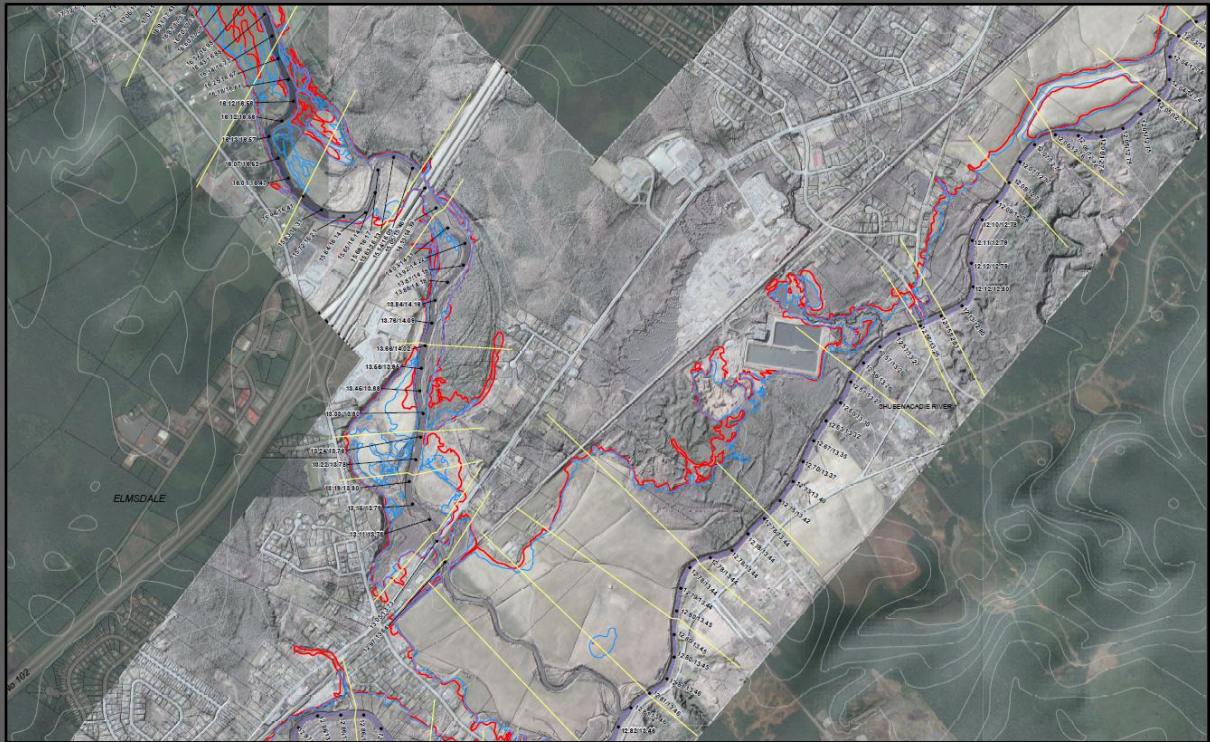

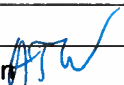

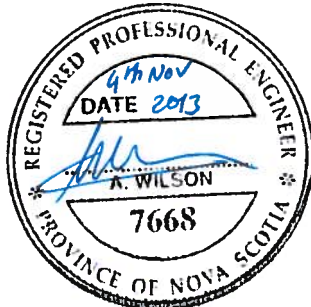


East Hants Floodplain Mapping Study

Final Report



Final Report	G. Smith 	11/04/2013	A. Wilson 
Draft Report	S. Murphy	07/02/2013	A. Wilson
Issue or Revision	Reviewed By:	Date	Issued By:
 <p>CBCL LIMITED Consulting Engineers</p> <p>This document was prepared for the party indicated herein. The material and information in the document reflects CBCL Limited's opinion and best judgment based on the information available at the time of preparation. Any use of this document or reliance on its content by third parties is the responsibility of the third party. CBCL Limited accepts no responsibility for any damages suffered as a result of third party use of this document.</p>			
<p>ISO 9001 Registered Company</p>			



July 2, 2013

Sean Gillis, Planner
Municipality of East Hants
230-15 Commerce Court
Elmsdale, NS B2S 3K5

Dear Mr. Gillis:

RE: Shubenacadie River Floodplain Mapping Study – Final Report

Please find below the floodplain mapping study completed for the Shubenacadie River, from Shubenacadie Grand Lake to the Village of Shubenacadie, including a portion of the Nine Mile River from Garden Road to its confluence with the Shubenacadie River.

We have also included a review of stormwater best management practices from the planning to the implementation levels, covering forestry activities as well as low and high density urban areas, for new or retrofit applications. Individual recommendations are also provided for each application, including stormwater management targets.

We have been very pleased to have had the opportunity to work on such an interesting analysis, and we hope that this report meets your expectations. Should you have any questions now or in the future, please do not hesitate to contact the undersigned.
Yours very truly,

CBCL Limited

Alexander Wilson, M.Eng., P.Eng.
Water Resources Engineer
Direct: (902) 421-7241, Ext. 2502
E-Mail: alexw@cbcl.ca

Project No: 131001.00

1489 Hollis Street
PO Box 606
Halifax, Nova Scotia
Canada B3J 2R7

Telephone: 902 421 7241

Fax: 902 423 3938

E-mail: info@cbcl.ca

www.cbcl.ca

**Solving
today's
problems
with
tomorrow
in mind**

ISO 9001
Registered Company



Contents

CHAPTER 1	Introduction and Data Analysis.....	1
1.1	Introduction	1
1.2	Data Collection.....	1
1.3	Data Analysis.....	2
1.3.1	Land Use Mapping	2
1.3.2	Floodplain Cross Sections	2
1.3.3	Bridge Data	3
1.3.4	Watershed Delineation and Watershed Properties	3
1.3.5	River Flow Estimations.....	4
1.3.6	Extreme Rainfall Events	7
1.3.7	Extreme Tide Levels	7
CHAPTER 2	Hydrology/Hydraulic Model Development and Calibration.....	9
2.1	Model Development	9
2.2	Model Calibration	9
2.3	Ice Build-Up Model	12
CHAPTER 3	Study Results and Floodplain Mapping	16
3.1	Existing Conditions Floodplain Mapping.....	16
3.2	Sensitivity Analysis.....	17
3.3	Future Conditions Floodplain Mapping	17
CHAPTER 4	Recommendations for Stormwater Management	18
4.1	Planning for Low Impact Development	19
4.2	Best Management Practices in Forested Areas	21
4.2.1	Recommendation to Use Nova Scotia’s Code of Forest Practice	21
4.2.2	Typical Forestry Best Management Practices.....	21
4.3	Recommendations for Stormwater Management in Urban Areas.....	23
4.3.1	Recommendations based on density of development and new Vs retrofit application	23
4.3.2	Description of each recommended site stormwater BMP measure	24
4.4	Summary of Recommendations and Proposed Targets	28
4.4.1	Planning Level	28
4.4.2	Forested Areas.....	28
4.4.3	Low Density and High Density Urban Areas – New Developments.....	29

	4.4.4	Low Density and High Density Urban Areas – Retrofit Applications	29
CHAPTER 5		Conclusions and Recommendations.....	30

CHAPTER 1 INTRODUCTION AND DATA ANALYSIS

1.1 Introduction

This floodplain mapping study was completed for the Municipality of East Hants to update and improve the previous floodline delineation completed by CBCL Limited in 1997. Improvements made to the floodline delineation methodology in this study as compared to the 1997 study include:

- Improved topographic information with LiDAR mapping at 1m resolution;
- Ability to use Environment Canada flow gauging data on the Shubenacadie River;
- Increased period of record supporting the Environment Canada Intensity-Duration-Frequency Rainfall curves;
- Additional detailed river survey from previous work in the area close to Grand Lake by the Municipality;
- Additional surveyed calibration points from George Searle identifying the 1971 floods in the Shubenacadie area;
- Improved hydraulic modelling techniques;
- Considerations of climate change and sea level rise; and
- Increased floodplain mapping extent.

The study was completed in three phases:

- Phase 1 – Data Collection, Review and Analysis;
- Phase 2 – Hydrologic/Hydraulic Model Development and Calibration; and
- Phase 3 – Floodplain Mapping and Study Results.

1.2 Data Collection

The following data was collected and reviewed for the floodplain mapping study:

- LiDAR mapping of the study area collected by Leading Edge Geomatics Ltd. at 1m resolution with an overall accuracy of $\pm 15\text{cm}$ or better;
- Topographic data (5m contours) provided by the Government of Nova Scotia;
- The topographic survey completed in 1997 for the previous Shubenacadie River Floodplain Mapping Study;
- The topographic survey completed in 2006 for the Low Flow Enhancement Pumping Options study;
- Bridge construction drawings;
- Bridge measurements obtained from field investigations;

- Aerial photography of the study area obtained by Leading Edge Geomatics Ltd.;
- Zoning and property mapping provided by the Municipality of East Hants;
- Municipal development data provided by the Municipality of East Hants;
- Watershed delineations provided by the Government of Nova Scotia;
- Soil and geology mapping provided by the Government of Nova Scotia;
- Flow gauging data provided by Environment Canada;
- Precipitation and climate data provided by Environment Canada;
- Tide prediction data provided by Fisheries and Oceans Canada;
- Tide gauging data obtained from a field investigation;
- Published reports on climate change and sea level rise;
- The hydrologic/hydraulic model completed for the 1997 Shubenacadie River Floodplain Mapping Study;
- The hydrologic/hydraulic model completed in 2006 for the Low Flow Enhancement Pumping Options study; and
- Historical water levels reported in the 1997 Shubenacadie River Floodplain Mapping Study and by MRMS (1981).

1.3 Data Analysis

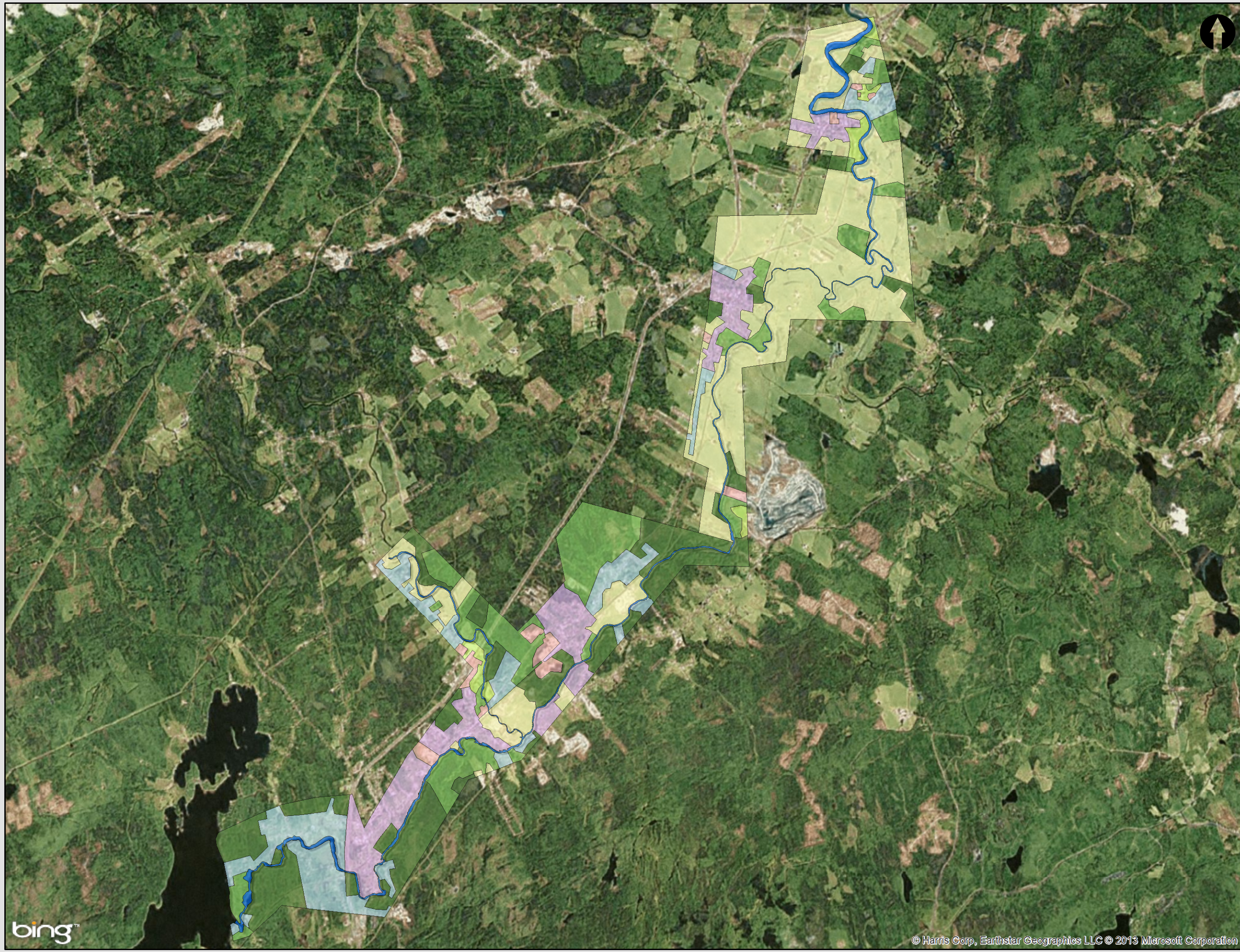
1.3.1 Land Use Mapping

Land use mapping of the study area was developed using the aerial photography, zoning and property mapping and is presented in Figure 1. The land use mapping was used to estimate roughness coefficients for the sub-watersheds (hydrology – affects the time of concentration) and floodplain sections (hydraulics – rougher channels will generate higher water levels for the same flow). As shown in Figure 1, land uses were divided into the following categories:

- Light Forest;
- Dense Forest;
- Grassland;
- Farmland;
- Low Density Development;
- Medium Density Development; and
- High Density Development.

1.3.2 Floodplain Cross Sections

The cross sections were produced generally every 350m (vs. ~650m for the 1997 model) as well as at floodplain contractions/expansions, sharper bends, and upstream/downstream of every bridge. The high accuracy of the LiDAR data was used to obtain the cross-section data in the river floodplain. Survey data was used to estimate the river portion of each cross section where the LiDAR data is intercepted by the surface of the water and becomes unreliable. Finalised floodplain cross sections used in the model were therefore a combination of the LiDAR data and the 1997 and 2006 river channel survey data.



**Shubenacadie River
Floodplain Mapping Study**

Legend:

- Land Use**
- Light Forest
 - Dense Forest
 - Grassland
 - Farmland
 - Low Density Development
 - Medium Density Development
 - High Density Development
 - River

Figure 1

Land Use Mapping



Date: July 2013
CBCL Project #: 131001.00

Coordinate System:
NAD83 UTM zone 20N
Projection: Transverse Mercator
Datum: North American Datum 1983
Units: Meter
Scale: 1:80,000

1.3.3 Bridge Data

Bridge data was collected for the twelve bridge crossings within the study area to be used for the hydrologic/hydraulic model. These represent critical points of energy losses and have a dominant role in generating peak water levels. Bridge opening geometry and bridge deck elevations were compiled from the 1997 survey, construction drawings and field measurements.

1.3.4 Watershed Delineation and Watershed Properties

Watershed delineations provided by the government of Nova Scotia were reviewed and refined using the LiDAR data and the 5m contours to delineate the sub-watersheds along the Shubenacadie and Nine Mile Rivers. Maps of the watershed delineations are presented in Figure 2 and Figure 3.

Watershed characteristics were estimated for each sub-watershed and are presented in Table 1. The watershed characteristics were estimated using the LiDAR data, aerial photography, land use mapping and soil mapping.

