the culvert is flowing full (surcharged) when the hydraulic grade line (HGL) or water surface elevation is above the elevation of the inlet (culvert entrance). Inlet control capacity depends on the geometry of the culvert inlet, where the culvert is said to be inlet controlled if the capacity of the barrel exceeds the capacity of the inlet. If this condition is met, the water surface elevation will equal or exceed the critical depth. Alternatively, the culvert is said to be outlet controlled when the capacity of either the barrel or the outlet is less than the inlet. This condition may be satisfied with excessive tailwater (depth of water measured from structure outlet invert). When the depth of flow at the culvert outlet is equal to the critical depth, the culvert is said to be outlet controlled.

HEC-RAS computes the energy required for the culvert inlet or outlet to be the governing control based on the culvert's unique geometry and characteristics. The higher energy requirement for any given flow scenario can determine the governing control. In situations where the upstream water surface elevation causes pressure flow for the entire length of the culvert barrel (flow does not transition to supercritical flow), the culvert is performing like an orifice. In this circumstance, a full flowing barrel will be governed by outlet control.

Hydraulic computation through a bridge differs from a culvert in some ways. The software has the capacity to run low flow (open channel), high flow (pressure flow), and highly submerged flow (over topped) conditions. In low flow situations, the flow control is determined by the end of the bridge (upstream or downstream cross section) that is most constricted (higher momentum). There are multiple classes of low flow. In high flow situations, where the water surface elevation meets the low chord of the bridge, pressure flow ensues. Orifice flow calculations take over when the bridge opening is flowing completely full or when the upstream side of the bridge is flooding. The program will automatically check for pressure flow and will adjust calculation method where appropriate.

More specific data calculated by HEC-RAS for culvert/bridge performance includes:

- **E.G. US.** (m) – Upstream energy grade elevation at bridge or culvert (specific to that opening, not necessarily the weighted average)
- **W.S. US.** (m) – Upstream water surface elevation upstream of bridge, culvert or weir (specific to that opening, not necessarily the energy weighted average)
- **Min. El. Prs.** (m) – Elevation at the bridge when pressure flow begins
- **BR Open Area** (m^2) – Total area of the entire bridge opening
- **Prs. O W.S.** (m) – Water surface elevation upstream of bridge for pressure only method
- **E.G. IC** (m) – Upstream energy grade line based on inlet control

- **E.G. OC** (m) – Energy grade line based on outlet control
- **Min. El. Weir Flow** (m) – Elevation where weir flow begins
- **Q Cul. Group** (m^3/s) – Flow through all barrels in a culvert
- **Q Weir** (m^3/s) – Flow over the weir
- **Q Total** (m^3/s) – Total flow in cross section
- **Delta W.S.** (m) – Change in water surface through culvert(s) and bridge(s)
- **Culv. Vel. US** (m/s) – Velocity in culvert at defined upstream
- **Culv. Vel. DS** (m/s) – Velocity in culvert at defined downstream
- **BR Sluice Coef.** – Bridge sluice flow coefficient

In the structure tables located in Appendix I, the depth of water overtopping the structure is relative to the minimum elevation of weir flow over the top of the structure. HEC-RAS computes weir flow based on the difference between upstream energy and the road crest (head) as energy takes into consideration approach velocity. In situations where the computed water surface elevation is below the energy grade, a weir calculation may be triggered without an associated flood depth.

The column labeled 'Outlet/Inlet Control' refers to whether or not the culvert is performing under outlet or inlet control for the specific scenario. For bridges listed in the structure tables, this column is left blank, as it is not applicable.

A bridge is considered under pressure when the water surface elevation becomes equal to the lower cord of the bridge. Weir flow is calculated when the bridge deck over tops (floods).

Capacity of the river itself was considered for the CC-CD and CLC-FD conditions. The capacity of the river is considered between the right and left bank lines. Areas of potential concern were assessed based on the extents of the inundation boundary directly upstream of a structure (structure is undersized) as well as in areas where the river is undersized. Refer to Map Set 1 and 2 for the inundation boundary extents at a 1:2500 scale for CC-CD and CLC-FD conditions respectfully.

The following list notes areas of the river, indicated by the structure number, where flooding occurs directly upstream of a culvert or bridge. This observation could be attributed to structures being under capacity, as well as other potential factors. A full capacity assessment of each structure is required to determine if the conditions causing flooding upstream of the structure are strictly attributed to capacity.

The following list notes areas of the river, indicated by appropriate land marks, where flooding occurs above the overbank and onto surrounding property:

- Area surrounding culvert KB28-KB29 (upstream and downstream)
- Bay Bulls Road between culvert KB32-KB33 and culvert KB23-KB24
- Bay Bulls Road between culvert KB23-KB24 and culvert KB18-KB19
- Bay Bulls Road between Connolly's Lane and KB8-KB9
- Residential properties behind Peppertree Place and Mahogany Place
- Waterford River section behind Doyle Street between Culvert 171-170 and Bridge 159-158
- Waterford River section downstream of Bridge 159-158 on Brookfield Road

- Various locations on Waterford River section between Bridge 206-205 and Bridge 193-192
- Section of river between culvert 244-243 and the confluence of Bremigens Pond with Nevilles Pond.
- Section of river between the confluence of Donovans Tributary and Waterford River and culvert 226-225
- Section of river between culvert 226-225 and Bridge 218-217 that overtops the Newfoundland T'Railway access road
- Section of river between UR26-UR27 and UR23B-23C
- Flooding on Waterford Bridge Road between Bridge 43-42 (Columbus Drive) and Bridge 20-19 (Symes Bridge Road)

For comparison purposes, historical flood prone structures were identified in the Fenco 1988 Waterford River Study. Figure 5-4 summarizes the findings.

FIGURE 5-4: FLOOD PRONE STRUCTURES IDENTIFIED ON THE WATERFORD RIVER (FENCO, 1988)

TABLE 7-3

SUMMARY OF FLOOD-PRONE STRUCTURES

Figure	Affected Structures	Comment
7-1	- four in risk area - eleven on fringe	- possible damage to contents of three structures (one a shed)
7-2	- 2 homes in risk area - 8 buildings on fringe	- possible damage to structure and contents of one home
7-3	- 5 buildings and Corpus Christ Church	- in the 1:20 year floodway
	- Bowring Park house	- damage to contents of lower floor during 1:100 year flows
7-4	- 1 commercial/industrial building and several out-buildings	- possibly an abandoned structure
	- flooding of Waterford Bridge Road	- potential traffic hazard
7-5	- 2-3 structures at Forest Avenue	- possible damage during 1:100 year flood. ONe is a garage
7-6	- one structure at Winston Avenue	- possible damage with floods in the 1:20 to 1:100 year range
7-7	- Newfoundland Fibrply	- possible flood damage with flows at, or less than, the 1:20 year case
	- 2 houses near the TCH culvert	- expected flood damage to one house with flows above the 1:20 year level
Total	19 - 20 structures	

CHAPTER 6 FLOOD FORECASTING SERVICE

CBCL evaluated the application of flood forecasting services for communities at risk within the study area. Consideration was given to the development and implementation of Real Time Data Transfer and Emergency Management Systems. Such systems allow emergency management services to receive flood warnings based on monitoring station data as it is recorded, and respond in a timely manner to the warning in the event of a potential flood. The relation between recorded data (tide level, rainfall, temperature) and flooding risks are based on results from the project hydrologic and hydraulic models and/or any other models provided by WRMD.

The Waterford River moves through the downtown area of the City of St. John's, placing private properties at risk of flooding. Predictive flood mapping may therefore have some value in offering additional emergency management officials additional time to prepare for a flood event, and reduce risks to public safety. To assess the value of setting up flood forecasting, it would be necessary to evaluate the following components:

1. The vulnerability of the floodplain stakeholders: high consequential damage from a flood would support the need for such a service. It is expected that since the downtown area of St John's is involved, the consequential damage could be very high.
2. The mechanisms leading to flooding: if the flooding happens fast, then there is little time to prepare once the rainfall occurs, which would also support the need for a forecasting service. A forecasting service would allow emergency services to plan ahead, issue warnings, and reduce risks to public safety. It is believed to be the case here, as the tributary watershed includes a large amount of development.

CBCL would like to note that since this service would be helping with resilience in the face of climate change, it may be suitable for some federal funding programs.

Steps in setting up the service would include:

Step 1 – Selecting the appropriate Numerical Weather Predictions (NWP) to use as model input

The Meteorological Service of Canada (MSC) HTTP data server is a source of several raw meteorological data types and forecast data. This service is aimed at specialized users with good meteorological and IT knowledge, and is mainly meant to be accessed in an automatic manner via the internet (ie. with python scripts). The server's URL is: http://dd.weather.gc.ca/.

A forecast product will need to be carefully selected, in context of its assumptions and limitations for use in predictive flood mapping. Through discussion with the Canadian Meteorological Centre (CMC, division of Environment and Climate Change Canada) staff, CBCL obtained a preliminary confirmation that the product most likely to be best adapted for predictive flood mapping is the High Resolution Deterministic Prediction System (HRDPS). However, there are several other products available, and these will also need be considered (ie., the Regional Deterministic Prediction System, with a 10 km grid cell, or the Regional Ensemble Prediction System, which provides probabilistic predictions), in order to have the most appropriate inputs into the hydrological/hydraulic model. For documentation of different products, documentation is available on the web, for example the Canadian Meteorological Centre products catalogue: http://collaboration.cmc.ec.gc.ca/cmc/cmoi/product_guide/

Step 2 – Setting up a Data Wire to EC's Datamart Service

To facilitate the retrieval of timely data on the Datamart, the MSC has set up a data wire for announcing file availability. This data wire uses the 'Advanced Message Queuing Protocol' (AMQP). All MSC products can be accessed free of charge (with the exception of 30 minute data which must be obtained through the AMQP data wire). Support from the CMC is also available for a cost-recovery monthly fee.

CBCL has previously been in close contact with the CMC to purchase, process, and debug radar measurements.

Step 3 – Creating a Hydrology/Hydraulic Model of the Waterford River

Since CBCL Limited already has a Hydrologic and Hydraulic model of the Waterford River, this step would be quite cost effectively addressed. Reviewing the calibration, ensuring the suitable format exists would be the main tasks involved in this step.

Step 4 – Integrating NWP into the Hydrological/Hydraulic Model

It appears that the aforementioned products are available in GRIB format (specifics to be confirmed), which is a common format for the storage and transport of gridded meteorological data. CBCL Limited is able to set up its hydrological/hydraulic software for real-time flood mapping, using radar measurements in GRIB format. The software simply generates a grid over the study area and populates each grid cell with a time series extracted from the GRIB file.

It is also noted that Environment Canada already has an experimental hydrodynamic modelling system in place that provides streamflow forecasts from HRDPS outputs for the Hudson's Bay watershed as well as for the Great Lakes and the St. Lawrence River. Hourly forecasts of streamflow are available in real-time for the next 84h. The models used (WATROUTE and H2D2) are open source. WATROUTE directly integrates with the data for forecasting through Green Kenue. The software used by CBCL (SWMM) has several important advantages over WATROUTE and H2D2 (ie., dynamic 2D modelling), but this alternative approach demonstrates the likely feasibility of predictive flood mapping using NWP.

CHAPTER 7 CONCLUSIONS

A comprehensive set of flood risk maps for the Waterford River were completed for existing climate and climate change conditions. The flood risk maps were developed through a three-step process:

1. Complete a hydrologic assessment using HEC-HMS to convert rainfall run-off data into a flood flow;
2. Convert the flood flow into a water surface elevation using HEC-RAS; and
3. Overlay the water surface result onto a digital terrain model to determine flood zone extents.

Calibration of both the hydrologic and hydraulic model was completed using metered data captured during significant weather events. A detailed description of the process involved in model development and calibration is presented in the enclosed report.

Results of the hydraulic structure analysis show that some structures are under capacity for future development and climate change conditions. As well, flood mitigation strategies, such as the use of levees, may be required in areas of excess flooding above the riverbanks.

Feedback form municipalities located in the study watershed has been comprehensive. Records of correspondence received from the City of St. John’s, the City of Mount Pearl and the Town of Paradise are contained in Appendix J.

The HEC software is continuously updated and improved. CBCL’s comments on software issues are presented in Appendix K.

CHAPTER 8 RECOMMENDATIONS

Key recommendations of the study are as presented below.

1. The City of St. John's, the City of Mount Pearl and the Town of Paradise should adopt the flood risk maps under their respective development regulations.
2. Maintain the model to ensure proper reflection of site conditions over time. Update the model as capital works projects within the watershed are completed and land use applications change.
3. Summaries of the hydraulic capacities of bridges and culverts may assist engineers in capital works master planning. The model results can be applied as a preliminary identifier of under capacity structures; however, further analysis of each hydraulic structure is required to confirm the outputs of the hydraulic model. Interpret model results within the context of the software strengths and limitations, including piped systems and steep bed slopes.
4. Flood risk maps should be considered by municipal planners to assist in developing appropriate land use policies.
5. Hazard maps can be used by early responders during flood situations.
6. Hydrologic and hydraulic models can be used in the development of real-time flood-forecasting systems.
7. Be aware of evolving technology and model capabilities (limitations and advancements). Monitor release notes on HEC-HMS and HEC-RAS solvers to ensure software bugs are documented and understood.
8. As new regional climate data becomes available, apply updated climate change IDFs.
9. Future technological developments in LiDAR may offer an opportunity to penetrate the water surface and capture riverbed geometry without the use of field survey.
10. Further detail, such as the inclusion of additional river reaches, should be considered for future iterations of flood risk mapping. Further, consideration must be given to the expected increase in accuracy of model output due to additional data sets against the desired level of effort. In its current state, the software is capable of handling additional data entry at an acceptable simulation duration.

APPENDIX A

IDF Curves

Table 12.2 Differences Between IDF Curves for Ruby Line and St. John's A

	Percent Difference in Precipitation Amount [%] (Difference in Precipitation Amount [mm])					
	Return Period [years]					
Duration	***2***	***5***	***10***	***25***	***50***	***100***
5-min	**-11.3 (-0.5)**	**-20.7 (-1.3)**	**-24.6 (-1.9)**	**-28.1 (-2.5)**	**-30.0 (-3.0)**	**-31.6 (-3.5)**
10-min	**-5.4 (-0.4)**	**-14.7 (-1.4)**	**-18.7 (-2.0)**	**-22.3 (-2.9)**	**-24.4 (-3.5)**	**-26.0 (-4.1)**
15-min	**-5.2 (-0.5)**	**-12.6 (-1.5)**	**-15.7 (-2.2)**	**-18.5 (-3.0)**	**-20.1 (-3.6)**	**-21.4 (-4.3)**
30-min	-3.4 (-0.4)	-1.8 (-0.3)	-1.1 (-0.2)	-0.4 (-0.1)	0.0 (0.0)	0.3 (0.1)
1-hr	**6.8 (1.2)**	**14.6 (3.2)**	**18.1 (4.6)**	**21.5 (6.3)**	**23.4 (7.6)**	**25.0 (8.9)**
2-hr	**22.0 (5.2)**	**23.0 (7.3)**	**23.4 (8.6)**	**23.8 (10.3)**	**24.0 (11.6)**	**24.2 (12.8)**
6-hr	**15.6 (6.4)**	**20.2 (10.3)**	**22.3 (12.9)**	**24.4 (16.1)**	**25.7 (18.5)**	**26.7 (20.9)**
12-hr	**15.7 (8.2)**	**26.4 (16.8)**	**31.5 (22.4)**	**36.7 (29.5)**	**39.8 (34.8)**	**42.4 (40.1)**
24-hr	**17.3 (10.8)**	**24.2 (18.2)**	**27.6 (23.1)**	**31.0 (29.3)**	**33.1 (33.9)**	**34.8 (38.5)**

Notes:
Red numbers indicate that the updated IDF curve is lower than the EC-IDF V2.3 IDF curve for that duration and return period.
Bold numbers indicate changes greater than 5 percent.

Where there are decreases greater than 5 percent, users should exercise caution when using the updated IDF curve, or use the EC IDF curve. Section 12.1 presents the IDF curve tables and figures for St. John's A. Section 12.2 presents the IDF curve tables and figures for Ruby Line.

12.1 St. John's A

```
              Office of Climate Change and Energy Efficiency

          Short Duration Rainfall Intensity-Duration-Frequency Data
         Données sur l'intensité, la durée et la fréquence des chutes
                           de pluie de courte durée

                Gumbel - Method of moments/Méthode des moments

                                  2015/03/20

================================================================================
```

ST JOHN'S A NL 8403506
Updated with 5-min data measured at Windsor Lake (City of St. John's Station) : 1999 - 2014
Latitude: 47 37'N Longitude: 52 44'W Elevation/Altitude: 140 m
Years/Années : 1949 - 2014 # Years/Années : 48

===

****

Table 1: Annual Maximum (mm)/Maximum annuel (mm)

****

	Year Année	5 min	10 min	15 min	30 min	1 h	2 h	6 h	12 h	24 h
EC-IDF	1949	8.9	8.9	10.2	17.5	28.2	52.6	61.7	62.0	63.5
EC-IDF	1961	3.0	4.3	5.3	6.9	8.6	13.5	25.7	35.6	38.6
EC-IDF	1962	2.8	4.6	4.6	8.1	13.0	20.6	33.8	54.9	59.7
EC-IDF	1963	10.2	11.2	11.7	13.7	18.5	23.6	40.9	52.3	57.9
EC-IDF	1964	4.3	6.9	7.9	11.2	19.3	28.2	54.9	72.6	77.5
EC-IDF	1965	5.3	7.4	9.9	13.0	17.8	19.6	32.3	51.8	59.7
EC-IDF	1966	8.4	13.2	17.0	25.4	29.7	43.7	48.5	64.5	85.3
EC-IDF	1967	2.3	3.8	5.3	9.9	10.9	16.3	29.5	44.4	58.4
EC-IDF	1968	6.3	12.7	13.7	14.7	17.5	22.4	41.9	55.1	61.7
EC-IDF	1969	5.6	7.1	8.4	8.6	11.7	19.0	30.7	34.5	48.3
EC-IDF	1970	5.6	7.1	10.7	15.2	16.3	19.6	42.4	62.5	87.4
EC-IDF	1971	6.3	10.4	14.5	16.0	19.0	22.1	34.3	41.1	77.7
EC-IDF	1972	4.8	5.3	6.6	10.9	15.0	20.6	47.8	72.6	89.2
EC-IDF	1973	5.3	6.9	7.9	10.4	16.5	30.0	49.5	65.8	67.1
EC-IDF	1974	3.6	5.6	6.3	9.9	16.3	22.4	42.4	53.3	72.9
EC-IDF	1975	8.1	10.4	12.2	17.8	19.0	19.6	46.5	71.9	82.3
EC-IDF	1976	3.6	4.8	6.1	8.4	12.7	19.0	33.8	42.2	53.6
EC-IDF	1977	3.8	5.6	7.6	11.7	17.5	23.4	38.6	40.4	41.4
EC-IDF	1978	4.0	5.9	7.4	7.6	12.9	13.1	27.1	37.6	43.0
EC-IDF	1979	3.2	4.2	5.9	10.2	16.2	18.1	29.3	41.9	49.2
EC-IDF	1980	3.2	6.1	7.4	12.2	17.4	23.9	33.6	41.6	69.8
EC-IDF	1981	-99.9	-99.9	-99.9	-99.9	15.0	22.4	46.7	72.5	82.6
EC-IDF	1982	5.1	9.0	12.9	17.1	24.5	35.9	80.3	82.4	84.0
EC-IDF	1983	1.6	3.2	4.8	9.6	19.2	26.5	47.3	52.8	54.7
EC-IDF	1984	5.0	9.9	13.0	21.5	27.1	36.6	61.0	74.0	75.3
EC-IDF	1985	5.2	7.1	9.8	11.3	14.1	18.5	36.0	54.9	82.9
EC-IDF	1986	3.1	4.8	7.2	14.3	23.3	27.9	40.2	58.9	70.6
EC-IDF	1987	5.1	7.3	8.6	16.2	23.5	24.2	30.6	36.6	46.8
EC-IDF	1988	6.6	10.6	13.2	17.4	23.4	25.9	44.8	45.8	49.0
EC-IDF	1989	2.9	4.5	6.2	8.0	10.9	19.7	43.4	51.6	51.6
EC-IDF	1990	3.7	5.9	6.5	12.6	19.2	28.5	48.1	68.7	85.2
EC-IDF	1991	7.8	11.4	15.9	23.3	28.8	29.5	51.2	52.2	59.7
EC-IDF	1993	4.4	7.0	7.6	11.5	20.0	31.3	47.6	49.4	55.3
EC-IDF	1994	6.2	9.1	10.3	12.6	12.8	14.9	-99.9	-99.9	67.5
EC-IDF	1995	5.2	9.8	14.5	16.6	27.6	46.7	55.9	58.8	61.6
EC-IDF	1996	4.8	6.2	7.4	10.2	15.4	27.2	40.2	44.0	48.4
UPDATE	1999	3.2	5.0	6.6	9.0	15.3	25.1	42.4	63.4	99.3
UPDATE	2000	3.8	6.7	8.6	13.0	21.5	29.9	43.4	58.9	70.5
UPDATE	2001	4.8	8.8	11.5	19.5	33.7	62.0	107.1	147.7	149.6
UPDATE	2003	5.5	8.6	11.3	19.3	32.4	42.2	50.4	76.1	92.4
UPDATE	2004	3.9	7.4	10.6	17.2	23.6	26.1	59.0	71.5	76.6
UPDATE	2005	5.0	7.1	8.4	13.1	21.2	28.6	65.4	82.3	98.9
UPDATE	2006	4.8	8.1	11.1	17.5	30.4	36.4	51.9	53.7	58.5
UPDATE	2007	6.3	10.3	14.6	27.2	41.1	48.1	79.2	104.2	104.9
UPDATE	2009	5.0	6.6	7.4	10.6	16.9	24.7	46.7	58.2	65.0
UPDATE	2010	4.1	7.5	10.2	14.2	21.2	36.2	62.7	75.0	113.8

UPDATE	2011	3.2	4.8	7.3	12.0	15.7	20.6	33.3	38.1	54.9
UPDATE	2013	4.4	6.6	8.5	11.3	15.9	27.2	46.3	56.1	76.3
UPDATE	2014	5.5	9.6	13.3	19.4	25.8	37.9	48.7	61.0	73.7
	# Yrs. Années	48	48	48	48	49	49	48	48	49
	Mean Moyenne	4.9	7.4	9.5	13.9	19.9	27.6	46.6	59.3	70.5
	Std. Dev. Écart-type	1.7	2.4	3.2	4.7	6.7	10.3	15.0	19.6	20.8
	Skew. Dissymétrie	0.92	0.48	0.54	0.90	0.94	1.32	1.73	2.15	1.29
	Kurtosis	4.29	2.76	2.54	3.67	3.99	4.95	7.87	10.98	6.15

*-99.9 Indicates Missing Data/Données manquantes
*   NM Indicates No Measurements/Aucunes mesures

Warning: annual maximum amount greater than 100-yr return period amount
Avertissement : la quantité maximale annuelle excède la quantité pour une période de retour de 100 ans

Year/Année	Duration/Durée	Data/Données	100-yr/ans
2001	2 h	62.0	60.0
2001	6 h	107.1	93.8
2001	12 h	147.7	120.7
2001	24 h	149.6	135.8
2007	1 h	41.1	41.0

****

Table 2a: Return Period Rainfall Amounts (mm)
Quantité de pluie (mm) par période de retour

****

Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années
UPDATE 5 min	4.6	6.1	7.2	8.5	9.4	10.4	48
UPDATE 10 min	7.0	9.1	10.5	12.3	13.6	14.9	48
UPDATE 15 min	8.9	11.7	13.6	15.9	17.6	19.3	48
UPDATE 30 min	13.1	17.2	20.0	23.4	26.0	28.6	48
UPDATE 1 h	18.8	24.7	28.6	33.6	37.3	41.0	49
UPDATE 2 h	25.9	35.0	41.1	48.7	54.4	60.0	49
UPDATE 6 h	44.1	57.4	66.2	77.3	85.6	93.8	48
UPDATE 12 h	56.1	73.4	84.9	99.3	110.1	120.7	48
UPDATE 24 h	67.1	85.5	97.7	113.1	124.5	135.8	49

* 5-min data were used for the update: all durations were updated

****

Table 2b:

Return Period Rainfall Rates (mm/h) - 95% Confidence limits
Intensité de la pluie (mm/h) par période de retour - Limites de confiance de 95%

****

Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années
UPDATE 5 min	55.3	73.7	86.0	101.5	112.9	124.3	48
	+/- 5.4	+/- 9.1	+/- 12.4	+/- 16.7	+/- 19.9	+/- 23.2	48
UPDATE 10 min	42.0	54.8	63.2	73.9	81.8	89.6	48
	+/- 3.7	+/- 6.3	+/- 8.5	+/- 11.5	+/- 13.7	+/- 16.0	48
UPDATE 15 min	35.8	46.9	54.3	63.6	70.5	77.4	48
	+/- 3.3	+/- 5.5	+/- 7.4	+/- 10.0	+/- 12.0	+/- 14.0	48
UPDATE 30 min	26.2	34.4	39.9	46.9	52.0	57.1	48
	+/- 2.4	+/- 4.1	+/- 5.5	+/- 7.5	+/- 8.9	+/- 10.4	48
UPDATE 1 h	18.8	24.7	28.6	33.6	37.3	41.0	49

```
                +/-  1.7 +/-  2.9 +/-  3.9 +/-  5.3 +/-  6.3 +/-  7.4       49
*UPDATE*  2 h       12.9      17.5      20.5      24.3      27.2      30.0       49
                +/-  1.3 +/-  2.2 +/-  3.0 +/-  4.1 +/-  4.9 +/-  5.7       49
*UPDATE*  6 h        7.3       9.6      11.0      12.9      14.3      15.6       48
                +/-  0.7 +/-  1.1 +/-  1.5 +/-  2.0 +/-  2.4 +/-  2.8       48
*UPDATE* 12 h        4.7       6.1       7.1       8.3       9.2      10.1       48
                +/-  0.4 +/-  0.7 +/-  1.0 +/-  1.3 +/-  1.6 +/-  1.8       48
*UPDATE* 24 h        2.8       3.6       4.1       4.7       5.2       5.7       49
                +/-  0.2 +/-  0.4 +/-  0.5 +/-  0.7 +/-  0.8 +/-  1.0       49
     * 5-min data were used for the update: all durations were updated

********************************************************************************

Table 3: Interpolation Equation / Équation d'interpolation: R = A*T^B

R = Interpolated Rainfall rate (mm/h)/Intensité interpolée de la pluie (mm/h)
RR = Rainfall rate (mm/h) / Intensité de la pluie (mm/h)
 T = Rainfall duration (h) / Durée de la pluie (h)

********************************************************************************
```

Statistics/Statistiques	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans
Mean of RR/Moyenne de RR	22.9	30.1	35.0	41.1	45.6	50.1
Std. Dev. /Écart-type (RR)	18.3	24.2	28.2	33.1	36.8	40.5
Std. Error/Erreur-type	3.0	3.9	4.6	5.4	6.0	6.6
Coefficient (A)	17.2	22.5	26.1	30.6	34.0	37.3
Exponent/Exposant (B)	-0.521	-0.525	-0.527	-0.528	-0.529	-0.530
Mean % Error/% erreur moyenne	7.4	7.9	8.2	8.4	8.6	8.8

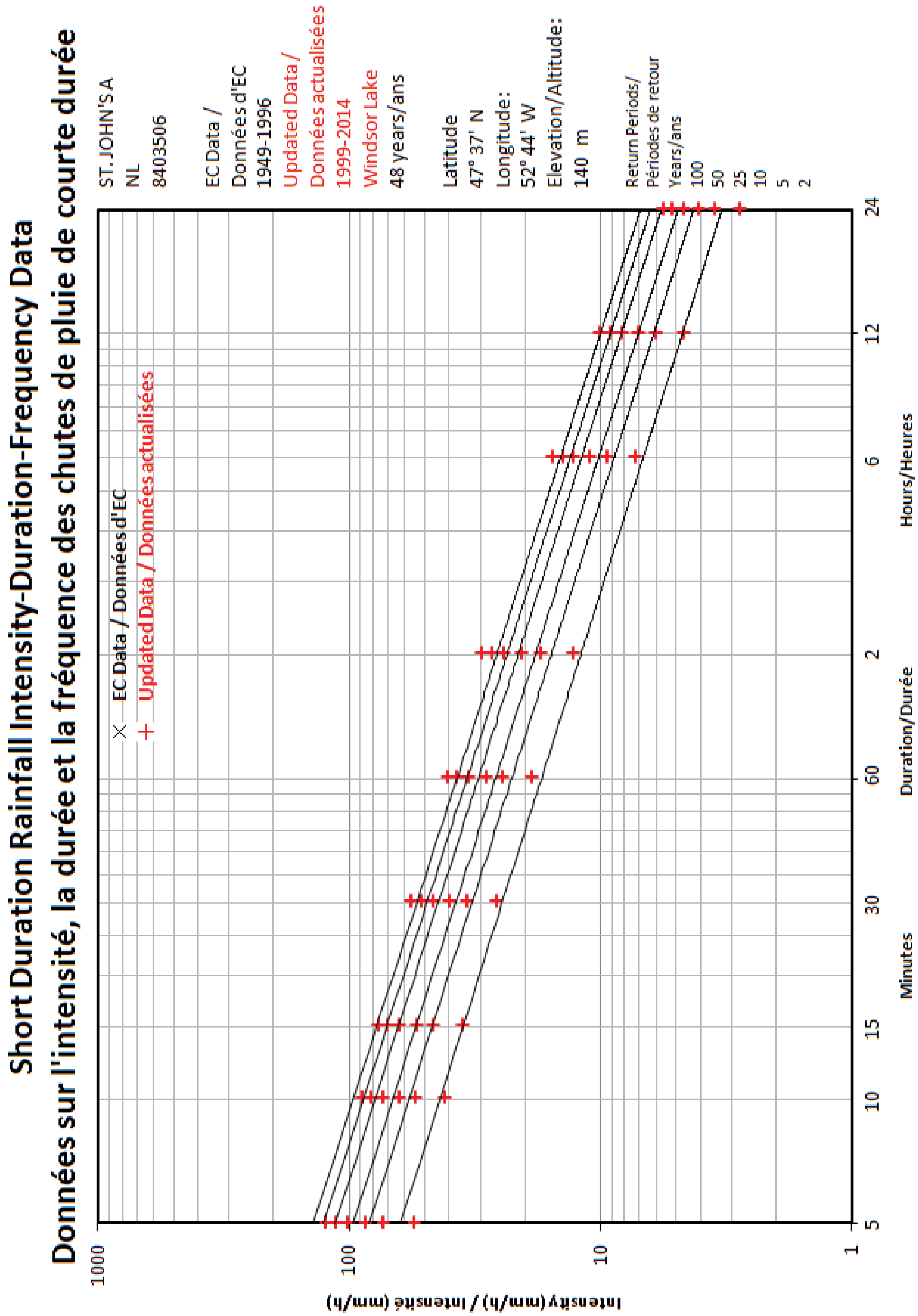


Figure 12.1 St John's A IDF Curve – Updated

Table 1.11 Future IDF Curves for St John's A (8403506)

Future IDF Curve for 2011-2040 Time Horizon Projected Precipitation Amount [mm]						
Duration	***Return Interval [years]***					
	2	***5***	***10***	***25***	***50***	***100***
5-min	4.8	6.4	7.5	8.8	9.7	10.7
10-min	7.4	9.8	11.2	13.0	14.4	15.8
15-min	9.6	12.7	14.7	17.1	18.9	20.8
30-min	14.4	19.0	22.0	25.6	28.3	31.0
1-hr	20.9	27.7	31.9	37.2	41.2	45.1
2-hr	29.0	39.2	45.5	53.5	59.5	65.4
6-hr	48.8	64.3	74.1	86.3	95.5	104.5
12-hr	61.4	81.9	95.1	111.3	123.4	135.5
24-hr	72.5	94.1	107.8	124.8	137.5	150.2
Future IDF Curve for 2041-2070 Time Horizon Projected Precipitation Amount [mm]						
Duration	***Return Interval [years]***					
	2	***5***	***10***	***25***	***50***	***100***
5-min	5.1	6.9	8.1	9.5	10.6	11.6
10-min	7.9	10.4	12.0	14.0	15.5	17.0
15-min	10.2	13.5	15.6	18.3	20.3	22.2
30-min	15.2	20.1	23.3	27.3	30.2	33.1
1-hr	22.1	29.2	33.8	39.4	43.7	48.0
2-hr	30.8	41.5	48.4	57.0	63.4	69.8
6-hr	51.5	67.8	78.3	91.3	101.0	110.8
12-hr	64.8	86.5	100.5	118.0	130.9	143.8
24-hr	76.1	98.9	113.6	131.9	145.5	159.0
Future IDF Curve for 2071-2100 Time Horizon Projected Precipitation Amount [mm]						
Duration	***Return Interval [years]***					
	2	***5***	***10***	***25***	***50***	***100***
5-min	5.2	7.0	8.2	9.8	11.0	12.1
10-min	8.0	10.5	12.2	14.4	16.0	17.7
15-min	10.4	13.7	15.9	18.8	21.0	23.2
30-min	15.5	20.4	23.7	28.1	31.3	34.5
1-hr	22.5	29.5	34.4	40.7	45.3	49.9
2-hr	31.5	42.1	49.4	59.0	66.0	72.9
6-hr	52.5	68.6	79.6	94.1	104.7	115.1
12-hr	66.1	87.6	102.2	121.3	135.5	149.3
24-hr	77.5	100.0	115.4	135.6	150.4	165.0

12.2 Ruby Line

Office of Climate Change and Energy Efficiency

Short Duration Rainfall Intensity-Duration-Frequency Data
Données sur l'intensité, la durée et la fréquence des chutes de pluie de courte durée

Gumbel - Method of moments/Méthode des moments

2015/03/20

==

RUBY LINE NL City of St. John's Station

Latitude: 47 29'24" N Longitude: 52 47'46" W Elevation/Altitude: 151 m
Years/Années : 1997 - 2014 # Years/Années : 16

==

****

Table 1: Annual Maximum (mm)/Maximum annuel (mm)

****

	Year Année	5 min	10 min	15 min	30 min	1 h	2 h	6 h	12 h	24 h
UPDATE	1997	4.7	4.9	6.2	8.0	12.2	21.9	46.1	61.4	68.3
UPDATE	1998	3.6	5.8	6.8	11.9	21.3	33.0	56.0	76.0	95.8
UPDATE	1999	4.0	5.8	6.7	9.4	15.3	25.4	37.1	55.4	83.2
UPDATE	2000	3.5	5.5	7.8	14.2	20.3	30.8	48.1	62.0	73.1
UPDATE	2001	5.1	8.6	11.0	18.6	32.6	55.5	95.9	133.1	135.9
UPDATE	2002	3.5	6.7	9.5	13.2	16.1	26.4	44.0	45.0	46.3
UPDATE	2004	4.1	7.4	9.6	13.1	22.5	22.6	43.8	55.2	58.7
UPDATE	2005	3.7	7.2	10.5	14.4	22.2	35.2	43.0	62.9	77.4
UPDATE	2006	2.8	5.1	6.4	8.6	12.2	19.0	36.3	42.5	53.5
UPDATE	2007	7.2	11.1	15.1	27.1	41.7	56.4	76.4	91.0	91.9
UPDATE	2008	5.0	8.0	8.3	11.4	15.6	23.2	45.9	57.8	63.1
UPDATE	2009	4.3	5.9	7.8	10.3	16.0	26.5	49.6	74.6	75.1
UPDATE	2010	5.7	7.2	8.4	11.4	21.4	34.9	56.3	65.3	111.2
UPDATE	2011	4.3	6.4	6.8	10.2	14.6	23.8	37.4	44.9	72.0
UPDATE	2013	3.6	7.0	8.4	10.3	12.8	21.9	37.1	47.7	55.5
UPDATE	2014	4.2	6.5	8.7	12.5	21.0	36.3	45.9	51.2	64.0
	# Yrs. Années	16	16	16	16	16	16	16	16	16
	Mean Moyenne	4.3	6.8	8.6	12.8	19.9	30.8	49.9	64.1	76.6
	Std. Dev. Écart-type	1.1	1.5	2.2	4.6	7.8	11.2	15.8	22.5	23.1
	Skew. Dissymétrie	1.38	1.46	1.67	2.22	1.72	1.50	2.06	2.13	1.24
	Kurtosis	6.01	6.43	7.02	9.15	6.60	5.08	7.68	8.73	5.08

*-99.9 Indicates Missing Data/Données manquantes
* NM Indicates No Measurements/Aucunes mesures

****

Table 2a: Return Period Rainfall Amounts (mm)
Quantité de pluie (mm) par période de retour

****

Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années
UPDATE 5 min	4.2	5.1	5.7	6.5	7.1	7.6	16
UPDATE 10 min	6.6	7.9	8.8	9.9	10.8	11.6	16
UPDATE 15 min	8.3	10.2	11.6	13.2	14.4	15.7	16
UPDATE 30 min	12.0	16.1	18.8	22.2	24.7	27.3	16
UPDATE 1 h	18.6	25.5	30.1	35.9	40.2	44.4	16
UPDATE 2 h	29.0	38.8	45.4	53.7	59.8	65.9	16
UPDATE 6 h	47.3	61.3	70.5	82.2	90.8	99.4	16
UPDATE 12 h	60.4	80.3	93.5	110.1	122.4	134.6	16
UPDATE 24 h	72.8	93.2	106.7	123.8	136.5	149.1	16

* 5-min data were used for the update: all durations were updated

****

Table 2b:

Return Period Rainfall Rates (mm/h) - 95% Confidence limits
Intensité de la pluie (mm/h) par période de retour - Limites de confiance de 95%

****

Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années
UPDATE 5 min	49.9	61.1	68.5	77.8	84.8	91.6	16
	+/- 5.7	+/- 9.6	+/- 12.9	+/- 17.4	+/- 20.9	+/- 24.3	16
UPDATE 10 min	39.4	47.5	52.9	59.7	64.7	69.7	16
	+/- 4.1	+/- 7.0	+/- 9.4	+/- 12.7	+/- 15.2	+/- 17.7	16
UPDATE 15 min	33.0	41.0	46.2	52.9	57.8	62.7	16
	+/- 4.0	+/- 6.8	+/- 9.2	+/- 12.4	+/- 14.8	+/- 17.3	16
UPDATE 30 min	24.1	32.2	37.6	44.4	49.5	54.5	16
	+/- 4.1	+/- 7.0	+/- 9.4	+/- 12.7	+/- 15.2	+/- 17.7	16
UPDATE 1 h	18.6	25.5	30.1	35.9	40.2	44.4	16
	+/- 3.5	+/- 5.9	+/- 8.0	+/- 10.8	+/- 12.9	+/- 15.1	16
UPDATE 2 h	14.5	19.4	22.7	26.8	29.9	32.9	16
	+/- 2.5	+/- 4.2	+/- 5.7	+/- 7.7	+/- 9.2	+/- 10.7	16
UPDATE 6 h	7.9	10.2	11.8	13.7	15.1	16.6	16
	+/- 1.2	+/- 2.0	+/- 2.7	+/- 3.6	+/- 4.3	+/- 5.1	16
UPDATE 12 h	5.0	6.7	7.8	9.2	10.2	11.2	16
	+/- 0.8	+/- 1.4	+/- 1.9	+/- 2.6	+/- 3.1	+/- 3.6	16
UPDATE 24 h	3.0	3.9	4.4	5.2	5.7	6.2	16
	+/- 0.4	+/- 0.7	+/- 1.0	+/- 1.3	+/- 1.6	+/- 1.9	16

* 5-min data were used for the update: all durations were updated

****

Table 3: Interpolation Equation / Équation d'interpolation: R = A*T^B

R = Interpolated Rainfall rate (mm/h)/Intensité interpolée de la pluie (mm/h)
RR = Rainfall rate (mm/h) / Intensité de la pluie (mm/h)
T = Rainfall duration (h) / Durée de la pluie (h)

****

Statistics/Statistiques	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans
Mean of RR/Moyenne de RR	21.7	27.5	31.3	36.2	39.8	43.3
Std. Dev. /Écart-type (RR)	16.3	19.7	21.9	24.8	26.9	29.1
Std. Error/Erreur-type	2.8	4.4	5.6	7.1	8.2	9.3
Coefficient (A)	17.0	21.9	25.2	29.2	32.2	35.2
Exponent/Exposant (B)	-0.483	-0.471	-0.466	-0.461	-0.458	-0.455
Mean % Error/% erreur moyenne	8.2	11.1	12.4	13.6	14.3	14.9

