Flood Risk Analysis of the Halifax Harbour to Support Evacuation Modeling

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1 Objective

Dalhousie University has undertaken a research project with the Marine Environmental Observation Prediction and Response Network (MEOPAR) entitled ”Evacuating the Halifax Peninsula: A Multidisciplinary Analysis and Training to Improve Evacuation from Coastal Floods”. The project focuses on the evacuation of peninsular Halifax with directives to better understand social responses to extreme weather events, to suggest policies which would improve evacuation processes, and to develop a decision-making game to train and assist emergency management officials with making better decisions during evacuation events.

The Nova Scotia Community College’s (NSCC) Applied Geomatics Research Group (AGRG) is a partner on the project and was tasked to execute the spatial flood analysis and intersection of roads infrastructure Geographic Information Systems (GIS) layers to support this evacuation analysis. The evacuation analysis required the development of an inventory of major Halifax peninsula roads impacted under various flooding scenarios, and to provide the flood depths and extents for five flooding scenarios. The development of this inventory involved the manipulation of spatial roads data provided by the National Road Network, as well as lidar elevation data provided by the Halifax Regional Municipality (HRM) to produce flood depth maps for Halifax. The depth maps and road inventory analysis were produced using a suite of GIS and proprietary modeling tools and software which are critical to the analysis of infrastructure vulnerability under various flood risk scenarios.

Five flood risk scenarios were selected for the study. Three of the scenarios are related to the water level seen during Hurricane Juan, which made landfall in the HRM as a Category 2 hurricane on September 29, 2003 and produced a maximum recorded water level of 2.1 m CGVD28 (Forbes et al., 2009). Had Hurricane Juan occurred on a higher high water large tide (HHWLT), the water level would have been 2.9 m CGVD28 (Figure 1). If Hurricane Juan were to happen in 100 years on HHWLT after a very conservative sea level rise of 1 m in 100 years (Richards and Daigle, 2011), the water level would be 3.9 m CGVD28. If a more extreme sea level rise of 5 m occurred over the next 100 years, the water level of a Hurricane Juan event happening on HHWLT would be 7.9 m CGVD28.

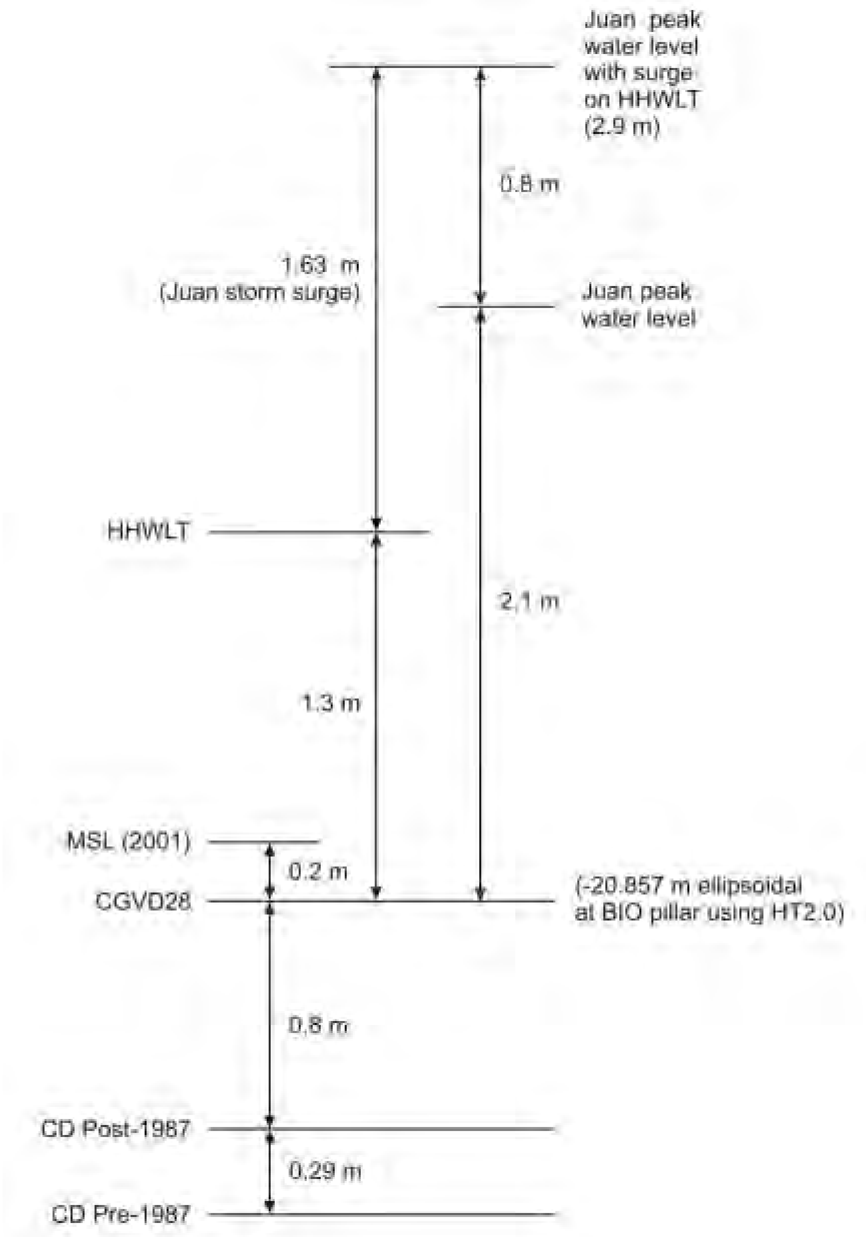

Figure 1. A figure from Forbes et. al. (2009) showing Juan's peak water level of 2.1 m CGVD28, though had it occurred on HHWLT the water level would have been 2.9 m CGVD28.

The other two scenarios are related to potential tsunamis impacting the Halifax Peninsula, as tsunamis are not an impossibility in this region. In 1929 an earthquake beneath the Laurentian Continental Slope, south of Newfoundland and east of Cape Breton, with a surface magnitude of 7.2 generated a tsunami which caused widespread destruction and 28 fatalities along Newfoundland's Burin Peninsula (Ruffman and Hann, 2006). The tsunami generated water levels 3 to 5 m above normal, which lifted houses from their foundations, tore vessels from their moorings, and destroyed virtually all property along the shore including wharves and fish stores (Ruffman and Hann, 2006). One of the largest tsunamis ever recorded ocurred on December 26, 2004 in the Indian Ocean. The tsunami had wave heights of 30 m which reached 6 km inland (Paris et al., 2007). For these reasons, the water levels selected to simulate tsunamis on the Halifax Peninsula are 15.0 m (simulating a moderate tsunami) and 30.0 m (simulating a large tsunami).