Table 1: Watershed Characteristics

Sub-Watershed Name	Surface Area (ha)	Percent Imperv. (%)	Ave. Slope (%)	Maximum Overland Flow Length (m)	Surface Roughness		Soil Infiltration	
					Imperv. Area n	Perv. Area n	Suction Head (mm)	Hydraulic Conductivity (mm/hr)
11D13_14A	139	13	0.5	3386	0.18	0.44	217	1.4
11D13_14B	153	15	1.1	854	0.11	0.33	209	1.0
11D13_14C	404	23	1.5	6730	0.09	0.36	209	1.0
11D13_14D	527	32	1.5	7070	0.07	0.20	203	1.5
11D13_15	22	29	1.1	1198	0.38	0.45	273	1.5
11D13_16	1091	10	1.8	19230	0.32	0.43	128	9.3
11D13_17	1549	15	2.2	24338	0.37	0.40	155	7.0
11D13_18	200	19	1.8	4177	0.27	0.40	249	1.9
11D13_19A	233	18	2.2	6772	0.22	0.43	215	1.0
11D13_19B	56	65	3.1	3234	0.33	0.22	160	3.3
11D13_19C	454	21	0.7	9181	0.20	0.39	218	1.3
11D13_52A	543	15	2.0	5275	0.39	0.49	162	4.5
11D13_52B	2312	21	1.9	8334	0.15	0.38	123	7.9
11D14_546	2282	12	1.9	38281	0.37	0.48	176	4.6
11D14_549	454	13	2.2	3330	0.19	0.37	167	6.3
11D14_568	2571	8	0.7	27439	0.18	0.37	201	1.4
11E03_122	1170	17	1.8	13298	0.12	0.26	231	1.0
11E03_124	462	8	1.0	5966	0.25	0.39	156	3.8
11E03_26A	713	10	3.4	13033	0.19	0.33	188	3.9
11E03_26B	623	8	1.8	2271	0.24	0.35	213	1.1
11E03_26C	687	6	4.4	7104	0.24	0.25	207	1.2
11E03_26D	222	9	2.8	4352	0.33	0.21	138	4.5

Sub-Watershed Name	Surface Area (ha)	Percent Imperv. (%)	Ave. Slope (%)	Maximum Overland Flow Length (m)	Surface Roughness		Soil Infiltration	
					Imperv. Area n	Perv. Area n	Suction Head (mm)	Hydraulic Conductivity (mm/hr)
11E03_49A	494	7	0.8	5217	0.21	0.32	210	1.3
11E03_49B	384	14	3.3	3792	0.14	0.20	214	1.3
11E03_53B	523	18	1.4	10251	0.30	0.42	203	1.3
11E03_53C	540	7	0.7	10216	0.20	0.37	198	1.5
11E03_53D	666	15	0.7	9690	0.10	0.36	186	2.1
11E03_55	990	13	2.3	8732	0.15	0.33	203	1.3
11E03_56A	498	7	2.1	5884	0.29	0.22	216	1.7
11E03_56B	314	16	1.9	2452	0.13	0.23	218	1.0
11E03_57	559	13	2.1	10313	0.09	0.25	200	1.6
11E03_58	307	18	3.8	4524	0.17	0.28	209	1.0
11E03_69	48	81	4.0	6395	0.39	0.20	263	1.0
11E04_43	1010	18	1.2	17499	0.17	0.36	205	1.6
Shubenacadie River Watershed*	34600	-	-	-	-	-	-	-
Nine Mile River Watershed*	25600	-	-	-	-	-	-	-
Gays River Watershed*	20400	-	-	-	-	-	-	-
St. Andrew's River Watershed*	10900	-	-	-	-	-	-	-

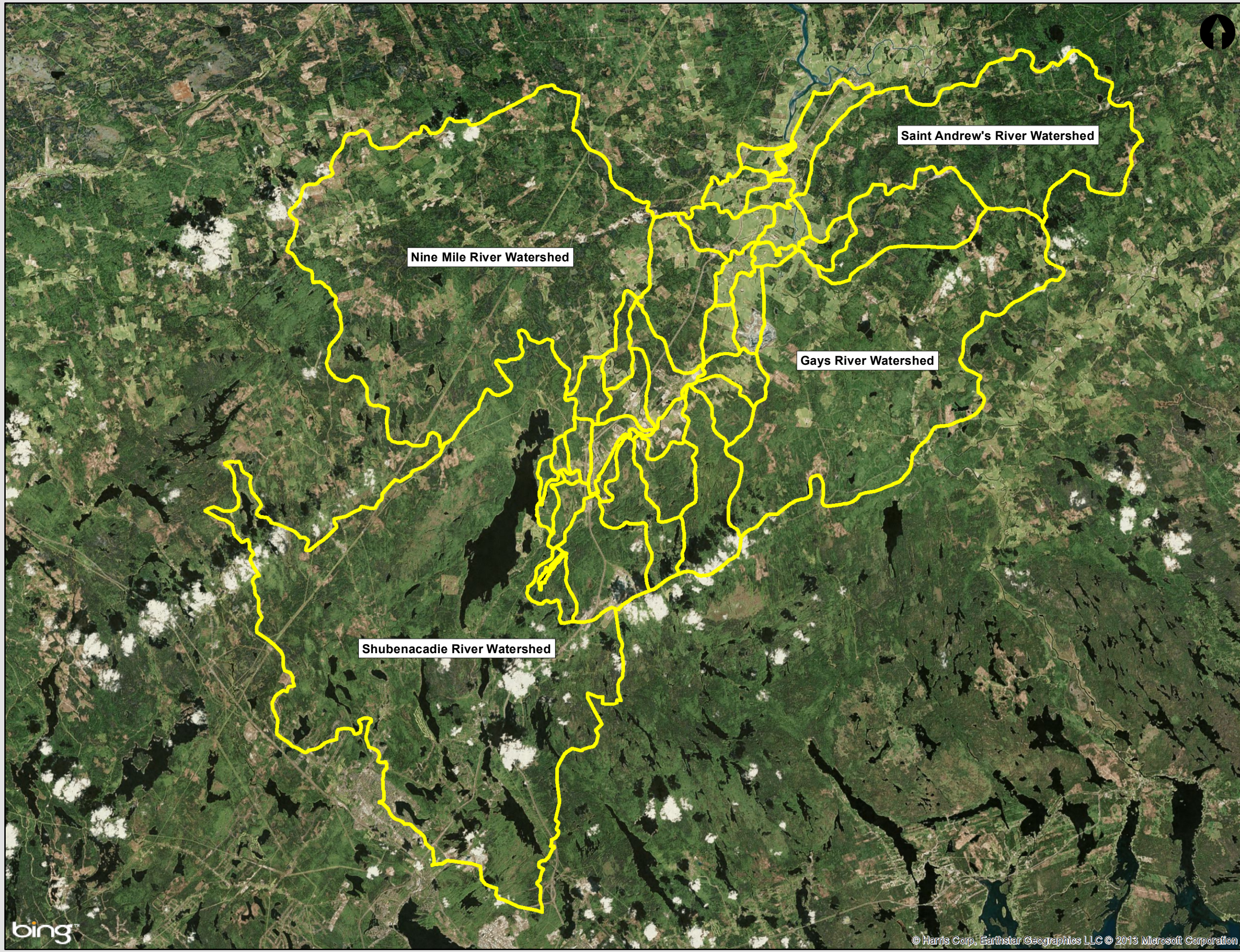
*Homogenous watershed characteristics for the Shubenacadie River, Nine Mile River, Gays River and St. Andrew's River watersheds were not estimated due to their large drainage areas. Flows from these watersheds were instead estimated using actual flow gauging data interpreted through statistical analyses as described below.

1.3.5 River Flow Estimations

Statistical analyses were carried out on flow gauging data from Environment Canada's Canadian Hydroclimatological Database (HYDAT 2012) to estimate extreme flows for the Shubenacadie River, Nine Mile River, Gays River and St. Andrew's River watersheds.

Shubenacadie River Watershed

Flow gauging data for the Shubenacadie River was obtained for hydrometric station 01DG006, Shubenacadie River at Enfield, which is located just a few kilometres downstream of Shubenacadie Grand Lake and has flow data available from 1974 to 1995. Statistical models were calculated for the instantaneous annual peak flows at station 01DG006 using several statistical distributions (Normal, Log-Normal, Three-Parameter-Log-Normal, Gumbel, Fréchet, Weibull and Log-Pearson III). The most



**Shubenacadie River
Floodplain Mapping Study**


Legend:
 Watershed Boundary

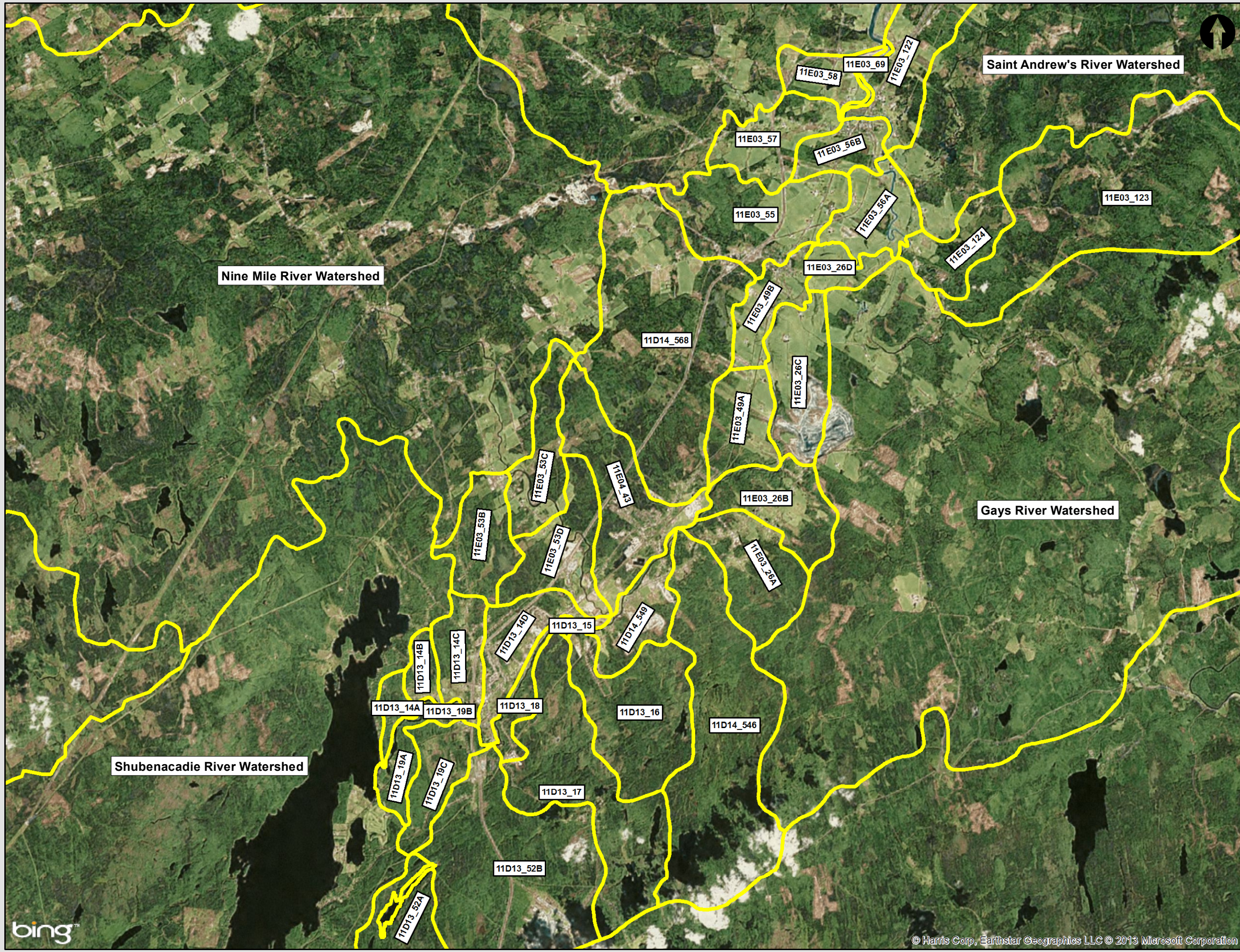
Figure 2

Watershed Delineation



Date: July 2013
 CBCL Project #: 131001.00

Coordinate System:
 NAD83 UTM zone 20N
 Projection: Transverse Mercator
 Datum: North American Datum 1983
 Units: Meter
 Scale: 1:200,000



Shubenacadie River Floodplain Mapping Study

Legend:
 Watershed Boundary

Figure 3

Watershed Delineation



Date: July 2013
 CBCL Project #: 131001.00

Coordinate System:
 NAD83 UTM zone 20N
 Projection: Transverse Mercator
 Datum: North American Datum 1983
 Units: Meter
 Scale: 1:100,000

representative distribution was then selected using statistical hypothesis testing (Chi-square test, T-test, correlation and coefficient of determination). The best fit statistical model for the data set (Weibull distribution) is shown in Figure 4 with its upper and lower 95% confidence limits. Based on the statistical analysis, the 1 in 100 year peak flow to the Shubenacadie River at Enfield station was estimated to be 102m³/s.

Nine Mile River, Gays River and St. Andrew's River Watersheds

Since no flow gauging data is available for the Nine Mile River, Gays River and St. Andrew's River, a regional flood frequency analysis was carried out using instantaneous annual peak flow data from eleven hydrometric stations within 150km of the study area. Statistical hypothesis testing was used to determine best fit statistical distributions for each of the eleven stations. The best fit statistical distributions were then prorated by tributary drainage areas for comparison, as shown in Figure 5.

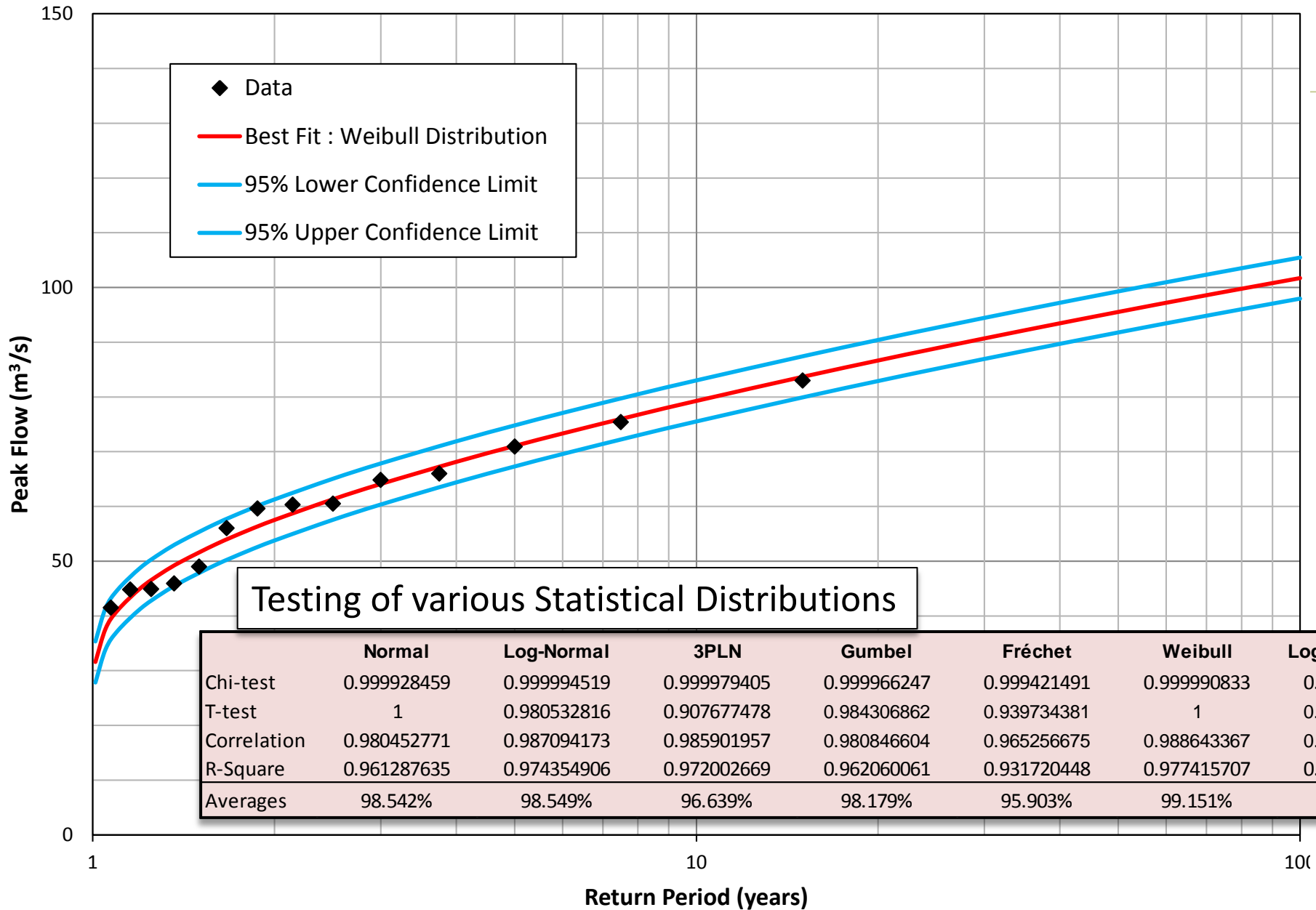
Watershed characteristics including drainage area, location, development characteristics, surface roughness, river slope, steepness of the valley walls, infiltration properties of the soil and flow attenuation by lakes and wetlands were reviewed for the watersheds tributary to each of the eleven stations (see Table 2). The watershed characteristics were then compared with the Nine Mile River, Gays River and St. Andrew's River watersheds to determine the most representative station(s) for the watershed flows. Special consideration was given to stations having the largest number of years of collected data, as a larger data set improves the quality of analysis.