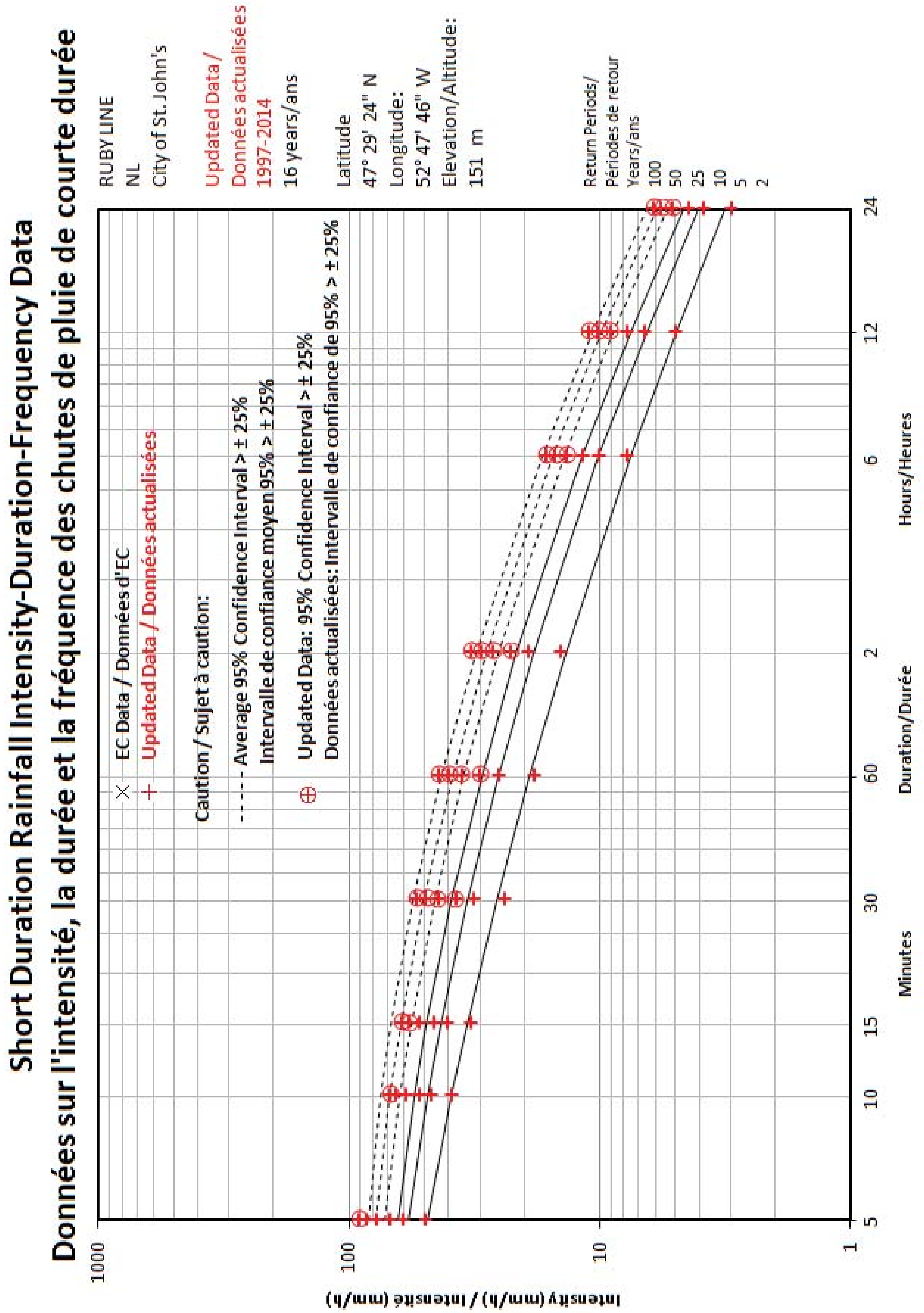


Figure 12.5 Ruby Line IDF Curve – Updated

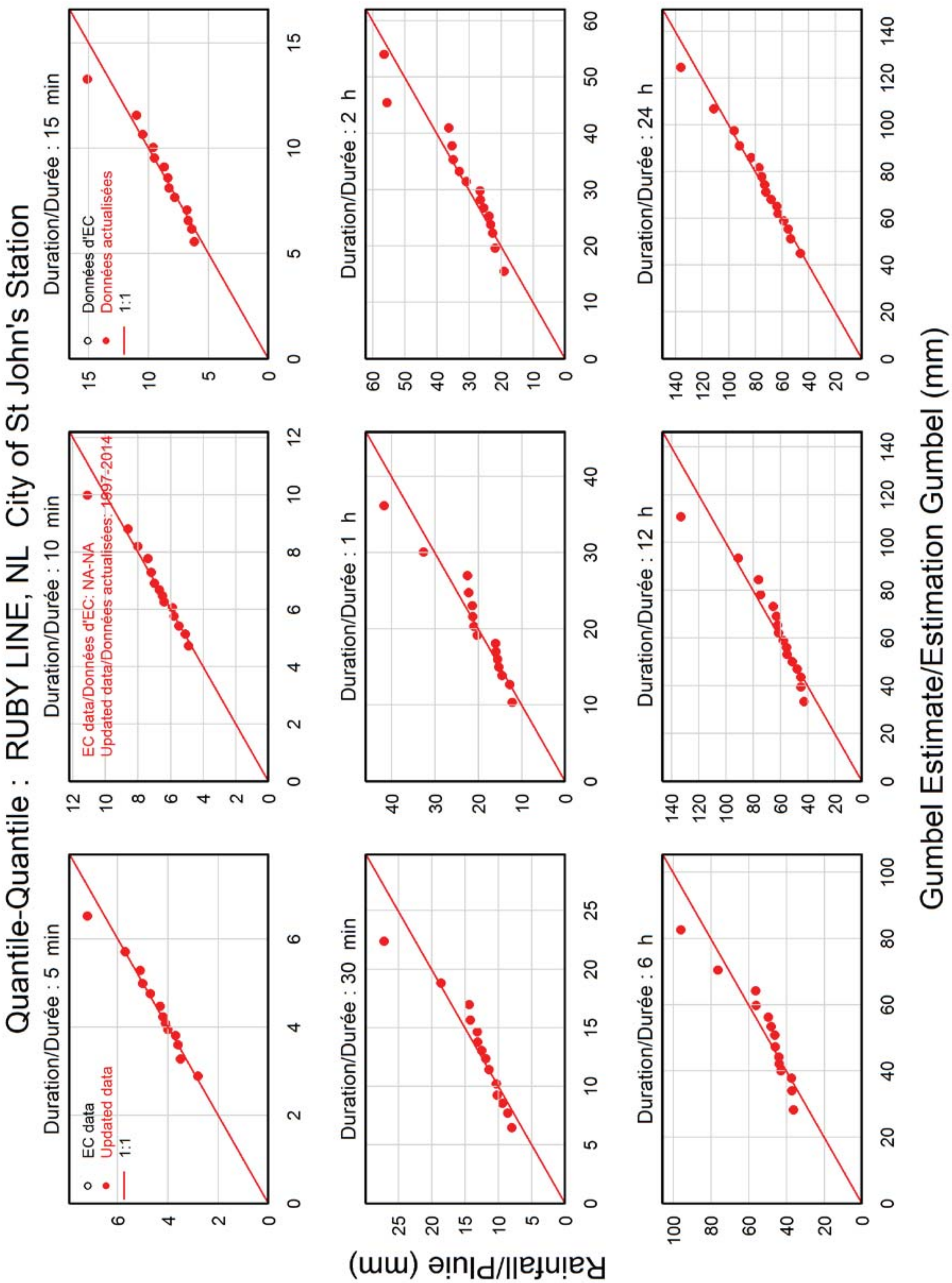


Figure 12.6 Ruby Line Quantile-Quantile Plot – Updated

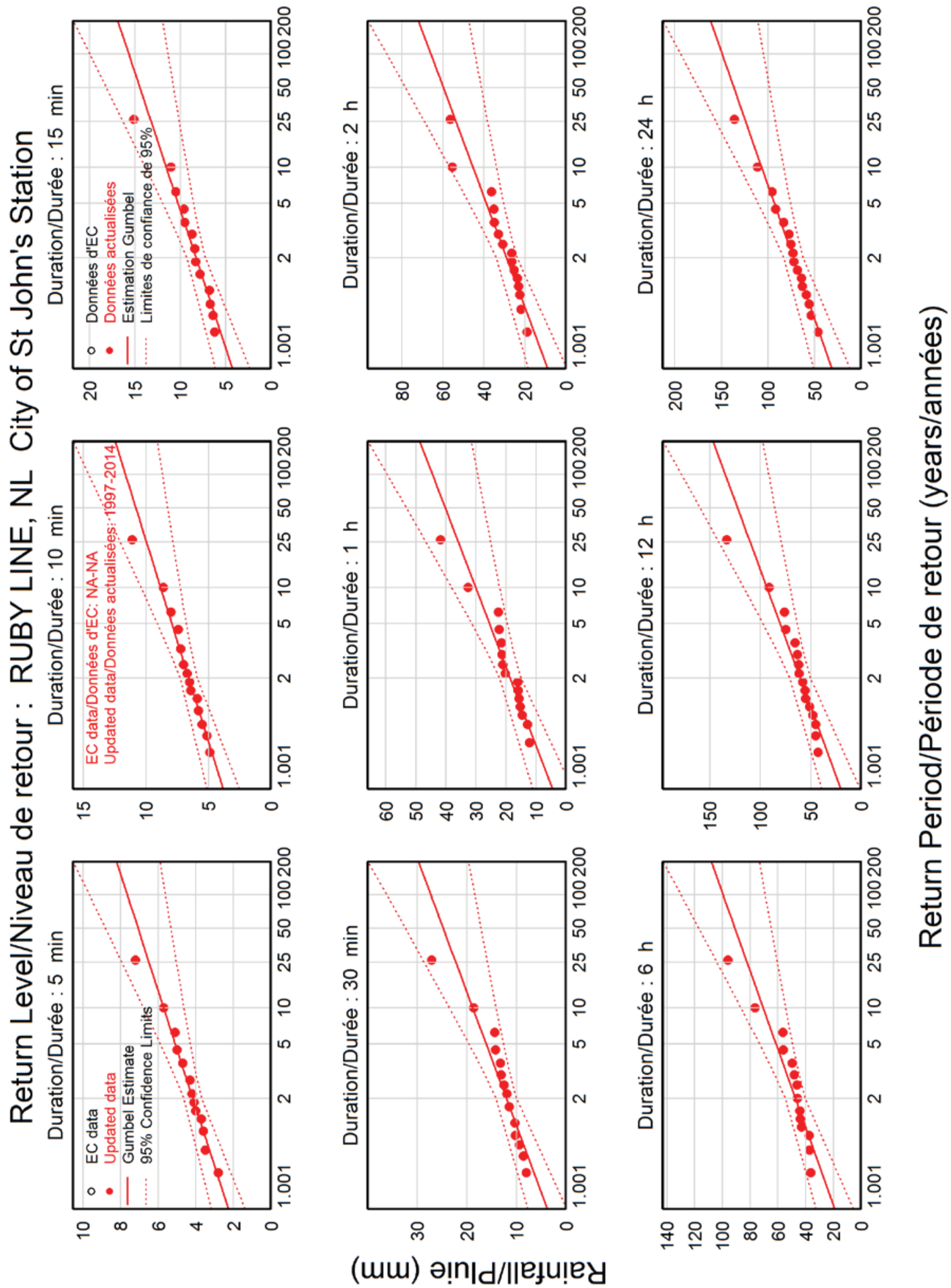


Figure 12.7 Ruby Line Return Level Plot – Updated

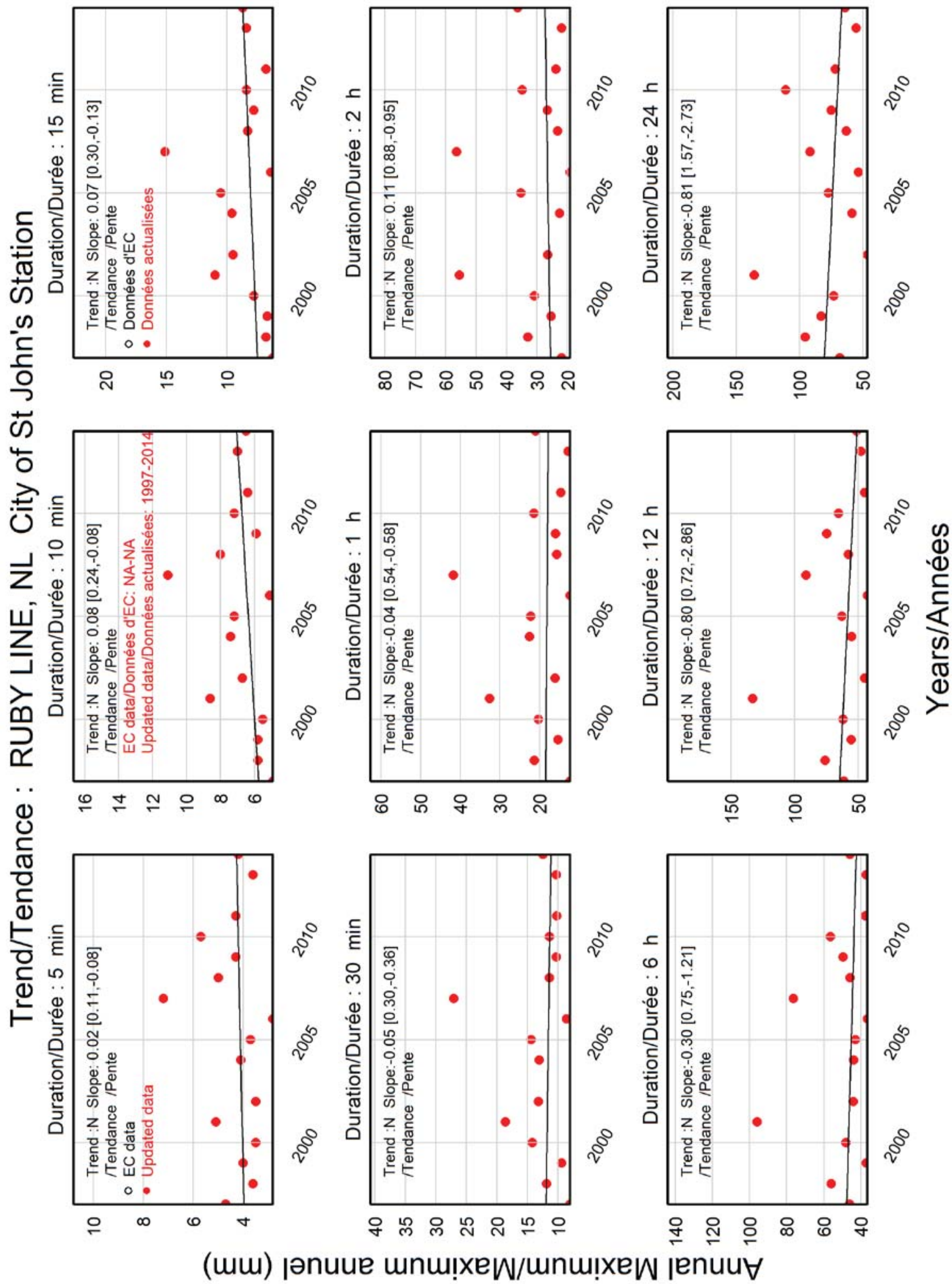


Figure 12.8 Ruby Line Trend Plot – Updated

Table 1.12 Future IDF Curves for Ruby Line (City of St. John's Station)

Future IDF Curve for 2011-2040 Time Horizon Projected Precipitation Amount [mm]						
Duration	***Return Interval [years]***					
	2	***5***	***10***	***25***	***50***	***100***
5-min	4.7	5.8	6.4	7.4	8.0	8.7
10-min	7.3	8.9	9.9	11.2	12.2	13.1
15-min	9.3	11.7	13.1	15.1	16.5	17.9
30-min	14.2	19.0	22.0	26.1	28.9	31.8
1-hr	22.3	30.5	35.4	42.4	47.2	52.1
2-hr	34.2	45.9	53.0	63.0	69.9	76.8
6-hr	54.8	71.3	81.3	95.4	105.1	114.9
12-hr	71.0	94.6	108.8	128.9	142.7	156.6
24-hr	83.6	107.9	122.6	143.2	157.4	171.7
Future IDF Curve for 2041-2070 Time Horizon Projected Precipitation Amount [mm]						
Duration	***Return Interval [years]***					
	2	***5***	***10***	***25***	***50***	***100***
5-min	4.8	6.0	6.8	7.7	8.4	9.0
10-min	7.5	9.2	10.4	11.7	12.7	13.6
15-min	9.7	12.1	13.9	15.8	17.2	18.6
30-min	15.0	20.0	23.6	27.5	30.4	33.3
1-hr	23.6	32.1	38.1	44.9	49.8	54.7
2-hr	36.1	48.3	56.9	66.5	73.5	80.5
6-hr	57.4	74.6	86.7	100.3	110.2	120.0
12-hr	74.8	99.3	116.6	135.9	150.0	164.0
24-hr	87.5	112.8	130.5	150.4	164.9	179.3
Future IDF Curve for 2071-2100 Time Horizon Projected Precipitation Amount [mm]						
Duration	***Return Interval [years]***					
	2	***5***	***10***	***25***	***50***	***100***
5-min	5.0	6.2	6.9	7.9	8.6	9.3
10-min	7.8	9.5	10.6	12.0	13.1	14.1
15-min	10.1	12.5	14.1	16.2	17.8	19.3
30-min	15.8	20.8	24.1	28.4	31.6	34.7
1-hr	24.9	33.5	39.1	46.4	51.7	57.1
2-hr	38.0	50.3	58.2	68.6	76.3	84.0
6-hr	60.1	77.4	88.7	103.3	114.2	124.9
12-hr	78.7	103.3	119.3	140.2	155.6	171.0
24-hr	91.5	116.8	133.3	154.8	170.7	186.5

APPENDIX B

LiDAR Report

Mount Pearl
LiDAR & Aerial Photo
Collection Report

Revision 2: August 15, 2016

SUBMITTED BY:

Leading Edge Geomatics
2384 Route 102 Hwy
Lincoln, NB
506.446.4403

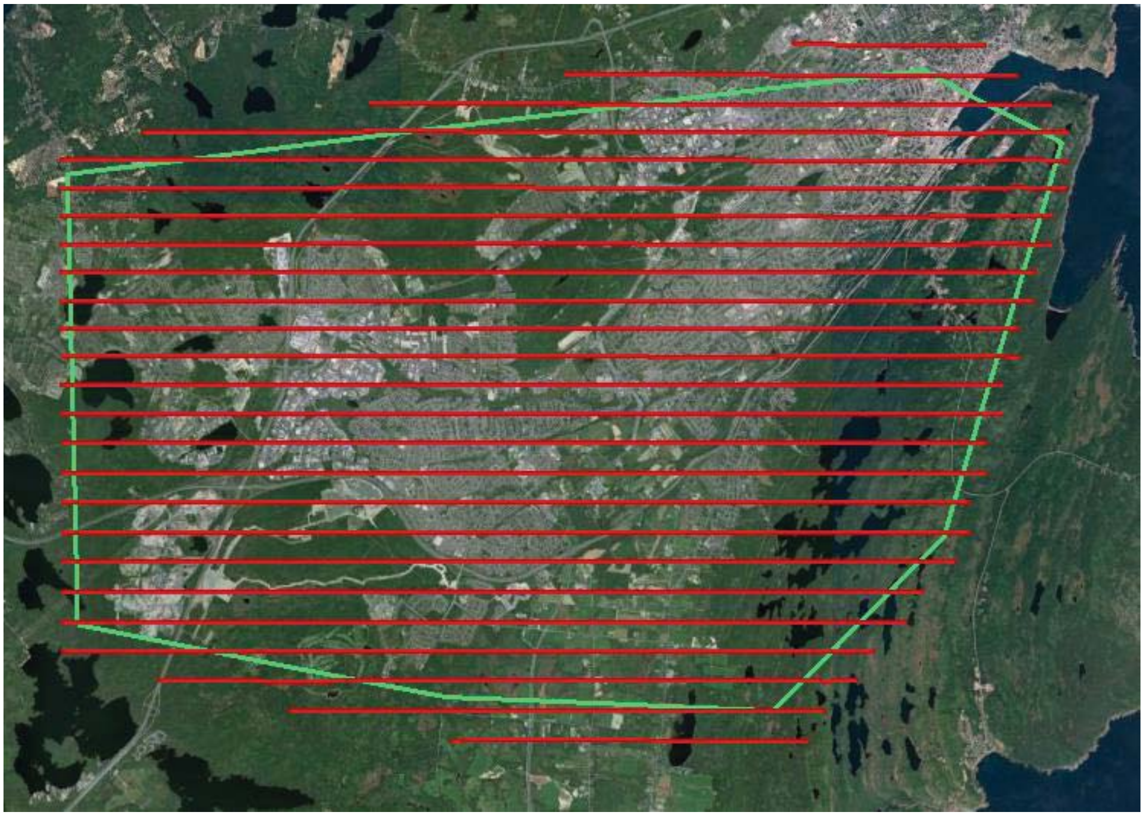
LEADING EDGE
GEOMATICS

Contents

Collection Report

Project Background

LEG flew this project to acquire LiDAR for a single area in Newfoundland, encompassing 119 km^2. This project was flown in two flights with a Riegl 780 Scanner and a single aerial photo flight with the UltraCam Lp camera. There were no major issues in the field acquisition or the post processing. In addition to the aircrews, there was a ground team on site to collect the RTK (Real Time Kinematic) ground survey control.



Flight details (LiDAR)

LiDAR flight: May 15, 2016
LiDAR Systems: Q780– SN:2221416,
Altitude: 900m AGL
Pulse Rate: 200 KHz
Position and Orientation System: Applanix POS AV 410
IMU: Litton LN-200

Flight details (Aerial Photo)

Photo flight: May 22, 2016
Camera: UltraCam Lp – SN UC-Lp-1-50015267
Altitude: 1750 m
Resolution: 15 cm

Acquisition Details

Leading Edge Geomatics planned 25 LiDAR passes total for the project areas in a series of parallel flight lines. In order to reduce any margin for error in the flight plan, Leading Edge Geomatics followed the following criteria:

- A digital flight line layout using Track Air flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- LiDAR and Photo coverage extended by a predetermined margin beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.
- Local restrictions related to air space and any controlled areas have been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, Leading Edge Geomatics will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

Leading Edge Geomatics monitored weather and atmospheric conditions and conducted LiDAR missions only when no conditions exist below the sensor that will affect the collection of data. These conditions include no snow, rain, fog, smoke, mist and low clouds.

Within 72-hours prior to the planned day(s) of acquisition, Leading Edge Geomatics closely monitored the weather, checking all sources for forecasts at least twice daily. As soon as weather conditions were conducive to acquisition, our aircraft mobilized to the project site to begin data collection. Once on site, the acquisition team took responsibility for weather analysis.

Leading Edge Geomatics LiDAR sensors and Cameras are calibrated at a designated site located in Fredericton, NB and are periodically checked and adjusted to minimize corrections at project sites.

Survey Control

Several survey monuments were employed for the airborne survey. The CAN-NET (http://www.can-net.ca/) active network in NL was employed to process the airborne trajectories. CAN-NET station STJS was checked for network consistency and used in processing with published coordinates.

This station was also used with processing static GPS base setups for the collection of RTK ground survey control. All data was collected in UTM Zone 22, NAD83 CSRS, CGVD28 via HT2 and transformed to MTM1 NAD83CSRS for processing and delivery.

LiDAR Results:

Tested Using 53 control points collected by RTK.
Mean Value: 0.0366 m
Accuracy Z: 0.0698 m at 95%

The expected horizontal accuracy of elevation products is determined from system studies or manufacturer documentation. The system used was the Riegl Q780 which has a stated horizontal accuracy = 1/3,885 x altitude (RMSE)
Horizontal Accuracy = 0.23 m RMSE

The Vertical Accuracy of the LiDAR is tested using 53 control points collected by RTK, the resulting accuracy report can be found in Appendix A, as LiDAR Quality Report. This Quality Report is generated using VG Software, and tests the accuracy of the final LiDAR tiles against the collected ground control.

Aerial Photo Results:

Testing using 27 control points collected by RTK
Horizontal Accuracy: 0.110 m RMSE
Horizontal Accuracy: 0.191 m at 95%

The Horizontal NSSDA (National Standard for Spatial Data Accuracy) Report for the aerial photos can be found in Appendix B, as Aerial Photo Horizontal Quality Report. This report calculates the residual difference between the ground survey control coordinates and the corresponding control point coordinates of the aerial photos. A resulting RMSE Horizontal Accuracy value and accuracy value at 95% confidence is produced.
Each ground survey control point of a photo identifiable ground object is identified and measured in all overlapping aerial photos containing the ground point. This photo location is given the ground survey position and held as a fixed location while the photos are adjusted during aerial triangulation. This process greatly increases the absolute accuracy of the photo project.

Concluding Remarks

There were no unusual obstacles or impediments that were encountered during this project at any phase.

Appendix A - LiDAR Quality Report

Date: 15/06/2016 11:28:26 AM
Mode: Nearest Neighbour
Control Listing: A:\2016\LiDAR\2016-1625-3038-Mount Pearl Watershed-LiDAR\Accuracy\MTPearl_ENH_ORTHOMETRIC_HT2_Nad83(CSRS)_UTM22.csv
Search Radius: 2
Units: Meter
ZDiffCutOff: 0.5
Mean Value: .027962
Standard Deviation: .022044
RMS Value: .035606
NSSDA AccuracyZ :.069788

LAS File: 371_5267_mt_pearl_allhits_cgvd28viaht2.LAS

PntNo	Dist	< Ang	DZ	#Hits	X-Value	Y-Value	Z-Value	LAS-X	LAS-Y	LAS-Z	File-ID	dX	dY	ScanAngle
102	0.261	< 253	-0.05800	115	371503.58000	5267819.45400	104.68800	371503.33000	5267819.38000	104.63000	22	0.250	0.074	-25
103	0.033	< 334	-0.01900	112	371470.68400	5267817.43000	104.03900	371470.67000	5267817.46000	104.02000	21	0.014	0.030	0
104	0.325	< 25	-0.02800	112	371429.15000	5267794.70700	103.26800	371429.29000	5267795.00000	103.24000	22	0.140	0.293	-26
105	0.070	< 143	-0.05400	107	371405.62800	5267766.42600	103.62400	371405.67000	5267766.37000	103.57000	22	0.042	0.056	-28
106	0.296	< 22	-0.03500	102	371388.74600	5267736.71700	105.05500	371388.86000	5267736.99000	105.02000	21	0.114	0.273	5
107	0.229	< 35	-0.02200	77	371380.39700	5267699.61300	106.71200	371380.53000	5267699.80000	106.69000	20	0.133	0.187	19
108	0.259	< 58	-0.04900	78	371369.92900	5267658.57500	108.48900	371370.15000	5267658.71000	108.44000	21	0.221	0.135	9
109	0.308	< 145	-0.00300	77	371359.55700	5267613.25500	110.25300	371359.73000	5267613.00000	110.25000	21	0.173	0.255	12
110	0.091	< 296	0.00100	72	371350.37100	5267567.64900	111.02900	371350.29000	5267567.69000	111.03000	20	0.081	0.041	12
111	0.270	< 151	-0.00500	74	371365.24200	5267518.10800	111.56500	371365.37000	5267517.87000	111.56000	21	0.128	0.238	18

Outlying Points :

LAS File: 368_5264_mt_pearl_allhits_cgvd28viaht2.LAS

PntNo	Dist	< Ang	DZ	#Hits	X-Value	Y-Value	Z-Value	LAS-X	LAS-Y	LAS-Z	File-ID	dX	dY	ScanAngle
304	0.292	< 37	-0.02600	129	368270.39400	5264005.58700	114.40600	368270.57000	5264005.82000	114.38000	10	0.176	0.233	-26
305	0.229	< 313	-0.03100	117	368275.17700	5264039.24400	112.46100	368275.01000	5264039.40000	112.43000	10	0.167	0.156	-28
306	0.198	< 302	-0.00900	118	368285.52700	5264080.23300	110.01900	368285.36000	5264080.34000	110.01000	12	0.167	0.107	6
307	0.316	< 240	-0.01900	125	368295.68600	5264114.65300	108.03900	368295.41000	5264114.50000	108.02000	10	0.276	0.153	-31
308	0.257	< 68	-0.07000	182	368305.79100	5264147.00600	105.90000	368306.03000	5264147.10000	105.83000	10	0.239	0.094	-32
309	0.140	< 293	-0.00300	80	368316.62900	5264181.79500	103.72300	368316.50000	5264181.85000	103.72000	13	0.129	0.055	14
310	0.246	< 32	-0.02300	70	368328.02800	5264217.73300	101.59300	368328.16000	5264217.94000	101.57000	12	0.132	0.207	14
311	0.252	< 39	-0.01600	82	368335.79000	5264248.87500	99.67600	368335.95000	5264249.07000	99.66000	13	0.160	0.195	10
312	0.308	< 318	-0.03600	82	368337.44600	5264282.68100	97.63600	368337.24000	5264282.91000	97.60000	13	0.206	0.229	8

Outlying Points :

LAS File: 368_5263_mt_pearl_allhits_cgvd28viaht2.LAS

PntNo	Dist	< Ang	DZ	#Hits	X-Value	Y-Value	Z-Value	LAS-X	LAS-Y	LAS-Z	File-ID	dX	dY	ScanAngle
302	0.327	< 28	-0.01900	136	368269.60200	5263935.88400	118.43900	368269.76000	5263936.17000	118.42000	10	0.158	0.286	-23
303	0.115	< 262	0.00400	124	368269.23400	5263970.62400	116.41600	368269.12000	5263970.61000	116.42000	12	0.114	0.014	-1

Outlying Points :

LAS File: 364_5265_mt_pearl_allhits_cgvd28viaht2.LAS

PntNo	Dist	< Ang	DZ	#Hits	X-Value	Y-Value	Z-Value	LAS-X	LAS-Y	LAS-Z	File-ID	dX	dY	ScanAngle
202	0.274	< 257	-0.06600	87	364070.15800	5265466.72700	183.96600	364069.89000	5265466.67000	183.90000	16	0.268	0.057	-22
203	0.345	< 193	-0.09700	88	364071.08000	5265436.96600	181.95700	364071.00000	5265436.63000	181.86000	16	0.080	0.336	-24
204	0.374	< 31	-0.01700	117	364072.35300	5265391.25200	178.44700	364072.55000	5265391.57000	178.43000	16	0.197	0.318	-26
205	0.299	< 71	-0.01400	118	364073.05600	5265351.92700	173.91400	364073.34000	5265352.02000	173.90000	15	0.284	0.093	3
206	0.352	< 52	-0.00100	112	364073.09000	5265322.66700	169.59100	364073.37000	5265322.88000	169.59000	15	0.280	0.213	5
207	0.068	< 355	-0.03700	88	364071.41500	5265281.60200	163.17700	364071.41000	5265281.67000	163.14000	15	0.005	0.068	8
208	0.024	< 209	-0.06200	94	364069.80200	5265239.65100	156.73200	364069.79000	5265239.63000	156.67000	15	0.012	0.021	10
209	0.165	< 9	0.00800	84	364067.93400	5265197.06700	150.12200	364067.96000	5265197.23000	150.13000	14	0.026	0.163	15
210	0.197	< 282	-0.02600	83	364066.06200	5265160.39700	145.64600	364065.87000	5265160.44000	145.62000	14	0.192	0.043	13
211	0.142	< 251	-0.07400	91	364063.50400	5265116.73600	141.42400	364063.37000	5265116.69000	141.35000	15	0.134	0.046	17
212	0.075	< 224	-0.06900	110	364058.31300	5265079.55300	138.17900	364058.26000	5265079.50000	138.11000	13	0.053	0.053	-31

Outlying Points :

LAS File: 364_5262_mt_pearl_allhits_cgvd28viaht2.LAS

PntNo	Dist	< Ang	DZ	#Hits	X-Value	Y-Value	Z-Value	LAS-X	LAS-Y	LAS-Z	File-ID	dX	dY	ScanAngle
502	0.496	< 242	0.02500	71	364617.15900	5262827.76100	136.89500	364616.72000	5262827.53000	136.92000	8	0.439	0.231	-9
503	0.266	< 211	-0.00700	65	364631.43900	5262810.37700	136.61700	364631.30000	5262810.15000	136.61000	8	0.139	0.227	-8
504	0.185	< 85	-0.03200	71	364643.90600	5262792.65400	136.39200	364644.09000	5262792.67000	136.36000	8	0.184	0.016	-7
505	0.189	< 102	-0.03100	87	364653.31600	5262778.20200	136.18100	364653.50000	5262778.16000	136.15000	9	0.184	0.042	-21
506	0.402	< 40	-0.04500	84	364663.21000	5262762.72300	135.97500	364663.47000	5262763.03000	135.93000	9	0.260	0.307	-22
507	0.420	< 245	0.01200	93	364675.22400	5262743.73100	135.66800	364674.84000	5262743.56000	135.68000	9	0.384	0.171	-23
508	0.296	< 113	-0.03400	96	364685.63800	5262727.74700	135.43400	364685.91000	5262727.63000	135.40000	9	0.272	0.117	-24
509	0.343	< 102	-0.03200	95	364693.93600	5262714.45600	135.28200	364694.27000	5262714.38000	135.25000	9	0.334	0.076	-24
510	0.245	< 209	-0.00800	88	364701.85100	5262702.46300	135.39800	364701.73000	5262702.25000	135.39000	9	0.121	0.213	-25
511	0.316	< 344	-0.04100	88	364713.92300	5262685.40500	135.75100	364713.84000	5262685.71000	135.71000	9	0.083	0.305	-26

Outlying Points :

LAS File: 360_5266_mt_pearl_allhits_cgvd28viaht2.LAS

PntNo	Dist	< Ang	DZ	#Hits	X-Value	Y-Value	Z-Value	LAS-X	LAS-Y	LAS-Z	File-ID	dX	dY	ScanAngle
402	0.240	< 109	-0.04500	113	360529.61400	5266838.42000	197.11500	360529.84000	5266838.34000	197.07000	17	0.226	0.080	-31
403	0.205	< 329	-0.00200	137	360515.36400	5266818.89300	197.65200	360515.26000	5266819.07000	197.65000	17	0.104	0.177	-30
404	0.252	< 189	-0.05100	119	360507.77100	5266798.72900	197.55100	360507.73000	5266798.48000	197.50000	17	0.041	0.249	-29
405	0.203	< 292	-0.00600	129	360505.92700	5266775.84100	196.70600	360505.74000	5266775.92000	196.70000	18	0.187	0.079	1
406	0.195	< 52	-0.01400	133	360504.36500	5266753.40200	195.70400	360504.52000	5266753.52000	195.69000	17	0.155	0.118	-26
407	0.098	< 158	-0.01800	136	360502.85400	5266728.29100	194.47800	360502.89000	5266728.20000	194.46000	18	0.036	0.091	-2
408	0.163	< 14	-0.00200	75	360501.49000	5266706.51200	193.56200	360501.53000	5266706.67000	193.56000	17	0.040	0.158	-24
409	0.250	< 184	-0.02400	89	360500.03000	5266684.19900	192.24400	360500.01000	5266683.95000	192.22000	18	0.020	0.249	-5
410	0.239	< 70	-0.02900	87	360498.77500	5266662.07000	190.82900	360499.00000	5266662.15000	190.80000	17	0.225	0.080	-21
411	0.296	< 275	-0.01900	90	360497.61500	5266640.72200	189.40900	360497.32000	5266640.75000	189.39000	17	0.295	0.028	-20
412	0.194	< 251	-0.00400	83	360497.29400	5266621.66200	188.20400	360497.11000	5266621.60000	188.20000	18	0.184	0.062	-9

Outlying Points :

Appendix B – Aerial Photo Horizontal Accuracy

Area:	Mount Pearl							Date:	15-Jun-16				
		Reference Points (Survey Points)			Data Points (Orthoimagery)								
Location		UTM NAD83CSRS			UTM NAD83CSRS			Residuals (Metres)			Residuals Squared		
ID	Tile	E	N	Elev	E	N	Elev	V(E)	V(N)	V(Elev)	V(E)*2	V(N)*2	V(Z)*2
112		369784.858	5268309.86		369784.793	5268309.766		0.065	0.094	No Data	0.004	0.009	Null
113		369762.817	5268343.878		369762.849	5268343.777		-0.032	0.101	No Data	0.001	0.010	Null
114		369730.053	5268388.754		369730.058	5268388.696		-0.005	0.058	No Data	0.000	0.003	Null
123		370012.117	5268610.45		370012.134	5268610.391		-0.017	0.059	No Data	0.000	0.003	Null
124		369814.475	5268604.137		369814.556	5268604.019		-0.081	0.118	No Data	0.007	0.014	Null
125		369870.423	5268538.693		369870.262	5268538.76		0.161	-0.067	No Data	0.026	0.004	Null
313		367366.697	5262363.357		367366.672	5262363.32		0.025	0.037	No Data	0.001	0.001	Null
314		367551.307	5262380.604		367551.293	5262380.516		0.014	0.088	No Data	0.000	0.008	Null
315		367549.172	5262402.73		367549.138	5262402.776		0.034	-0.046	No Data	0.001	0.002	Null
332		366713.912	5265575.225		366713.892	5265575.294		0.020	-0.069	No Data	0.000	0.005	Null
333		366544.945	5265575.424		366544.859	5265575.438		0.086	-0.014	No Data	0.007	0.000	Null
334		366386.937	5265603.001		366386.961	5265602.921		-0.024	0.080	No Data	0.001	0.006	Null
335		366360.071	5265432.077		366360.011	5265432.152		0.060	-0.075	No Data	0.004	0.006	Null
336		366385.039	5265294.151		366384.952	5265294.206		0.087	-0.055	No Data	0.008	0.003	Null
337		366415.277	5265199.687		366415.213	5265199.663		0.064	0.024	No Data	0.004	0.001	Null
338		366229.456	5265183.404		366229.399	5265183.355		0.057	0.049	No Data	0.003	0.002	Null
339		366233.638	5265309.991		366233.643	5265309.905		-0.005	0.086	No Data	0.000	0.007	Null
413		360551.344	5266449.014		360551.218	5266449.014		0.126	0.000	No Data	0.016	0.000	Null
414		360607.854	5266381.861		360607.719	5266381.821		0.135	0.040	No Data	0.018	0.002	Null
422		360322.805	5266276.622		360322.61	5266276.596		0.195	0.026	No Data	0.038	0.001	Null
423		360201.759	5266085.729		360201.645	5266085.839		0.114	-0.110	No Data	0.013	0.012	Null
424		360237.492	5266022.462		360237.356	5266022.445		0.136	0.017	No Data	0.018	0.000	Null

512		363095.242	5261347.633		363095.161	5261347.622		0.081	0.011	No Data	0.007	0.000	Null
513		363311.64	5261251.966		363311.582	5261252.042		0.058	-0.076	No Data	0.003	0.006	Null
520		363155.796	5261107.754		363155.754	5261107.756		0.042	-0.002	No Data	0.002	0.000	Null
521		362971.476	5261016.792		362971.304	5261016.845		0.172	-0.053	No Data	0.030	0.003	Null
522		363137.279	5260947.901		363137.283	5260947.982		-0.004	-0.081	No Data	0.000	0.007	Null
51								Number of samples:			27.000	27.000	0.000
100								Sum of Residuals squared:			0.212	0.116	0.000
101								RMSE of each coordinate:			**0.089**	**0.066**	**Null**
102													
103		**0.110**	f. Tested:	**0.191**	Metres horizontal **accuracy** at 95% confidence level.								
104		**Null**	f. Tested:	**Null**	Metres vertical **accuracy** at 95% confidence level.								

APPENDIX C

Water Survey of Canada Station 02ZM008 Data

02ZM008_Curve#32_rec'd from HWills 8-Feb-16

STATION NUMBER 02ZM008 WATERFORD RIVER AT KILBRIDE
SOURCE AGENCY:
LATITUDE 47.52906 LONGITUDE -52.74506
Date Processed: 02/08/2016 14:03:20 UTC-03:30 By howie.wills
Rating for Discharge (m^3/s)
Created by howie.wills on 12/15/2014 @ 13:30:55 UTC, Updated by howie.wills on 12/15/2014 @ 14:20:44 UTC
Remarks: CURVE # 32 BASED ON 2014 MM RESULTS WHICH INDICATED A CHANGE BELOW GH 1.238- SLIGHT REFINEMENT ABOVE 1.238

Offset1: 0.20

EXPANDED CAQRating TABLE

Stage (m) Discharge (m^3/s)

Stage (m)	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009	DIFF IN Q PER .01 UNITS
0.35									0.2886	0.2925	0.039
0.36	0.2965	0.3005	0.3045	0.3085	0.3126	0.3167	0.3209	0.3250	0.3292	0.3334	0.041
0.37	0.3377	0.3420	0.3463	0.3506	0.3549	0.3593	0.3637	0.3682	0.3727	0.3772	0.044
0.38	0.3817	0.3862	0.3908	0.3954	0.4001	0.4047	0.4094	0.4141	0.4189	0.4237	0.047
0.39	0.4285	0.4333	0.4382	0.4431	0.4480	0.4529	0.4579	0.4629	0.4680	0.4730	0.050
0.40	0.4781	0.4832	0.4884	0.4935	0.4988	0.5040	0.5092	0.5145	0.5198	0.5252	0.052
0.41	0.5306	0.5360	0.5414	0.5469	0.5523	0.5579	0.5634	0.5690	0.5746	0.5802	0.055
0.42	0.5859	0.5915	0.5973	0.6030	0.6088	0.6146	0.6204	0.6263	0.6322	0.6381	0.058
0.43	0.6440	0.6500	0.6560	0.6620	0.6681	0.6742	0.6803	0.6864	0.6926	0.6988	0.061
0.44	0.7050	0.7113	0.7176	0.7239	0.7302	0.7366	0.7430	0.7494	0.7559	0.7624	0.064
0.45	0.7689	0.7755	0.7820	0.7886	0.7953	0.8019	0.8086	0.8153	0.8221	0.8289	0.067
0.46	0.8357	0.8425	0.8494	0.8563	0.8632	0.8702	0.8771	0.8841	0.8912	0.8983	0.070
0.47	0.9053	0.9125	0.9196	0.9268	0.9340	0.9413	0.9485	0.9558	0.9632	0.9705	0.073
0.48	0.9779	0.9853	0.9928	1.000	1.008	1.015	1.023	1.030	1.038	1.046	0.075
0.49	1.053	1.061	1.069	1.077	1.084	1.092	1.100	1.108	1.116	1.124	0.079
0.50	1.132	1.140	1.148	1.156	1.164	1.172	1.180	1.188	1.197	1.205	0.081
0.51	1.213	1.221	1.230	1.238	1.246	1.255	1.263	1.272	1.280	1.289	0.084
0.52	1.297	1.306	1.315	1.323	1.332	1.341	1.349	1.358	1.367	1.376	0.088
0.53	1.385	1.393	1.402	1.411	1.420	1.429	1.438				

								1.447	1.456	1.466	0.090
0.54	1.475	1.484	1.493	1.502	1.512	1.521	1.530	1.540	1.549	1.558	0.093
0.55	1.568	1.577	1.587	1.596	1.606	1.616	1.625	1.635	1.644	1.654	0.096
0.56	1.664	1.674	1.684	1.693	1.703	1.713	1.723	1.733	1.743	1.753	0.099
0.57	1.763	1.773	1.783	1.793	1.803	1.814	1.824	1.834	1.844	1.855	0.102
0.58	1.865	1.875	1.886	1.896	1.907	1.917	1.928	1.938	1.949	1.959	0.105
0.59	1.970	1.981	1.991	2.002	2.013	2.024	2.034	2.045	2.056	2.067	0.108
0.60	2.078	2.089	2.100	2.111	2.122	2.133	2.144	2.155	2.167	2.178	0.111
0.61	2.189	2.200	2.212	2.223	2.234	2.246	2.257	2.269	2.280	2.292	0.114
0.62	2.303	2.315	2.326	2.338	2.350	2.361	2.373	2.385	2.396	2.408	0.117
0.63	2.420	2.432	2.444	2.456	2.468	2.480	2.492	2.504	2.516	2.528	0.120
0.64	2.540	2.552	2.565	2.577	2.589	2.601	2.614	2.626	2.638	2.651	0.123
0.65	2.663	2.676	2.688	2.701	2.713	2.726	2.738	2.751	2.764	2.777	0.126
0.66	2.789	2.802	2.815	2.828	2.841	2.853	2.866	2.879	2.892	2.905	0.129
0.67	2.918	2.932	2.945	2.958	2.971	2.984	2.997	3.011	3.024	3.037	0.133
0.68	3.051	3.064	3.077	3.091	3.104	3.118	3.131	3.145	3.159	3.172	0.135
0.69	3.186	3.199	3.213	3.227	3.241	3.255	3.268	3.282	3.296	3.310	0.138
0.70	3.324	3.338	3.352	3.366	3.380	3.394	3.408	3.423	3.437	3.451	0.141
0.71	3.465	3.480	3.494	3.508	3.523	3.537	3.552	3.566	3.581	3.595	0.145
0.72	3.610	3.624	3.639	3.654	3.668	3.683	3.698	3.713	3.727	3.742	0.147
0.73	3.757	3.772	3.787	3.802	3.817	3.832	3.847	3.862	3.877	3.892	0.151
0.74	3.908	3.923	3.938	3.953	3.969	3.984	3.999	4.015	4.030	4.046	0.153

STATION NUMBER 02ZM008   WATERFORD RIVER AT KILBRIDE
SOURCE AGENCY:
LATITUDE 47.52906   LONGITUDE -52.74506
Date Processed: 02/08/2016 14:03:20 UTC-03:30 By howie.wills
Rating for Discharge (m^3/s)
Created by howie.wills on 12/15/2014 @ 13:30:55 UTC, Updated by howie.wills on 12/15/2014 @ 14:20:44 UTC
Remarks: CURVE # 32 BASED ON 2014 MM RESULTS WHICH INDICATED A CHANGE BELOW GH 1.238- SLIGHT REFINEMENT ABOVE 1.238