2 Methodology

2.1 Coordinate Systems

All spatial data were projected in North American Datum (NAD) of 1983, Universal Transverse Mercator (UTM) zone 20 North. The vertical datum is referenced to the Canadian Geodetic Vertical Datum of 1928 (CGVD28).

2.2 Data Collection

Three spatial datasets were used during the flood risk analysis. The spatial roads dataset used is from the National Road Network 2014, while the streams (water) network is from the NS Topographic Database 2012 (Figure 2). The lidar-derived digital elevation model was provided by HRM and available at NSCC-AGRG, and the lidar used to construct this dataset was acquired in 2011. In addition, Quickbird satellite imagery acquired in 2008 was provided by HRM and is used as the backdrop for many of the figures provided in the report and the layered PDFs (Figure 3, bottom).

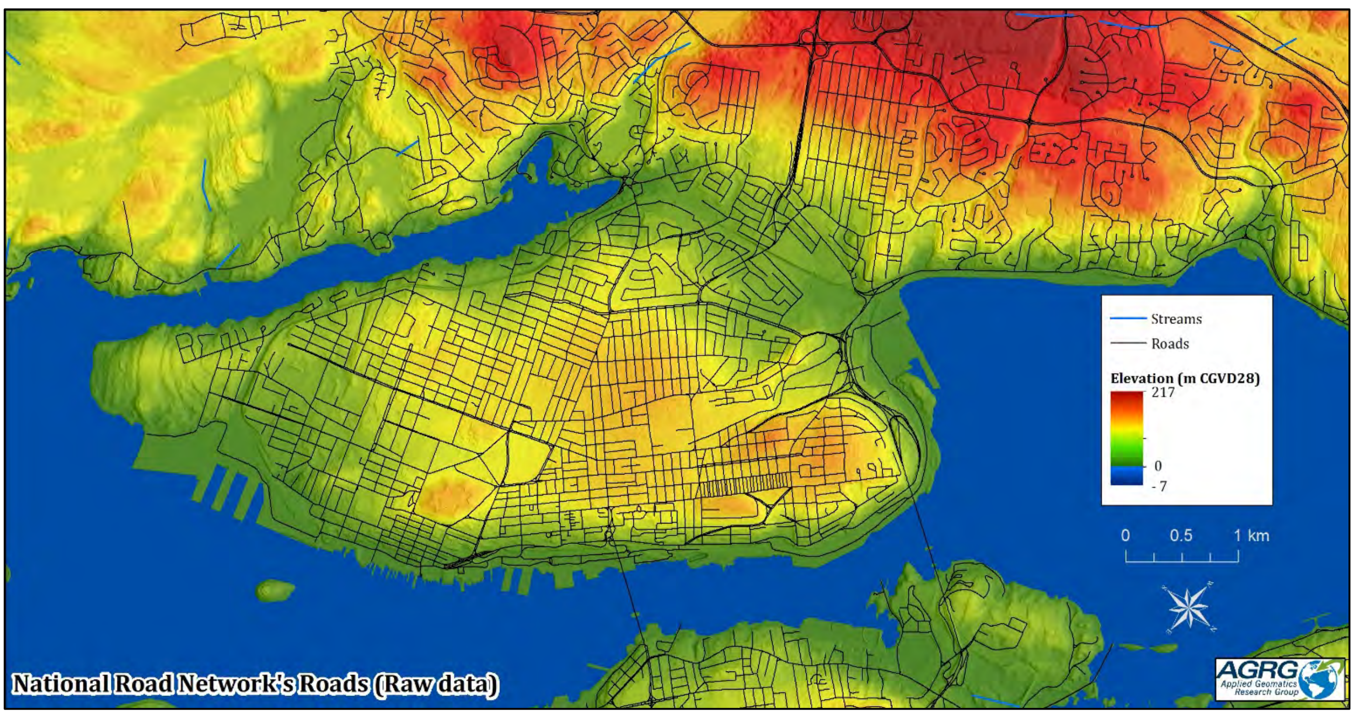

Figure 2. The original National Roads Network roads dataset (in black) and the NSTDB streams dataset (in blue) shown on a colour-shaded relief of the peninsula.

