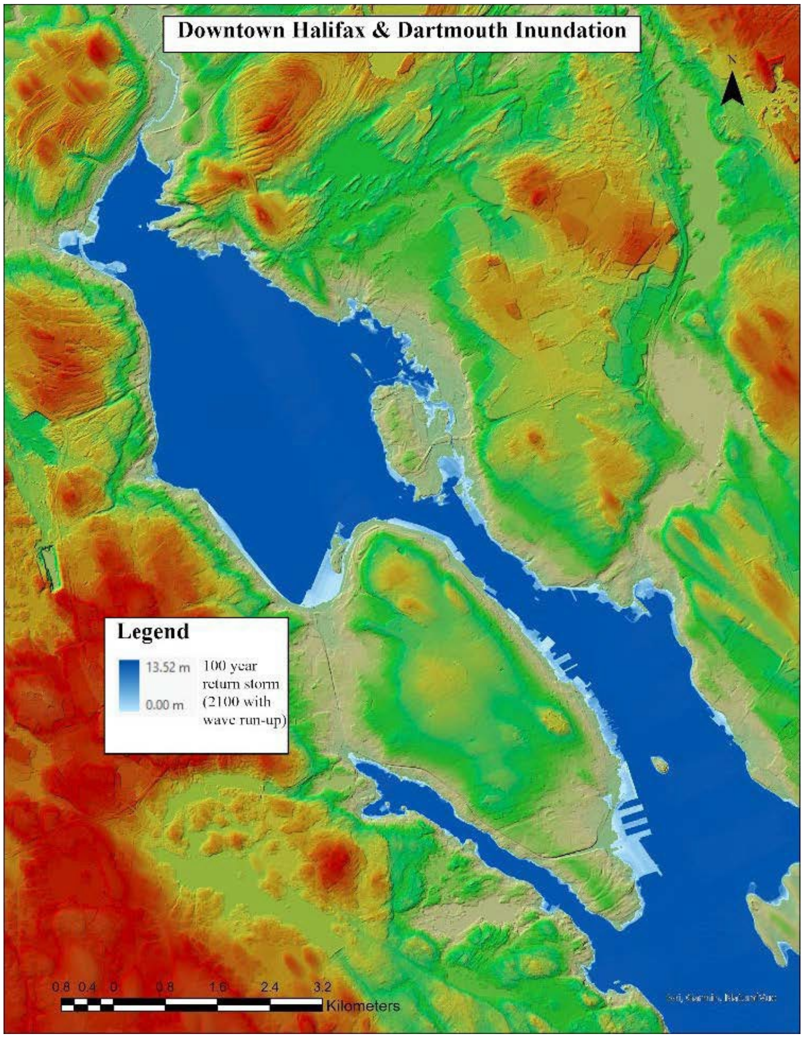

CLIMAtlantic Storm Surge Flood Layers; Today and in the Future

Methods to Construct Flood Layers for Atlantic Canada

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CLIMAtlantic Storm Surge Flood Layers: Present Day, 2050, 2100 and 2150

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Executive Summary

Researchers at the Applied Geomatics Research Group - NSCC constructed flood layers encompassing Atlantic Canada, with the addition of Les Îles-de-la- Madeleine, PQ and a Hurricane Fiona high water wrack line for CLIMAtlantic. A total of 16 flood scenarios were considered, including floods resulting from 20-year and 100-year storm surge events considered under present-day conditions and with relative sea level rise conditions for 2050, 2100, and 2150. Each variation was also constructed with and without a 0.5 m and 1.0 m wave run-up for layers considering 20-year and 100-year storm surge, respectively. A series of geographic data were acquired from a variety of sources to build flood layers for Atlantic Canada. Storm Surge return period water levels were used from Zhang & Sheng (2013), Higher High Water Large Tide (HHWLT) from the Canadian Hydrographic Service (2015), Relative Sea Level (RSL) grids from the IPCC AR6 report (James & Brierley-Green, in-prep), and DEM data (Natural Resources Canada, 2023-2024) (Solomon, 2024) (AGRG, 2024), were used to synthesize vector flood layers and raster flood depth layers. Real time kinematic GNSS observations (Jardine Consulting, 2023) (Bérubé, 2023) (AGRG, 2023), acquired post-hurricane Fiona were used to develop the high-water wrack line. Data products were constructed according to the best practices available.

1. Introduction

A contract between CLIMAtlantic and the Applied Geomatics Research Group (AGRG) – Nova Scotia Community College (NSCC) resulted in a set of vector flood layers and raster flood depth layers covering Atlantic Canada, including Les Îles-de-la-Madeleine, with additional Hurricane Fiona high water lines encompassing the extent of available data were constructed. Vector and raster flood layers represent current day and future inundation predictions resulting from 20-year and 100-year return storm events and relative sea level rise into the future. Storm surge return period water level grids developed by Zhang & Sheng (2013) were used as storm surge input data. The years 2020, 2050, 2100, and 2150 were considered with and without 0.5m and 1.0m wave run-up values for 20-year and 100-year return storm events, respectively. Relative sea level (RSL) rise projection grids from James & Brierley-Green (in prep) based on the IPCC AR6 report were used to build flood layers predicting inundation for the future years. The RSL grids from James & Brierley-Green (in prep) were produced considering global sea-level rise trends together with isostatic adjustment. All flood conditions were considered with the additional water level associated with Higher High Water Large Tide (HHWLT), a grid file derived from HyVSEP points provided by the Canadian Hydrographic Service (CHS, 2015) and described by Robin et al. (2015). High Resolution Digital Elevation Models (DEMs) provided by Natural Resources Canada (NRCAN, 2024) covering parts of New Brunswick, Prince Edward Island (PEI), and portions of Newfoundland and Labrador (NFLD) and from Jasmine Solomon (Solomon, 2024) for Les Îles-de-la- Madeleine, were used as an elevation surface to construct the flood layers. Elevation data provided by NRCAN in the Canadian Digital Elevation Data (CDED) was used as an elevation surface for most of NFLD where high resolution lidar DEM data were unavailable. Total lidar coverage of Atlantic Canada is shown in (Figure 1).

The water levels associated with the storm surge return periods of 20 and 100 years were compared to published values for the coast and New Brunswick by ClimAtlantic and a set of adjustments were defined so the surge levels better matched previous studies. HHWLT, RSL, and storm surge grids were resampled to match the resolution of the underlying elevation data, producing intermediate HHWLT, RSL, and storm surge layers. The intermediate HHWLT, RSL, and storm surge layers were added together, forming flood level raster layers. Wave run-up values of 0.5 and 1.0 m were considered for the 20-year and 100-year surge events and a set of output flood products were developed that did and did not include wave run-up. Pixels in the underlying DEMs with an elevation less than that of the overlying flood level raster layers were considered inundated. These pixels were extracted from the DEM using a combination of methods in ArcGIS Pro and Python.

Hurricane Fiona high-water lines were derived using GPS referenced elevation data acquired by researchers and agencies in New Brunswick and PEI (Bérubé & Jardine Consulting, 2023), as well as the research staff at AGRG who compiled wrack line elevation data for Nova Scotia (Figure 2). The Government of NFLD used oblique aerial photos for portions of NFLD to derive high-water lines for the area. Hurricane Fiona high-water lines covering PEI, Nova Scotia, and New Brunswick were interpolated over the extent of available data using processing techniques in ArcGIS Pro and Python.

CLIMAtlantic received vector flood and raster flood depth layers that cover the extent of Atlantic Canada for each of 16 agreed upon flooding scenarios, plus a vectorized Hurricane Fiona high-water line. CLIMAtlantic also received all hydrologically enforced digital elevation models (DEMs) used to build the flood layers.