Station 01DG003, Beaver Bank River near Kinsac, was selected as the most representative station for all three watersheds based on its tributary watershed characteristics and years of collected flow data. The best fit statistical model for the data set of Station 01DG003 (Weibull Distribution) is shown in Figure 6 with its upper and lower 95% confidence limits. Based on the selected flow gauge station, the 1 in 100 year peak flows from Nine Mile River, Gays River and St. Andrew's River watersheds were estimated to be 23m³/s, 19m³/s and 10m³/s, respectively.

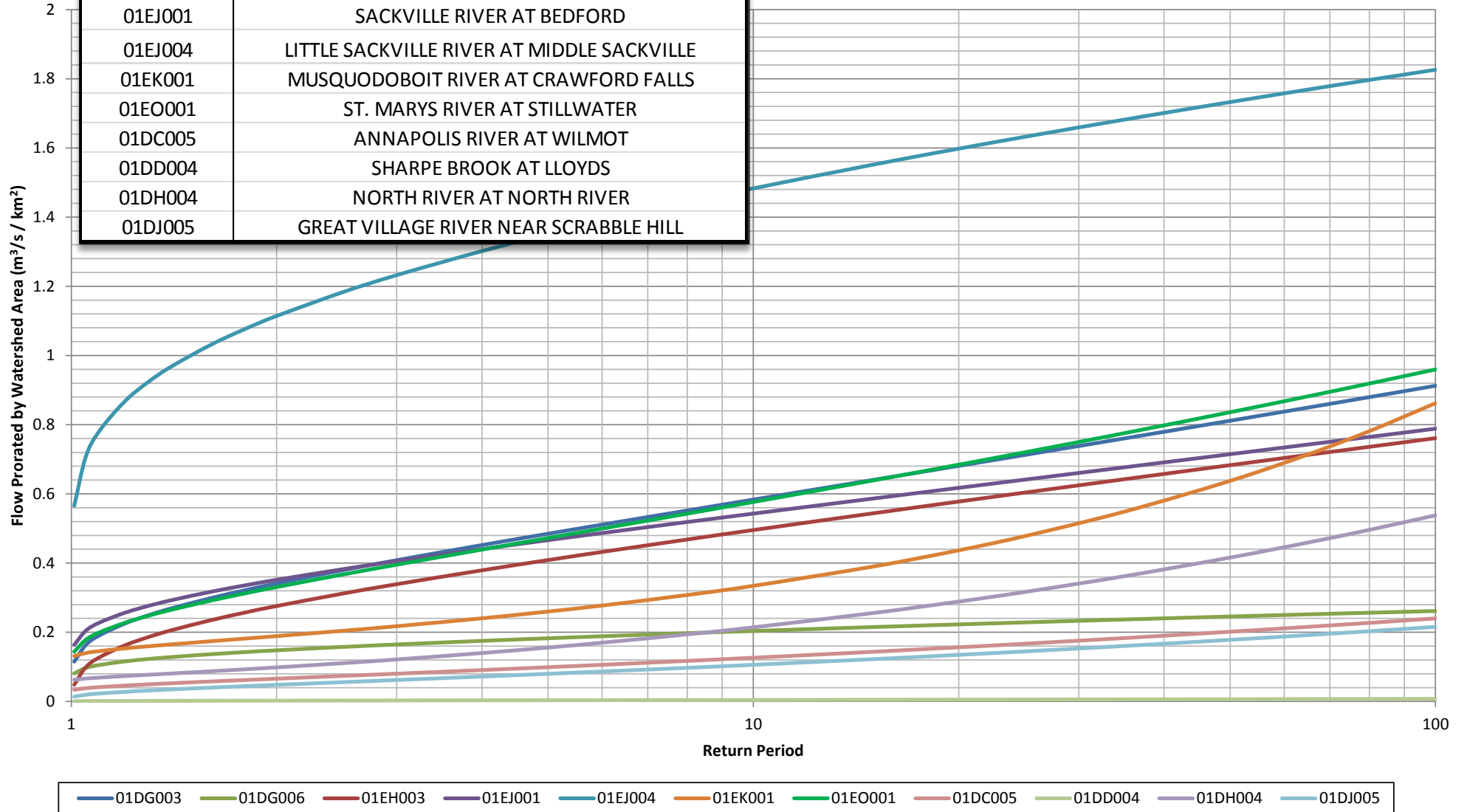
Table 2: Watershed Characteristics for Hydrometric Stations

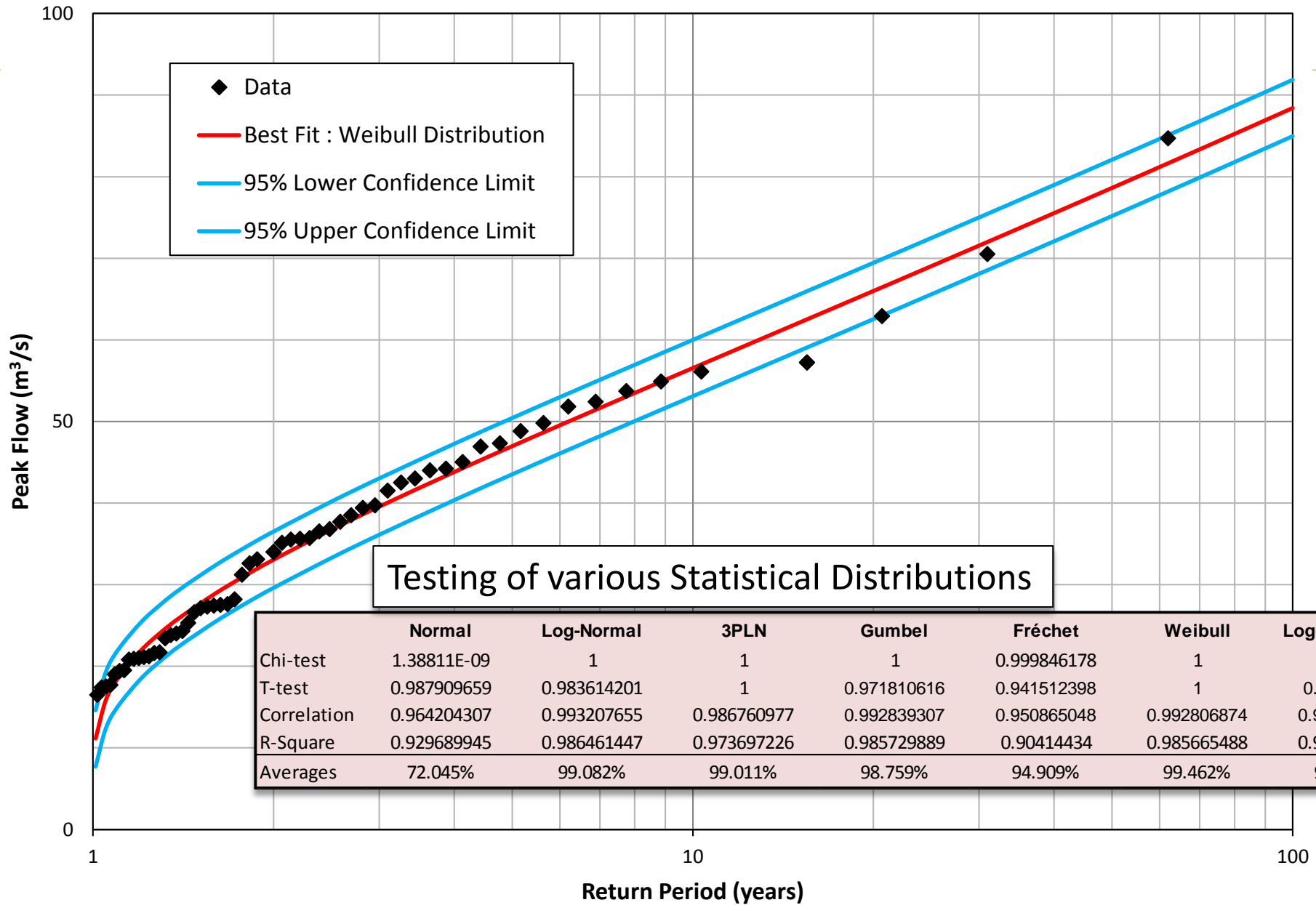
Station ID	Station Name	Watershed Area (km ²)	Years of Data	Watershed Development	Comparison with Nine Mile River, Gays River and St. Andrew's River Watersheds	1 in 100 Year Peak Flow Prorated by Watershed Area (m ³ /s / m ²)
01DG003	BEAVER BANK RIVER NEAR KINSAC	96.9	90	Suburban Development, Forested Areas with Lakes	Similar	0.91
01DG006	SHUBENACADIE RIVER AT ENFIELD	389	22	Suburban Development, Forested Areas with Lakes, Shubenacadie Grand Lake before Outlet	Too much flow attenuation from lakes	0.26

Station ID	Station Name	Watershed Area (km ²)	Years of Data	Watershed Development	Comparison with Nine Mile River, Gays River and St. Andrew's River Watersheds	1 in 100 Year Peak Flow Prorated by Watershed Area (m ³ /s/m ²)
01EH003	EAST RIVER AT ST. MARGARETS BAY	26.9	71	Suburban Development, Forested Areas with Lakes	Similar, but part of different drainage basin	0.76
01EJ001	SACKVILLE RIVER AT BEDFORD	146	42	Urban and Suburban Development in Downstream Region, Forested Areas with Lakes in Upstream Region	Too developed	0.79
01EJ004	LITTLE SACKVILLE RIVER AT MIDDLE SACKVILLE	13.1	31	Urban and Suburban Development, Forested Areas with Lakes in Upstream Region	Too developed	1.83
01EK001	MUSQUODOBOIT RIVER AT CRAWFORD FALLS	650	81	Minor Development, Forested Areas with Lakes;	Too large	0.86
01EO001	ST. MARYS RIVER AT STILLWATER	1350	96	Minor Development, Forested Areas with Lakes	Too large	0.96
01DC005	ANNAPOLIS RIVER AT WILMOT	546	48	Urban and Suburban Development, Agricultural and Forested Areas	Too different	0.24
01DD004	SHARPE BROOK AT LLOYDS	8.81	29	Natural Forested Areas	Drainage Area too small and flow too low	0.01
01DH004	NORTH RIVER AT NORTH RIVER	202	20	Minor Development, Forested Areas	Too different	0.54
01DJ005	GREAT VILLAGE RIVER NEAR SCRABBLE HILL	89	16	Minor Development, Forested Areas	Flow too low	0.22



Station ID	Station Name
01DG003	BEAVERBANK RIVER NEAR KINSAC
01DG006	SHUBENACADIE RIVER AT ENFIELD
01EH003	EAST RIVER AT ST. MARGARETS BAY
01EJ001	SACKVILLE RIVER AT BEDFORD
01EJ004	LITTLE SACKVILLE RIVER AT MIDDLE SACKVILLE
01EK001	MUSQUODOBOIT RIVER AT CRAWFORD FALLS
01EO001	ST. MARYS RIVER AT STILLWATER
01DC005	ANNAPOLIS RIVER AT WILMOT
01DD004	SHARPE BROOK AT LLOYDS
01DH004	NORTH RIVER AT NORTH RIVER
01DJ005	GREAT VILLAGE RIVER NEAR SCRABBLE HILL





	Normal	Log-Normal	3PLN	Gumbel	Fréchet	Weibull	Log-Pearson III
Chi-test	1.38811E-09	1	1	1	0.999846178	1	1
T-test	0.987909659	0.983614201	1	0.971810616	0.941512398	1	0.99636057
Correlation	0.964204307	0.993207655	0.986760977	0.992839307	0.950865048	0.992806874	0.992009045
R-Square	0.929689945	0.986461447	0.973697226	0.985729889	0.90414434	0.985665488	0.984081945
Averages	72.045%	99.082%	99.011%	98.759%	94.909%	99.462%	99.311%

1.3.6 Extreme Rainfall Events

Rainfall hyetographs for the 1 in 2, 1 in 20 and 1 in 100 year storm events that follow the Chicago Distribution with 5-minute discretization intervals were developed for the hydrologic/hydraulic model. The hyetographs are based on Intensity-Duration-Frequency (IDF) curves from Environment Canada for the Halifax Stanfield International Airport Climate Station, since it is located in a central location within the watershed area tributary to the study area.

Rainfall hyetographs for future conditions were then developed by scaling the 1 in 2, 1 in 20 and 1 in 100 hyetographs to predicted increases in 24-hour rainfall amounts for the year 2100 obtained from “Climate Change Scenarios for Atlantic Canada Utilizing a Statistical Downscaling Model Based on Two Global Climate Models,” a study completed in 2008 by Environment Canada. The following Table 3 presents results extracted from this report. The Greenwood and Shearwater Climate stations are the closest to the study area available in the report.

Table 3: Climate Change Rainfall Analysis Results Extracted from EC Report

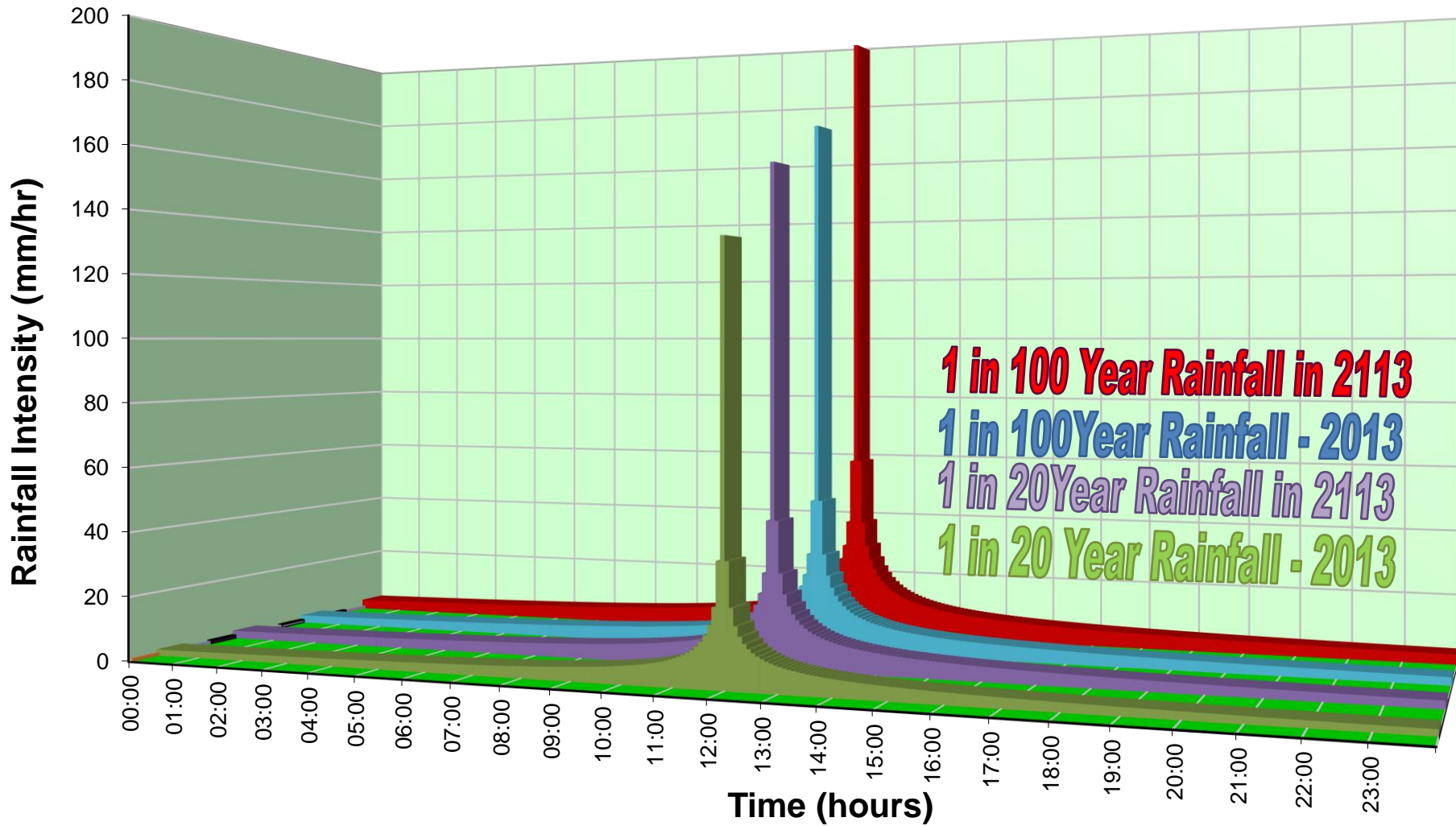
Location	Model		1 in 100 year Return Period Projections			
			Current	2020s	2050s	2080s
Greenwood	CGCM2	amount in mm:	110.2	185.3	154.7	142.3
		% increase :	-	68%	40%	29%
Greenwood	HadCM3	amount in mm:	110.2	142.1	110.3	124
		% increase :	-	29%	0%	13%
Shearwater	CGCM2	amount in mm:	149.1	225.4	180.8	193.7
		% increase :	-	51%	21%	30%
Shearwater	HadCM3	amount in mm:	149.1	172.2	142.6	154.9
		% increase :	-	15%	-4%	4%

As can be seen on the figure, there is a fair range of variability (-4% to +68%) between the projections from the two locations, and also in the projected horizon. In order to pick a value that fit within the projections, without being too conservative or underestimate risks, a value of +30% was selected.