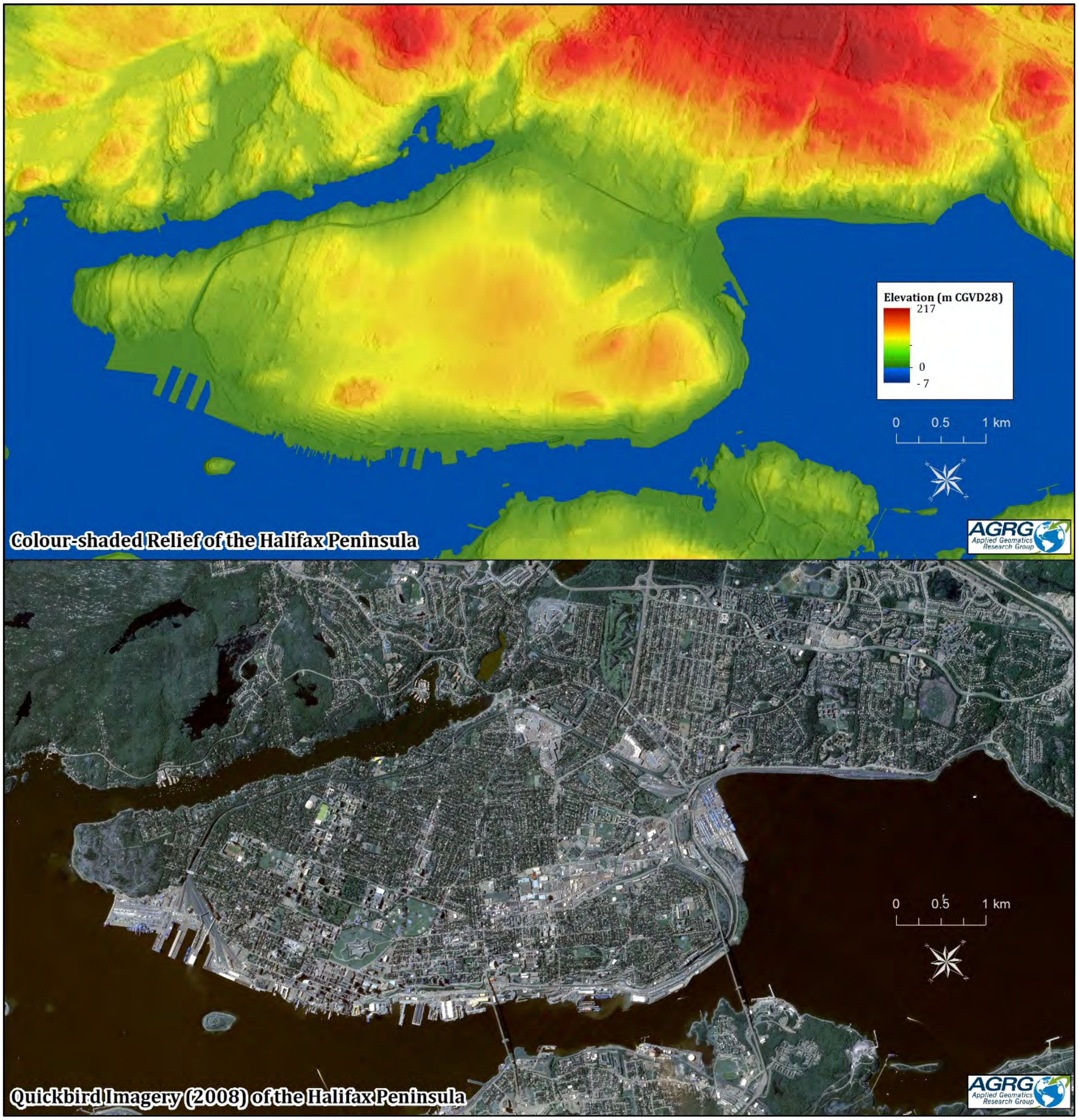

Figure 3. A hillshaded relief of the Halifax Harbour DEM, coloured by elevation (top) and the 2008 Quickbird satellite imagery of the Halifax Harbour (bottom).

2.3 Flood Layer Generation

Flood layers were generated using an AGRG proprietary tool that raises flood water on a flat plane (known as "still-water") to inundate low areas that are hydraulically connected to the coast as described in Webster et al., (2006). As the tool requires an elevation model with correct connectivity, all culverts or bridges within the study area need to be represented as low areas in the DEM. As no culvert datasets exist that are publicly available, culverts were generated manually. The datasets used for this analysis included the National Road Network (NRN), which is the most complete and publicly available spatial road database, and the river/stream spatial dataset provided by the Nova Scotia Topographic Database (NSTDB) of 2012. First, an AGRG proprietary tool which intersects spatial roads data with the spatial river/stream data was used to generate an initial culvert database. This dataset was then visually inspected for accuracy against the lidar, as well as using Google Street View as an additional tool to ensure correct interpretation of culverts and bridges. The culverts are then used to notch the DEM to allow a path for the water to move, resulting in a hydraulically connected DEM.

The lidar digital elevation model (DEM) used for the culvert and subsequent flooding analysis is 2 m resolution, thus the resulting flood layers are 2 m resolution. The flood levels for the 5 scenarios selected for analysis are listed in Table 1. Two of the water level scenarios use the water level generated by the momentous Hurricane Juan in Halifax on Sept 29, 2003 as a reference. If Hurricane Juan occurred today at High High Water Large Tide (HHWLT), the elevation of the water would be 2.9 m (relative to CGVD28) (Forbes et al., 2009).

Table 1. Water levels scenarios selected for which to generate flood extents and flood depth maps for evacuation modeling of the Halifax Peninsula (Hurricane Juan levels as per Forbes et al., 2009).

5 Flooding Scenarios	
Water Level (relative to CGVD28)	**Significance**
2.9 m	If Hurricane Juan occurred today at HHWLT
3.9 m	Hurricane Juan at HHWLT + conservative 100-year Sea Level Rise of 1 m
7.9 m	Hurricane Juan at HHWLT + extreme 100-year Sea Level Rise of 5 m
15.0 m	Moderate Tsunami
30.0 m	Large Tsunami

Maps of the study area extent were generated for each of the flooding scenarios. Quickbird satellite imagery provided by HRM, as well as elevation colour shaded reliefs, were used to help construct the maps.

2.4 Roads Preparation

As the main roads exiting the peninsula were the focus of the study, the NRN roads network required preparation in advance of the flood modeling analysis. The raw data are very detailed as it is the representation of a continuous accurate centerline for all non-restricted use roadways 5 m or more in width (Department of Natural Resources Canada, 2015), and are generally divided into road classes including highway/expressway, local road, lane, resource road, and ramp, though all roads on the Halifax peninsula are classified as local roads except Highway 102 off of Joseph Howe Drive and Bayers Road, which is classified as highway/expressway. This required the major routes exiting the peninsula to be selected. The newly selected major routes were reclassified into 3 categories (classes) – Major 4-Lane Highway (formerly Expressway/Highway), Major Local Road/Street (formerly local / street), and Major Rotary (formerly local/street) (Figure 4). The Armdale Rotary was assigned its own class due to its unique nature, location, and significance as a major hub while entering/exiting the peninsula. The length of road impacted under each flood scenario was determined for each road class through GIS overlay analysis.

The streets were also grouped by street name (Figure 5). The segments of road directly involved in the Armdale Rotary were named after the rotary, though technically only the circular part of the roundabout is actually named the ‘Armdale Roundabout’ (Figure 6). The segments of road immediately leading up to the MacDonald and MacKay bridge are named ‘MacDonald Bridge Ramp’ and ‘MacKay Bridge Ramp’, while the small segments of bridge where they touch land are named after the respective bridge. The length of road impacted under each flood scenario was determined for each of the separate roads.

Figure 4. The major roads on the Halifax peninsula were classified as one of three classes: Major 4-Lane Highway (yellow), Major Local Road/Street (orange), and Major Rotary (green).

Figure 5. The major roads on the Halifax peninsula were grouped by road name, with the Armdale Rotary exchange having its own name.