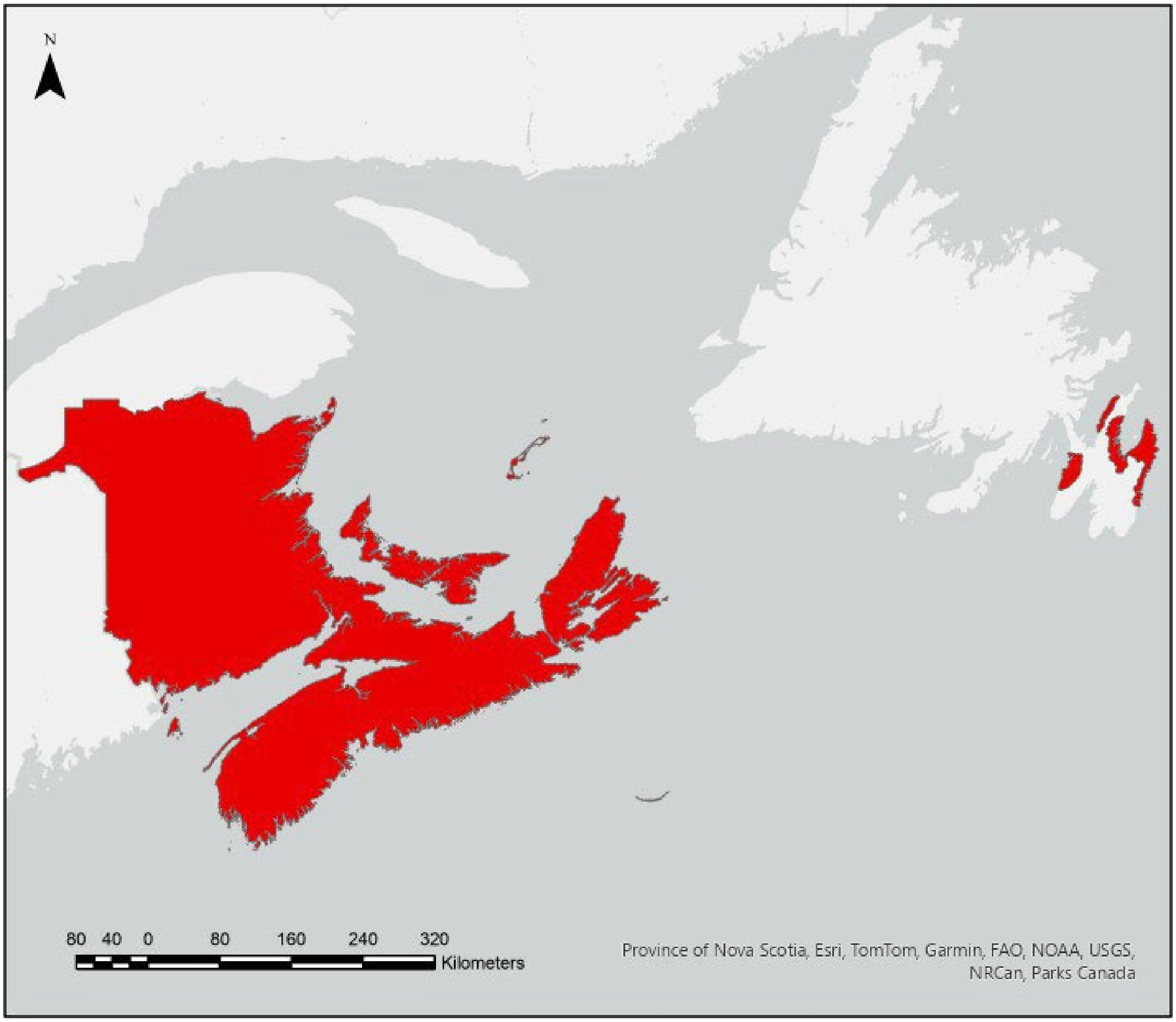


Figure 1 This map displays the high resolution lidar coverage in red over Atlantic Canada.

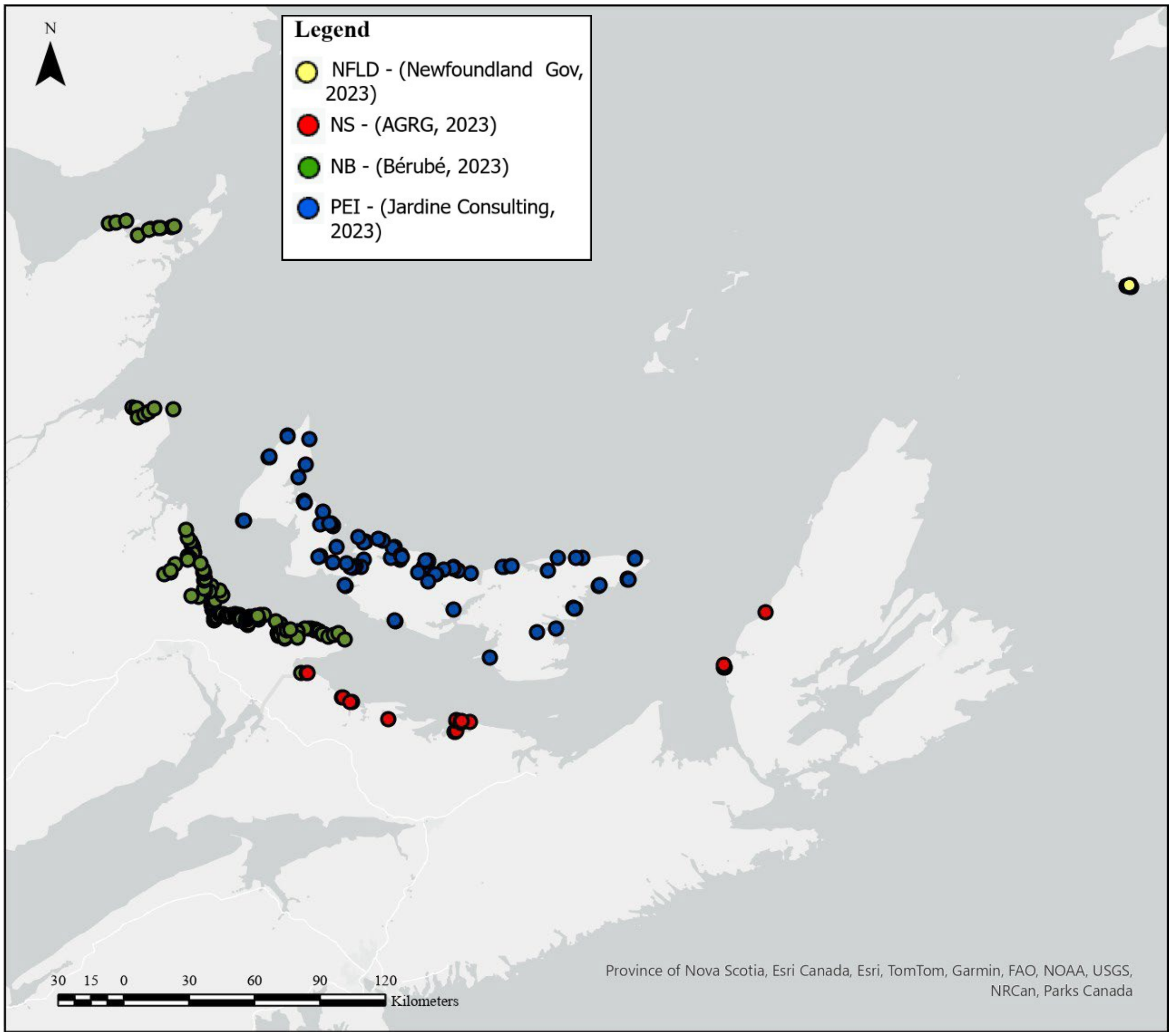


Figure 2 This map highlights the Hurricane Fiona Wrack-Line elevation raw data acquired by AGRG, Bérubé D (2023), and Jardine Consulting (2023).

2. Methods

2.1 Input Data

Storm surge return period water level data were provided by Zhang & Sheng (2013). Their study produced storm surge water level return periods using a parametric vortex simulation to estimate surge conditions for 50-year and 100-year return storm surge across the Atlantic Ocean (Figure 3). The simulation was based on water levels derived from atmospheric variables including wind & pressure in a six-hour time step, thus, producing surge levels at 6- hour intervals (Zhang & Sheng, 2013). The relatively short-lived nature of hurricane induced storm surge makes it unlikely that measurements obtained at 6-hour intervals captured the maximum water level reached by such storm surges as reported by Zhang & Sheng (2013). AGRG believed the 50-year and 100-year storm surge grids by Zhang & Sheng (2013) underestimated the true potential storm surge height resulting from 50-year and 100-year storms in Atlantic Canada. CLIMAtlantic undertook a preliminary comparison between surge water levels produced using Zhang & Shang (2013) and surge levels used by R J Daigle Enviro (2020) for the NB Flood Hazard Maps, which incorporated storm surge model results from Bernier (2005). Storm surge model results from Bernier (2005) are believed to underestimate the true potential storm surge in Atlantic Canada because of the similar method uses as Zang & Sheng (2013) e.g. 6-hour wind and pressure data driving the storm surge model (Webster et al, 2012). CLIMAtlantic found flood layers produced by R J Daigle for 20-year return water levels projected to 2100 agreed closely with flood levels produced for 2100 using Zhang & Sheng (2013) 50-year return storm surge plus a 0.5 m adjustment (Table 1). CLIMAtlantic also analyzed the flood layers produced by R J Daigle for 100-year return period storm surge projected to 2100 and found they agreed closely with flood levels produced for 2100 using Zhang & Sheng (2013) 100-year return storm surge with the addition of a 1.0 m adjustment (Table 2). Thus, the methods used in this project treat the 50-year return storm surge grid plus 0.5 m adjustment as a 20-year return storm surge grid and the 100-year return storm surge grid plus 1.0 m adjustment as a 100-year return storm surge to compensate for potential underestimates of Zhang & Sheng (2013). AGRG also added a wave run-up value of 0.5 m and 1.0 m to the 50-year and 100-year storm surge grids, respectively for an option in the final flood layers.