All rainfall hyetographs developed for the model for existing and future conditions are presented in Figure 7.

1.3.7 Extreme Tide Levels

Extreme tide levels were estimated for the Cobequid Bay at the mouth of the Shubenacadie River. Existing and future tide level estimations for the Burncoat Head tidal port were obtained from “Scenarios and Guidance for Adaptation to Climate Change and Sea Level Rise – NS and PEI Municipalities,” a report prepared for Nova Scotia Environment by William Richards and Réal Daigle.



The published tide level estimations in the report are comprised of the Higher High Water Large Tide (HHWLT), storm surge residuals for various return periods, global sea level rise estimations from present to 2100 and local crustal subsidence estimations. Burncoat Head is the closest tidal port to the Cobequid Bay in the Bay of Fundy and is therefore the closest location to the study area that contains published tide data (see Figure 8).

Since there is still a large amount of uncertainty remaining with the use of this data, a tidal measurement field program was undertaken. In addition to using published tide data for the study, tide gauge data was collected near the outlet of the study area to relate water levels in the Shubenacadie River with tidal patterns in the Cobequid Bay. A tide gauge was installed below the Highway #2 bridge crossing in Shubenacadie and collected water level data between March 12 and March 28, 2013. A second tide gauge was installed for quality control purposes 200m downstream at the railway crossing (see Figure 9). The tide gauging data was then compared with astronomical tidal and rainfall amounts during the data collection period to understand the factors affecting water levels during the measurements.

Figure 10 shows the data results, as well as tidal predictions at the mouth of the Shubenacadie River during a period with no rainfall. This data, as explained in the next chapter, was used to calibrate the model response to tidal elevations in the Bay of Fundy.



Solving Today's
problems with
Tomorrow
in mind



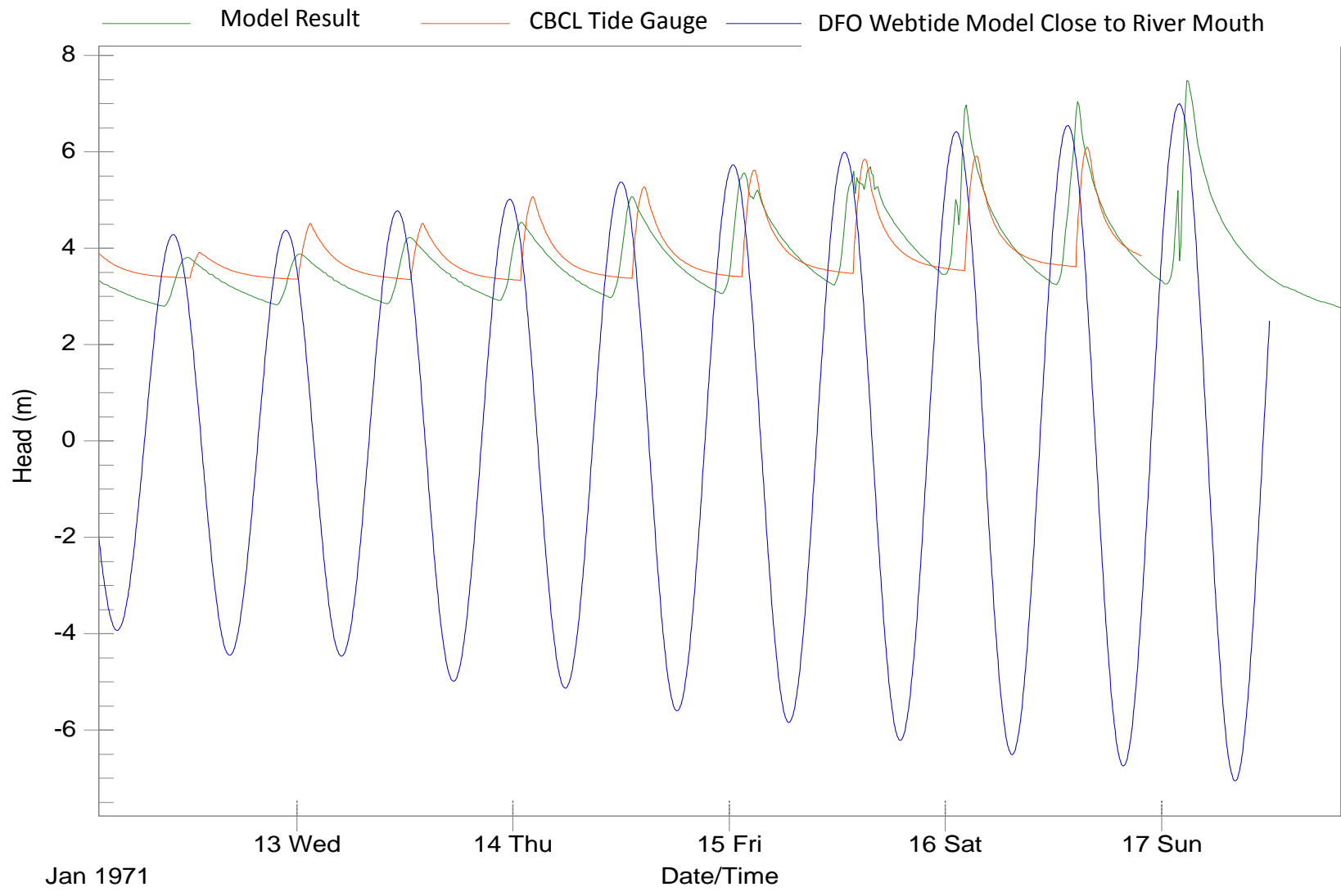
**Highway 2
Bridge**



**CBCL Tide
Gauge
Instrument**



Railroad Bridge



CHAPTER 2 **HYDROLOGY/HYDRAULIC MODEL DEVELOPMENT AND CALIBRATION**

The hydrologic/hydraulic modelling software used for this study was Version 5 of the Storm Water Management Model (SWMM). This model, first developed in 1971, has a very high recognition from the engineering and scientific community, and is both a hydrologic and hydraulic model, dynamically solving the continuity and momentum equations with a finite difference scheme. It is capable of performing unsteady flow calculations to simulate flow reversals from tidal flows up the river, pressurised flow at overtopped bridges and the complex interaction of flows from Shubenacadie Grand Lake, local watershed runoff along the river and tidal patterns at the river outlet.

2.1 Model Development

The model was developed by entering the hydrologic characteristics (watershed and climatic details) and hydraulic characteristics (river channel layout, floodplain cross sections and bridge data, tidal levels). Roughness coefficients along the floodplain and at the bridges were estimated based on the values used in the 1997 study, the land use mapping, aerial photos and photos collected of the river and of the bridges. The model was then extended to include the floodplain downstream of the study area to the mouth of the Shubenacadie River such that tidal inputs in the Cobequid Bay could be input into the model.

2.2 Model Calibration

Model calibration was completed to verify that the modelled water level response to climatic and tidal inputs is representative of the existing Shubenacadie River floodplain water level response. The model was calibrated to historical water level data for the February 1971 and August 1971 flood events by modifying watershed characteristics, channel roughness coefficients and river cross sections.

Measurements of peak historical water levels are critical to a satisfactory model calibration. This is because they are measurements of the closest water levels to those the model is trying to estimate. If the model is accurately able to reproduce measured peak water levels, then the level of confidence of extreme water level calculation will be much greater.

Historical water levels were obtained from 3 sources:

- The survey conducted by George Searle at several private properties in the Shubenacadie area as part of this assessment;
- The survey conducted by CBCL Limited at several private properties throughout the study area (Table 4); and
- The survey conducted by MRMS in 1981 at several bridge locations (Table 5).

Historical water level locations and details are presented on the map in Figure 11. As the Figure shows, surveyed water levels are spread throughout the Shubenacadie River in the study area. The Nine Mile River, in comparison, did not have any high water level reports other than at its confluence with the Shubenacadie River.

Table 4: Resident Data from CBCL Limited 1997 Study

Homeowner	Location	High Water Elevation (location as indicated by homeowner)
Elmsdale Landscaping	Elmsdale	11.52 m
Allan Preeper	Lantz	12.54 m
Harry Smith	Shubenacadie	8.62 m
Ernest Ellsworth	Shubenacadie	8.70 m

Accounts from homeowners:

Mr. Harry Smith - Shubenacadie

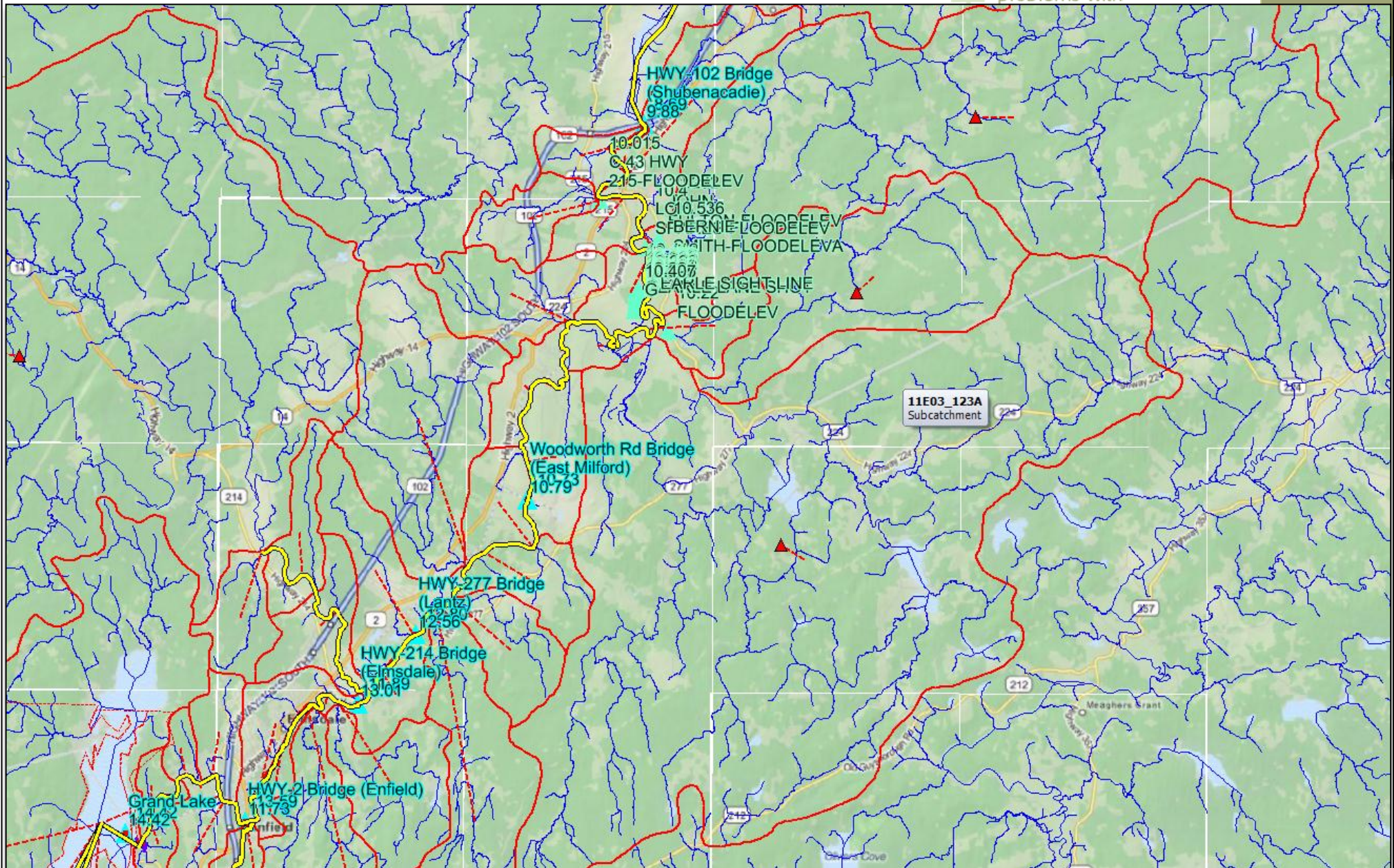
Mr. Smith has resided in Shubenacadie at his present location for 94 years. He recalled an extremely high flood in 1935 due to ice jam in the Shubenacadie River. His property and house were flooded as well as the No. 2 Highway. In the past few years he has also noted that high spring tides will flood a marsh adjacent to the river and behind his barn but generally the water does not proceed past the barn. Normal high tide levels just reach the top of the riverbank. Mr. Smith was not sure of the low tide levels but during the survey the river was approaching low tide and the water level appeared to be 0.9-1.2 m below the top of the riverbank (this is just a rough estimate to indicate a lower limit of drop between tides).

Mr. Ernest Ellsworth-Shubenacadie

Mr. Ellsworth has lived at 43 Maitland Road for 35 years. The highest water level he has seen was in 1971 as a spring flood. Water rose 2.4 m and overflowed the 215 highway. He notes that normal high tides reach the top of the riverbank and generally proceed onto his property 0.6-1.2 m. A normal low tide will have a decrease in height approximately 1.2 m. High spring tides normally flood Mr. Ellsworth's property 4.6-6.0 m from the riverbank.

Mr. Allan Preeper-Lantz

Mr. Preeper has resided at Preeper's Lane on the highway 277 for 70 years. The normal high water mark due to spring flooding is adjacent to his house approximately 50 m from the riverbank. Spring tides are 76 mm (3 inches) above normal high tides. An ice jam caused a flood approximately 27 years ago which flooded his property and the highway 277. Mr. Preeper stated that he had 5 feet (1447 mm) of water flooding his basement at that time. Also, a very dry summer and a week of steady rainfall in



August of 1969 caused flooding of his property. Mr. Preeper also stated that the current water level of the Shubenacadie River is the lowest that he has ever seen.

Mr. Denis Coupar - Elmsdale

The Elmsdale Landscaping Company has been located at the confluence of the Shubenacadie and Nine Mile rivers in Elmsdale for 40 years. The company has a flood buffer which separates the company buildings and equipment from the rivers. The highest water level seen by Mr. Coupar was in August about 25 years ago when the entire buffer was flooded. The water level was at one point deep enough for children to dive into from loading structures on the property. Normal spring flooding covers 30-40 % of the buffer with a water depth of 0.9 m. The high water mark was located approximately 620 m from the Shubenacadie River and 220 m from the Nine Mile River.

Table 5: Water Levels (Geod.) Observed at Bridges from 1981 MRMS Floodplain Mapping Study

Location	Aug. 15/16 1971	Feb. 16/19 1971
Grand Lake	14.42 m	
Enfield CNR Bridge		13.20/12.53 m
Enfield HW #2 Bridge	13.59 m	11.73 m
Elmsdale Bridge	11.89 m	(13.01*)/10.61 m
Lantz Bridge	(12.80 m*)	12.56/10.06 m
Milford Quarrie		11.03/9.42 m
Milford Bridge	10.73 m	10.79/9.30 m
Shubenacadie Bridge	8.69 m	9.88/7.83 m

* There seems to have been an error with this data point as it is not consistent with the other data points - it was therefore not used.

To simulate the 1971 events, the following data was input into the model:

- **Discharge from Shubenacadie Grand Lake:** since no river flow data is available for the Shubenacadie River in 1971, flows from Shubenacadie Grand Lake during the 1971 events were estimated by modelling the watershed upstream of the study area using the hydrologic/hydraulic model previously completed by CBCL Limited in 2006 as part of the Low Flow Enhancement Pumping Options study (part of the Engineered Spring design) for the Municipality of East Hants. The model of the upstream watershed was previously calibrated to the daily flow data for the Shubenacadie River hydrometric station from 1974 to 1995. This model was then input into the Shubenacadie River floodplain model. Flows from the Shubenacadie Grand Lake during the 1971 events were then estimated by the model using hourly precipitation data for the Halifax Stanfield International Airport Climate Station;
- **Discharge from the Nine Mile River, Gays River and St. Andrew’s River Watersheds:** daily flow data for 1971 from the Beaver Bank hydrometric station was prorated by watershed area for each of the three watersheds and input into the model;
- **Local Watershed Runoff:** flows discharged from the local watersheds were estimated by the model using hourly precipitation data for the Halifax Stanfield International Airport Climate Station; and
- **Tidal Flows:** tidal flows during the 1971 events were estimated by inputting 1971 tidal predictions at the mouth of the Shubenacadie River into the model. To ensure that the relationship between

tidal predictions at the mouth of the Shubenacadie River and water levels at the outlet of the study area was modelled representatively, the downstream portion of the model was first calibrated to water levels from the 2013 tide gauging data. Calibration results for the 2013 tidal gauging period are presented in Figure 10.