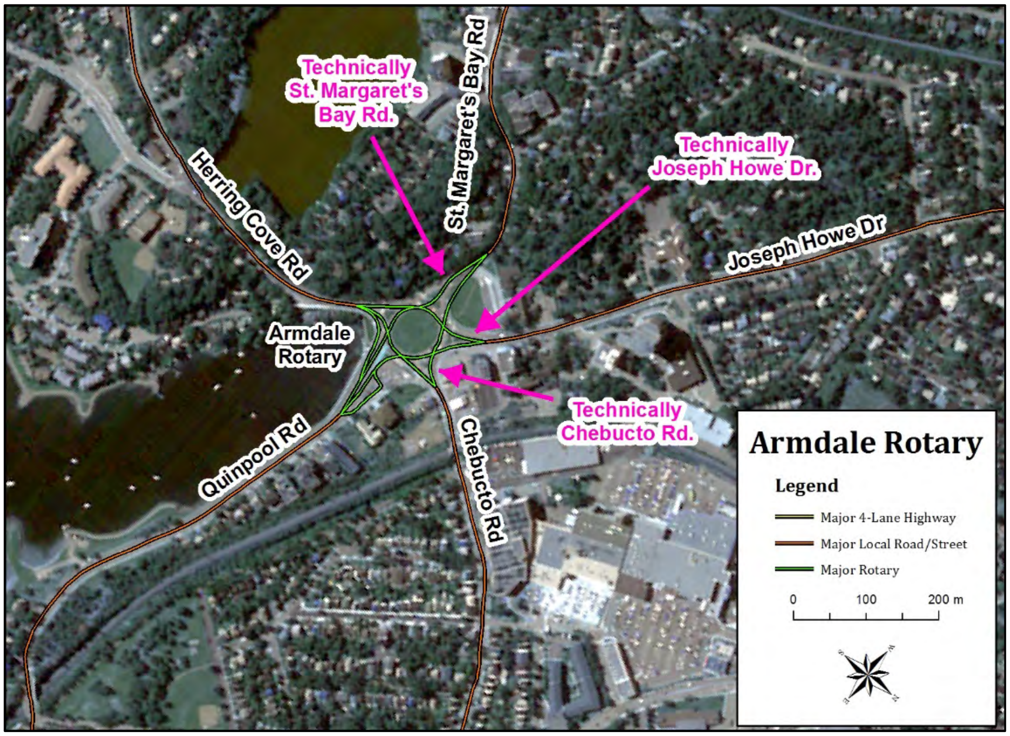

Figure 6. The portion of road named 'Armdale Rotary' in this project (in green) includes sections of roads directly involved in the rotary, despite the ramps into and out of the rotary actually being named otherwise.

2.5 Flood Depth Analysis

As per the deliverables, the depth of water over the land for each of the 5 flooding scenarios was calculated by subtracting the water level flood surface from the DEM. This analysis results in depth rasters that provide a depth value for each 2 m pixel. These rasters are informative but are not suitable for the subsequent analysis determining the depth of water over each metre of inundated major roads as the depth maps are continuous in nature and must be grouped into discrete classes to simplify for subsequent analysis. For example, some areas contained extensive flooding over roads (>2 km inundated), thus reporting the exact depth of water over the each metre of road would produce very extensive results that would require further summarization and analysis. Therefore it was determined that water depth would be divided into 6 categories, and that the total length of a particular road class affected by that water depth would be provided. Maps depicting the location and depth of flooding were also constructed. The water depth data were divided as outlined in Table 2. These classes of water depth can be found in the attribute tables as **DepthClass** in the roads GIS database. Roads sorted by class and roads sorted by name were analyzed and flood depth shapefiles were provided for the all 5 flood scenarios.

Table 2. Six classes dividing depth of flood water over features.

DepthClass	Water Depth
1	≤ 0.5 m
2	> 0.5 to 1 m
3	> 1 to 2 m
4	> 2 to 5 m
5	> 5 m to 10 m
6	> 10 m

The length (m) of roads inundated was determined both by road class and by road name for each flooding scenario and summarized in the results. Reporting the inundated roads by name allows the user to disregard any roads they deem too minor to contribute to evacuation of the peninsula.

3 Results

3.1 Flood Extent and Depth Maps

Maps showing the results of the flood extents and flood depths for each of the 5 flooding scenarios were constructed for the Halifax peninsula. In addition, the maps show the roads under each flooding event. The data are provided in GIS format and the maps are provided as layered PDFs, which allow the user to turn the roads and flood layers on and off. An example of simulating the water level from Hurricane Juan (2.9 m CGVD28) is found in Figure 7.

Figure 7. The flooding extent and depth of flooding of the Halifax Peninsula under a 2.9 m flooding scenario, representing a Hurricane Juan event today occurring at high high water large tide.

Figure 8. The flooding extent and depth of flooding of downtown Halifax under a 2.9 m flooding scenario, representing a Hurricane Juan event today occurring at high high water large tide.