Table 1 The 20-year total return water levels at 2100 m (CGVD2013) including 0.5 m adjustment. The zone numbers are from R J Daigle Enviro 2020 as used in the NB Flood Hazard Maps.

Zone	Zhang & Sheng (2013)	CLIMAtlantic (proposed + 0.5 m adjustment)	NB Flood Hazard Map (Daigle Enviro, 2020)	Difference
1	3.2	3.7	3.7	0.0
2	2.8	3.3	3.3	0.0
3	2.4	2.9	3.1	-0.2
4	2.3	2.8	2.8	0.0
5	1.9	2.4	2.5	-0.1
6	2.3	2.8	3.0	-0.2
7	2.3	2.8	3.1	-0.3
8	2.4	2.9	3.3	-0.4
9	2.3	2.8	3.1	-0.3
10	2.9	3.4	3.2	+0.2
11	5.1	5.6	5.9	-0.3
12	5.5	6.0	6.0	0.0
13	7.9	8.4	8.5	-0.1
14	9.7	10.2	9.5	+0.7

Table 2 The 100-year total return water Levels at 2100 m (CGVD2013) including 1 m adjustment. Zone numbers are from R J Daigle Enviro 2020 as used in NB Flood Hazard Maps.

Zone	Zhang & Sheng (2013) + 1.0 m adjustment	NB Flood Hazard Map (Daigle Enviro, 2020)	Difference
1	4.3	4.2	+0.1
2	3.8	3.7	+0.1
3	3.5	3.4	+0.1
4	3.4	3.1	+0.3
5	3.0	2.7	+0.3
6	3.4	3.4	0.0
7	3.4	3.5	-0.1
8	3.5	3.7	-0.2
9	3.4	3.5	-0.1
10	4.0	4.2	-0.2
11	6.1	6.1	0.0
12	6.5	6.2	+0.3
13	8.6	8.7	-0.1
14	9.9	9.7	+0.2

Storm surge grids were provided as raster geo-tiffs with a pixel resolution of 0.0667 × 0.0667 degrees in a geographic projection (Figure 3). The grid files were provided in WGS 1984 and projected to the custom Mercator Atlantic Canada projection (cell size 6248.4 × 6248.4 m).

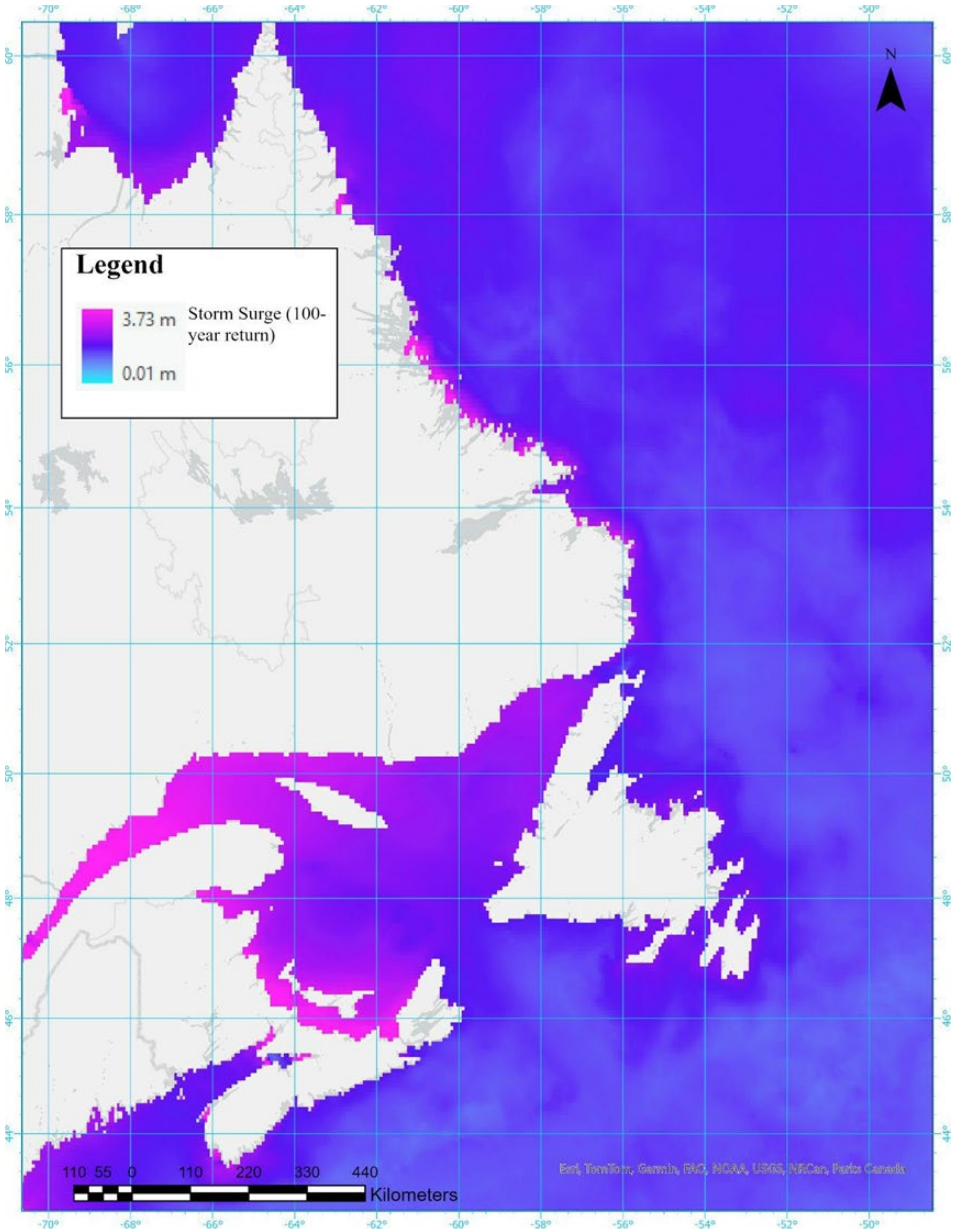


Figure 3 The 100-year return period storm surge water level grid, (Source Zhang & Sheng, 2013).

AGRG originally agreed with CLIMAtlantic to use upper confidence AR5 RCP 8.5 for the relative sea level (RSL) rise projections to build flood layers for 2050, 2100, and 2150 (James et al., 2021). However, an amendment to the original agreement changed the RSL input layers to those produced by James & Brierley Green (in prep) for the Intergovernmental Panel on Climate Change (IPCC) AR6 sea level rise scenarios, based on Shared Socioeconomic Pathways (SSPs). AGRG used the medium confidence (83%) SSP5-8.5 (Very High Emissions) values from the RSL layers for 2050, 2100, and 2150 to produce flood layers for those years. We compared the RSL grids produced by James et al. (2021 and in prep) that used the AR5 RCP values and the AR6 SSP values to determine how different they are. The medium confidence RSL values using AR6 SSP5-8.5 (83%) projections are in close agreement with the RSL values of the upper confidence (95%) RCP 8.5 AR5 projections in the year 2050 but deviate further above upper confidence RCP 8.5 AR5 RSL estimates in the year 2100 (Table 3). In the years 2100 and 2150, the RSL is higher in the latest AR6 projections than the previous AR5 report.

Table 3 Selected locations within Atlantic Canada were used to compare upper confidence AR5 RCP 8.5 RSL projections with medium confidence AR6 SSP5-8.5 projections. Medium confidence AR6 SSP5-8.5 RSL projection data tends to agree with upper confidence AR5 RCP 8.5 RSL data in the year 2050 with an average difference of –1.1 cm. Medium confidence AR6 SSP5-8.5RSL projection data tends to deviate further above upper confidence AR5 RCP 8.5 RSL predictions in 2100 and 2150, with an average difference of 13.7 cm and 35.5 cm, respectively.