Calibration results for the August 1971 flood event are presented in Table 6.

Table 6: Comparison of Model and Surveyed Results for August 1971 Event

FROM 1981 MRMS Study	Peak Head (m)	
	MODEL	SURVEYED
Grand Lake	14.60	14.42
HWY2 Bridge (Enfield)	13.60	13.59
HWY214 Bridge (Elmsdale)	11.85	11.89
Woodworth Rd Bridge	10.71	10.73
HWY102 (Shubenacadie)	8.70	8.69
From 1995 CBCL Survey		
Nine Mile River (Elmsdale Landscaping): 113 Elmsdale Road	11.78	11.52
Harry Smith, Shubenacadie, just Upstream HWY2	8.79	8.62
Ernest Ellsworth, 300m upstream of Shubenacadie Railway Bridge by HWY2	8.76	8.70

As can be seen on the table, there is very little difference between the modelled and surveyed results. The model calibration was also adjusted so that modelled results were almost never below the surveyed results (4cm difference in the worst case), to avoid underestimating any risks.

2.3 Ice Build-Up Model

Even though the model used for peak water level calculations (SWMM) is one of the best recognised models for this application, it does not include ice jam processes. Since the worst flood event in the last 40 years resulted from an ice jam, it is very important to include such an event in this analysis. For this purpose, the US Army Corps of Engineers Hydrologic Engineering Centers River Analysis System (HEC RAS) model was used. It also has extensive recognition in the domain, and has an ice jam module supported by extensive research.

The model HEC RAS 4.0 includes an ice build-up module, in which it simulates the formation of ice jams, and its effect on the peak water levels. The user specifies the existing ice cover thickness on the river and its banks prior to the jam, the ice surface roughness, and for wide river ice jams, its internal friction angle, porosity, cohesion and maximum average velocity under the ice cover. The program will calculate the ice build-up in the river, as it is extracted from upstream sections, pushed and packed together by the flow of water, and its effect on water levels.

Ice jam formation can occur during the freeze-up period at the beginning of winter, or during the break-up period in spring. The Environment Canada website gives clear explanations of how ice jams can form and affect water levels.

During the freeze-up period, ice forms on the river surface beginning at the banks. Ice crystals may also develop within the river as frazil ice, which is very common in rapids. The ice crystals tend to coalesce and accumulate, and may become attached to the underside of the ice cover or to the river bed as anchor ice.

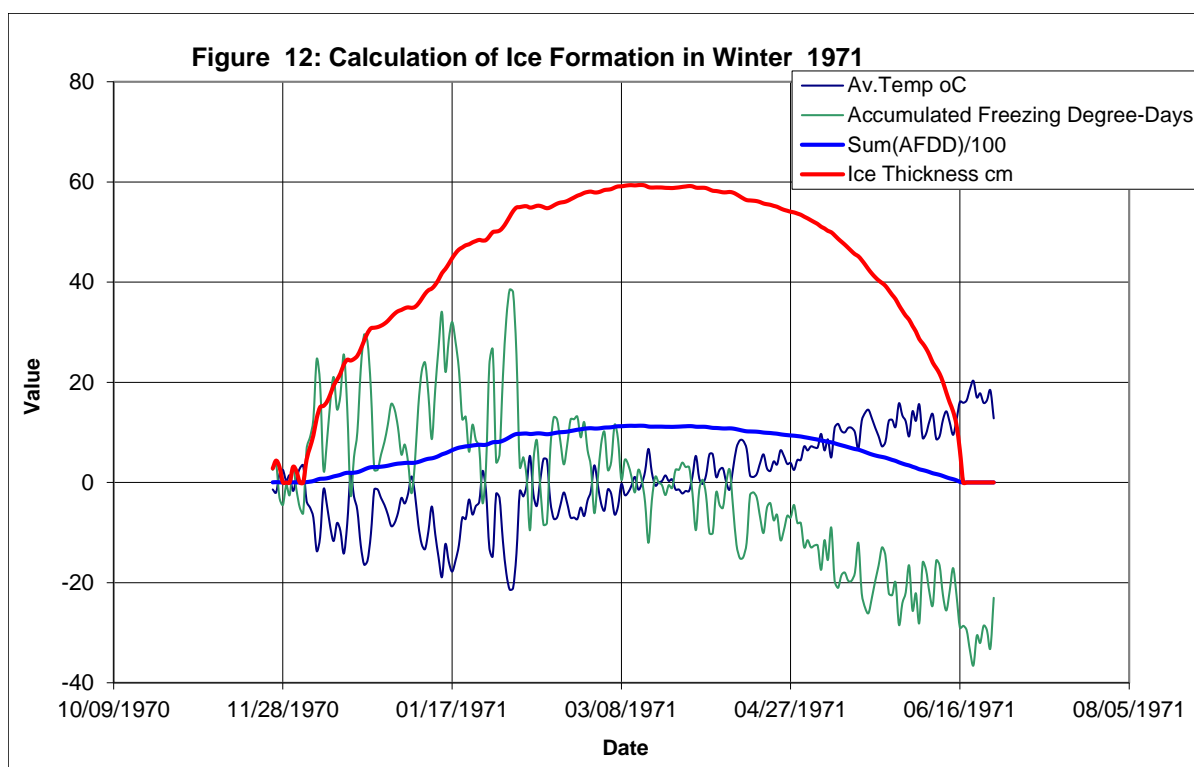
Frazil pans and floes are major components in the formation of a river's initial ice cover. In tranquil reaches, this cover is a mere surface layer of ice floes and pans, but elsewhere it can be several layers thick.

Ice jams during the freeze-up period usually form where floating ice slush or blocks encounter a stable ice cover. There are, however, certain features that, in conjunction with ice cover, enhance the probability of ice jam formation: bridge piers, islands, bends, shallows, slope reductions, and constrictions.

During breakup in the spring, or during winter thaws, an ice jam results from the accumulation of ice from the breakup of the upstream ice cover. A rise in water levels may result from the spring snowmelt, or a sudden midwinter thaw, common in Atlantic Canada. Midwinter thaws are often accompanied by substantial rainfall, resulting in a rapid increase in water levels and severe ice jams.

Ice jams cause flooding because of two main features. First, ice jam thicknesses can be considerable, amounting to several metres. Secondly, the underside of the ice cover is usually very rough. Under open water conditions, the only frictional resistance retarding the flow of the water is the streambed. The rougher the streambed, the greater the depth required to pass a given discharge. With an ice jam in place, the additional ice and very rough lower surface retard flow. Therefore, the flow depth has to be much greater than for open water.

An important factor to the level of ice build-up is the amount of ice existing on the banks just prior to the jam occurring. This amount is dependent on many factors, such as the variation in temperature and water levels in the entire winter period leading to the ice jam. Since the model uses this information as input, it does not calculate the potential depth of ice cover prior to the jam. An analysis was therefore carried out using the US Army Corps of Engineers' Ice Engineering publication: "Method to Estimate River Ice Thickness Based on Meteorological Data". This publication describes a formalised approach to estimating maximum potential ice thicknesses based on climate data and heat transfer processes, using the concept of "Accumulated Freezing Degree Days". Temperature Data was obtained from the Halifax Stanfield International Airport from 1953 to present. Figure 12 shows this calculation for the year 1971. The maximum annual ice thicknesses were then compiled and analysed with statistical distributions. This method shows that the 1 in 100 year ice accumulation may reach 63 cm, thereby creating the conditions for a potential ice jam of even greater proportions.



The February 1971 ice jam conditions were therefore reproduced with the model by re-creating the conditions just prior to the ice jam and allowing the model to reproduce the ice jam. This was achieved by:

- Estimating the river flows by using climate data in the hydrologic model to reproduce flows in the Shubenacadie River upstream areas;
- Prorating flows in the Beaver Bank River to estimate inflows from tributaries in the downstream reaches of the river; and
- Estimating the initial ice thickness from the method described above.

The river flows at the time of the February 1971 ice jam event were found to be quite average, even common. It would be the climatic conditions, and perhaps the precise evolution of freezing and thawing, combined with a particular river bed configuration, that would have allowed the ice jam to form upstream of Highway 2 in Shubenacadie. The model had to be further calibrated to reproduce the conditions as witnessed by the various residents. It was found that ice jams were very unlikely to develop in the model (whether it is a reality, a result of different river conditions, missing factors from the survey or missing processes in the model is unknown), even with the 1 in 100 year initial ice conditions. In this case, the initial ice conditions would simply be sustained and not lead to accumulation in any particular area. On the other hand, when an artificial ice accumulation was input in the model, the model allowed it to be sustained and not wash away naturally. This result would tend to indicate that even though ice jam formation is very unlikely, if one does occur, it can reach very high proportions. It was therefore estimated that the ice jam as experienced was important to consider and was assigned a return period of 1 in 100 year event. The ice jam input in the model to reproduce the surveyed water levels in February 1971 is shown on Figure 13.

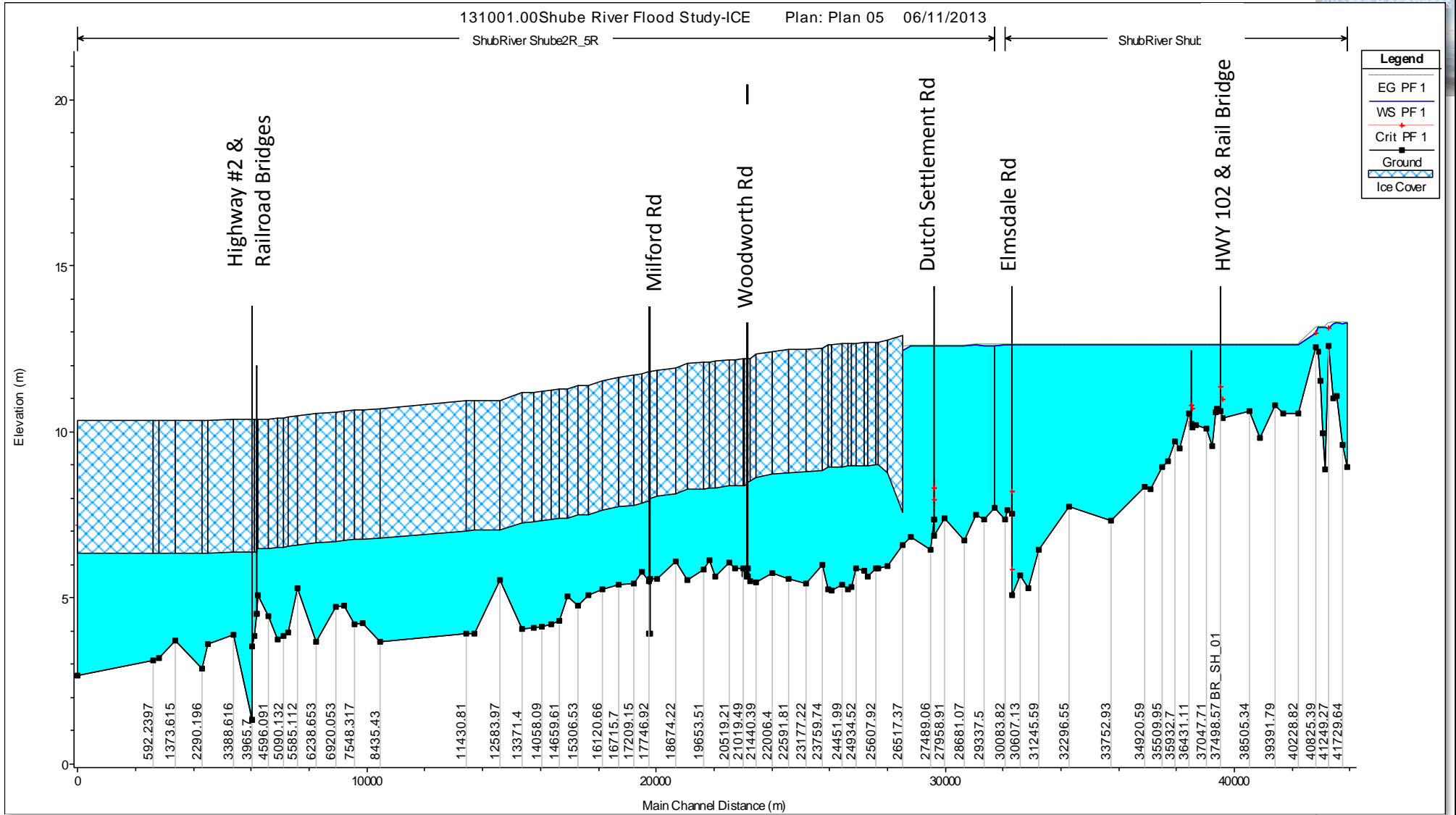


Table 7: Comparison of Model and Surveyed Results for February 1971 Event (Ice Jam)

FROM 1981 MRMS Study		MODEL	SURVEYED
HWY277 Bridge (Lantz)	J27611	12.58	12.8
From 1995 CBCL Survey			
Alan Preeper (Lantz), Preeper's Lane	J27958.91	12.58	12.54
From 2013 CBCL Survey (George Searle)			
HWY215 / Beattie Dr (Ernie Ellsworth)	BR-SH-08_DS (4039.858)	10.04	10.02
Rte224 John Fullton	J6238.653	10.24	10.29
Rte 224 - Lois Spares Farm	J6920.053	10.27	10.40
Rte 224 - Bernie Smith	J7215.023	10.32	10.54
Rte 224 - George Searle	J8435.43	10.38	10.40
Rte 224 by Oxbow	J11430.81	10.60	10.22

The results of the ice jam model were also used for floodline delineation. The floodlines delineate the greater of the various water level calculations.

CHAPTER 3 **STUDY RESULTS AND FLOODPLAIN MAPPING**

3.1 Existing Conditions Floodplain Mapping

Extreme water levels were estimated using the hydrodynamic model (SWMM) and the ice jam model (HEC RAS). In order to create the 1 in 20 year and 1 in 100 year peak flows and therefore peak water levels, the following inputs were used in the model:

- 1 in 20 year and 1 in 100 year peak flows at the Subenacadie River at Enfield gauging station;
- Prorated 1 in 20 year and 1 in 100 year peak flow from the Beaver Bank river for the other large watersheds;
- 24-hour rainfall 1 in 20 year and 1 in 100 year event estimated from the Environment Canada Intensity-Duration-Frequency curves; and
- Ice jamming conditions as surveyed during the February 1971 event.

The 1 in 20 year floodline was estimated by modelling the following two scenarios and calculating the highest water surface elevation of the two scenarios at each floodplain cross section:

- 1 in 20 year flow with no low tide; and
- 1 in 2 year flow with 1 in 20 year tide.

The 1 in 100 year floodline was estimated by modelling the following three scenarios and calculating the highest water surface elevation of the three scenarios at each floodplain cross section:

- 1 in 100 year flow with no low tide;
- 1 in 2 year flow with 1 in 100 year tide; and
- 1 in 100 year ice jam.

Floodplain mapping for existing conditions was developed based on the model results for the 1 in 20 year and 1 in 100 year floodlines. The floodplain mapping for existing conditions is included in the form of electronic shape files provided to the Municipality with the report. Since they are not recommended for use for planning purposes, their use is purely for comparison purposes and do not need to be included in this report as full scale maps. It was found that the peak water levels were mainly found to be governed ice jams, with the tide governing in perhaps 20% of the river length for the 1 in 100 year event, while for the 1 in 20 year event, a balance of 40% flow, 60% peak tides was found to be governing.

3.2 Sensitivity Analysis

The sensitivity analysis is necessary to reduce the risk of underestimating a flood level. With each parameter affecting flows and water levels, there is an uncertainty. Some of these parameters (such as watershed slope) do not have much influence on the water levels (low sensitivity), while other parameters (such as surface roughness) have a greater influence on peak water levels (greater sensitivity).

While the 1 in 20 year and 1 in 100 year floodlines described above strive to represent average parameter values (for those events), the sensitivity analysis endeavours to represent conditions near the more conservative end of the normal range of each parameter.

With this in mind, the following parameters were adjusted:

- The rainfall calculation was adjusted to the upper 95% confidence limit;
- The flow calculation was adjusted to the upper 95% confidence limit;
- The surface roughness in the channels and in the floodplains were adjusted to the rougher end of summer heavy brush conditions; and
- Other parameters, such as soil infiltration, were also adjusted near the end of their typical ranges.

The 1 in 20 year and 1 in 100 year models were then run with those modifications, and the resulting water levels were deemed to represent the 95% upper confidence limit of the calculations. The floodlines for the 95% upper confidence limit are shown adjacent to the “average parameter values” floodlines.

It was found that the impact on the peak water level calculation was mostly insignificant, but with a difference reaching approximately 0.6m in a couple of locations.