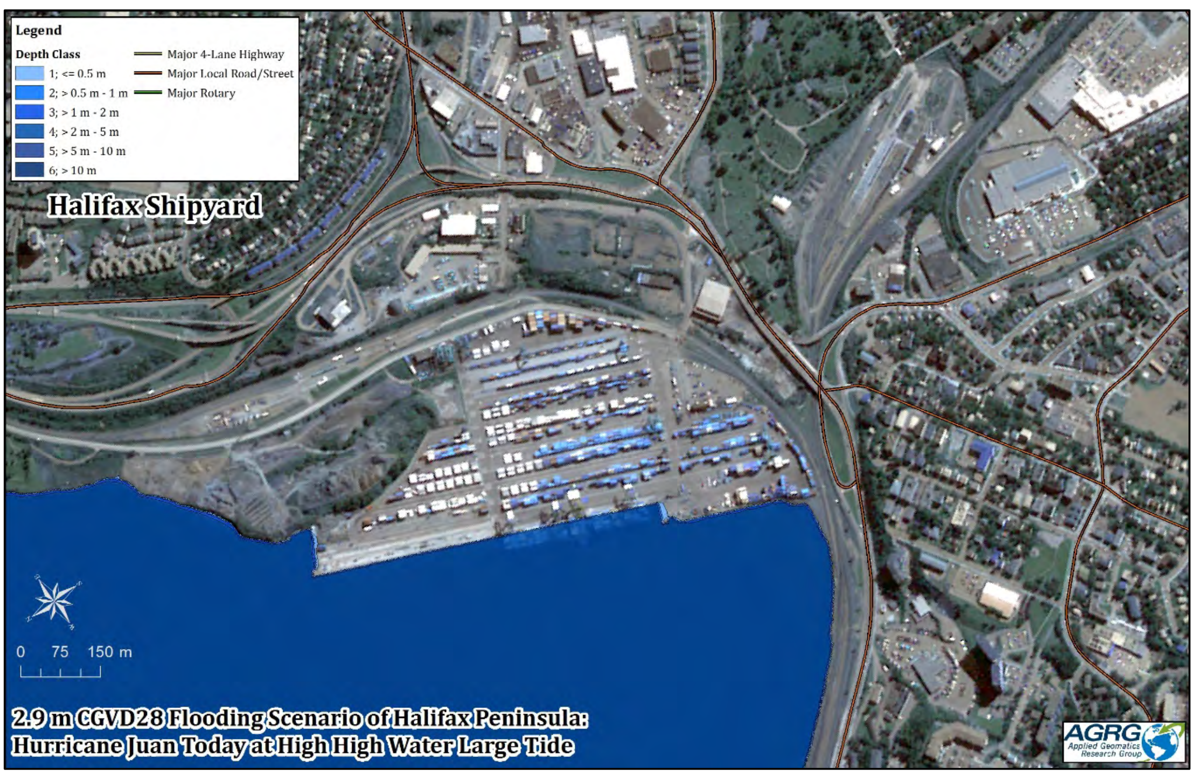

Figure 9. The flooding extent and depth of flooding of the Halifax Shipyard under a 2.9 m flooding scenario, representing a Hurricane Juan event today occurring at high high water large tide.

In addition to the more probable flood results from storm surges associated with hurricanes, we also investigated the case of a possible tsunami at 2 extreme water levels. The most extreme water level simulated was 30 m CGVD28, which show the flooding extents for the entire Halifax Peninsula (in Figure 10) and for downtown Halifax (Figure 11).

Figure 10. The flooding extent and depth of flooding of the Halifax Peninsula under a 30.0 m flooding scenario, representing a large tsunami hitting the peninsula.

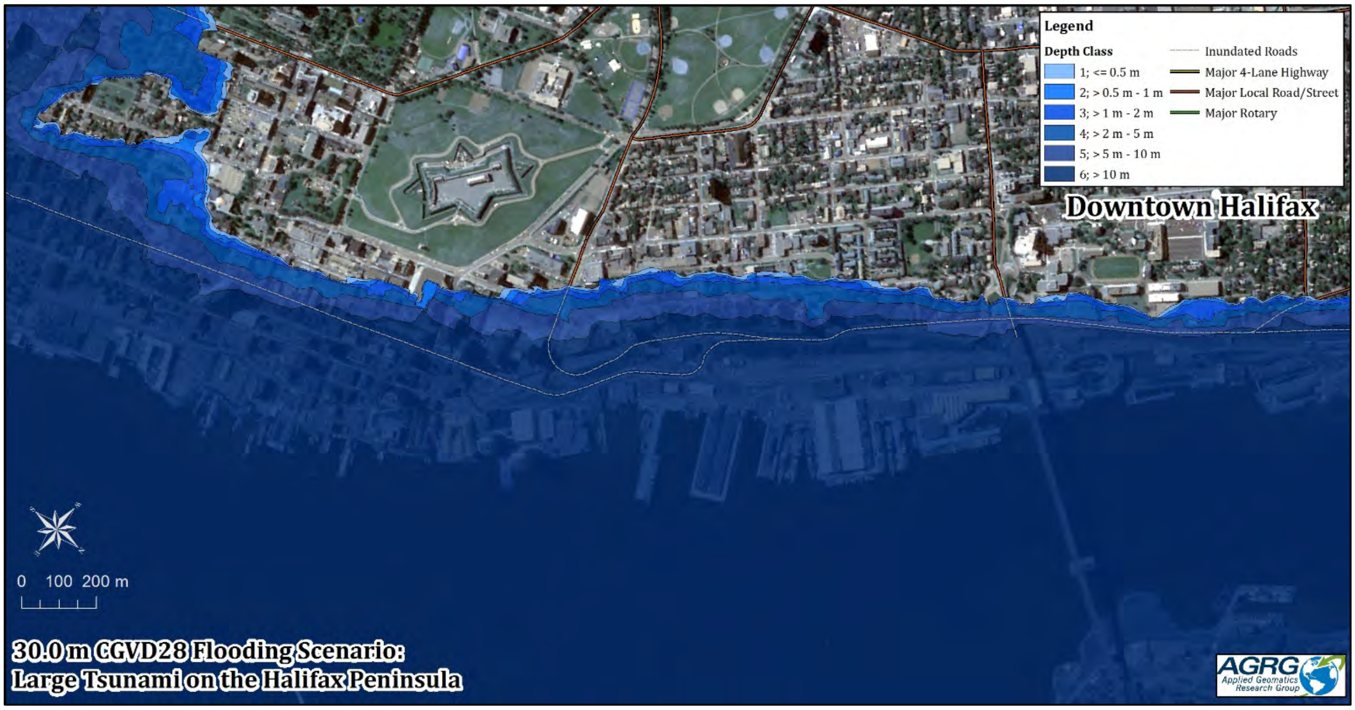

Figure 11. The flooding extent and depth of downtown Halifax under a 30.0 m flooding scenario, representing a large tsunami hitting the peninsula.

Figure 12. The flooding extent and depth of the Halifax Shipyard under a 30.0 m flooding scenario, representing a large tsunami hitting the peninsula.

3.2 Analysis on Roads Impacted

All major classes of road saw flooding under at least one of the flooding scenarios (Table 3). The major highway was the road class least impacted with only 412 m of road obstructed in the most extreme flooding scenario, a 30 m tsunami. However the other road classes experience flooding under every flooding scenario (Table 3). The major rotary and the major roads/streets experience similar flooding under a 2.9 m flooding scenario, and not surprisingly the major street flooding is near the major rotary on Quinpool Street (Appendix A). The rotary is the most susceptible piece of road on the peninsula, with over 43% of the rotary impacted under the 3.9 m flood scenario and over 88% impacted under the 7.9 m flood scenario (Figure 13).

Table 3. By class, the total length of each road impacted by each flooding scenario, the original overall length of that class of road, and the percent of each road class affected for each scenario.