Location	2050 difference (cm) (AR6 – AR5)	2100 difference (cm) (AR6 – AR5)	2150 difference (cm) (AR6 – AR5)
Northumberland Strait	-2.2	+ 18.6	+ 44.2
Bay of Fundy	-3.0	+ 10.7	+ 30.2
Saint John’s	+ 1.1	+ 13.5	+ 34.9
Halifax	-5.5	+ 2.0	+ 20.0
Minas Basin	-3.1	+ 9.0	+ 30.6
Chaleur Bay	-3.2	+ 8.9	+ 30.0
Cabot Strait	-3.7	+ 10.7	+ 33.5
Placentia Bay	-0.8	+14.3	+ 36.0
White Bay	+ 0.3	+ 15.7	+ 38.2
Nain	+ 7.6	+ 30.5	+ 56.4
Goose Bay	6.3	+ 24.2	+ 47.8
Hebron	-0.7	+ 16.1	+ 33.7
Canso	-2.8	+ 10.3	+ 33.6
Mirimichi	-6.0	+ 6.7	+ 28.6
Average	-1.1	+ 13.7	+ 35.5

Medium confidence (83%) AR6 SSP5-8.5 RSL layers were provided in NetCDF format before conversion to raster geo-tiffs in ArcGIS Pro in a geographic latitudinal/longitudinal coordinate system with a pixel resolution of 0.1000 × 0.1000 degrees (Figure 4). The medium confidence (83%) AR6 SSP5-8.5 RSL grid for 2100 provided by James & Brierley-Green (in prep) relative to CGVD 2013.). The source NetCDF files were projected to the Custom Mercator Atlantic Canada projection resulting in a pixel resolution of 12,906.2 m. In previous studies, such as the NS coastal flood recommendations, the IPCC AR5 report using the RCP8.5 scenario (business as usual for CO2 production) at the 95% confidence interval was recommended. However, in this study the latest RSL projects from James et al. (in prep) uses the IPCC AR6 report with a SSP5-8.5 scenario, the highest emissions and associated sea level rise in the report (high CO2 production), at a medium confidence interval of 83%. A medium confidence interval is used to denote moderate agreement among experts on the model treatment of key processes (e.g. those used in the IPCC AR6 SSPs) and moderate lines of evidence supporting model outputs.

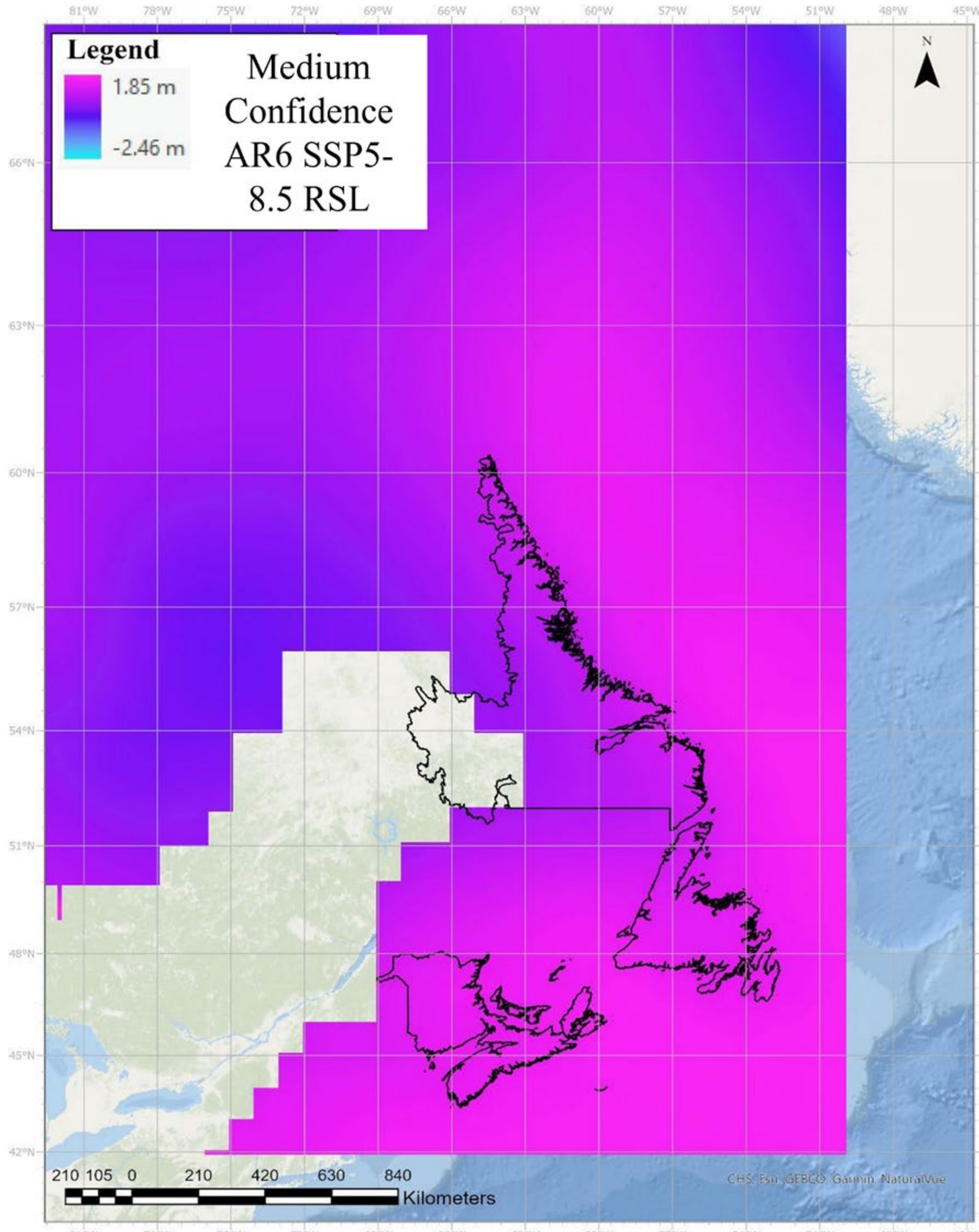


Figure 4 The medium confidence (83%) AR6 SSP5-8.5 RSL grid for 2100 relative to CGVD 2013 (Source James & Brierley-Green, in prep).

The Higher High Water Large Tide (HHWLT) data were used in this work and provided as a point file in a geographic projection with average point spacing of 0.00097 degrees (CHS, 2015) (Figure 5). The HHWLT raster grid derived from HyVSEP point data provided by the Canadian Hydrographic Service (2015).). The

HHWLT point file was projected to the custom Mercator Atlantic Canada projection and a raster grid was produced at 95 m pixel resolution. The HHWLT data were derived from Hydrographic Vertical Separation surfaces for Canadian waters (HyVSEPs) which were constructed by the Canadian Hydrographic Service in partnership with the Canadian Geodetic Service as defined by Robin et al, (2015). The HyVSEP surfaces map tide level and hydrographic datums to NAD83 on the CGVD2013 geoid using a combination of ocean models, GNSS observations, sea level trends, and satellite altimetry (Robin et al, 2015). AGRG leveraged the HyVSEP surface to incorporate HHWLT, defined as the average of the highest high waters, 1 from each of 19 years of predictions, in our flood mapping models to simulate flood events involving the highest tides.