3.3 Future Conditions Floodplain Mapping

Floodplain mapping for future conditions (2113) were developed for the 1 in 20 year and 1 in 100 year floodlines with their associated upper 95% confidence intervals. The floodplain mapping for future conditions is presented in Maps 1 to 5, in Appendix A (black and white) and in Appendix B (colour). The future conditions model included the impacts of sea level rise, increased precipitation as well as watershed development.

The development and zoning information provided by the Municipality of East Hants was used to estimate the impacts of growth on watershed runoff.

Comparing the governing influences between peak flows, tides and ice jam conditions, a similar balance was found as compared to existing conditions.

CHAPTER 4 **RECOMMENDATIONS FOR STORMWATER MANAGEMENT**

One of the most efficient ways to deal with flooding risks is to manage the issue of high runoff at its source. Flooding is only amplified when runoff is allowed to increase, and infiltration of water into the ground is decreased. Most often, development allows this to happen and therefore increases flooding risks. The more water is encouraged to infiltrate in the ground, the more the high water levels are controlled, and the more the overall river health is protected. Stormwater Management has the following benefits for the river, the riverine residents, the overall watershed community and the Municipality:

- Decreases flooding risks and entailed risks to infrastructure, land value, liability and public safety;
- Decreases peak flows, resulting in smaller infrastructure costs;
- Aquifer recharge, reducing the strain on water supply sources;
- Reduces pollution to drinking water supplies, recreational waters and wetlands, saving future expenditures for restoration of valuable water resources;
- Protects water quality and increases low flows in the river, enhancing fish habitat in this uniquely valuable river system;
- Reduces energy costs by constructing new green roofs or retrofitting existing roofs, and
- Through the above results, improves the quality of life and increases property value.

A more concentrated (cluster) subdivision design, with less impervious area and smaller infrastructure (stormwater drainage and other utilities), also means significant cost savings to developers (who will therefore show less resistance in implementing this type of design) and reduces maintenance costs for municipalities.

These aspects show that even if the original target for stormwater management is the reduction of flooding risks, there are a host of other associated benefits to the overall community, which all contribute to more sustainable development. This makes stormwater management through Low Impact Development (LID) and Best Management Practices (BMPs) an important recommendation for implementation at the planning and by-law levels in the Municipality.

Stormwater management is no longer an innovative or rare approach. It is now very well understood and implemented in a majority of communities across North America. There is a multitude of very-well researched documents describing comprehensively how-to approaches to Low Impact Development (LID) from the planning level to the lot development stage, including retrofitting existing developments. This section of the report gives a summary of typical approaches in various settings from areas with proven records of successfully implementing LID and BMPs. General recommendations on typical targets for results are also included at the end of the chapter.

4.1 Planning for Low Impact Development

The LID approach provides opportunities to build homes and businesses, while conserving natural areas and drainage patterns. LID is accomplished as a two-step process;

- thoughtful site planning and,
- incorporation of "natural" stormwater best management practices (BMPs).

Thoughtful site planning begins with the identification of critical site features such as wetlands, habitat areas, and /or drinking water protection areas that should be set aside as protected open space. Natural features, such as vegetated buffers and view sheds, will also play an integral role in any LID planning exercise. After the critical open space areas are identified and set aside, sustainable development areas are then identified as "building envelopes". General goals include the following:

- **Concentrate Development and Mix Uses:** The LID site planning process sets aside key natural features and focuses development into clustered patterns on the remaining land. The LID planning process results in housing that makes more efficient use of land and conserves critical natural features such as wetlands, vegetated buffers, and drinking water protection areas.
- **Protect Land and Ecosystems:** The reduction of impervious surfaces reduces the amount of surface runoff and through the infiltration of stormwater recharges the groundwater system, thereby restoring the natural hydrologic cycle. This preserves groundwater supplies and base flow to streams and wetlands.

The Credit Valley Conservation a community conservation area in Ontario, has published a comprehensive guide to implementing sustainable development through Low Impact Development and Stormwater Best Management Practices ("Low Impact Development Stormwater Management Planning and Design Guide", Version 1.0 – 2011). An extract is presented below, which tabulates the summary of stormwater management and land use planning steps in order to achieve Low Impact Development. This guide presents a very well organised approach, without being overly prescriptive on individual approaches to achieving Low Impact Development. This document could serve as an example for creating a similar document in the Municipality of East Hants.

Table 2.2.1 Summary of stormwater management planning at key scales and land use planning stages

Scale	Planning Stage	Description
Watershed plans	Master Plans Growth Plan Official Plan	Major themes and objectives for the municipality's future growth are established, and challenges and opportunities for growth are identified, such as municipal policy direction for innovative SWM approaches and other climate change initiatives.
Community/ Subwatershed	Secondary Plan	Major elements of the natural heritage system are identified including terrestrial, aquatic and water resources (hydrology, hydrogeology, fluvial geomorphology, etc.). Stormwater management objectives for surface and groundwater resources. Future drainage boundaries, locations of stormwater management facilities and watercourse realignments are established.
	Block Plan	The location of lots, roads, parks and open space blocks, natural heritage features and buffers, and stormwater management facilities are defined. A full range of opportunities to achieve stormwater management objectives are identified, establishing a template for the more detailed resolution of the design of stormwater management facilities at subsequent stages in the planning and design process.
Neighbourhood	Draft Plan of Subdivision/ Functional Servicing Plan	Conceptual design is carried out for stormwater management facilities. Consideration must be given to how stormwater management objectives can be achieved and how these objectives influence the location and configuration of each of the components listed above
	Registered Plan	Detailed design is carried out for stormwater management facilities.
Site	Site Plan	Site-specific opportunities are identified to integrate stormwater management facilities into all of the components of a development including landscaped areas, parking lots, roof tops and subsurface infrastructure. Solutions must be considered in the context of the overall stormwater management strategy for the block or secondary plan area to ensure that functional requirements are achieved
Site	CA Permits and other approvals	Detailed design of SWM for the site

It is recommended that at the planning level, the system described above be adopted, which includes the development of:

- Watershed Master Plans, a Growth Plan and an Official Plan;
- Community / Subwatershed Secondary and Block Plans;
- Neighbourhood Draft Plan of Subdivision / Functional Servicing Plan, followed by the Registered Plan;
- Site Plan with site specific opportunities, while staying consistent with the direction of the higher level plans; and
- Site Permits and approvals.

Stormwater management planning is closely linked with resource, land use and community planning. This is essential since it establishes the linkage and inter-dependence of community planning with stormwater management planning at all levels. At the higher watershed level, it typically requires the

cooperation of several municipalities to incorporate into their official planning documents the approaches recommended in the watershed plan. Full descriptions of each type of plan are given in the “Infraguide :Stormwater Management Planning”, NRC, 2005 document.

4.2 Best Management Practices in Forested Areas

Sources of pollution associated with forestry activities include removal of streamside vegetation, road construction and use, timber harvesting, and mechanical preparation for the planting of trees. Of these, road construction and road use are the primary sources of pollution on forested lands, contributing up to 90 percent of the total sediment from forestry operations.

Harvesting trees in the area beside a stream can affect water quality by reducing the stream bank shading that regulates water temperature and by removing vegetation that stabilizes the stream banks. These changes can harm aquatic life by limiting sources of food, shade and shelter.

4.2.1 Recommendation to Use Nova Scotia’s Code of Forest Practice

Nova Scotia has recently published a very good document in this specific area, which describes an approach to implementing sustainable forest management techniques. The document was produced for Crown Land, but it is applicable to any forested area in the province. The document indeed recommends that it be used for forest management in the province wherever possible.

The reference for this document is the following:

Nova Scotia’s Code of Forest Practice
A Framework for the Implementation of Sustainable Forest Management
Guidelines for Crown Land
Nova Scotia Natural Resources
August 2012

It is recommended that this document be made a requirement for all forestry activities in the Shubenacadie River and Nine Mile River watersheds.

General recommendations for forestry Best Management Practices to include in a preharvest plan are listed in the following section, extracted from the USEPA.

4.2.2 Typical Forestry Best Management Practices

Preharvest Planning: Opportunities to Prevent Pollution

To limit water quality impacts caused by forestry, public and private forest managers have developed and followed site-specific forest management plans.

Following properly designed preharvest plans can result in logging activities that are both profitable and highly protective of water quality. Such plans address the full range of forestry activities that can cause

pollution. They clearly identify the area to be harvested; locate special areas of protection, such as wetlands and streamside vegetation; plan for the proper timing of forestry activities; describe management measures for road layout, design, construction, and maintenance, as well as for harvesting methods and forest regeneration.

Public meetings should be held to provide residents with an opportunity to review and comment on the development of forest management plans.

Factors Considered in the Preharvest Plan

Surveying the Site

Preactivity surveys can help identify areas that might need special protection or management during forestry operations. Sensitive landscapes usually have steep slopes, a greater potential for landslides, sensitive rock formations, high precipitation levels, snowpack, or special ecological functions such as those provided by streamside vegetation. Forestry activities occurring in these areas have a high potential of affecting water quality.

Timing

Because most forestry activities disturb soil and contribute to erosion and runoff, timing operations carefully can significantly reduce their impact on water quality and aquatic life. Rainy seasons and fish migration and spawning seasons, for example, should be avoided when conducting forestry activities.

Establishing Streamside Management Areas (SMAs)

Plans often restrict forestry activities in vegetated areas near streams (also known as buffer strips or riparian zones), thereby establishing special SMAs. The vegetation in an SMA is highly beneficial to water quality and aquatic habitat. Vegetation in the SMA stabilizes streambanks, reduces runoff and nutrient levels in runoff, and traps sediment generated from upslope activities before it reaches surface waters. SMA vegetation moderates water temperature by shading surface water and provides habitat for aquatic life. For example, large trees provide shade while alive and provide aquatic habitat after they die and fall into the stream as large woody debris.

Managing Road Construction, Layout, Use, and Maintenance

Good road location and design can greatly reduce the transport of sediment to water bodies. Whenever possible, road systems should be designed to minimize road length, road width, and the number of places where water bodies are crossed. Roads should also follow the natural contours of the land and be located away from steep gradients, landslide-prone areas, and areas with poor drainage. Proper road maintenance and closure of unneeded roads can help reduce pollution impacts from erosion over the long term.

Managing Timber Harvesting

Most detrimental effects of harvesting are related to the access and movement of vehicles and machinery, and the dragging and loading of trees or logs. These effects include soil disturbance, soil compaction, and direct disturbance of stream channels. Poor harvesting and transport techniques can

increase sediment production by 10 to 20 times and disturb as much as 40 percent of the soil surface. In contrast, careful logging disturbs as little as 8 percent of the soil surface.

Careful selection of equipment and methods for transporting logs from the harvest area to areas where logs are gathered can significantly reduce the amount of soil disturbed and delivered to water bodies. Stream channels should be protected from logging debris at all times during harvesting operations.

Managing Replanting

Forests can be regenerated from either seed or seedlings. Seeding usually requires that the soil surface be prepared before planting. Seedlings can be directly planted with machines after minimal soil preparation. In either case, the use of heavy machinery, if not performed carefully, can result in significant soil disturbance.

4.3 Recommendations for Stormwater Management in Urban Areas

This section will focus on the stormwater management practices that are most suited to urban areas, which cover a large part of the study area. The following descriptions reference the USEPA “National Menu of Stormwater Best Management Practices”, which is very comprehensive and constantly updated (it contains close to 150 fact sheets on individual approaches, from education to implementation).

Typical BMPS at the site level are shown below, distinguished by whether they apply best to new developments or as retrofits to existing developments.

4.3.1 Recommendations based on density of development and new Vs retrofit application

Table 4.1 below shows the various approaches that are recommended depending on whether a site is located within a high density or low density development, as well as whether the project involves a new development or a retrofit application.

Table 4.1: Recommendations Based on Density of Development and New Vs Retrofit Application

Recommendations for Stormwater Management in Low-Density Urban Areas	
New Development	Retrofit Applications
<ul style="list-style-type: none"> Grassed swales 	<ul style="list-style-type: none"> Curb and gutter elimination
<ul style="list-style-type: none"> Infiltration trenches 	<ul style="list-style-type: none"> Permeable pavement
<ul style="list-style-type: none"> Permeable pavement 	<ul style="list-style-type: none"> Sand and organic filters
<ul style="list-style-type: none"> Riparian buffers 	<ul style="list-style-type: none"> Soil amendments
<ul style="list-style-type: none"> Sand and organic filters 	<ul style="list-style-type: none"> Vegetated filter strips
<ul style="list-style-type: none"> Soil amendments 	<ul style="list-style-type: none"> Rain barrels and cisterns
<ul style="list-style-type: none"> Vegetated filter strips 	
Recommendations for Stormwater Management in High-Density Urban Areas	
New developments	Retrofit Applications
<ul style="list-style-type: none"> Bioretention cells 	<ul style="list-style-type: none"> Inlet protection devices
<ul style="list-style-type: none"> Green parking design 	<ul style="list-style-type: none"> Permeable pavement
<ul style="list-style-type: none"> Infiltration trenches 	<ul style="list-style-type: none"> Permeable pavers
<ul style="list-style-type: none"> Inlet protection devices 	<ul style="list-style-type: none"> Rain barrels and cisterns
<ul style="list-style-type: none"> Permeable pavement 	<ul style="list-style-type: none"> Sand and organic filters
<ul style="list-style-type: none"> Permeable pavers 	<ul style="list-style-type: none"> Soil amendments
<ul style="list-style-type: none"> Rain barrels and cisterns 	<ul style="list-style-type: none"> Stormwater planters
<ul style="list-style-type: none"> Sand and organic filters 	<ul style="list-style-type: none"> Tree box filter
<ul style="list-style-type: none"> Soil amendments 	
<ul style="list-style-type: none"> Stormwater planters 	
<ul style="list-style-type: none"> Tree box filters 	
<ul style="list-style-type: none"> Vegetated filter strips 	
<ul style="list-style-type: none"> Vegetated roofs 	

Each of these measures is described in detail below.

4.3.2 Description of Each Recommended Site Stormwater BMP Measure

Grassed swales

Grassed swales are shallow grass-covered hydraulic conveyance channels that help to slow runoff and facilitate infiltration. The suitability of grassed swales depends on land use, soil type, imperviousness of the contributing watershed, and dimensions and slope of the grassed swale system. In general, grassed swales can be used to manage runoff from drainage areas that are less than 4 hectares (10 acres) in size, with slopes no greater than 5 percent. Use



of natural, low-lying areas is encouraged and natural drainage courses should be preserved and utilized.

Infiltration trenches

Infiltration trenches are rock-filled ditches with no outlets. These trenches collect runoff during a storm event and release it into the soil by infiltration (the process through which stormwater runoff penetrates into soil from the ground surface). Infiltration trenches may be used in conjunction with another stormwater management device, such as a grassed swale, to provide both water quality control and peak flow attenuation. Runoff that contains high levels of sediments or hydrocarbons (for example, oil and grease) that may clog the trench are often pretreated with other techniques such as water quality inlets (a series of chambers that promote sedimentation of coarse materials and separation of free oil from storm water), inlet protection devices, grassed swales, and vegetated filter strips.

Permeable pavement

As an alternative to asphalt or concrete surfaces, permeable pavement allows stormwater to drain through the porous surface to a stone reservoir underneath. The reservoir temporarily stores surface runoff and allows it to infiltrate into the subsoil. The appearance of the alternative surface is often similar to asphalt or concrete, but it is manufactured without fine materials and instead incorporates void spaces that allow for storage and infiltration. Underdrains may also be used below the stone reservoir if soil conditions are not conducive to complete infiltration of runoff.



Riparian buffers

A riparian, or forested, buffer is an area along a shoreline, wetland, or stream where development is restricted or prohibited. The primary function of aquatic buffers is to physically protect and separate a stream, lake, or wetland from future disturbance or encroachment. If properly designed, a buffer can provide stormwater management and can act as a right-of-way or floodplain during floods, sustaining the integrity of stream ecosystems and habitats.

Sand and organic filters

Sand and organic filters direct stormwater runoff through a sand bed to remove floatables, particulate metals, and pollutants. Sand and organic filters provide water quality treatment, reducing sediment, biochemical oxygen demand (BOD), and fecal coliform bacteria, although dissolved metal and nutrient removal through sand filters is often low. Sand and organic filters are typically used as a component of a treatment train to remove pollution from stormwater before discharge to receiving waters, to groundwater, or for collection and reuse. Variations on the traditional surface sand filter (such as the underground sand filter, perimeter sand filter, organic media filter, and multi-chamber treatment train) can be made to fit sand filters into more challenging design sites or to improve pollutant removal.



Soil amendments

Soil amendments increase the soil's infiltration capacity and help

reduce runoff from the site. They have the added benefit of changing physical, chemical, and biological characteristics so that the soils become more effective at maintaining water quality. Soil amendments, which include both soil conditioners and fertilizers, make the soil more suitable for the growth of plants and increase water retention capabilities. The use of soil amendments is conditional on their compatibility with existing vegetation, particularly native plants.