Offset1: 0.20

EXPANDED CAQRating TABLE

Stage (m)	Discharge (m^3/s) .000	.001	.002	.003	.004	.005	.006	.007	.008	.009	DIFF IN Q PER .01 UNITS
0.75	4.061	4.077	4.092	4.108	4.124	4.139	4.155	4.171	4.186	4.202	0.157
0.76	4.218	4.234	4.250	4.265	4.281	4.297	4.313	4.329	4.345	4.362	0.160
0.77	4.378	4.394	4.410	4.426	4.442	4.459	4.475	4.491	4.508	4.524	0.162
0.78	4.540	4.557	4.573	4.590	4.606	4.623	4.640	4.656	4.673	4.690	0.166
0.79	4.706	4.723	4.740	4.757	4.774	4.790	4.807	4.824	4.841	4.858	0.169
0.80	4.875	4.892	4.910	4.927	4.944	4.961	4.978	4.996	5.013	5.030	0.173
0.81	5.048	5.065	5.082	5.100	5.117	5.135	5.152	5.170	5.187	5.205	0.175
0.82	5.223	5.240	5.258	5.276	5.294	5.311	5.329	5.347	5.365	5.383	0.178
0.83	5.401	5.419	5.437	5.455	5.473	5.491	5.510	5.528	5.546	5.564	0.181
0.84	5.582	5.601	5.619	5.638	5.656	5.674	5.693	5.711	5.730	5.748	0.185
0.85	5.767	5.786	5.804	5.823	5.842	5.860	5.879	5.898	5.917	5.936	0.188
0.86	5.955	5.974	5.993	6.012	6.031	6.050	6.069	6.088	6.107	6.126	0.191
0.87	6.146	6.165	6.184	6.203	6.223	6.242	6.262	6.281	6.300	6.320	0.193
0.88	6.339	6.359	6.379	6.398	6.418	6.438	6.457	6.477	6.497	6.517	0.198
0.89	6.537	6.556	6.576	6.596	6.616	6.636	6.656	6.676	6.696	6.717	0.200
0.90	6.737	6.757	6.777	6.797	6.818	6.838	6.858	6.879	6.899	6.920	0.203
0.91	6.940	6.961	6.981	7.002	7.022	7.043	7.064	7.084	7.105	7.126	0.207
0.92	7.147	7.167	7.188	7.209	7.230	7.251	7.272	7.293	7.314	7.335	0.209
0.93	7.356	7.377	7.398	7.420	7.441	7.462	7.483	7.505	7.526	7.548	0.213
0.94	7.569	7.590	7.612	7.633	7.655	7.677	7.698	7.720	7.741	7.763	0.216
0.95	7.785	7.807	7.828	7.850	7.872	7.894	7.916	7.938	7.960	7.982	0.219
0.96	8.004	8.026	8.048	8.070	8.092	8.115	8.137	8.159	8.182	8.204	0.222
0.97	8.226	8.249	8.271	8.294	8.316	8.339	8.361	8.384	8.406	8.429	0.226
0.98	8.452	8.474	8.497	8.520	8.543	8.566	8.588	8.611	8.634	8.657	0.228
0.99	8.680	8.703	8.726	8.749	8.773	8.796	8.819	8.842	8.865	8.889	0.232

1.00	8.912	8.935	8.959	8.982	9.006	9.029	9.053	9.076	9.100	9.123	0.235
1.01	9.147	9.171	9.194	9.218	9.242	9.266	9.289	9.313	9.337	9.361	0.238
1.02	9.385	9.409	9.433	9.457	9.481	9.505	9.529	9.554	9.578	9.602	0.241
1.03	9.626	9.651	9.675	9.699	9.724	9.748	9.773	9.797	9.822	9.846	0.245
1.04	9.871	9.895	9.920	9.945	9.969	9.994	10.02	10.04	10.07	10.09	0.249
1.05	10.12	10.14	10.17	10.19	10.22	10.24	10.27	10.29	10.32	10.34	0.250
1.06	10.37	10.39	10.42	10.45	10.47	10.50	10.52	10.55	10.57	10.60	0.250
1.07	10.62	10.65	10.67	10.70	10.73	10.75	10.78	10.80	10.83	10.85	0.260
1.08	10.88	10.91	10.93	10.96	10.98	11.01	11.04	11.06	11.09	11.11	0.260
1.09	11.14	11.17	11.19	11.22	11.25	11.27	11.30	11.33	11.35	11.38	0.260
1.10	11.40	11.43	11.46	11.48	11.51	11.54	11.56	11.59	11.62	11.64	0.270
1.11	11.67	11.70	11.73	11.75	11.78	11.81	11.83	11.86	11.89	11.91	0.270
1.12	11.94	11.97	12.00	12.02	12.05	12.08	12.11	12.13	12.16	12.19	0.270
1.13	12.21	12.24	12.27	12.30	12.33	12.35	12.38	12.41	12.44	12.46	0.280
1.14	12.49	12.52	12.55	12.57	12.60	12.63	12.66	12.69	12.71	12.74	0.280

STATION NUMBER 02ZM008 WATERFORD RIVER AT KILBRIDE
SOURCE AGENCY:
LATITUDE 47.52906 LONGITUDE -52.74506
Date Processed: 02/08/2016 14:03:21 UTC-03:30 By howie.wills
Rating for Discharge (m^3/s)
Created by howie.wills on 12/15/2014 @ 13:30:55 UTC, Updated by howie.wills on 12/15/2014 @ 14:20:44 UTC
Remarks: CURVE # 32 BASED ON 2014 MM RESULTS WHICH INDICATED A CHANGE BELOW GH 1.238- SLIGHT REFINEMENT ABOVE 1.238

Offset1: 0.20

EXPANDED CAQRating TABLE

Stage (m)	Discharge (m^3/s) .000	.001	.002	.003	.004	.005	.006	.007	.008	.009	DIFF IN Q PER .01 UNITS
1.15	12.77	12.80	12.83	12.86	12.88	12.91	12.94	12.97	13.00	13.03	0.280
1.16	13.05	13.08	13.11	13.14	13.17	13.20	13.23	13.25	13.28	13.31	0.290
1.17	13.34	13.37	13.40	13.43	13.46	13.48	13.51				

13.54	13.57	13.60	0.290						
	1.18		13.63	13.66	13.69	13.72	13.75	13.78	13.80
13.83	13.86	13.89	0.290						
	1.19		13.92	13.95	13.98	14.01	14.04	14.07	14.10
14.13	14.16	14.19	0.300						
	1.20		14.22	14.25	14.28	14.31	14.34	14.37	14.40
14.43	14.46	14.49	0.300						
	1.21		14.52	14.55	14.58	14.61	14.64	14.67	14.70
14.73	14.76	14.79	0.300						
	1.22		14.82	14.85	14.88	14.91	14.94	14.97	15.00
15.03	15.06	15.09	0.300						
	1.23		15.12	15.16	15.19	15.22	15.25	15.28	15.31
15.34	15.37	15.40	0.310						
	1.24		15.43	15.46	15.50	15.53	15.56	15.59	15.62
15.65	15.68	15.71	0.320						
	1.25		15.75	15.78	15.81	15.84	15.87	15.90	15.93
15.97	16.00	16.03	0.310						
	1.26		16.06	16.09	16.12	16.16	16.19	16.22	16.25
16.28	16.32	16.35	0.320						
	1.27		16.38	16.41	16.44	16.48	16.51	16.54	16.57
16.60	16.64	16.67	0.320						
	1.28		16.70	16.73	16.77	16.80	16.83	16.86	16.90
16.93	16.96	16.99	0.330						
	1.29		17.03	17.06	17.09	17.12	17.16	17.19	17.22
17.26	17.29	17.32	0.320						
	1.30		17.35	17.39	17.42	17.45	17.49	17.52	17.55
17.59	17.62	17.65	0.340						
	1.31		17.69	17.72	17.75	17.79	17.82	17.85	17.89
17.92	17.95	17.99	0.330						
	1.32		18.02	18.05	18.09	18.12	18.16	18.19	18.22
18.26	18.29	18.32	0.340						
	1.33		18.36	18.39	18.43	18.46	18.49	18.53	18.56
18.60	18.63	18.67	0.340						
	1.34		18.70	18.73	18.77	18.80	18.84	18.87	18.91
18.94	18.98	19.01	0.340						
	1.35		19.04	19.08	19.11	19.15	19.18	19.22	19.25
19.29	19.32	19.36	0.350						
	1.36		19.39	19.43	19.46	19.50	19.53	19.57	19.60
19.64	19.67	19.71	0.350						
	1.37		19.74	19.78	19.81	19.85	19.89	19.92	19.96
19.99	20.03	20.06	0.360						
	1.38		20.10	20.13	20.17	20.21	20.24	20.28	20.31
20.35	20.38	20.42	0.360						
	1.39		20.46	20.49	20.53	20.56	20.60	20.64	20.67
20.71	20.74	20.78	0.360						
	1.40		20.82	20.85	20.89	20.93	20.96	21.00	21.03
21.07	21.11	21.14	0.360						
	1.41		21.18	21.22	21.25	21.29	21.33	21.36	21.40
21.44	21.47	21.51	0.370						
	1.42		21.55	21.59	21.62	21.66	21.70	21.73	21.77
21.81	21.84	21.88	0.370						
	1.43		21.92	21.96	21.99	22.03	22.07	22.11	22.14
22.18	22.22	22.26	0.370						
	1.44		22.29	22.33	22.37	22.41	22.44	22.48	22.52
22.56	22.60	22.63	0.380						
	1.45		22.67	22.71	22.75	22.78	22.82	22.86	22.90
22.94	22.98	23.01	0.380						

Stage	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009	DIFF IN Q PER .01 UNITS
1.46	23.05	23.09	23.13	23.17	23.20	23.24	23.28	23.32	23.36	23.40	0.390
1.47	23.44	23.47	23.51	23.55	23.59	23.63	23.67	23.71	23.75	23.78	0.380
1.48	23.82	23.86	23.90	23.94	23.98	24.02	24.06	24.10	24.14	24.17	0.390
1.49	24.21	24.25	24.29	24.33	24.37	24.41	24.45	24.49	24.53	24.57	0.400
1.50	24.61	24.65	24.69	24.73	24.77	24.81	24.85	24.88	24.92	24.96	0.390
1.51	25.00	25.04	25.08	25.12	25.16	25.20	25.24	25.28	25.32	25.36	0.400
1.52	25.40	25.45	25.49	25.53	25.57	25.61	25.65	25.69	25.73	25.77	0.410
1.53	25.81	25.85	25.89	25.93	25.97	26.01	26.05	26.09	26.13	26.18	0.410
1.54	26.22	26.26	26.30	26.34	26.38	26.42	26.46	26.50	26.54	26.59	0.410

STATION NUMBER 02ZM008 WATERFORD RIVER AT KILBRIDE

SOURCE AGENCY:

LATITUDE 47.52906 LONGITUDE -52.74506

Date Processed: 02/08/2016 14:03:21 UTC-03:30 By howie.wills

Rating for Discharge (m^3/s)

Created by howie.wills on 12/15/2014 @ 13:30:55 UTC, Updated by howie.wills on 12/15/2014 @ 14:20:44 UTC

Remarks: CURVE # 32 BASED ON 2014 MM RESULTS WHICH INDICATED A CHANGE BELOW GH 1.238- SLIGHT REFINEMENT ABOVE 1.238

Offset1: 0.20

EXPANDED CAQRating TABLE

Stage (m)	Discharge (m^3/s) .000	.001	.002	.003	.004	.005	.006	.007	.008	.009	DIFF IN Q PER .01 UNITS
1.55	26.63	26.67	26.71	26.75	26.79	26.83	26.87	26.92	26.96	27.00	0.410
1.56	27.04	27.08	27.12	27.16	27.21	27.25	27.29	27.33	27.37	27.42	0.420
1.57	27.46	27.50	27.54	27.58	27.62	27.67	27.71	27.75	27.79	27.84	0.420
1.58	27.88	27.92	27.96	28.00	28.05	28.09	28.13	28.17	28.22	28.26	0.420
1.59	28.30	28.34	28.39	28.43	28.47	28.51	28.56	28.60	28.64	28.69	0.430
1.60	28.73	28.77	28.81	28.86	28.90	28.94	28.99	29.03	29.07	29.12	0.430
1.61	29.16	29.20	29.24	29.29	29.33	29.37	29.42	29.46	29.51	29.55	0.430
1.62	29.59	29.64	29.68	29.72	29.77	29.81	29.85	29.90	29.94	29.99	0.440
1.63	30.03	30.07	30.12	30.16	30.20	30.25	30.29	30.34	30.38	30.43	0.440

1.64	30.47	30.51	30.56	30.60	30.65	30.69	30.74	30.78	30.82	30.87	0.440
1.65	30.91	30.96	31.00	31.05	31.09	31.14	31.18	31.23	31.27	31.32	0.450
1.66	31.36	31.40	31.45	31.49	31.54	31.58	31.63	31.67	31.72	31.77	0.450
1.67	31.81	31.86	31.90	31.95	31.99	32.04	32.08	32.13	32.17	32.22	0.450
1.68	32.26	32.31	32.36	32.40	32.45	32.49	32.54	32.58	32.63	32.68	0.460
1.69	32.72	32.77	32.81	32.86	32.90	32.95	33.00	33.04	33.09	33.14	0.460
1.70	33.18	33.23	33.27	33.32	33.37	33.41	33.46	33.51	33.55	33.60	0.470
1.71	33.65	33.69	33.74	33.78	33.83	33.88	33.92	33.97	34.02	34.07	0.460
1.72	34.11	34.16	34.21	34.25	34.30	34.35	34.39	34.44	34.49	34.54	0.470
1.73	34.58	34.63	34.68	34.72	34.77	34.82	34.87	34.91	34.96	35.01	0.480
1.74	35.06	35.10	35.15	35.20	35.25	35.29	35.34	35.39	35.44	35.49	0.470
1.75	35.53	35.58	35.63	35.68	35.72	35.77	35.82	35.87	35.92	35.97	0.480
1.76	36.01	36.06	36.11	36.16	36.21	36.26	36.30	36.35	36.40	36.45	0.490
1.77	36.50	36.55	36.59	36.64	36.69	36.74	36.79	36.84	36.89	36.94	0.480
1.78	36.98	37.03	37.08	37.13	37.18	37.23	37.28	37.33	37.38	37.43	0.490
1.79	37.47	37.52	37.57	37.62	37.67	37.72	37.77	37.82	37.87	37.92	0.500
1.80	37.97	38.02	38.07	38.12	38.17	38.22	38.27	38.32	38.37	38.42	0.500
1.81	38.47	38.52	38.57	38.62	38.67	38.72	38.77	38.82	38.87	38.92	0.500
1.82	38.97	39.02	39.07	39.12	39.17	39.22	39.27	39.32	39.37	39.42	0.500
1.83	39.47	39.52	39.57	39.62	39.67	39.72	39.77	39.83	39.88	39.93	0.510
1.84	39.98	40.03	40.08	40.13	40.18	40.23	40.28	40.33	40.39	40.44	0.510
1.85	40.49	40.54	40.59	40.64	40.69	40.74	40.80	40.85	40.90	40.95	0.510
1.86	41.00	41.05	41.11	41.16	41.21	41.26	41.31	41.36	41.42	41.47	0.520
1.87	41.52	41.57	41.62	41.68	41.73	41.78	41.83	41.88	41.94	41.99	0.520
1.88	42.04	42.09	42.15	42.20	42.25	42.30	42.35	42.41	42.46	42.51	0.520
1.89	42.56	42.62	42.67	42.72	42.78	42.83	42.88	42.93	42.99	43.04	0.530
1.90	43.09	43.15	43.20	43.25	43.30	43.36	43.41	43.46	43.52	43.57	0.530
1.91	43.62	43.68	43.73	43.78	43.84	43.89	43.94	44.00	44.05	44.10	0.540
1.92	44.16	44.21	44.26	44.32	44.37	44.43	44.48				

Stage (m)	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009	DIFF IN Q PER .01 UNITS
								44.53	44.59	44.64	0.540
1.93	44.70	44.75	44.80	44.86	44.91	44.97	45.02	45.07	45.13	45.18	0.540
1.94	45.24	45.29	45.34	45.40	45.45	45.51	45.56	45.62	45.67	45.73	0.540

STATION NUMBER 02ZM008 WATERFORD RIVER AT KILBRIDE
SOURCE AGENCY:
LATITUDE 47.52906 LONGITUDE -52.74506
Date Processed: 02/08/2016 14:03:21 UTC-03:30 By howie.wills
Rating for Discharge (m^3/s)
Created by howie.wills on 12/15/2014 @ 13:30:55 UTC, Updated by howie.wills on 12/15/2014 @ 14:20:44 UTC
Remarks: CURVE # 32 BASED ON 2014 MM RESULTS WHICH INDICATED A CHANGE BELOW GH 1.238- SLIGHT REFINEMENT ABOVE 1.238

Offset1: 0.20

EXPANDED CAQRating TABLE

Stage (m)	Discharge (m^3/s) .000	.001	.002	.003	.004	.005	.006	.007	.008	.009	DIFF IN Q PER .01 UNITS
1.95	45.78	45.84	45.89	45.94	46.00	46.05	46.11	46.16	46.22	46.27	0.550
1.96	46.33	46.38	46.44	46.49	46.55	46.60	46.66	46.71	46.77	46.82	0.550
1.97	46.88	46.93	46.99	47.05	47.10	47.16	47.21	47.27	47.32	47.38	0.550
1.98	47.43	47.49	47.55	47.60	47.66	47.71	47.77	47.82	47.88	47.94	0.560
1.99	47.99	48.05	48.10	48.16	48.22	48.27	48.33	48.38	48.44	48.50	0.560
2.00	48.55	48.61	48.67	48.72	48.78	48.84	48.89	48.95	49.00	49.06	0.570
2.01	49.12	49.17	49.23	49.29	49.34	49.40	49.46	49.52	49.57	49.63	0.570
2.02	49.69	49.74	49.80	49.86	49.91	49.97	50.03	50.09	50.14	50.20	0.570
2.03	50.26	50.32	50.37	50.43	50.49	50.54	50.60	50.66	50.72	50.78	0.570
2.04	50.83	50.89	50.95	51.01	51.06	51.12	51.18	51.24	51.30	51.35	0.580
2.05	51.41	51.47	51.53	51.59	51.64	51.70	51.76	51.82	51.88	51.93	0.580
2.06	51.99	52.05	52.11	52.17	52.23	52.28	52.34	52.40	52.46	52.52	0.590
2.07	52.58	52.64	52.70	52.75	52.81	52.87	52.93	52.99	53.05	53.11	0.590
2.08	53.17	53.23	53.28	53.34	53.40	53.46	53.52	53.58	53.64	53.70	0.590
2.09	53.76	53.82	53.88	53.94	54.00	54.06	54.12	54.17	54.23	54.29	0.590

2.10	54.35	54.41	54.47	54.53	54.59	54.65	54.71	54.77	54.83	54.89	0.600
2.11	54.95	55.01	55.07	55.13	55.19	55.25	55.31	55.37	55.43	55.49	0.600
2.12	55.55	55.61	55.68	55.74	55.80	55.86	55.92	55.98	56.04	56.10	0.610
2.13	56.16	56.22	56.28	56.34	56.40	56.46	56.53	56.59	56.65	56.71	0.610
2.14	56.77	56.83	56.89	56.95	57.01	57.07	57.14	57.20	57.26	57.32	0.610
2.15	57.38	57.44	57.50	57.57	57.63	57.69	57.75	57.81	57.87	57.94	0.620
2.16	58.00	58.06	58.12	58.18	58.24	58.31	58.37	58.43	58.49	58.55	0.620
2.17	58.62	58.68	58.74	58.80	58.87	58.93	58.99	59.05	59.11	59.18	0.620
2.18	59.24	59.30	59.36	59.43	59.49	59.55	59.61	59.68	59.74	59.80	0.630
2.19	59.87	59.93	59.99	60.05	60.12	60.18	60.24	60.31	60.37	60.43	0.620
2.20	60.49	60.56	60.62	60.68	60.75	60.81	60.87	60.94	61.00	61.06	0.640
2.21	61.13	61.19	61.25	61.32	61.38	61.45	61.51	61.57	61.64	61.70	0.630
2.22	61.76	61.83	61.89	61.96	62.02	62.08	62.15	62.21	62.28	62.34	0.640
2.23	62.40	62.47	62.53	62.60	62.66	62.72	62.79	62.85	62.92	62.98	0.650
2.24	63.05	63.11	63.18	63.24	63.31	63.37	63.43	63.50	63.56	63.63	0.640
2.25	63.69	63.76	63.82	63.89	63.95	64.02	64.08	64.15	64.21	64.28	0.650
2.26	64.34	64.41	64.47	64.54	64.60	64.67	64.74	64.80	64.87	64.93	0.660
2.27	65.00	65.06	65.13	65.19	65.26	65.33	65.39	65.46	65.52	65.59	0.650
2.28	65.65	65.72	65.79	65.85	65.92	65.98	66.05	66.12	66.18	66.25	0.660
2.29	66.31	66.38	66.45	66.51	66.58	66.65	66.71	66.78	66.85	66.91	0.670
2.30	66.98	67.04	67.11	67.18	67.24	67.31	67.38	67.44	67.51	67.58	0.670
2.31	67.65	67.71	67.78	67.85	67.91	67.98	68.05	68.11	68.18	68.25	0.670
2.32	68.32	68.38	68.45	68.52	68.59	68.65	68.72	68.79	68.85	68.92	0.670
2.33	68.99*	69.06	69.13	69.19	69.26	69.33	69.40	69.46	69.53	69.60	0.680
2.34	69.67	69.74	69.80	69.87	69.94	70.01	70.08	70.14	70.21	70.28	0.680

02ZM008_Curve#32_rec'd from HWills 8-Feb-16
Created by howie.wills on 12/15/2014 @ 13:30:55 UTC,
Updated by howie.wills on 12/15/2014 @ 14:20:44 UTC
Remarks: CURVE # 32 BASED ON 2014 MM RESULTS WHICH INDICATED A CHANGE BELOW GH 1.238- SLIGHT REFINEMENT ABOVE 1.238

Offset1: 0.20

EXPANDED CAQRating TABLE

Stage (m)	Discharge (m^3/s) .000	.001	.002	.003	.004	.005	.006	.007	.008	.009	DIFF IN Q PER .01 UNITS
2.35	70.35	70.42	70.49	70.55	70.62	70.69	70.76	70.83	70.90	70.96	0.680
2.36	71.03	71.10	71.17	71.24	71.31	71.38	71.45	71.51	71.58	71.65	0.690
2.37	71.72	71.79	71.86	71.93	72.00	72.07	72.13	72.20	72.27	72.34	0.690
2.38	72.41	72.48	72.55	72.62	72.69	72.76	72.83	72.90	72.97	73.04	0.700
2.39	73.11	73.18	73.25	73.32	73.39	73.46	73.53	73.59	73.66	73.73	0.690
2.40	73.80	73.87	73.94	74.01	74.08	74.16	74.23	74.30	74.37	74.44	0.710
2.41	74.51	74.58	74.65	74.72	74.79	74.86	74.93	75.00	75.07	75.14	0.700
2.42	75.21	75.28	75.35	75.42	75.49	75.57	75.64	75.71	75.78	75.85	0.710
2.43	75.92	75.99	76.06	76.13	76.20	76.28	76.35	76.42	76.49	76.56	0.710
2.44	76.63	76.70	76.77	76.85	76.92	76.99	77.06	77.13	77.20	77.28	0.720
2.45	77.35	77.42	77.49	77.56	77.63	77.71	77.78	77.85	77.92	77.99	0.720
2.46	78.07	78.14	78.21	78.28	78.35	78.43	78.50	78.57	78.64	78.72	0.720
2.47	78.79	78.86	78.93	79.01	79.08	79.15	79.22	79.30	79.37	79.44	0.720
2.48	79.51	79.59	79.66	79.73	79.81	79.88	79.95	80.02	80.10	80.17	0.730
2.49	80.24	80.32	80.39	80.46	80.54	80.61	80.68	80.76	80.83	80.90	0.740
2.50	80.98	81.05	81.12	81.20	81.27	81.34	81.42	81.49	81.56	81.64	0.730
2.51	81.71	81.79	81.86	81.93	82.01	82.08	82.16	82.23	82.30	82.38	0.740
2.52	82.45	82.53	82.60	82.67	82.75	82.82	82.90	82.97	83.05	83.12	0.740
2.53	83.19	83.27	83.34	83.42	83.49	83.57	83.64	83.72	83.79	83.87	0.750
2.54	83.94	84.02	84.09	84.17	84.24	84.32	84.39	84.47	84.54	84.62	0.750
2.55	84.69	84.77	84.84	84.92	84.99	85.07	85.14	85.22	85.29	85.37	0.750
2.56	85.44	85.52	85.60	85.67	85.75	85.82	85.90				

								85.97	86.05	86.13	0.760
2.57	86.20	86.28	86.35	86.43	86.51	86.58	86.66	86.73	86.81	86.89	0.760
2.58	86.96	87.04	87.11	87.19	87.27	87.34	87.42	87.50	87.57	87.65	0.770
2.59	87.73	87.80	87.88	87.96	88.03	88.11	88.19	88.26	88.34	88.42	0.760
2.60	88.49	88.57	88.65	88.72	88.80	88.88	88.96	89.03	89.11	89.19	0.770
2.61	89.26	89.34	89.42	89.50	89.57	89.65	89.73	89.81	89.88	89.96	0.780
2.62	90.04	90.12	90.19	90.27	90.35	90.43	90.50	90.58	90.66	90.74	0.780
2.63	90.82	90.89	90.97	91.05	91.13	91.21	91.28	91.36	91.44	91.52	0.780
2.64	91.60	91.68	91.75	91.83	91.91	91.99	92.07	92.15	92.23	92.30	0.780
2.65	92.38	92.46	92.54	92.62	92.70	92.78	92.85	92.93	93.01	93.09	0.790
2.66	93.17	93.25	93.33	93.41	93.49	93.57	93.65	93.72	93.80	93.88	0.790
2.67	93.96	94.04	94.12	94.20	94.28	94.36	94.44	94.52	94.60	94.68	0.800
2.68	94.76	94.84	94.92	95.00	95.08	95.16	95.24	95.32	95.40	95.48	0.800
2.69	95.56	95.64	95.72	95.80	95.88	95.96	96.04	96.12	96.20	96.28	0.800
2.70	96.36	96.44	96.52	96.60	96.68	96.76	96.84	96.92	97.00	97.08	0.800
2.71	97.16	97.24	97.33	97.41	97.49	97.57	97.65	97.73	97.81	97.89	0.810
2.72	97.97	98.05	98.14	98.22	98.30	98.38	98.46	98.54	98.62	98.70	0.820
2.73	98.79	98.87	98.95	99.03	99.11	99.19	99.27	99.36	99.44	99.52	0.810
2.74	99.60	99.68	99.77	99.85	99.93	100.0	100.1	100.2	100.3	100.3	0.800

STATION NUMBER 02ZM008 WATERFORD RIVER AT KILBRIDE
SOURCE AGENCY:
LATITUDE 47.52906 LONGITUDE -52.74506
Date Processed: 02/08/2016 14:03:21 UTC-03:30 By howie.wills
Rating for Discharge (m^3/s)
Created by howie.wills on 12/15/2014 @ 13:30:55 UTC, Updated by howie.wills on 12/15/2014 @ 14:20:44 UTC
Remarks: CURVE # 32 BASED ON 2014 MM RESULTS WHICH INDICATED A CHANGE BELOW GH 1.238- SLIGHT REFINEMENT ABOVE 1.238

Offset1: 0.20

EXPANDED CAQRating TABLE

Stage (m) Discharge (m^3/s)
DIFF IN Q PER
.000 .001 .002 .003 .004 .005 .006 .007 .008 .009 .01 UNITS

2.75	100.4	100.5	100.6	100.7	100.7	100.8	100.9	101.0	101.1	101.2	0.800
2.76	101.2	101.3	101.4	101.5	101.6	101.7	101.7	101.8	101.9	102.0	0.900
2.77	102.1	102.2	102.2	102.3	102.4	102.5	102.6	102.7	102.7	102.8	0.800
2.78	102.9	103.0	103.1	103.2	103.2	103.3	103.4	103.5	103.6	103.7	0.800
2.79	103.7	103.8	103.9	104.0	104.1	104.2	104.2	104.3	104.4	104.5	0.900
2.80	104.6	104.7	104.7	104.8	104.9	105.0	105.1	105.2	105.2	105.3	0.800
2.81	105.4	105.5	105.6	105.7	105.7	105.8	105.9	106.0	106.1	106.2	0.900
2.82	106.3	106.3	106.4	106.5	106.6	106.7	106.8	106.8	106.9	107.0	0.800
2.83	107.1	107.2	107.3	107.4	107.4	107.5	107.6	107.7	107.8	107.9	0.900
2.84	108.0	108.0	108.1	108.2	108.3	108.4	108.5	108.6	108.6	108.7	0.800
2.85	108.8	108.9	109.0	109.1	109.2	109.2	109.3	109.4	109.5	109.6	0.900
2.86	109.7	109.8	109.8	109.9	110.0	110.1	110.2	110.3	110.4	110.4	0.800
2.87	110.5	110.6	110.7	110.8	110.9	111.0	111.0	111.1	111.2	111.3	0.900
2.88	111.4	111.5	111.6	111.7	111.7	111.8	111.9	112.0	112.1	112.2	0.900
2.89	112.3	112.3	112.4	112.5	112.6	112.7	112.8	112.9	113.0	113.0	0.800
2.90	113.1	113.2	113.3	113.4	113.5	113.6	113.7	113.7	113.8	113.9	0.900
2.91	114.0	114.1	114.2	114.3	114.4	114.4	114.5	114.6	114.7	114.8	0.900
2.92	114.9	115.0	115.1	115.2	115.2	115.3	115.4	115.5	115.6	115.7	0.900
2.93	115.8	115.9	115.9	116.0	116.1	116.2	116.3	116.4	116.5	116.6	0.900
2.94	116.7	116.7	116.8	116.9	117.0	117.1	117.2	117.3	117.4	117.5	0.800
2.95	117.5	117.6	117.7	117.8	117.9	118.0	118.1	118.2	118.3	118.4	0.900
2.96	118.4	118.5	118.6	118.7	118.8	118.9	119.0	119.1	119.2	119.2	0.900
2.97	119.3	119.4	119.5	119.6	119.7	119.8	119.9	120.0	120.1	120.1	0.900
2.98	120.2	120.3	120.4	120.5	120.6	120.7	120.8	120.9	121.0	121.0	0.900
2.99	121.1	121.2	121.3	121.4	121.5	121.6	121.7	121.8	121.9	122.0	0.900
3.00	122.0	122.1	122.2	122.3	122.4	122.5	122.6	122.7	122.8	122.9	1.000
3.01	123.0	123.0	123.1	123.2	123.3	123.4	123.5	123.6	123.7	123.8	0.900
3.02	123.9	124.0	124.1	124.1	124.2	124.3	124.4	124.5	124.6	124.7	0.900

3.03 124.8*

"*" indicates a rating descriptor point

```
  ID          Starting Date                       Ending Date               Aging
Comments
  ----  ------------------------        ------------------------        -----
----------------------
32.000  2014-01-26 17:45:00 [UTC-03:30]                                       3
CURVE # 32 BASED ON 2014 MM RESULTS WHICH INDICATED A CHANGE BELOW GH 1.238- SLIGHT
REFINEMENT ABOVE 1.238
```

APPENDIX D

Structure Data Sheets

Bridge Data Sheet

Date of Survey: 17-Jun-16

Bridge No.:	BP26-BP27	Underside of Deck Elevation:	108.4 m
River:	Branscombe's Pond River	Top of Deck Elevation:	108.5 m
Location:	Branscombe's Pond	Height (underside of bridge to river):	0.7 m
GPS Coordinates:	5265163.7, 320998.9		
Span:	2.4 m	No. of Piers:	0
Length (parrallel to river):	2.3 m	Width of Pier:	N/A mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Small wooden footbridge

Channel Conditions:

U/S:	Alignment:	Open area, channel not well-defined	Substrate:	Earth material with some vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material with some vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	17-Jun-16			
Culvert No.:	BP22-BP23	Inlet Configuration:	Square	
River:	Branscombe's Pond River	Top Elevation:	109.1	m
Location:	Goldeneye Pl	Headwall Material:	Concrete	
GPS Coordinates:	5265115.1, 321028.3	Wingwall Angle:	45	Deg (approx.)
Shape:	Pipe Arch	Upstream Invert Elevation:	106.5	m
Measured Size (m):	1.35 (span) x 1.00 (rise)	Downstream Invert Elevation:	106.1	m
Material:	CMP	Length:	30.6	m
No. of Barrels:	1			

Comments:

Condition: Culvert shows no sign of deterioration or deformation
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Light grass/brush	Right Bank:	Light brush/trees
	Left Floodplain:	Light brush/trees	Right Floodplain:	Light brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
	Left Floodplain:	Light brush/trees	Right Floodplain:	Light brush/trees

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey: 17-Jun-16

Bridge No.: BP18-BP19
River: Branscombe's Pond River
Location: Goldeneye Pl Playground
GPS Coordinates: 5265050.9, 321065.4

Underside of Deck Elevation: 105.2 m
Top of Deck Elevation: 105.3 m
Height (underside of bridge to river): 0.4 m

Span: 1.1 m
Length (parrallel to river): 0.6 m

No. of Piers: 0
Width of Pier: N/A mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Small wooden footbridge

Channel Conditions:

U/S:

Alignment: Fairly regular, relatively straight and uniform
Left Bank: Light grass/brush
Left Floodplain: Light brush/trees
Substrate: Gravel/cobble
Right Bank: Light grass/brush
Right Floodplain: Light brush/trees

D/S:

Alignment: Fairly regular, relatively straight and uniform
Left Bank: Light grass/brush
Left Floodplain: Light brush/trees
Substrate: Gravel/cobble
Right Bank: Light grass/brush
Right Floodplain: Light brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 17-Jun-16

Culvert No.:	BP14-BP15	Inlet Configuration:	Square	
River:	Branscombe's Pond River	Top Elevation:	106.0	m
Location:	Harlequin Cres	Headwall Material:	Concrete	
GPS Coordinates:	5265021.3, 321136.4	Wingwall Angle:	45	Deg (approx.)
Shape:	Pipe Arch	Upstream Invert Elevation:	104.0	m
Measured Size (m):	1.35 (span) x 1.00 (rise)	Downstream Invert Elevation:	103.3	m
Material:	CMP	Length:	30.3	m
No. of Barrels:	1			

Comments:

Condition: Culvert shows no sign of deterioration or deformation
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light grass/brush	Right Bank:	Light brush/trees
	Left Floodplain:	Light brush/trees	Right Floodplain:	Light brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light grass/brush	Right Bank:	No to sparse vegetation
	Left Floodplain:	Light brush/trees	Right Floodplain:	Light brush/trees

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey: 17-Jun-16

Bridge No.:	BP6-BP7	Underside of Deck Elevation:	85.8 m
River:	Branscombe's Pond River	Top of Deck Elevation:	85.9 m
Location:	Dunn's Rd - Greenwood Cr	Height (underside of bridge to river):	1.5 m
GPS Coordinates:	5264862.3, 321457.1		
Span:	14.0 m	No. of Piers:	0
Length (parrallel to river):	2.0 m	Width of Pier:	N/A mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Steel footbridge

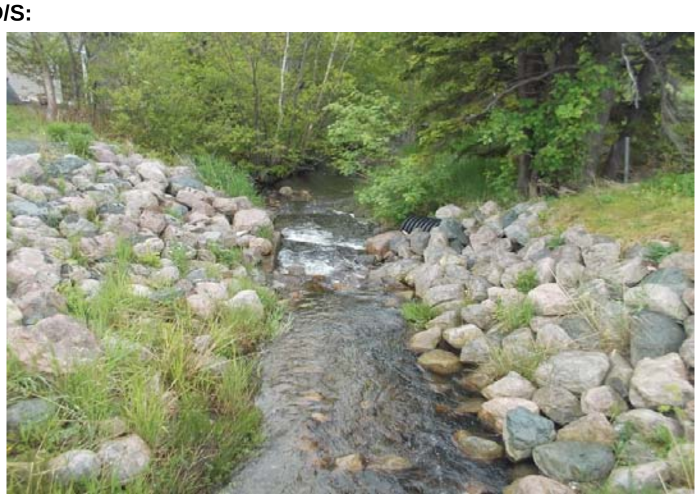
Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	No to sparse vegetation (boulders)	Right Bank:	No to sparse vegetation (boulders)
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	No to sparse vegetation (boulders)	Right Bank:	No to sparse vegetation (boulders)
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush

Photos:

U/S:

D/S:



Bridge Data Sheet

Date of Survey:	17-Jun-16		
Bridge No.:	BP2-BP3	Underside of Deck Elevation:	81.6 m
River:	Branscombe's Pond River	Top of Deck Elevation:	81.9 m
Location:	Dunn's Rd	Height (underside of bridge to river):	1.1 m
GPS Coordinates:	5264800.8, 321511.1		
Span:	9.8 m	No. of Piers:	0
Length (parrallel to river):	2.4 m	Width of Pier:	N/A mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Wooden deck on steel beams

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Gabion wall (no to sparse vegetation)	Right Bank:	Light grass/brush
Left Floodplain:	Light grass/brush (above gabions)	Right Floodplain:	Light grass/brush

D/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
Left Floodplain:	Light grass/brush	Right Floodplain:	Light brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	22-Jul-16	Inlet Configuration:	Square
Culvert No.:	UR59-60	Top Elevation:	170.0 m
River:	Donovans Tributary	Headwall Material:	Concrete
Location:	Glencoe Dr	Wingwall Angle:	30 (right only) Deg (approx)
GPS Coordinates:	316204.3, 5263696.7		
Shape:	Standard Arch	Upstream Invert Elevation:	168.0 m
Measured Size:	2.9 (span) x 1.8 (rise) m	Downstream Invert Elevation:	168.0 m
Material:	CMP	Length:	17.1 m
No. of Barrels:	1		

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:

Alignment:	Open area, channel not well-defined	Substrate:	Earth material with dense vegetation
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

D/S:

Alignment:	Open area, channel not well-defined	Substrate:	Earth material with dense vegetation
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Light brush/trees	Right Floodplain:	Light brush/trees

Photos:

U/S:


D/S:


Culvert Data Sheet

Date of Survey:	22-Jul-16			
		Inlet Configuration:	Square	
Culvert No.:	UR52.5_B - UR52.5_C	Top Elevation:	165.3	m
River:	Donovans Tributary	Headwall Material:	Concrete	
Location:	No. 134 Clyde Ave	Wingwall Angle:	30	Deg (approx)
GPS Coordinates:	316479.3, 5263973.9			
Shape:	Standard Arch	Upstream Invert Elevation:	162.9	m
Measured Size:	2.4 (span) x 1.4 (rise) m	Downstream Invert Elevation:	162.9	m
Material:	CMP	Length:	9.9	m
No. of Barrels:	1			

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with some vegetation
	Left Bank:	No to sparse vegetation (sloped)	Right Bank:	No to sparse vegetation (sloped)
	Left Floodplain:	Light grass/brush	Right Floodplain:	No to sparse vegetation
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with some vegetation
	Left Bank:	Light brush/trees	Right Bank:	Medium to dense brush/trees
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	22-Jul-16						
		Inlet Configuration:	Projecting from fill				
Culvert No.:	UR50-51	Top Elevation:	163.5			m	
River:	Donovans Tributary	Headwall Material:	N/A				
Location:	No. 127 Clyde Ave	Wingwall Angle:	N/A			Deg (approx)	
GPS Coordinates:	316530.6, 5264130.1						
			Left:	*Center:*	*Right:*		
Shape:	Pipe Arch						
Measured Size (m):	1.75 (span) x 1.2 (rise)	Upstream Invert Elevation:	162.0	161.9	162.2	m	
Material:	CMP	Downstream Invert Elevation:	162.0	161.9	162.0	m	
No. of Barrels:	3	Length:	9.0	9.1	9.1	m	

Comments:

Condition:	Culvert rusted, bottoms mostly intact
Date of Construction:	Unknown
Other:	

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with dense vegetation
	Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with dense vegetation
	Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	22-Jul-16					
		Inlet Configuration:	Projecting from fill			
Culvert No.:	UR47-48	Top Elevation:	163.5	m		
River:	Donovans Tributary	Headwall Material:	Rock, Wood			
Location:	No. 119 Clyde Ave	Wingwall Angle:	N/A	Deg (approx)		
GPS Coordinates:	316537.8, 5264152.5					

			Left:	*Center:*	*Right:*	
Shape:	Pipe Arch					
Measured Size:	1.8 (span) x 0.9 (rise) m	Upstream Invert Elevation:	162.1	161.8	162.0	m
Material:	CMP	Downstream Invert Elevation:	162.0	161.7	161.8	m
No. of Barrels:	3	Length:	9.2	9.2	9.3	m

Comments:

Condition: Culverts slightly deformed but intact
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Medium to dense brush/trees	Right Bank:	Medium to dense brush/trees
Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush

D/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush

Photos:

U/S:


D/S:


Culvert Data Sheet

Date of Survey:	22-Jul-16					
		Inlet Configuration:	Projecting from fill			
Culvert No.:	UR43-44	Top Elevation:	163.4			m
River:	Donovans Tributary	Headwall Material:	Rock			
Location:	No. 119 Clyde Ave	Wingwall Angle:	N/A			Deg (approx)
GPS Coordinates:	316554.0, 5264203.3					
			Left:	*Center:*	*Right:*	
Shape:	Pipe Arch					
Measured Size (m):	1.65 (span) x 1.0 (rise)	Upstream Invert Elevation:	161.6	161.6	161.5	m
Material:	CMP	Downstream Invert Elevation:	161.6	161.4	161.6	m
No. of Barrels:	3	Length:	9.1	9.1	9.1	m

Comments:

Condition:	Culverts rusted but still intact
Date of Construction:	Unknown
Other:	

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 22-Jul-16

Culvert No.: UR39-40
River: Donovans Tributary
Location: No. 117 Clyde Ave
GPS Coordinates: 316588.2, 5264307.4

Inlet Configuration: Projecting from concrete
Top Elevation: 162.6 m
Headwall Material: Concrete
Wingwall Angle: N/A Deg (approx)

Shape: Pipe Arch
Measured Size (m): 1.75 (span) x 0.9 (rise)
Material: CMP
No. of Barrels: 3

	Left:	Center:	Right:	
Upstream Invert Elevation:	161.2	160.9	161.1	m
Downstream Invert Elevation:	161.0	160.8	160.8	m
Length:	9.3	9.0	9.9	m

Comments:

Condition: Culverts slightly deformed and rusted, bottoms partially deteriorated
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:
Alignment: Fairly regular, relatively straight and uniform
Substrate: Gravel/cobble with little vegetation
Left Bank: Medium to dense brush/trees
Right Bank: Medium to dense brush/trees
Left Floodplain: Light grass/brush
Right Floodplain: Light grass/brush

D/S:
Alignment: Fairly regular, relatively straight and uniform
Substrate: Gravel/cobble with little vegetation
Left Bank: Light brush/trees
Right Bank: Light brush/trees
Left Floodplain: Light grass/brush
Right Floodplain: Light grass/brush

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	02-Nov-16	Inlet Configuration:	Mitered to concrete
Culvert No.:	UR36_B - UR36_C	Top Elevation:	159.3 m
River:	Donovans Tributary	Headwall Material:	N/A
Location:	Behind No. 103 Clyde Ave	Wingwall Angle:	N/A Deg (approx)
GPS Coordinates:	316743.0, 5264468.4		

Shape:	Circular		Left:	Center:	Right:	
Measured Size:	1.5 (span) x 1.4 (rise) m	Upstream Invert Elevation:	156.4	156.3	156.4	m
Material:	CMP	Downstream Invert Elevation:	155.8	155.8	156.1	m
No. of Barrels:	3	Length:	25.3	26.9	25.2	m