Road Class	Flooding Scenario Water Level (m CGVD28)	Length of Roads Flooded (m)	Original Length of Road (m)	% of Road Impacted by Flooding
Major Highway	2.9 m	0.0	2,732.3	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	0.0		0.0%
	30 m	412.0		15.1%
Major Local Road/Street	2.9 m	245.4	55,304.3	0.4%
	3.9 m	560.8		1.0%
	7.9 m	3,424.6		6.2%
	15 m	9,206.1		16.6%
	30 m	25,019.9		45.2%
Major Rotary	2.9 m	234.6	1,324.3	17.7%
	3.9 m	576.1		43.5%
	7.9 m	1,175.1		88.7%
	15 m	1,324.3		100.0%
	30 m	1,324.3		100.0%

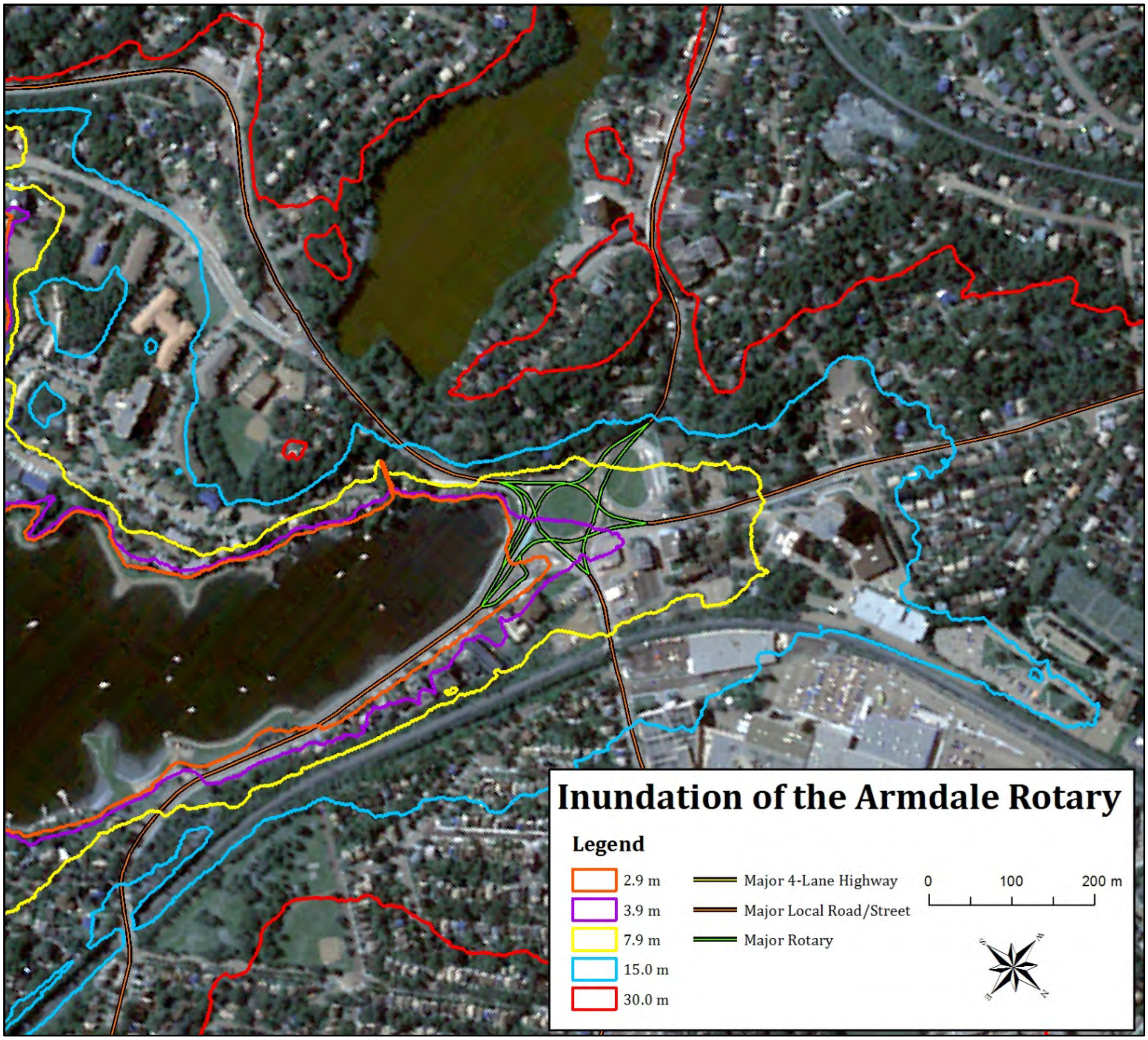

Figure 13. The Armdale Rotary in Halifax is highly susceptible to storm surge and tsunami flooding, with 88% of the rotary roads (in green) submerged at a 7.9 m flood event (in yellow).

The length of each road class impacted by 6 different flood water depths for each of the 5 flooding scenarios is summarized in Table 4. The most sensitive roads infrastructure to a repeat of Hurricane Juan occurring at HHWLT (2.9 m flooding scenario) are major local roads and the major rotary. Over 92 m of major local roads are flooded with less than 0.5 m of water, while over 150 m of road would be submerged between 0.5 and 1 m of water. Similarly, the most sensitive roads to a 3.9 m CGVD28 water level are major local roads, 254 m of which will be covered with at least 1 m of water, and the major rotary which will have 234 m of road covered with more than 1 m of flood water (Table 4).

A full summary of the length of roads affected by class and by road name are found in Appendices B and C, as well as in a separate spreadsheet which is part of the deliverables.

Table 4. By class, the length of each road impacted by a certain depth of water over the road for each of the 5 flooding scenarios.

Road Class	Flooding Scenario Water Level (m CGVD28)	Length of Road Inundated (in metres), by Depth Class of Water Depth Above the Road					
		1	2	3	4	5	6
		≤ 0.5 m	> 0.5 m - 1 m	> 1 m - 2 m	> 2 m - 5 m	> 5 m - 10 m	> 10 m
Major Highway	2.9 m	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-
	15 m	-	-	-	-	-	-
	30 m	14.6	8.8	12.5	153.1	223.1	-
Major Local Road/Street	2.9 m	92.3	153.1	-	-	-	-
	3.9 m	167.0	148.4	245.4	-	-	-
	7.9 m	225.3	276.9	957.0	1,720.0	245.4	-
	15 m	454.5	451.6	875.0	2,802.3	3,487.8	1,134.9
	30 m	572.8	806.1	1,153.8	3,222.5	5,387.4	13,877.3
Major Rotary	2.9 m	124.6	110.0	-	-	-	-
	3.9 m	162.3	179.1	234.6	-	-	-
	7.9 m	13.2	18.8	144.7	763.8	234.6	-
	15 m	4.0	23.8	68.8	381.8	846.0	-
	30 m	-	-	-	-	-	1,324.3