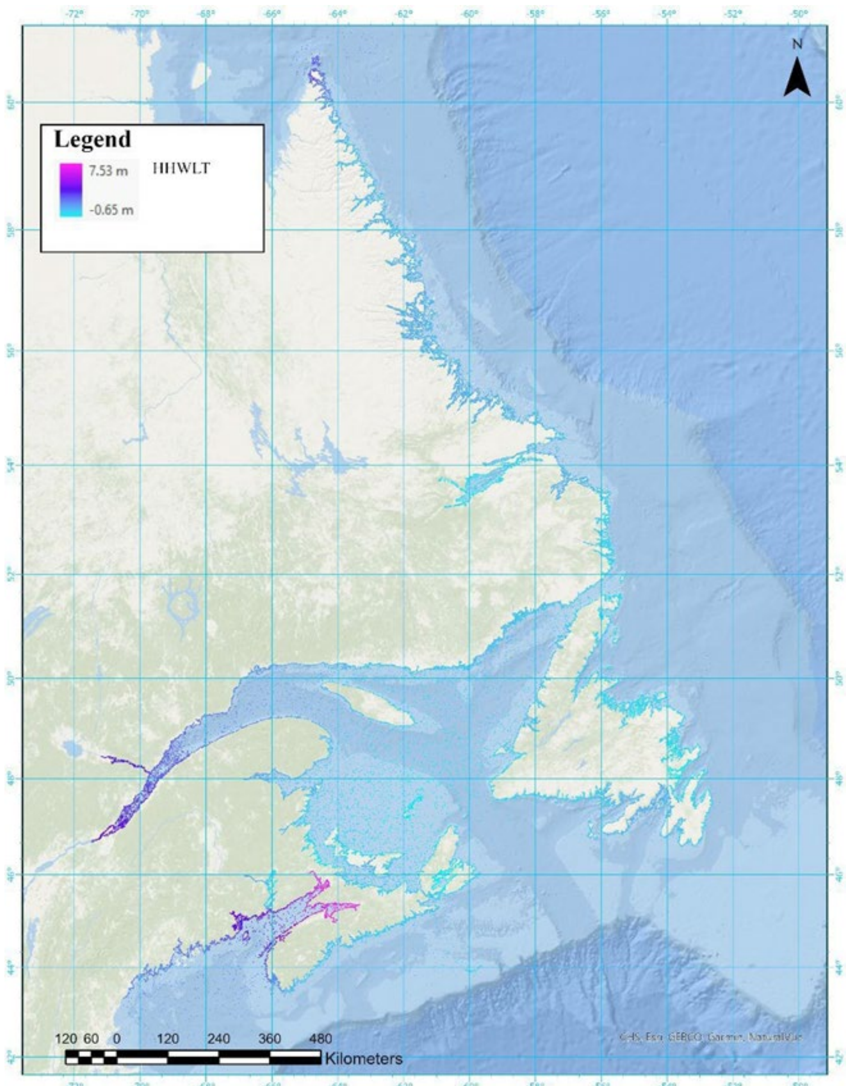


Figure 5 The HHWLT raster grid relative to CGVD2013 derived from HyVSEP point data, (Source Canadian Hydrographic Service, 2015).

AGRG used the best available DEMs to derive flood products integrating RSL, storm surge, and HHWLT. Topographic lidar derived DEMs were available for Nova Scotia, New Brunswick, PEI, Les Îles-de-la-Madeleine, and portions of NFLD. All lidar DEMs had a 1 × 1 m pixel resolution. Lidar DEM data covering

New Brunswick and PEI were sourced in NAD83 CSRS UTM Zone 20N, whereas lidar data covering portions of Newfoundland were provided in WGS 1984 Web Mercator (auxiliary sphere). The original projection of lidar data covering Nova Scotia was NAD83 (CSRS) v6 UTM Zone 20N. Lidar data covering Nova Scotia and parts of New Brunswick were constructed at AGRG, whereas the HRDEM – CanElevation Series (NRCAN, 2024) provided all lidar DEM data for PEI, additional portions of New Brunswick, and parts of Newfoundland. Les Îles-de-la-Madeleine lidar DEM data were provided by Solomon (2024) in NAD83 CSRS MTM 4. Lidar derived DEM data were unavailable for much of NFLD. As such, AGRG substituted lidar with the CDEM provided by the Government of Canada at a 20 × 20 m pixel resolution, defined in NAD 1983 (CSRS). The CDEM stems from the existing Canadian Digital Elevation Data (CDED). The latter were extracted from the hypsographic and hydrographic elements of the National Topographic Data Base (NTDB) at the scale of 1:50 000, the Geospatial Database (GDB), various scaled positional data acquired by the provinces and territories, or remotely sensed imagery. In the CDEM data, elevations can be either ground or reflective surface elevations. The CDEM data covers the Canadian Landmass. The typical vertical accuracy of the CDEM ranges from 2 – 17 m. All DEMs were reprojected to the custom Mercator Atlantic Canada projection.

Post Hurricane Fiona wrack line elevation data were acquired using high precision GNSS rovers with a vertical precision of ± 2 cm. Wrack line elevation data were received from an agglomeration of sources including AGRG (2023), Jardine Consulting (2023), and Dominique Bérubé (2023). Wrack line location was approximated by identifying the height of washed-up material along coastline impacted by Hurricane Fiona. AGRG received wrack line observation data covering the coastline of PEI in NAD83 (CSRS) v7 (Figure 2). Wrack line data received from New Brunswick extended along the coastline from Pokeshaw to Tidnish Bridge and were defined in NAD83 CSRS New Brunswick Stereographic. Data acquired for Nova Scotia were defined in NAD83 CSRS UTM Zone 20N and spanned the Nova Scotian coastline from Tidnish Bridge to Inverness (Figure 2). This map highlights the Hurricane Fiona Wrack-Line elevation raw data acquired by AGRG, Bérubé D (2023), and Jardine Consulting (2023).). Data received covering Newfoundland were limited to Port Aux Basques and were defined in NAD83 CSRS UTM Zone 21N (Figure 2). All wrack line data were reprojected to the custom Mercator Atlantic Canada projection.

2.2 Data Pre-Processing

The custom Mercator Atlantic Canada (MAC) projection was used for all the input layers used in this project (Figure 6). The processing zones used in this project. Lidar DEM coverage in Nova Scotia, New Brunswick, and Newfoundland was divided into smaller scale chunks for processing.). The MAC projection is based on the Mercator projection with a central meridian of at -56° (west longitude) with a standard parallel at 46° (north latitude). The MAC projection centralized raw input layers on Atlantic Canada, minimizing the stretching inherent with the geographic latitudinal/longitudinal coordinate systems belonging to many of the raw grid files. Projecting the grids to MAC also defined the linear unit (meters), simplifying processing methods. NAD83 CSRS v7 was the horizontal datum applied to all layers in the project and the vertical datum was CGVD2013.

Adjusted storm surge, RSL, and HHWLT data layers were resampled using a variety of techniques in ArcGIS Pro and Python to match the resolution of the underlying DEM data. This necessary step was executed to ensure resulting flood layers preserved the detail of the DEM data. Atlantic Canada data, apart from most of NFLD where DEM data was much coarser (20m × 20m), were divided into county scale chunks for processing (Figure 6). This illustration describes the watershed methodology whereby pixels belonging to each watershed were assigned the value of the nearest pour point. PEI and Les Îles-de-la-Madeleine were processed as individual zones. Lidar DEMs were clipped to each zone along with the input RSL, storm surge, and HHWLT data layers.