Comments:

Condition: Culverts rusted, bottoms of downstream ends are partially deteriorated
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material with little vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material with little vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	22-Jul-16					
		Inlet Configuration:	Mitered to concrete			
Culvert No.:	UR33-34	Top Elevation:	158.1			m
River:	Donovans Tributary	Headwall Material:	Concrete			
Location:	Sagona Ave near Clyde Ave	Wingwall Angle:	N/A			Deg (approx)
GPS Coordinates:	316856.7, 5264640.0					
			Left:	*Center:*	*Right:*	
Shape:	Pipe Arch					
Measured Size:	1.8 (span) x 1.1 (rise) m	Upstream Invert Elevation:	155.7	155.7	155.7	m
Material:	CMP	Downstream Invert Elevation:	155.7	155.7	155.8	m
No. of Barrels:	3	Length:	23.5	23.7	23.6	m

Comments:

Condition: Culverts rusted but still intact
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with some vegetation
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Light grass/brush

D/S:

Alignment:	Irregular, winding or sluggish	Substrate:	Gravel/cobble with dense vegetation
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	22-Jul-16	Inlet Configuration:	Square
Culvert No.:	UR29-30	Top Elevation:	154.1 m
River:	Donovans Tributary	Headwall Material:	Concrete
Location:	Clyde Ave Irving	Wingwall Angle:	N/A Deg (approx)
GPS Coordinates:	316933.3, 5264774.8		
Shape:	Standard Arch	Upstream Invert Elevation:	151.9 m
Measured Size:	4.2 (span) x 1.6 (rise) m	Downstream Invert Elevation:	151.6 m
Material:	CMP	Length:	18.0 m
No. of Barrels:	1		

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Light grass/brush (sloped)	Right Bank:	Light grass/brush (sloped)
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Light grass/brush (sloped)	Right Bank:	Light grass/brush (sloped)
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 22-Jul-16

Culvert No.: UR26-27
River: Donovans Tributary
Location: Bruce St / Clyde Ave
GPS Coordinates: 316963.8,5264813.2

Inlet Configuration: Mitered to concrete
Top Elevation: 153.0 m
Headwall Material: Concrete/Stone
Wingwall Angle: N/A Deg (approx)

Shape: Pipe Arch
Measured Size: 1.8 (span) x 1.2 (rise) m
Material: CMP
No. of Barrels: 3

	Left:	*Center:*	*Right:*	
Upstream Invert Elevation:	151.3	151.2	151.3	m
Downstream Invert Elevation:	150.5	150.5	150.6	m
Length:	75.3	73.8	71.5	m

Comments:

Condition: Culverts rusted, bottoms partially deteriorated
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:
Alignment: Fairly regular, relatively straight and uniform
Left Bank: Light grass/brush (sloped)
Left Floodplain: Light grass/brush
Substrate: Gravel/cobble with some vegetation
Right Bank: Light grass/brush (sloped)
Right Floodplain: Light grass/brush

D/S:
Alignment: Fairly regular, relatively straight and uniform
Left Bank: Light brush/trees
Left Floodplain: Medium to dense brush/trees
Substrate: Gravel/cobble with little vegetation
Right Bank: Light brush/trees
Right Floodplain: Medium to dense brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	01-Nov-16	Inlet Configuration:	Mitered to concrete
Culvert No.:	UR23_B - UR23_C	Top Elevation:	147.8 m
River:	Donovans Tributary	Headwall Material:	Concrete/Stone
Location:	Between No. 58 and 60 Clyde Ave	Wingwall Angle:	N/A Deg (approx)
GPS Coordinates:	316963.8,5264813.2		

Shape:	Pipe Arch		*Left:*	*Center:*	*Right:*	
Measured Size (m):	1.8 (span) x 1.0 (rise)	Upstream Invert Elevation:	145.6	145.8	145.6	m
Material:	CMP	Downstream Invert Elevation:	145.6	145.8	145.9	m
No. of Barrels:	3	Length:	10.6	10.3	10.7	m

Comments:

Condition: Culverts rusted, bottoms partially deteriorated
Date of Construction: Unknown
Other: Two distinct parallel channels immediately downstream

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	22-Jul-16	Inlet Configuration:	Projecting from fill
Culvert No.:	UR20-21	Top Elevation:	145.0 m
River:	Donovans Tributary	Headwall Material:	N/A
Location:	Near No. 26 Glencoe Dr	Wingwall Angle:	N/A Deg (approx)
GPS Coordinates:	316978.2, 5265146.9		

			Left:	Center:	Right:	
Shape:	Pipe Arch					
Measured Size:	1.2 (span) x 1.0 (rise) m	Upstream Invert Elevation:	143.9	144.0	144.1	m
Material:	CMP	Downstream Invert Elevation:	144.0	143.8	143.7	m
No. of Barrels:	3	Length:	21.6	21.7	21.4	m

Comments:

Condition: Culverts rusted, bottoms deteriorated
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:	Alignment:	Irregular, winding or sluggish	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:


D/S:


Culvert Data Sheet

Date of Survey:	22-Jul-16	Inlet Configuration:	Mitered to concrete		
Culvert No.:	UR14-15	Top Elevation:	142.2		m
River:	Donovans Tributary	Headwall Material:	Concrete/Stone		
Location:	Near No. 3 Glencoe Dr	Wingwall Angle:	N/A		Deg (approx)
GPS Coordinates:	317095.1, 5265430.0				

			Left:	*Center:*	*Right:*	
Shape:	Pipe Arch					
Measured Size:	1.7 (span) x 1.1 (rise) m	Upstream Invert Elevation:	140.6	140.5	140.7	m
Material:	CMP	Downstream Invert Elevation:	140.5	140.5	140.6	m
No. of Barrels:	3	Length:	13.6	13.3	13.5	m

Comments:

Condition: Culverts rusted, bottoms deteriorated
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

D/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	22-Jul-16	Inlet Configuration:	Square
Culvert No.:	UR11_A - UR11_B	Top Elevation:	141.6 m
River:	Donovans Tributary	Headwall Material:	Concrete
Location:	No. 3 Glencoe Dr (parking lot)	Wingwall Angle:	N/A Deg (approx)
GPS Coordinates:	317148.4, 5265418.0		

			Left:	Right:	
Shape:	Rectangular				
Measured Size:	2.4 (span) x 1.0 (rise) m	Upstream Invert Elevation:	140.3	140.3	m
Material:	Concrete	Downstream Invert Elevation:	139.9	139.9	m
No. of Barrels:	2	Length:	53.5	53.5	m

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Culvert runs under parking lot

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Medium to dense grass/brush (sloped)	Right Bank:	Medium to dense grass/brush (sloped)
Left Floodplain:	No to sparse vegetation (asphalt)	Right Floodplain:	No to sparse vegetation (asphalt)

D/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
Left Floodplain:	Concrete wall (asphalt above)	Right Floodplain:	Concrete wall (asphalt above)

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	22-Jul-16			
		Inlet Configuration:	Square	
Culvert No.:	UR10_A - UR10_B	Top Elevation:	141.3	m
River:	Donovans Tributary	Headwall Material:	Concrete	
Location:	No. 3 Glencoe Dr (parking lot)	Wingwall Angle:	N/A	Deg (approx)
GPS Coordinates:	317235.1, 5265393.8			

			Left:	*Right:*	
Shape:	Rectangular				
Measured Size:	2.4 (span) x 1.0 (rise) m	Upstream Invert Elevation:	139.8	139.8	m
Material:	Concrete	Downstream Invert Elevation:	139.5	139.5	m
No. of Barrels:	2	Length:	29.8	29.8	m

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Culvert runs under parking lot

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	Concrete wall (asphalt above)	Right Floodplain:	Concrete wall (asphalt above)
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light grass/brush	Right Bank:	Light brush/trees
	Left Floodplain:	Light brush/trees	Right Floodplain:	Light brush/trees

Photos:

U/S:


D/S:


Bridge Data Sheet

Date of Survey:	22-Jul-16		
Bridge No.:	UR4-5	Underside of Deck Elevation:	136.2 m
River:	Donovans Tributary	Top of Deck Elevation:	137.0 m
Location:	T'Railway near Kenmount	Height (underside of bridge to river):	1.4 m
GPS Coordinates:	317355.3, 5265616.8		
Span:	3.6 m	No. of Piers:	0
Length (parrallel to river):	7.5 m	Width of Pier:	N/A mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Concrete bridge

Channel Conditions:

U/S:

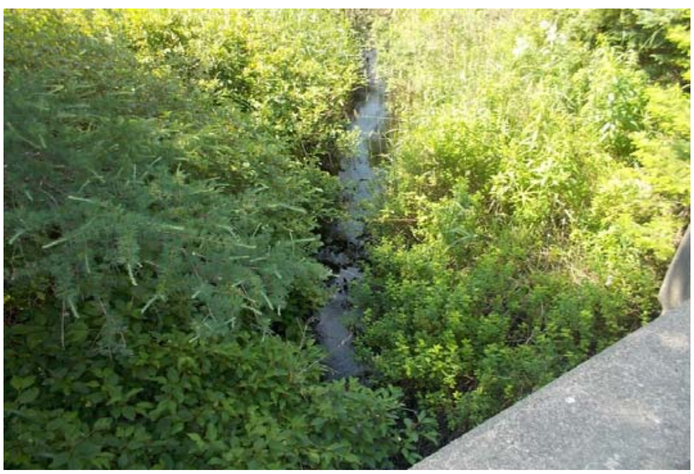
Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with some vegetation
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

D/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
Left Bank:	Wooden wall	Right Bank:	Light grass/brush
Left Floodplain:	No to sparse vegetation (above wall)	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:



D/S:

Bridge Data Sheet

Date of Survey: 22-Jul-16

Bridge No.:	UR2-3	Underside of Deck Elevation:	136.2 m
River:	Donovans Tributary	Top of Deck Elevation:	136.7 m
Location:	T'Railway near Kenmount	Height (underside of bridge to river):	1.5 m
GPS Coordinates:	317358.5, 5265624.2		
Span:	3.4 m	No. of Piers:	0
Length (parrallel to river):	2.8 m	Width of Pier:	N/A mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Wooden footbridge on steel beams

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Wooden wall	Right Bank:	Light grass/brush
	Left Floodplain:	No to sparse vegetation (above wall)	Right Floodplain:	Medium to dense brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Light brush/trees	Right Bank:	No to sparse vegetation
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Light brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 04-Jul-16

Culvert No.:	KB57-KB58	Inlet Configuration:	Projecting from fill
River:	Kilbride Brook	Top Elevation:	132.8
Location:	Ruby Line near Bay Bulls Rd	Headwall Material:	N/A
GPS Coordinates:	322055.6, 5261042.5	Wingwall Angle:	N/A

Shape:	Circular	Upstream Invert Elevation:	131.5 m
Measured Size:	0.75 dia. m	Downstream Invert Elevation:	131.2 m
Material:	Concrete	Length:	15.1 m
No. of Barrels:	1		

Comments:

Condition: Small amount of damage to top of U/S end of culvert
Date of Construction: Unknown
Other: Round hole cut in top of D/S end

Channel Conditions:

U/S:	Alignment:	Open area, channel not well-defined	Substrate:	Earth material with dense vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush
D/S:	Alignment:	Open area, channel not well-defined	Substrate:	Earth material with dense vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	30-Jun-16		
Culvert No.:	KB52-KB53	Inlet Configuration:	Projecting from fill
River:	Kilbride Brook	Top Elevation:	126.6
Location:	No. 448 Bay Bulls Rd (driveway)	Headwall Material:	N/A
GPS Coordinates:	322277.6, 5261317.9	Wingwall Angle:	N/A
Shape:	Circular	Upstream Invert Elevation:	125.3 m
Measured Size:	1.1 dia. m	Downstream Invert Elevation:	125.4 m
Material:	CMP	Length:	6.2 m
No. of Barrels:	1		

Comments:

Condition:	Bottom rusted but mostly intact
Date of Construction:	Unknown
Other:	Ends of culvert overgrown with grass

Channel Conditions:

U/S:	Alignment:	Open area, channel not well-defined	Substrate:	Earth material with dense vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush
D/S:	Alignment:	Open area, channel not well-defined	Substrate:	Earth material with dense vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 30-Jun-16

Culvert No.: KB47-KB48
River: Kilbride Brook
Location: Lundrigan Rd / Bay Bulls Rd
GPS Coordinates: 322319.8, 5261473.6

Inlet Configuration: Projecting from fill
Top Elevation: 125.5
Headwall Material: N/A
Wingwall Angle: N/A

Shape: Circular
Measured Size: 2.0 (span) x 1.1 (rise) m
Material: CMP
No. of Barrels: 1

Upstream Invert Elevation: 124.5 m
Downstream Invert Elevation: 124.4 m
Length: 12.1 m

Comments:

Condition: Top of U/S end is bent, bottom of culvert is rusted and deteriorating
Date of Construction: Unknown
Other: Ends of culvert overgrown with grass

Channel Conditions:

U/S:
Alignment: Fairly regular, relatively straight and uniform
Left Bank: Medium to dense grass/brush
Left Floodplain: Medium to dense grass/brush
Substrate: Earth material with dense vegetation
Right Bank: Medium to dense grass/brush
Right Floodplain: No to sparse vegetation (road)

D/S:
Alignment: Fairly regular, relatively straight and uniform
Left Bank: Medium to dense grass/brush
Left Floodplain: Medium to dense brush/trees
Substrate: Earth material with dense vegetation
Right Bank: Medium to dense grass/brush
Right Floodplain: No to sparse vegetation (road)

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	30-Jun-16		
Culvert No.:	KB43-KB44	Inlet Configuration:	Projecting from fill
River:	Kilbride Brook	Top Elevation:	125.9
Location:	Bay Bulls Rd near Lundrigan Rd	Headwall Material:	N/A
GPS Coordinates:	322323.8, 5261549.7	Wingwall Angle:	N/A
Shape:	Pipe Arch	Upstream Invert Elevation:	124.3 m
Measured Size:	1.9 (span) x 1.1 (rise) m	Downstream Invert Elevation:	124.2 m
Material:	CMP	Length:	18.4 m
No. of Barrels:	1		

Comments:

Condition: Bottom of culvert is rusted and deteriorated
Date of Construction: Unknown
Other: Ends of culvert overgrown with grass

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material with dense vegetation
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush (sloped)
Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	No to sparse vegetation

D/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material with some vegetation
Left Bank:	Medium to dense grass/brush (sloped)	Right Bank:	Medium to dense brush/trees
Left Floodplain:	No to sparse vegetation	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:


D/S:


Culvert Data Sheet

Date of Survey: 30-Jun-16

Culvert No.:	KB40-KB41	Inlet Configuration:	Projecting from fill
River:	Kilbride Brook	Top Elevation:	125.9
Location:	No. 381 Bay Bulls Rd (driveway)	Headwall Material:	N/A
GPS Coordinates:	322346.3, 5261568.8	Wingwall Angle:	N/A
Shape:	Circular	Upstream Invert Elevation:	124.3 m
Measured Size:	1.5 dia. m	Downstream Invert Elevation:	124.1 m
Material:	CMP	Length:	9.3 m
No. of Barrels:	1		

Comments:

Condition: Bottom of U/S end has rusted and deteriorated, D/S end is rusted but still intact
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material with some vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Light brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material with dense vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 30-Jun-16

Culvert No.:	KB36-KB37	Inlet Configuration:	Projecting from fill
River:	Kilbride Brook	Top Elevation:	125.7
Location:	No. 381 Bay Bulls Rd (driveway)	Headwall Material:	N/A
GPS Coordinates:	322359.4, 5261605.3	Wingwall Angle:	N/A
Shape:	Pipe Arch	Upstream Invert Elevation:	123.8 m
Measured Size (m):	1.65 (span) x 1.10 (rise)	Downstream Invert Elevation:	123.9 m
Material:	CMP	Length:	15.5 m
No. of Barrels:	1		

Comments:

Condition: Bottom of U/S end has rusted and deteriorated, D/S end is rusted but still intact
Date of Construction: Unknown
Other: Ends of culvert overgrown with grass

Channel Conditions:

U/S:	Alignment: Fairly regular, relatively straight and uniform		Substrate: Earth material with dense vegetation	
	Left Bank: Medium to dense grass/brush		Right Bank: Medium to dense grass/brush	
	Left Floodplain: Medium to dense grass/brush		Right Floodplain: Medium to dense grass/brush	
D/S:	Alignment: Fairly regular, relatively straight and uniform		Substrate: Earth material with dense vegetation	
	Left Bank: Medium to dense grass/brush		Right Bank: Medium to dense grass/brush	
	Left Floodplain: Medium to dense grass/brush		Right Floodplain: Medium to dense grass/brush	

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 30-Jun-16

Culvert No.:	KB32-KB33	Inlet Configuration:	Projecting from fill
River:	Kilbride Brook	Top Elevation:	124.9
Location:	No. 367 Bay Bulls Rd (driveway)	Headwall Material:	N/A
GPS Coordinates:	322381.1, 5261666.4	Wingwall Angle:	N/A
Shape:	Circular	Upstream Invert Elevation:	123.1 m
Measured Size:	1.5 dia. m	Downstream Invert Elevation:	123.4 m
Material:	CMP	Length:	6.2 m
No. of Barrels:	1		

Comments:

Condition: Bottom of U/S end has rusted and deteriorated, D/S end is rusted but still intact
Date of Construction: Unknown
Other: Ends of culvert overgrown with grass

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material with dense vegetation
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

D/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material with dense vegetation
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Light grass/brush

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 04-Jul-16

Culvert No.:	KB28-KB29	Inlet Configuration:	Projecting from fill
River:	Kilbride Brook	Top Elevation:	123.2
Location:	No. 355 Bay Bulls Rd (driveway)	Headwall Material:	N/A
GPS Coordinates:	322424.5, 5261780.9	Wingwall Angle:	N/A
Shape:	Circular	Upstream Invert Elevation:	121.4 m
Measured Size:	1.46 dia. m	Downstream Invert Elevation:	121.8 m
Material:	CMP	Length:	6.3 m
No. of Barrels:	1		

Comments:

Condition: Both ends are rusted and culvert bottom has deteriorated
Date of Construction: Unknown
Other: Rock buildup in bottom of culvert

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material with dense vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush
D/S:	Alignment:	Irregular, winding or sluggish	Substrate:	Earth material with dense vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 04-Jul-16

Culvert No.: KB23-KB24
River: Kilbride Brook
Location: No. 307 Bay Bulls Rd (driveway)
GPS Coordinates: 5262052.7, 322643.4

Inlet Configuration: Square
Top Elevation: 118.2
Headwall Material: Stone
Wingwall Angle: N/A

Shape: Left: Arch, Right: Circular
Measured Size (m): Left: 1.2 (span) x 0.98 (rise)
Right: 1.3 dia.
Material: CMP
No. of Barrels: 2

	Left:	*Right:*	
Upstream Invert Elevation:	116.3	116.6	m
Downstream Invert Elevation:	116.8	116.5	m
Length:	7.6	6.4	m

Comments:

Condition: Right culvert is intact, left has significant rust and deterioration (partially filled in, little flow)
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material with some vegetation
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

D/S:

Alignment:	Open area, channel not well-defined	Substrate:	Earth material with dense vegetation
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey: 04-Jul-16

Bridge No.:	KB18-KB19		Underside of Deck Elevation:	112.5 m
River:	Kilbride Brook		Top of Deck Elevation:	113.0 m
Location:	Valleyview Rd		Height (underside of bridge to river):	1.5 m
GPS Coordinates:	5262320.9, 322852.5			
Span:	11.6 m		No. of Piers:	0
Length (parrallel to river):	15.0 m		Width of Pier:	N/A mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Concrete road bridge
45 deg. wingwalls U/S & D/S, storm drain outlets on D/S side

Channel Conditions:

U/S:

Alignment:	Irregular, winding or sluggish	Substrate:	Earth material with some vegetation
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

D/S:

Alignment:	Irregular, winding or sluggish	Substrate:	Earth material with some vegetation
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Light brush/trees	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey: 04-Jul-16

Bridge No.: KB13-KB14
River: Kilbride Brook
Location: Connollys Ln
GPS Coordinates: 5262476.1, 322787.0

Underside of Deck Elevation: 109.7 m
Top of Deck Elevation: 110.6 m
Height (underside of bridge to river): 1.5 m

Span: 9.2 m
Length (parrallel to river): 15.3 m

No. of Piers: 0
Width of Pier: N/A mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Concrete Road Bridge
	45-deg headwalls U/S & D/S, storm drain outlets on D/S side

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Light brush/trees	Right Floodplain:	Light brush/trees
D/S:	Alignment:	Open area, channel not well-defined	Substrate:	Earth material with dense vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:


D/S:



Bridge Data Sheet

Date of Survey: 04-Jul-16

Bridge No.:	KB8-KB9	Underside of Deck Elevation:	102.3 m
River:	Kilbride Brook	Top of Deck Elevation:	102.4 m
Location:	Near Bay Bulls Rd / Cape Pine St	Height (underside of bridge to river):	0.9 m
GPS Coordinates:	5262811.8, 322945.5		
Span:	7.2 m	No. of Piers:	0
Length (parrallel to river):	1.4 m	Width of Pier:	N/A mm

Comments:

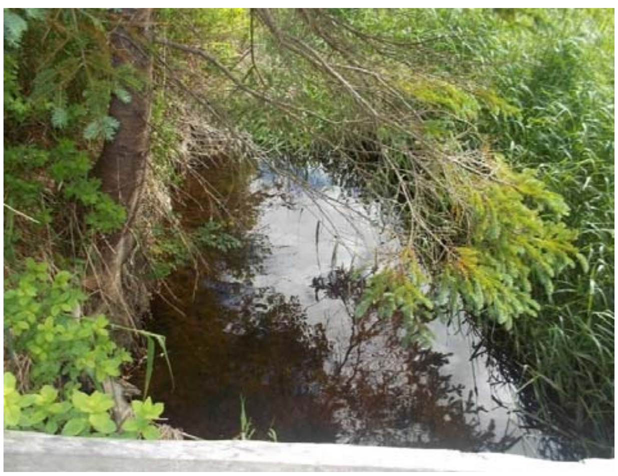
Condition: No deficiencies noted
Date of Construction: Unknown
Other: Small wooden footbridge

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material
	Left Bank:	Medium to dense grass/brush	Right Bank:	Light brush/trees
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:



D/S:

Bridge Data Sheet

Date of Survey: 08-Jul-16

Bridge No.:	KB4-KB5	Underside of Deck Elevation:	102.0 m
River:	Kilbride Brook	Top of Deck Elevation:	102.7 m
Location:	Bay Bulls Rd / Griffins Ln	Height (underside of bridge to river):	1.8 m
GPS Coordinates:	5262906.0, 322904.4		
Span:	10.0 m	No. of Piers:	0
Length (parrallel to river):	18.2 m	Width of Pier:	N/A mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Concrete road bridge, 45 deg. wingwalls
City of St. John's owned water level gauge

Channel Conditions:

U/S:

Alignment:	Open area, channel not well-defined	Substrate:	Earth material with dense vegetation
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

D/S:

Alignment:	Irregular, winding or sluggish	Substrate:	Earth material with some vegetation
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	08-Dec-15			
Bridge No.:	KB68-KB69	Underside of Deck Elevation:	82.7	m
River:	Kilbride Brook	Top of Deck Elevation:	83.4	m
Location:	Old Bay Bulls Rd / Chafes Ln	Height (underside bridge to river):	1.8	m
GPS Coordinates:	322627.7, 5263554.5			
Span:	7.3 m	No. of Piers:	0	
Length (parrallel to river):	20.0 m	Width of Pier:	N/A	mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Concrete road bridge

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light grass/brush	Right Bank:	No to sparse vegetation
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	No to sparse vegetation	Right Bank:	No to sparse vegetation
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 24-May-16

Culvert No.:	NP14-NP15	Inlet Configuration:	Square/Rock Headwall
River:	Nevilles Pond River	Top Elevation:	152.0 m
Location:	Hollyberry Dr	Headwall Material:	Rock
GPS Coordinates:	316363.8, 5265866.7	Wingwall Angle:	90 Deg (approx.)
Shape:	Pipe Arch	Upstream Invert Elevation:	149.7 m
Measured Size:	3.1 (span) x 1.8 (rise) m	Downstream Invert Elevation:	149.4 m
Material:	CMP	Length:	18.0 m
No. of Barrels:	1		

Comments:

Condition: Culvert bottom rusted but still intact
Date of Construction: Unknown
Other:

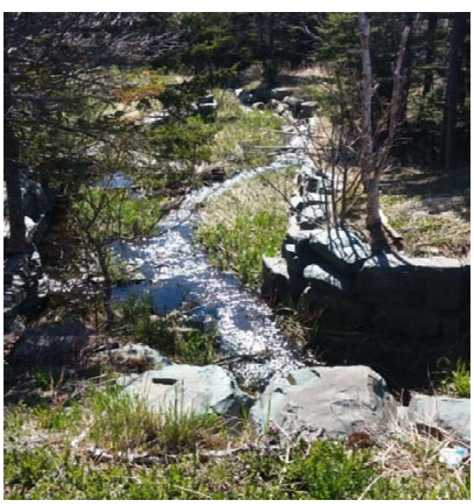
Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Rock wall	Right Bank:	Rock wall
	Left Floodplain:	Light grass/brush (above wall)	Right Floodplain:	Light grass/brush (above wall)
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	Light brush/trees	Right Floodplain:	Light brush/trees

Photos:

U/S:


D/S:




Culvert Data Sheet

Date of Survey: 24-May-16

Culvert No.:	NP10-NP11	Inlet Configuration:	Projecting from fill
River:	Nevilles Pond River	Top Elevation:	147.2 m
Location:	Trans Canada Hwy	Headwall Material:	N/A
GPS Coordinates:	316437.7, 5265843.5	Wingwall Angle:	N/A Deg (approx.)
Shape:	Circular	Upstream Invert Elevation:	144.9 m
Measured Size:	2.4 (span) x 2.3 (rise) m	Downstream Invert Elevation:	141.0 m
Material:	CMP	Length:	76.9 m
No. of Barrels:	1		

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	Light brush/trees	Right Floodplain:	Light brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 04-Oct-16

Culvert No.:	NP7-NP8	Inlet Configuration:	Projecting from fill
River:	Nevilles Pond River	Top Elevation:	141.0 m
Location:	Near Outer Ring Rd (West)	Headwall Material:	N/A
GPS Coordinates:	316500.0, 5265798.3	Wingwall Angle:	N/A Deg (approx.)
Shape:	Circular	Upstream Invert Elevation:	139.8 m
Measured Size:	0.9 dia. m	Downstream Invert Elevation:	139.7 m
Material:	CMP	Length:	18.1 m
No. of Barrels:	1		

Comments:

Condition: Culvert bottoms rusted but still intact
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
Left Floodplain:	Light brush/trees	Right Bank:	Light brush/trees

D/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	No to sparse vegetation	Right Bank:	Light grass/brush
Left Floodplain:	No to sparse vegetation	Right Floodplain:	No to sparse vegetation

Photos:

U/S:


D/S:


Culvert Data Sheet

Date of Survey: 04-Oct-16

Culvert No.:	NP2-NP3	Inlet Configuration:	Mitered to conform to slope	
River:	Nevilles Pond River	Top Elevation:	140.6	m
Location:	St Annes Cres	Headwall Material:	N/A	
GPS Coordinates:	316590.0, 5265852.5	Wingwall Angle:	N/A	Deg (approx.)

			Left:	*Right:*	
Shape:	Circular				
Measured Size (m):	Left: 1.5 dia.	Upstream Invert Elevation:	138.3	138.2	m
	Right: 1.5 dia.	Downstream Invert Elevation:	136.3	136.2	m
Material:	CMP	Length:	377.0	376.6	m
No. of Barrels:	2				

Comments:

Condition: Culvert bottoms rusted but still intact
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush

D/S:

Alignment:	Open area, channel not well-defined	Substrate:	Earth material with some vegetation
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 20-Nov-15

Culvert No.:	126-127	Inlet Configuration:	Square
River:	South Brook	Top Elevation:	155.2 m
Location:	Treetop Dr near Great Southern Dr	Headwall Material:	Brick and mortar
GPS Coordinates:	318900.3, 5261835.1	Wingwall Angle:	30 (Left), 45 (Right) Deg (approx)
Shape:	Low Profile Arch	Upstream Invert Elevation:	152.0 m
Measured Size:	6.0 (span) x 2.2 (rise) m	Downstream Invert Elevation:	151.8 m
Material:	CMP	Length:	20.9 m
No. of Barrels:	1		

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	20-Nov-15			
Bridge No.:	123-124	Underside of Deck Elevation:	153.1	m
River:	South Brook	Top of Deck Elevation:	153.5	m
Location:	Near Treetop Dr	Height (underside of bridge to river):	1.6	m
GPS Coordinates:	318925.4, 5261804.4			
Span:	6.7 m	No. of Piers:	0	
Length (parrallel to river):	1.9 m	Width of Pier:	N/A	mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Wooden footbridge, arched

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light brush/trees	Right Bank:	Medium to dense brush/trees
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	20-Nov-15			
Culvert No.:	119-120		Inlet Configuration:	Square
River:	South Brook		Top Elevation:	152.9 m
Location:	Great Southern Dr		Headwall Material:	Brick and mortar
GPS Coordinates:	319004.4, 5261828.2		Wingwall Angle:	N/A Deg (approx)
Shape:	Low Profile Arch		Upstream Invert Elevation:	150.2 m
Measured Size:	5.9 (span) x 2.0 (rise) m		Downstream Invert Elevation:	150.2 m
Material:	CMP		Length:	2.9 m
No. of Barrels:	1			

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

D/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
Left Floodplain:	Light brush/trees	Right Floodplain:	Light brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 20-Nov-15

Culvert No.:	116-117	Inlet Configuration:	Square
River:	South Brook	Top Elevation:	153.4 m
Location:	Southlands Blvd near Great Southern Dr	Headwall Material:	Concrete
GPS Coordinates:	319049.7, 5261826.9	Wingwall Angle:	45 Deg (approx)
Shape:	Open Bottom Arch	Upstream Invert Elevation:	149.1 m
Measured Size (m):	5.60 (span) x 3.65 (rise)	Downstream Invert Elevation:	149.1 m
Material:	CMP	Length:	36.0 m
No. of Barrels:	1		

Comments:

Condition: No deficieincies noted
Date of Construction: Unknown
Other: Concrete Base

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush

D/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 20-Nov-15

Culvert No.:	111-112	Inlet Configuration:	Square
River:	South Brook	Top Elevation:	147.3 m
Location:	Sprucedale Dr	Headwall Material:	Concrete
GPS Coordinates:	319322.8, 5261777.3	Wingwall Angle:	45 Deg (approx)
Shape:	Low Profile Arch	Upstream Invert Elevation:	144.8 m
Measured Size (m):	7.10 (span) x 2.15 (rise)	Downstream Invert Elevation:	144.6 m
Material:	CMP	Length:	18.1 m
No. of Barrels:	1		

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with some vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with some vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 20-Nov-15

Culvert No.:	106-107	Inlet Configuration:	Square
River:	South Brook	Top Elevation:	143.2 m
Location:	Green Acre Dr near Bulrush Ave	Headwall Material:	Concrete
GPS Coordinates:	319648.1, 5261742.4	Wingwall Angle:	45 Deg (approx)
Shape:	Low Profile Arch	Upstream Invert Elevation:	140.0 m
Measured Size:	9.1 (span) x 2.7 (rise) m	Downstream Invert Elevation:	139.8 m
Material:	CMP	Length:	25.5 m
No. of Barrels:	1		

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Flow measurement apparatus present

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	No to sparse vegetation	Right Bank:	No to sparse vegetation
	Left Floodplain:	No to sparse vegetation	Right Floodplain:	Light grass/brush

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	23-Nov-15		
Bridge No.:	100-101	Underside of Deck Elevation:	130.9 m
River:	South Brook	Top of Deck Elevation:	131.1 m
Location:	No. 55 Heavy Tree Rd	Height (underside of bridge to river):	1.3 m
GPS Coordinates:	320332.3, 5261919.0		
Span:	2.2 m	No. of Piers:	0
Length (parrallel to river):	3.6 m	Width of Pier:	N/A mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Wooden deck, abutments at approx. 45 degs, 2 steel beams on underside

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Earth/rock wall, then light brush/trees
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Light grass/brush

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	23-Nov-15			
Bridge No.:	96-97	Underside of Deck Elevation:	130.1	m
River:	South Brook	Top of Deck Elevation:	130.4	m
Location:	No. 59 Heavy Tree Rd	Height (underside of bridge to river):	1.3	m
GPS Coordinates:	320402.4, 5261929.0			
Span:	3.7 m	No. of Piers:	0	
Length (parrallel to river):	3.5 m	Width of Pier:	N/A	mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Wooden deck on steel beams, concrete abutments

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:


D/S:


Culvert Data Sheet

Date of Survey:	23-Nov-15			
Culvert No.:	92-93	Inlet Configuration:	Projecting from fill	
River:	South Brook	Top Elevation:	128.5	m
Location:	No. 75 Heavy Tree Rd	Headwall Material:	Stone blocks	
GPS Coordinates:	320533.6, 5262041.3	Wingwall Angle:	N/A	Deg (approx)

			Left:	Right:	
Shape:	Pipe Arch				
Measured Size (m):	Left: 1.47 (span) x 1.27 (rise)	Upstream Invert Elevation:	126.6	126.5	m
	Right: 1.22 (span) x 0.96 (rise)	Downstream Invert Elevation:	126.4	126.4	m
Material:	CMP	Length:	24.0	24.7	m
No. of Barrels:	2				

Comments:

Condition: Bottom of left culvert has rusted and deteriorated. Right culvert is rusted but still intact
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense brush/trees
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:


D/S:


Bridge Data Sheet

Date of Survey:	23-Nov-15			
Bridge No.:	88-89	Underside of Deck Elevation:	127.0	m
River:	South Brook	Top of Deck Elevation:	127.4	m
Location:	No. 78 Heavy Tree Rd	Height (underside of bridge to river):	1.6	m
GPS Coordinates:	320612.2, 5262068.3			
Span:	5.3 m	No. of Piers:	0	
Length (parrallel to river):	5.3 m	Width of Pier:	N/A	mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Small open-bottom concrete bridge

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense brush/trees	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense brush/trees	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	23-Nov-15				
Culvert No.:	83-84	Inlet Configuration:	Projecting from fill		
River:	South Brook	Top Elevation:	125.1		m
Location:	Robert E Howlett Memorial Dr	Headwall Material:	N/A		
GPS Coordinates:	320748.0, 5262277.1	Wingwall Angle:	N/A		Deg (approx)
Shape:	Circular		*Left:*	*Right:*	
Measured Size:	Left: 2.0 dia. m	Upstream Invert Elevation:	122.8	122.8	m
	Right: 2.0 dia. m	Downstream Invert Elevation:	122.4	122.3	m
Material:	CMP	Length:	39.2	39.7	m
No. of Barrels:	2				

Comments:

Condition: Culvert bottoms are rusted but still intact
Date of Construction: Unknown
Other: Concrete weir just upstream from culverts

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Light grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	No to sparse vegetation	Right Floodplain:	Light grass/brush

D/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey: 23-Nov-15

Bridge No.:	76-77	Underside of Deck Elevation:	95.2	m
River:	South Brook	Top of Deck Elevation:	96.2	m
Location:	Pearltown Rd	Height (underside of bridge to river):	2.2	m
GPS Coordinates:	321939.1, 5262962.7			
Span:	7.8 m	No. of Piers:	0	
Length (parrallel to river):	12.4 m	Width of Pier:	N/A	mm

Comments:

Condition: New
Date of Construction: 2016
Other: Concrete road bridge

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	08-Dec-15		
Bridge No.:	65-66	Underside of Deck Elevation:	85.0 m
River:	South Brook	Top of Deck Elevation:	86.5 m
Location:	Pitts Memorial Dr / Chafes Ln	Height (underside bridge to river):	4.8 m
GPS Coordinates:	322551.1, 5263605.4		
Span:	21.1 m	No. of Piers:	0
Length (parrallel to river):	13.1 m	Width of Pier:	N/A mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Concrete highway bridge

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	Light grass/brush	Right Floodplain:	No to sparse vegetation
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	No to sparse vegetation	Right Bank:	Light grass/brush
	Left Floodplain:	No to sparse vegetation	Right Floodplain:	No to sparse vegetation

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	08-Dec-15			
Bridge No.:	63-64	Underside of Deck Elevation:	85.0	m
River:	South Brook	Top of Deck Elevation:	86.5	m
Location:	Pitts Memorial Dr / Chafes Ln	Height (underside bridge to river):	5.0	m
GPS Coordinates:	322539.2, 5263621.1			
Span:	21.0 m	No. of Piers:	0	
Length (parrallel to river):	13.2 m	Width of Pier:	N/A	mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Concrete highway bridge

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	No to sparse vegetation	Right Bank:	Light grass/brush
	Left Floodplain:	No to sparse vegetation	Right Floodplain:	No to sparse vegetation
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	No to sparse vegetation	Right Bank:	Light grass/brush
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	No to sparse vegetation

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	24-Nov-15		
Bridge No.:	58-59	Underside of Deck Elevation:	62.8 m
River:	South Brook	Top of Deck Elevation:	63.0 m
Location:	Bowring Park	Height (underside of bridge to river):	4.4 m
GPS Coordinates:	323218.4, 5264315.2		
Span:	21.2 m	No. of Piers:	0
Length (parrallel to river):	1.8 m	Width of Pier:	N/A mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Steel footbridge, concrete abutments

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light brush/trees	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense brush/trees	Right Bank:	No to sparse vegetation
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	24-Nov-15			
Culvert No.:	51-52	Inlet Configuration:	Square	
River:	South Brook	Top Elevation:	38.1	m
Location:	Bowring Park	Headwall Material:	Cobblestone	
GPS Coordinates:	323878.5, 5265287.4	Wingwall Angle:	90	Deg (approx)
Shape:	Low Profile Arch	Upstream Invert Elevation:	34.9	m
Measured Size (m):	7.1 (span) x 2.65 (rise)	Downstream Invert Elevation:	34.9	m
Material:	CMP	Length:	4.4	m
No. of Barrels:	1			

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Arched footbridge above

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Concrete wall	Right Bank:	Concrete wall, medium to dense grass/brush
	Left Floodplain:	Light grass/brush	Right Floodplain:	Medium to dense grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	27-Nov-15		
Bridge No.:	47-48	Underside of Deck Elevation:	37.2 m
River:	South Brook	Top of Deck Elevation:	39.1 m
Location:	Bowring Park	Height (underside of bridge to river):	3.7 m
GPS Coordinates:	324004.0, 5265431.0		
Span:	15.1 m	No. of Piers:	0
Length (parrallel to river):	3.7 m	Width of Pier:	N/A mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Steel bridge with wooden deck and stone piers
	City of St. John's owned water level gauge

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light brush/trees (steep slope)
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:


D/S:


Culvert Data Sheet

Date of Survey:	13-Nov-15			
Culvert No.:	268-269	Inlet Configuration:	Square	
River:	Waterford	Top Elevation:	178.1	m
Location:	Bremigen's Blvd	Headwall Material:	Gabion	
GPS Coordinates:	5263803.8, 314774.6	Wingwall Angle:	0	Deg (approx)
Shape:	Standard Arch	Upstream Invert Elevation:	173.2	m
Measured Size (m):	3.00 (span) x 1.80 (rise)	Downstream Invert Elevation:	173.1	m
Material:	CMP	Length:	21.8	m
No. of Barrels:	1			

Comments:

Condition: Culvert shows no sign of deterioration or deformation
Date of Construction: Unknown
Other: Height measured to bottom of channel

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
	Left Floodplain:	Medium to dense trees	Right Floodplain:	Medium to dense trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
	Left Floodplain:	Light brush/trees	Right Floodplain:	Light brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 13-Nov-15

Culvert No.:	261-262	Inlet Configuration:	Projecting from fill	
River:	Waterford	Top Elevation:	156.4	m
Location:	Kenmount Rd	Headwall Material:	N/A	
GPS Coordinates:	5263803.8, 314774.6	Wingwall Angle:	N/A	Deg (approx)

			Left:	*Right:*	
Shape:	Pipe Arch				
Measured Size (m):	Left: 2.10 (span) x 1.30 (rise)	Upstream Invert Elevation:	153.6	153.7	m
	Right: 1.58 (span) x 1.12 (rise)	Downstream Invert Elevation:	152.3	152.7	m
Material:	CMP	Length:	47.6	42.1	m
No. of Barrels:	2				

Comments:

Condition: Culverts rusted but still intact
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

D/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey:	13-Nov-16				
Culvert No.:	259-260	Inlet Configuration:	Projecting from fill		
River:	Waterford	Top Elevation:	155.0		m
Location:	Outer Ring Rd West Onramp	Headwall Material:	N/A		
GPS Coordinates:	5263803.8, 314774.6	Wingwall Angle:	N/A		Deg (approx)
Shape:	Pipe Arch		*Left:*	*Right:*	
Measured Size (m):	Left: 2.00 (span) x 1.42 (rise)	Upstream Invert Elevation:	152.6	152.7	m
	Right: 1.70 (span) x 1.17 (rise)	Downstream Invert Elevation:	152.1	152.3	m
Material:	CMP	Length:	17.3	17.1	m
No. of Barrels:	2				

Comments:

Condition:	Culverts rusted, U/S bottom of right culvert deteriorated
Date of Construction:	Unknown
Other:	

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush
D/S:	Alignment:	Open area, channel not well-defined	Substrate:	Gravel/cobble with some vegetation
	Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 13-Nov-15

Culvert No.:	255-256	Inlet Configuration:	Projecting from fill	
River:	Waterford	Top Elevation:	156.2	m
Location:	Outer Ring Rd	Headwall Material:	N/A	
GPS Coordinates:	5263803.8, 314774.6	Wingwall Angle:	N/A	Deg (approx)

			Left:	*Right:*	
Shape:	Pipe Arch				
Measured Size (m):	Left: 1.65 (span) x 1.07 (rise)	Upstream Invert Elevation:	150.2	149.8	m
	Right: 2.03 (span) x 1.40 (rise)	Downstream Invert Elevation:	147.7	147.3	m
Material:	CMP	Length:	87.2	87.0	m
No. of Barrels:	2				

Comments:

Condition: Culverts rusted, D/S bottom of left culvert deteriorated
Date of Construction: Unknown
Other: Left culvert has no flow (standing water)

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Medium to dense brush/trees	Right Bank:	Medium to dense brush/trees
Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

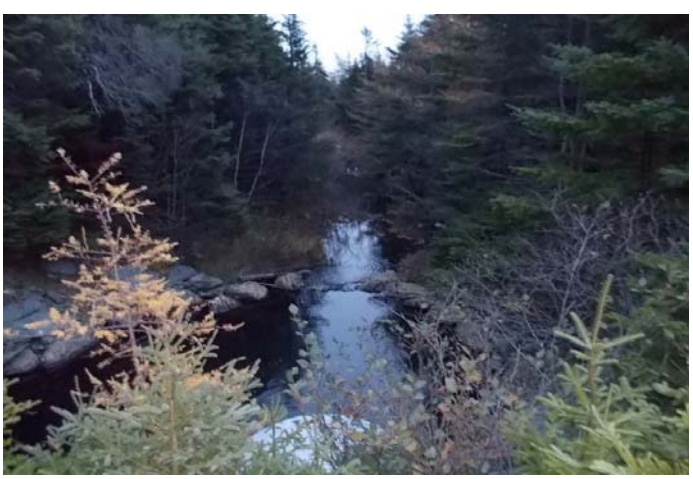
D/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	No to sparse vegetation	Right Bank:	Light brush/trees
Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:

D/S:



Culvert Data Sheet

Date of Survey:	13-Nov-15			
Culvert No.:	251-252	Inlet Configuration:	Projecting from fill	
River:	Waterford	Top Elevation:	147.2	m
Location:	Kenmount Rd / Outer Ring Rd Offramp	Headwall Material:	N/A	
GPS Coordinates:	5263803.8, 314774.6	Wingwall Angle:	N/A	Deg (approx)

			Left:	*Right:*	
Shape:	Pipe Arch				
Measured Size (m):	Left: 2.00 (span) x 1.42 (rise)	Upstream Invert Elevation:	145.1	145.4	m
	Right: 1.58 (span) x 1.02 (rise)	Downstream Invert Elevation:	144.3	144.6	m
Material:	CMP	Length:	23.4	22.8	m
No. of Barrels:	2				

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Light brush/trees	Right Bank:	Light grass/brush
Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

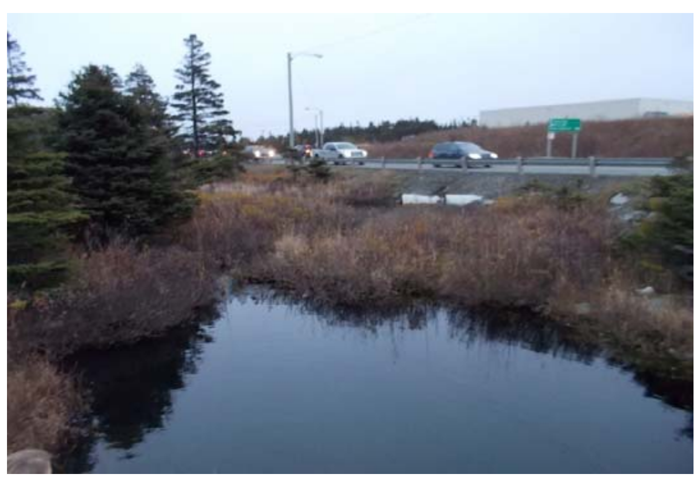
D/S:

Alignment:	Open area, channel not well-defined	Substrate:	Gravel/cobble
Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush

Photos:

U/S:

D/S:



Culvert Data Sheet

Date of Survey: 13-Nov-15

Culvert No.: 247-248
River: Waterford
Location: Kenmount Rd/Bruce St Onramp
GPS Coordinates: 5263803.8, 314774.6

Inlet Configuration: Projecting from fill
Top Elevation: 145.6 m
Headwall Material: N/A
Wingwall Angle: N/A Deg (approx)

Shape: Pipe Arch
Measured Size (m): Left: 2.00 (span) x 1.42 (rise)
Right: 1.55 (span) x 1.22 (rise)
Material: CMP
No. of Barrels: 2

	Left:	*Right:*	
Upstream Invert Elevation:	143.3	143.7	m
Downstream Invert Elevation:	143.1	143.5	m
Length:	16.9	16.9	m

Comments:

Condition: Culvert bottoms are rusted but intact
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:

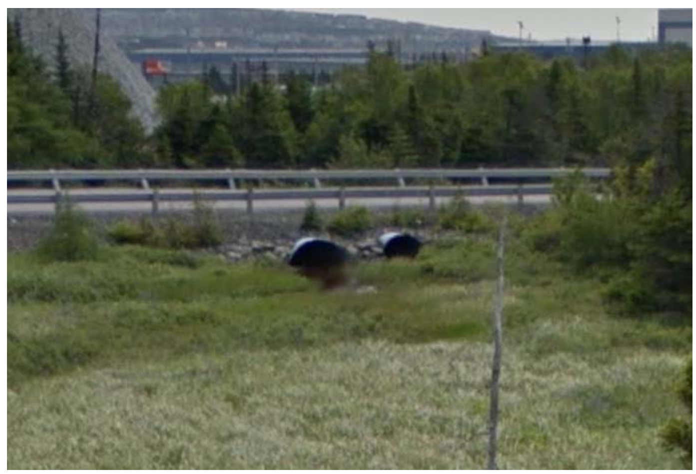
Alignment: Open area, channel not well-defined
Left Bank: Medium to dense grass/brush
Left Floodplain: Medium to dense grass/brush
Substrate: Earth material, dense grass
Right Bank: Medium to dense grass/brush
Right Floodplain: Medium to dense brush/trees

D/S:

Alignment: Fairly regular, relatively straight and uniform
Left Bank: Light brush/trees
Left Floodplain: Medium to dense brush/trees
Substrate: Gravel/cobble
Right Bank: Light brush/trees
Right Floodplain: Medium to dense brush/trees

Photos:

U/S:



D/S:

Culvert Data Sheet

Date of Survey: 17-Nov-15

Culvert No.:	243-244	Inlet Configuration:	Projecting from fill	
River:	Waterford	Top Elevation:	143.1	m
Location:	No. 986 Kenmount Rd	Headwall Material:	N/A	
GPS Coordinates:	5263803.8, 314774.6	Wingwall Angle:	N/A	Deg (approx)

Shape:	Circular		*Left:*	*Right:*	
Measured Size (m):	Left: 1.47 dia.	Upstream Invert Elevation:	141.7	141.7	m
	Right: 1.47 dia.	Downstream Invert Elevation:	141.7	141.6	m
Material:	CMP	Length:	13.8	13.8	m
No. of Barrels:	2				

Comments:

Condition: Bottom is rusted but still intact
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:	Alignment:	Irregular, winding or sluggish	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	No to sparse vegetation
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	No to sparse vegetation (sloped)	Right Floodplain:	No to sparse vegetation (sloped)

Photos:

U/S:


D/S:


Bridge Data Sheet

Date of Survey: 17-Nov-15

Bridge No.:	237-238	Underside of Deck Elevation:	137.3 m
River:	Waterford	Top of Deck Elevation:	137.7 m
Location:	T'Railway near Wynnford Dr	Height (underside bridge to river):	1.8 m
GPS Coordinates:	317138.2, 5265681.0		
Span:	9.9 m	No. of Piers:	0
Length (parrallel to river):	2.4 m	Width of Pier:	N/A mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Wooden footbridge on steel beams

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material, little vegetation
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Light grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	No to sparse vegetation	Right Bank:	No to sparse vegetation
	Left Floodplain:	N/A (culvert sidewall)	Right Floodplain:	N/A (culvert sidewall)

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 17-Nov-15

Culvert No.:	235-236	Inlet Configuration:	Projecting from fill	
River:	Waterford	Top Elevation:	144.4	m
Location:	T'Railway / Kenmount Rd	Headwall Material:	N/A	
GPS Coordinates:	5263803.8, 314774.6	Wingwall Angle:	N/A	Deg (approx)
Shape:	Open Bottom Arch	Upstream Invert Elevation:	135.8	m
Measured Size (m):	10.86 (span) x 7.10 (rise)	Downstream Invert Elevation:	135.4	m
Material:	CMP	Length:	46.6	m
No. of Barrels:	1			

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Large highway culvert

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	No to sparse vegetation	Right Floodplain:	No to sparse vegetation
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	No to sparse vegetation	Right Floodplain:	Light grass/brush

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey: 17-Nov-15

Bridge No.: 231-232
River: Waterford
Location: T'Railway near Kenmount
GPS Coordinates: 317358.4, 5265624.1

Underside of Deck Elevation: 136.6 m
Top of Deck Elevation: 137.3 m
Height (underside of bridge to river): 2.0 m

Span: 2.5 m
Length (parrallel to river): 3.0 m

No. of Piers: 0
Width of Pier: N/A mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Wooden deck on steel beams

Channel Conditions:

U/S:
Alignment: Fairly regular, relatively straight and uniform
Left Bank: Light grass/brush
Left Floodplain: Medium to dense brush/trees
Substrate: Gravel/cobble
Right Bank: Medium to dense brush/trees
Right Floodplain: Medium to dense brush/trees

D/S:
Alignment: Fairly regular, relatively straight and uniform
Left Bank: Medium to dense brush/trees
Left Floodplain: Medium to dense brush/trees
Substrate: Gravel/cobble
Right Bank: Light brush/trees
Right Floodplain: Medium to dense brush/trees

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 14-Nov-16

Culvert No.:	228_B - 228_A	Inlet Configuration:	Square	
River:	Waterford	Top Elevation:	136.4	m
Location:	T'Railway near Country Ribbon	Headwall Material:	Concrete	
GPS Coordinates:	5265695.9, 317409.3	Wingwall Angle:	90	Deg (approx)
Shape:	Pipe Arch	Upstream Invert Elevation:	133.7	m
Measured Size:	3.2 (span) x 2.1 (rise) m	Downstream Invert Elevation:	133.5	m
Material:	CMP	Length:	6.2	m
No. of Barrels:	1			

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Strings tied between left and right banks on upstream and downstream sides
Weir across inlet (top elev. 134.2 m)

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material with some vegetation
	Left Bank:	Concrete wall, light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	Paved surface	Right Floodplain:	Paved surface
D/S:	Alignment:	Open area with ponding	Substrate:	Earth material with some vegetation
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	Paved surface	Right Floodplain:	Paved surface

Photos:

U/S:




Culvert Data Sheet

Date of Survey: 13-Nov-15

Culvert No.:	225-226	Inlet Configuration:	Square
River:	Waterford	Top Elevation:	137.6 m
Location:	Corisande Dr	Headwall Material:	Concrete
GPS Coordinates:	5263803.8, 314774.6	Wingwall Angle:	45 Deg (approx)
Shape:	Open Bottom Arch	Upstream Invert Elevation:	132.8 m
Measured Size:	8.3 (span) x 2.9 (rise) m	Downstream Invert Elevation:	132.9 m
Material:	CMP	Length:	16.1 m
No. of Barrels:	1		

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other:

Channel Conditions:

U/S:

Alignment:	Open area, channel not well-defined	Substrate:	Earth material with some vegetation
Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
Left Floodplain:	Light brush/trees	Right Floodplain:	Light brush/trees

D/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
Left Floodplain:	No to sparse vegetation (sloped)	Right Floodplain:	Light grass/brush

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	17-Nov-15			
Bridge No.:	217-218	Underside of Deck Elevation:	117.2	m
River:	Waterford	Top of Deck Elevation:	117.9	m
Location:	T'Railway near Roosevelt Dr	Height (underside bridge to river):	3.5	m
GPS Coordinates:	318882.4, 5264879.5			
Span:	14.6 m	No. of Piers:	0	
Length (parralel to river):	2.0 m	Width of Pier:	N/A	mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Steel footbridge

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense brush/trees	Right Bank:	Light brush/trees
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense brush/trees	Right Bank:	Medium to dense brush/trees
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	17-Nov-15				
Bridge No.:	212-213		Underside of Deck Elevation:	112.5	m
River:	Waterford		Top of Deck Elevation:	113.3	m
Location:	Commonwealth Ave		Height (underside of bridge to river):	3.1	m
GPS Coordinates:	319313.5, 5264784.5				
Span:	10.8	m	No. of Piers:	0	
Length (parrallel to river):	18.0	m	Width of Pier:	N/A	mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Concrete road bridge

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium brush/trees	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense trees	Right Floodplain:	Medium to dense trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:


D/S:


Bridge Data Sheet

Date of Survey:	16-Nov-15			
Bridge No.:	205-206		Underside of Deck Elevation:	105.5 m
River:	Waterford		Top of Deck Elevation:	106.1 m
Location:	Forsey Pl		Height (underside of bridge to river):	1.8 m
GPS Coordinates:	319964.3, 5264785.1			
Span:	18.0 m		No. of Piers:	0
Length (parrallel to river):	1.9 m		Width of Pier:	N/A mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Wooden footbridge on steel beams

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material with some vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material with some vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	16-Nov-15				
Bridge No.:	198-199		Underside of Deck Elevation:	104.0	m
River:	Waterford		Top of Deck Elevation:	104.7	m
Location:	Forest Ave		Height (underside of bridge to river):	2.9	m
GPS Coordinates:	320756.7, 5264899.0				
Span:	23.6	m	No. of Piers:	0	
Length (parrallel to river):	1.8	m	Width of Pier:	N/A	mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Wooden footbridge on steel beams

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material with some vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Medium to dense grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Earth material with some vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	No to sparse vegetation (sloped)	Right Floodplain:	Light brush/trees

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey: 16-Nov-15

Bridge No.: 192-193
River: Waterford
Location: T'Railway near Valleyview Ave
GPS Coordinates: 321067.6, 5264712.2

Underside of Deck Elevation: 95.5 m
Top of Deck Elevation: 95.9 m
Height (underside bridge to river): 2.6 m

Span: 16.6 m
Length (parrallel to river): 1.5 m

No. of Piers: 0
Width of Pier: N/A mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Wooden footbridge on steel truss

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense brush/trees	Right Bank:	Medium to dense brush/trees
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense brush/trees	Right Bank:	Medium to dense brush/trees
	Left Floodplain:	Medium to dense brush/trees (sloped)	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	16-Nov-15			
Bridge No.:	187-188	Underside of Deck Elevation:	90.9	m
River:	Waterford	Top of Deck Elevation:	91.1	m
Location:	T'Railway, Valleyview Ave	Height (underside of bridge to river):	3.7	m
GPS Coordinates:	321182.0, 5264666.8			
Span:	27.0 m	No. of Piers:	0	
Length (parrallel to river):	2.0 m	Width of Pier:	N/A	mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Wooden footbridge on steel beams

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	16-Nov-15			
Bridge No.:	182-183	Underside of Deck Elevation:	79.2	m
River:	Waterford	Top of Deck Elevation:	79.8	m
Location:	T'Railway near Avery Pl	Height (underside of bridge to river):	3.2	m
GPS Coordinates:	321522.3, 5264662.4			
Span:	9.2 m	No. of Piers:	0	
Length (parrallel to river):	1.8 m	Width of Pier:	N/A	mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Wooden footbridge on steel beams

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense brush/trees	Right Bank:	Medium to dense brush/trees (sloped)
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Roadway (top of slope)
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light brush/trees	Right Bank:	Medium to dense brush/trees (sloped)
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Roadway (top of slope)

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey: 16-Nov-15

Bridge No.:	176-177	Underside of Deck Elevation:	76.4 m
River:	Waterford	Top of Deck Elevation:	77.3 m
Location:	Dunn's Rd	Height (underside of bridge to river):	1.8 m
GPS Coordinates:	321599.2, 5264696.6		
Span:	8.0 m	No. of Piers:	0
Length (parrallel to river):	13.6 m	Width of Pier:	N/A mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Concrete road bridge

Channel Conditions:

U/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Medium to dense grass/brush	Right Bank:	Light brush/trees (sloped)
Left Floodplain:	Light grass/brush	Right Floodplain:	Roadway (top of slope)

D/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Light brush/trees (sloped)	Right Bank:	No to sparse vegetation (sloped)
Left Floodplain:	Light grass/brush	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Culvert Data Sheet

Date of Survey: 16-Nov-15

Culvert No.: 170-171
River: Waterford
Location: Team Gushue Highway Ext.
GPS Coordinates: 5263803.8, 314774.6

Inlet Configuration: Square
Top Elevation: 83.2 m
Headwall Material: Concrete Panels
Wingwall Angle: 30 Deg (approx)

Shape: Open Bottom Arch
Measured Size: 10.1 (span) x 4.3 (rise) m
Material: Concrete
No. of Barrels: 1

Upstream Invert Elevation: 63.2 m
Downstream Invert Elevation: 62.8 m
Length: 70.1 m

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Large highway culvert

Channel Conditions:

U/S:

Alignment: Fairly regular, relatively straight and uniform
Left Bank: Light brush/trees
Left Floodplain: Medium to dense brush/trees
Substrate: Gravel/cobble
Right Bank: Light brush/trees
Right Floodplain: Medium to dense brush/trees

D/S:

Alignment: Fairly regular, relatively straight and uniform
Left Bank: No to sparse vegetation
Left Floodplain: No to sparse vegetation (sloped)
Substrate: Gravel/cobble
Right Bank: No to sparse vegetation
Right Floodplain: No to sparse vegetation (sloped)

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	27-Nov-15			
Bridge No.:	158-159	Underside of Deck Elevation:	56.6	m
River:	Waterford	Top of Deck Elevation:	57.9	m
Location:	Brookfield Rd	Height (underside of bridge to river):	1.7	m
GPS Coordinates:	322780.5, 5265113.4			
Span:	14.2 m	No. of Piers:	0	
Length (parrallel to river):	15.5 m	Width of Pier:	N/A	mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Concrete road bridge with 45 degree wingwalls

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Light brush/trees	Right Floodplain:	Medium to dense grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush	Right Floodplain:	Light grass/brush

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	24-Nov-15			
Bridge No.:	150-151	Underside of Deck Elevation:	53.7	m
River:	Waterford	Top of Deck Elevation:	54.6	m
Location:	Waterford Bridge Road	Height (underside of bridge to river):	1.8	m
GPS Coordinates:	323273.6, 5265252.2			
Span:	10.3 m	No. of Piers:	0	
Length (parrallel to river):	19.1 m	Width of Pier:	N/A	mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Concrete Road Bridge, underside of bridge sloped at ends
	Left wingwall (U/S) is at 45 deg. back toward river

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light brush/trees (sloped)	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	No to sparse vegetation	Right Floodplain:	Medium to dense grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	Medium to dense grass/brush (sloped)	Right Floodplain:	Medium to dense grass/brush (sloped)

Photos:

U/S:


D/S:


Bridge Data Sheet

Date of Survey:	24-Nov-15			
Bridge No.:	145-146	Underside of Deck Elevation:	49.7	m
River:	Waterford	Top of Deck Elevation:	49.8	m
Location:	Bowring Park	Height (underside of bridge to river):	3.3	m
GPS Coordinates:	323503.3, 5265343.4			
Span:	7.4 m	No. of Piers:	0	
Length (parrallel to river):	2.1 m	Width of Pier:	N/A	mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Wooden footbridge, wooden abutment Gabions in U/S right bank

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense grass/brush	Right Bank:	Gabion wall
	Left Floodplain:	Light brush/trees	Right Floodplain:	Light brush/trees (above wall)
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light brush/trees	Right Bank:	Light brush/trees
	Left Floodplain:	Light brush/trees	Right Floodplain:	Light brush/trees

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	24-Nov-15		
Bridge No.:	141-142	Underside of Deck Elevation:	43.1 m
River:	Waterford	Top of Deck Elevation:	44.4 m
Location:	Bowring Park	Height (underside of bridge to river):	1.9 m
GPS Coordinates:	323622.3, 5265405.5		
Span:	9.8 m	No. of Piers:	0
Length (parrallel to river):	1.6 m	Width of Pier:	N/A mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Wooden footbridge
	See: http://www.360cities.net/image/bowring-park-bridge-360-by-brian-carey

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	No to sparse vegetation (sloped)	Right Bank:	No to sparse vegetation (sloped)
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	No to sparse vegetation (sloped)	Right Bank:	No to sparse vegetation (sloped)
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush

Photos:

U/S:


D/S:


Bridge Data Sheet

Date of Survey: 27-Nov-15

Bridge No.: 136-137
River: Waterford
Location: Bowring Park
GPS Coordinates: 323792.5, 5265404.1

Underside of Deck Elevation: 38.0 m
Top of Deck Elevation: 38.8 m
Height (underside of bridge to river): 3.0 m

Span: 12.4 m
Length (parrallel to river): 2.4 m

No. of Piers: 0
Width of Pier: N/A mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Steel footbridge, 45 deg. Wingwalls on banks

Channel Conditions:

U/S:

Alignment: Fairly regular, relatively straight and uniform
Left Bank: Medium to dense grass/brush
Left Floodplain: Light brush/trees
Substrate: Gravel/cobble
Right Bank: Medium to dense grass/brush
Right Floodplain: Light brush/trees

D/S:

Alignment: Fairly regular, relatively straight and uniform
Left Bank: Stone wall
Left Floodplain: Light grass/brush
Substrate: Gravel/cobble
Right Bank: No to sparse vegetation
Right Floodplain: Light brush/trees

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	27-Nov-15			
Bridge No.:	132_B - 133	Underside of Deck Elevation:	36.1	m
River:	Waterford	Top of Deck Elevation:	36.8	m
Location:	Bowring Park	Height (underside of bridge to river):	2.6	m
GPS Coordinates:	323862.6, 5265475.8			
Span:	11.3 m	No. of Piers:	0	
Length (parrallel to river):	7.9 m	Width of Pier:	N/A	mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Concrete bridge, flow measurement apparatus present

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Stone wall	Right Bank:	Light grass/brush
	Left Floodplain:	Light brush/trees	Right Floodplain:	Light grass/brush
D/S:	Alignment:	Open area, channel not well-defined	Substrate:	Gravel/cobble
	Left Bank:	Light brush/trees	Right Bank:	No to sparse vegetation
	Left Floodplain:	No to sparse vegetation	Right Floodplain:	No to sparse vegetation

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey: 27-Nov-15

Bridge No.:	271-272 (A)	Underside of Deck Elevation:	35.7 m
River:	Waterford	Top of Deck Elevation:	36.2 m
Location:	Bowring Park Duck Pond	Height (underside of bridge to river):	2.8 m
GPS Coordinates:	323952.6, 5265515.2		
Span:	16.6 m	No. of Piers:	0
Length (parrallel to river):	2.3 m	Width of Pier:	N/A mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Steel footbridge with wooden deck, 45-deg. wingwalls

Channel Conditions:

U/S:

Alignment:	Open area, channel not well-defined	Substrate:	Gravel/cobble
Left Bank:	Small rock wall	Right Bank:	Small rock wall
Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush

D/S:

Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
Left Floodplain:	Concrete wall (light brush/trees above)	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Weir Data Sheet

Date of Survey:	27-Nov-15			
Structure No.:	271-272 (A)	Top Elevation:	34.1	m
River:	Waterford	Bottom Elevation:	33.1	m
Location:	Bowring Park Duck Pond	Height:	1.0	m
GPS Coordinates:	323952.6, 5265515.2	Width:	16.4	m
Structure Type:	Broad-Crested Weir			
Material:	Concrete			

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Notch opening in weir (1.0 m wide, 1.0 m deep)

Channel Conditions:

U/S:	Alignment:	Open area, channel not well-defined	Substrate:	Gravel/cobble
	Left Bank:	Small rock wall	Right Bank:	Small rock wall
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Concrete wall (light brush/trees above)	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	27-Nov-15		
Bridge No.:	271-272 (B)	Underside of Deck Elevation:	35.8 m
River:	Waterford	Top of Deck Elevation:	36.2 m
Location:	Bowring Park Duck Pond	Height (underside of bridge to river):	2.8 m
GPS Coordinates:	323963.2, 5265482.0		
Span:	11.6 m	No. of Piers:	0
Length (parrallel to river):	2.3 m	Width of Pier:	N/A mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Steel footbridge with wooden deck
	Bowring Park duck pond feeds into short channel before bridge

Channel Conditions:

U/S:	Alignment:	Open area, channel not well-defined	Substrate:	Gravel/cobble
	Left Bank:	Small rock wall	Right Bank:	Small rock wall
	Left Floodplain:	Light brush/trees	Right Floodplain:	Light grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Small rock wall	Right Bank:	Small rock wall
	Left Floodplain:	Light brush/trees	Right Floodplain:	Light brush/trees

Photos:

U/S:

D/S:

Structure Data Sheet

Date of Survey: 27-Nov-15

Structure No.:	271-272 (B)	Top Channel Elevation:	33.8	m
River:	Waterford	Bottom Channel Elevation:	32.3	m
Location:	Bowring Park Duck Pond			
GPS Coordinates:	323963.2, 5265482.0			
		No. Steps:	3	
Structure Type:	Fish Ladder	Step Height:	0.75	m
Material:	Stone	Width:	4.4	m

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Notch in top step (0.6 m wide, 0.3 m deep)

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Small rock wall	Right Bank:	Small rock wall
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Small rock wall	Right Bank:	Small rock wall
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush

Photos:

U/S:


D/S:


Bridge Data Sheet

Date of Survey:	27-Nov-15		
Bridge No.:	42-43	Underside of Deck Elevation:	Unknown m
River:	Waterford	Top of Deck Elevation:	46.2 m
Location:	Columbus Dr	Height (underside of bridge to river):	Unknown m
GPS Coordinates:	324003.1, 5265564.1		
Span:	Unknown m	No. of Piers:	2 (not in river)
Length (parrallel to river):	19.0 m	Width of Pier:	1.4 m

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Columbus Dr overpass, concrete

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Concrete wall	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense grass/brush (above wall)	Right Floodplain:	Concrete wall (light grass/brush above)
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Concrete wall	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Light grass/brush (above wall)	Right Floodplain:	Light brush/trees

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey: 03-Dec-15

Bridge No.:	37-38	Underside of Deck Elevation:	33.7 m
River:	Waterford	Top of Deck Elevation:	34.8 m
Location:	Bay Bulls Rd, Southside Rd	Height (underside of bridge to river):	2.9 m
GPS Coordinates:	324280.7, 5265618.3		
Span:	10.8 m	No. of Piers:	0
Length (parrallel to river):	10.3 m	Width of Pier:	N/A mm

Comments:

Condition:	Some cracking in concrete beams and abutments on underside of bridge
Date of Construction:	Unknown
Other:	Concrete road bridge, flow measurement apparatus present
	Curved U/S wingwalls start at ~45 degrees, only right wingwall present D/S

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with some vegetation
	Left Bank:	Light grass/brush	Right Bank:	Rock wall
	Left Floodplain:	Light brush/trees	Right Floodplain:	Light grass/brush (above wall)
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble with little vegetation
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Light brush/trees	Right Floodplain:	Gabion wall (light grass/brush above)

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey: 03-Dec-15

Bridge No.:	30-31	Underside of Deck Elevation:	25.7 m
River:	Waterford	Top of Deck Elevation:	27.1 m
Location:	Waterford Lane	Height (underside of bridge to river):	2.9 m
GPS Coordinates:	324687.3, 5266183.7		
Span:	15.3 m	No. of Piers:	0
Length (parrallel to river):	10.8 m	Width of Pier:	N/A mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Concrete road bridge
	Underside of bridge is arched

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Light grass/brush	Light grass/brush (sloped)	Right Bank:	Light grass/brush (sloped)
	Left Floodplain:	Light grass/brush	Right Floodplain:	Light grass/brush
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush (sloped)
	Left Floodplain:	Light brush/trees	Right Floodplain:	Light grass/brush

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	03-Dec-15			
Bridge No.:	19-20	Underside of Deck Elevation:	13.0	m
River:	Waterford	Top of Deck Elevation:	14.1	m
Location:	Symes Bridge Rd	Height (underside of bridge to river):	3.0	m
GPS Coordinates:	325561.9, 5267188.0			
Span:	18.2 m	No. of Piers:	1	
Length (parrallel to river):	5.5 m	Width of Pier:	2.1	mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Concrete road bridge, 45 deg. wingwalls 2 spans

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Medium to dense brush/trees	Right Floodplain:	Medium to dense brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Medium to dense grass/brush	Right Bank:	Medium to dense grass/brush
	Left Floodplain:	Rock wall (light grass/bruch above)	Right Floodplain:	Medium to dense grass/brush

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey:	03-Dec-15				
Bridge No.:	12-13		Underside of Deck Elevation:	5.7	m
River:	Waterford		Top of Deck Elevation:	8.0	m
Location:	Blackhead Rd		Height (underside of bridge to river):	4.2	m
GPS Coordinates:	325953.8, 5267757.9				
Span:	27.2	m	No. of Piers:	0	
Length (parrallel to river):	19.1	m	Width of Pier:	N/A	mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Concrete road bridge
	City of St. John's owned water level gauge

Channel Conditions:

U/S: Alignment:	Fairly regular, relatively straight and uniform		Substrate:	Gravel/cobble with some vegetation
Left Bank:	No to sparse vegetation (sloped)		Right Bank:	Light grass/brush (sloped)
Left Floodplain:	No to sparse vegetation		Right Floodplain:	No to sparse vegetation
D/S: Alignment:	Fairly regular, relatively straight and uniform		Substrate:	Gravel/cobble with some vegetation
Left Bank:	Light grass/brush (sloped)		Right Bank:	Light grass/brush (sloped)
Left Floodplain:	No to sparse vegetation		Right Floodplain:	Light brush/trees

Photos:

U/S:


D/S:


Bridge Data Sheet

Date of Survey: 08-Dec-15

Bridge No.:	6-7	Underside of Deck Elevation:	2.3 m
River:	Waterford	Top of Deck Elevation:	3.0 m
Location:	Southside Rd	Height (underside of bridge to river):	3.1 m
GPS Coordinates:	326399.4, 5268227.2		
Span:	17.2 m	No. of Piers:	1
Length (parrallel to river):	2.9 m	Width of Pier:	300 mm

Comments:

Condition: No deficiencies noted
Date of Construction: Unknown
Other: Steel footbridge

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	No to sparse vegetation	Right Floodplain:	Light brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	No to sparse vegetation	Right Floodplain:	No to sparse vegetation

Photos:

U/S:

D/S:

Bridge Data Sheet

Date of Survey: 08-Dec-15

Bridge No.:	3-4	Underside of Deck Elevation:	2.4 m
River:	Waterford	Top of Deck Elevation:	3.1 m
Location:	Southside Rd	Height (underside of bridge to river):	2.9 m
GPS Coordinates:	326413.6, 5268236.7		
Span:	28.0 m	No. of Piers:	1
Length (parrallel to river):	1.7 m	Width of Pier:	300 mm

Comments:

Condition:	No deficiencies noted
Date of Construction:	Unknown
Other:	Wooden footbridge on steel beams
	Corrugated sheet metal on left bank (U/S)

Channel Conditions:

U/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	No to sparse vegetation	Right Floodplain:	Light brush/trees
D/S:	Alignment:	Fairly regular, relatively straight and uniform	Substrate:	Gravel/cobble
	Left Bank:	Light grass/brush	Right Bank:	Light grass/brush
	Left Floodplain:	No to sparse vegetation	Right Floodplain:	No to sparse vegetation

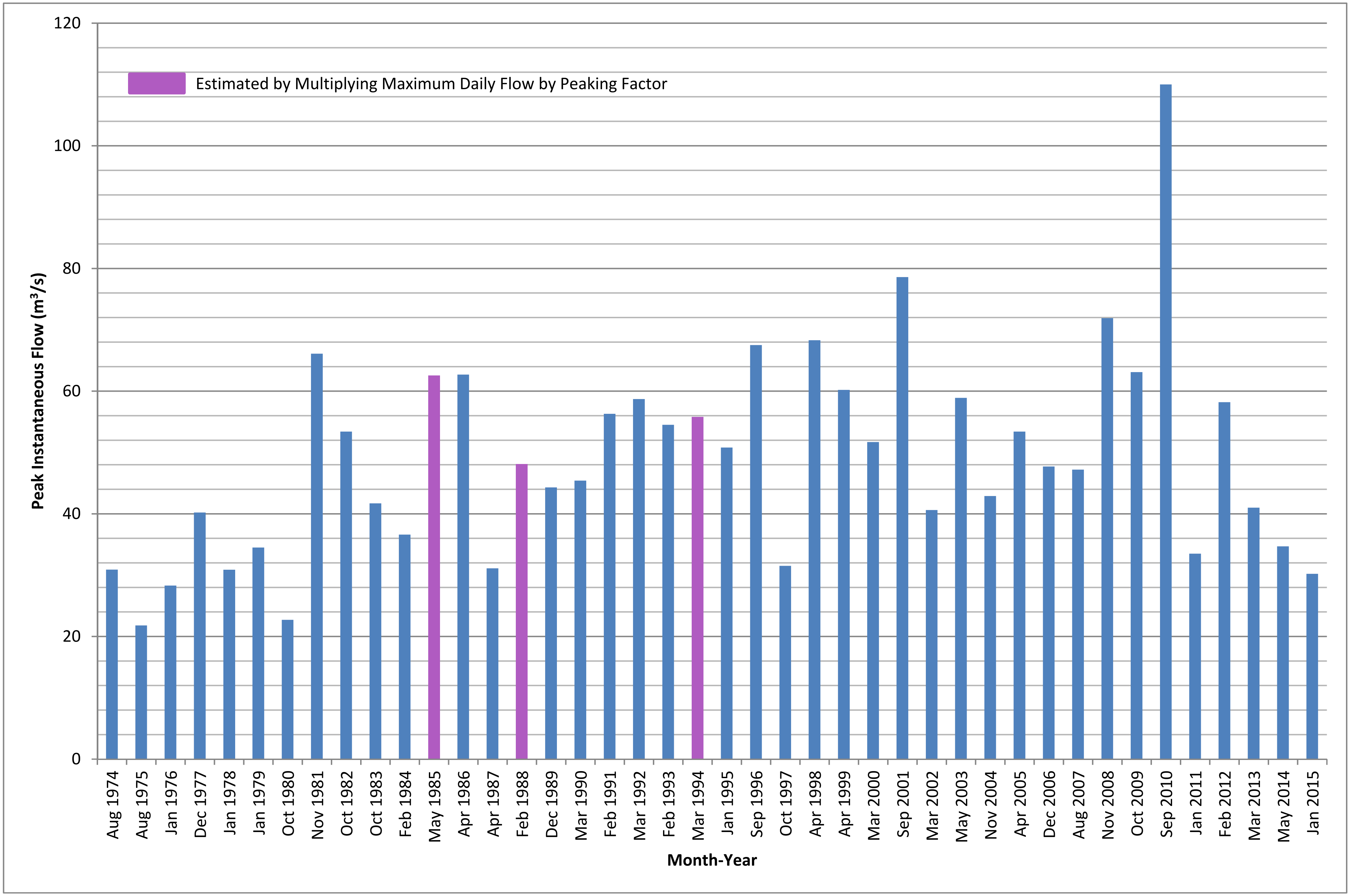
Photos:

U/S:


D/S:


APPENDIX E

Single Station Flood Frequency Analysis Data



Estimated by Multiplying Maximum Daily Flow by Peaking Factor
Peak Instantaneous Flow (m³/s)
0
20
40
60
80
100
120
Aug 1974
Aug 1975
Jan 1976
Dec 1977
Jan 1978
Jan 1979
Oct 1980
Nov 1981
Oct 1982
Oct 1983
Feb 1984
May 1985
Apr 1986
Apr 1987
Feb 1988
Dec 1989
Mar 1990
Feb 1991
Mar 1992
Feb 1993
Mar 1994
Jan 1995
Sep 1996
Oct 1997
Apr 1998
Apr 1999
Mar 2000
Sep 2001
Mar 2002
May 2003
Nov 2004
Apr 2005
Dec 2006
Aug 2007
Nov 2008
Oct 2009
Sep 2010
Jan 2011
Feb 2012
Mar 2013
May 2014
Jan 2015
Month-Year

--- SPEARMAN TEST FOR INDEPENDENCE ---

02ZM008 Waterford River at Kilbride

ANNUAL MAXIMUM DAILY FLOW SERIES 1974 TO 2015 DRAINAGE AREA = 52.70000

SPEARMAN RANK ORDER SERIAL CORRELATION COEFF = .182 D.F.= 39

CORRESPONDS TO STUDENTS T = 1.156

CRITICAL T VALUE AT 5% LEVEL = 1.685 NOT SIGNIFICANT

\- - - - 1% - = 2.426 NOT SIGNIFICANT

Interpretation: The null hypothesis is that the correlation is zero.

At the 5% level of significance, the correlation is not significantly different from zero. That is, the data do not display significant serial dependence.

--- SPEARMAN TEST FOR TREND ---

02ZM008 Waterford River at Kilbride

ANNUAL MAXIMUM DAILY FLOW SERIES 1974 TO 2015 DRAINAGE AREA = 52.70000

SPEARMAN RANK ORDER CORRELATION COEFF = -.321 D.F.= 40

CORRESPONDS TO STUDENTS T =-2.141

CRITICAL T VALUE AT 5% LEVEL =-2.021 SIGNIFICANT

\- - - - 1% - =-2.704 NOT SIGNIFICANT

Interpretation: The null hypothesis is that the serial (lag-one) correlation is zero.

At the 5% level of significance, the correlation is significantly different from zero, but is not so at the 1% level of significance. That is, the trend is significant but not highly so.

--- RUN TEST FOR GENERAL RANDOMNESS ---

02ZM008 Waterford River at Kilbride

ANNUAL MAXIMUM DAILY FLOW SERIES 1974 TO 2015 DRAINAGE AREA = 52.70000

THE NUMBER OF RUNS ABOVE AND BELOW THE MEDIAN (RUNAB) = 19

THE NUMBER OF OBSERVATIONS ABOVE THE MEDIAN(N1) = 21

THE NUMBER OF OBSERVATIONS BELOW THE MEDIAN(N2) = 21

(NOTE: Z IS THE STANDARD NORMAL VARIATE.)

For this test, Z = .937

Critical Z value at the 5% level = 1.960 NOT SIGNIFICANT

Interpretation: The null hypothesis is that the data are random.

At the 5% level of significance, the null hypothesis cannot be rejected. That is, the sample is significantly random.

--- MANN-WHITNEY SPLIT SAMPLE TEST FOR HOMOGENEITY ---

02ZM008 Waterford River at Kilbride

ANNUAL MAXIMUM FLOW SERIES 1974 TO 2015 DRAINAGE AREA= 52.70000

SPLIT BY TIME SPAN, SUBSAMPLE 1 SAMPLE SIZE= 21

SUBSAMPLE 2 SAMPLE SIZE= 21

(NOTE: Z IS THE STANDARD NORMAL VARIATE.)

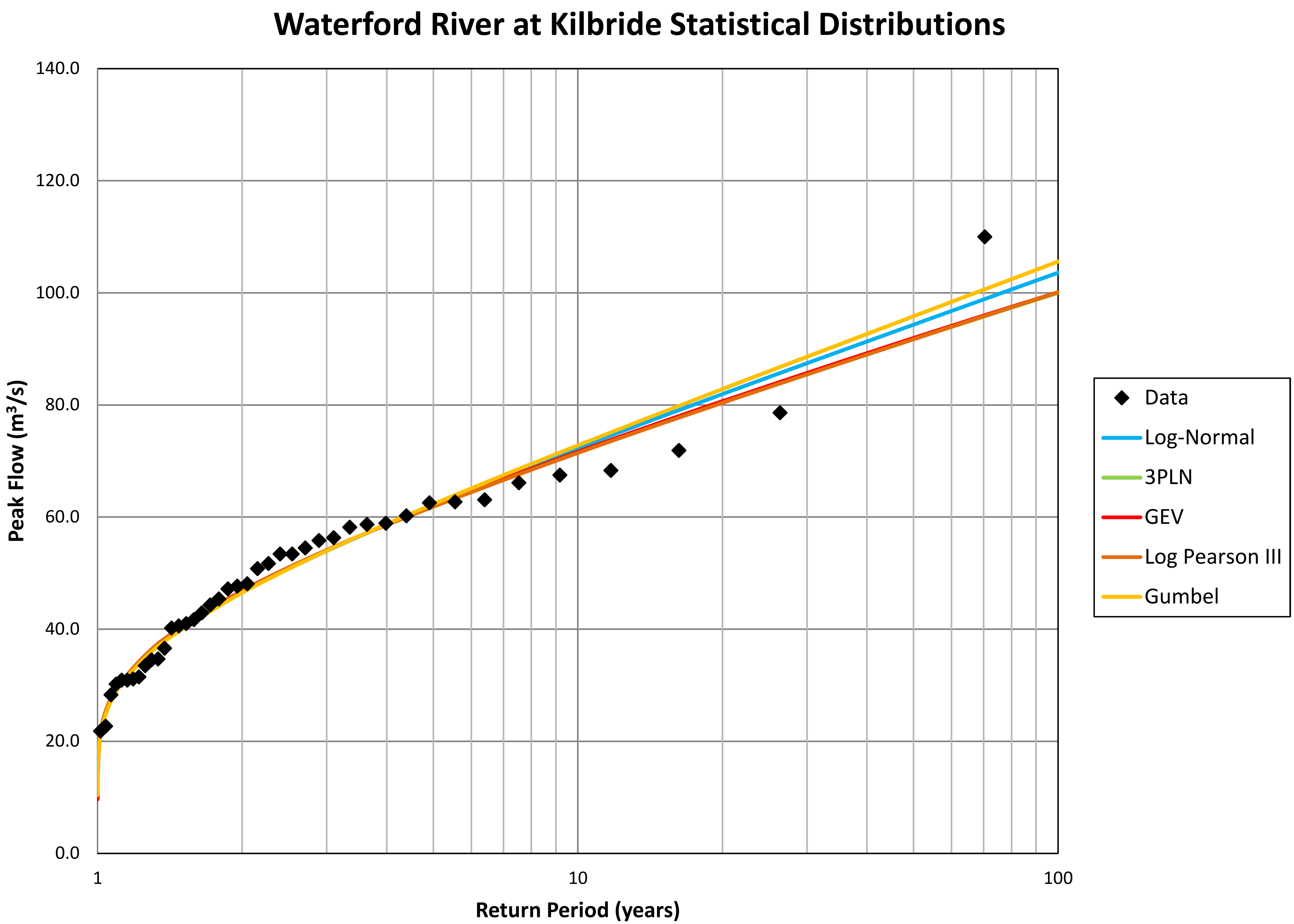
For this test, Z = -1.786

CRITICAL Z VALUE AT 5% SIGNIFICANT LEVEL = -1.645 SIGNIFICANT

- - - - 1% - - = -2.326 NOT SIGNIFICANT

Interpretation: The null hypothesis is that there is no location difference between the two samples.

At the 5% level of significance, there is a significant difference in location, but not so at the 1% level. That is, the location difference is significant, but not highly so.



Waterford River at Kilbride Statistical Distributions
Peak Flow (m³/s)
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
1
10
100
Return Period (years)
Data
Log-Normal
3PLN
GEV
Log Pearson III
Gumbel

APPENDIX F

Regional Flood Frequency Analysis Data

Watershed Name: Waterford River at Kilbride Brook Gauge (02ZM008)
Region #: 3
(NW=1, NE=2, SE=3, SW=4 or Labrador=5)

Parameters:	Value	Units	Range in Region: lowest	2nd lowest	2nd highest	highest	Remarks:
DA	52.7	km^2	3.70	5.40	210.70	295.70	
PERIM		km	11.13	16.20	177.11	179.26	Parameter out of range
LAF	26	(-)	8.79	20.80	512.00	588.00	
LSF		(-)	1.36	1.40	1.95	1.95	Parameter out of range
FACLS		(-)	0.39	0.50	1.00	1.00	Parameter out of range
FLAKE		(-)	0.04	0.04	0.13	0.14	Parameter out of range
FSWAMP		(-)	0.00	0.00	0.08	0.17	
FLSAR		(-)	0.04	0.07	0.16	0.21	Parameter out of range
FTREE		(-)	0.09	0.16	0.75	0.88	Parameter out of range
FBAR'N		(-)	0.00	0.04	0.73	0.79	Parameter near extreme
SLOPEM2		(%)	0.23	0.34	2.42	2.43	Parameter out of range
DRAIND		(km/km^2)	0.55	0.96	1.55	1.62	Parameter out of range
SHAPE		(-)	1.62	1.70	3.23	3.46	Parameter out of range

Results:		Estimate	*L95%L*	*U95%L*
DA+LAF or LSF	Q_2 =	**36.18**	*21.05*	*62.18*
	Q_5 =	**49.64**	*29.28*	*84.17*
	Q_{10} =	**58.86**	*34.56*	*100.26*
	Q_{20} =	**67.68**	*39.20*	*116.85*
	Q_{50} =	**79.07**	*44.98*	*139.00*
	Q_{100} =	**87.71**	*49.22*	*156.29*
	Q_{200} =	**96.50**	*53.19*	*175.09*

Results:		Estimate	*L95%L*	*U95%L*
DA only	Q_2 =	**30.03**	*15.61*	*57.78*
	Q_5 =	**41.30**	*21.66*	*78.74*
	Q_{10} =	**48.94**	*25.55*	*93.73*
	Q_{20} =	**56.24**	*29.10*	*108.69*
	Q_{50} =	**65.68**	*33.53*	*128.66*
	Q_{100} =	**72.83**	*36.68*	*144.62*
	Q_{200} =	**80.12**	*39.80*	*161.26*

Regional Flood Frequency Analysis for Newfoundland and Labrador - 2014 Update **Version 2014**

Consult "Regional Flood Frequency Analysis for Newfoundland and Labrador - 2014 Update - User's Guide and Electronic Spreadsheet" for instructions on use.