Vegetated filter strips

Filter strips are bands of dense vegetation planted downstream of a runoff source. The use of natural or engineered filter strips is limited to gently sloping areas where vegetative cover can be established and channelized flow is not likely to develop. Filter strips are well suited for treating runoff from roads and highways, roof downspouts, very small parking lots, and other small or linear impervious surfaces. They are also ideal components for the fringe of a stream buffer, or as pretreatment for a structural practice.

Curb and gutter elimination

Curbs and gutters transport flow as quickly as possible to a stormwater drain without allowing for infiltration or pollutant removal. Eliminating curbs and gutters can increase sheet flow and reduce runoff volumes. Sheet flow, the form runoff takes when it is uniformly dispersed across a surface, can be established and maintained in an area that does not naturally concentrate flow, such as parking lots. Maintaining sheet flow by eliminating curbs and gutters and directing runoff into vegetated swales or bioretention basins helps to prevent erosion and more closely replicate predevelopment hydraulic conditions. A level spreader, which is an outlet designed to convert concentrated runoff to sheet flow and disperse it uniformly across a slope, may also be incorporated to prevent erosion.

Bioretention cells

A bioretention cell or rain garden is a depressed area with porous backfill (material used to refill an excavation) under a vegetated surface. These areas often have an underdrain to encourage filtration and infiltration, especially in clayey soils. Bioretention cells provide groundwater recharge, pollutant removal, and runoff detention. Bioretention cells are an effective solution in parking lots or urban areas where green space is limited.



Green parking design

Green parking refers to several techniques that, applied together, reduce the contribution of parking lots to total impervious cover. Green parking lot techniques include: setting maximums for the number of parking lots created; minimizing the dimensions of parking lot spaces; utilizing alternative / porous pavers in overflow parking areas; using bioretention areas to treat stormwater; encouraging shared parking; and providing economic incentives for structured parking.



Rain barrels and cisterns

Rain barrels and cisterns harvest rainwater for reuse. Rain barrels are placed outside a building at roof

downspouts to store rooftop runoff for later reuse in lawn and garden watering. Cisterns store rainwater in significantly larger volumes in manufactured tanks or underground storage areas. Rainwater collected in cisterns may also be used in non-potable water applications such as toilet flushing. Both cisterns and rain barrels can be implemented without the use of pumping devices by relying on gravity flow instead. Rain barrels and cisterns are low-cost water conservation devices that reduce runoff volume and, for very small storm events, delay and reduce the peak runoff flow rates. Both rain barrels and cisterns can provide a source of chemically untreated “soft water” for gardens and compost, free of most sediment and dissolved salts.



Stormwater planters

Stormwater planters are small landscaped stormwater treatment devices that can be placed above or below ground and can be designed as infiltration or filtering practices. Stormwater planters use soil infiltration and biogeochemical processes to decrease stormwater quantity and improve water quality, similar to rain gardens and green roofs but smaller in size—stormwater planters are typically a few square feet of surface area compared to hundreds or thousands of square feet for rain gardens and green roofs. Types of stormwater planters include contained planters, infiltration planters, and flow-through planters.

Tree box filters

Tree box filters are in-ground containers used to control runoff water quality and provide some detention capacity. Often premanufactured, tree box filters contain street trees, vegetation, and soil that help filter runoff before it enters a catch basin or is released from the site. Tree box filters can help meet a variety of stormwater management goals, satisfy regulatory requirements for new development, protect and restore streams, control combined sewer overflows (CSOs), retrofit existing urban areas, and protect reservoir watersheds. The compact size of tree box filters allows volume and water quality control to be tailored to specific site characteristics. Tree box filters provide the added value of aesthetics while making efficient use of available land for stormwater management. Typical landscape plants (for example, shrubs, ornamental grasses, trees and flowers) are an integral part of the bioretention system. Ideally, plants should be selected that can withstand alternating inundation and drought conditions and that do not have invasive root systems, which may reduce the soil’s filtering capacity.

Vegetated roofs

Green roofs consist of an impermeable roof membrane overlaid with a lightweight planting mix with a high infiltration rate and vegetated with plants tolerant of heat, drought, and periodic inundations. In addition to reducing runoff volume and frequency and improving runoff water quality, a green roof can reduce the effects of atmospheric pollution, reduce energy costs, and create an attractive environment. They have reduced replacement and



maintenance costs and longer life cycles compared to traditional roofs.

4.4 Summary of Recommendations and Proposed Targets

One of the most efficient ways to deal with flooding risks is to manage the issue of high runoff at its source. Municipal Plan policies could include statements such as “expansion of the built environment or forestry operations shall be managed according to Best Management Practices and the BMP documents referenced”. At the implementation (regulatory) level, specific BMPs could be incorporated into language in the municipal regulations – such as requirements for a certain width of stream buffer or how the buffer would be calculated for example. Several examples are presented here as a general guide. In order not to be too prescriptive, the documents referenced focus more on the objectives rather than on the detailed approach to reaching them. Attaining the objectives will be made through a combination of various measures, both at the planning and site level. Since every site and every development is different, it is recommended that the policies and By-laws produced be generic enough to allow flexibility of method employed, while focusing on the ultimate objective of controlling runoff volumes and runoff water quality.

In this spirit, some good reference documents are presented, and a range of best management practices are described. Some standard objectives are proposed, which are not expected to be excessively stringent or expensive to implement. Costs can be best controlled with a clear watershed master plan and efficient site plans that blends stormwater management practices smoothly into the local site characteristics.

4.4.1 Planning Level

The Credit Valley Conservation, a community conservation area in Ontario, has published a comprehensive guide to implementing sustainable development through Low Impact Development and Stormwater Best Management Practices (“Low Impact Development Stormwater Management Planning and Design Guide”, Version 1.0 – 2011). It is recommended that at the planning level, the main steps in the document mentioned above be followed, which refers to the development of:

- Watershed Master Plans, a Growth Plan and an Official Plan
- Community / Subwatershed Secondary and Block Plans
- Neighbourhood Draft Plan of Subdivision / Functional Servicing Plan, followed by the Registered Plan
- Site Plan with site specific opportunities, while staying consistent with the direction of the higher level plans
- Site Permits and approvals

4.4.2 Forested Areas

Nova Scotia has recently published a very good document in this specific area, which describes an approach to implementing sustainable forest management techniques. The document was produced for Crown Land, but it is applicable to any forested area in the province. The document indeed recommends that it be used for forest management in the province wherever possible.

The reference for this document is the following:

Nova Scotia's Code of Forest Practice
A Framework for the Implementation of Sustainable Forest Management
Guidelines For Crown Land
Nova Scotia Natural Resources
August 2012

It is recommended that forestry operations in the Shubenacadie River and Nine Mile River watersheds shall be managed according to Forestry Best Management Practices as described in this document.

4.4.3 Low Density and High Density Urban Areas – New Developments

It is recommended that by-laws be implemented which require no increase through lot development of:

- Total Suspended Solids in surface runoff;
- Phosphorous in surface runoff;
- Nitrates and ammonia in surface runoff;
- Peak flows; or
- Total Runoff Volume

To help achieve these targets, it is recommended that the practices listed in section 5.3 and any others the Municipality feels are relevant be encouraged through education and incentives.

4.4.4 Low Density and High Density Urban Areas – Retrofit Applications

For development of previously developed sites, it is probably quite challenging to re-establish pre-development level aspects. For these areas, it is therefore recommended that by-laws be implemented which require a 25% reduction through on-lot development of:

- Total Suspended Solids in surface runoff;
- Phosphorous in surface runoff (not applicable if only hard surface);
- Nitrates and ammonia in surface runoff (not applicable if only hard surface);
- Peak flows; and
- Total Runoff Volume.

These would apply to the surface area being re-developed and not the entire site. For areas that already include stormwater management features that work very efficiently, the percentage reduction requirement can be decreased if the developer can show that this would bring runoff volume to a lower level than the runoff volume of the original natural treed site.

To help achieve these targets, it is recommended that the practices listed in section 5.4 and any others the Municipality feels are relevant be encouraged through education and incentives.

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

This report was completed with the objective of updating and improving the 1997 CBCL Limited Floodplain Mapping Study. Improvements made to the floodline delineation methodology in this study as compared to the 1997 study include:

- Improved topographic information with LiDAR mapping at 1m resolution;
- Ability to use Environment Canada flow gauging data on the Shubenacadie River;
- Increased period of record supporting the Environment Canada Intensity-Duration-Frequency Rainfall curves;
- Additional detailed river survey from previous work in the close to Grand Lake by the Municipality;
- Additional surveyed calibration points from George Searle identifying the 1971 floods in the Shubenacadie area;
- Improved hydraulic modelling techniques;
- Considerations of climate change and sea level rise, and
- Increased floodplain mapping extent.

Comparing the two delineations, it was found that the updated 1 in 20 year and 1 in 100 year flood lines for existing conditions have a similar extent as those produced for the 1997 floodplain study. The LiDAR data used for the new study allowed for a higher resolution floodline that takes into account local irregularities in the topography, and is based on more river cross-sections with also a finer resolution. Overall, the extents are slightly narrower, although in the downstream end, the extents are slightly wider, as a result of higher water level calculations due to tides. The floodlines for future conditions are generally wider than for the previous study, mainly due to climate change impacts.

Modelling of the 1 in 20 and 1 in 100 year events was undertaken by modelling the three main governing processes that impact water levels:

1. Peak flows.
2. Peak tidal levels.
3. Ice accumulation and ice jams.

Detailed modelling was conducted using the hydrodynamic SWMM model and the ice jam HEC-RAS models to compare the peak water level calculations. A combination of rainfall data, gauged flow data on the river itself and prorated gauged flow data from the Beaver Bank River was used to estimate peak flows in the river. Hydrologic and hydraulic characteristics of the river and watersheds were estimated

using aerial photography, site surveys and site visits. The model was calibrated through 3 sources of information:

- The survey conducted by George Searle at several private properties in the Shubenacadie area as part of this assessment;
- The survey conducted by CBCL Limited in 1996 at several private properties throughout the study area; and
- The survey conducted by MRMS in 1981 at several bridge locations,

The values from the three processes (flow, tidal and ice) were compared and the peak value was selected at each river cross-section (159 in total used in this model).

In order to limit the risk of underestimating flood levels as a result of uncertainty of certain parameters, a sensitivity analysis was conducted and further modelling was undertaken to produce 95% upper confidence limit floodlines. Even though the difference between the two floodline extents is not significant, it is recommended that the 95% upper confidence limit floodlines be used for land use zoning.

Future conditions, including climate change impacts to precipitation and sea level rise, and further development in the watershed, were estimated using the Municipality's Land Use Mapping and the latest climate change research from Environment Canada and Nova Scotia Environment. 95% upper confidence limits were also produced for this calculation.

It is recommended that the current zoning extents related to the floodlines (High Risk Floodplain zone and Moderate Risk Floodplain zone) be updated to the new calculation results. It is recommended that the future (2013 – 95% Upper Confidence Limit) floodlines be used to update the zoning extents.

In order to help reduce flooding risks, counter the effects of climate change, and counter the effects of development in the watersheds, the following comments are made:

- The Shubenacadie River has a vast watershed (approximately 400 km² only to Grand Lake, 800 km² directly tributary to the study area), a third of which is in the Halifax Regional Municipality and cannot be regulated by the Municipality of East Hants;
- Existing development is close to the river, especially in Enfield, Elmsdale and Lantz, which impacts peak flows resulting from short, intense rainfall events, and also degrades water quality in the river. Overall, development is such that little impacts are expected in the Shubenacadie River as a result of existing or proposed development;
- In the Nine Mile River, the situation is different. This river has fewer lakes in its watershed to regulate peak flows, and it is therefore more directly impacted by development. Even though current development levels are low, there is already a fair amount of clearing that has occurred, which affects peak flows and peak water levels; and
- Since development has the potential to further increase flooding risks in the Nine Mile River and at its confluence with the Shubenacadie River, it is recommended that development be very carefully regulated to ensure that development does not increase runoff peak flows, but also volumes (maintaining groundwater recharge).

Overall, even though the watersheds in the study area are vast, development still has an impact on peak flows and peak water levels. It is therefore recommended that policies that not only prohibit increases in peak flows from development, but also prohibit an increase in total runoff volume (maintaining groundwater recharge) be implemented. As described in Chapter 4, if this is applied not only to new developments, but also modifications to existing developments, a positive effect will be made, and climate change impacts will be mitigated. It is worth noting that such measures will also have beneficial effects on water quality, as well as maintaining low river flows in this very sensitive, salmon-bearing watercourse.

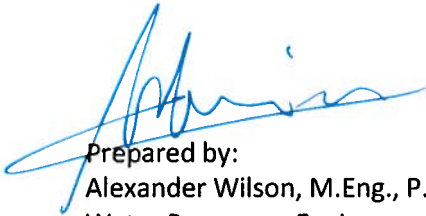
Concerning any potential improvements to increase the level of confidence of the next floodplain mapping study, it is noted that even though the ground mapping that was obtained had a very high level of detail and accuracy, that the computer modelling methods used were among the best available, there are still areas where additional improvement is possible:

- Quantity and quality of calibration information:
Even though every effort was made to obtain as much calibration information as possible (including an additional survey), and even though the data available is estimated to cover fairly well the study area, more calibration data always improves the quality of the modelling effort. Additional data on ice jams in the river would also be helpful, and further data collection and calibration of tidal ingress would also be beneficial to improve the level of quality of this assessment.
- Channel bathymetry:
Cross-sections were surveyed in the river at approximately 300m intervals. Further definition of the river bed may improve the modelling results, although it would probably require a fairly significant investment.
- Modelling approach:
Current computer processing technology does not allow the modelling of such a long stretch of river by any other approach than a 1-dimensional analysis within the current time and budget constraints. However, this may not be the case in 5 or 10 years, by which time two or even three dimensional models may be applied to the entire river. Perhaps at this time, LiDAR data can be collected again, this time using technology that allows submerged topography to be collected (currently available up to 2 times Secchi depth, but has a high cost)

It is also noted that the floodlines delineated in this study only apply to the Shubenacadie and Nine mile rivers themselves, and do not consider any flooding occurring within smaller tributaries, or even at any culvert within the drainage system. Such an analysis would provide a more comprehensive picture of risks of flooding within the communities of Enfield, Elmsdale, Lantz and Shubenacadie. This analysis would be carried out under a Master Drainage Plan, which would provide an analysis of limiting capacities within the system, or a Stormwater Management Plan, which would in addition investigate the most cost-effective options for alleviating flooding risks in the short and long term.

We have been very pleased to have had the opportunity to work on such an interesting analysis, and we hope that this report meets your expectations. Should you have any questions now or in the future, please do not hesitate to contact the undersigned.

Best Regards,



Prepared by:
Alexander Wilson, M.Eng., P.Eng.
Water Resources Engineer



Reviewed by:
Gordon Smith, CSLA, MCIP
Principal and Group Leader Landscape Architecture
+ Planning







This document was prepared for the party indicated herein. The material and information in the document reflects CBCL Limited's opinion and best judgment based on the information available at the time of preparation. Any use of this document or reliance on its content by third parties is the responsibility of the third party. CBCL Limited accepts no responsibility for any damages suffered as a result of third party use of this document.