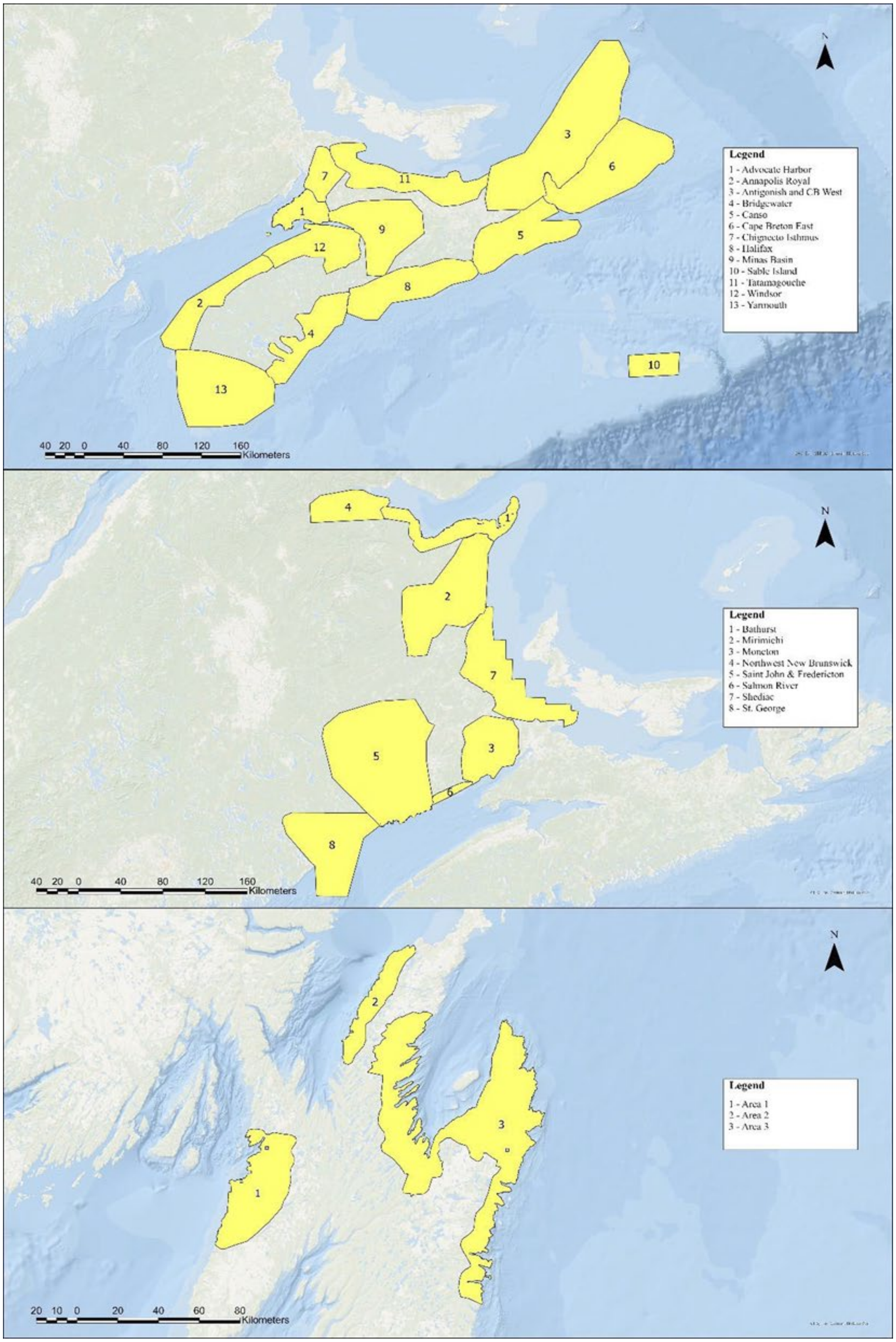


Figure 6 The processing zones used in this project. Lidar DEM coverage in Nova Scotia, New Brunswick, and Newfoundland was divided into smaller scale chunks for processing.

Medium confidence (83%) AR6 SSP5-8.5 RSL grids were interpolated using a spline with barriers technique coupled with bilinear resampling events. Each grid was clipped to a predefined processing region and resampled by a factor of 100 to a finer pixel resolution (129 × 129 m) using a bilinear resampling method. Resampled grids were passed into a spline tool incorporating watershed boundaries as interpolation barriers. Watershed shapefiles were acquired from GeoNB (2023) for New Brunswick. Watershed boundaries were derived using spatial analyst tools in ArcGIS Pro for other regions including Nova Scotia, PEI, Les Îles- de-la-Madeleine, and NFLD. RSL grid outputs from the spline tool were resampled to a 1 × 1 m pixel resolution using a bilinear interpolation method. The methods used to pre-process the RSL grids were executed in ArcGIS Pro and a standalone Python script.

HHWLT and adjusted storm surge grids and were processed using a watershed methodology developed at AGRG (McGuigan, pers comm). A standalone Python script was developed containing the tools necessary to execute the watershed procedure. A clipping operation to the area of interest (AOI), followed with a bilinear resampling event initiated the procedure, reducing pixel resolution of source grids to 5 × 5 m. Resampled grids were converted to point feature classes and coupled with the DEM of each AOI for integration with the watershed analysis tool provided by ESRI. In this context the watershed analysis tool determined the pixels in the DEM contributing to the nearest hydrologically connected point (pour point) within the input shapefile (Figure 7). The above graphic depicts the method used to generate the flood layers in this project. The elevation value of the pour point was adopted by the pixels within the contributing watershed. Watershed raster outputs were resampled to a final resolution of 1 × 1m using a bilinear interpolation method.

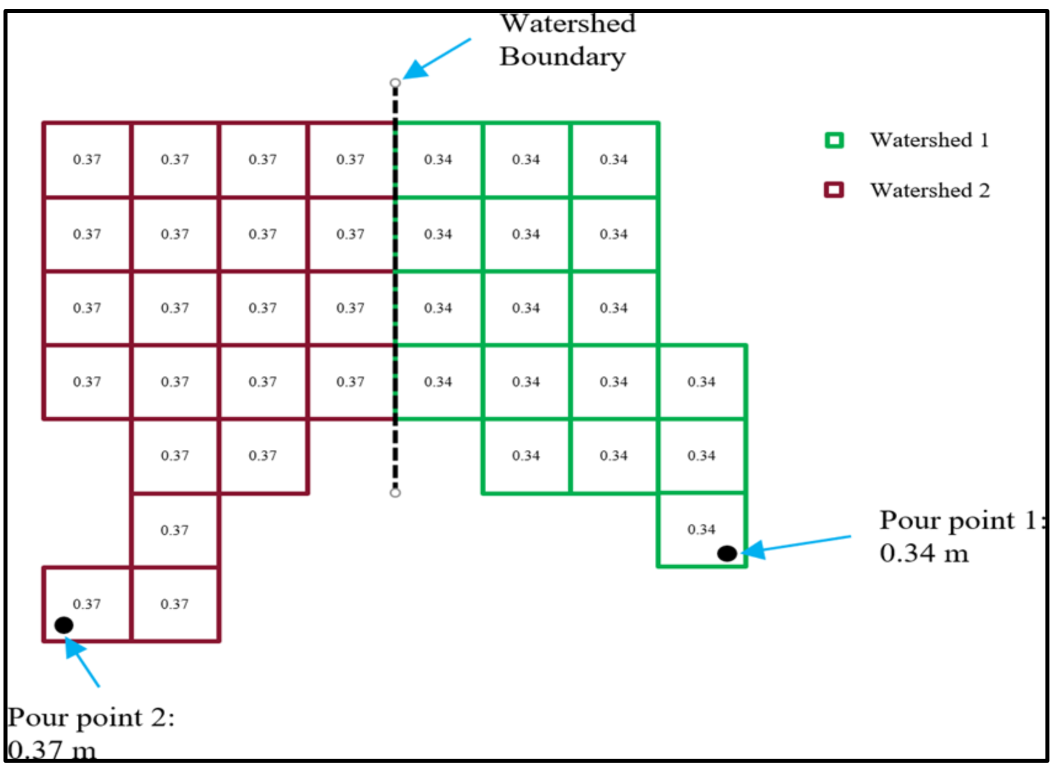


Figure 7 This illustration describes the watershed methodology whereby pixels belonging to each watershed were assigned the value of the nearest pour point.

All DEMs were hydrologically connected (hydro enforced) by burning in hydrological pathways. Hydrological pathways are any locations in the DEM where a culvert, causeway, or river crossing exists, excluding aboiteau, hydro-dam, or other manmade structures that inhibit the flow of water. Hydrological pathways allow and direct the flow of water, defining the realized extent of floodplains in many cases. The importance of hydrological connectivity with respect to accurate flood mapping necessitated the identification of hydrological pathways within DEM data. A standalone Python script was developed to assist with hydrological pathway detection and generation and in some cases, pathways were manually identified and drawn in ArcGIS Pro. Hydrological pathways were built as line shapefiles before conversion to binary raster layers. The pathways were burned into the DEM using a raster calculation, simulating hydrological connectivity where flow channels existed.

Raw Hurricane Fiona wrack line data covering New Brunswick and PEI were received in CSV format, whereas data covering Nova Scotia were provided as a point shapefile. Files covering New Brunswick and PEI were converted to point shapefiles in ArcGIS Pro. Each shapefile was projected to the MAC projection. Shapefiles were organized and processed in groups with respect to the data provider.

3. Results

3.1 Flood Layers

The general approach taken to generate the flood layers involved adding the processed adjusted storm surge, RSL, and HHWLT grids with the appropriate wave run-up value forming a water level raster layer that was conditionally subtracted from the hydrologically conditioned DEM within a raster calculator operation (Figure 8). The 100-yr return storm event flood layers (year 2100) centered on a subregion in Halifax County. The top map frame displays the 'with wave run-up' variant (+ 1.0 m) whilst the bottom map frame displays the 'without wave run-up' variant. The conditional logic applied in the raster calculation identified pixels within the DEM below the elevation of the water level raster layer and converted selected pixels to a binary raster file. The binary raster files were vectorized to build shapefiles representing each flood scenario. Vector shapefiles were selected based on their hydrological connectivity to the ocean, excluding unconnected polygons from the output flood shapefile. Final flood shapefiles were smoothed to eliminate acute vertex junctions (Figure 9). This diagram describes the interpolation algorithm applied to wrack line points that derived elevation values at interpolated point locations. The process was executed using a script developed in Python which integrated various geoprocessing tools available from the arcpy Python library.