Government of Newfoundland and Labrador
Department of Environment and Labour
Water Resources Management Division
PO Box 8700, St. John's, NF, A1B 4J6

Phone: (709) 729 2563
Fax: (709) 729 0320

APPENDIX G

C-CORE Land Classification Report

Generation of Land Cover Information in Support of Waterford River Flood Risk Mapping Study

Report
R-15-089-1273

Prepared for:
CBCL

Revision 1.0
February, 2016

Captain Robert A. Bartlett Building
Morrissey Road
St. John's, NL
Canada A1B 3X5

T: (709) 864-8354
F: (709) 864-4706

Info@c-core.ca
www.c-core.ca

Registered to ISO 9001:2008

This page is intentionally left blank

Generation of Land Cover Information in Support of Waterford River Flood Risk Mapping Study

Prepared for:
CBCL

Prepared by:
C-CORE

C-CORE Report Number:
R-15-089-1273
Revision 1.0
February, 2016

Smart Solutions for Challenging Environments

Captain Robert A. Bartlett Building
Morrissey Road
St. John's, NL
Canada A1B 3X5

T: (709) 864-8354
F: (709) 864-4706
Info@c-core.ca
www.c-core.ca

Registered to ISO 9001:2008

The correct citation for this report is:
C-CORE. 2016. *Generation of Land Cover Information in Support of Waterford River Flood Risk Mapping Study*, C-CORE Report R-15-089-1273, Revision 1.0.

PROJECT TEAM
Sherry Warren (Project Manager)
Mike Lynch
Thomas Puestow

REVISION HISTORY

VERSION	SVN	NAME	COMPANY	DATE OF CHANGES	COMMENTS
1.0	21	Thomas Puestow	C-CORE	02/01/16	Submitted to Client

DISTRIBUTION LIST

COMPANY	NAME	NUMBER OF COPIES
CBCL	Jennifer Bursey Greg Sheppard	1 electronic

Table of Contents

List of Tables

List of Figures

1 Introduction

This document describes the procedures followed in generating a land cover map in support of a flood risk study carried out for the Waterford River drainage basin. The location of the study area and preliminary watershed boundary is presented in Figure 1.

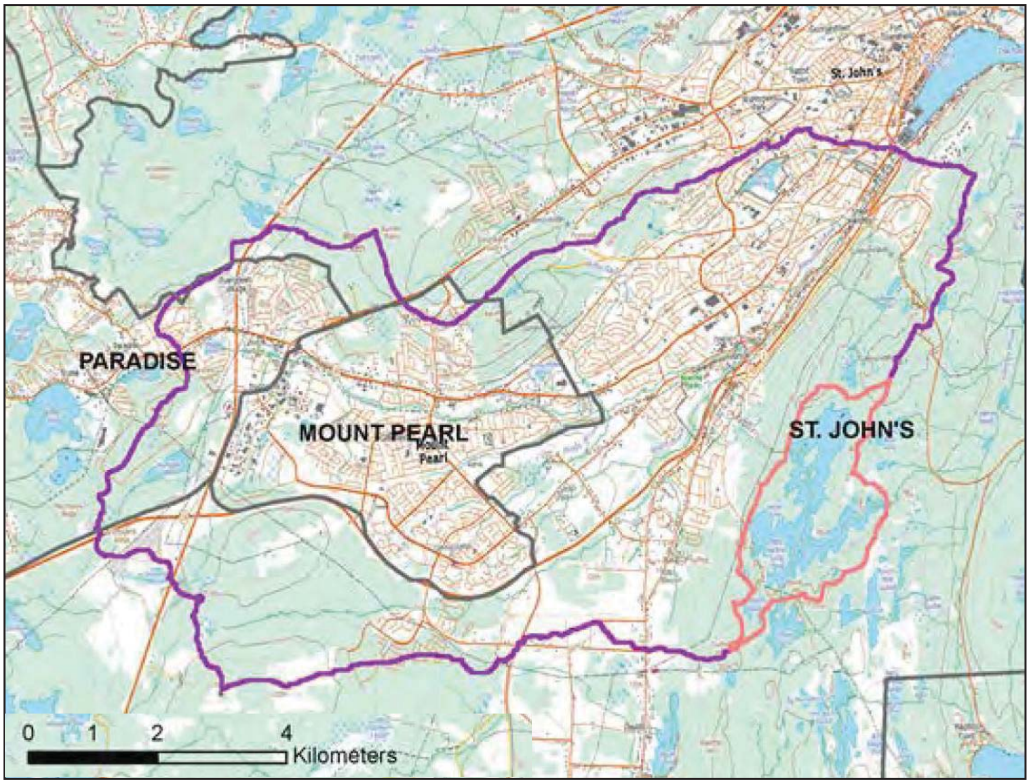


Figure 1. Study area[1]

Using optical satellite imagery as the primary data source, land cover information was generated for the area of interest (AOI) to support runoff modeling using the curve number method. The following sections describe in detail the approach adopted, including data sources, pre-processing procedures, land cover classification, post-processing and product generation.

[1] From: WRMD Request for Proposals: Flood Risk Mapping Study: Waterford River Area, 2015-2016

2 Approach

2.1 Data

The principal data source for generating land cover information comprised an orthorectified mosaic of pansharpened satellite scenes as presented in Table 1 and Figure 2.

Table 1. Components of satellite image mosaic

Mission	Acquisition Date	Level of Processing	Spectral Bands	Spatial Resolution
WorldView-2	August 2, 2013	Pansharpened Orthorectified	3 visible 1 near-infrared (NIR) 1 panchromatic (PAN)	0.5 m
	August 30, 2014			
GeoEye1-1	October 10, 2014			

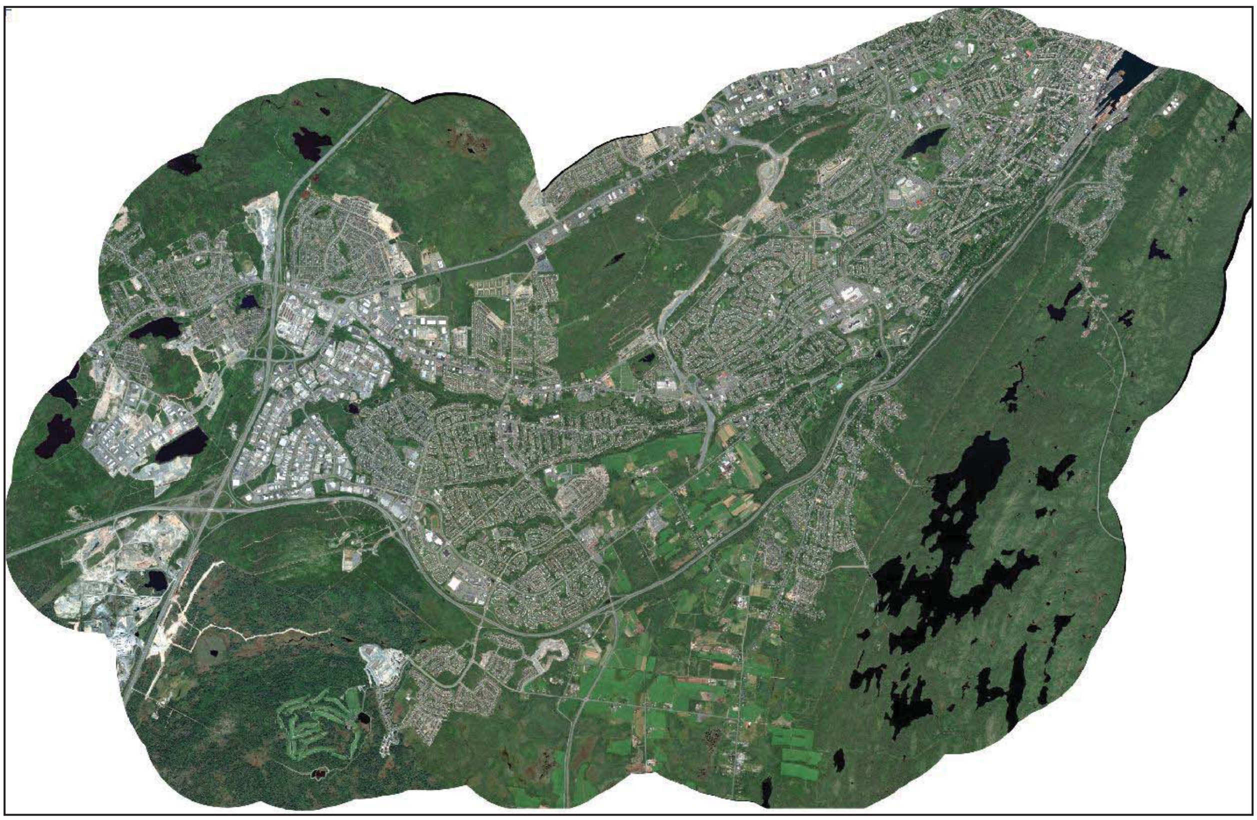


Figure 2. Satellite ortho-mosaic of AOI

Pansharpening is a data fusion technique used to combine the high spatial resolution of a panchromatic channel with the high spectral resolution offered by multiple spectral bands. While this level of processing is useful for visual image interpretation, the altering of original image values during the pansharpening process can negatively affect automated algorithms used for classification. It is therefore preferable to use uncorrected multispectral bands over pansharpened data for automated and semi-automated image classification. However, as the original spectral bands were not provided in this instance, image classification was carried out using the pansharpened and orthorectified mosaic.

Given that the satellite images described above were acquired in 2013 and 2014 and that the AOI is undergoing rapid urban development, additional satellite imagery was used to capture major land use changes between 2013 and 2015. To this end, change detection was carried out using the LANDSAT-8 images presented in Table 2. The LANDSAT-8 scenes were obtained free of charge from the US Geological Survey (USGS). The change detection process is described in detail in Section 2.2.

Table 2. Satellite imagery used in change detection

Mission	Acquisition Date	Spectral Bands	Spatial Resolution
LANDSAT-8	September 10, 2013	4 visible 2 NIR 2 shortwave infrared (SWIR) 2 thermal infrared (TIR) 1 PAN	30 m
	August 15, 2015		

All satellite data was initially received in UTM coordinates, Zone 21, NAD83. In addition to satellite imagery, a vector layer comprising highways, secondary roads and residential roads was used in the delineation of residential areas. This vector dataset had previously been derived from the primary satellite imagery via stereoscopy. It was made available to C-CORE for use in the extraction of land cover information.

2.2 Image Pre-Processing

The pansharpening and mosaic generation processes altered the original image digital numbers (DN) significantly. It was therefore not possible to convert DN values to units of radiance and reflectance. In consequence, no further radiometric and atmospheric correction was carried out.

The pixel spacing of 50 cm is useful for visual interpretation, but the resulting high spatial variability of brightness values and prevalence of shadows would increase the noise level of any automated classification. In an effort to approximate the spatial resolution and associated noise characteristics of the original multispectral image channels, the pansharpened ortho-mosaic was resampled to a pixel spacing of 3 meters.

The red and NIR channels of the ortho-mosaic were converted to a non-calibrated normalized difference vegetation index (NDVI) according to the following relationship:

$$NDVI = (NIR - Red) / (NIR + Red)$$

A threshold value of 0.2 was subsequently selected to generate masks of vegetated (NDVI > 0.2) and non-vegetated areas (NDVI <= 0.2) in preparation for unsupervised classification.

The red and NIR spectral bands of the pair of LANDSAT-8 images were radiometrically normalized to facilitate multi-date image comparison. Invariant objects of varying brightness were selected to compute a least-squares fit between the spectral bands of both image dates. In preparation for change detection analysis, NDVI images were generated from the radiometrically normalized spectral bands. The difference between the 2013 and 2015 NDVI images was calculated, and a threshold of 5% was applied to the frequency distribution of difference image to highlight areas that have changed from vegetated to non-vegetated surfaces. The layer of changed areas edited to remove obvious noise, errors and inconsistencies, and the result was combined with the final land cover map.

2.3 Extraction of Land Cover Information

The land cover categories of relevance to this investigation and are presented in Table 3.

Table 3. Land cover categories

Land Cover Categories	Description	Sub-Categories
Forest	Contiguous stands of trees and large shrubs	n/a
Residential	Small homes and sub-divisions	Average lot size = 1/8 acres Average lot size = 1/4 acres Average lot size = 1/3 acres Average lot size = 1/2 acres Average lot size = 1 acre Average lot size = 2 acres
Commercial	Large building and parking lots, schools, shopping malls, industries, plants, etc.	Commercial Industrial
Deforested	Patches of treed and un-treed areas adjacent to forest roads, areas with open green fields in forested zones.	n/a
Barren	Bare soil, non-vegetated areas	n/a
Open	Fields, pastures, agricultural areas, farmer fields; parks, cemeteries, golf courses, etc. within urban area, low lying grass areas near airport, vegetated area.	n/a
Wetlands/Water	Wetlands, lakes, ponds, and rivers.	Water (lakes, ponds and rivers) Wetlands (primarily bogs/fens)
Major Roads	Major traffic arteries in AOI	n/a

Land cover was extracted from the resampled pansharpened ortho-mosaic in the following stages:

- The major land cover categories *Forest*, *Deforested, Barren* and *Open*, as well as the sub-categories *Water* and *Wetlands*, were extracted by means of unsupervised classification. The ortho-mosaic was subjected to an unsupervised fuzzy-k-means classification to generate a large number of spectral classes. Separate classification runs were carried out using the masks of vegetated and non-vegetated areas, with 50 initial spectral clusters generated in each instance. The initial spectral clusters subsequently aggregated by an analyst to yield the land cover categories of interest.

- The land cover classes *Residential* and *Commercial* were extracted by editing the stereoscopy-derived transportation vector layer to form closed polygons. The sub-category *Industrial* was subsequently defined by on-screen digitizing using local knowledge of the AOI.

- The category Major Roads was extracted via visual image interpretation of the full-resolution pansharpened ortho-mosaic and on-screen digitizing.

- The average lot size for *Residential* sub-categories was determined by overlaying the *Residential* polygon layer over the full-resolution pansharpened ortho-mosaic and measuring lot size within each polygon.

- Using the full-resolution ortho-mosaic as a baseline for interpretation, the output of the LANDSAT-8 change detection analysis was integrated into the land cover map, and individual changed areas were assigned to the land cover categories *Residential*, *Commercial* or *Barren.*

The individual components described above were combined into a single initial land cover map. Spatial filtering was applied to remove small polygons and reduce the amount of noise in the classified product. A sieve filter was first applied to retain only polygons consisting of at least 20 contiguous pixels. This was followed by two mode filters with window sizes of 3x3 and 7x7 pixels, respectively.

Final editing and correction of residual errors was performed using visual interpretation of the full-resolution ortho-mosaic and on-screen digitizing. The final product was converted to GeoTIFF format and reprojected to the Modified 3 - Degree Transverse Mercator (MTM) projection, Zone 1, used for the province of Newfoundland and Labrador.

2.4 Accuracy Assessment

The accuracy of the final classification product was assessed using a validation sample of 198 pixels selected at random from the full-resolution ortho-mosaic. The land cover of each pixel was determined by principles of visual image interpretation. The analysis was limited to the principle land cover categories as described presented in Table 3, with the exception of *Major Roads*. Classification accuracy was calculated using a confusion matrix to compare predicted and reference land cover at each location in the validation sample.

3 Results

The final land cover map for the Waterford River watershed is presented in Figure 3. The result of the accuracy assessment is shown in Table 4. Reference data and classified map agree well with an overall classification accuracy of 94.95%. The corresponding 95%-confidence limits are 91.90% and 98.00%, respectively. As the samples for accuracy assessment were selected at random, the variation of sample sizes across the different land cover categories reflects their occurrence and distribution in the AOI.

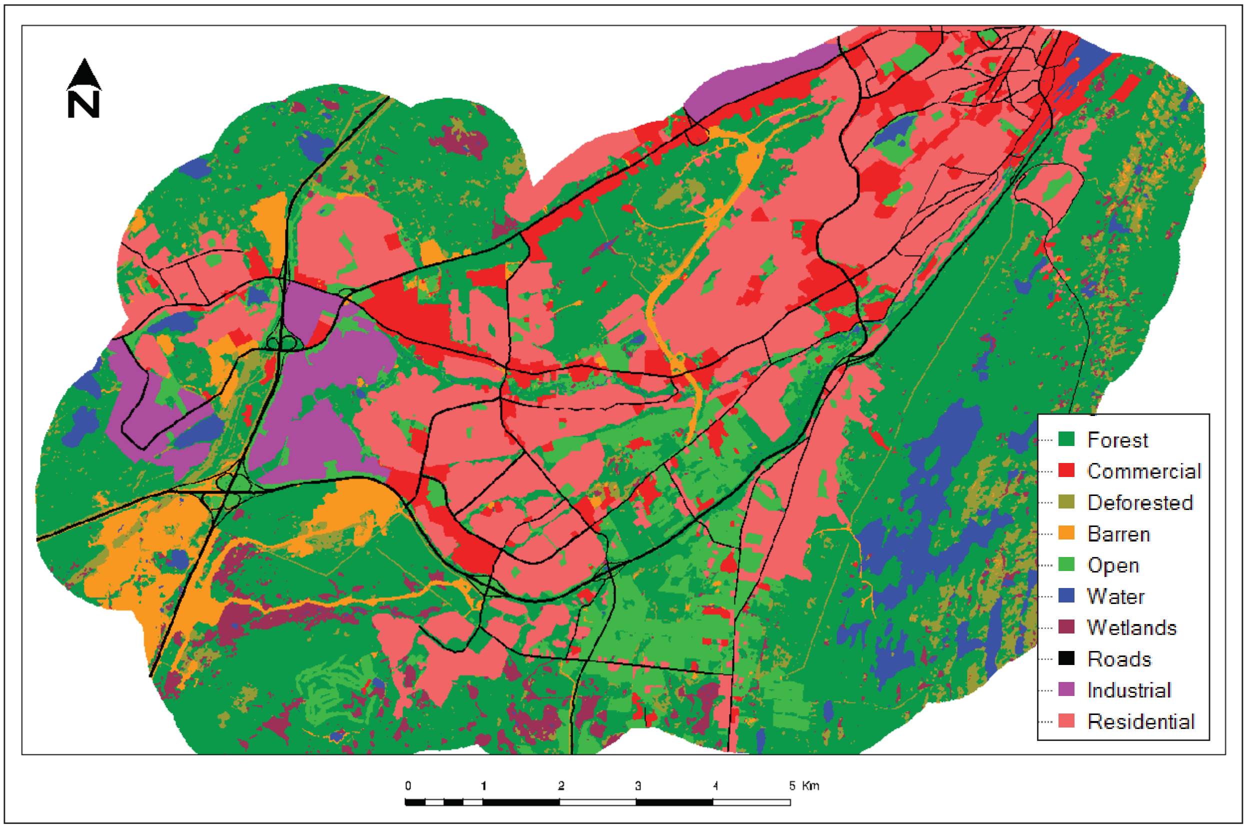


Figure 3. Final land cover map

Table 4. Confusion matrix

Classification	Reference						
	Forest	Residential	Commercial	Deforested	Barren	Open	Wetland/Water
Forest	**45**	0	0	3	0	0	0
Residential	2	**71**	0	0	0	3	0
Commercial	0	0	**20**	0	0	0	0
Deforested	0	0	0	**6**	0	2	0
Barren	0	0	0	0	**7**	0	0
Open	0	0	0	0	0	**18**	0
Wetlands/Water	0	0	0	0	0	0	**21**

LAST PAGE OF DOCUMENT

APPENDIX H

Flood Risk Maps

Notes:

Legend:

1:20 AEP Floodline
1:100 AEP Floodline
Watercourse Centreline
Map Extents

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Content may not reflect National Geographic's current map policy.
Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC,

3	12/01/2017	ISSUED FOR FINAL REPORT
2	03/31/2017	ISSUED FOR DRAFT FINAL REPORT
1	02/27/2017	ISSUED FOR DRAFT REPORT
No	Date	Issue/Revision

Newfoundland Labrador
Department of Municipal Affairs and Environment

Project:

MAE - WATERFORD RIVER AREA
FLOOD RISK MAPPING

Drawing Title:

INUNDATION BOUNDARY FOR
CURRENT CLIMATE, CURRENT
DEVELOPMENT CONDITIONS (CC-CD)
OVERVIEW MAP

CBCL CBCL LIMITED
Consulting Engineers

Scale: 1:12,500
WHEN PLOTTED 36" x 48"
0 125 250 500 750 1,000
Meters
0 375 750 1,500 2,250 3,000
Feet
Coordinate System: NAD 1983 MTM ZONE 1

Drawn:	SMO	Designed:	LNW
Checked:	LNW	Approved:	GES
Date:	JAN 2017	Drawing No:	1-0
Project No:	153113.00		

Notes:

Legend:

1:20 AEP Floodline
1:100 AEP Floodline
Watercourse Centreline
Map Extents

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Content may not reflect National Geographic's current map policy.
Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC,

No	Date	Issue/Revision
3	12/01/2017	ISSUED FOR FINAL REPORT
2	03/31/2017	ISSUED FOR DRAFT FINAL REPORT
1	02/27/2017	ISSUED FOR DRAFT REPORT

Newfoundland Labrador
Department of Municipal Affairs and Environment

Project:
MAE - WATERFORD RIVER AREA
FLOOD RISK MAPPING

Drawing Title:
INUNDATION BOUNDARY FOR
CLIMATE CHANGE, FUTURE
DEVELOPMENT CONDITIONS (CLC-FD)
OVERVIEW MAP

CBCL LIMITED
Consulting Engineers

Scale: 1:12,500
WHEN PLOTTED 36" x 48"
0 125 250 500 750 1,000
Meters
0 375 750 1,500 2,250 3,000
Feet
Coordinate System: NAD 1983 MTM ZONE 1

Drawn:	SMO	Designed:	LNW
Checked:	LNW	Approved:	GES
Date:	JAN 2017	Drawing No:	2-0
Project No:	153113.00		

Notes:

Legend:

Velocity Distribution
- 0.0 - 1.0 m/s
- 1.0 - 2.0 m/s
- 2.0 - 3.0 m/s
- 3.0 - 4.0 m/s
- 4.0 - 5.0 m/s
- Greater than 5.0 m/s
- Watercourse Centreline
- Map Extents

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Content may not reflect National Geographic's current map policy.
Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC,

No	Date	Issue/Revision
3	12/01/2017	ISSUED FOR FINAL REPORT
2	03/31/2017	ISSUED FOR DRAFT FINAL REPORT
1	02/27/2017	ISSUED FOR DRAFT REPORT

Newfoundland Labrador
Department of Municipal Affairs and Environment

Project:
MAE - WATERFORD RIVER AREA
FLOOD RISK MAPPING

Drawing Title:
1:20 YEAR VELOCITY DISTRUBUTION
FOR CURRENT CLIMATE, CURRENT
DEVELOPMENT CONDITIONS (CC-CD)
OVERVIEW MAP

CBCL LIMITED
Consulting Engineers

Scale:1:12,500
WHEN PLOTTED 36" x 48"
0 125 250 500 750 1,000
Meters
0 375 750 1,500 2,250 3,000
Feet
Coordinate System: NAD 1983 MTM ZONE 1

Drawn:	SMO	Designed:	LNW
Checked:	LNW	Approved:	GES
Date:	JAN 2017	Drawing No:	3-0
Project No:	153113.00		

Notes:

Legend:

Velocity Distribution

- 0.0 - 1.0 m/s
- 1.0 - 2.0 m/s
- 2.0 - 3.0 m/s
- 3.0 - 4.0 m/s
- 4.0 - 5.0 m/s
- Greater than 5.0 m/s
- Watercourse Centreline
- Map Extents

No	Date	Issue/Revision
3	12/01/2017	ISSUED FOR FINAL REPORT
2	03/31/2017	ISSUED FOR DRAFT FINAL REPORT
1	02/27/2017	ISSUED FOR DRAFT REPORT

Newfoundland Labrador
Department of Municipal Affairs and Environment

Project:

MAE - WATERFORD RIVER AREA
FLOOD RISK MAPPING

Drawing Title:

1:100 YEAR VELOCITY DISTRUBUTION
FOR CURRENT CLIMATE, CURRENT
DEVELOPMENT CONDITIONS (CC-CD)
OVERVIEW MAP

CBCL LIMITED
Consulting Engineers

Scale: 1:12,500
WHEN PLOTTED 36" x 48"
0 125 250 500 750 1,000
Meters
0 375 750 1,500 2,250 3,000
Feet
Coordinate System: NAD 1983 MTM ZONE 1

Drawn:	SMO	Designed:	LNW
Checked:	LNW	Approved:	GES
Date:	JAN 2017	Drawing No:	4-0
Project No:	153113.00		

Notes:

Legend:

Velocity Distribution

- 0.0 - 1.0 m/s
- 1.0 - 2.0 m/s
- 2.0 - 3.0 m/s
- 3.0 - 4.0 m/s
- 4.0 - 5.0 m/s
- Greater than 5.0 m/s
- Watercourse Centreline
- Map Extents

No	Date	Issue/Revision
3	12/01/2017	ISSUED FOR FINAL REPORT
2	03/31/2017	ISSUED FOR DRAFT FINAL REPORT
1	02/27/2017	ISSUED FOR DRAFT REPORT

Newfoundland Labrador
Department of Municipal Affairs and Environment

Project:

MAE - WATERFORD RIVER AREA
FLOOD RISK MAPPING

Drawing Title:

1:20 YEAR VELOCITY DISTRUBUTION
FOR CLIMATE CHANGE, FUTURE
DEVELOPMENT CONDITIONS (CLC-FD)
OVERVIEW MAP

CBCL LIMITED
Consulting Engineers

Scale: 1:12,500
WHEN PLOTTED 36" x 48"
0 125 250 500 750 1,000
Meters
0 375 750 1,500 2,250 3,000
Feet
Coordinate System: NAD 1983 MTM ZONE 1

Drawn:	SMO	Designed:	LNW
Checked:	LNW	Approved:	GES
Date:	JAN 2017	Drawing No:	5-0
Project No:	153113.00		

Notes:

Legend:

Velocity Distribution
- 0.0 - 1.0 m/s
- 1.0 - 2.0 m/s
- 2.0 - 3.0 m/s
- 3.0 - 4.0 m/s
- 4.0 - 5.0 m/s
- Greater than 5.0 m/s
- Watercourse Centreline
- Map Extents

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Content may not reflect National Geographic's current map policy.
Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC,

No	Date	Issue/Revision
3	12/01/2017	ISSUED FOR FINAL REPORT
2	03/31/2017	ISSUED FOR DRAFT FINAL REPORT
1	02/27/2017	ISSUED FOR DRAFT REPORT

Newfoundland Labrador
Department of Municipal Affairs and Environment

Project:
MAE - WATERFORD RIVER AREA
FLOOD RISK MAPPING

Drawing Title:
1:100 YEAR VELOCITY DISTRUBUTION
FOR CLIMATE CHANGE, FUTURE
DEVELOPMENT CONDITIONS (CLC-FD)
OVERVIEW MAP

CBCL LIMITED
Consulting Engineers

Scale: 1:12,500
WHEN PLOTTED 36" x 48"
0 125 250 500 750 1,000
Meters
0 375 750 1,500 2,250 3,000
Feet
Coordinate System: NAD 1983 MTM ZONE 1

Drawn:	SMO	Designed:	LNW
Checked:	LNW	Approved:	GES
Date:	JAN 2017	Drawing No:	6-0
Project No:	153113.00		

Notes:

Legend:

Degree of Flood Hazard

Low		Caution
Moderate		Danger for Some. Includes children, the elderly and the infirm
Significant		Danger for Most. Includes the general public
Extreme		Danger for All. Includes the emergency services

Watercourse Centreline

Map Extents

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Content may not reflect National Geographic's current map policy.
Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC,

No	Date	Issue/Revision
3	12/01/2017	ISSUED FOR FINAL REPORT
2	03/31/2017	ISSUED FOR DRAFT FINAL REPORT
1	02/27/2017	ISSUED FOR DRAFT REPORT

Newfoundland Labrador
Department of Municipal Affairs and Environment

Project:
MAE - WATERFORD RIVER AREA
FLOOD RISK MAPPING

Drawing Title:
1:20 YEAR FLOOD HAZARD
FOR CURRENT CLIMATE, CURRENT
DEVELOPMENT CONDITIONS (CC-CD)
OVERVIEW MAP

CBCL LIMITED
Consulting Engineers

Scale: 1:12,500
WHEN PLOTTED 36" x 48"
0 125 250 500 750 1,000
Meters
0 375 750 1,500 2,250 3,000
Feet
Coordinate System: NAD 1983 MTM ZONE 1

Drawn:	SMO	Designed:	LNW
Checked:	LNW	Approved:	GES
Date:	JAN 2017	Drawing No:	7-0
Project No:	153113.00		

Notes:

Legend:

Degree of Flood Hazard

Low		Caution
Moderate		Danger for Some. Includes children, the elderly and the infirm
Significant		Danger for Most. Includes the general public
Extreme		Danger for All. Includes the emergency services
	Watercourse Centreline	
	Map Extents	

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Content may not reflect National Geographic's current map policy.
Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC,

No	Date	Issue/Revision
3	12/01/2017	ISSUED FOR FINAL REPORT
2	03/31/2017	ISSUED FOR DRAFT FINAL REPORT
1	02/27/2017	ISSUED FOR DRAFT REPORT

Newfoundland Labrador
Department of Municipal Affairs and Environment

Project:
MAE - WATERFORD RIVER AREA
FLOOD RISK MAPPING

Drawing Title:
1:100 YEAR FLOOD HAZARD
FOR CURRENT CLIMATE, CURRENT
DEVELOPMENT CONDITIONS (CC-CD)
OVERVIEW MAP

CBCL LIMITED
Consulting Engineers

Scale: 1:12,500
WHEN PLOTTED 36" x 48"
0 125 250 500 750 1,000
Meters
0 375 750 1,500 2,250 3,000
Feet
Coordinate System: NAD 1983 MTM ZONE 1

Drawn:	SMO	Designed:	LNW
Checked:	LNW	Approved:	GES
Date:	JAN 2017	Drawing No:	8-0
Project No:	153113.00		

Notes:

Legend:

Degree of Flood Hazard

Low		Caution
Moderate		Danger for Some. Includes children, the elderly and the infirm
Significant		Danger for Most. Includes the general public
Extreme		Danger for All. Includes the emergency services

Watercourse Centreline

Map Extents

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Content may not reflect National Geographic's current map policy.
Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC,

No	Date	Issue/Revision
3	12/01/2017	ISSUED FOR FINAL REPORT
2	03/31/2017	ISSUED FOR DRAFT FINAL REPORT
1	02/27/2017	ISSUED FOR DRAFT REPORT

Newfoundland Labrador
Department of Municipal Affairs and Environment

Project:

MAE - WATERFORD RIVER AREA
FLOOD RISK MAPPING

Drawing Title:

1:20 YEAR FLOOD HAZARD
FOR CLIMATE CHANGE, FUTURE
DEVELOPMENT CONDITIONS (CLC-FD)
OVERVIEW MAP

CBCL LIMITED
Consulting Engineers

Scale: 1:12,500
WHEN PLOTTED 36" x 48"
0 125 250 500 750 1,000
Meters
0 375 750 1,500 2,250 3,000
Feet
Coordinate System: NAD 1983 MTM ZONE 1

Drawn:	SMO	Designed:	LNW
Checked:	LNW	Approved:	GES
Date:	JAN 2017	Drawing No:	9-0
Project No:	153113.00		

Notes:

Legend:

Degree of Flood Hazard

Low		Caution
Moderate		Danger for Some. Includes children, the elderly and the infirm
Significant		Danger for Most. Includes the general public
Extreme		Danger for All. Includes the emergency services

Watercourse Centreline

Map Extents

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Content may not reflect National Geographic's current map policy.
Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC,

No	Date	Issue/Revision
3	12/01/2017	ISSUED FOR FINAL REPORT
2	03/31/2017	ISSUED FOR DRAFT FINAL REPORT
1	02/27/2017	ISSUED FOR DRAFT REPORT

Newfoundland Labrador
Department of Municipal Affairs and Environment

Project:
MAE - WATERFORD RIVER AREA
FLOOD RISK MAPPING

Drawing Title:
1:100 YEAR FLOOD HAZARD
FOR CLIMATE CHANGE, FUTURE
DEVELOPMENT CONDITIONS (CLC-FD)
OVERVIEW MAP

CBCL LIMITED
Consulting Engineers

Scale: 1:12,500
WHEN PLOTTED 36" x 48"
0 125 250 500 750 1,000
Meters
0 375 750 1,500 2,250 3,000
Feet
Coordinate System: NAD 1983 MTM ZONE 1

Drawn:	SMO	Designed:	LNW
Checked:	LNW	Approved:	GES
Date:	JAN 2017	Drawing No:	10-0
Project No:	153113.00		

Notes:

Legend:

Climate Change - Future Development (CLC-FD) AEP Floodline

Current Condition - Current Development (CC-CD) AEP Floodline

Watercourse Centreline

Map Extents

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Content may not reflect National Geographic's current map policy.
Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC,

No	Date	Issue/Revision
3	12/01/2017	ISSUED FOR FINAL REPORT
2	03/31/2017	ISSUED FOR DRAFT FINAL REPORT
1	02/27/2017	ISSUED FOR DRAFT REPORT

Newfoundland Labrador
Department of Municipal Affairs and Environment

Project:
MAE - WATERFORD RIVER AREA
FLOOD RISK MAPPING

Drawing Title:
1:20 YEAR COMPARISON INUNDATION BOUNDARY FOR CURRENT CLIMATE, CURRENT DEVELOPMENT (CC-CD) AND CLIMATE CHANGE, FUTURE DEVELOPMENT (CLC-FD) CONDITIONS
OVERVIEW MAP

CBCL LIMITED
Consulting Engineers

Scale: 1:12,500
WHEN PLOTTED 36" x 48"
0 125 250 500 750 1,000
Meters
0 375 750 1,500 2,250 3,000
Feet
Coordinate System: NAD 1983 MTM ZONE 1

Drawn:	SMO	Designed:	LNW
Checked:	LNW	Approved:	GES
Date:	JAN 2017	Drawing No:	11-0
Project No:	153113.00		

Notes:

Legend:

Climate Change - Future Development (CLC-FD) AEP Floodline

Current Condition - Current Development (CC-CD) AEP Floodline

Watercourse Centreline

Map Extents

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Content may not reflect National Geographic's current map policy.
Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC,

No	Date	Issue/Revision
3	12/01/2017	ISSUED FOR FINAL REPORT
2	03/31/2017	ISSUED FOR DRAFT FINAL REPORT
1	02/27/2017	ISSUED FOR DRAFT REPORT

Newfoundland Labrador
Department of Municipal Affairs and Environment

Project:
MAE - WATERFORD RIVER AREA FLOOD RISK MAPPING

Drawing Title:
1:100 YEAR COMPARISON INUNDATION BOUNDARY FOR CURRENT CLIMATE, CURRENT DEVELOPMENT (CC-CD) AND CLIMATE CHANGE, FUTURE DEVELOPMENT (CLC-FD) CONDITIONS OVERVIEW MAP

CBCL LIMITED
Consulting Engineers

Scale: 1:12,500
WHEN PLOTTED 36" x 48"
0 125 250 500 750 1,000
Meters
0 375 750 1,500 2,250 3,000
Feet
Coordinate System: NAD 1983 MTM ZONE 1

Drawn:	SMO	Designed:	LNW
Checked:	LNW	Approved:	GES
Date:	JAN 2017	Drawing No:	12-0
Project No:	153113.00		

Notes:

Legend:

Historical AEP Floodline

Current Condition - Current Development (CC-CD) AEP Floodline

Watercourse Centreline

Map Extents

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC,

3	12/01/2017	ISSUED FOR FINAL REPORT
2	03/31/2017	ISSUED FOR DRAFT FINAL REPORT
1	02/27/2017	ISSUED FOR DRAFT REPORT
No	Date	Issue/Revision

Newfoundland Labrador
Department of Municipal Affairs and Environment

Project:

MAE - WATERFORD RIVER AREA
FLOOD RISK MAPPING

Drawing Title:

1:20 YEAR COMPARISON INUNDATION BOUNDARY FOR CURRENT CLIMATE, CURRENT DEVELOPMENT (CC-CD) AND HISTORICAL FLOOD ZONE CONDITIONS OVERVIEW MAP

CBCL LIMITED
Consulting Engineers

Scale: 1:12,500
WHEN PLOTTED 36" x 48"
0 125 250 500 750 1,000
Meters
0 375 750 1,500 2,250 3,000
Feet
Coordinate System: NAD 1983 MTM ZONE 1

Drawn:	SMO	Designed:	LNW
Checked:	LNW	Approved:	GES
Date:	JAN 2017	Drawing No:	13-0
Project No:	153113.00		

Notes:

Legend:

Historical AEP Floodline

Current Condition - Current Development (CC-CD) AEP Floodline

Watercourse Centreline

Map Extents

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Content may not reflect National Geographic's current map policy.
Sources: National Geographic, Esri, DeLorme, HERE, UNEP-WCMC,

No	Date	Issue/Revision
3	12/01/2017	ISSUED FOR FINAL REPORT
2	03/31/2017	ISSUED FOR DRAFT FINAL REPORT
1	02/27/2017	ISSUED FOR DRAFT REPORT

Newfoundland Labrador
Department of Municipal Affairs and Environment

Project:

MAE - WATERFORD RIVER AREA
FLOOD RISK MAPPING

Drawing Title:

1:100 YEAR COMPARISON INUNDATION BOUNDARY FOR CURRENT CLIMATE, CURRENT DEVELOPMENT (CC-CD) AND HISTORICAL FLOOD ZONE CONDITIONS OVERVIEW MAP

CBCL LIMITED
Consulting Engineers

Scale: 1:12,500
WHEN PLOTTED 36" x 48"
0 125 250 500 750 1,000
Meters
0 375 750 1,500 2,250 3,000
Feet
Coordinate System: NAD 1983 MTM ZONE 1

Drawn:	SMO	Designed:	LNW
Checked:	LNW	Approved:	GES
Date:	JAN 2017	Drawing No:	14-0
Project No:	153113.00		

APPENDIX I

Structure Tables

Structure Table 1: 1:100 AEP

<table>
<tr><th rowspan="2">River</th><th rowspan="2">Reach</th><th rowspan="2">Structure ID</th><th rowspan="2">Number of Structures</th><th rowspan="2">Structure Type</th><th>Structure Geometry</th><th rowspan="2">Profile</th><th>Q Total</th><th>Depth Overtop</th><th rowspan="2">Outlet/ Inlet Control</th><th rowspan="2">Comments</th></tr>
<tr><th>(m)</th><th>(m^3/s)</th><th>cm</th></tr>
<tr><td rowspan="2">Waterford River</td><td rowspan="2">Upper Waterford</td><td rowspan="2">16486.17
268-269</td><td rowspan="2">1 Culvert</td><td rowspan="2">Culvert #1</td><td rowspan="2"><u>Culvert #1</u>
CMP Standard Arch
Span: 3.0
Rise: 1.8
Length: 21.8</td><td>CC_CD 100</td><td>8.5</td><td></td><td>O</td><td></td></tr>
<tr><td>CLC_FD 100</td><td>14.6</td><td></td><td>O</td><td></td></tr>
<tr><td rowspan="4">Waterford River</td><td rowspan="4">Upper Waterford</td><td rowspan="4">14248.03
261-262</td><td rowspan="4">2 Culverts</td><td>Culvert #1</td><td rowspan="4"><u>Culvert #1</u>
CMP Pipe Arch
Span: 1.85
Rise: 1.3
Length: 47.6

<u>Culvert #2</u>
CMP Pipe Arch
Span: 1.83
Rise: 1.12
Length: 42.1</td><td rowspan="2">CC_CD 100</td><td rowspan="2">8.5
(Total 2 Culverts)</td><td rowspan="2"></td><td>O</td><td></td></tr>
<tr><td>Culvert #2</td><td>O</td><td></td></tr>
<tr><td>Culvert #1</td><td rowspan="2">CLC_FD 100</td><td rowspan="2">14.6
(Total 2 Culverts and Weir)</td><td rowspan="2">14</td><td>O</td><td></td></tr>
<tr><td>Culvert #2</td><td>O</td><td></td></tr>
</table>

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Waterford River	*Upper Waterford*	**14202.04** 259-260	2 Culverts	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.89 Rise: 1.42 Length: 17.3	CC_CD 100	8.5 (Total 2 Culverts)		O	
				Culvert #2					O	
				Culvert #1	Culvert #2 CMP Pipe Arch Span: 1.83 Rise: 1.17 Length: 17.1	CLC_FD 100	14.6 (Total 2 Culverts and Weir)	10	O	
				Culvert #2					O	
Waterford River	*Upper Waterford*	**14025.25** 255-256	2 Culverts	Culvert #1	Culvert #1 CMP Arch Span: 1.75 Rise: 1.07 Length: 87.2	CC_CD 100	8.5 (Total 2 Culverts)		O	
				Culvert #2					O	
				Culvert #1	Culvert #2 CMP Arch Span: 1.86 Rise: 1.42 Length: 87.0	CLC_FD 100	14.6 (Total 2 Culverts)		O	
				Culvert #2					O	

<table>
<thead>
<tr><th rowspan="2">River</th><th rowspan="2">Reach</th><th rowspan="2">Structure ID</th><th rowspan="2">Number of Structures</th><th rowspan="2">Structure Type</th><th>Structure Geometry</th><th rowspan="2">Profile</th><th>Q Total</th><th>Depth Overtop</th><th rowspan="2">Outlet/ Inlet Control</th><th rowspan="2">Comments</th></tr>
<tr><th>(m)</th><th>(m^3/s)</th><th>cm</th></tr>
</thead>
<tbody>
<tr><td rowspan="4">Waterford River</td><td rowspan="4">Upper Waterford</td><td rowspan="4">13832.02
251-252</td><td rowspan="4">2 Culverts</td><td>Culvert #1</td><td rowspan="2"><u>Culvert #1</u>
CMP Arch
Span: 1.89
Rise: 1.42
Length: 23.4</td><td rowspan="2">CC_CD 100</td><td rowspan="2">8.5
(Total 2 Culverts)</td><td rowspan="2"></td><td>O</td><td></td></tr>
<tr><td>Culvert #2</td><td>O</td><td></td></tr>
<tr><td>Culvert #1</td><td rowspan="2"><u>Culvert #2</u>
CMP Arch
Span: 1.67
Rise: 1.02
Length: 22.8</td><td rowspan="2">CLC_FD 100</td><td rowspan="2">14.6
(Total 2 Culverts and Weir)</td><td rowspan="2">22</td><td>O</td><td></td></tr>
<tr><td>Culvert #2</td><td>O</td><td></td></tr>
<tr><td rowspan="4">Waterford River</td><td rowspan="4">Upper Waterford</td><td rowspan="4">13603
247-248</td><td rowspan="4">2 Culverts</td><td>Culvert #1</td><td rowspan="2"><u>Culvert #1</u>
CMP Arch
Span: 1.89
Rise: 1.42
Length: 16.9</td><td rowspan="2">CC_CD 100</td><td rowspan="2">8.5
(Total 2 Culverts)</td><td rowspan="2"></td><td>O</td><td></td></tr>
<tr><td>Culvert #2</td><td>O</td><td></td></tr>
<tr><td>Culvert #1</td><td rowspan="2"><u>Culvert #2</u>
CMP Arch
Span: 1.84
Rise: 1.22
Length: 16.9</td><td rowspan="2">CLC_FD 100</td><td rowspan="2">14.6
(Total 2 Culverts and Weir)</td><td rowspan="2">23</td><td>O</td><td></td></tr>
<tr><td>Culvert #2</td><td>O</td><td></td></tr>
</tbody>
</table>