Appendix A:

Floodplain Mapping: Future Conditions (2114) – Upper 95% Confidence Limit (Black and White)

**Shubenacadie River
Floodplain Mapping Study**

Legend:

-  Model Cross Sections
-  5m Contours
-  Parcel
-  1 in 20 Year Flood Line (upper 95% confidence limit)
-  1 in 100 Year Flood Line (upper 95% confidence limit)
-  11.56/12.38 1 in 20 Year Flood Level/1 in 100 Year Flood Level

NOTE:
Flood Level values are in Metre CGD Elevations

Map 1

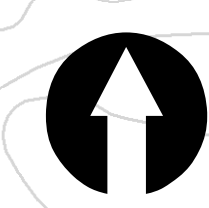
**Future Conditions (Year 2114)
Floodplain Mapping
1 of 5**



Date: August 2013
CBCL Project #: 131001.00







Coordinate System:
NAD83 UTM zone 20N
Datum: North American Datum 1983
Units: Metre
Scale: 1:10,000

0 250 500 1,000 Meters



Shubenacadie River Floodplain Mapping Study

Legend:

-  Model Cross Sections
-  5m Contours
-  Parcel
-  1 in 20 Year Flood Line (upper 95% confidence limit)
-  1 in 100 Year Flood Line (upper 95% confidence limit)
-  11.56/12.38 1 in 20 Year Flood Level/1 in 100 Year Flood Level

NOTE:
Flood Level values are in Metre CGD Elevations

Map 2

Future Conditions (Year 2114) Floodplain Mapping 2 of 5



Date: August 2013
CBCL Project #: 131001.00





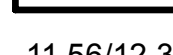
Coordinate System:
NAD83 UTM zone 20N
Datum: North American Datum 1983
Units: Metre
Scale: 1:10,000

0 250 500 1,000 Meters



Shubenacadie River Floodplain Mapping Study

Legend:

-  Model Cross Sections
-  5m Contours
-  Parcel
-  1 in 20 Year Flood Line (upper 95% confidence limit)
-  1 in 100 Year Flood Line (upper 95% confidence limit)
- 11.56/12.38 1 in 20 Year Flood Level/1 in 100 Year Flood Level

NOTE:
Flood Level values are in Metre CGD Elevations

Map 3

Future Conditions (Year 2114) Floodplain Mapping 3 of 5



Date: August 2013
CBCL Project #: 131001.00







Coordinate System:
NAD83 UTM zone 20N
Datum: North American Datum 1983
Units: Metre
Scale: 1:10,000

0 250 500 1,000 Meters



Shubenacadie River Floodplain Mapping Study

Legend:

-  Model Cross Sections
-  5m Contours
-  Parcel
-  1 in 20 Year Flood Line (upper 95% confidence limit)
-  1 in 100 Year Flood Line (upper 95% confidence limit)
-  11.56/12.38 1 in 20 Year Flood Level/1 in 100 Year Flood Level

NOTE:
Flood Level values are in Metre CGD Elevations

Map 4

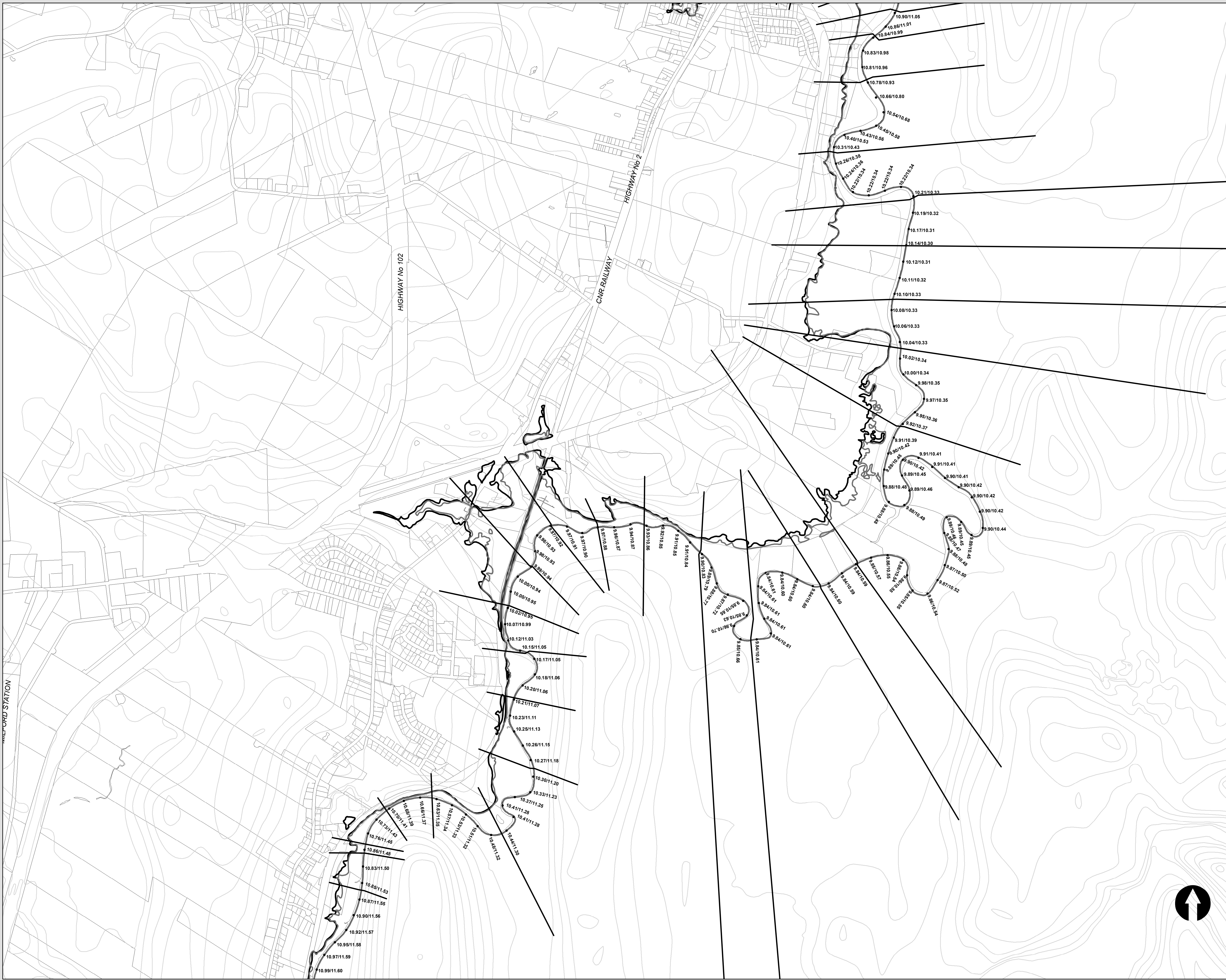
Future Conditions (Year 2114) Floodplain Mapping 4 of 5



Date: August 2013
CBCL Project #: 131001.00







Coordinate System:
NAD83 UTM zone 20N
Datum: North American Datum 1983
Units: Metre
Scale: 1:10,000

0 250 500 1,000 Meters



**Shubenacadie River
Floodplain Mapping Study**

Legend:

-  Model Cross Sections
-  5m Contours
-  Parcel
-  1 in 20 Year Flood Line (upper 95% confidence limit)
-  1 in 100 Year Flood Line (upper 95% confidence limit)
-  11.56/12.38 1 in 20 Year Flood Level/1 in 100 Year Flood Level

NOTE:
Flood Level values are in Metre CGD Elevations



Map 5

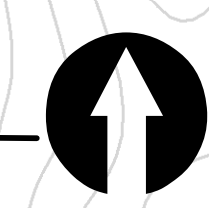
**Future Conditions (Year 2114)
Floodplain Mapping
5 of 5**



Date: August 2013
CBCL Project #: 131001.00

Coordinate System:
NAD83 UTM zone 20N
Datum: North American Datum 1983
Units: Metre
Scale: 1:10,000

0 250 500 1,000 Meters








Appendix A:

Floodplain Mapping: Future Conditions (2114) – Upper 95% Confidence Limit (Colour)

Shubenacadie River Floodplain Mapping Study

Legend:

-  Model Cross Sections
-  5m Contours
-  Parcel
-  1 in 20 Year Flood Line (upper 95% confidence limit)
-  1 in 100 Year Flood Line (upper 95% confidence limit)

11.56/12.38 1 in 20 Year Flood Level/1 in 100 Year Flood Level

NOTE:
Flood Level values are in Metre CGD Elevations

Map 1

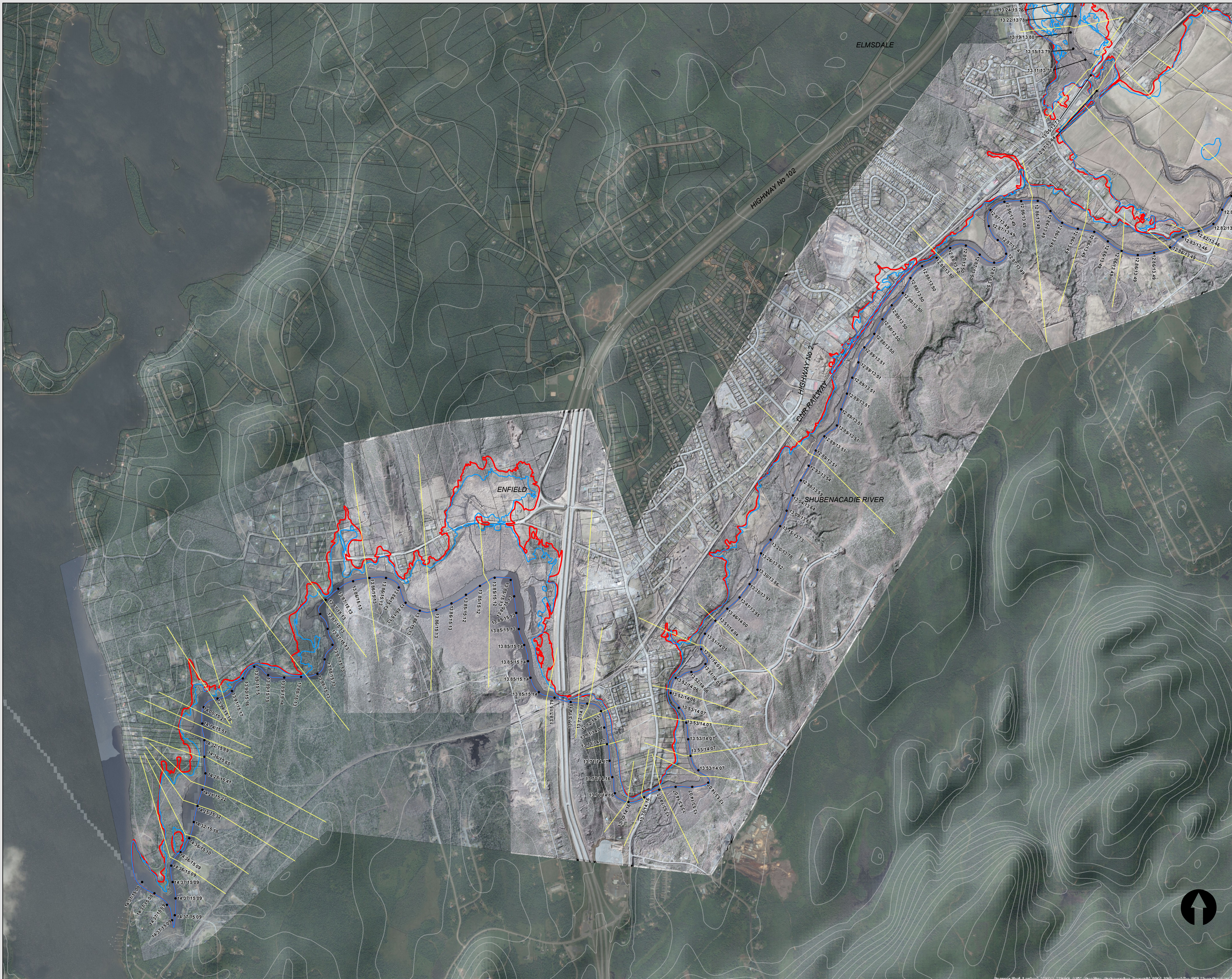
Future Conditions (Year 2114) Floodplain Mapping 1 of 5



Date: October 2013
CBCL Project #: 131001.00






Coordinate System:
NAD83 UTM zone 20N
Datum: North American Datum 1983
Units: Metre
Scale: 1:10,000

0 250 500 1,000 Meters



Shubenacadie River Floodplain Mapping Study

Legend:

-  Model Cross Sections
 -  5m Contours
 -  Parcel
 -  1 in 20 Year Flood Line (upper 95% confidence limit)
 -  1 in 100 Year Flood Line (upper 95% confidence limit)
- 11.56/12.38 1 in 20 Year Flood Level/1 in 100 Year Flood Level

NOTE:
Flood Level values are in Metre CGD Elevations

Map 2

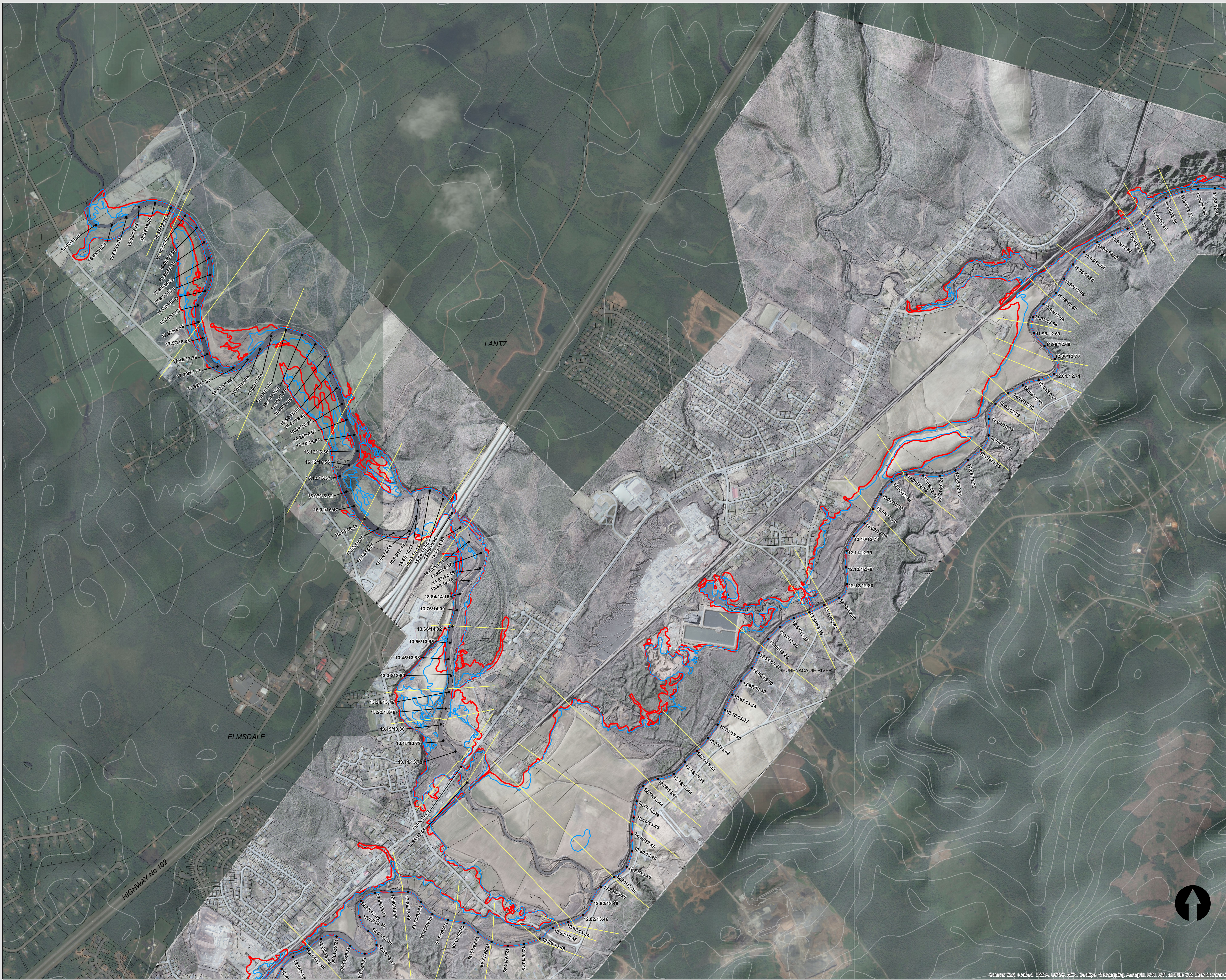
Future Conditions (Year 2114) Floodplain Mapping 2 of 5



Date: October 2013
CBCL Project #: 131001.00

Coordinate System:
NAD83 UTM zone 20N
Datum: North American Datum 1983
Units: Metre
Scale: 1:10,000

0 250 500 1,000 Meters



Shubenacadie River Floodplain Mapping Study

Legend:

- Model Cross Sections
 - 5m Contours
 - Parcel
 - 1 in 20 Year Flood Line (upper 95% confidence limit)
 - 1 in 100 Year Flood Line (upper 95% confidence limit)
- 11.56/12.38 1 in 20 Year Flood Level/1 in 100 Year Flood Level

NOTE:
Flood Level values are in Metre CGD Elevations

Map 3

Future Conditions (Year 2114) Floodplain Mapping 3 of 5



Date: October 2013
CBCL Project #: 131001.00

Coordinate System:
NAD83 UTM zone 20N
Datum: North American Datum 1983
Units: Metre
Scale: 1:10,000






0 250 500 1,000 Meters



Source: Esri, DeLorme, USGS, AIRC, GeoEye, AeroGRID, IGN, SPP, and the GIS User Community

**Shubenacadie River
Floodplain Mapping Study**

Legend:

-  Model Cross Sections
 -  5m Contours
 -  Parcel
 -  1 in 20 Year Flood Line (upper 95% confidence limit)
 -  1 in 100 Year Flood Line (upper 95% confidence limit)
- 11.56/12.38 1 in 20 Year Flood Level/1 in 100 Year Flood Level

NOTE:
Flood Level values are in Metre CGD Elevations

Map 5

**Future Conditions (Year 2114)
Floodplain Mapping
5 of 5**



Date: October 2013
CBCL Project #: 131001.00

Coordinate System:
NAD83 UTM zone 20N
Datum: North American Datum 1983
Units: Metre
Scale: 1:10,000

0 250 500 1,000 Meters