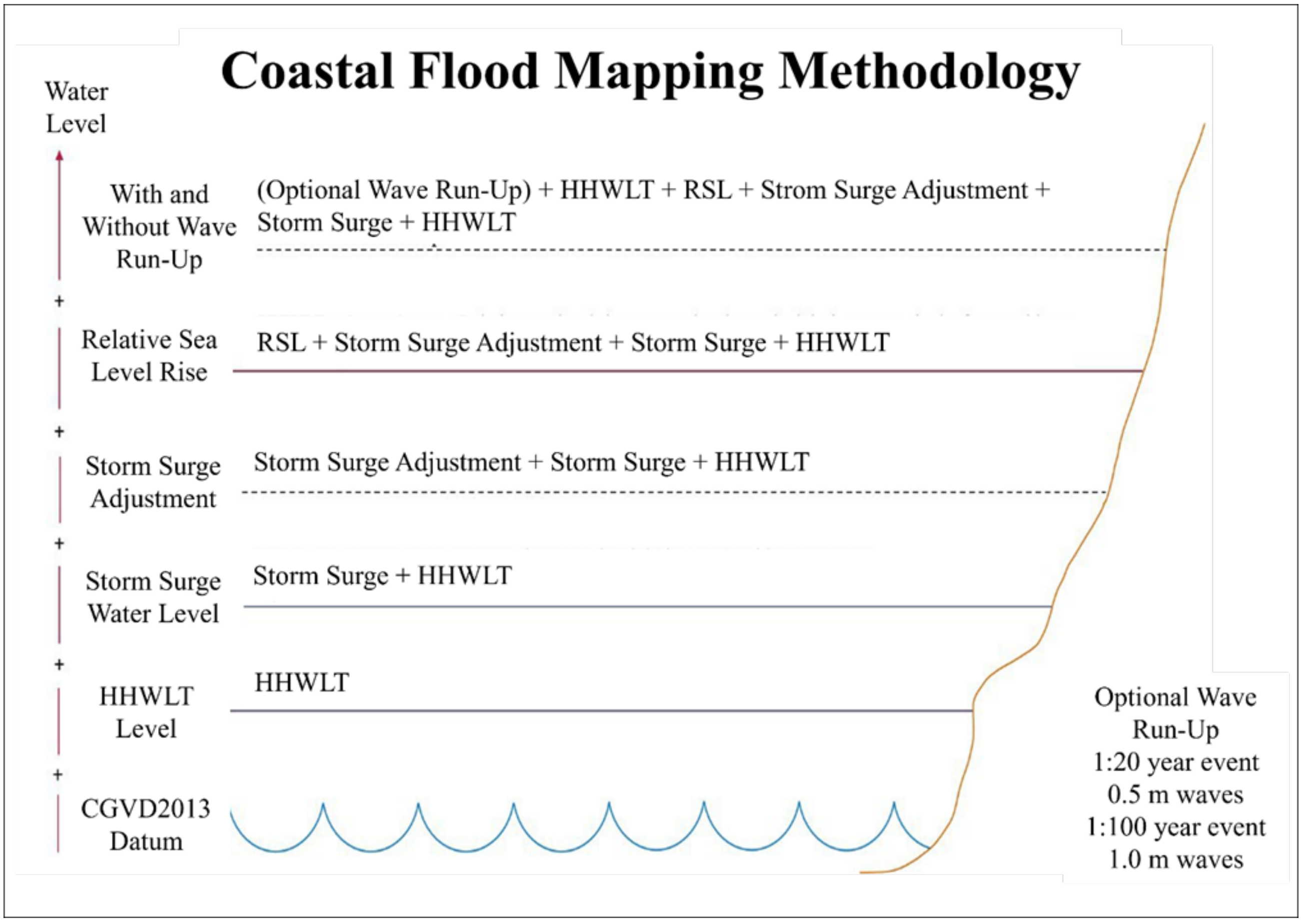
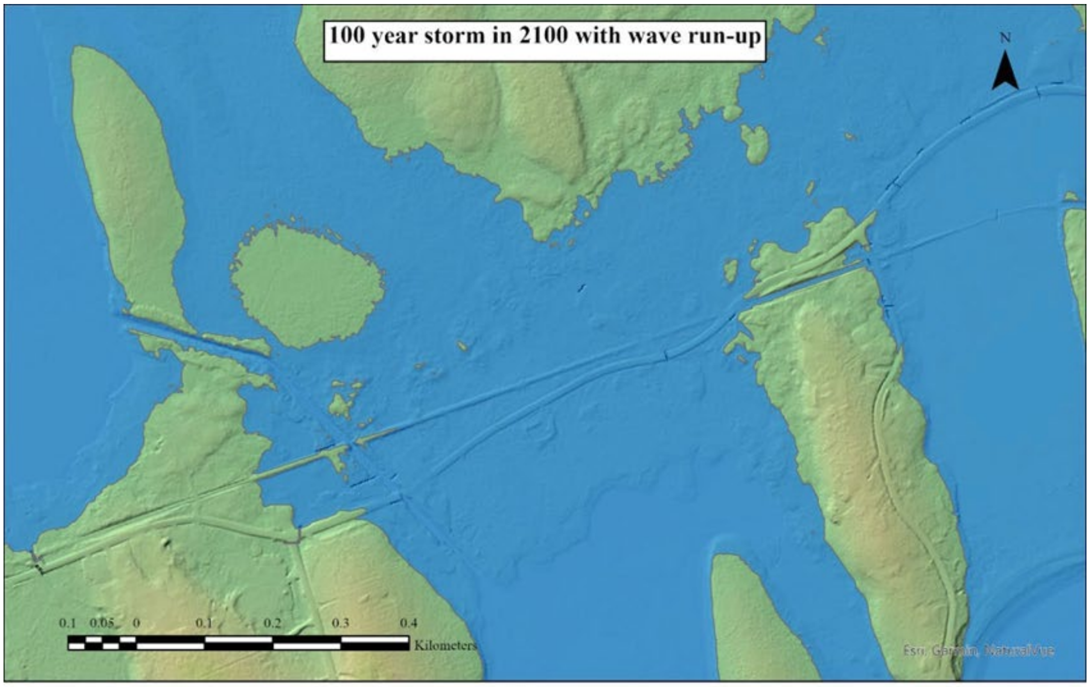


Figure 8 The above graphic depicts the method used to generate the flood layers in this project.

Flood depth raster layers were produced in another raster calculator operation which added the adjusted storm surge, RSL, and HHWLT grids together with the appropriate wave run-up value to form a water level raster that was conditionally subtracted from the hydrologically conditioned DEM. The conditional calculation selected DEM pixels below the elevation of the water level raster and subtracted the value in pixels of the overlying water level raster from selected DEM pixels, building a separate raster layer which stored the flood depth information. Outputs from the operation were clipped to the matching vector shapefile to exclude non-hydro-connected pixels. Final flood depth raster layers were constructed using LZW compression, a lossless compression algorithm applied to reduce file size. As the water surface within the DEMs used in this project was not cleaned, there may be some artifacts present in flood depth layers as a result. The process was executed using a script developed in Python.