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Waterford River	*Upper Waterford*	**13413.93** 243-244	2 Culverts	Culvert #1	Culvert #1 CMP Circular Dia.: 1.47 Length: 13.8	CC_CD 100	8.5 (Total 2 Culverts and Weir)	8	O	
				Culvert #2					O	
				Culvert #1	Culvert #2 CMP Circular Dia.: 1.47 Length: 13.8	CLC_FD 100	14.6 (Total 2 Culverts and Weir)	23	O	
				Culvert #2					O	
Waterford River	*US of Donovans Tributary*	**12760.69** 237-238 **Multiple opening*	1 Bridge + 3 Culverts	Bridge	Span: 9.9 Length: 2.4 Height: 1.8	CC_CD 100	22.64 (Total Bridge and Weir)	33		Multiple opening structure is submerged upstream and downstream. Flow through structure is representative of downstream conditions.
						CLC_FD 100	35.08 (Total Bridge and Weir)	80		
				Culvert #1	Culvert #1 CMP Circular Dia.: 0.6 Length: 6.3	CC_CD 100	1.56 (Total 3 Culverts and Weir)	27	O	
				Culvert #2					O	
				Culvert #3	Culvert #2 CMP Circular Dia.: 0.6 Length: 6.3				O	
				Culvert #1		CLC_FD 100	2.42 (Total 3 Culverts and Weir)	73	O	
				Culvert #2	Culvert #3 CMP Circular Dia.: 0.6 Length: 6.4				O	
				Culvert #3					O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Waterford River	*US of Donovans Tributary*	**12729.73** 235-236	1 Culvert	Culvert #1	Culvert #1 CMP Arch Span: 10.86 Rise: 7.0 Length: 46.6	CC_CD 100	24.2		O	
						CLC_FD 100	37.5		O	
Waterford River	*US of Donovans Tributary*	**12567.9** 231-232	1 Bridge	Bridge	Span: 2.5 Length: 3.0 Height: 2.0	CC_CD 100	24.2 (Total Bridge and Weir)	39		CLC_FD 100 flow results may be low, see calculation messages for details.
						CLC_FD 100	37.5 (Total Bridge and Weir)	76		
Waterford River	*US of Branscombe*	**12431.8** 228_B-229_A	1 Culvert	Culvert #1	Culvert #1 CMP Pipe Arch + Rect. Weir Span: 3.23 Rise: 2.1 Length: 6.2	CC_CD 100	43.4 (Total Culvert and Weir)	42	O	Structure has a blocked depth of 0.51m and is submerged upstream and downstream. Flow through structure is representative of downstream conditions.
						CLC_FD 100	64.1 (Total Culvert and Weir)	80	O	
Waterford River	*US of Branscombe*	**12129.69** 225-226	1 Culvert	Culvert #1	Culvert #1 CMP Open Bottom Arch Span: 8.3 Rise: 2.9 Length: 16.2	CC_CD 100	43.4		O	
						CLC_FD 100	64.1		O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Waterford River	*US of Branscombe*	**10480.73** 217-218	1 Bridge	Bridge	Span: 14.6 Length: 2.0 Height: 3.5	CC_CD 100	43.4			
						CLC_FD 100	64.1			
Waterford River	*US of Branscombe*	**10024.95** 212-213	1 Bridge	Bridge	Span: 10.8 Length: 18.0 Height: 3.1	CC_CD 100	43.4			
						CLC_FD 100	64.1			
Waterford River	*US of Branscombe*	**9194.803** 205-206	1 Bridge	Bridge	Span: 18.0 Length: 1.9 Height: 1.8	CC_CD 100	43.4			
						CLC_FD 100	64.1			
Waterford River	*US of Branscombe*	**8019.17** 198-199	1 Bridge	Bridge	Span: 23.6 Length: 1.8 Height: 2.9	CC_CD 100	54.8			
						CLC_FD 100	74.3			
Waterford River	*US of Branscombe*	**7610.337** 192-193	1 Bridge	Bridge	Span: 16.6 Length: 1.5 Height: 2.6	CC_CD 100	54.8			
						CLC_FD 100	74.3			
Waterford River	*US of Branscombe*	**7451.063** 187-188	1 Bridge	Bridge	Span: 27.0 Length: 2.0 Height: 3.7	CC_CD 100	54.8			
						CLC_FD 100	74.3			

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Waterford River	*US of Branscombe*	**7092.577** 182-183	1 Bridge	Bridge	Span: 9.2 Length: 1.8 Height: 3.2	CC_CD 100	54.8			
						CLC_FD 100	74.3			
Waterford River	*US of South Brook*	**7006.117** 176-177	1 Bridge	Bridge	Span: 8.0 Length: 13.6 Height: 1.8	CC_CD 100	68 (Total Bridge and Weir)	37		CLC-FD flow results through structure may be low, see calculation messages for details.
						CLC_FD 100	98.2 (Total Bridge and Weir)	97		
Waterford River	*US of South Brook*	**6660.091** 170-171	1 Culvert	Culvert #1	Culvert #1 CMP Open Bottom Arch Span: 10.1 Rise: 4.3 Length: 71.0	CC_CD 100	68.0		O	
						CLC_FD 100	98.2		O	
Waterford River	*US of South Brook*	**5464.561** 158-159	1 Bridge	Bridge	Span: 14.2 Length: 15.5 Height: 1.7	CC_CD 100	82 (Total Bridge and Weir)	36		Structure is submerged upstream and downstream.
						CLC_FD 100	116.7 (Total Bridge and Weir)	64		
Waterford River	*US of South Brook*	**4885.659** 150-151	1 Bridge	Bridge	Span: 10.3 Length: 19.1 Height: 1.8	CC_CD 100	82 (Total Bridge and Weir)	3		Reported total flow for profile CLC-FD may be low – backflow condition through structure possible. See calculation messages for details.
						CLC_FD 100	116.7 (Total Bridge and Weir)	50		

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Waterford River	*US of South Brook*	**4622.255** 145-146	1 Bridge	Bridge	Span: 7.4 Length: 2.1 Height: 3.3	CC_CD 100	82 (Total Bridge and Weir)	56		Structure is submerged upstream and downstream.
						CLC_FD 100	116.7 (Total Bridge and Weir)	55		
Waterford River	*US of South Brook*	**4484.719** 141-142	1 Bridge	Bridge	Span: 9.8 Length: 1.6 Height: 1.9	CC_CD 100	82 (Total Bridge and Weir)	74		
						CLC_FD 100	116.7 (Total Bridge and Weir)	85		
Waterford River	*US of South Brook*	**4297.113** 136-137	1 Bridge	Bridge	Span: 12.4 Length: 2.4 Height: 3.0	CC_CD 100	82			
						CLC_FD 100	116.7 (Total Bridge and Weir)	45		
Waterford River	*US of South Brook*	**4187.59** 132_B-133	1 Bridge	Bridge	Span: 11.3 Length: 7.9 Height: 2.6	CC_CD 100	82			
						CLC_FD 100	116.7 (Total Bridge and Weir)	77		
Waterford River	*Lower Waterford*	**4017.424** 42-43	1 Bridge	Bridge	Span: Unknown Length: 19.0 Height: Unknown	CC_CD 100	118.5			
						CLC_FD 100	166.9			

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Waterford River	*Lower Waterford*	**3722.053** 37-38	1 Bridge	Bridge	Span: 10.8 Length: 10.3 Height: 2.9	CC_CD 100	118.5			
						CLC_FD 100	166.9			
Waterford River	*Lower Waterford*	**2973.547** 30-31	1 Bridge	Bridge	Span: 15.3 Length: 10.8 Height: 2.9	CC_CD 100	124.1			
						CLC_FD 100	174.8			
Waterford River	*Lower Waterford*	**1583.763** 19-20	1 Bridge	Bridge	Span: 18.2 Length: 5.5 Height: 3.0	CC_CD 100	130.7 (Total Bridge and Weir)	8		
						CLC_FD 100	184.6 (Total Bridge and Weir)	34		
Waterford River	*Lower Waterford*	**862.6913** 12-13	1 Bridge	Bridge	Span: 27.2 Length: 19.1 Height: 4.2	CC_CD 100	130.7			
						CLC_FD 100	184.6			
Waterford River	*Lower Waterford*	**189.1353** 6-7	1 Bridge	Bridge	Span: 17.2 Length: 2.9 Height: 3.1	CC_CD 100	136.7 (Total Bridge and Weir)	38		
						CLC_FD 100	195 (Total Bridge and Weir)	41		

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Waterford River	*Lower Waterford*	**144.8533** 3-4	1 Bridge	Bridge	Span: 28.0 Length: 1.7 Height: 2.9	CC_CD 100	136.7 (Total Bridge and Weir)	15		Calculation for weir flow failed to converge. See calculation messages for details.
						CLC_FD 100	195 (Total Bridge and Weir)	16		
Donovans Tributary	*Donovans Tributary*	**2719.669** UR59-60	1 Culvert	Culvert #1	Culvert #1 CMP Standard Arch Span: 2.9 Rise: 1.8 Length: 17.2	CC_CD 100	8.4		O	
						CLC_FD 100	12 (Total Culvert and Weir)	16	O	
Donovans Tributary	*Donovans Tributary*	**2286.604** UR52.5_B-52.5_C	1 Culvert	Culvert #1	Culvert #1 CMP Standard Arch Span: 2.4 Rise: 1.4 Length: 9.9	CC_CD 100	8.4 (Total Culvert and Weir)	1	O	
						CLC_FD 100	12 (Total Culvert and Weir)	17	O	

<table>
<thead>
<tr><th rowspan="2">River</th><th rowspan="2">Reach</th><th rowspan="2">Structure ID</th><th rowspan="2">Number of Structures</th><th rowspan="2">Structure Type</th><th>Structure Geometry</th><th rowspan="2">Profile</th><th>Q Total</th><th>Depth Overtop</th><th rowspan="2">Outlet/ Inlet Control</th><th rowspan="2">Comments</th></tr>
<tr><th>(m)</th><th>(m^3/s)</th><th>cm</th></tr>
</thead>
<tbody>
<tr><td rowspan="6">Donovans Tributary</td><td rowspan="6">Donovans Tributary</td><td rowspan="6">2120.999
UR50-51</td><td rowspan="6">3 Culverts</td><td>Culvert #1</td><td rowspan="6"><u>Culvert #1</u>
CMP Pipe Arch
Span: 1.84
Rise: 1.2
Length: 9.0

<u>Culvert #2</u>
CMP Pipe Arch
Span: 1.84
Rise: 1.2
Length: 9.1

<u>Culvert #3</u>
CMP Pipe Arch
Span: 1.84
Rise: 1.2
Length: 9.1</td><td rowspan="3">CC_CD 100</td><td rowspan="3">8.4
(Total 3 Culverts and Weir)</td><td rowspan="3">18</td><td>O</td><td rowspan="6">Structure is submerged upstream and downstream. Flow through structure is representative of downstream conditions.</td></tr>
<tr><td>Culvert #2</td><td>O</td></tr>
<tr><td>Culvert #3</td><td>O</td></tr>
<tr><td>Culvert #1</td><td rowspan="3">CLC_FD 100</td><td rowspan="3">12.0
(Total 3 Culverts and Weir)</td><td rowspan="3">28</td><td>O</td></tr>
<tr><td>Culvert #2</td><td>O</td></tr>
<tr><td>Culvert #3</td><td>O</td></tr>
</tbody>
</table>

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Donovans Tributary	*Donovans Tributary*	**2097.912** UR47-48	3 Culverts	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.45 Rise: 0.9 Length: 9.2 Culvert #2 CMP Pipe Arch Span: 1.45 Rise: 0.9 Length: 9.2 Culvert #3 CMP Pipe Arch Span: 1.45 Rise: 0.9 Length: 9.3	CC_CD 100	8.4 (Total 3 Culverts and Weir)	11	O	Structure is submerged upstream and downstream. Flow through structure is representative of downstream conditions.
				Culvert #2					O	
				Culvert #3					O	
				Culvert #1		CLC_FD 100	12 (Total 3 Culverts and Weir)	22	O	
				Culvert #2					O	
				Culvert #3					O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Donovans Tributary	*Donovans Tributary*	**2044.66** UR43-44	3 Culverts	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.64 Rise: 1.0 Length: 9.1 Culvert #2 CMP Pipe Arch Span: 1.64 Rise: 1.0 Length: 9.1 Culvert #3 CMP Pipe Arch Span: 1.64 Rise: 1.0 Length: 9.1	CC_CD 100	8.4 (Total 3 Culverts)		O	
				Culvert #2					O	
				Culvert #3					O	
				Culvert #1		CLC_FD 100	12.0 (Total 3 Culverts and Weir)	11	O	
				Culvert #2					O	
				Culvert #3					O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Donovans Tributary	*Donovans Tributary*	**1935.31** UR39-40	3 Culverts	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.45 Rise: 0.9 Length: 9.3 Culvert #2 CMP Pipe Arch Span: 1.45 Rise: 0.9 Length: 9.0 Culvert #3 CMP Pipe Arch Span: 1.45 Rise: 0.9 Length: 9.9	CC_CD 100	8.4 (Total 3 Culverts and Weir)	12	I	
				Culvert #2					I	
				Culvert #3					I	
				Culvert #1		CLC_FD 100	12 (Total 3 Culverts and Weir)	21	I	
				Culvert #2					I	
				Culvert #3					I	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Donovans Tributary	*Donovans Tributary*	**1726.505** UR36B-36C	3 Culverts	Culvert #1	<u>Culvert #1</u> CMP Circular Dia.: 1.5 Length: 25.3 <u>Culvert #2</u> CMP Circular Dia.: 1.5 Length: 26.9 <u>Culvert #3</u> CMP Circular Dia.: 1.5 Length: 25.2	CC_CD 100	8.4 (Total 3 Culverts)		O	
				Culvert #2					O	
				Culvert #3					O	
				Culvert #1		CLC_FD 100	12 (Total 3 Culverts)		O	
				Culvert #2					O	
				Culvert #3					O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Donovans Tributary	*Donovans Tributary*	**1459.808** UR33-34	3 Culverts	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.8 Rise: 1.1 Length: 23.5 Culvert #2 CMP Pipe Arch Span: 1.8 Rise: 1.1 Length: 23.7 Culvert #3 CMP Pipe Arch Span: 1.8 Rise: 1.1 Length: 23.6	CC_CD 100	8.4 (Total 3 Culverts)		O	
				Culvert #2					O	
				Culvert #3					O	
				Culvert #1		CLC_FD 100	12 (Total 3 Culverts and Weir)	6	O	
				Culvert #2					O	
				Culvert #3					O	
Donovans Tributary	*Donovans Tributary*	**1291.697** UR29-30	1 Culvert	Culvert #1	Culvert #1 CMP Standard Arch Span: 4.2 Rise: 1.6 Length: 18.5	CC_CD 100	8.4		O	
						CLC_FD 100	12		O	

<table>
<tr><th rowspan="2">River</th><th rowspan="2">Reach</th><th rowspan="2">Structure ID</th><th rowspan="2">Number of Structures</th><th rowspan="2">Structure Type</th><th>Structure Geometry</th><th rowspan="2">Profile</th><th>Q Total</th><th>Depth Overtop</th><th rowspan="2">Outlet/ Inlet Control</th><th rowspan="2">Comments</th></tr>
<tr><th>(m)</th><th>(m^3/s)</th><th>cm</th></tr>
<tr><td rowspan="6">Donovans Tributary</td><td rowspan="6">Donovans Tributary</td><td rowspan="6">1213.08
UR26-27</td><td rowspan="6">3 Culverts</td><td>Culvert #1</td><td rowspan="6">Culvert #1
CMP Pipe Arch
Span: 1.84
Rise: 1.2
Length: 75.3

Culvert #2
CMP Pipe Arch
Span: 1.84
Rise: 1.2
Length: 73.8

Culvert #3
CMP Pipe Arch
Span: 1.84
Rise: 1.2
Length: 71.5</td><td rowspan="3">CC_CD 100</td><td rowspan="3">8.4
(Total 3 Culverts)</td><td rowspan="3"></td><td>O</td><td rowspan="3"></td></tr>
<tr><td>Culvert #2</td><td>O</td></tr>
<tr><td>Culvert #3</td><td>O</td></tr>
<tr><td>Culvert #1</td><td rowspan="3">CLC_FD 100</td><td rowspan="3">12
(Total 3 Culverts and Weir)</td><td rowspan="3">2</td><td>O</td><td rowspan="3"></td></tr>
<tr><td>Culvert #2</td><td>O</td></tr>
<tr><td>Culvert #3</td><td>O</td></tr>
</table>

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry	Profile	Q Total	Depth Overtop	Outlet/ Inlet Control	Comments
					(m)		(m^3/s)	cm		
Donovans Tributary	*Donovans Tributary*	**955.8469** UR23_B-23_C	3 Culverts	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.64 Rise: 1.0 Length: 10.6 Culvert #2 CMP Pipe Arch Span: 1.54 Rise: 0.95 Length: 10.3 Culvert #3 CMP Pipe Arch Span: 1.84 Rise: 1.2 Length: 10.7	CC_CD 100	8.4 (Total 3 Culverts)		O	
				Culvert #2					I	
				Culvert #3					O	
				Culvert #1		CLC_FD 100	12 (Total 3 Culverts)		O	
				Culvert #2					O	
				Culvert #3					O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Donovans Tributary	*Donovans Tributary*	**832.8687** UR20-21	3 Culverts	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.64 Rise: 1.0 Length: 21.5 Culvert #2 CMP Pipe Arch Span: 1.64 Rise: 1.0 Length: 21.7 Culvert #3 CMP Pipe Arch Span: 1.64 Rise: 1.0 Length: 21.4	CC_CD 100	8.4 (Total 3 Culverts)		O	
				Culvert #2					O	
				Culvert #3					O	
				Culvert #1		CLC_FD 100	12 (Total 3 Culverts and Weir)	10	O	
				Culvert #2					O	
				Culvert #3					I	

<table>
<tr><th rowspan="2">River</th><th rowspan="2">Reach</th><th rowspan="2">Structure ID</th><th rowspan="2">Number of Structures</th><th rowspan="2">Structure Type</th><th>Structure Geometry</th><th rowspan="2">Profile</th><th>Q Total</th><th>Depth Overtop</th><th rowspan="2">Outlet/ Inlet Control</th><th rowspan="2">Comments</th></tr>
<tr><th>(m)</th><th>(m^3/s)</th><th>cm</th></tr>
<tr><td rowspan="6">Donovans Tributary</td><td rowspan="6">Donovans Tributary</td><td rowspan="6">442.2058
UR14-15</td><td rowspan="6">3 Culverts</td><td>Culvert #1</td><td rowspan="6">Culvert #1
CMP Pipe Arch
Span: 1.8
Rise: 1.1
Length: 13.6

Culvert #2
CMP Pipe Arch
Span: 1.8
Rise: 1.1
Length: 13.3

Culvert #3
CMP Pipe Arch
Span: 1.8
Rise: 1.1
Length: 13.5</td><td rowspan="3">CC_CD 100</td><td rowspan="3">8.4
(Total 3 Culverts)</td><td rowspan="3"></td><td>O</td><td></td></tr>
<tr><td>Culvert #2</td><td>O</td><td></td></tr>
<tr><td>Culvert #3</td><td>O</td><td></td></tr>
<tr><td>Culvert #1</td><td rowspan="3">CLC_FD 100</td><td rowspan="3">12
(Total 3 Culverts and Weir)</td><td rowspan="3">10</td><td>O</td><td></td></tr>
<tr><td>Culvert #2</td><td>O</td><td></td></tr>
<tr><td>Culvert #3</td><td>O</td><td></td></tr>
<tr><td rowspan="2">Donovans Tributary</td><td rowspan="2">Donovans Tributary</td><td rowspan="2">362.0152
UR11_A-11_B</td><td rowspan="2">1 Culvert</td><td rowspan="2">Culvert #1</td><td rowspan="2">Culvert #1
2x Concrete Rectangle
Span: 2.4
Rise: 1.0
Length: 53.5</td><td>CC_CD 100</td><td>8.4</td><td></td><td>O</td><td></td></tr>
<tr><td>CLC_FD 100</td><td>12
(Total Culvert and Weir)</td><td>20</td><td>O</td><td></td></tr>
</table>

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Donovans Tributary	*Donovans Tributary*	**305.5169** UR10_A-10_B	1 Culvert	Culvert #1	Culvert #1 2x Concrete Rectangle Span: 2.4 Rise: 1.0 Length: 29.8	CC_CD 100	8.4		O	
						CLC_FD 100	12.0 (Total Culvert and Weir)	9	I	
Donovans Tributary	*Donovans Tributary*	**34.58622** UR4-5	1 Bridge	Bridge	Span: 3.6 Length: 7.5 Height: 1.4	CC_CD 100	8.4 (Total Bridge and Weir)	11		Structure is submerged upstream and downstream.
						CLC_FD 100	12 (Total Bridge and Weir)	10		
Donovans Tributary	*Donovans Tributary*	**26.72258** UR2-3	1 Bridge	Bridge	Span: 3.4 Length: 2.8 Height: 1.5	CC_CD 100	8.4 (Total Bridge and Weir)	46		Structure is submerged upstream and downstream. See calculation messages for details.
						CLC_FD 100	12 (Total Bridge and Weir)	44		
South Brook	*Upper South Brook*	**8175.728** 126-127	1 Culvert	Culvert #1	Culvert #1 CMP Low Profile Arch Span: 6.0 Rise: 2.24 Length: 20.8	CC_CD 100	12.0		O	
						CLC_FD 100	17.1		O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
South Brook	*Upper South Brook*	**8134.739** 123-124	1 Bridge	Bridge	Span: 6.7 Length: 1.9 Height: 1.6	CC_CD 100	12 (Total Bridge and Weir)	115		Structure is submerged upstream and downstream. See calculation messages for details.
						CLC_FD 100	17.1 (Total Bridge and Weir)	140		
South Brook	*Upper South Brook*	**8042.167** 119-120	1 Culvert	Culvert #1	Culvert #1 CMP Low Profile Arch Span: 5.9 Rise: 2.0 Length: 2.9	CC_CD 100	12.0		O	
						CLC_FD 100	17.1		O	
South Brook	*Upper South Brook*	**8000.736** 116-117	1 Culvert	Culvert #1	Culvert #1 CMP Open Bottom Arch Span: 5.6 Rise: 3.65 Length: 36.1	CC_CD 100	12.0		O	
						CLC_FD 100	17.1		O	
South Brook	*Upper South Brook*	**7693.693** 111-112	1 Culvert	Culvert #1	Culvert #1 CMP Low Profile Arch Span: 7.10 Rise: 2.15 Length: 18.2	CC_CD 100	12.0		O	
						CLC_FD 100	17.1		O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
South Brook	*Upper South Brook*	**7296.719** 106-107	1 Culvert	Culvert #1	Culvert #1 CMP Low Profile Arch Span: 9.1 Rise: 2.7 Length: 25.5	CC_CD 100	12.0		O	
						CLC_FD 100	17.1		O	
South Brook	*Upper South Brook*	**6359.932** 100-101	1 Bridge	Bridge	Span: 2.2 Length: 3.6 Height: 1.3	CC_CD 100	19.4 (Total Bridge and Weir)	28		Structure is submerged upstream and downstream.
						CLC_FD 100	27.5 (Total Bridge and Weir)	49		
South Brook	*Upper South Brook*	**6287.631** 96-97	1 Bridge	Bridge	Span: 3.7 Length: 3.5 Height: 1.3	CC_CD 100	19.4 (Total Bridge and Weir)	42		Structure is submerged upstream and downstream. Energy only calculation – see calculation
						CLC_FD 100	27.5 (Total Bridge and Weir)	58		

<table>
<tr><th rowspan="2">River</th><th rowspan="2">Reach</th><th rowspan="2">Structure ID</th><th rowspan="2">Number of Structures</th><th rowspan="2">Structure Type</th><th>Structure Geometry</th><th rowspan="2">Profile</th><th>Q Total</th><th>Depth Overtop</th><th rowspan="2">Outlet/ Inlet Control</th><th rowspan="2">Comments</th></tr>
<tr><th>(m)</th><th>(m^3/s)</th><th>cm</th></tr>
<tr><td rowspan="4">South Brook</td><td rowspan="4">Upper South Brook</td><td rowspan="4">6106.488
92-93</td><td rowspan="4">2 Culverts</td><td>Culvert #1</td><td rowspan="4"><u>Culvert #1</u>
CMP Pipe Arch
Span: 1.84
Rise: 1.27
Length: 22.0

<u>Culvert #2</u>
CMP Pipe Arch
Span: 1.56
Rise: 0.96
Length: 22.5</td><td rowspan="2">CC_CD 100</td><td rowspan="2">19.4
(Total 2 Culverts and Weir)</td><td rowspan="2">3</td><td>O</td><td rowspan="2"></td></tr>
<tr><td>Culvert #2</td><td>O</td></tr>
<tr><td>Culvert #1</td><td rowspan="2">CLC_FD 100</td><td rowspan="2">27.5
(Total 2 Culverts)</td><td rowspan="2"></td><td>O</td><td rowspan="2"></td></tr>
<tr><td>Culvert #2</td><td>O</td></tr>
<tr><td rowspan="2">South Brook</td><td rowspan="2">Upper South Brook</td><td rowspan="2">6013.835
88-89</td><td rowspan="2">1 Bridge</td><td rowspan="2">Bridge</td><td rowspan="2">Span: 5.3
Length: 5.3
Height: 1.6</td><td>CC_CD 100</td><td>19.4
(Total Bridge and Weir)</td><td>2</td><td></td><td rowspan="2"></td></tr>
<tr><td>CLC_FD 100</td><td>27.5
(Total Bridge and Weir)</td><td>11</td><td></td></tr>
</table>

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
South Brook	*Upper South Brook*	**5755.717** 83-84	2 Culverts	Culvert #1	Culvert #1 CMP Circular Dia.: 2.0 Length: 39.2	CC_CD 100	19.4 (Total 2 Culverts)		O	
				Culvert #2					O	
				Culvert #1	Culvert #2 CMP Circular Dia.: 2.0 Length: 39.7	CLC_FD 100	27.5 (Total 2 Culverts)		O	
				Culvert #2					O	
South Brook	*Upper South Brook*	**4091.01** 76-77	1 Bridge	Bridge	Span: 7.8 Length: 12.4 Height: 2.2	CC_CD 100	19.4			
						CLC_FD 100	27.5			
South Brook	*Lower South Brook*	**2974.586** 65-66	1 Bridge	Bridge	Span: 21.1 Length: 13.1 Height: 4.8	CC_CD 100	39.5			
						CLC_FD 100	56.2			
South Brook	*Lower South Brook*	**2954.736** 63-64	1 Bridge	Bridge	Span: 21.0 Length: 13.2 Height: 5.0	CC_CD 100	39.5			
						CLC_FD 100	56.2			

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
South Brook	*Lower South Brook*	**1749.166** 58-59	1 Bridge	Bridge	Span: 21.2 Length: 1.8 Height: 4.4	CC_CD 100	39.5			
						CLC_FD 100	56.2			
South Brook	*Lower South Brook*	**309.5599** 51-52	1 Culvert	Culvert #1	Culvert #1 CMP Low Profile Arch Span: 7.1 Rise: 2.65 Length: 4.4	CC_CD 100	39.5		O	
						CLC_FD 100	56.2 (Total Culvert and Weir)	5	O	
South Brook	*Lower South Brook*	**107.3237** 47-48	1 Bridge	Bridge	Span: 15.1 Length: 3.7 Height: 3.7	CC_CD 100	39.5			
						CLC_FD 100	56.2			
Nevilles Pond	*Nevilles Pond*	**686.4924** NP14-15	1 Culvert	Culvert #1	Culvert #1 CMP Pipe Arch Span: 2.61 Rise: 1.8 Length: 18.0	CC_CD 100	9.6		O	
						CLC_FD 100	13.6 (Total Culvert and Weir)	7	O	
Nevilles Pond	*Nevilles Pond*	**586.5468** NP10-11	1 Culvert	Culvert #1	Culvert #1 CMP Circular Span: 2.4 Rise: 2.3 Length: 76.9	CC_CD 100	9.6		O	
						CLC_FD 100	13.6		O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Nevilles Pond	*Nevilles Pond*	**508.077** NP7-8	1 Culvert	Culvert #1	Culvert #1 CMP Circular Dia.: 0.9 Length: 18.1	CC_CD 100	9.6		O	
						CLC_FD 100	13.6 (Total Culvert and Weir)	1	O	
Nevilles Pond	*Nevilles Pond*	**219.3916** NP2-3	2 Culverts	Culvert #1	Culvert #1 CMP Circular Dia.: 1.5 Length: 377.0	CC_CD 100	9.6 (Total 2 Culverts and Weir)	62	O	Structure is submerged upstream and downstream. Flow through structure is representative of downstream conditions.
				Culvert #2					O	
				Culvert #1	Culvert #1 CMP Circular Dia.: 1.5 Length: 376.6	CLC_FD 100	13.6 (Total 2 Culverts and Weir)	73	O	
				Culvert #2					O	
Kilbride Brook	*Kilbride Brook*	**3411.558** KB57-58	1 Culvert	Culvert #1	Culvert #1 Concrete Circular Dia.: 0.75 Length: 15.1	CC_CD 100	10.9 (Total Culvert and Weir)	23	O	Structure is submerged upstream and downstream.
						CLC_FD 100	15.6 (Total Culvert and Weir)	28	O	
Kilbride Brook	*Kilbride Brook*	**3041.233** KB52-53	1 Culvert	Culvert #1	Culvert #1 CMP Circular Dia.: 1.1 Length: 6.2	CC_CD 100	10.9 (Total Culvert and Weir)	28	O	Structure is submerged upstream and downstream.
						CLC_FD 100	15.6 (Total Culvert and Weir)	34	O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Kilbride Brook	*Kilbride Brook*	**2869.003** KB47-48	1 Culvert	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.8 Rise: 1.1 Length: 12.1	CC_CD 100	10.9 (Total Culvert and Weir)	62	O	Structure is submerged upstream and downstream.
						CLC_FD 100	15.6 (Total Culvert and Weir)	60	O	
Kilbride Brook	*Kilbride Brook*	**2788.58** KB43-44	1 Culvert	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.8 Rise: 1.1 Length: 18.4	CC_CD 100	10.9 (Total Culvert and Weir)	36	O	Structure is submerged upstream and downstream.
						CLC_FD 100	15.6 (Total Culvert and Weir)	28	O	
Kilbride Brook	*Kilbride Brook*	**2762.228** KB40-41	1 Culvert	Culvert #1	Culvert #1 CMP Circular Dia.: 1.5 Length: 9.3	CC_CD 100	10.9 (Total Culvert and Weir)	40	O	Structure is submerged upstream and downstream.
						CLC_FD 100	15.6 (Total Culvert and Weir)	33	O	
Kilbride Brook	*Kilbride Brook*	**2721.006** KB36-37	1 Culvert	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.8 Rise: 1.1 Length: 15.5	CC_CD 100	10.9 (Total Culvert and Weir)	32	O	Structure is submerged upstream and downstream.
						CLC_FD 100	15.6 (Total Culvert and Weir)	22	O	
Kilbride Brook	*Kilbride Brook*	**2658.963** KB32-33	1 Culvert	Culvert #1	Culvert #1 CMP Circular Dia.: 1.5 Length: 6.2	CC_CD 100	10.9 (Total Culvert and Weir)	35	O	Structure is submerged upstream and downstream.
						CLC_FD 100	15.6 (Total Culvert and Weir)	40	O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Kilbride Brook	*Kilbride Brook*	**2532.529** KB28-29	1 Culvert	Culvert #1	Culvert #1 CMP Circular Dia.: 1.46 Length: 6.3	CC_CD 100	10.9 (Total Culvert and Weir)	15	O	Structure is submerged upstream and downstream.
						CLC_FD 100	15.6 (Total Culvert and Weir)	21	O	
Kilbride Brook	*Kilbride Brook*	**2166.053** KB23-24	2 Culverts	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.2 Rise: 0.98 Length: 7.6 Culvert #2 CMP Circular Dia.: 1.3 Length: 6.4	CC_CD 100	10.9 (Total 2 Culverts and Weir)	21	O	Structure is submerged upstream and downstream.
				Culvert #2					O	
				Culvert #1		CLC_FD 100	15.6 (Total 2 Culverts and Weir)	26	O	
				Culvert #2					O	
Kilbride Brook	*Kilbride Brook*	**1766.234** KB18-19	1 Bridge	Bridge	Span: 11.6 Length: 15.0 Height: 1.5	CC_CD 100	10.9			
						CLC_FD 100	15.6			
Kilbride Brook	*Kilbride Brook*	**1557.307** KB13-14	1 Bridge	Bridge	Span: 9.2 Length: 15.3 Height: 1.5	CC_CD 100	10.9			
						CLC_FD 100	15.6			

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Kilbride Brook	*Kilbride Brook*	**1137.745** KB8-9	1 Bridge	Bridge	Span: 7.2 Length: 1.4 Height: 0.9	CC_CD 100	10.9 (Total Bridge and Weir)	37		
						CLC_FD 100	15.6 (Total Bridge and Weir)	52		
Kilbride Brook	*Kilbride Brook*	**1021.724** KB4-5	1 Bridge	Bridge	Span: 10.0 Length: 18.2 Height: 1.8	CC_CD 100	10.9			
						CLC_FD 100	15.6			
Kilbride Brook	*Kilbride Brook*	**45.19533** 68-69	1 Bridge	Bridge	Span: 7.3 Length: 20.0 Height: 1.8	CC_CD 100	10.9			
						CLC_FD 100	15.6			
Branscombe Pond	*Branscombe Pond*	**231.619** BP6-7	1 Bridge	Bridge	Span: 14.0 Length: 2.0 Height: 1.5	CC_CD 100	7.4			
						CLC_FD 100	10.8			
Branscombe Pond	*Branscombe Pond*	**148.3324** BP2-3	1 Bridge	Bridge	Span: 9.8 Length: 2.4 Height: 1.1	CC_CD 100	7.4			
						CLC_FD 100	10.8			

Notes:

1. Results presented in this table must be interpreted in conjunction with model profiles, inundation mapping, and calculation messages.
2. Pipe arch rise is interpolated from span. See culvert data sheet for exact field measurement.
3. The culvert flow may be low with respect to the total flow due to the nature of the culvert geometry and the downstream hydraulic conditions created under the flood scenario.
4. Based on the selected computation method, results for weir flow may not be computed and are calculated in this table for information only.

Structure Table 2: 1:20 AEP

<table>
<tr><th rowspan="2">River</th><th rowspan="2">Reach</th><th rowspan="2">Structure ID</th><th rowspan="2">Number of Structures</th><th rowspan="2">Structure Type</th><th>Structure Geometry</th><th rowspan="2">Profile</th><th>Q Total</th><th>Depth Overtop</th><th rowspan="2">Outlet/ Inlet Control</th><th rowspan="2">Comments</th></tr>
<tr><th>(m)</th><th>(m^3/s)</th><th>cm</th></tr>
<tr><td rowspan="2">Waterford River</td><td rowspan="2">Upper Waterford</td><td rowspan="2">16486.17
268-269</td><td rowspan="2">1 Culvert</td><td rowspan="2">Culvert #1</td><td rowspan="2"><u>Culvert #1</u>
CMP Standard Arch
Span: 3.0
Rise: 1.8
Length: 21.8</td><td>CC_CD 20</td><td>5.7</td><td></td><td>O</td><td></td></tr>
<tr><td>CLC_FD 20</td><td>9.6</td><td></td><td>O</td><td></td></tr>
<tr><td rowspan="4">Waterford River</td><td rowspan="4">Upper Waterford</td><td rowspan="4">14248.03
261-262</td><td rowspan="4">2 Culverts</td><td>Culvert #1</td><td rowspan="4"><u>Culvert #1</u>
CMP Pipe Arch
Span: 1.85
Rise: 1.3
Length: 47.6

<u>Culvert #2</u>
CMP Pipe Arch
Span: 1.83
Rise: 1.12
Length: 42.1</td><td rowspan="2">CC_CD 20</td><td rowspan="2">5.7
(Total 2 Culverts)</td><td rowspan="2"></td><td>O</td><td></td></tr>
<tr><td>Culvert #2</td><td>O</td><td></td></tr>
<tr><td>Culvert #1</td><td rowspan="2">CLC_FD 20</td><td rowspan="2">9.6
(Total 2 Culverts)</td><td rowspan="2"></td><td>O</td><td></td></tr>
<tr><td>Culvert #2</td><td>O</td><td></td></tr>
</table>

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Waterford River	*Upper Waterford*	**14202.04** 259-260	2 Culverts	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.89 Rise: 1.42 Length: 17.3	CC_CD 20	5.7 (Total 2 Culverts)		O	
				Culvert #2					O	
				Culvert #1	Culvert #2 CMP Pipe Arch Span: 1.83 Rise: 1.17 Length: 17.1	CLC_FD 20	9.6 (Total 2 Culverts)		O	
				Culvert #2					O	
Waterford River	*Upper Waterford*	**14025.25** 255-256	2 Culverts	Culvert #1	Culvert #1 CMP Arch Span: 1.75 Rise: 1.07 Length: 87.2	CC_CD 20	5.7 (Total 2 Culverts)		O	
				Culvert #2					O	
				Culvert #1	Culvert #2 CMP Arch Span: 1.86 Rise: 1.42 Length: 87.0	CLC_FD 20	9.6 (Total 2 Culverts)		O	
				Culvert #2					O	

<table>
<tr><th rowspan="2">River</th><th rowspan="2">Reach</th><th rowspan="2">Structure ID</th><th rowspan="2">Number of Structures</th><th rowspan="2">Structure Type</th><th>Structure Geometry</th><th rowspan="2">Profile</th><th>Q Total</th><th>Depth Overtop</th><th rowspan="2">Outlet/ Inlet Control</th><th rowspan="2">Comments</th></tr>
<tr><th>(m)</th><th>(m^3/s)</th><th>cm</th></tr>
<tr><td rowspan="4">Waterford River</td><td rowspan="4">Upper Waterford</td><td rowspan="4">13832.02
251-252</td><td rowspan="4">2 Culverts</td><td>Culvert #1</td><td rowspan="4"><u>Culvert #1</u>
CMP Arch
Span: 1.89
Rise: 1.42
Length: 23.4

<u>Culvert #2</u>
CMP Arch
Span: 1.67
Rise: 1.02
Length: 22.8</td><td rowspan="2">CC_CD 20</td><td rowspan="2">5.7
(Total 2 Culverts)</td><td rowspan="2"></td><td>O</td><td></td></tr>
<tr><td>Culvert #2</td><td>O</td><td></td></tr>
<tr><td>Culvert #1</td><td rowspan="2">CLC_FD 20</td><td rowspan="2">9.6
(Total 2 Culverts)</td><td rowspan="2"></td><td>O</td><td></td></tr>
<tr><td>Culvert #2</td><td>I</td><td></td></tr>
<tr><td rowspan="4">Waterford River</td><td rowspan="4">Upper Waterford</td><td rowspan="4">13603
247-248</td><td rowspan="4">2 Culverts</td><td>Culvert #1</td><td rowspan="4"><u>Culvert #1</u>
CMP Arch
Span: 1.89
Rise: 1.42
Length: 16.9

<u>Culvert #2</u>
CMP Arch
Span: 1.84
Rise: 1.22
Length: 16.9</td><td rowspan="2">CC_CD 20</td><td rowspan="2">5.7
(Total 2 Culverts)</td><td rowspan="2"></td><td>O</td><td></td></tr>
<tr><td>Culvert #2</td><td>O</td><td></td></tr>
<tr><td>Culvert #1</td><td rowspan="2">CLC_FD 20</td><td rowspan="2">9.6
(Total 2 Culverts)</td><td rowspan="2"></td><td>O</td><td></td></tr>
<tr><td>Culvert #2</td><td>O</td><td></td></tr>
</table>

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Waterford River	*Upper Waterford*	**13413.93** 243-244	2 Culverts	Culvert #1	<u>Culvert #1</u> CMP Circular Dia.: 1.47 Length: 13.8	CC_CD 20	5.7 (Total 2 Culverts)		O	
				Culvert #2					O	
				Culvert #1	<u>Culvert #2</u> CMP Circular Dia.: 1.47 Length: 13.8	CLC_FD 20	9.6 (Total 2 Culverts and Weir)	12	O	
				Culvert #2					O	
Waterford River	*US of Donovans Tributary*	**12760.69** 237-238 **Multiple opening*	1 Bridge + 3 Culverts	Bridge	Span: 9.9 Length: 2.4 Height: 1.8	CC_CD 20	15.53 (Total Bridge and Weir)	29		Multiple opening structure is submerged upstream and downstream. Flow through structure is representative of downstream conditions.
						CLC_FD 20	22.92 (Total Bridge and Weir)	33		
				Culvert #1	<u>Culvert #1</u> CMP Circular Dia.: 0.6 Length: 6.3	CC_CD 20	1.07 (Total 3 Culverts and Weir)	23	O	
				Culvert #2					O	
				Culvert #3	<u>Culvert #2</u> CMP Circular Dia.: 0.6 Length: 6.3				O	
				Culvert #1		CLC_FD 20	1.58 (Total 3 Culverts and Weir)	28	O	
				Culvert #2	<u>Culvert #3</u> CMP Circular Dia.: 0.6 Length: 6.4				O	
				Culvert #3					O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Waterford River	*US of Donovans Tributary*	**12729.73** 235-236	1 Culvert	Culvert #1	Culvert #1 CMP Arch Span: 10.86 Rise: 7.0 Length: 46.6	CC_CD 20	16.6		O	
						CLC_FD 20	24.5		O	
Waterford River	*US of Donovans Tributary*	**12567.9** 231-232	1 Bridge	Bridge	Span: 2.5 Length: 3.0 Height: 2.0	CC_CD 20	16.6 (Total Bridge and Weir)	50		CC_CD flow results through structure may be low. See calculation messages for details.
						CLC_FD 20	24.5 (Total Bridge and Weir)	40		
Waterford River	*US of Branscombe*	**12431.8** 228_B-229_A	1 Culvert	Culvert #1	Culvert #1 CMP Pipe Arch + Rect. Weir Span: 3.23 Rise: 2.1 Length: 6.2	CC_CD 20	29.7 (Total Culvert and Weir)	15	O	Structure has a blocked depth of 0.51m and is submerged upstream and downstream.
						CLC_FD 20	41.9 (Total Culvert and Weir)	40	O	
Waterford River	*US of Branscombe*	**12129.69** 225-226	1 Culvert	Culvert #1	Culvert #1 CMP Open Bottom Arch Span: 8.3 Rise: 2.9 Length: 16.2	CC_CD 20	29.7		O	
						CLC_FD 20	41.9		O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Waterford River	*US of Branscombe*	**10480.73** 217-218	1 Bridge	Bridge	Span: 14.6 Length: 2.0 Height: 3.5	CC_CD 20	29.7			
						CLC_FD 20	41.9			
Waterford River	*US of Branscombe*	**10024.95** 212-213	1 Bridge	Bridge	Span: 10.8 Length: 18.0 Height: 3.1	CC_CD 20	29.7			
						CLC_FD 20	41.9			
Waterford River	*US of Branscombe*	**9194.803** 205-206	1 Bridge	Bridge	Span: 18.0 Length: 1.9 Height: 1.8	CC_CD 20	29.7			
						CLC_FD 20	41.9			
Waterford River	*US of Branscombe*	**8019.17** 198-199	1 Bridge	Bridge	Span: 23.6 Length: 1.8 Height: 2.9	CC_CD 20	34.4			
						CLC_FD 20	48.3			
Waterford River	*US of Branscombe*	**7610.337** 192-193	1 Bridge	Bridge	Span: 16.6 Length: 1.5 Height: 2.6	CC_CD 20	34.4			
						CLC_FD 20	48.3			
Waterford River	*US of Branscombe*	**7451.063** 187-188	1 Bridge	Bridge	Span: 27.0 Length: 2.0 Height: 3.7	CC_CD 20	34.4			
						CLC_FD 20	48.3			