4 Conclusion

GIS layers depicting the flooding extents for each of the 5 flood scenarios were developed using a hydraulically connected DEM of the Halifax peninsula. The depths of the flood waters for each water level were determined and provided in two formats – a raster depicting the precise depth of water for each 2 m pixel, and a polygon shapefile which reclassified the depths into 6 categories as per Table 2. The major roads on the Halifax peninsula were selected and grouped in two ways – by road class (highway, local major road, or rotary) and by road name (ex. Robie St., Barrington St.). Each group of roads was compared with the overall flood extents to produce the overall length of road impacted by flood waters for each flooding scenario. In addition, each group of roads was compared with the reclassified flood depths to provide the lengths of each road impacted by the depth of water in each flooding scenario. The results of the roads analysis were summarized and provided in a spreadsheet, as well as in this report, and the resulting line GIS files are part of the deliverables.

The results indicate that the Armdale Rotary is the most vulnerable piece of roads infrastructure on the peninsula, with 17.7% of the rotary inundated at 2.9 m, 43.5% inundated at 3.9 m water level, and 88.7 % inundated at a 7.9 m water level, which is a Hurricane Juan event in 100 years plus a 5 m rise in sea level. Quinpool Road and Barrington Street are the next vulnerable roads in the study. Quinpool Rd. experiences flooding over 10% of its length at a 2.9 m water level, and both roads experience flooding under a 3.9 m water level scenario (16.5% and 2.1% of their lengths, respectively). The Bedford Highway is relatively safe in the 2.9 m and 3.9 m scenarios, however over 1.8 km of the highway is inundated with a water level of 7.9 m.

In the rare event of a large 30.0 m tsunami hitting the Halifax area, the peninsula turns into an island and all roads exiting the peninsula are submerged.

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6 Appendix A – Flood Depth Maps - Overview

6.1 2.9 m CGVD28 Flooding – Hurricane Juan today at HHWLT

6.2 3.9 m CGVD28 Flooding – Hurrican Juan + 1 m 100-year Sea Level Rise

6.3 7.9 m CGVD28 Flooding – Hurrican Juan + 5 m 100-year Sea Level Rise

6.4 15.0 m CGVD28 Flooding – Moderate Tsunami

6.5 30.0 m CGVD28 Flooding – Large Tsunami

7 Appendix B – Roads Impacted – Summary of Roads (by Name) Impacted by Each Flooding Scenario Extent

Table 5. Summary of length road impacted under each flooding scenario for each road by name.

Road Class	Flooding Scenario Water Level (m CGVD28)	Length of Roads Flooded (m)	Original Length of Road (m)	% of Road Impacted by Flooding
Hwy 102/Bicentennial Hwy	2.9 m	0.0	2,732.3	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	0.0		0.0%
	30 m	412.0		15.1%
Armdale Rotary	2.9 m	234.6	1,324.3	17.7%
	3.9 m	576.1		43.5%
	7.9 m	1,175.1		88.7%
	15 m	1,324.3		100.0%
	30 m	1,324.3		100.0%
Barrington Street	2.9 m	0.0	7,782.2	0.0%
	3.9 m	162.4		2.1%
	7.9 m	660.5		8.5%
	15 m	2,634.4		33.9%
	30 m	7,680.5		98.7%
Beaufort Avenue	2.9 m	0.0	1,009.3	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	0.0		0.0%
	30 m	848.3		84.0%
Bedford Highway	2.9 m	0.0	3,974.6	0.0%
	3.9 m	0.0		0.0%
	7.9 m	1,898.9		47.8%
	15 m	3,775.1		95.0%
	30 m	3,973.2		100.0%
Bayers Road	2.9 m	0.0	2,001.2	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	0.0		0.0%
	30 m	932.3		46.6%
Bayview Road	2.9 m	0.0	1,082.8	0.0%
	3.9 m	0.0		0.0%

	7.9 m	40.3		3.7%
	15 m	114.1		10.5%
	30 m	343.7		31.7%
Chebucto Road	**2.9 m**	0.0	2,201.2	0.0%
	3.9 m	0.0		0.0%
	7.9 m	79.0		3.6%
	15 m	193.0		8.8%
	30 m	485.4		22.1%
Cogswell Street	**2.9 m**	0.0	1,816.8	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	553.9		30.5%
	30 m	859.4		47.3%
Connaught Avenue	**2.9 m**	0.0	3,309.1	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	0.0		0.0%
	30 m	912.5		27.6%
Devonshire Avenue	**2.9 m**	0.0	1,173.0	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	0.0		0.0%
	30 m	212.7		18.1%
Dutch Village Road	**2.9 m**	0.0	829.8	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	0.0		0.0%
	30 m	631.2		76.1%
Herring Cove Road	**2.9 m**	0.0	2,117.7	0.0%
	3.9 m	0.0		0.0%
	7.9 m	22.2		1.0%
	15 m	125.6		5.9%
	30 m	912.0		43.1%
Joseph Howe Drive	**2.9 m**	0.0	2,873.3	0.0%
	3.9 m	0.0		0.0%
	7.9 m	149.2		5.2%
	15 m	896.3		31.2%
	30 m	2,105.8		73.3%
Kearney Lake Road	**2.9 m**	0.0	269.4	0.0%
	3.9 m	0.0		0.0%

	7.9 m	110.2		40.9%
	15 m	276.0		102.5%
	30 m	477.1		177.1%
Lady Hammond Road	**2.9 m**	0.0	618.0	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	0.0		0.0%
	30 m	292.2		47.3%
MacDonald Bridge	**2.9 m**	0.0	115.5	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	0.0		0.0%
	30 m	112.7		97.6%
MacKay Bridge Ramp	**2.9 m**	0.0	1,035.4	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	0.0		0.0%
	30 m	444.4		42.9%
MacKay Bridge	**2.9 m**	0.0	166.7	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	0.2		0.1%
	30 m	118.8		71.3%
Main Avenue	**2.9 m**	0.0	2,001.7	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	0.0		0.0%
	30 m	167.5		8.4%
Quinpool Road	**2.9 m**	245.4	2,420.7	10.1%
	3.9 m	398.4		16.5%
	7.9 m	464.3		19.2%
	15 m	564.6		23.3%
	30 m	796.1		32.9%
Robie Street	**2.9 m**	0.0	5,587.6	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	0.0		0.0%
	30 m	707.1		12.7%
South Park Street	**2.9 m**	0.0	1,180.5	0.0%
	3.9 m	0.0		0.0%