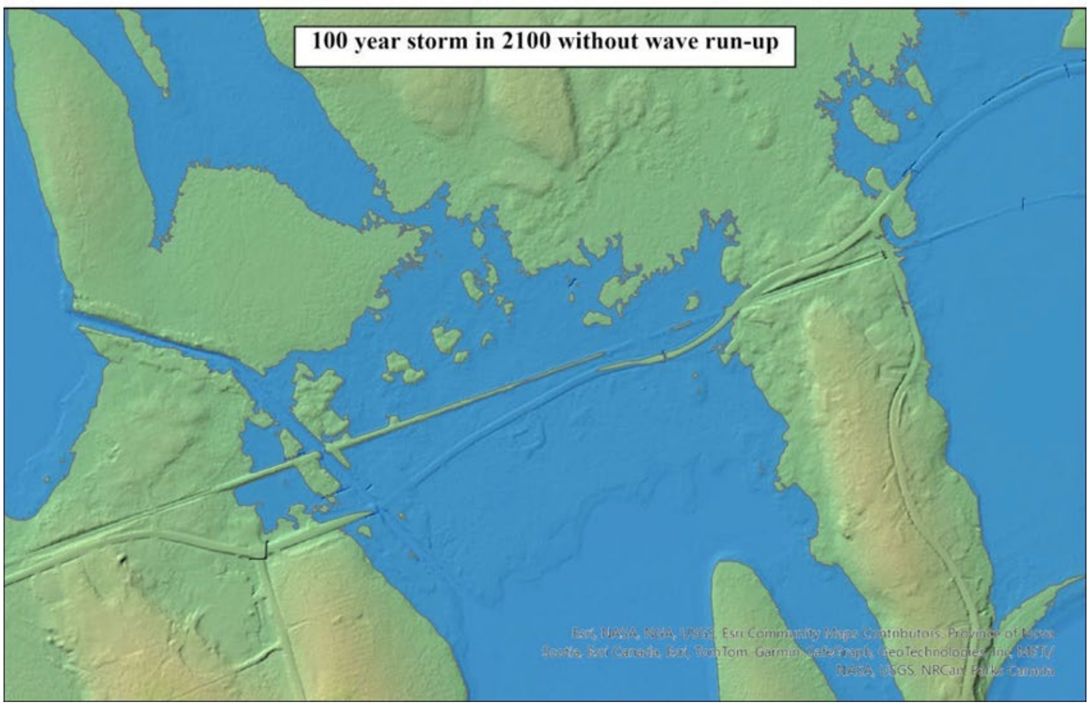


Figure 9 The 100-yr return storm event flood layers (year 2100) centered on a subregion in Halifax County. The top map frame displays the 'with wave run-up' variant (+ 1.0 m) whilst the bottom map frame displays the 'without wave run-up' variant.

3.2 Fiona Wrack Line

The Hurricane Fiona wrack line was derived from source elevation values using the network analysis toolbox in ArcGIS Pro to order known elevation points along the coastline. Additional points were generated along the coastline at 1km intervals to fill gaps in source data. Elevation values for additional points were interpolated using the gradient of change between the two neighboring elevation wrack line values along the coastline (Figure 10). This diagram describes the interpolation algorithm applied to wrack line points that derived elevation values at interpolated point locations. The formula applied to ascertain interpolated elevation values was in the form [Start(x) + (((n-1) *((End(x) – Start(x))/(End(n) – Start(n)))], where (x) represents the elevation value and (n) represents the point number in sequence along the line. This calculation was iteratively executed for each interpolated point using a script developed in Python. The final point shapefile was converted to a raster layer in ArcGIS Pro. DEM pixel values below those in the wrack line raster were selected and extracted as a binary raster layer using a conditional statement executed by the raster calculator in ArcGIS Pro. A polygon conversion was performed on the binary raster layer before creating a line shapefile of the innermost extent reached by the inundation polygon. The final line shapefile was cleaned and smoothed to eliminate any acute vertex junctions.

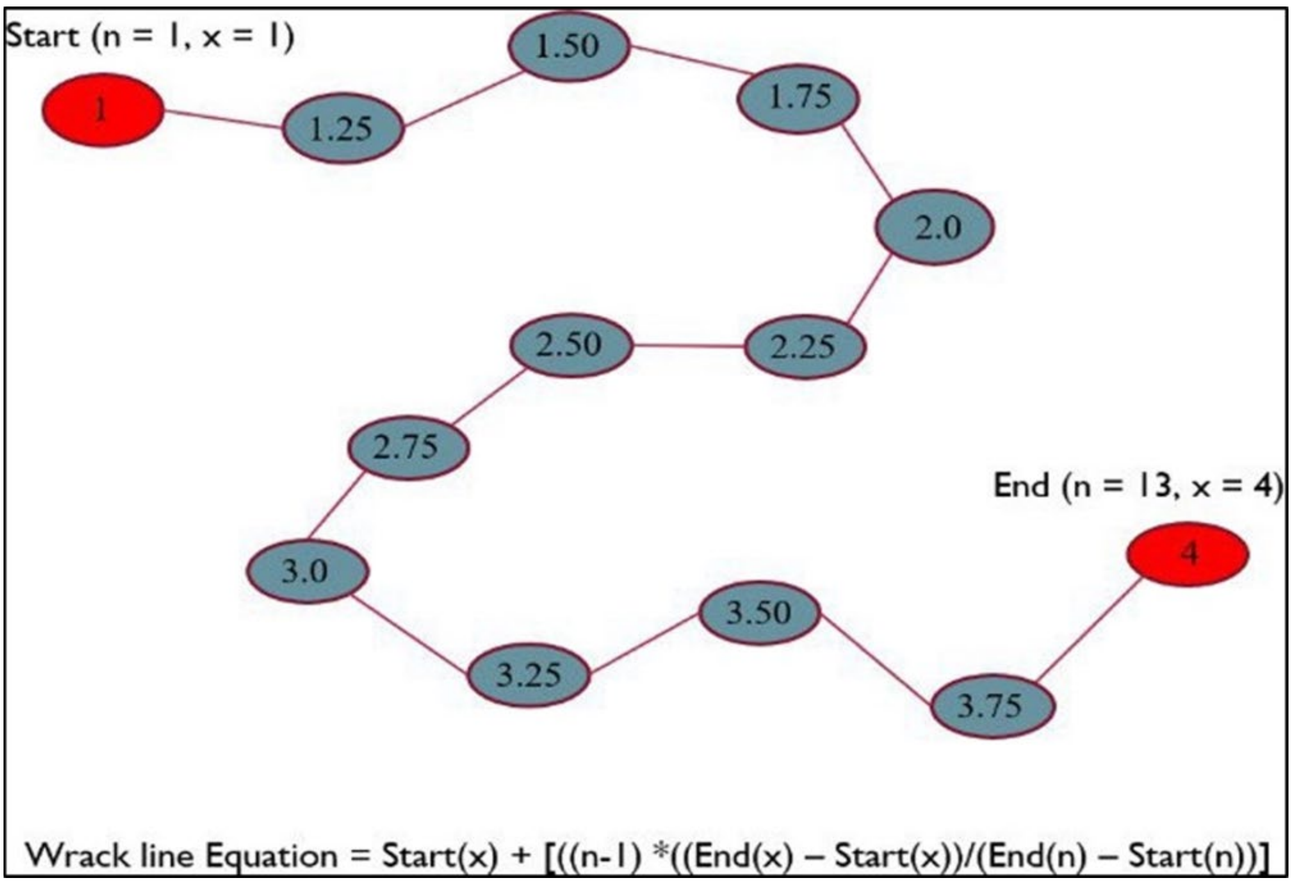


Figure 10 This diagram describes the interpolation algorithm applied to wrack line points that derived elevation values at interpolated point locations.

4. Conclusions

AGRG completed all flood layers and the Hurricane Fiona wrack line requested by CLIMAtlantic. CLIMAtlantic received vector flood layers and raster flood depth layers covering Atlantic Canada for all flooding scenarios considered in the project. CLIMAtlantic also received the Hurricane Fiona wrack line and all hydrologically connected DEMs produced in this project. All deliverables were uploaded to a hard drive and delivered to CLIMAtlantic through courier mail.

This project represents the latest in coastal flood inundation mapping from 1 in 20-year and 1 in 100-year storm surge events today and into the future considering the latest science. Although the adjusted storm surge water levels for the 20-year and 100-year levels match those used in the New Brunswick coastal flooding scenarios, they are probably still an underestimation of actual return period water levels, considering they were derived from Bernier (2005), whose storm surge modelling was similar to that of Zang and Sheng (2013). However, given these surge return period water levels were added to the HHWLT water level compensates for the surge value shortcomings. The latest sea level projects from IPCC AR6 report were utilized along with crustal isostatic adjustments for the RSL layers provided by James et al (in prep). A comparison of the RSL grids from James et al. (2012) based on AR5 RCP 8.5 at the 95% to the latest RSL grids from James et al. (in-prep) based on AR6 SSP5-8.5 at 83% confidence shows that the two projections agree quite closely to 2050, but then the latest RSL based on AR6 SSP5-8.5, 83% exceeds the previous estimates in 2100 and 2150. This shows that such mapping must be constantly revised as new IPCC and crustal isostatic adjustment data are revised in the future to ensure citizens have the most up to date and accurate maps possible. Innovative GIS processing techniques used in this project include the use of watershed boundaries to ensure water levels were not being interpolated across regions of dissimilar oceanographic characteristics. An innovative interpolation approach was also employed to estimate a wrack line of Hurricane Fiona from point measurements. The measurement of the wrack line elevation and comparison with still water measurements by tide gauges highlighted the importance to consider wave run-up for such inundation mapping exercises, and thus a 0. 5 m and 1.0 m vertical wave run-up factors were added to the 20-year and 100-year storm surge scenarios respectively. The flood raster and vector layers were combined to the provincial scale for the various flood scenarios and climate change projections into the future 2050, 2100 and 2150.

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