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Waterford River	*US of Branscombe*	**7092.577** 182-183	1 Bridge	Bridge	Span: 9.2 Length: 1.8 Height: 3.2	CC_CD 20	34.4			
						CLC_FD 20	48.3			
Waterford River	*US of South Brook*	**7006.117** 176-177	1 Bridge	Bridge	Span: 8.0 Length: 13.6 Height: 1.8	CC_CD 20	46 (Total Bridge and Weir)	12		
						CLC_FD 20	63.9 (Total Bridge and Weir)	34		
Waterford River	*US of South Brook*	**6660.091** 170-171	1 Culvert	Culvert #1	Culvert #1 CMP Open Bottom Arch Span: 10.1 Rise: 4.3 Length: 71.0	CC_CD 20	46		O	
						CLC_FD 20	63.9		O	
Waterford River	*US of South Brook*	**5464.561** 158-159	1 Bridge	Bridge	Span: 14.2 Length: 15.5 Height: 1.7	CC_CD 20	56.2			
						CLC_FD 20	76.7 (Total Bridge and Weir)	31		
Waterford River	*US of South Brook*	**4885.659** 150-151	1 Bridge	Bridge	Span: 10.3 Length: 19.1 Height: 1.8	CC_CD 20	56.2			
						CLC_FD 20	76.7 (Total Bridge and Weir)	10		

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Waterford River	*US of South Brook*	**4622.255** 145-146	1 Bridge	Bridge	Span: 7.4 Length: 2.1 Height: 3.3	CC_CD 20	56.2 (Total Bridge and Weir)	11		
						CLC_FD 20	76.7 (Total Bridge and Weir)	39		
Waterford River	*US of South Brook*	**4484.719** 141-142	1 Bridge	Bridge	Span: 9.8 Length: 1.6 Height: 1.9	CC_CD 20	56.2 (Total Bridge and Weir)	10		
						CLC_FD 20	76.7 (Total Bridge and Weir)	64		
Waterford River	*US of South Brook*	**4297.113** 136-137	1 Bridge	Bridge	Span: 12.4 Length: 2.4 Height: 3.0	CC_CD 20	56.2			
						CLC_FD 20	76.7			
Waterford River	*US of South Brook*	**4187.59** 132_B-133	1 Bridge	Bridge	Span: 11.3 Length: 7.9 Height: 2.6	CC_CD 20	56.2			
						CLC_FD 20	76.7			
Waterford River	*Lower Waterford*	**4017.424** 42-43	1 Bridge	Bridge	Span: Unknown Length: 19.0 Height: Unknown	CC_CD 20	80.5			
						CLC_FD 20	109.2			

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Waterford River	*Lower Waterford*	**3722.053** 37-38	1 Bridge	Bridge	Span: 10.8 Length: 10.3 Height: 2.9	CC_CD 20	80.5			
						CLC_FD 20	109.2			
Waterford River	*Lower Waterford*	**2973.547** 30-31	1 Bridge	Bridge	Span: 15.3 Length: 10.8 Height: 2.9	CC_CD 20	84.3			
						CLC_FD 20	114			
Waterford River	*Lower Waterford*	**1583.763** 19-20	1 Bridge	Bridge	Span: 18.2 Length: 5.5 Height: 3.0	CC_CD 20	88.5			
						CLC_FD 20	119.8 (Total Bridge and Weir)	12		
Waterford River	*Lower Waterford*	**862.6913** 12-13	1 Bridge	Bridge	Span: 27.2 Length: 19.1 Height: 4.2	CC_CD 20	88.5			
						CLC_FD 20	119.8			
Waterford River	*Lower Waterford*	**189.1353** 6-7	1 Bridge	Bridge	Span: 17.2 Length: 2.9 Height: 3.1	CC_CD 20	91.7			No weir flow reported for CC-CD. See calculation messages for details.
						CLC_FD 20	124.7 (Total Bridge and Weir)	39		

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Waterford River	*Lower Waterford*	**144.8533** 3-4	1 Bridge	Bridge	Span: 28.0 Length: 1.7 Height: 2.9	CC_CD 20	91.7			No weir flow reported. See calculation messages for details.
						CLC_FD 20	124.7			
Donovans Tributary	*Donovans Tributary*	**2719.669** UR59-60	1 Culvert	Culvert #1	Culvert #1 CMP Standard Arch Span: 2.9 Rise: 1.8 Length: 17.2	CC_CD 20	5.6		O	
						CLC_FD 20	7.6		O	
Donovans Tributary	*Donovans Tributary*	**2286.604** UR52.5_B-52.5_C	1 Culvert	Culvert #1	Culvert #1 CMP Standard Arch Span: 2.4 Rise: 1.4 Length: 9.9	CC_CD 20	5.6		O	
						CLC_FD 20	7.6 (Total Culvert and Weir)	1	O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Donovans Tributary	*Donovans Tributary*	**2120.999** UR50-51	3 Culverts	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.84 Rise: 1.2 Length: 9.0 Culvert #2 CMP Pipe Arch Span: 1.84 Rise: 1.2 Length: 9.1 Culvert #3 CMP Pipe Arch Span: 1.84 Rise: 1.2 Length: 9.1	CC_CD 20	5.6 (Total 3 Culverts)		O	
				Culvert #2					O	
				Culvert #3					O	
				Culvert #1		CLC_FD 20	7.6 (Total 3 Culverts and Weir)	18	O	Structure is submerged upstream and downstream. Flow through structure is representative of downstream conditions. See calculation messages.
				Culvert #2					O	
				Culvert #3					O	

<table>
<tr><th rowspan="2">River</th><th rowspan="2">Reach</th><th rowspan="2">Structure ID</th><th rowspan="2">Number of Structures</th><th rowspan="2">Structure Type</th><th>Structure Geometry</th><th rowspan="2">Profile</th><th>Q Total</th><th>Depth Overtop</th><th rowspan="2">Outlet/ Inlet Control</th><th rowspan="2">Comments</th></tr>
<tr><th>(m)</th><th>(m^3/s)</th><th>cm</th></tr>
<tr><td rowspan="6">Donovans Tributary</td><td rowspan="6">Donovans Tributary</td><td rowspan="6">2097.912
UR47-48</td><td rowspan="6">3 Culverts</td><td>Culvert #1</td><td rowspan="6"><u>Culvert #1</u>
CMP Pipe Arch
Span: 1.45
Rise: 0.9
Length: 9.2

<u>Culvert #2</u>
CMP Pipe Arch
Span: 1.45
Rise: 0.9
Length: 9.2

<u>Culvert #3</u>
CMP Pipe Arch
Span: 1.45
Rise: 0.9
Length: 9.3</td><td rowspan="3">CC_CD 20</td><td rowspan="3">5.6
(Total 3 Culverts)</td><td rowspan="3"></td><td>I</td><td rowspan="6">Structure is submerged upstream and downstream. Flow through structure is representative of downstream conditions.</td></tr>
<tr><td>Culvert #2</td><td>O</td></tr>
<tr><td>Culvert #3</td><td>O</td></tr>
<tr><td>Culvert #1</td><td rowspan="3">CLC_FD 20</td><td rowspan="3">7.6
(Total 3 Culverts and Weir)</td><td rowspan="3">3</td><td>O</td></tr>
<tr><td>Culvert #2</td><td>O</td></tr>
<tr><td>Culvert #3</td><td>O</td></tr>
</table>

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Donovans Tributary	*Donovans Tributary*	**2044.66** UR43-44	3 Culverts	Culvert #1	<u>Culvert #1</u> CMP Pipe Arch Span: 1.64 Rise: 1.0 Length: 9.1 <u>Culvert #2</u> CMP Pipe Arch Span: 1.64 Rise: 1.0 Length: 9.1 <u>Culvert #3</u> CMP Pipe Arch Span: 1.64 Rise: 1.0 Length: 9.1	CC_CD 20	5.6 (Total 3 Culverts)		O	
				Culvert #2					O	
				Culvert #3					O	
				Culvert #1		CLC_FD 20	7.6 (Total 3 Culverts)		O	
				Culvert #2					O	
				Culvert #3					O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Donovans Tributary	*Donovans Tributary*	**1935.31** UR39-40	3 Culverts	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.45 Rise: 0.9 Length: 9.3 Culvert #2 CMP Pipe Arch Span: 1.45 Rise: 0.9 Length: 9.0 Culvert #3 CMP Pipe Arch Span: 1.45 Rise: 0.9 Length: 9.9	CC_CD 20	5.6 (Total 3 Culverts)		O	
				Culvert #2					O	
				Culvert #3					O	
				Culvert #1		CLC_FD 20	7.6 (Total 3 Culverts)		O	
				Culvert #2					I	
				Culvert #3					O	

<table>
<tr><th rowspan="2">River</th><th rowspan="2">Reach</th><th rowspan="2">Structure ID</th><th rowspan="2">Number of Structures</th><th rowspan="2">Structure Type</th><th>Structure Geometry</th><th rowspan="2">Profile</th><th>Q Total</th><th>Depth Overtop</th><th rowspan="2">Outlet/ Inlet Control</th><th rowspan="2">Comments</th></tr>
<tr><th>(m)</th><th>(m^3/s)</th><th>cm</th></tr>
<tr><td rowspan="6">Donovans Tributary</td><td rowspan="6">Donovans Tributary</td><td rowspan="6">1726.505
UR36B-36C</td><td rowspan="6">3 Culverts</td><td>Culvert #1</td><td rowspan="6"><u>Culvert #1</u>
CMP Circular
Dia.: 1.5
Length: 25.3

<u>Culvert #2</u>
CMP Circular
Dia.: 1.5
Length: 26.9

<u>Culvert #3</u>
CMP Circular
Dia.: 1.5
Length: 25.2</td><td rowspan="3">CC_CD 20</td><td rowspan="3">5.6
(Total 3 Culverts)</td><td rowspan="3"></td><td>O</td><td rowspan="3"></td></tr>
<tr><td>Culvert #2</td><td>O</td></tr>
<tr><td>Culvert #3</td><td>O</td></tr>
<tr><td>Culvert #1</td><td rowspan="3">CLC_FD 20</td><td rowspan="3">7.6
(Total 3 Culverts)</td><td rowspan="3"></td><td>O</td><td rowspan="3"></td></tr>
<tr><td>Culvert #2</td><td>O</td></tr>
<tr><td>Culvert #3</td><td>O</td></tr>
</table>

<table>
<thead>
<tr><th rowspan="2">River</th><th rowspan="2">Reach</th><th rowspan="2">Structure ID</th><th rowspan="2">Number of Structures</th><th rowspan="2">Structure Type</th><th>Structure Geometry</th><th rowspan="2">Profile</th><th>Q Total</th><th>Depth Overtop</th><th rowspan="2">Outlet/ Inlet Control</th><th rowspan="2">Comments</th></tr>
<tr><th>(m)</th><th>(m^3/s)</th><th>cm</th></tr>
</thead>
<tbody>
<tr><td rowspan="6">Donovans Tributary</td><td rowspan="6">Donovans Tributary</td><td rowspan="6">1459.808
UR33-34</td><td rowspan="6">3 Culverts</td><td>Culvert #1</td><td rowspan="6"><u>Culvert #1</u>
CMP Pipe Arch
Span: 1.8
Rise: 1.1
Length: 23.5

<u>Culvert #2</u>
CMP Pipe Arch
Span: 1.8
Rise: 1.1
Length: 23.7

<u>Culvert #3</u>
CMP Pipe Arch
Span: 1.8
Rise: 1.1
Length: 23.6</td><td rowspan="3">CC_CD 20</td><td rowspan="3">5.6
(Total 3 Culverts)</td><td rowspan="3"></td><td>O</td><td rowspan="3"></td></tr>
<tr><td>Culvert #2</td><td>O</td></tr>
<tr><td>Culvert #3</td><td>O</td></tr>
<tr><td>Culvert #1</td><td rowspan="3">CLC_FD 20</td><td rowspan="3">7.6
(Total 3 Culverts)</td><td rowspan="3"></td><td>O</td><td rowspan="3"></td></tr>
<tr><td>Culvert #2</td><td>O</td></tr>
<tr><td>Culvert #3</td><td>O</td></tr>
<tr><td rowspan="2">Donovans Tributary</td><td rowspan="2">Donovans Tributary</td><td rowspan="2">1291.697
UR29-30</td><td rowspan="2">1 Culvert</td><td rowspan="2">Culvert #1</td><td rowspan="2"><u>Culvert #1</u>
CMP Standard Arch
Span: 4.2
Rise: 1.6
Length: 18.5</td><td>CC_CD 20</td><td>5.6</td><td></td><td>O</td><td></td></tr>
<tr><td>CLC_FD 20</td><td>7.6</td><td></td><td>O</td><td></td></tr>
</tbody>
</table>

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Donovans Tributary	*Donovans Tributary*	**1213.08** UR26-27	3 Culverts	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.84 Rise: 1.2 Length: 75.3	CC_CD 20	5.6 (Total 3 Culverts)		O	
				Culvert #2	Culvert #2 CMP Pipe Arch Span: 1.84 Rise: 1.2 Length: 73.8				O	
				Culvert #3	Culvert #3 CMP Pipe Arch Span: 1.84 Rise: 1.2 Length: 71.5				O	
				Culvert #1		CLC_FD 20	7.6 (Total 3 Culverts)		O	
				Culvert #2					O	
				Culvert #3					O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Donovans Tributary	*Donovans Tributary*	**955.8469** UR23_B-23_C	3 Culverts	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.64 Rise: 1.0 Length: 10.6 Culvert #2 CMP Pipe Arch Span: 1.54 Rise: 0.95 Length: 10.3 Culvert #3 CMP Pipe Arch Span: 1.84 Rise: 1.2 Length: 10.7	CC_CD 20	5.6 (Total 3 Culverts)		O	
				Culvert #2					O	
				Culvert #3					O	
				Culvert #1		CLC_FD 20	7.6 (Total 3 Culverts)		O	
				Culvert #2					O	
				Culvert #3					O	

<table>
<thead>
<tr><th rowspan="2">River</th><th rowspan="2">Reach</th><th rowspan="2">Structure ID</th><th rowspan="2">Number of Structures</th><th rowspan="2">Structure Type</th><th>Structure Geometry</th><th rowspan="2">Profile</th><th>Q Total</th><th>Depth Overtop</th><th rowspan="2">Outlet/ Inlet Control</th><th rowspan="2">Comments</th></tr>
<tr><th>(m)</th><th>(m^3/s)</th><th>cm</th></tr>
</thead>
<tbody>
<tr><td rowspan="6">Donovans Tributary</td><td rowspan="6">Donovans Tributary</td><td rowspan="6">832.8687
UR20-21</td><td rowspan="6">3 Culverts</td><td>Culvert #1</td><td rowspan="6"><u>Culvert #1</u>
CMP Pipe Arch
Span: 1.64
Rise: 1.0
Length: 21.5

<u>Culvert #2</u>
CMP Pipe Arch
Span: 1.64
Rise: 1.0
Length: 21.7

<u>Culvert #3</u>
CMP Pipe Arch
Span: 1.64
Rise: 1.0
Length: 21.4</td><td rowspan="3">CC_CD 20</td><td rowspan="3">5.6
(Total 3 Culverts)</td><td rowspan="3"></td><td>O</td><td></td></tr>
<tr><td>Culvert #2</td><td>O</td><td></td></tr>
<tr><td>Culvert #3</td><td>O</td><td></td></tr>
<tr><td>Culvert #1</td><td rowspan="3">CLC_FD 20</td><td rowspan="3">7.6
(Total 3 Culverts)</td><td rowspan="3"></td><td>O</td><td></td></tr>
<tr><td>Culvert #2</td><td>O</td><td></td></tr>
<tr><td>Culvert #3</td><td>O</td><td></td></tr>
</tbody>
</table>

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Donovans Tributary	*Donovans Tributary*	**442.2058** UR14-15	3 Culverts	Culvert #1	<u>Culvert #1</u> CMP Pipe Arch Span: 1.8 Rise: 1.1 Length: 13.6 <u>Culvert #2</u> CMP Pipe Arch Span: 1.8 Rise: 1.1 Length: 13.3 <u>Culvert #3</u> CMP Pipe Arch Span: 1.8 Rise: 1.1 Length: 13.5	CC_CD 20	5.6 (Total 3 Culverts)		O	
				Culvert #2					O	
				Culvert #3					O	
				Culvert #1		CLC_FD 20	7.6 (Total 3 Culverts)		O	
				Culvert #2					O	
				Culvert #3					O	
Donovans Tributary	*Donovans Tributary*	**362.0152** UR11_A-11_B	1 Culvert	Culvert #1	<u>Culvert #1</u> 2x Concrete Rectangle Span: 2.4 Rise: 1.0 Length: 53.5	CC_CD 20	5.6		O	
						CLC_FD 20	7.6		O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Donovans Tributary	*Donovans Tributary*	**305.5169** UR10_A-10_B	1 Culvert	Culvert #1	Culvert #1 2x Concrete Rectangle Span: 2.4 Rise: 1.0 Length: 29.8	CC_CD 20	5.6		O	
						CLC_FD 20	7.6		O	
Donovans Tributary	*Donovans Tributary*	**34.58622** UR4-5	1 Bridge	Bridge	Span: 3.6 Length: 7.5 Height: 1.4	CC_CD 20	5.6			Structure is submerged upstream and downstream. See calculation messages for details.
						CLC_FD 20	7.6			
Donovans Tributary	*Donovans Tributary*	**26.72258** UR2-3	1 Bridge	Bridge	Span: 3.4 Length: 2.8 Height: 1.5	CC_CD 20	5.6 (Total Bridge and Weir)	28		Structure is submerged upstream and downstream. See calculation messages for details.
						CLC_FD 20	7.6 (Total Bridge and Weir)	41		
South Brook	*Upper South Brook*	**8175.728** 126-127	1 Culvert	Culvert #1	Culvert #1 CMP Low Profile Arch Span: 6.0 Rise: 2.24 Length: 20.8	CC_CD 20	7.8		O	
						CLC_FD 20	10.6		O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
South Brook	*Upper South Brook*	**8134.739** 123-124	1 Bridge	Bridge	Span: 6.7 Length: 1.9 Height: 1.6	CC_CD 20	7.8 (Total Bridge and Weir)	76		Critical water surface elevation applied. See calculation messages for details.
						CLC_FD 20	10.6 (Total Bridge and Weir)	103		
South Brook	*Upper South Brook*	**8042.167** 119-120	1 Culvert	Culvert #1	Culvert #1 CMP Low Profile Arch Span: 5.9 Rise: 2.0 Length: 2.9	CC_CD 20	7.8		O	
						CLC_FD 20	10.6		O	
South Brook	*Upper South Brook*	**8000.736** 116-117	1 Culvert	Culvert #1	Culvert #1 CMP Open Bottom Arch Span: 5.6 Rise: 3.65 Length: 36.1	CC_CD 20	7.8		O	
						CLC_FD 20	10.6		O	
South Brook	*Upper South Brook*	**7693.693** 111-112	1 Culvert	Culvert #1	Culvert #1 CMP Low Profile Arch Span: 7.10 Rise: 2.15 Length: 18.2	CC_CD 20	7.8		O	
						CLC_FD 20	10.6		O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
South Brook	*Upper South Brook*	**7296.719** 106-107	1 Culvert	Culvert #1	Culvert #1 CMP Low Profile Arch Span: 9.1 Rise: 2.7 Length: 25.5	CC_CD 20	7.8		O	
						CLC_FD 20	10.6		O	
South Brook	*Upper South Brook*	**6359.932** 100-101	1 Bridge	Bridge	Span: 2.2 Length: 3.6 Height: 1.3	CC_CD 20	12.9 (Total Bridge and Weir)	35		Structure is submerged upstream and downstream. See calculation messages for details.
						CLC_FD 20	17.2 (Total Bridge and Weir)	38		
South Brook	*Upper South Brook*	**6287.631** 96-97	1 Bridge	Bridge	Span: 3.7 Length: 3.5 Height: 1.3	CC_CD 20	12.9 (Total Bridge and Weir)	20		
						CLC_FD 20	17.2			

<table>
<tr><th rowspan="2">River</th><th rowspan="2">Reach</th><th rowspan="2">Structure ID</th><th rowspan="2">Number of Structures</th><th rowspan="2">Structure Type</th><th>Structure Geometry</th><th rowspan="2">Profile</th><th>Q Total</th><th>Depth Overtop</th><th rowspan="2">Outlet/ Inlet Control</th><th rowspan="2">Comments</th></tr>
<tr><th>(m)</th><th>(m^3/s)</th><th>cm</th></tr>
<tr><td rowspan="4">South Brook</td><td rowspan="4">Upper South Brook</td><td rowspan="4">6106.488
92-93</td><td rowspan="4">2 Culverts</td><td>Culvert #1</td><td rowspan="2">Culvert #1
CMP Pipe Arch
Span: 1.84
Rise: 1.27
Length: 22.0</td><td rowspan="2">CC_CD 20</td><td rowspan="2">12.9
(Total 2 Culverts and Weir)</td><td rowspan="2">12</td><td>O</td><td rowspan="2"></td></tr>
<tr><td>Culvert #2</td><td>O</td></tr>
<tr><td>Culvert #1</td><td rowspan="2">Culvert #2
CMP Pipe Arch
Span: 1.56
Rise: 0.96
Length: 22.5</td><td rowspan="2">CLC_FD 20</td><td rowspan="2">17.2
(Total 2 Culverts and Weir)</td><td rowspan="2">7</td><td>O</td><td rowspan="2"></td></tr>
<tr><td>Culvert #2</td><td>O</td></tr>
<tr><td rowspan="2">South Brook</td><td rowspan="2">Upper South Brook</td><td rowspan="2">6013.835
88-89</td><td rowspan="2">1 Bridge</td><td rowspan="2">Bridge</td><td rowspan="2">Span: 5.3
Length: 5.3
Height: 1.6</td><td>CC_CD 20</td><td>12.9</td><td></td><td></td><td rowspan="2"></td></tr>
<tr><td>CLC_FD 20</td><td>17.2
(Total Bridge and Weir)</td><td>10</td><td></td></tr>
</table>

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
South Brook	*Upper South Brook*	**5755.717** 83-84	2 Culverts	Culvert #1	Culvert #1 CMP Circular Dia.: 2.0 Length: 39.2	CC_CD 20	12.9 (Total 2 Culverts)		O	
				Culvert #2					O	
				Culvert #1	Culvert #2 CMP Circular Dia.: 2.0 Length: 39.7	CLC_FD 20	17.2 (Total 2 Culverts)		O	
				Culvert #2					O	
South Brook	*Upper South Brook*	**4091.01** 76-77	1 Bridge	Bridge	Span: 7.8 Length: 12.4 Height: 2.2	CC_CD 20	12.9			
						CLC_FD 20	17.2			
South Brook	*Lower South Brook*	**2974.586** 65-66	1 Bridge	Bridge	Span: 21.1 Length: 13.1 Height: 4.8	CC_CD 20	26.5			
						CLC_FD 20	35.3			
South Brook	*Lower South Brook*	**2954.736** 63-64	1 Bridge	Bridge	Span: 21.0 Length: 13.2 Height: 5.0	CC_CD 20	26.5			
						CLC_FD 20	35.3			

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
South Brook	*Lower South Brook*	**1749.166** 58-59	1 Bridge	Bridge	Span: 21.2 Length: 1.8 Height: 4.4	CC_CD 20	26.5			
						CLC_FD 20	35.3			
South Brook	*Lower South Brook*	**309.5599** 51-52	1 Culvert	Culvert #1	Culvert #1 CMP Low Profile Arch Span: 7.1 Rise: 2.65 Length: 4.4	CC_CD 20	26.5		O	
						CLC_FD 20	35.3		O	
South Brook	*Lower South Brook*	**107.3237** 47-48	1 Bridge	Bridge	Span: 15.1 Length: 3.7 Height: 3.7	CC_CD 20	26.5			
						CLC_FD 20	35.3			
Nevilles Pond	*Nevilles Pond*	**686.4924** NP14-15	1 Culvert	Culvert #1	Culvert #1 CMP Pipe Arch Span: 2.61 Rise: 1.8 Length: 18.0	CC_CD 20	6.6		O	
						CLC_FD 20	8.8		O	
Nevilles Pond	*Nevilles Pond*	**586.5468** NP10-11	1 Culvert	Culvert #1	Culvert #1 CMP Circular Dia: 2.3 Length: 76.9	CC_CD 20	6.6		O	
						CLC_FD 20	8.8		O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Nevilles Pond	*Nevilles Pond*	**508.077** NP7-8	1 Culvert	Culvert #1	Culvert #1 CMP Circular Dia.: 0.9 Length: 18.1	CC_CD 20	6.6		O	
						CLC_FD 20	8.8		O	
Nevilles Pond	*Nevilles Pond*	**219.3916** NP2-3	2 Culverts	Culvert #1	Culvert #1 CMP Circular Dia.: 1.5 Length: 377.0	CC_CD 20	6.6 (Total 2 Culverts and Weir)	26	O	
				Culvert #2					O	
				Culvert #1	Culvert #1 CMP Circular Dia.: 1.5 Length: 376.6	CLC_FD 20	8.8 (Total 2 Culverts and Weir)	58	O	
				Culvert #2					O	
Kilbride Brook	*Kilbride Brook*	**3411.558** KB57-58	1 Culvert	Culvert #1	Culvert #1 Concrete Circular Dia.: 0.75 Length: 15.1	CC_CD 20	7.3 (Total Culvert and Weir)	20	O	
						CLC_FD 20	9.9 (Total Culvert and Weir)	23	O	
Kilbride Brook	*Kilbride Brook*	**3041.233** KB52-53	1 Culvert	Culvert #1	Culvert #1 CMP Circular Dia.: 1.1 Length: 6.2	CC_CD 20	7.3 (Total Culvert and Weir)	21	O	
						CLC_FD 20	9.9 (Total Culvert and Weir)	26	O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Kilbride Brook	*Kilbride Brook*	**2869.003** KB47-48	1 Culvert	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.8 Rise: 1.1 Length: 12.1	CC_CD 20	7.3 (Total Culvert and Weir)	40	O	Flow through structure is representative of downstream conditions.
						CLC_FD 20	9.9 (Total Culvert and Weir)	51	O	
Kilbride Brook	*Kilbride Brook*	**2788.58** KB43-44	1 Culvert	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.8 Rise: 1.1 Length: 18.4	CC_CD 20	7.3 (Total Culvert and Weir)	11	O	Flow through structure is representative of downstream conditions.
						CLC_FD 20	9.9 (Total Culvert and Weir)	22	O	
Kilbride Brook	*Kilbride Brook*	**2762.228** KB40-41	1 Culvert	Culvert #1	Culvert #1 CMP Circular Dia.: 1.5 Length: 9.3	CC_CD 20	7.3 (Total Culvert and Weir)	16	O	Flow through structure is representative of downstream conditions.
						CLC_FD 20	9.9 (Total Culvert and Weir)	26	O	
Kilbride Brook	*Kilbride Brook*	**2721.006** KB36-37	1 Culvert	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.8 Rise: 1.1 Length: 15.5	CC_CD 20	7.3 (Total Culvert and Weir)	7	O	Flow through structure is representative of downstream conditions.
						CLC_FD 20	9.9 (Total Culvert and Weir)	18	O	
Kilbride Brook	*Kilbride Brook*	**2658.963** KB32-33	1 Culvert	Culvert #1	Culvert #1 CMP Circular Dia.: 1.5 Length: 6.2	CC_CD 20	7.3 (Total Culvert and Weir)	63	I	Flow through structure is representative of downstream conditions.
						CLC_FD 20	9.9 (Total Culvert and Weir)	33	O	

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Kilbride Brook	*Kilbride Brook*	**2532.529** KB28-29	1 Culvert	Culvert #1	Culvert #1 CMP Circular Dia.: 1.46 Length: 6.3	CC_CD 20	7.3 (Total Culvert and Weir)	52	O	Flow through structure is representative of downstream conditions.
						CLC_FD 20	9.9 (Total Culvert and Weir)	13	O	
Kilbride Brook	*Kilbride Brook*	**2166.053** KB23-24	2 Culverts	Culvert #1	Culvert #1 CMP Pipe Arch Span: 1.2 Rise: 0.98 Length: 7.6 Culvert #2 CMP Circular Dia.: 1.3 Length: 6.4	CC_CD 20	7.3 (Total 2 Culverts and Weir)	8	O	Flow through structure is representative of downstream conditions.
				Culvert #2					O	
				Culvert #1		CLC_FD 20	9.9 (Total 2 Culverts and Weir)	17	O	
				Culvert #2					O	
Kilbride Brook	*Kilbride Brook*	**1766.234** KB18-19	1 Bridge	Bridge	Span: 11.6 Length: 15.0 Height: 1.5	CC_CD 20	7.3			
						CLC_FD 20	9.9			
Kilbride Brook	*Kilbride Brook*	**1557.307** KB13-14	1 Bridge	Bridge	Span: 9.2 Length: 15.3 Height: 1.5	CC_CD 20	7.3			
						CLC_FD 20	9.9			

River	Reach	Structure ID	Number of Structures	Structure Type	Structure Geometry (m)	Profile	Q Total (m^3/s)	Depth Overtop cm	Outlet/ Inlet Control	Comments
Kilbride Brook	*Kilbride Brook*	**1137.745** KB8-9	1 Bridge	Bridge	Span: 7.2 Length: 1.4 Height: 0.9	CC_CD 20	7.3 (Total Bridge and Weir)	30		
						CLC_FD 20	9.9 (Total Bridge and Weir)	35		
Kilbride Brook	*Kilbride Brook*	**1021.724** KB4-5	1 Bridge	Bridge	Span: 10.0 Length: 18.2 Height: 1.8	CC_CD 20	7.3			
						CLC_FD 20	9.9			
Kilbride Brook	*Kilbride Brook*	**45.19533** 68-69	1 Bridge	Bridge	Span: 7.3 Length: 20.0 Height: 1.8	CC_CD 20	7.3			
						CLC_FD 20	9.9			
Branscombe Pond	*Branscombe Pond*	**231.619** BP6-7	1 Bridge	Bridge	Span: 14.0 Length: 2.0 Height: 1.5	CC_CD 20	4.9			
						CLC_FD 20	6.8			
Branscombe Pond	*Branscombe Pond*	**148.3324** BP2-3	1 Bridge	Bridge	Span: 9.8 Length: 2.4 Height: 1.1	CC_CD 20	4.9			
						CLC_FD 20	6.8			

Notes:

1. Results presented in this table must be interpreted in conjunction with model profiles, inundation mapping, and calculation messages.
2. Pipe arch rise is interpolated from span. See culvert data sheet for exact field measurement.
3. The culvert flow may be low with respect to the total flow due to the nature of the culvert geometry and the downstream hydraulic conditions created under the flood scenario.
4. Based on the selected computation method, results for weir flow may not be computed and are calculated in this table for information only.

APPENDIX J

Comments from Municipalities Located in Watershed

CBCL Response to City of St. John's comments dated July 10, 2017

These complimentary comments from the City of St. John's are appreciated.

CBCL Response to City of Mount Pearl comments dated July 18, 2017

It is understood that the WRMD is addressing the comments on the recommendations section.

CBCL has addressed the labelling comments.

With respect to the area around 16 Winston Place, the culvert mentioned in the email is not included in the model because 1D modelling techniques were used for the study. 1D modelling does not permit the inclusion of hydraulic structures which are not located on main river reaches or tributaries. Our results indicate that this area does not flood.

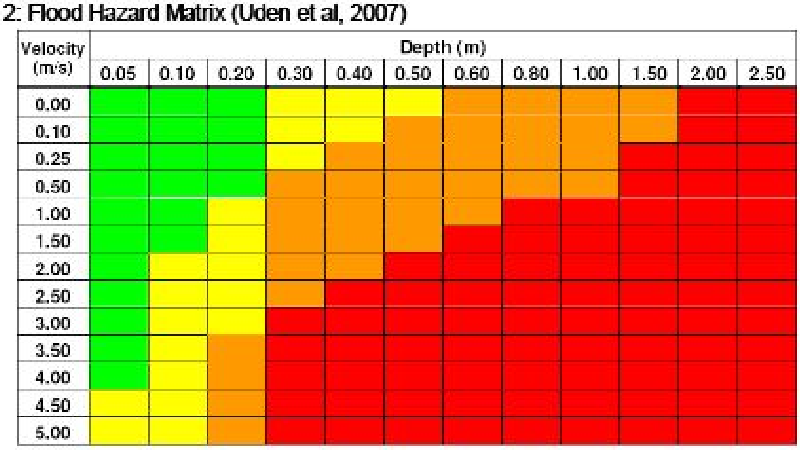
CBCL Response to Town of Paradise comments dated September 15, 2017

Major storage areas, such as natural ponds, were modelled in HEC-HMS. Storage areas were not modelled in HEC-RAS.

In some instances, an average curve number value was used while in other instances one soil group was selected over the other. This was done based on CBCL's interpretation of the soils report.

The Royal Haskoning Flood Hazard Matrix is a method that is used to assess flood hazards in consideration of water depths and velocities. See figure below for further information.

Figure 2: Flood Hazard Matrix (Uden et al, 2007)



Degree of flood hazard	Colour Code	Description
Low		**Caution**
Moderate		**Danger for Some** Includes children, the elderly, and the infirm
Significant		**Danger for most** Includes the general public
Extreme		**Danger for All** Includes the emergency services

From: Dave Wadden
To: Sheppard, Greg
Subject: Re: FW: Waterford River Flood Risk Mapping Study
Date: July-10-17 4:23:17 PM

Greg:

We have reviewed the report and it is well done. There were some minor items we noted in our review but nothing that would probably change the results. We feel there are some areas that would have benefited from a 2D analysis where the river jumps its banks but in the end WMRD elected to go with a 1D model. Overall, it's a timely update for the river system and we look forward to seeing the final report.

Regards,

Dave Wadden, M.Eng., P.Eng.
Manager of Development - Engineering
Department of Planning, Engineering & Regulatory Services
City of St. John's
Phone: (709)-576-8260
Fax: (709)-576-8625
e-mail: dwadden@stjohns.ca

-----"Sheppard, Greg" <gregs@cbcl.ca> wrote: -----

> To: 'Dave Wadden' <dwadden@stjohns.ca>
> From: "Sheppard, Greg" <gregs@cbcl.ca>
> Date: 07/10/2017 03:21PM
> Subject: FW: Waterford River Flood Risk Mapping Study
>
> Dave,
>
> Does the City have any comments on the draft report? If so, please provide a date by which you plan to send them to me.
>
> WRMD is anxious to complete this study.
>
> Regards,
>
> Greg
>
> From: Sheppard, Greg
> Sent: May-26-17 10:02 AM
> To: 'Dave Wadden'
> Subject: FW: Waterford River Flood Risk Mapping Study
>
> Dave,
>
> Does the City have any comments on the draft report? If so, please provide a date by which you plan to send them to me.
>
> Regards,
>
> Greg

From: Sheppard, Greg
Sent: May-01-17 1:21 PM
To: 'Dave Wadden'
Subject: RE: Waterford River Flood Risk Mapping Study

Dave,

Yes, I will copy the files to a CD and forward it to you.

Greg

From: Dave Wadden [mailto:DWadden@stjohns.ca]
Sent: May-01-17 1:20 PM
To: Sheppard, Greg
Subject: Re: Waterford River Flood Risk Mapping Study

Greg:

Can I get an electronic copy of the model and associated electronic files to review?

Dave Wadden, M.Eng., P.Eng.
Manager of Development - Engineering
Department of Planning, Engineering & Regulatory Services
City of St. John's
Phone: (709)-576-8260
Fax: (709)-576-8625
e-mail: dwadden@stjohns.ca<mailto:dwadden@stjohns.ca>

"This information is provided as a convenience to you only and is without warranty, guarantee or responsibility of any kind, either expressed or implied. The City does not guarantee that the information that is provided is current or accurate. You should verify that the information is accurate before acting on it."

From: "Sheppard, Greg" <gregs@cbcl.ca<mailto:gregs@cbcl.ca>>
To: 'Dave Wadden' <dwadden@stjohns.ca<mailto:dwadden@stjohns.ca>>
Date: 2017/05/01 01:19 PM
Subject: Waterford River Flood Risk Mapping Study

____

Dave,

CBCL has provided a CD to you containing the draft final report and mapping for the above noted project. We would appreciate receiving your comments on the report and mapping by May 10, 2017. If you need additional review time, please let me know and we will accommodate you.

Call me with any questions.

Regards,

From: Stuckless, Mark
To: Sheppard, Greg
Cc: Schwarz, Julia; Howe, Peter; Antle, Gerry; Fleet, Harold
Subject: RE: Waterford River Flood Risk Mapping Study
Date: July-18-17 4:47:51 PM
Attachments: image002.png

Hi Greg,

My apologies for not getting this to you sooner. These comments were compiled back in May, but were not forwarded on to you due to an oversight on my part. In any case, the City of Mount Pearl notes the following:

Commentary on Recommendations Section

- Adoption of study is not only to be undertaken by municipalities but also by the Province, as it will govern provincial reviews and permitting (e.g. Water Resources Division and Act; Flood Plain policy etc.).
- It is recommended that the Province considers adopting the study as part of the Regional Plan also.
- The City also recommends making reference to consistent approach by Province and municipalities to development / permitting requirements with the 15 meter buffer within the watershed area.
- There is reference to the model needing to be maintained in the future, however, there is no recommendation as to who would be responsible. The City assumes that this will be a Provincial responsibility.
- Recommendation 4 needs to include provincial reviews (by Water Resources Division) as well as municipal reviews.
- The City is requesting that the Province provide the LIDAR data to municipalities.

Labelling on Mapping

- It is noted that one of the tributaries in Donovan's Business Park is labelled 'unnamed tributary', while City of Mount Pearl staff refer to it regularly as "Donovan's Tributary"; the consultant may wish to review changing the label.
- Branscombes Pond appears on the mapping twice. One label is closer to the Bowring Park Duck Pond. For review.

In addition to the above, our LIS Division noted the following:

> In the image below, the area in red is being removed from the 1:20 year flood zone and the area in blue is added as the 1:20 climate change flood zone. Attached are photos from Tropical Storm Chantal from August 1, 2007 showing the house at 16 Winston Avenue (red arrow) and from the end of Birch Avenue looking north west towards the T'Railway (orange arrow - the end of Birch Avenue has been paved since this photo was taken, so there may be changes there). The yellow arrow shows the approximate location of a culvert crossing under the T'Railway (yellow arrow – photos attached). This is difficult to locate as it is covered with grass . Can it be confirmed that this culvert was included in the model and that the flood plain in this area is accurate?

Just let us know if you require any additional information.

Best Regards,
Mark

From: Sheppard, Greg [mailto:gregs@cbcl.ca]
Sent: Monday, July 10, 2017 3:20 PM
To: Stuckless, Mark

Subject: FW: Waterford River Flood Risk Mapping Study

Mark,

Does the City have any comments on the draft report? If so, please provide a date by which you plan to send them to me.

WRMD is anxious to complete this study.

Regards,

Greg

From: Sheppard, Greg
Sent: May-26-17 10:00 AM
To: Stuckless, Mark
Subject: FW: Waterford River Flood Risk Mapping Study

Mark,

Does the City have any comments on the draft report? If so, please provide a date by which you plan to send them to me.

Regards,

Greg

From: Sheppard, Greg
Sent: May-01-17 1:20 PM
To: Stuckless, Mark
Subject: Waterford River Flood Risk Mapping Study

Mark,

CBCL has provided a CD to you containing the draft final report and mapping for the above noted project. We would appreciate receiving your comments on the report and mapping by May 10, 2017. If you need additional review time, please let me know and we will accommodate you.

Call me with any questions.

Regards,

Greg

From:	Tracy-Lynn Goosney
To:	Sheppard, Greg
Cc:	Vanessa Barry
Subject:	RE: Waterford River Flood Risk Mapping Study
Date:	September-15-17 4:15:11 PM

HI Greg – Vanessa and I spoke about the study, we have no issue with moving this forward for approval.

I did however have some questions about the study:

1. How were the storage areas modelled in HMS, RAS?
2. For the C-Core study, some soil groups were combined (ie. BC). Did you use an average CN value for these between the two soil groups?
3. What is the Royal Haskoning Flood Hazard Matrix listed on page 32?

Let me know if you want to discuss.

Tracy

From: Sheppard, Greg [mailto:gregs@cbcl.ca]
Sent: Friday, September 15, 2017 4:09 PM
To: Tracy-Lynn Goosney
Cc: Vanessa Barry
Subject: Waterford River Flood Risk Mapping Study

Hi Tracy-Lynn,

Are you able to provide the Town's comments on the Waterford River study for this Monday?

Thanks,

Greg

APPENDIX K

Software Issues

Hydrologic Engineering Center – Hydrologic Modeling System (HEC- HMS)
An error developed in the HEC-GeoHMS model at a flow change location, where the model produced a warning detailing that the referenced basin header table could not be found. When checked for, the table could be viewed and opened in the geodatabase as well as in the HEC-GeoHMS mxd file (ArcMAP map document file). Reference to this error was made by other software users and was assumed to be a software bug.

Hydrologic Engineering Center – River Analysis System (HEC- RAS)
In HEC-RAS version 5.0.0, the software freezes during the "Write Geometry Information" step while running a simulation from time to time. If left untouched, eventually the software will crash and close. After reviewing HEC-RAS user reports and blogs, it was determined that there is a software bug in this version that causes the geometry to randomly corrupt when the project is set up in SI units only. This has made the error difficult to trouble shoot as most available information is references US customary units. Converting the model to US customary units was attempted, but it proved difficult during post processing to line up the results with the DEM and projection in SI units. This error was resolved in version 5.0.3.

There is a second software bug in version 5.0.1 that causes 1D velocity results (in SI units only) to compute and plot incorrectly. This was updated in version 5.0.2. In software version 5.0.2 there is a bug with the RAS Mapper function that causes some of the results to not refresh or plot after a new simulation run (the error reads: Unhandled exception has occurred in a component in your application). This issue was fixed in version 5.0.3. See release notes for reference.

There is a remaining bug with version 5.0.3 where certain geometry changes (to XSs and structures) will cause the model to stop running. A work-around to this issue can be made by completing updates to the model geometry in version 5.0.1, writing the geometry to a new file, and then uploading and running the updated geometry file in version 5.0.3. This issue may be resolved in later software versions.