	7.9 m	0.0		0.0%
	15 m	0.0		0.0%
	30 m	684.8		58.0%
St. Margaret's Bay Road	**2.9 m**	0.0	1,538.9	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	10.3		0.7%
	30 m	419.5		27.3%
Young Avenue	**2.9 m**	0.0	890.2	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	62.5		7.0%
	30 m	890.2		100.0%
Young Street	**2.9 m**	0.0	1,337.5	0.0%
	3.9 m	0.0		0.0%
	7.9 m	0.0		0.0%
	15 m	0.0		0.0%
	30 m	12.6		0.9%

8 Appendix C – Roads Impacted – Summary of Depth of Water over Roads By Name

Table 6. Summary of water depth over the roads under each flooding scenario for each road by name.

Road Class	Flooding Scenario Water Level (m CGVD28)	Length of Road Inundated (in metres), by Depth Class of Water Depth Above the Road					
		1	2	3	4	5	6
		< 0.5 m	0.5 m - 1 m	1 m - 2 m	2 m - 5 m	5 m - 10 m	> 10 m
Hwy 102/Bicentennial Hwy	2.9 m	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-
	15 m	-	-	-	-	-	-
	30 m	14.6	8.8	12.5	153.1	223.1	-
Armdale Rotary	2.9 m	124.6	110.0	-	-	-	-
	3.9 m	162.3	179.1	234.6	-	-	-
	7.9 m	13.2	18.8	144.7	763.8	234.6	-
	15 m	-	4.0	23.8	68.8	381.8	846.0
	30 m	-	-	-	-	-	1,324.3
Barrington Street	2.9 m	-	-	-	-	-	-
	3.9 m	100.7	61.7	-	-	-	-
	7.9 m	37.6	37.8	96.1	489.1	-	-
	15 m	304.3	286.5	569.2	668.2	400.3	405.9
	30 m	28.4	34.9	167.0	419.9	1,823.0	5,207.3
Beaufort Avenue	2.9 m	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-
	15 m	-	-	-	-	-	-
	30 m	75.2	138.2	142.5	414.2	78.2	-
Bedford Highway	2.9 m	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	130.2	180.2	669.9	918.6	-	-
	15 m	60.1	70.8	119.1	1,143.4	2,129.4	252.2
	30 m	-	-	-	-	20.7	3,952.5
Bayers Road	2.9 m	-	-	-	-	-	-

	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-
	15 m	-	-	-	-	-	-
	30 m	10.4	8.3	21.5	132.3	739.9	19.9
Bayview Road	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	5.4	5.9	29.0	-	-	-
	15 m	6.6	6.8	11.0	29.8	59.8	-
	30 m	8.4	8.9	22.6	61.6	63.8	178.4
Chebucto Road	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	7.4	10.3	25.8	35.6	-	-
	15 m	9.1	8.9	18.2	52.4	89.3	15.1
	30 m	6.6	7.2	14.3	49.2	92.9	315.3
Cogswell Street	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-
	15 m	32.4	30.8	68.7	355.0	67.1	-
	30 m	6.5	4.8	13.4	58.9	65.7	710.2
Connaught Avenue	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-
	15 m	-	-	-	-	-	-
	30 m	25.2	28.9	53.9	160.9	635.9	7.7
Devonshire Avenue	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-
	15 m	-	-	-	-	-	-
	30 m	9.6	13.0	19.6	55.5	81.3	33.6
Dutch Village Road	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-

	15 m	-	-	-	-	-	-
	30 m	7.7	50.9	278.1	185.3	109.3	-
Herring Cove Road	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	10.6	10.4	1.2	-	-	-
	15 m	5.7	5.2	11.8	49.2	53.7	-
	30 m	10.3	10.3	30.3	573.4	92.9	194.7
Joseph Howe Road	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	17.5	15.0	33.9	82.8	-	-
	15 m	16.2	18.7	48.4	370.2	402.3	40.4
	30 m	40.5	29.8	121.3	269.2	350.7	1,294.3
Kearney Lake Road	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	8.7	9.5	87.0	5.1	-	-
	15 m	8.3	7.6	12.9	76.9	170.3	-
	30 m	5.6	4.6	10.1	31.5	65.8	359.5
Lady Hammond Road	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-
	15 m	-	-	-	-	-	-
	30 m	11.3	10.8	20.6	68.3	181.2	-
MacDonald Bridge	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-
	15 m	-	-	-	-	-	-
	30 m	5.2	4.5	8.9	33.1	36.4	24.7
MacKay Bridge Ramp	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-
	15 m	-	-	-	-	-	-
	30 m	103.3	34.7	48.7	133.9	123.9	-

MacKay Bridge	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-
	15 m	0.2	-	-	-	-	-
	30 m	2.4	2.5	7.9	34.2	37.6	34.2
Main Avenue	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-
	15 m	-	-	-	-	-	-
	30 m	4.7	3.6	7.3	21.6	37.2	93.1
Quinpool Road	**2.9 m**	92.3	153.1	-	-	-	-
	3.9 m	66.3	86.7	245.4	-	-	-
	7.9 m	8.0	7.9	14.1	188.8	245.4	-
	15 m	5.7	7.9	13.3	41.7	74.8	421.3
	30 m	11.2	11.1	17.9	47.4	67.5	641.0
Robie Street	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-
	15 m	-	-	-	-	-	-
	30 m	70.8	236.9	94.0	305.3	-	-
South Park Street	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-
	15 m	-	-	-	-	-	-
	30 m	23.0	25.5	37.2	124.9	411.7	62.5
St. Margaret's Bay Road	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-
	15 m	6.0	4.2	-	-	-	-
	30 m	102.0	132.3	14.7	42.0	66.7	61.8
Young Avenue	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-

	7.9 m	-	-	-	-	-	-
	15 m	3.9	2.2	15.6	40.8	-	-
	30 m	-	-	-	-	205.0	686.6
Young Street	**2.9 m**	-	-	-	-	-	-
	3.9 m	-	-	-	-	-	-
	7.9 m	-	-	-	-	-	-
	15 m	-	-	-	-	-	-
	30 m	4.5	6.1	2.1	-	-	-